2023

Design and Construction Standards Manual

Division of Campus Planning, Infrastructure, and Facilities

Effective July 2023

DIVISION OF CAMPUS PLANNING, INFRASTRUCTURE, AND FACILITIES
VIRGINIA TECH.

Vice President of Campus Planning, Infrastructure, and Facilities
Sterrett Center, Suite 112
230 Sterrett Drive
Blacksburg, Virginia 24061

MEMORANDUM

TO: Christopher H. Kiwus, Vice President of Campus Planning, Infrastructure, and Facilities CHK

FROM: Mary-Ann Ibeziako, Assistant Vice President for Infrastructure and Chief Sustainability Officer MI

DATE: June 15, 2023

SUBJECT: 2023 Virginia Tech Design and Construction Standards Manual

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This Memorandum shall serve as a request for review and authorization of the 2023 Virginia Tech Design and Construction Standards Manual.

Pursuant to the Restructured Higher Education Financial and Administrative Operations Act, § 23.1-1002 et seq. of the Code of Virginia and the resulting Management Agreement Between the Commonwealth of Virginia and Virginia Polytechnic Institute and State University, Virginia Tech has the authority to develop design standards for all university construction projects.

Upon your approval and signature, the 2023 Virginia Tech Design and Construction Standards Manual will be effective July 01, 2023.

DocuSigned by:
Christopher H. Kiwus
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Christopher H. Kiwus,
Vice President of Campus Planning, Infrastructure, and Facilities

7/5/2023
Date

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VIRGINIA TECH DESIGN AND CONSTRUCTION STANDARDS MANUAL

The Virginia Tech Design and Construction Standards Manual (DCSM) is intended to provide architects and engineers (A/Es), Contractors, project managers (PMs), and internal Virginia Tech staff with procedural and technical requirements that apply to all design and construction. The current DCSM at the time of contract approval shall be used to develop and submit construction documents and shall be adhered to for all University projects unless specifically waived in accordance with DCSM section 1.3.5. It is the responsibility of the user of the DCSM to read and understand the requirements stated in this document.

This document outlines the design standards for building components and systems for renovation and new construction projects at Virginia Tech. It is to be used in conjunction with the Virginia Tech Construction and Professional Services Manual, latest edition.

The Vice President of Campus Planning, Infrastructure, and Facilities (VPCPIF) has ultimate authority over the content and execution of the Virginia Tech Design and Construction Standards. Any modifications, additions, or deletions to such Standards shall be under the purview of the VPCPIF.

Requirements found in the Virginia Uniform Statewide Building Code (VUSBC) and its referenced standards are not repeated in the DCSM. The current adopted version of the VUSBC and its referenced standards are applicable to all Virginia Tech buildings. If unintentional conflicts between the DCSM and other requirements or regulations occur, then the more restrictive requirement for the situation shall apply.

Questions and suggestions are welcomed and should be submitted to the Design and Construction Standards Team at designstandards@vt.edu.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

TABLE OF CONTENTS

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

TABLE OF TABLES

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

TABLE OF FIGURES

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 1 – GENERAL REQUIREMENTS

The Virginia Tech Design and Construction Standards Manual (DCSM) and the Virginia Tech Construction and Professional Services Manual (VT CPSM) provide the design standards and procedural requirements for Virginia Tech construction projects. Project-specific requirements will be addressed by the Office of University Planning (OUP) and the University Building Official (UBO).

1.1 Acronyms and Terms

1.1.1 Acronyms

Some of the acronyms used in the DCSM are listed here. Many acronyms are industry specific and users are advised to consult industry terminology if additional information is needed. Whenever used in the DCSM, including the appendices and the standard forms, the following acronyms have the meanings indicated, which apply to both singular and plural and are not gender specific.

A/E – Architect/Engineer
AARB – Art and Architecture Review Board
ACM – asbestos-containing material
ADA – The Americans with Disabilities Act of 1990
AIA – American Institute of Architects
BAS – Building Automation System
CC – Virginia Tech Capital Construction
CFR – Construction Field Representative or Code of Federal Regulations
CPIF – Division of Campus Planning, Infrastructure, and Facilities
CPSM – Commonwealth of Virginia Construction and Professional Services Manual
DCSM – Virginia Tech Design and Construction Standards Manual
DEB – Division of Engineering & Buildings, a division of the Virginia Department of General Services
DEQ – Virginia Department of Environmental Quality
DGS – Virginia Department of General Services
DHR – Virginia Department of Historic Resources
DLI – Virginia Department of Labor and Industry
EHS – Virginia Tech Department of Environmental Health and Safety
EPA – United States Environmental Protection Agency
GSA – General Services Administration, U.S. Federal government agency
LEED – Leadership in Energy and Environmental Design Building Rating System
MRSWA – Montgomery (County) Regional Solid Waste Authority

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

NI&S – Virginia Tech Network Infrastructure & Services
O&M – Operation and Maintenance
OEM – Office of Emergency Management
OS – Virginia Tech Office of Sustainability
OSHA – Occupational Safety and Health Administration
OUP – Virginia Tech Office of University Planning
RFP – Request for Proposal
SFMO – State Fire Marshal's Office
SID – Virginia Tech Site and Infrastructure Development
UBO – Virginia Tech University Building Official
USGBC – U.S. Green Building Council
VCC – Virginia Construction Code
VDOT – Virginia Department of Transportation
VOSH – Virginia Occupational Safety and Health Regulations
VSFPC – Virginia Statewide Fire Prevention Code
VPCPIF – Vice President of Campus Planning, Infrastructure, and Facilities
VT – Virginia Polytechnic Institute and State University (Virginia Tech)
VTAS&S – Virginia Tech Annual Standards and Specifications for Erosion and Sediment Control and Stormwater Management
VT CAC – Virginia Tech Climate Action Commitment
VT CPSM – Virginia Tech Construction and Professional Services Manual
VTES – Virginia Tech Electric Service
VTPD – Virginia Tech Police Department
VT PM – Virginia Tech Project Manager
VUSBC – Virginia Uniform Statewide Building Code

1.1.2 Terms

Some of the terms used in the DCSM are defined here. Many terms are industry specific and users are advised to consult industry guides and handbooks if additional clarification is needed.

Accessible and Accessibility – These terms are capitalized when referring to requirements related to the ADA Standards for Accessible Design.

Architect/Engineer (A/E) – The term used to refer to the A/E who provides the architectural and/or engineering services for a Project. The A/E is a separate contractor and is not an agent of the University. This term also includes any associates or consultants employed by the A/E to assist the A/E in providing services.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Capital project – The term for a project with a total budget of $3 million or higher or an area of 5,000 square feet or more.

Non-capital project – The term for a project with a total budget of less than $3 million and an area of less than 5,000 square feet.

Code – Virginia Uniform Statewide Building Code (VUSBC)

Universal – This term is capitalized when referring to Universal Design principles.

University – Virginia Tech

1.2 University Design Principles and Master Plans

1.2.1 General

1.2.1.1 Program Goals

It is the University's intent to maximize the design potential of each campus building project in terms of accommodating the programs to be served, fostering collegiality on the campus, and contributing to the public realm that defines the Virginia Tech campus as a unique place.

In order to achieve the programmatic goals of each project, the design must cost-effectively overlay the specific, user-generated objectives for the project with the University objectives of institutional identity, durability, longevity, flexibility, and adaptability.

In order to foster collegiality, each project must create environments, which encourage interaction and discourse among students, faculty and staff. This potential shall be recognized in the development of interior and exterior environments.

While a major responsibility of programmatic accommodation is to the development of the "insides" of the project, every project also has a responsibility to the greater whole of the campus. This responsibility to the public realm recognizes the importance of the architectural and planning traditions at Virginia Tech and strives to contribute to the further development of the campus as a highly imaginative, unique, and inspiring place.

To achieve these goals, it is incumbent upon the project design team to invest in an understanding not only of immediate program goals but also of the history of planning and architecture on the campus, of the goals and objectives of the current campus master plan, and particularly of the immediate context (precinct and site) for the project.

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230 Sterrett Drive
Blacksburg, Virginia 24061

Further elaboration of many of these points can be found in the OUP Campus Master Plan on the web.

1.2.1.2 Alternate Location Design Requirements

For Virginia Tech projects located in cities, towns, developments, or other areas with already established design requirements, the design requirements for that location will take precedence over the standards within the DCSM. Design waivers for these differences in design will not be required unless the proposed changes will be in direct conflict with Virginia Tech policies on Accessible, Universal, or Sustainable Design.

1.2.1.3 Signage

1. All signage shall follow the standards established by OUP. See the standards provided in Appendix F: Campus Wayfinding Guidelines and Appendix E: Interior Signage Standards Manual.
2. Additional discussion must occur on a project-level basis regarding incorporation of a university mark. When a mark is needed, signage shall feature the new university mark. OUP shall be consulted on the presence of a university mark on signage packages.
3. Signage components are required to match existing signage systems. See DCSM section 4.5 for exterior signage requirements and DCSM section 5.11 for interior signage requirements.
4. The A/E shall provide a signage package.
5. All donor recognitions must be approved by OUP.
6. For lighted building sign electrical requirements, see DCSM section 4.8.14.7.10.
7. For signage on construction fencing and other project signage, see DCSM sections 7.7 and 7.8.2.

1.2.2 Master Plans

Contracted firms will adhere to the latest versions of the principles, guidelines, and Master Plans.

- Beyond Boundaries Campus Master Plan
- Campus Design Principles
- Parking and Transportation Master Plan
- Bike Parking Master Plan
- Universal Design Principles Checklist
- Virginia Tech Student Experience: Virginia Tech's Next 20 Years

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.2.3 Accessible Design

It is the University's policy to create learning and working environments that foster participation by all persons who visit, attend, and work for Virginia Tech. Virginia Tech complies with the ADA Standards for Accessible Design, latest edition, for all new construction and renovations.

In addition to the ADA Standards for Accessible Design, Virginia Tech has the following requirements:

1. All doors shall have a minimum width of 36 inches (see DCSM section 5.7).
2. Automatic operators (see DCSM sections 5.7.1, 5.7.2, and 5.7.4.1, and) shall be provided for:
    a. At least a single door along an Accessible route,
    b. Main building entrances,
    c. Access into all restrooms, and
    d. Access into a minimum of 50% of all classrooms, with a minimum of one door in all classrooms with two doors, and with a preference for classrooms with higher occupancies.
3. Accessible routes from main pedestrian areas shall be clearly marked (e.g., the drillfield). Accessible routes shall be shown on submitted plans (see the drawing checklists for the specific design phase).
4. Classroom hallway widths shall be in accordance with DCSM section 1.7.2.2.1.
5. Knee spaces for Accessible seating at tables or counters shall be at least 30 inches high, 32 inches wide, and 19 inches deep.
6. Auto-flush devices shall be installed on all Accessible water closets (see DCSM section 6.6.6.11).
7. Where emergency power is provided in the building, at least one elevator shall be provided with emergency power to allow operation during a power outage (see DCSM section 6.5).

Accessibility shall be included in the initial planning of all new facilities, not as an afterthought in a code review of a design that is complete. Accessible Design standards cannot be removed or diminished as a result of Value Engineering.

Where feasible, new construction and renovation projects should provide additional Accessible Design elements. Examples include:

1. Add an additional 6 inches in width and length in Accessible restroom stalls.
2. Increase turning radius to 6 feet in Accessible restrooms.
3. Add an additional 6 inches to the overall width for Accessible ramps.

4. Maintain a minimum of 60 inches for the clear width at a 180-degree turn for an Accessible route (see Figure 403.5.2 in the 2010 ADA Standards for Accessible Design).

Coordinate with OUP for project-specific goals.

1.2.4 Universal Design

Universal Design to incorporate equal access for all persons shall be a primary planning criterion at Virginia Tech. Addressing the diverse needs of the campus population will require a broad framework for evaluating future building, interior, and site design projects. In new construction, there shall be integrated access for persons with disabilities and the general population.

At the beginning of the planning process, the A/E is encouraged to evaluate exterior and interior circulation conditions and propose innovations in Accessible routes, spaces, and amenities to create a more welcoming and inclusive campus. The A/E shall develop a design that strives to minimize hazards, eliminate auditory and visual barriers, and provide the appropriate space for approach, reach, manipulation, and use of campus elements regardless of the user's body size, posture, or mobility.

Where feasible, new construction and renovation projects should provide additional Universal Design elements. Examples include:
1. Make the main entrance to the building Accessible.
2. Add additional space for maneuverability of larger wheelchairs.
3. Increase quantity of Accessible restrooms/stalls.
4. Provide additional grab bars in Accessible restrooms.
5. Provide Accessible parking near Accessible entrances with a clearly marked Accessible route.
6. Provide additional wheelchair locations in assembly areas.
7. Provide additional wheelchair seating at tables and counters.

Coordinate with OUP for project-specific goals.

1.2.5 Sustainable Design

Per the latest revision of the Presidential Policy Memorandum No. 262, the Virginia Tech Climate Action Commitment (VT CAC), Virginia Tech will be a leader in campus sustainability and programs to achieve sustainability goals will be represented in the University's Strategic Plan. Innovations in construction and building design have raised the benchmark for certification standards for buildings since 2013. The VT Division of Campus Planning, Infrastructure, and Facilities (CPIF)

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

will strive to incorporate a maximum amount of sustainability improvements to honor the VT CAC to the limits of affordability for each design project.

The University is committed to the principles of energy conservation. All designs shall strive to maximize energy efficiency, and comply with the energy conservation requirements contained in these standards and Campus Energy, Water, and Waste Reduction Policy – No. 5505.

See DCSM section 5.3 for reduced-carbon concrete using blended cement.

See DCSM section 5.5.9 for vegetative roofs.

1.2.5.1 LEED Certification

In order to incorporate sustainable design solutions in new construction and renovation projects, Virginia Tech has joined the U.S. Green Building Council (USGBC) and fully supports the principles of the LEED (Leadership in Energy and Environmental Design) Building Rating System. The pursuit of high-performance green buildings that are energy efficient and environmentally sensitive will help to lower operating and energy costs, improve employee productivity, promote improved learning, and enhance the health, and well-being of the students, faculty and staff at Virginia Tech. All projects shall address sustainability as it relates to site issues, water, energy efficiency, materials and resources, and indoor air quality in accordance with the VT CAC.

In the early stages of design, the A/E shall strive to meet or exceed the minimum number of points needed for LEED certification under the rating system appropriate for the project in accordance with the VT CAC. The A/E shall determine the most cost-effective means of achieving these points, and shall take full credit for points achieved through compliance with other University standards that address sustainability issues, such as building commissioning. The A/E shall submit for the University's review and approval a LEED Project Checklist, identifying the specific measures proposed to be incorporated into the project to achieve the target number of points. The A/E should consider the ParkSmart certification for projects involving parking garages.

1.2.6 Waste Management

Virginia Tech is a jurisdictional member of the Montgomery Regional Solid Waste Authority. All members transitioned to single-stream recycling effective July 1, 2015.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

The Office of Sustainability in CPIF has developed the Virginia Tech Comprehensive Waste Management Plan to ensure compliance with all regulations and encourage the pursuit of methods and procedures to improve stewardship in the community. The latest edition of the plan is available on the Office of Sustainability website. The plan catalogs the current state of waste management on campus and provides the contact information for the responsible parties for waste disposal. The plan will be updated annually.

To achieve the recycle rate goal stated in the VT CAC, Virginia Tech requires an appropriate number of waste stations, both outside and inside of our facilities. All recycling containers for new construction and major renovations must be able to accommodate single-stream recycling.

1. Outside the building:
    a. The design of the waste management serving area shall:
        i. Accommodate an 8 cu. yd. single-stream recycling container and another 8 cu. yd. trash container placed side-by-side;
        ii. Provide enough space for sufficient access for personnel and vehicles in-and-out of the waste collection area; and
        iii. Provide an access route to accommodate an AASHTO WB-40 design vehicle. To accommodate this design vehicle during loading and unloading operations, a concrete road surface shall be placed along the entire width of the concrete slab and shall extend outward and perpendicular for the length of the concrete slab.
    b. Outdoor waste stations for personal use should consist of an appropriate number of pairs of containers placed side-by-side with one designated and labeled for "single-stream recycling" and the other designated and labeled for "trash." The containers must conform to our design standards for outdoor furnishings.
2. Inside the building:
    a. Indoor waste stations shall consist of an appropriate number of pairs of non-combustible collection containers placed side-by-side with one designated and labeled for "single-stream recycling" and the other designated and labeled for "trash."
    b. Ideally containers will be recessed into the interior walls of the building so as to not protrude into the hallway space. If that is not possible the containers shall be placed on the floor and secured to the building structure to meet fire code.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. The quantity and design for indoor waste stations in residential buildings will vary. Coordinate with Student Affairs during the initial design.

1.3 Design Approvals and Permits

The A/E of record shall supply all materials and data necessary for required reviews by the University and state boards and departments. OUP shall be consulted on any requirements.

All projects requiring approval, whether by the Board of Visitors or Virginia Art and Architecture Review Board (AARB), shall provide:

1. Project data sheet
2. Written narrative
3. Rendered site plan – one with and one without labels
4. Rendered planting plan – one with and one without labels
5. Planting schedule
6. Color-coded rendered floor plans with legend: one set showing furniture with no labels, one set not showing furniture or labels, and one set showing both furniture and labels
7. Exterior perspective renderings (including entourage): all cardinal elevations and major project elements. Rendered elevations may be substituted for projects that are small in scale by permission from OUP.
8. Illustrative images – building materials and plantings
9. Material samples
10. Cost estimates – reflective of the designs shown in these materials

Projects shall not be eligible for a review if cost estimates do not show the designs depicted as within budget. No A/E logos shall be included on submission materials. OUP shall be consulted for any additional examples of presentation materials.

1.3.1 Virginia Art and Architecture Review Board

1. All projects involving the new construction of a facility, the removal, remodeling of, or addition to an existing facility, or the attachment/placement of any appurtenant structures to an existing facility must receive design approval by the AARB. This requirement does not include ordinary maintenance and repair.
   a. Submittals to the AARB are required at the schematic and/or preliminary design stages. Consult with OUP for project-specific requirements.
   b. All capital projects and all major renovations that require AARB approval shall budget for two presentations by the A/E of record to the AARB.

2. All demolitions of structures with state building numbers requires review by the AARB. The review by the AARB takes place as part of the submission to the Governor.
3. All works of art to be placed in, upon, or to extend over any university property for a period of more than two years must receive approval by the AARB.

1.3.2 Board of Visitors

All capital projects and demolitions of structures with state building numbers require approval by the Board of Visitors. Regular Board of Visitor meetings are held quarterly, typically in the months of March, June, August, and November. Documents are typically required to be submitted approximately two months prior to the meeting. Coordinate with the Virginia Tech Project Manager (VT PM) and OUP regarding specific meeting dates and submittal deadline dates.

1.3.3 Virginia Department of Historic Resources

The Virginia Department of Historic Resources (DHR) provides input to the Governor regarding demolition of any structures with state building numbers.

1.3.4 Environmental Impact Reports

The University will procure and submit an Environmental Impact Report (EIR) when a project or real property acquisition has a total project cost of $500,000 or more as defined in the *Code of Virginia* § 10.1-1188. Regulatory authority is assigned to the Virginia Department of Environmental Quality (DEQ) in *Code of Virginia* § 10.1-1191. Submission requirements can be found at the Virginia DEQ website. An EIR may not be required by DEQ for interior renovations and work covered by a previous EIR. However, the University will submit its request to DEQ citing the nature of the work and justification for excluding the project from the requirements for an EIR. DEQ will decide the validity of the request and provide a written response on its findings.

OUP must receive all EIRs prior to issuance to the DEQ to allow for coordination with the DHR.

1.3.5 Design Standard Waiver Requirements

The DCSM shall be used on all university projects. Deviations from the standards require pre-approval through the use of the design standard waiver. See the VT Design Standard Forms Library for the link to the VT Design Waiver Request.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.3.5.1 Initiating a Request

The A/E shall provide the initial request for the design waiver to the VT PM. It is the responsibility of the A/E to provide supporting documentation to the VT PM when the initial request is made.

If a design decision requires a waiver, the A/E shall submit the waiver to the VT PM promptly for resolution during that phase of design. Submit design waiver requests as soon as the need for a waiver has been identified, regardless of where that is in the design process. Waivers will be considered upon their merits. Failure to submit a timely waiver is not a consideration.

To facilitate the approval process, the VT PM shall use supporting documents in preliminary discussions with all affected departments, including review comments and responses, and should obtain written approval of the design change from each of the affected departments.

1.3.5.2 Signature Routing and Approvals

The VT PM shall initiate a design waiver request and include supporting documents for electronic approval routing. Statements of agreement (emails, meeting minutes, etc.) from the departments affected by the design change shall be included as supporting documents for the waiver.

The design waiver approval sequence is based on the type of project. The VT PM must initiate the routing for Capital Construction, Renovations, Engineering Services, or Electro-Mechanical Operations projects. Refer to the Design Waiver Approval Routing Flowchart on the Design and Construction Standards home page for the latest approval routing path for design waivers.

1.3.5.3 Design Reviews and Permits

To prevent unnecessary comments on design changes during each phase of drawing review, submit approved waivers as part of each design phase submission.

Approved waiver requests shall be included with 100% drawings for permit requests prior to plan review. Permits will not be issued for projects with unresolved waiver requests.

1.3.6 Environmental Permits

Before the start of construction, projects with wetland impacts must have obtained the appropriate permits from the regulating federal, state, and local agencies. This includes the Virginia Department of Environmental Quality, the Virginia Marine Resources Commission, and the U.S. Army Corps of Engineers.

1.3.7 Land Disturbance Permits

Virginia Tech's Annual Standards and Specifications for Erosion and Sediment Control and Stormwater Management (VTAS&S) program is managed by Virginia Tech Site and Infrastructure Development (SID). As part of that program, SID issues Land Disturbance Permits for all regulated projects on university property. See the VTAS&S for more information and for permit requirements.

The Virginia Tech Land Disturbance Permit does not replace the requirement for the Contractor to submit for a DEQ Construction General Permit when applicable. Information for the Construction General Permit can be found on the DEQ website.

1.3.8 Building Permits

The UBO is the authority for code and standard compliance for all construction activities on university property and/or buildings. The UBO is responsible for the review of the working drawings/bid documents to assure conformance with the applicable codes and standards established. The A/E shall design to all applicable codes and standards regardless of the UBO review. A building permit shall be issued by the UBO and is required for work in accordance with the VUSBC.

The VT PM shall submit an Application for Building Permit (HECO-17) to the UBO. Any required permits for projects shall be obtained through the UBO.

The construction documents submitted for Building Permit shall have sufficient information, sizes, dimensions, details, material descriptions, loads and load capacities, plans, sections, elevations and details for the UBO to determine that the proposed work conforms to the requirements of the Building Code and applicable standards and policies. For most projects, this submittal will be plans and specifications. For repairs, remodels and minor improvements, it may be plans and specs or sketches with dimensions or even a narrative of the work to be done. In any case, the documentation must describe what is to be done and show that the work will conform to the requirements of the building code and applicable standards and policies.

1.3.8.1 Partial Building Permits

When Construction Management at Risk and Design-Build procedures are used, the opportunity may exist for construction to start before the complete building design has been finalized. Ensure all required Virginia Department of

General Services (DGS) forms are submitted prior to issuance of partial building permits.

Partial building permits can be issued for early construction. If partial permitting is used, a separate building permit submittal shall be made for each portion of the work. Subsequent building permits shall supersede any previously issued partial permits with the full building permit governing the project once that permit is issued. The manner in which the project is separated into partial permits shall be subject to the approval of the UBO.

The minimum required submittal is the complete working drawing submittal as described in DCSM section 2.7 and the working drawing checklists.

1.3.8.2 Demolition Permits

The VT PM shall apply for a Demolition Permit, HECO-17.1, to the UBO. Use the current edition of the HECO-17.1 on the VT Facilities Forms web page. The following attachments are required with the submission of the HECO-17.1:

1. Copy of the submission to the Governor regarding the planned demolition. The AARB hearing date for the submission shall be a minimum of 30 days prior to the application for the demolition permit.
2. Photographs of exterior and interior of building.
3. Site plan or aerial image.
4. Other information as deemed appropriate by the University to support the application.
5. Clarifications of information for the HECO-17.1 form.
6. Completed surveys of hazardous materials (asbestos and lead paint). If hazardous materials were found and not previously abated, abatement designs must be complete and incorporated as part of the Demolition Contract.
7. Completed Date of Release by Utilities with Release dates noted (no future dates accepted). The only exception allowed is when the Releases are required as part of the Contractor’s work in the Demolition Contract, which shall be noted on the HECO-17.1.

1.3.8.3 Permits for Temporary Structures

1. Permits allow the erection, use, and occupancy of temporary structures, subject to the stipulations on the permit.
2. Hazards or deviations in use from the permit must be corrected or the permit will be revoked and the structure must be removed.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. A Permit/Temporary Certificate of Use is required for all:
    a. Tents
        i. Greater than 900 sq. ft., or
        ii. Having an occupancy exceeding 50 persons;
    b. Events with anticipated participants over 300;
    c. Stages and platforms;
    d. Amusement devices as defined by the Virginia Amusement Device Regulations such as, but not limited to, climbing walls, bouncy houses, zip lines, Ferris wheels, and other motor-driven rotating machines;
    e. Any structure within 20 feet of another structure, equipment, or plantings;
    f. All construction trailers; and
    g. Similar temporary structures which are not a part of an existing structure.
4. Tents located at or within 20 feet of each other will be considered as one virtual tent for square footage calculations. The combined square footage for the virtual tent may lead to additional requirements for the permit application.
5. All temporary structures must meet building permit guidelines and the requirements of the following documents:
    a. VUSBC or the Virginia Industrialized Building Safety Regulations and Virginia Manufactured Home Safety Regulations
    b. Virginia Statewide Fire Prevention Code (VSFPC)
    c. American Society of Civil Engineers 37 (ASCE 37)
    d. Virginia Tech Design and Construction Standards Manual
    e. Virginia Tech Policy No. 5406, Requirements for Temporary Structures/Tents/Stages/Amusement Devices
6. All temporary structures must meet Accessibility requirements. An Accessible path must be available from the public way or Accessible parking to the entrances and activities conducted in the temporary structure.
7. All applications for permits for temporary structures must include the fully completed online application for the permit, a site plan, and a floor plan.
8. Additional documents required for permit applications for temporary structures will vary based upon the type, size, and location of the structure. Applications may require engineered drawings or certificates of flame resistance.
9. Applications and all supporting documents must be submitted at least 10 business days, preferably 30 days, before the proposed day of erection or first use of the temporary structure.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.3.8.3.1 Length of Use

Temporary structures used 180 days or less can include tents, stages, platforms, bleachers, amusement devices, or other structures.

For structures designed to be used for more than 180 days, the location and the aesthetics of the proposed structure shall be approved by the AARB.

1.3.8.3.2 Location and Erection of Structure

1. Tents or membrane structures shall not be located within 20 feet of lot lines, buildings, other tents or membrane structures, parked vehicles, or internal combustion engines. For the purpose of determining required distances, support ropes and guy wires shall be considered as part of the temporary membrane structure or tent. Exceptions may be approved by the UBO.
2. All structures and equipment used as part of the temporary structure must not damage or interfere with any underground utilities.
   a. If the temporary structure will be staked, Virginia 811 (va811.com) must be contacted at least 5 business days before assembly and erection of the structure.
   b. No ground pins, stakes, or other devices shall be implanted and the temporary structure shall not be assembled until the underground utilities are marked.
3. If an existing means of egress or emergency access is to be blocked or impaired by the temporary structure, an alternate means of egress or emergency access must be provided.
4. Structures may not be erected before a permit is issued.
5. Structures may not be erected more than two days prior to the event and must be disassembled and removed within two days after the event.
   a. Exceptions to this policy may be requested in writing. In such cases, the supplier/installer shall acknowledge responsibility for safety and security of the structure and area.
   b. Any structure that is planned to be erected for more than two weeks shall submit engineered plans and calculations to the UBO for approval.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.3.8.3.3 Submittals for Permits

1. Site Plans
   a. Show the location of the structure and indicate distances to adjacent buildings or structures (permanent or temporary), equipment, and plantings.
   b. Show Accessible routes from the temporary structure to the public way and/or Accessible parking areas.
   c. Indicate property lines, roads, sidewalks, and grades greater than 5%.
   d. Indicate the method of tie-down or anchorage, including the proposed wind and live loads, for tents and other temporary structures that must be secured to the ground.
   e. Indicate the means of egress lighting, exit signage, and power for structures that are proposed to be used at night.
2. Engineered Plans and Calculations
   a. All engineered plans and calculations must be prepared by a licensed Virginia engineer and must provide ballasting or staking requirements to withstand modified wind loads per ASCE 37 as an alternate method to satisfy the VUSBC and VSFPC.
   b. Engineered plans and calculations are required in the site plan for:
      i. Ballasted tents that are 2,400 sq. ft. or less; these must be designed for 40-mph wind loads.
      ii. All tents or virtual tents (multiple tents located within 20 feet of each other) greater than 2,400 sq. ft., whether staked or ballasted; these must be designed using ASCE 37.
   c. Engineered plans for staked structures (tents, inflatables, etc.) must consider the soil conditions for the location to ensure the stakes can withstand wind loads per ASCE 37.
3. Floor Plans
   a. Provide a description of the function or activity to take place.
   b. Indicate the proposed maximum occupant load.
   c. Indicate the means of egress, aisles, exits, furnishings, and equipment. Indicate Accessible paths within the structure.
   d. Indicate the method of ventilation and when tents are proposed to be conditioned.
4. Provide a certificate of flame resistance for each tent. Include tent serial numbers and descriptions (size, color, etc.) on the certificates.

1.3.8.3.4 Safety and Inspection

1. Open flames, space heaters, and food cooking or heating devices (except approved electrical appliances) are not permitted under or within 20 feet of a tent. A waiver may be reviewed on a case-by-case basis by the UBO.
2. If wind speeds of 40 mph or greater are forecasted, then the top must be removed for all tents that do not have engineered plans and for all ballasted tents that are 2,400 sq. ft. or less.
3. The UBO shall inspect the installation for compliance with the approved documents.

1.4 Project Design

1.4.1 Pre-design Conference

The VT PM shall arrange for a pre-design conference for all capital projects and appropriate non-capital projects. Participants should include university representatives and the A/E Project Manager and the responsible A/E in each discipline (architect, civil, structural, mechanical, electrical and others if needed). The purpose of the pre-design conference is to clarify the procedures, needs and requirements for the particular project. For projects pursuing LEED, the pre-design conference can serve as the initial meeting in the certification process.

1.4.2 Value Engineering

Capital projects with a project cost greater than $5 million shall have a 40-hour Value Engineering (VE) Study conducted on the design according to the *Code of Virginia* § 2.2-1133. The study shall be conducted by a qualified VE Team concurrent with the preliminary design review utilizing the five-step job plan as recognized by the Society of American Value Engineers (SAVE). A presentation of the study results shall be made to the University. The University shall be provided a summary of cost savings that have been incorporated into the design as well as potential cost savings that were considered but not incorporated.

For projects that are designed utilizing the Design-Build method and have the value engineering process as an integral component, the VT PM shall participate in all cost savings decisions before modifications to the design may be finalized. All stakeholders and the VT PM shall be provided a summary of cost savings that have been incorporated into the design as well as potential cost savings that were considered but not incorporated. The summary is not a Value Engineering Study as defined by DCSM section 1.4.2.1. The summary shall be reviewed and re

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

commendations shall be made to the VT PM prior to approval of preliminary design documents and prior to the issuance of any building permits.

The Construction Manager at Risk construction delivery method does not require a VE study per the policies set by CC.

1.4.2.1 Scope of VE Study

The VE Study shall be made by a multi-discipline team of five VE qualified professionals. The VE report shall encompass the recommendations of the VE study group and include detailed cost estimates, life cycle analysis and sketches, as necessary. VE services shall be performed in a timely manner concurrently with the normal preliminary design review.

1.4.2.2 Qualifications of VE Team

The VE proposer/consultant shall provide one team consisting of a Certified Value Specialist Team Leader and at least one licensed architect and one licensed professional engineer from each discipline which have significant work on the project, separate and completely independent from the Project A/E and its consultant firms.

The VE Study shall be coordinated, supervised and led by a person having Certified Value Specialist (CVS) credentials that qualify him/her to perform such services. The CVS shall be certified by SAVE and shall have had a minimum of eight years combined college education and practical on-the-job VE experience. Practical experience is considered to have been gained by being actively engaged as a consultant in VE activities.

Members of the team shall be registered architects and professional engineers licensed in the Commonwealth of Virginia. Team members shall be knowledgeable of the design and operational requirements and characteristics of the systems applicable to their discipline and the type of facility being studied.

1.4.2.3 Information Supplied to the VE Team

Prior to commencing the VE study, the A/E will forward the following information to the VE Team in the format requested and with the number of copies requested for each:

1. Preliminary design drawings
2. Outline specifications and systems checklists
3. Detailed cost estimate

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4. Basis of design
5. Design calculations (structural, mechanical, electrical)
6. Boring logs and soil reports
7. Scope of project/program requirements

1.4.2.4 VE Report Requirements

The results of the VE study performed on the project shall be documented as follows:

1. Contents page
2. Brief description of total project and project requirements with a copy of the university program requirements
3. Brief summary of VE recommendations
4. One site plan, floor plan and elevation on 8-1/2″ × 11″ or fold out
5. Summary sheet (only) of preliminary design cost estimate
6. VE cost model of project
7. Each VE recommendation shall be described Before and After VE and shall be accompanied with a detailed cost estimate of savings, life cycle cost analysis and sketches as necessary.
8. Complete Six Step Job Plan (workshops) of all work shall be submitted as appendices for reference.

All reports shall be systematically assembled and must be short and concise, yet informative enough for decision making. VE Reports shall be prepared and submitted on 8-1/2″ × 11″ bond paper and bound under hardback cover appropriately identified. Sketches may be 8-1/2″ × 11″ or fold-out. Pages must be sequentially numbered in the lower right-hand corner to facilitate assembly. Tabs should be used for quick reference of important sections of report.

1.4.2.5 Oral Presentation

At the completion of the Value Engineering Study, the VE team leader and members as appropriate shall make an oral presentation to the University and the Design A/E of the items recommended to be implemented on the project.

1.4.2.6 A/E Participation

The design A/E responsibilities include the following:

1. Present an overview of the project criteria and development to the value engineering team.
2. Provide comments on the VE study report to the University within 14 days of receipt of the report.

3. Participate in joint preliminary design review/VE resolution meeting at Virginia Tech, if required.
4. Submit a final report within 14 calendar days of the resolution meeting to the University.
5. Implement all finally accepted VE recommendations into the project design.

1.4.2.7 Criteria Challenge

In the package of documentation which the design A/E prepares for the Value Engineering Consultant, the design A/E may include a Criteria Challenge Package to question specific project design criteria, instructions and/or user requirements and to identify alternate items or procedures that might satisfy the required functions at a lower life cycle cost.

Each challenge must include Code references, a life cycle analysis supported by recent research and testing, and any calculations that are necessary to support the challenge. A brief narrative describing the advantages, disadvantages and magnitude of potential savings shall be included as well.

The Criteria Challenge Package with the documentation provided to the Value Engineering Consultant shall be marked VALUE ENGINEERING and submitted with the preliminary submittal to the University.

1.4.2.8 A/E Action on VE Study

The following clarifies the specific submittals and approval procedures required for the VE Study responses and proposed action:

1. Both the University and the A/E shall review and evaluate the Value Engineering recommendations. Not all VE recommendations are automatically appropriate for inclusion in state projects.
2. The A/E shall provide a written comment and/or evaluation of each VE recommendation to the University along with the A/E recommendation to accept, to reject, or to accept with modifications each VE recommendation. The A/E shall also provide its responses to the University's preliminary review comments.
3. The A/E shall provide justification for rejection of, or modification to, any VE recommendation.
4. The A/E shall prepare a Summary of Value Engineering Recommendations and indicate its recommended disposition of each item. The completed electronic summary sheet shall accompany the detailed responses sent by the A/E to the University.

5. The University shall review the A/E evaluation and recommendations on the VE Study and the A/E responses to the University's review comments. The University shall indicate its proposed action (acceptance, rejection, or acceptance as modified) on the summary sheet.
6. If any proposed action deviates from the requirements of the VUSBC or the DCSM, the VT PM shall submit a request for code modification or waiver of the DCSM requirements for each item along with appropriate justification.
7. Upon resolution of the VE Study and comment responses, the HECO-5 will be approved and authorization given to prepare working drawings.

1.4.3 Life Cycle Costs and Energy Analysis

The Building Life Cycle Cost Summary worksheet (form DGS-30-228) can be used to calculate costs.

Costs are to be computed over a 30-year period, except as noted below.

Table 1-1. Time Periods for Life Cycle Costs

Building Envelope Studies	30 years
Central Heating/Cooling Plants	30 years
Building Heating, Ventilation, and Air Conditioning (HVAC) Systems	20 years
Fuel Selection Studies	20 years

Costs for each alternative must be shown on the Life Cycle Cost Worksheet. Include appropriate backup to support the summary figures shown on the worksheet (i.e., indicate how the various costs were calculated and note the basis or source of the cost data).

Average service lives of mechanical equipment shall be based upon the Average Service Life shown in the ASHRAE Applications Handbook.

The type of system and the energy source shall be clearly noted on the Life Cycle Cost Worksheet.

The supporting backup shall clearly show the various fuel/energy rates ($/gallon, $/kWh, etc.) and the data source for each.

1.4.3.1 Instructions for Completing Worksheets

1. Use a new Worksheet for each alternative.
2. Complete all general information at the top of the Worksheet.
3. Fill in columns "a" thru "f" for each year. Use escalated costs. On the Worksheet, specify the annual escalation rate used for each cost category. In

the supporting documentation, identify the source/basis for the chosen escalation rates.

4. Sum columns "a" thru "e" for each year; subtract salvage value (column "f") and place results in column "g."
5. Multiply the column "g" figures by the corresponding discount factor in column "h" and place results in column "i."
6. Sum column "i" and place results in the box at the bottom of the Worksheet.

1.5 Project Submittal Standards

1.5.1 Project Submission Requirements

The A/E shall provide adequate copies of plans, specifications, cost estimates, and other applicable data to the VT PM. An electronic version of all documents is required with each submittal. The VT PM will distribute appropriate documents (both electronic and hard copy) to the UBO and Site and Infrastructure Development (SID) for permit reviews and to Engineering Services and OUP for the University's use and review. SID submittal is required only when land disturbance is involved. See the VTAS&S for more information. Specific projects may have different requirements; coordinate with the VT PM.

Minimum hard copy requirements for documents submitted to the VT PM by the A/E:

1. Construction site – one full-size stamped copy of all approved plans, specifications, and narratives including the approved erosion and sediment control (ESC) and stormwater narratives (as applicable)
2. OUP – one full-size copy of the plans, specifications, and narratives of each design phase submittal
3. Engineering Services – one full-size copy of the working drawing submittal and the approved plans, specifications, and narratives

1.5.2 Capital Project Initiation

The University will be authorized to initiate the design of a capital construction project upon receipt of an approved HECO-2. The University shall notify (using the form CO-2A) the chief administrative officer of the county, city, or town in which the University intends to undertake the capital project. The CO-2A shall be submitted at the initiation of the EIR.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.5.2.1 Preplanning Studies

Preplanning studies are authorized to allow the University to develop a more detailed definition of cost and scope for a future capital budget request. A preplanning study may include the following elements, as appropriate:

1. Statement of program definition including functional space requirements, estimates of gross and net square footage, and functional adjacency requirements;
2. Analysis of program execution options, including review of new construction versus renovation alternatives, necessary phasing or sequencing of the project, and coordination with other ongoing or proposed capital projects;
3. Site analysis, including options considered and, for the site chosen, any specific issues related to topography, utilities, or environment;
4. Condition assessment of systems or infrastructure elements such as roofs, plumbing, or electrical to determine the extent of repair or replacement work that needs to be done;
5. Presentation, including site plan, conceptual floor plans and elevations, and conceptual exterior;
6. Identification of any VUSBC compliance or permit requirements unique to the project; and
7. Cost estimate for the project to include total cost of the project, construction cost for the project, total cost per square foot, construction cost per square foot, costing methodology, and identification of any factors unique to the project that may affect overall project cost.

1.5.2.2 Construction Projects

The three-digit university code and the five-digit project code assigned to the project in the Appropriation Act shall be the basic project identifier for the life of the project. A project that will be accomplished by separate contracts at multiple locations or acquisitions at multiple locations; or a single project to be accomplished through two or more construction contracts, shall assign a three-digit sub-project code for each undertaking.

1.5.3 Non-capital Outlay Projects

Projects shall be designed by and sealed, signed and dated by a Virginia licensed A/E. The UBO may waive this requirement based on size and scope. Coordinate with the UBO. Working drawings ready for bidding and the appropriate information for the HECO-17 shall be submitted to the UBO for review and issuance of a Building Permit. Refer to DCSM section 1.3.8 for further information.

The CO forms in the table below shall be used for execution of the construction contract.

Table 1-2. CO Forms for Execution of the Construction Contract

CO-9	Contract Between Owner and Contractor
CO-9.1	Notice of Award
CO-9.2	Notice to Proceed
CO-10	Standard Performance Bond
CO-10.1	Standard Labor and Material Payment Bond
CO-10.2	Standard Bid Bond
CO-11	Contract Change Order
CO-12	Schedule of Values and Certificate for Payment
CO-13	Affidavit of Payment of Claims
HECO-13.1A	Certificate of Substantial Completion by Architect/Engineer
HECO-13.2A	Certificate of Substantial Completion by Contractor

1.5.4 Specification Standards

Specifications shall be in sufficient detail to describe without ambiguity, all materials, equipment, supplies and other pertinent information. Required tests and guarantees shall be indicated in the specifications. The specific elements of the project manual may vary depending on project size. Coordinate specific requirements with the VT PM.

1.5.4.1 Project Manual/Specifications Arrangement

Specifications shall be on 8-1/2″ × 11″ sheets with bid sets preferably printed on both sides of the sheet. Font size shall be suitable for scanning and shall not be smaller than 10-point font size. The table of contents pages shall be dated with the same date as the drawings and shall be sealed and signed.
The project manual shall include:

- Table of Contents
- Notice of Invitation to Bid (refer to sample format in DGS-30-256)
- Instructions to Bidders (CO-7A)
- Prebid Question Form (DGS-30-272)
- Bid Form (refer to format in DGS-30-220)
- Standard Bid Bond Form (CO-10.2)
- Commonwealth of Virginia General Conditions of the Construction Contract (CO-7, CO-7CM, CO-7DB)
- Supplemental General Conditions, if applicable (refer to samples in DGS-30-376)
- Contract Between Owner and Contractor (CO-9)
- Workers Compensation Insurance Certificate (CO-9A)

- Standard Performance Bond (CO-10)
- Standard Labor and Material Payment Bond (CO-10.1)
- Change Order Blank (CO-11)
- Change Order Estimate (General Contractor) (GC-1)
- Change Order Estimate (Subcontractor) (SC-1)
- Change Order Estimate (Sub-subcontractor) (SS-1)
- Schedule of Values and Certificate for Payment (CO-12)
- Affidavit of Payment of Claims (CO-13)
- Certificate of Completion by Architect/Engineer (HECO-13.1)
- Certificate of Partial or Substantial Completion by A/E (HECO-13.1A)
- Final Report of Structural and Special Inspections (HECO-13.1B)
- Certificate of Completion by Contractor (HECO-13.2)
- Certificate of Partial or Substantial Completion by Contractor (HECO-13.2A)
- List of Drawings
- Submittal Register Format (refer to sample in DGS-30-364)
- Special Inspections List (HECO-6A, HECO-6B)
- Special Requirements for Low Slope Roofing Membranes (DGS-30-326)
- Division 1 – General Requirements, Special Conditions, etc.
- Hokie Stone Specifications
- Technical Specifications
    - Technical Specification Sections shall be numbered with appropriate section numbers corresponding to an industry-standard specifications format, such as one of the two CSI MasterFormat numbering systems. The numbering system shall be consistent within the entire submittal.
    - Technical Sections should, where possible, be subdivided into the Part I – General, Part II – Products, Part III – Execution format.
- Appendices containing Soils Report, Asbestos Inspection Survey Report, Lead Inspection Survey Report and/or other information pertinent to the project but not a part of the Work. Such material should be noted as "INFORMATION ONLY" for use by the Contractor.

1.5.4.2 Types of Specifications

There are three types of specifications used on state projects:

1.5.4.2.1 Non-proprietary and Performance Specifications

This is the preferred method of specifying materials, equipment and systems. A non-proprietary specification shall be written either as a generic performance specification (preferred) or as a specification naming a minimum of three manufacturers with model or series numbers.

A generic performance specification must be written to describe the required characteristics, performance standards, capacities, quality, size or dimensions, etc., of the item or system. A minimum of three manufacturers must be able to meet all requirements shown in the specification. The specification shall not be contrived to exclude any of the three manufacturers or to benefit any one manufacturer over any of the other manufacturers. The performance specification shall not name manufacturers or brand name products.

A non-proprietary manufacturer/model number-type specification must list at least three manufacturers with their respective model numbers. Each of the listed manufacturers/model numbers must be determined by the A/E to meet the specifications and be acceptable. If a named manufacturer pre-packages or pre-assembles its item or system, the model number shall be specified. If the named manufacturer(s) custom builds the item or system, naming of model numbers is not required.

The manufacturer/model specification must describe the required characteristics, performance standards and capacities which will be used to determine equal products as allowed by section 26 of the General Conditions of the Construction Contract, form CO-7. Do not specify extraneous characteristics that do not relate to the product's performance or suitability for the project. If only two acceptable manufacturers can be found and documented by model number but other equal products are acceptable if found by the bidder, the A/E may request permission from the VPCPIF, to list only those two manufacturers but consider equals if proposed by the Contractor.

1.5.4.2.2 Proprietary Specifications

A specification is proprietary if it specifies a product or requirements which only one manufacturer can meet but the product is available from multiple vendors or sources. Although a proprietary specification should be avoided because it restricts competition, circumstances such as space limitations, mandatory performance standards, compatibility with an existing system, etc., may leave no other reasonable choice.

Proprietary specifications may be used when approved by the VPCPIF. Refer to the VT CPSM for proprietary procurement procedures.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.5.4.2.3 Sole Source Specifications

A specification is sole source when it names only one manufacturer or product to the exclusion of others, or when it is contrived so that only one manufacturer, product, or supplier can satisfy the specification. Because it eliminates all competition, it can be used only in the most exceptional circumstances and under the strictest conditions. A product, piece of equipment or service which is available only thru an area franchised vendor is also considered to be a sole source item.

Sole source procurement may be used when approved by the VPCPIF. Refer to the VT CPSM for sole source procurement procedures.

1.5.4.3 Hardware Specifications and Schedules

Hardware specifications and schedules may be written to specify the applicable Builders Hardware Manufacturer's Association (BHMA)/American National Standards Institute (ANSI) standards and designations or the specifications and schedules may be written by specifying three manufacturers and model numbers for each item. In either case the specifications must give sufficient information of the type, size, function, finish, etc., for the vendor to know what is required and for the A/E to evaluate the submittals.

1.5.4.4 Approvals, Equals, and Substitutes

Deviations from design product specifications should be submitted for approval via a request for information (RFI) to the VT PM. Where color selections are available, provide three options from which OUP may choose.

1.5.4.4.1 Brand Names

Unless otherwise stated in the specifications, the name of a certain brand, make or manufacturer denotes the characteristics, quality, workmanship, economy of operation and suitability for the intended purpose of the article desired, but does not restrict bidders to the specific brand, make, or manufacturer. The brand names are shown to convey to the Contractor the general style, type, character and quality of article specified. If brand names are listed in the specifications, specify a minimum of three brands with model numbers.

1.5.4.4.2 Equal Materials, Equipment, or Assemblies

Any brand, make or manufacturer of a product, assembly or equipment which in the opinion of the A/E is the equal of that specified, considering quality, capabilities, workmanship, configuration, economy of operation, useful life, compatibility with design of the work, and suitability for the intended purpose, will be accepted unless rejected by the University as not being equal.

1.5.4.4.3 Substitute Materials, Equipment, or Assemblies

The General Conditions permit the Contractor to propose a substitute or alternate material, product, equipment, or assembly which deviates from the requirements of the Contract Documents but which the Contractor deems will perform the same function and have equal capabilities, service life, economy of operations, and suitability for the intended purpose. Examples of substitutes or alternates include proposing to substitute "precast concrete" for "cast-in-place concrete" floors or to substitute "precast concrete panels" for "masonry" walls. The Contractor's proposal must include any cost differentials proposed.

The University would have the A/E provide an initial evaluation of such proposed substitutes to include a recommendation on acceptability and indicate the A/E redesign fee to incorporate the substitution in the design. If the proposed substitute is acceptable to the University, a Change Order would be proposed to the Contractor to accept the substitute and to deduct the cost of the A/E redesign fee and the proposed cost savings from the Contractor's Contract amount. The University will have the right to limit or reject substitutions at its sole discretion.

1.5.5 Plans, Sections, and Details of Equipment or Systems

1.5.5.1 Design Intent

The drawings shall have sufficient plans, sections and details to generally indicate the intended equipment or system configuration in the space. Recognizing that it is often necessary to use some piece of equipment as a basis for designing, dimensioning and detailing, the drawings (but not the specifications) may be noted to indicate that the A/E has designed or detailed around a particular brand of equipment. In doing so, the A/E shall ensure that there is adequate space, capacity, etc., available to accommodate the other brands indicated in the specifications.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.5.5.2 Basis of Design

Where a particular manufacturer's product is indicated as the basis for design and detail, the following statement shall be placed on the drawing with appropriate noting/references:

"The design [detail] [section] shown is based on [manufacturer and model] equipment and is intended only to show the general size, configuration, location, connections and support for equipment or systems specified with relation to the other building systems. See specification section [xxx] for technical requirements pertaining to the equipment."

1.6 Site Planning Requirements

All projects on university property are required to comply with the DEQ-approved Virginia Tech Annual Standards and Specifications for Erosion and Sediment Control and Stormwater Management (VTAS&S) in addition to the DCSM. Consideration of stormwater management requirements shall be made early in the project planning and design process. Coordinate project-specific requirements with the VT Erosion and Sediment Control and Stormwater Management Program Administrator.

1.6.1 State Building Construction in Floodplains

New construction of state-owned buildings within the 500-year floodplain shall be in accordance with Executive Order 45.

1.6.2 SID Inspections

SID shall complete erosion and sediment control and stormwater management (ESC/SWM) inspections in accordance with the VTAS&S. Refer to the VTAS&S for specific SID inspection requirements.

ESC/SWM Inspections shall be made by DEQ-certified inspectors. For inspections that are only erosion and sediment control (ESC) inspections, the inspector shall be certified as an ESC Inspector through the DEQ. For stormwater management (SWM) inspections, the inspector shall be certified as a SWM inspector through the DEQ.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.7 Building Planning Requirements

1.7.1 Mock-Up Requirements

Provide a detail of a mock-up wall section that is representative of all building materials proposed for exterior. It should emphasize material joining, conditions, flashing, etc. Refer to VT Facilities Procedure 15134 and DCSM section 5.4.4 for more information on Hokie Stone design and construction procedures.

Provide a mock-up for pavers. Coordinate mock-up requirements with OUP.

Provide a detail of a mock-up wall section that is representative of all building materials proposed for the interior.

Mock-ups shall be standalone, separate, and not part of the final building. Approved mock-ups shall remain available for reference/review during construction, but shall be demolished and removed from project site prior to close out of project.

Specific mock-up requirements for renovation projects shall be determined by OUP.

1.7.2 Statewide Building Code Requirements

The building code for all university buildings is the current edition of the VUSBC with additional requirements and information in the DCSM.

The Virginia Department of Transportation (VDOT) has authority over structures (e.g., bridges) in the right of way that are not regulated by the VUSBC. Occupiable buildings located within the right of way are regulated by the VUSBC and are under the jurisdiction of the State Building Official.

1.7.2.1 Applicable Code

The A/E should estimate when working drawings will be completed and determine what code(s) will be in effect at that time. Where a new edition of the VUSBC is adopted during a project, the newest version shall apply to any project that does not have approved preliminary drawings as described below. Mixing of code requirements between two editions of the code is not permitted.

1. If preliminary drawings are approved during the 12 months before the effective date of a new edition of VUSBC, the applicable code will be designated by the UBO at the time of the preliminary approval.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. If construction of the project does not begin within one year of the approval of the Schedule of Special Inspections (HECO-6), the UBO will clarify if a newer version of code applies. Prior to reactivating a project that has been inactive for a period during which the effective code has changed, the UBO will determine what code applies and will confirm any change of code in writing. The plans and specifications shall be revised as necessary to comply.

1.7.2.2 Code Clarifications

Code clarification requests should be made in writing to the UBO. The following are code clarifications that shall be applied to state-owned buildings and structures.

1.7.2.2.1 Buildings at Colleges and Universities

1. Buildings for business and vocational training shall be classified and designed for the Use Group corresponding to the training taught.
2. Academic/educational buildings having classroom-type education functions (including associated professor/teacher office spaces), shall include the following additional requirements:
    a. Provide 72″ minimum corridor widths in the classroom corridors.
    b. Calculate the occupant load for each space based on Virginia Construction Code (VCC) Chapter 10 and the type of occupancy (not Use Group) of the space.
3. Buildings housing research, testing and science laboratories shall include a fire alarm system.
4. Dormitories, fraternity and sorority houses and similar dwelling units with sleeping accommodations – provide one of the following:
    a. Written university policy which prohibits the use of these residences as housing for persons/groups/occupants for periods of less than 30 days, or
    b. Design that complies with the most stringent requirements of both Group R-1 (hotels) and Group R-2 (dormitory)
5. Dormitory occupant load calculations and plumbing fixture calculations:
    a. The number of occupants shall be computed per VCC Chapter 10 with the following changes to the maximum floor area allowances per occupant:
        i. Dormitory sleeping areas – 1 occupant/50 net sq. ft.
        ii. Other occupied areas – 1 occupant/unit of area based on function/occupancy of space
        iii. Remaining areas – 1 occupant/200 gross sq. ft.

b. The minimum number of required plumbing fixtures shall be based on the occupant load and plumbing classification/occupancy, but will not include occupants identified in the “remaining areas.”

1.7.2.3 Accessibility Standards for University Facilities

The Americans with Disabilities Act, 1990: Title II, Subtitle A (and not Title III) applies to all university buildings and structures.

1.7.2.3.1 Conflicting Standards/Modifications

The 2010 ADA Standards for Accessible Design incorporates by reference editions of the International Building Code. The applicable code for the project shall be that which is adopted by the Commonwealth at the time of building design and permit, as described in DCSM section 1.7.2.1.

Where codes and standards conflict, the more stringent standard shall be used in designing Accessible facilities. That is, the code or standard more favorable or advantageous to the disabled shall be used. As ADA is a federal law, modification or waiver of the ADA law requirements cannot be granted by the University.

1.7.2.3.2 Clarifications for University Buildings and Buildings on University Property

Accessible facilities must be provided at the completion of construction. Adaptable facilities do not meet the requirements for Accessibility in state buildings and buildings constructed or placed on state-owned property.

Provide vertical grab bars in accordance with ICC A117.1 *Accessible and Usable Buildings and Facilities*. Vertical grab bars may be omitted from buildings with anti-ligature requirements. Vertical grab bars may not conflict with Accessible locations for toilet tissue dispensers. Toilet room accessories shall be located according to ADA requirements.

Clarification for sections in the 2010 ADA Standards for Accessible Design is provided in the following table.

Table 1-3. Clarification for Sections of the ADA Standards for Accessible Design

Category	Section	Clarification
Elevator Access	206.2.3	All passenger elevators shall be Accessible to the disabled.
Elevator Access	206.2.3	Exception 4 does not apply. Residential facilities shall include at least one Accessible route to connect each story and each mezzanine in multi-story buildings and facilities.
Stairways	210.1	All stairways shall be Accessible to the disabled.

Category	Section	Clarification
Stairways	210.1	Exception 3 does not apply. Aisle stairways for assembly areas shall comply with ADA Standards for Accessible Design, latest edition, Section 504.
Handrails	505.10	Handrail extensions shall not be turned to the side or back. Handrail extensions shall continue straight and parallel to the stair run.
Dormitories	233.3.1.1	Scope of fully Accessible dormitory rooms shall comply with this section; however, all dormitory rooms shall be located on an Accessible route and doors to all rooms shall be Accessible.
Employee Work Areas	203.9	All spaces and elements normally occupied by employees or the public in state-owned buildings, individually or shared, shall be fully Accessible.
Site Elements	201.1	Addition: Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of Way (PROWAG) dated July 26, 2011 shall apply to the design of site elements provided on state-owned property that are not regulated by the ADA Standards for Accessible Design, latest edition, and are not in the Virginia Department of Transportation Right-of-Way. The PROWAG guidelines are available for free download from the Access Board. These site elements are defined in PROWAG and are generally provided as part of an agency outdoor program.
Walk-in Coolers and Freezers	203.9	Walk-in coolers and freezers are considered employee work areas and shall comply with the requirements of Employee Work Areas, Section 203.9.
Unisex Toilets and Bathing Rooms	213.2.1	Comply with VCC Chapter 11 Section for Family or assisted-use toilet and bathing rooms.
Signs	216	Use the language from VCC Chapter 11 Section Signage as guidance for scope compliance.
Identification of Accessible Parking Spaces	502.6 and 2018 VCC, Section 1106.8	Signs (including the International Symbol of Accessibility, and identifying Accessible van parking spaces) shall be located 84 inches (2135 mm) maximum, and 60 inches minimum, above the finish floor or parking surface measured to the bottom of the sign. Additionally, provide a sign including the following language: PENALTY, $100-500 Fine, TOW-AWAY-ZONE. The bottom edge of the PENALTY sign shall be no lower than 4 feet above the parking surface.
Cabinets	225.2	Under counter and over counter cabinets may be defined as the same "type" if the same arrangement of shelves is provided to comply with the reach ranges specified in Section 308.
Lavatories	606	Comply with VCC Chapter 11 Sections Lavatories and Sinks.
Assistive Listening Systems	706	Use the language from VCC Chapter 11 Section Special Occupancies: Assistive Listening Systems as guidance for scope compliance. The technical criteria in the ADA Standards for Accessible Design, latest edition, shall be incorporated into the design. The Hearing Loop (the Audio Frequency Induction Loop System or AFILS) is the preferred technology in most facilities.
Benches	903	Where interior or exterior benches are provided, 5% minimum or at least one in each area shall comply with the

Category	Section	Clarification
		ADA Standards for Accessible Design, latest edition, Section 903. Grab bars and armrests are not required.
Maneuvering Clearance	305.7	Where either side of an alcove exceeds the dimension stated, the minimum maneuvering clearance shall be provided.
Vertical Grab Bars in Accessible Toilet Compartments	604	Provide vertical grab bars on the sidewall of wheelchair-accessible toilet compartments above the horizontal grab bar and on both sidewalls of ambulatory Accessible toilet compartments.
Vertical Grab Bars in Accessible Bathtubs	607	Provide vertical grab bars on the control wall of Accessible bathtubs.
Vertical Grab Bars in Accessible Transfer Shower Compartments	608	Provide vertical grab bars on the control wall of Accessible transfer shower compartments.

1.7.2.4 UBO Inspections

In addition to the required Special Inspections, A/E Inspections and Substantial Completion Inspection, the UBO will conduct construction inspections to assure that the work performed is in accordance with the approved building permit documents. See DCSM section 8.2 and the VT CPSM for information on the scope of Special Inspections and the A/E inspections.

1.7.2.4.1 Inspector Qualifications

Inspections will be made by an individual familiar with the project, with the knowledge, skill, and experience necessary to read and understand the documents, and meeting the following minimum criteria:

1. An individual certified by the Department of Housing and Community Development (DHCD) or by the International Code Council (ICC) in the specialty being inspected, and
2. A Virginia licensed Architect or Engineer

1.7.2.4.2 Required Inspections

Inspections will be performed in accordance with the code and will include, but may not be limited to, the following:

1. Footing excavations and reinforcement material for concrete footings prior to placement of concrete.
2. Foundation systems during phases of construction necessary to assure code compliance.
3. Preparatory work prior to the placement of concrete.
4. Structural members and fasteners prior to concealment.

5. Electrical, mechanical, and plumbing materials, equipment and systems prior to concealment. This also includes fire suppression sprinkler systems, clean agent systems and fire detection and alarm systems.
6. All Accessible restrooms, bathing rooms and public common area kitchens, lounges and other common use areas open to the public for required clearances, mounting heights and accessories.
7. Energy conservation material prior to concealment.
8. Any other inspections the UBO deems necessary to ensure compliance with code.
9. Final inspection.

Some of the required inspections may be included in the special inspections and the A/E inspections. Despite this, construction inspections shall be made of the work as it is being performed to assure that conditions inspected by the special inspections and the A/E inspections are preserved.

1.7.2.4.3 VT PM Responsibilities

The VT PM shall notify the UBO to schedule inspections by sending a request a minimum of five business days in advance of the requested inspection date. The request shall contain the following:

1. Project number
2. Project name
3. Type of inspection required
4. Contact information to schedule the inspections
5. Email address for follow up to the UBO Inspection Reports

The VT PM shall provide email verification that comments generated by the UBO Inspection have been resolved.

1.7.2.5 Underground and Above Ground Storage Tank Systems

Technical standards related to USTs and ASTs are contained in the DEQ Water Division Regulations: 9VAC25-580, Underground Storage Tanks: Technical Standards and Corrective Action Requirements; 9VAC25-91-100, Facility and Aboveground Storage Tank Registration Requirements; and 9VAC25-91-130, Aboveground Storage Tank Pollution Prevention Requirements.

All permits for storage tank installation or removal shall be processed through the UBO. The VT PM shall include Environmental Health and Safety (EHS) in project design discussions and provide EHS with a copy of the permit.

1.7.3 Space Planning

The space management program facilitates the procedures associated with the University's space management policy. It supports the decision-making and approval process for all space initiatives. For more information, see Appendix C: University Space Management and the University Space Management website.

Virginia Tech has square footage guidelines for designing space based on Virginia state standards and the Commonwealth of Virginia A/E Manual.

This is a living program and, based upon feedback from users, materials and guidelines will be updated on the University Space Management website to ensure continual improvements to the program for the benefit of the university community.

The following program space provisions, sizes, and criteria are program standards to be met unless a waiver has been approved by OUP. In building renovations, specified sizes and criteria may not be achievable in all cases. Space program spreadsheets or data sheets shall document such waivers.

1.7.3.1 Assigned Workspace

Assigned workspace includes offices and workstations that are assigned to individuals for long-term use. Sizing is based according to the position of the occupant as outlined in the table below. Workspaces can be designated as private, semi-private, or open. These designations are referenced when calculating circulation space.

Table 1-4. Assigned Workspace per Occupant

Role	Square Feet per Occupant
President	350 sf
Provost	300 sf
Assistant/Associate Provost	250 sf
Vice Provost	250 sf
Vice President	250 sf
Dean	180 sf
Assistant/Associate Vice President	180 sf
Assistant/Associate Vice Provost	180 sf
Assistant/Associate Dean	180 sf
Executive Director	180 sf
Director	150 sf
Department Chair	150 sf
Senior Associate Director	150 sf
Assistant/Associate Director	150 sf

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Role	Square Feet per Occupant
Professor	120 sf
Assistant/Associate Professor	120 sf
Collegiate Faculty	120 sf
AP Faculty	120 sf
Athletics Coach	120 sf
Senior Staff	120 sf
Research Associate	64 sf
Professor Emeritus	64 sf
Adjunct Faculty	64 sf
Professional Staff	64 sf
Office Manager	64 sf
Office Support Staff	48 sf
Graduate Teaching/Research Assistant	48 sf
Postdoctoral Fellow	48 sf
Research Assistant	48 sf

1.7.3.2 Shared Workspace

Shared workspace includes offices and workstations that are open to the public or are scheduled to individuals for short-term use (hoteling). Sizing is based on the desired layout for the space as outlined in the table below.

Table 1-5. Shared Workspace Sizing

Layout	Square Feet per Workspace
Open	30 sf
Semi-Private	48 sf
Private	100 sf

1.7.3.3 Support Workspace

Support workspace accounts for shared areas such as kitchen/break rooms, file/general storage, reception and waiting areas, copy/mail areas, coat storage, and the like. An area of 30 sq. ft. may be portioned for each full-time occupant to account for this space.

1.7.3.4 Conference Space

The purpose of conference space is to provide a comfortable area for group discussion and collaboration. Sizing is based on the desired seating capacity for the room as outlined in the following table.

Table 1-6. Conference Space Sizing

Seating Capacity	Square Feet per Room
4-6	150 sf
6-8	200 sf
8-10	250 sf
10-15	375 sf
15-20	500 sf

1.7.3.5 Support Space

Support spaces are to be incorporated into the design of new buildings and also into major building renovations where achievable. Recycling container storage rooms may not be needed for residence halls or dining halls. Coordinate with the VT PM for requirements for storage rooms and other specialized service rooms, such as hazardous material storage areas in research buildings.

Table 1-7. Support Space Guidelines

Space Category	Area Guideline
All Gender Restrooms	min. 72 nsf, min. 1 per floor
Lactation Room	min. 54 nsf, min. 1 per building
Housekeeping Closets	min. 56 nsf, min. 1 per floor or 2 per floor if floor exceeds 18,000 nsf
Housekeeping Supply Closet	min. 100 nsf, min. 1 per building
Recycling Container Storage Room	min. 100 nsf, 1 per building
Housekeeping Supervisor Office	min. 100 nsf, 1 per building
Preventive Maintenance Office	min. 120 nsf, 1 per building

1.7.3.5.1 All Gender Restrooms

1. All gender restrooms shall be included in each new capital project and major renovations at Virginia Tech. Coordinate project-specific requirements with OUP.
2. Every floor shall have one all gender restroom that complies with the latest edition of the ADA Standards for Accessible Design and is available to the general public. The all gender Universal restroom shall be located nearby the men’s and women’s multi-user restrooms whenever possible.

3. Appropriate signage shall be displayed for the restroom as well as directional signage if it is not feasible for the restroom to be located near the men's and women's multi-user restrooms.
4. Each all gender restroom shall be designed as a single occupancy restroom with appropriate locking and closer mechanisms for operation of the fully Accessible door. The door shall have an automatic operator.
5. The toilet, lavatory, and all required accessories shall comply with the latest edition of the ADA Standards for Accessible Design.

1.7.3.5.2 Lactation Rooms

1. Lactation rooms shall be included in each new capital project and major renovations at Virginia Tech. Coordinate project-specific requirements with OUP.
2. Lactation rooms shall be Accessible for mothers with disabilities, including those using wheelchairs. Apply reach ranges to the design for components of the room (e.g., countertop, sink, outlets, dispensers, coat hooks, blind or shade controls, and signage).
3. Physical space requirements:
   a. Room: Design for a minimum size of 9 feet by 6 feet.
   b. Doors and windows:
      i. Provide keypad access (preferable) or key lock access with an automatic lock upon closing.
      ii. Provide blinds or shades for any windows in the room. Windowless doors are preferred.
   c. Ventilation and lighting: Provide air conditioning and heat. Provide a ceiling light, preferably with a dimmer switch.
   d. Power: Provide a minimum of two outlets in the room. One outlet shall be centered over the countertop.
   e. Countertop: Design for a minimum size of 4 ft. wide and 2 ft. deep with tabletop height. Include an opening to allow seating at the countertop.
   f. Storage space: Provide cabinets above and below the countertop. Cabinets below the countertop shall have drawers and shall be to the side of the seating space at the countertop.
   g. Sink: Provide a sink with soap and a towel dispenser if a sink is not available in a close location to the lactation room. See DCSM section 5.13 for handwashing area requirements.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4. Furnishings and other provisions:
    a. Chair: Provide an upholstered chair with arm and back supports and a footrest and without casters.
    b. Sanitation: Optimally, provide disinfectant surface cleaner, disinfecting hand soap, and a diaper disposal bin as part of the sanitation arrangements for the room.
    c. Miscellaneous: Provide a coat hook, clock, and a trash can. Optimally, provide a bulletin board, magazine/literature rack, and a small refrigerator.
    d. Signage: “Lactation Room” or “Nursing Room” to identify the room and an “In Use/Available” sign for the door
5. Interior decorating style preferences should be provided by OUP. Minimally, the room should have a calm, pastel color. Components and trim should match the style, but still be easy to clean and disinfect.
6. Lactation rooms are not required on residential floors of residence halls. Coordinate with the VT PM.

1.7.3.5.3 Baby Changing Facilities

The A/E shall consider including baby changing facilities in design plans for new construction and large renovations. Baby changing facilities should be included in the design if the completed project will be frequently accessed by the public (athletics facilities, auditoriums or music venues, lecture halls, student activity buildings, etc.). Baby changing facilities are not typically included in residence halls; however, they should be considered for mixed-use facilities where non-residents/public members frequently access the facility.

For new construction, a minimum of one set of baby changing facilities should be provided in both men’s and women’s restrooms on the main entrance level. Alternatively, baby changing facilities may be provided in family or assisted-use restrooms. A baby changing facility may be located within a lactation room, but it cannot be the only baby changing facility included in the design.

For large renovations that include restrooms, a minimum of one set of baby changing facilities should be provided in both men’s and women’s restrooms on the main entrance level. Alternately, baby changing facilities may be provided in family or assisted-use restrooms.

Baby changing facilities may be furnishings or equipment. At a minimum, baby changing facilities shall include:

1. A table or wall-mounted baby changing unit that is suitable for changing the diaper of a child aged three or younger,
2. A wall hook for baby changing bags, and
3. Sufficient adjacent space to allow other patrons to access the restroom while the baby changing facility is in use.

The installation and operational configuration of wall-mounted or folding baby changing facilities shall not interfere with the clear floor areas required for Accessible routes within the restrooms, restroom doors, partition doors, and restroom fixtures or accessories. The baby changing facilities shall comply with all applicable codes and ADA requirements for Accessibility.

1.7.3.6 Single-User Toilet Facility and Bathing Room Fixtures

The plumbing fixtures located in single-user toilet facilities and bathing rooms, including family, all gender, or assisted-use toilet and bathing rooms that are required by section 1109.2.1 of the 2018 VCC, shall contribute, at an even ratio, toward the total number of required plumbing fixtures for a building or tenant space. Single-user toilet facilities and bathing rooms and family or assisted-use toilet rooms and bathing rooms shall be identified for use by either gender.

1.7.3.7 Lavatory Distribution

Where two or more toilet rooms are provided for each gender, the required number of lavatories shall be distributed proportionally to the number of water closets.

1.7.3.8 Labs

Lab space is sized according to the intended number of occupants, whether the lab will be used for research or instruction, and the level of intensity for anticipated lab activities.

Levels of intensity can be broken into the following three categories:

1. Highly intensive: Wet labs and labs with large equipment. Highly intensive labs include Textiles, Dramatic Arts, most labs in the College of Engineering, College of Agriculture and Life Sciences, College of Natural Resources, Physics, Chemistry and College of Veterinary Medicine.
2. Moderately intensive: Labs with moderate space requirements, including, Education, Psychology and Communications, Computer Science, Electrical, and GIS, and Music labs.

3. Non-intensive: Labs requiring computers but little in the way of other supporting equipment. Non-intensive labs include Social Sciences, Mathematics and Statistics, Business, and Public Affairs.

Table 1-8. Laboratory Sizing

	Highly Intensive	Moderately Intensive	Non-Intensive
Research Labs	260 sf/occupant	90 sf/occupant	25 sf/occupant
Instructional Labs	85 sf/occupant	60 sf/occupant	40 sf/occupant

1.7.3.9 Classrooms

Classroom space is sized according to both the desired quantity of seats as well as the seating arrangement that will be implemented. As seen in the following table, some seating configurations are not considered practical for large or small classrooms and therefore are not listed within certain seating capacity brackets.

Table 1-9. Classroom Sizing

Room Category	Seating Capacity	Movable Chairs with Tablet Arms	Fixed Chairs with Tablet Arms	Movable Tables and Chairs	Fixed Table and Chairs	Auditorium Seating
Seminar / Small Classrooms	0-25	20 sf	17 sf	21 sf	21 sf	-
Classrooms	26-49	17 sf	17 sf	21 sf	19 sf	-
Classrooms & Lecture Rooms	50-99	15 sf	13 sf	19 sf	19 sf	15 sf
	100-149	-	13 sf	19 sf	19 sf	13 sf
	150-299	-	-	19 sf	18 sf	12 sf
	300+	-	-	19 sf	17 sf	12 sf

1.7.3.10 Circulation Space

Circulation space as calculated in this section is for the use by internal VT staff and is not used for calculations submitted to the Virginia Division of Engineering and Buildings (DEB) for Building Efficiency Ratios. See DCSM section 1.7.3.11 for DEB requirements.

Circulation space accounts for the portion of non-assignable area which is required for physical access to other spaces. It includes areas such as corridors, lobbies, elevators, stairs, etc.

To calculate circulation space, a Circulation Multiplier is applied to the net area. In general, more circulation space is needed for open workstation layouts than for private workstation layouts. For this reason, the VT Square Footage

Calculator uses two Circulation Multipliers: one that is applied to workspaces, and another that is applied to all other space.

1. Workspace
   The Circulation Multiplier for workspace is applied to assigned, shared, and support workspace subtotals. The multiplier itself is calculated based on the ratio of open workstations to private workstations according to the following function:
   Circulation Multiplier = (0.2) (open workstation count/total workstation count) + 0.4
   This means that an additional 40% of workspace will be allocated for circulation if all workspaces are private or semi-private, and an additional 60% will be allocated if all workspaces are open.
2. Other Space
   The Circulation Multiplier for all other space is set at a constant 0.4.

1.7.3.11 Building Efficiency Ratios

1.7.3.11.1 General

Building efficiency is the ratio of Assignable Area to Gross Building Area expressed as a percentage and is determined based on the definitions and calculation procedures shown below. The minimum building efficiency ratios are a composite of the ratios or factors taken from recognized standards and are based on the definitions and procedures shown below. The minimum building efficiency ratios are intended to provide achievable minimum standards for design of an efficient, functional layout.

The definitions and procedures described below shall be used to determine the "Building Efficiency Ratio." Use the VCC definition of Building Area for determining the allowable area for the building for code compliance.

1.7.3.11.2 Definitions

Gross Area (GSF): The total area of all floors of a building measured to the exterior face of the exterior walls, or to the horizontal projection of the roof or floor above for areas that are not provided with exterior walls. This is not to be confused with the definition of "Area, Building" in the VCC which is used for building area limitations.

Assignable Area (ASF): The area or the sum of all areas on all floors of a building assigned to, or available for assignment to, an occupant, including every type of space functionally usable by an occupant except non-

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

assignable areas defined below. The area of a closet or private toilet within an office or suite space shall be included in the calculation of the assignable area of that space. Assignable square footage shall include only program-related spaces; however, not all program related spaces are necessarily considered assignable.

Non-assignable Area: The area or the sum of all areas on all floors of a building not available for assignment to building occupants but which are necessary for the general operation of the building. Non-assignable space areas include corridors, stairs, lobbies, foyers, atria, entry vestibules, walls, columns, elevators, mechanical shafts, toilets (common and public), janitorial closets, housekeeping, circulation, mechanical, HVAC, and utility spaces, structural areas, and open (shaft and atrium) spaces.

Housekeeping Area: That portion of the non-assignable area which is the sum of all areas of the building used for its protection, care, and maintenance. These include janitor's closets, storage areas for housekeeping supplies and equipment, trash rooms, and housekeeping locker rooms.

Circulation Area: That portion of the non-assignable area which is required for physical access to other spaces, whether directly bounded by partitions or not. Circulation space includes corridors, elevator shafts, stairs, loading platforms, entry vestibules, foyers, atria, lobbies, tunnels and bridges. When determining circulation area, only spaces required for general access should be included. Aisles which are used for circulation within open office suites, auditoriums and other work areas are included in the calculation of the assignable area.

Mechanical Area: That portion of the non-assignable area designed to house mechanical/HVAC equipment, mechanical shafts, plumbing and sprinkler risers, electrical equipment rooms/closets, telephone and communications equipment rooms/closets, other utility services, and common or public (non-private) toilet facilities.

Structural Area: That portion of the non-assignable area which cannot be occupied or put to use because of the presence of structural features of the building. Included are columns, exterior walls, fire walls, and permanent partitions.

1.7.3.11.3 Calculations

The areas shall be determined from the actual floor plans for the facility. Assignable square feet (ASF) as a percentage of gross square feet (GSF) shall be no less than the ratios listed below. Exceptions to these building efficiency factors for state-funded projects must be approved by the Director of DEB. Requests must be supported by written justification submitted by the University stating why these ratios cannot be obtained.

1.7.3.11.4 Building Efficiency Ratios

The baseline building efficiency ratio is 65% unless shown otherwise in the following table.

Table 1-10. Building Efficiency Ratios

Building Type	Ratio: ASF to GSF
Office/Classroom Building (where classrooms are 29% or less of the assignable area)	70%
Classroom Building	66%
Classroom and Office Building (where classrooms are 70% or more of the assignable area)	66%
Engineering/Laboratory Building	72%
Instructional Shop Building	90%
Library Building	75%
Fine Arts Building	72%
Science Building w/Laboratories	65%
Physical Plant Service Building	85%
Auditorium/Theater	70%
Warehouse	93%
Maintenance Garage	85%

1.7.4 Hazards

1.7.4.1 Electrical

Field labeling of arc flash hazards shall be provided per NFPA 70E-2018, 130.5(H).

High and low voltage equipment in the same space shall be separated in accordance with 29 CFR 1910.303(h)(5)(ii).

1.7.4.2 Procedures for Asbestos Abatement

Asbestos-containing materials (building materials that contain greater than 1% asbestos) which can be disturbed by demolition or renovation work shall be abated in university buildings. Asbestos-containing materials (ACM) shall not b

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

e included in any new construction. The University shall have existing structures inspected by a Virginia licensed or certified asbestos inspector for ACM prior to submittal of the preliminary design in accordance with the Asbestos Operations and Maintenance Program through EHS and the DCSM.

1.7.4.2.1 Renovation/Demolition/Addition Projects

All ACM that will be disturbed as a result of a renovation, demolition, or addition work must be removed. All suspect materials must be physically sampled and analyzed. The asbestos inspector shall provide the University with a report of the inspection which indicates those places where samples were taken, the results of the analyses, and drawings which indicate those areas, if any, where asbestos was found and where ACM must be abated. The asbestos inspection report must be made available to the project A/E for information and use in preparing the project documents.

If ACM is found, the University shall have a Virginia licensed or certified asbestos project designer coordinate with the A/E to prepare asbestos abatement project design specifications. The designer's license or certification number, name and signature shall appear at the beginning of the asbestos specifications. The project designer shall indicate on the construction drawings all locations where ACM is to be removed or will be disturbed. The asbestos inspection report is to be included as an appendix to the project specifications. The VCC requires a permit prior to the removal or disruption of any ACM during the construction or demolition of a building or structure, including additions. This permit may be issued by the UBO.

ACM is to be removed by a Virginia licensed asbestos abatement contractor. The asbestos abatement contractor shall indicate on record drawings the areas where asbestos was abated, areas where asbestos was encapsulated, and areas where ACM exist but were left in place.

The University will ensure that asbestos abatement project specifications are followed by using a Virginia licensed or certified asbestos project monitor to monitor the project and perform air quality testing throughout the duration and at final completion of the project. No asbestos materials are to be removed without the asbestos project monitor being on-site.

1.7.4.2.2 Asbestos Disclosure Statement

The A/E shall note on the Title page of the drawings and in the specifications for all projects that no ACM shall be used on the project. All pages of the

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

drawings shall have an Asbestos Disclosure Statement indicating one of the following:

1. An asbestos inspection was performed and no ACM was found. The asbestos inspection report is included as an appendix to the project specifications.
2. An asbestos inspection was performed and ACM was found generally in the areas indicated. However, the work in this project is not intended to disturb the existing ACM. The asbestos inspection report is included as an appendix to the project specifications.
3. An asbestos inspection was performed and ACM was found generally in the area(s) indicated. The asbestos inspection report is included as an appendix to the project specifications. The VT PM shall submit an application for permit to have the ACM abated by a licensed asbestos contractor using approved procedures as specified prior to issuing a Notice to Proceed to the General Contractor. Any ACM that is to remain and the new non-ACM shall be labeled accordingly. The asbestos abatement contractor shall mark up the record drawings resulting from its work to include areas where asbestos was abated and areas where ACM exist but were left in place. The General Contractor shall review and certify the locations where ACM was abated and areas where ACM was left in place as marked on the record drawings and will provide the drawings to the A/E.
4. An asbestos inspection was performed and ACM was found generally in the area(s) indicated. The asbestos inspection report is included as an appendix to the project specifications. ACM shall not be disturbed in this work except where specifically indicated and required. Where such actions are required, the Contractor shall have the ACM removed by a licensed asbestos contractor using approved procedures as specified. The work required for asbestos abatement is permitted within the overall building permit issued. The ACM that is to remain and the new non-asbestos-containing material shall be labeled accordingly. The asbestos abatement contractor shall mark up the record drawings resulting from its work to include areas where asbestos was abated and areas where ACM exist but were left in place. The General Contractor shall review and certify the locations where ACM was abated and areas where ACM was left in place as marked on the record drawings and will provide the drawings to the A/E.

1.7.4.2.3 Asbestos Contracting

The University has two contracting options for use in removal of asbestos from a structure, although option (2) is the preferred method:

1. A separate contract for removal of the asbestos prior to renovation, demolition or addition.
2. A contract where the abatement is an integral part of the renovation, addition or demolition project in which the General Contractor is licensed as an asbestos contractor or hires a licensed asbestos abatement subcontractor to perform the work.

1.7.4.2.4 Asbestos Related Work – Insurance Requirements

Section 11(e) of General Conditions of the Contract for capital outlay projects requires the asbestos contractor or subcontractor to name the A/E as an additional insured on the contractor's liability insurance with asbestos coverage. Where the A/E for the renovation project prepares the asbestos project drawings, the requirement of section 11(e) to name the A/E as an insured party is waived. Professional liability/errors and omissions insurance, with asbestos coverage, in an amount not less than $1 million is required.

1.7.4.2.5 Demolition/Renovation Notification Requirements

Any proposed demolition within or of a building which contains asbestos must be reported 10 working days in advance of any demolition and 20 working days in advance of any abatement activity to the Virginia Department of Labor and Industry (DLI). The United States Environmental Protection Agency (EPA) and the DLI interpret these regulations to include non-friable materials which may be disturbed and rendered friable by the demolition (or renovation) activity.

1.7.4.2.6 Removal of Spray-on Fireproofing

See DCSM section 3.10.4.3 for requirements on the removal of spray-on fireproofing materials.

1.7.4.3 Procedures for Lead-Containing Paint

The EHS Lead Hazard Control Program provides requirements on the use, handling, and disposal of lead and lead-containing materials, including lead-containing paint. Contractors shall follow all regulatory and DCSM requirements for lead-containing materials.

1.7.4.3.1 Lead Survey

For renovation, demolition, or addition projects, the University shall have the facility inspected for the presence of lead-containing paint by a Virginia licensed lead inspector or risk assessor and document all quantities and locations found. Where lead-containing paint is suspected or pre-determined, an estimated cost for any special procedures required shall be included in the cost estimate supporting the construction budget or budget request. In areas to be renovated, a copy of the lead inspection report shall be included as an appendix to the project specifications.

1.7.4.3.2 Lead Materials Disclosure Statement

The construction documents for all renovation, demolition and addition projects shall indicate all locations where lead-containing paint is to be disturbed or to remain, and shall include a Lead-Containing Paint Disclosure Statement indicating one of the following:

1. A lead-containing paint inspection was performed and no lead-containing paint was found.
2. A lead-containing paint inspection was performed and lead-containing paint was found in indicated areas. However, the work in this project is not intended to disturb existing lead-containing paint.
3. A lead-containing paint inspection was performed and lead-containing paint was found in the areas indicated. The Contractor shall be responsible for compliance with all VOSHA regulations regarding lead-containing paint protection for workers.

Following removal of lead-containing paint, additional Toxicity Characteristic Leaching Procedure (TCLP) tests in accordance with EPA guidelines shall be done on these materials to determine disposal requirements as hazardous waste or as ordinary construction debris. It is unlawful for materials identified as hazardous waste to be disposed of with ordinary construction debris.

1.7.5 Demolition of Buildings

Demolition of any building regardless of size and type shall be authorized by the Board of Visitors and the Governor prior to proceeding (*Code of Virginia* § 2.2-2402, B.). If the University submits a request to the Governor to remove a building constructed with general funds and the Governor fails to disapprove the new design in writing within 30 days of the AARB hearing date, the University has the authority to proceed.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Requests for demolitions of existing buildings which must be done to allow for the new construction should be requested before preliminary drawings for the new construction are prepared. The University is required to complete and submit the HECO-17.1 with the attachments listed in DCSM section 1.3.8.2 to request authorization to demolish any building or structure on state property.

1.8 Commissioning

Commissioning is the systematic process of review, documentation, inspection, and performance testing by a Commissioning Agent to assure that the facility and systems meet the University's requirements. Commissioning starts with the design and extends through the construction and the occupancy of the facility.

For most projects, the University will hire an independent, third-party Commissioning Agent or utilize the University's Facilities Commissioning Agent to provide the scope of commissioning services defined herein and in DCSM section 6.2. For some projects, the Contractor will be required to hire the Commissioning Agent and conduct the commissioning scope of work.

When commissioning services are not procured by the University or by the Contractor, the University may opt to provide the commissioning service using university representatives. In this situation, the Contractor would be expected to support the commissioning process in the same manner as an independent third party.

Virginia Tech shall be consulted on each project to determine who the Commissioning Agent will be and to identify the specific systems to be commissioned for the particular project.

1. Objectives
    a. Commissioning shall ensure proper, reliable, and safe operation of HVAC, plumbing, piping, electrical power, and communications systems upon occupancy of each facility.
    b. Commissioning may also ensure the proper selection, installation, and operation of other building systems, such as architectural systems, at the discretion of the University.
2. Commissioning Specifications
    a. When third-party commissioning or the University's Facilities Commissioning Agent is used, the independent Commissioning Agent or the university representative will develop the commissioning specifications for inclusion in the Project Documents by the A/E of record.

   b. When the Contractor is providing the commissioning services, the A/E shall be responsible for developing the appropriate commissioning specifications sections.
3. Systems to be commissioned shall be at the discretion of the University and based on the project's LEED goals and overall design. The A/E shall provide both the certification being sought and all the design aspects required for the certification to the appropriate Commissioning Agent for the system being certified. Design aspects shall be indicated on drawings and may include existing conditions and material use and disposal.
4. Contractors and subcontractors shall provide all necessary support for the successful completion of the scope of the commissioning work for the project. See DCSM section 7.4 for Contractor responsibilities for commissioning.
5. Completion resolution requirements for project closeout shall include:
   a. the review and recommendation of approval by the Commissioning Agent of operation and maintenance (O&M) manuals and warranty information, and
   b. the completion of all testing and the submission of all commissioning-related reports, certifications, and manuals.
6. The Contractor and Commissioning Agent shall coordinate the development of materials and methods for providing training on the operation and maintenance of all major equipment and controls.

1.9 Project Closeout

Every capital project which has an approved HECO-2 authorizing the project to be initiated shall be closed out by the completion and submission of a Project Completion Report, CO-14. This includes projects which may have been cancelled by the University and never constructed, projects where funds were reverted, projects which were combined with another project and the funds transferred, and projects where the funding was never allotted.

A project may be reported as 100% complete in the semiannual capital outlay status report when a Certificate of Use and Occupancy, HECO-13.3A, has been issued by the UBO. Upon issuance of the HECO-13.3A, the VT PM shall prepare the VT–New Building Information form and shall submit it to Risk Management. Coordinate with Risk Management for the latest version of the form.

The Project Completion Report, CO-14, shall be submitted to DEB as soon as practical after the project is physically complete and the associated administrative steps have been concluded, but no later than 12 months after the University occupies the building or the work has been accepted as substantially complete. Included in this generalized statement are such things as the Contractor's submission of warranty, operating manuals, maintenance procedures and other user required documentation; submission of the record drawings by the A/E; release of retainage to the Contractor and final payment for any outstanding invoices and other ancillary or associated work/equipment provided by vendors and contractors not associated with the general construction. If the requirements for the project close out as stated above cannot be met within 12 months, the agency shall submit a summary of the outstanding items and an estimated date (within 12 months) that the project can be closed out to DEB.

1.9.1 Final Cleaning

Final cleaning shall include, but not be limited to, cleaning in compliance with manufacturer's instructions, interior and exterior glass, mirrors, floors, other interior finishes, mechanical and electrical equipment, removal of stains and foreign substances exposed to view, vacuuming of clean soft surfaces, polishing of transparent or glossy surfaces, and other such requirements to leave the project area in finished condition. Final cleaning will be inspected by the VT PM.

1.9.2 Site Restoration

The Contractor is required to stabilize all disturbed areas in accordance with the project documents and the VTAS&S. Final site inspections will be completed by SID and the VT PM.

1.9.3 Record Reports

All projects require the submission of as-built information. Specific requirements for the different as-built documents are shown in the DCSM and the VTAS&S. Coordinate with the VT PM on specific requirements for the project.

1.9.3.1 A/E Statement of Preparation on Record Drawings and Specifications

The statement of preparation as shown below shall be affixed to each and every drawing sheet and on the cover and title page of the project manual of a completed set of "Record Documents." The drawings are not required to be sealed and signed. This criterion applies to documents created manually and in electronic formats. It is the expectation of the University that during the preparation of the record drawings and specifications the A/E is responsible to ensure that all information from Change Orders, RFIs, and other forms of document modifications used during the construction of the project are properly incorporated into the final record documents.

Statement of Preparation of Record Documents

These Record Documents have been prepared in part based on information provided by the Contractor in accordance with section 23, Plans and Specifications of the General Conditions of the Construction Contract. The A/E is not responsible for either errors in information provided by Contractor or others, or for information omitted by Contractor from the as-built drawings. Neither as-built drawings nor record drawings change or modify the duties and obligations of the A/E of Record to perform inspections in accordance with section 16, Inspection and section 44, Inspection for Substantial Completion & Final Inspection or other requirements of the contract.

____

A/E of Record Date

1.9.4 Operation and Maintenance Manuals/Data

A specific set of operating and maintenance instructions written for the specific project shall be provided to the University at the final inspection. This shall consist of a compiled document prepared by the A/E team for the project. These documents generally include the operation and control sequencing narrative, the control diagrams, an equipment chart indicating periodic maintenance requirements, and the operation and maintenance manuals for the equipment. All systems needing regular maintenance and requiring adjustments must be covered. The schedule for required minor and major maintenance must be included. Relevant design criteria and assumptions needed to understand the operation of the systems will be furnished in narrative form including the control systems settings and concept of operation. One hard copy and one electronic copy of the compiled documents, along with the record drawings and specifications, shall be provided to the VT PM.

Manuals which do not provide specific data but simply reference the drawings, specifications and manufacturers are not acceptable.

1.9.5 Warranties

Specifications shall identify product warranties that differ from the standard manufacturer's warranty for the product.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.9.6 Land Disturbance Permit/Construction General Permit Termination

The Contractor shall ensure compliance of all closeout requirements stated in the VTAS&S prior to requesting a land disturbance permit termination. The Contractor shall refer to the DEQ regulations in terminating the construction general permit, as applicable.

1.9.7 Certificate of Occupancy/Final Inspection

Final inspection shall be in accordance with chapter 8 of the DCSM.

1.10 Reporting Requirements for DEB

DGS is responsible for coordinating with, and collecting data from, other state agencies to compile legislatively mandated reports.

1.10.1 Capital Outlay Progress Report

1.10.1.1 Reporting Requirement

Virginia Tech is required to submit a report listing all active capital outlay projects. Active projects are defined as those for which an approved HECO-2 form has been issued. Projects are removed from the report the first reporting cycle following the submittal of the CO-14 form.

1.10.1.2 Reporting Frequency

The report is required to be submitted annually. The university report is due to DEB by July 30. The data reported shall encompass the previous fiscal year (July 1 through June 30).

1.10.1.3 General Instructions

Following are the general reporting instructions:

1. At least three weeks prior to the due date for the report, the University will be provided via email with an Excel spreadsheet of its portion of the most recent report submitted to the State Legislature.
2. The University shall edit this spreadsheet to show additions, deletions or changes in status as of June 30.
3. If a project shows no progress since the last report, an explanation must be given in the remarks column or on an attached sheet. Indicate the reason for lack of progress and what steps are being taken to get the project back on schedule.
4. Email the completed report to DEB at coforms@dgs.virginia.gov by July 30.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1.10.1.4 Specific Instructions

Following is an explanation of the data required in each column of the report. The data fields below are listed in the order in which they appear on the report.

1. Project Identification: 3-digit Agency or Sub-Agency Code, plus 5-digit Project Code under which the Appropriation is listed. Add the 3-digit Sub-Project code. Give abbreviated project title.
2. Biennium: Biennium in which the initial Appropriation was made. For even numbered years, use the double designation such as 2014-2016. For Appropriations made during the odd numbered years or mini-session, use 2015. Subsequent yearly or biennial additions or deletions to the Appropriation will be noted in remarks.
3. Appropriated Amount: Total of all funds appropriated for the project, including all funds added to or deleted from the project.
4. Obligated to Date: Value of all expenditures to date of all funds that are obligated by signed contract or purchase order.
5. HECO-2 Approved: Denotes date of approval of the initial HECO-2 by the Governor. Dates of revised forms are not required.
6. Design Percent Complete: Show percentages as follows:
   A/E hired (CO-3) 5%
   Design Criteria (schematics) Approved 20%
   Preliminary Plan & Specifications Approved 40%
   Working Drawings & Specifications Approved 100%
7. Interpolate percentages to indicate status between points denoted. If plans are not required to be prepared either by Consultant or In-House personnel, then mark Column 6 as 'N/A'.
8. Contract Amount: Figure denotes accepted low bid amount, plus or minus increases or decreases as generated by approved change orders. When a Contractor is not utilized (i.e., when the work is performed by the University), then use the budgeted amount for construction.
9. Construction Percent Complete: Show percentages as follows:
   Contract Awarded 1%
   Work Begun 10%
   Estimated Progress-Interpolate ....Between 10% and 95%
   Substantial Completion 95%
10. Estimated Completion Date: As shown on the HECO-8 and as revised by change orders or university estimate of substantial completion when work is

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

done by the University. Include in the listing the planned or estimated Construction Completion Dates for all Projects under design.

11. Remarks: Identify any variation to normal procedures in addition to those used as described in the explanation above (e.g., Project on hold, Contractor walked off site, or Project under litigation).

1.10.2 Value Engineering Utilization Report

1.10.2.1 Reporting Requirement

The Director of DGS is required by the *Code of Virginia* § 2.2-1133 to report to the Governor and the General Assembly on or before September 15 of each year, the following:

1. The number and value of the state capital projects where Value Engineering was employed.
2. The identity of the capital projects for which a waiver of the requirements of *Code of Virginia* § 2.2-1133, B was granted, including a statement of the compelling reasons for granting the waiver.

1.10.2.2 Reporting Frequency

The report is required to be submitted annually. University reports are due to DEB by July 15. This data reported shall encompass the previous fiscal year (July 1 through June 30).

1.10.2.3 General Instructions

At least three weeks prior to the due date for the report, the University will be provided via email with a data input form to complete. The University shall edit this form to list all VE studies completed during the reporting period. The University shall also list all projects which qualified for a VE study, but for which a VE study was not prepared. The reason for not having a VE study prepared shall be provided (i.e., "A waiver granted because the project was…").

Email the completed report to DEB at capout@dgs.virginia.gov by the specified due date.

1.10.3 Annual Permit Activity Report

1.10.3.1 Reporting Requirement

In accordance with the current adopted version of the VCC section on Permits, Types of Permits, and in accordance with the Annual Permit for Construction of State Owned Buildings and Structures, agencies with Annual Permit Authority

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

granted by the State Building Official shall maintain a detailed record of construction work performed under this delegated authority.

1.10.3.2 Reporting Frequency

The report is required to be submitted annually. University reports are due to DEB by January 31. This data reported shall encompass the period from January 1 through December 31.

1.10.3.3 General Instructions

Detailed records and the report format shall be as proposed by the University and approved by DEB. Submit the report to capout@dgs.virginia.gov.

1.10.4 State One- and Two-Family Dwelling Inspection Report

1.10.4.1 Reporting Requirement

In accordance with the current adopted version of the Virginia Maintenance Code section on Rental Inspections, agencies that own one- and two-family dwellings shall maintain a detailed record of the inspections of these structures performed prior to property acquisition, every five years, and as a result of a valid complaint by the resident. Interim inspections may be performed with the University determining the reporting criteria, inspection criteria, and timeline for correcting deficiencies. Inspectors shall be certified as home inspectors by DPOR.

Home inspection reports will be maintained for the University by the UBO. The timeline for correcting deficiencies found during inspections will be set by the UBO. The UBO will decide if the structure is fit for occupancy and will issue permits accordingly.

1.10.4.2 Reporting Frequency

University reports are due to DEB by January 31. This data reported shall encompass the period from January 1 through December 31.

1.10.4.3 General Instructions

Annual reports shall list the dwellings inspected, the factor instigating the inspection (acquisition, five years, or complaint), the inspection date and inspector's name, and deficiencies corrected and outstanding. Detailed records and the report format shall be as proposed by the University and approved by DEB. Submit the report to capout@dgs.virginia.gov.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 2 – DOCUMENT AND DRAWING REQUIREMENTS

Requirements for narratives and drawings for all phases of design are located in checklists labeled for the specific design phase and trade area. Checklists are available as downloads through the VT Design and Construction Standards website. Checklists will be updated as needed. Obtain the latest version of the checklist before submitting.

The A/E shall provide the applicable completed checklists with all submittals. Additional requirements during the design phases are in this chapter. It is the responsibility of the A/E to follow all project requirements.

2.1 Basis of Design Narratives

The basis of design and code compliance narratives are descriptions of the project submitted as a bound presentation of facts. Narratives shall be completed in accordance with the DCSM and narrative checklist requirements and shall be sufficiently complete to expedite university reviews of the appropriate submittals. Non-capital renovation projects may not require a complete basis of design narrative. Coordinate specific requirements with the VT PM.

Narrative requirements checklists for each phase of design shall be completed and provided with submittals. Checklists may be obtained through the VT Design and Construction Standards website as a downloadable package specific to each design phase. Provide the latest version of the checklists with submittals.

2.1.1 Specific Disciplines

When a project consists primarily of mechanical, electrical, structural, or another discipline, the basis of design shall provide more detailed information for the major discipline. The narrative shall address or list the factors indicated for each section. Data may be presented in tabular form where appropriate.

The importance of early resolution of fire protection requirements cannot be overemphasized.

2.1.2 Post-construction Basis of Design Update

The A/E is required to update the basis of design narratives to reflect the final design of the building. This includes any system changes during development of working drawings as well as any construction changes.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.2 Cost Estimate Standards

Accurate quantity take-off, inclusion of all appropriate standard systems, and accurate unit prices for the project's location are fundamental to the development of a good cost estimate. Properly prepared cost estimates provide a check of the plans and specifications for constructability, coordination, conflicts, discrepancies, and omissions. They are used to establish or verify budgets, to develop historical data for future estimates, and for verification of the Contractor's Initial Schedule of Values (CO-12).

At the conclusion of both the schematic design and the preliminary design phases for General Fund projects, the VT PM shall prepare and include an updated CR-2 (form DGS-30-198) indicating all of the anticipated soft costs for the project with the submission.

2.2.1 General Cost Estimate Requirements

1. Separate estimates will be prepared for each new non-identical building, structure, or addition costing over $50,000 contract cost. Costs of alteration work to existing buildings will not be included with the building addition costs.
2. Non-capital renovation projects may not require detailed cost estimates. Coordinate specific requirements with the VT PM.
3. When the estimates exceed the approved or proposed construction budgets, the University, in consultation with their design and cost consultants, shall describe how they will address this issue.
4. When one construction contract contains more than one type of work (new construction, repair, equipment installation, etc.), the estimate shall be structured such that each type of work is identified separately.
   a. Include an overall or master summary sheet.
   b. Include a separate summary sheet for each type of work.
   c. Costs from separate summary sheets must be directly transferable to the master summary sheet. Refer to the notes on the Building Cost Summary form.

2.2.2 Cost Estimate Format

1. All cost estimates (A/E or independent estimator) and estimate backups shall be prepared and submitted in two formats:
   a. The systems format, using the Building Cost Summary form, DGS-30-224, to provide the estimate.

   b. The divisions format, using the Construction Specifications Institute (CSI) MasterFormat divisions, categories, and subcategories.
2. Printed copies of the cost estimates and the associated supporting estimate backups shall be provided with each submission.
3. Unless waived by the VPCPIF, the University shall require their design and cost consultants to submit electronic copies of both cost estimate formats.
4. Pricing must reflect all requirements of the contract plans and specifications.

2.2.2.1 Systems Format

1. The Building Cost Summary form utilizes ASTM Uniformat II cost breakdown structure in ASTM Uniformat II Classification Standard extracted, with permission, from the ASTM E1557-09 Standard Classification for Building Elements and Related Sitework-UNIFORMAT II.
2. A detailed breakdown of the components of each system or assembly shall be calculated, quantified and cost-estimated.
3. The total system cost, a system quantity, a unit cost for the system, and a unit cost per square foot of gross building area shall be calculated for each system and summarized on the Building Cost Summary spreadsheet.

2.2.3 Estimate Backup

1. The estimate must be summarized using the Building Cost Summary spreadsheet and using the CSI MasterFormat divisions format.
2. Backup estimating information, including quotes of estimated cost for major items of equipment or built-in systems, shall be included in the submission.
3. The estimate backup material for each submittal shall be consistent with the level of design required for that submittal.

2.2.4 Construction Delivery Method Requirements

The requirements for detailed cost estimates depend on the construction delivery method and budget limitations.

1. Design-Bid-Build (DBB)
   a. A detailed cost estimate consistent with the level of design is required from the A/E with each submittal (schematic, preliminary, and working drawing).
   b. The University shall obtain independent cost estimates at the conclusion of each design phase (schematic, preliminary, and working drawing).

2. Design-Build (DB)
    a. A detailed cost estimate consistent with the level of design is required from the A/E (Criteria Consultant) at the conclusion of the Criteria Document phase.
    b. The University shall obtain an independent cost estimate at the conclusion of the Criteria Document phase only.
3. Construction Manager at Risk (CM, CMaR)
    a. A detailed cost estimate consistent with the level of design is required from the A/E for schematic and preliminary design submittals.
    b. A detailed cost estimate consistent with the level of design is required from the CM for schematic and preliminary design submittals.
    c. The University shall obtain independent cost estimates at the conclusion of the schematic and preliminary design phases.

2.2.5 Estimator Qualifications and Ethics

1. Capital project estimate submissions must be prepared by professional cost estimators.
2. The estimate at each submittal is expected to reflect the best information and experience of the independent estimator hired by the A/E or the University.
3. Certification as a cost engineer by the Association for the Advancement of Cost Engineering (AACE), or as a certified professional estimator by the American Society of Professional Estimators (ASPE), is supporting evidence of an estimator's qualifications, although it is not required.
4. The standards of practice described in the Canons of Ethics published by the AACE and the ASPE apply to all estimating services.

2.3 Space Data

2.3.1 Room Numbering

1. Room numbers shall be included on floor plan drawings and record drawings.
    a. Coordinate project-specific room numbering reviews as part of the schematic and preliminary design phase meetings. The A/E, the VT PM, and the Space Data group shall participate in the room numbering reviews.
    b. The room numbering philosophy should be discussed based upon the shape and configuration of the building and agreed upon during the schematic design review meeting.
    c. The room numbering should be finalized during the preliminary design phase.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. The first number in the room number sequence shall indicate the floor of the building; numbers following the first shall indicate the room and general location (side or distance) in building. For example, room 101 would be assigned to a room on the first floor, would be on the side of the building with odd-numbered rooms, and would be close to the primary entrance for the building. Use 3-digit room numbers for new construction. Room numbering changes occurring from renovation projects should follow the room numbering already in place for the building.
3. The same room numbering sequence shall be used on all floors of the same building with lower room numbers at one end of the building and higher room numbers at the other end of the building. Even room numbers shall be on one side of the primary hallway and odd room numbers on the other side.
4. Room numbering shall be coordinated to provide the same or similar numbers for rooms vertically aligned in the building. For example, rooms 115, 215, and 315 should all be located directly above or below each other or as close as possible.
   a. The floor of the building with the most rooms, the busiest floor, shall be selected as the starting point for the numbering sequence.
   b. Numbers shall be assigned first to the corner rooms of the busiest floor. The numbering for these corner rooms shall be used as an anchor to begin the room numbering for rest of the floor and for the other floors of the building.
   c. Using the corner room numbering as the guide, assignments for room numbers on other floors should match or be close to the room numbers established for the busiest floor.
5. Room numbering shall allow for renovation changes. Rooms shall be numbered in such a manner that, should renovations occur in the future, intervening numbers will be available for room assignments. For example, larger rooms may be subdivided into smaller rooms at some time in the future.
6. A room number shall be assigned to all accessible spaces. If an area of a room has a different use function or is not clearly delineated by walls and doors (for example, an area off a corridor that is used for a work area), then dashed lines shall be added to the floor plan to clearly identify the space and it shall be identified by a room number.
7. All assignable rooms (including offices, labs, classrooms, conference rooms, etc.) shall have a room number that begins with a numeric character. The first digit shall specify the floor number.
8. All non-assignable rooms (including bathrooms, corridors, stairs, elevators, janitor closets, mechanical and electrical rooms, etc.) shall have a room number that begins with an alphabetic character followed by a numeric room number.

The first character shall specify the floor number with “A” being the first floor, “B” being the second floor, etc.

9. All interior rooms accessed from a primary room (including suites) shall have an alphabetic character (“A”, “B”, etc.) following the primary room number. A secondary interior room (e.g., a closet) should have a single digit (“1”, “2”, etc.) following the alphabetic character of the first level interior room. For example, room “101A1” is accessed from room “101A” that is accessed from room “101”.
10. When renovating a large room to include other rooms, the new interior room(s) shall maintain the primary room number followed by an alphabetic character (“A”, “B”, etc.). For example, 180 (primary) interior rooms would be 180A, 180B, 180C, etc. If room numbers in the building are 4-digit numbers, then follow the same room numbering sequence. The first space of the corridor or other entrance will retain its number.
11. The VT PM should coordinate with Space Data (GIS-Space-g@vt.edu) for specific project requirements.

2.3.2 Floor Plan Drawings

Architectural drawings showing the “shell” of a building and its interior are used in the preparation of floor plan safety signage with escape routes, AED locations, and first aid kits. These drawings show the polyline of the exterior and interior wall structure and have minimal labeling to identify the building interior spaces. These drawings are used for calculating square footage and managing the space in the building.

This section establishes the technical standards and specifications for the creation of AutoCAD floor plan drawings for Virginia Tech. Virginia Tech will accept files for the current AutoCAD release or up to five years prior to the current version of the software. Files shall be DWG format only. See DCSM section 2.8.5 for AutoCAD drawing requirements.

1. Architectural floor plans shall be provided for all floor levels.
2. Every room and space in the listed buildings shall be field-verified and measured to 0.25″ accuracy.
3. For each room on the AutoCAD drawings, the A/E shall verify the accuracy of the room number with the identification on the physical door or faceplate for the room. If the room identifier is not available, the room shall be labeled as “no-number” on the drawing.
4. For data and communication closets (telephone closet, data closet, etc.) and mechanical/electrical closets and rooms, space shall be measured and verified. Equipment shall not be drawn in the space.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. Measuring and survey standards shall follow the guidelines provided by the U.S. Department of Education, National Center for Education Statistics, in the *Postsecondary Education Facilities Inventory and Classification Manual (FICM): 2006 Edition*.
6. All drawings shall be created in model space and drawn to full size (1:1 scale).
7. All entities (e.g., lines, arcs, polylines, and blocks) shall be drawn at elevation (0), have a thickness of (0), have a width of (0), have their color set to "BYLAYER", and have their line weight set to "BYLAYER".
8. No duplicate or overlapping lines or arcs shall be used. The "overkill" AutoCAD command may be used to help eliminate any duplicate or overlapping lines and arcs.
9. No externally referenced data (i.e., Xrefs), non-standard fonts, or other non-standard drawing entities shall be used.
10. All AutoCAD drawings shall be purged of empty, unused, and non-essential drawing data.
11. All blocks used (e.g., doors and plumbing fixtures) shall be created on layer "0" and inserted on their proper layer.
12. The current layer shall be set to "0".
13. Files shall be named using this convention: bbbbSAff.DWG
    Where: bbbb = 4-digit (with leading zeros) building number; may have alpha suffix
    SA = schematic architectural
    ff = 2-digit (with leading zeros) floor level number

2.4 Design Drawing Requirements

1. The UBO may waive certain drawing requirements based on the size and scope of the project. Coordinate with the VT PM.
2. All drawings shall have a font size that allows it to be legible and easily readable. Fonts selected for drawings shall have graphically different characters for "0" and "O", and "I" and "1".
3. Drawing requirements checklists for each phase of design shall be completed and provided with submittals. Checklists may be obtained through the VT Design and Construction Standards website as a downloadable package specific to each design phase. Provide the latest version of the checklists with submittals.
4. For requirements related to plan changes during construction, see DCSM section 2.7.6.

2.4.1 Professional Seals

All drawings and specifications submitted in support of application for a building permit shall bear the Virginia professional seal(s) of the individual(s) responsible for its design. Schematic and preliminary phase documents are not required to display professional seals. Working drawings are required to display professional seals of the individual design disciplines. Final documents are required to display signed and dated professional seals. Work that is not regulated by the Virginia Department of Professional and Occupational Regulation (DPOR) does not require professional seals.

2.4.1.1 Use of Electronic Seal, Signature and Date

The *Code of Virginia* § 59.1-42.1, Uniform Electronic Transactions Act, regulates the use of electronic records, signatures and contracts. In accordance with the Virginia Administrative Code (VAC) § 18VAC10-20-760 – Board for Architects, Professional Engineers, Land Surveyors, Certified Interior Designers and Landscape Architects Regulations – Use of seal: an electronic seal, signature and date may be used in place of an original seal, signature and date when it is a unique identification of the professional, is verifiable and its use is under the professional's direct control. The electronic seal shall be 2 inches in diameter, meeting all criteria of the regulations referenced above. The printed name shall appear above the license number and both shall be legible. An electronic signature, which may contain digital signature verification, is acceptable as long as all relevant text is legible.

2.4.2 Units of Measurement for Dimensions

All dimensions on drawings shall be expressed in feet, inches and fractions of inches. Metric dimensions are not acceptable.

2.4.3 Size of Drawings

Drawing sheet size, except in special cases approved by the UBO, shall be 24″ × 36″ (preferred) or, alternatively, 22″ × 34″ or 30″ × 42″. Sheet sizes of 11″ × 17″ are acceptable with prior approval by the VT PM.

2.4.4 Size of Lettering

Mechanical (CADD, BIM) lettering shall be 1/10″ minimum and in all caps. The minimum height for hand lettering on all projects shall be 1/8″. Spacing between lines shall be equal to one-half the letter height.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

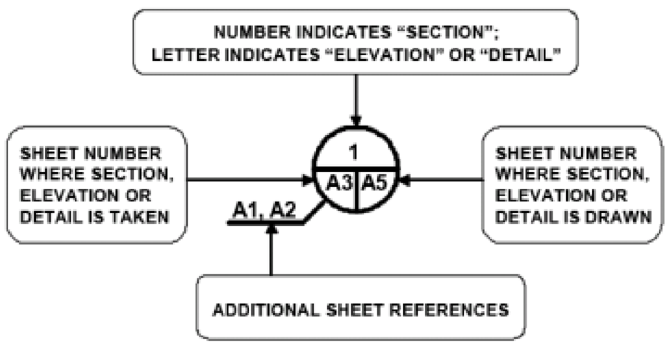
2.4.5 Orientation

It is customary for a building plan to be oriented with the main entrance toward the bottom or right edge of the sheet, depending upon the building shape. All plans shall have a north arrow for orientation. All discipline building plans shall be consistent in orientation insofar as practicable.

2.4.6 Section and Detail Designation

The standard section symbol below is representative of the information required for section and detail "tags." The symbol used on the drawing sheet(s) shall indicate where the section or detail is taken and the drawing sheet where the section or detail is drawn.

Figure 2-1. Standard Section Symbol



STANDARD SECTION, ELEVATION OR DETAIL SYMBOL

NOTE: SYMBOL SHOULD ALWAYS APPEAR AS PART OF TITLE, PLACED UNDER THE VIEW

2.4.7 Limits of the Work

The drawings shall describe/show the work to be provided by the Contractor. Existing features, structures, or improvements to remain shall be so noted. Existing features, structures, or improvements to be demolished and/or removed shall be noted or identified. Work, improvements, demolition or construction which the University will perform or have performed by separate contract shall be identified as "Not in Contract" or "NIC" if the abbreviation has been defined.

2.4.8 Date of Construction Documents

All drawings and the specifications shall be dated with the same date which is established by the A/E as the date the documents are (or will be) complete, sealed and ready for bid. Documents printed for bidding shall bear the date described above with no revision numbers or dates and no revision bubbles or clouds.

2.4.9 Determination of Building Area

The building area shall be indicated on the drawings based upon the context of its usage as described below.

2.4.9.1 Building Area for Code Compliance

The square footage provided shall reflect the VCC definition of Building Area when determining compliance with VCC Table 506.2 – Allowable Area Factor (A_t=NS, S1, S13R, or SM, as applicable) in Square Feet.

2.4.9.2 Gross Building Area for CO Forms and Cost Estimates

The square footage provided shall be determined utilizing the guidelines on form DGS-30-219, Area Calculation for Gross Building Area for CO Forms and Cost Estimates. This calculation includes items not included in the VCC Building Area such as exterior walls, mechanical penthouses, mezzanines, balconies, and other areas that contribute to the overall building size and scope for the purposes of determining HECO-2 square footage, estimates, or other forms related to the capital outlay process.

2.4.10 Tabulation of Units

Indicate the number of beds (dormitory or hospital), fixed seats (auditorium) or parking spaces (parking deck), and other information relating to capacity of the facility as applicable.

2.4.11 Abbreviations

Provide a master listing of all applicable abbreviations and symbols used in the set of drawings or provide a listing of the discipline-specific abbreviations and symbols at the beginning of each discipline.

2.4.12 Scale of Drawings

Each drawing shall, as a minimum, have a graphic scale shown for the predominant scale used on that sheet. Minimum required scales are given in the following table.

Table 2-1. Minimum Required Scales for Drawings

Plans	Description	Scale Required
Foundation and Floor	Show all necessary dimensions	Minimum of 1/8″ = 1′-0″
Roof	Preferred scale	1/8″ = 1′-0″
a. Roof	a. without mechanical equipment	1/16″ = 1′-0″
b. Roof	b. metal/shingled pitched	1/16″ = 1′-0″
Elevations		1/8″ = 1′-0″
Walls	Typical wall sections	Minimum of 3/4″ = 1′-0″
Details		
a. Window, Door, and Special Openings	Typical openings	1-1/2″ = 1′-0″
b. Interior and Exterior	Include special doors, windows, woodwork, paneling or other decorative work, toilets, washrooms, etc.	1/4″ = 1′-0″
c. Construction		Minimum of 3/4″ = 1′-0″
Mechanical and Electrical Rooms		Minimum of 1/4″ = 1′-0″

2.4.13 Landscape Architecture Drawings

Drawings shall include all plans required by the University Landscape Architect. Not every drawing plan type is required for all submittals. See the landscape architecture drawings checklist for each design phase.

Drawings must contain plan scale, north arrow, project limits of disturbance, other applicable boundaries with survey computations, and existing contours. All of the plans (except for the planting plan) can be located in either civil or landscape plan sets, but should not be located in both.

2.4.14 Asbestos Project Design

Asbestos drawings and specifications shall have the name, signature and Virginia license number of the asbestos project designer shown on each asbestos drawing sheet and at the beginning of the asbestos specifications section.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.5 Schematic Design Phase

2.5.1 Submittal Requirements

Provide a completed schematic submittal requirements checklist in the design package.

2.5.1.1 CR-2 Form

For pool projects, a completed CR-2 form shall be submitted as part of the schematic submittal indicating, in sufficient detail, construction costs (detail provided in A/E estimate), soft costs, delivery method, anticipated bid date, anticipated construction duration, project square footage, and all anticipated project funding sources.

2.5.1.2 Verification of Existing Conditions

The A/E shall visit the site and ascertain pertinent local conditions which must be addressed in the design. As part of the required services, it is the responsibility of the A/E to verify, by on-site observations of applicable existing buildings, the configurations, locations, dimensions, sizes, and conditions accessible for verification. Certain assumptions are made regarding existing conditions in the remodeling and or rehabilitation of an existing building. Some of these assumptions may not be verifiable without additional exploration or investigation of the building or site. To minimize the risk during construction of uncovering conditions that are not as shown on the documents and delaying project progress, the University should consider and evaluate the advice of the A/E to conduct additional investigation, verifications or checks to verify.

2.5.2 Capital Project Requirements

Unless waived by the HECO-2 Action Wording, a schematic design/project criteria submittal shall be made to the University for review. The purpose of the schematic submittal is to further develop data, detail and scope including schematic plans, as well as verify the data and program contained in the Capital Project Request. The project scope established by the schematic design, as agreed to by the University and the A/E shall become a part of the A/E Contract as further definition of the scope described in the Capital Project Request data.

The A/E shall coordinate with UBO and SID early in the schematic design phase to ensure compliance with code and university standards.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

The schematic submittal shall include an updated/current project scope profile, or a listing of the assignable rooms and spaces, which was used as the basis for development of the schematic design.

All review issues must be resolved before the A/E is authorized to proceed with the preliminary design.

2.5.3 Cost Estimate Requirements

The schematic design construction cost estimate shall be developed in the systems format. Each system shall include a description or listing of the components or items included in that unit cost. To the extent possible, major systems or commodities should be quantified. Where quantification is not practical, the key assumptions made while developing the estimate must be described.

2.5.4 Basis of Design Narrative Requirements

The schematic submittal shall include a basis of design narrative and completed schematic narrative checklists. The required information may be provided in narrative or tabular format and includes requirements such as general computations supporting system selection, member depth, floor-to-floor heights, and expected mechanical and electrical loads.

2.5.5 Drawing Requirements

The schematic submittal shall include completed schematic drawings checklists.

2.6 Preliminary Design Phase

2.6.1 Submittal Requirements

Provide a completed preliminary submittal requirements checklist in the design package.

2.6.1.1 CR-2 Form

For pool projects, a completed CR-2 form shall be submitted as part of the preliminary submittal indicating, in sufficient detail, construction costs (detail provided in A/E and independent cost estimates), soft costs, delivery method, anticipated bid date, construction duration, project area calculated in accordance with form DGS-30-219, and all project funding sources.

2.6.1.2 Calculations

Submit one copy of calculations for each discipline. Indicate design criteria, loadings, assumptions, evaluations and comparisons of alternative systems,

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

cost factors and other considerations which support the systems selected and shown on the drawings. Calculations shall include the HVAC systems life cycle cost and energy analysis and the fuel source life cycle cost and energy analysis. See DCSM section 1.4.3.

2.6.1.3 Delegated Design

Engineered systems and products that the A/E believes are most effectively and efficiently designed and engineered by a subcontractor or manufacturer in shop drawings may be submitted to the University for review and approval for the use of delegated design.

1. The A/E shall provide the delegated design list with the preliminary submittal, and shall include the delegated design list in a single location on the title sheet of the drawings.
2. The UBO review of delegated design systems for appropriateness and scope will be made at preliminary design. The UBO review for compliance with the building code of delegated design systems is contingent upon the construction documents providing the design criteria of graphic configuration and specifications.
3. Systems for which delegated design may be considered include, but are not limited to, the following:
   a. Systems requiring delegated design review and approval by the UBO:
      i. Fire suppression systems
      ii. Fire alarm systems
      iii. Rammed aggregate piers
      iv. Helical piers
      v. Segmental block retaining walls
      vi. Pre-engineered metal buildings
      vii. Fabric arch buildings
      viii. Precast concrete buildings
      ix. Precast structural concrete
      x. Precast concrete cladding
      xi. Wood and light gauge steel trusses
      xii. Steel stairway structure including handrails and guards
      xiii. Bolted and welded steel connections
      xiv. Curtain walls
      xv. Exterior storefront
      xvi. Lightning protection
      xvii. Electrical coordination studies

xviii. Fault and arc flash studies
xix. Short circuit studies

b. Systems requiring delegated design review and approval by the A/E:
   i. Common steel structural connections
   ii. Access control (security) systems
   iii. Interior non-load bearing metal stud walls
   iv. Architectural mock-ups
   v. Ductwork support hangers
   vi. Piping support hangers
   vii. In-building emergency communications infrastructure

4. The A/E shall be responsible for compatibility of the delegated design systems and products with the design and construction of the building, and shall verify compatibility during review of the delegated design items. The A/E review and approval shall be completed before the UBO review.

2.6.2 Capital Project Requirements

Based on the previous approvals and direction, the A/E shall prepare the preliminary design consisting of drawings and other documents to fix and describe the size and character of the entire project as to exterior appearance; foundation, structural, mechanical, and electrical system; materials; and such other essentials as may be appropriate. The A/E shall visit the site and ascertain the pertinent local conditions required to be addressed in the submittal. If any change from the information submitted at the schematic stage relating to the mix or amount of space occurs, the University shall submit new information in the format of an updated/current project scope profile, or a listing of the assignable rooms and spaces which was used as the basis for development of the preliminary design.

The submittal documents along with the review comments and the agreed upon resolutions of the comments shall be the basis of the approval for the A/E to prepare the working drawings.

2.6.3 Cost Estimate Requirements

The preliminary estimate shall be based on a materials take-off from the preliminary documents. The estimate for this submittal shall reflect cost based on reasonably accurate take-off of material and systems consistent with the level of design. For those elements of the project where the status of design does not permit a reasonably accurate take-off of quantities or firm pricing of individual items of work, system unit prices may be used. Lump sum costs are not acceptable. Use of empirical costs shall be minimized. The Preliminary Building Cost Summary backup shall use the systems format. If the difference between the A/E cost estimate and the independent cost estimate is 10% or greater, the University shall provide a reconciliation of the two estimates.

2.6.4 Basis of Design Narrative Requirements

The requirements within the DCSM and in the preliminary narrative checklists are for new building construction projects but are applicable to renovation and addition projects by addressing those portions relevant to the particular project. When a project consists primarily of mechanical, electrical, structural, or another discipline, the basis of design shall provide more detailed information for the major discipline. The narrative shall address or list the factors indicated for each section. Data may be presented in tabular form where appropriate.

Information within this section shall be paired with the requirements listed in the preliminary narrative checklists for a complete understanding of the requirements for the project.

The narrative shall describe the project scope, the functional and operational criteria to be met, the justification for the decisions or choices made and any proposed deviations from the standards required in the DCSM and the preliminary narrative checklists.

2.6.4.1 Architectural Requirements

The furniture footprint demonstrates the A/E plan for the various functions that are housed in the facility. The A/E shall use standard furniture sizes to demonstrate adequacy of space and to communicate utility and service requirements to development, these drawings are not included in the final construction bid package.

Room dimensions shall not restrict equipment items to the products of any single manufacturer. The A/E should assure that equipment of more than one manufacturer can be accommodated in the space allocated. This policy will not be interpreted as sanctioning an increase in equipment space to accommodate some particular manufacturer’s product when such would result in structural costs being greater than the probable resultant saving in equipment costs.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.6.4.2 Structural Requirements

1. The usual accepted means of structural system selection is economy. Demonstrate this with cost comparisons of various appropriate framing systems such as:
   a. Typical bay member sizing and cost comparisons of alternate structural systems
   b. Horizontal force resisting system for wind and earthquake
   c. Consideration of unusual geometry (long span, high bay, deep cuts, etc.)
   d. Consideration of heavy equipment supports
2. For details using horizontal HSS tubes as beams, do not recommend using HSS tubes as horizontal beams where they are required to be fire rated. There is no UL listing for this condition. HSS tubes used as columns and X-bracing can be UL listed.

2.6.4.3 Heating, Ventilation, and Air Conditioning (HVAC) Requirements

For systems in which the heating, ventilating and/or air conditioning are combined, repetition may be eliminated by consolidating the aforementioned requested information. Describe changeover procedures and requirements.

Computer energy analysis (block load type) shall be used to study energy conservation features for buildings larger than 8,000 square feet that require heating and cooling and for buildings larger than 20,000 square feet that require heating only. Concurrence of systems to be studied should be obtained prior to the conducting study. If a valid computer analysis was prepared during the budget study preparation for the project, this may suffice. When computer analyses are performed, the total annual energy consumption estimate should be clearly stated.

2.6.4.4 Electronic Systems Requirements

1. Identify separately from the other project elements the requirements for intrusion detection systems (IDS). Any of the following items and their interconnecting circuits may be considered part of an IDS:
   a. Annunciation panels and cabinets
   b. Visual and audible annunciators
   c. Magnetic switches
   d. Proximity sensors
   e. Volumetric sensors
   f. Wire grids

   g. Vibration detectors
   h. Power supplies integral to items on this list
   i. Closed circuit television cameras and monitors
   j. Video recorders used for intrusion detection purposes
   k. Access control systems
2. IDS installation can be divided into three general functional categories:
   a. Sensitive compartmented information facilities
   b. Conventional arms, ammunition, and explosives storage sites (AA&E)
   c. All other (including, but not limited to, communication facilities, special training facilities, special operational facilities, intelligence facilities, etc.)

2.6.4.5 Dust and Erosion Control

Dust and erosion control will be considered an integral part of all design and construction projects. Such controls will be generally limited to areas actually scarred or denuded in the process of constructing a project. Dust and erosion control will not be confused with landscaping. Preliminary submittal will contain the necessary design data, and costs for dust and erosion control measures where applicable. The basis of design will include a narrative regarding the type of treatment selected, affected areas, and reasons for selection of type and determination of areas.

2.6.5 Drawing Requirements

Preliminary drawings shall include requirements in the DCSM and in the preliminary drawing checklists unless such information is not applicable to the project.

If the project delivery method is one that will require early release packages for phased permitting, refer to specific requirements in the code compliance narrative requirements and preliminary drawing requirements for the following systems:
1. Fire suppression systems–sprinklers/standpipes
2. Fire suppression systems–alternate automatic systems
3. Fire pumps
4. Fire detection and fire alarm systems

For smoke control systems, the A/E shall develop and submit a preliminary Rational Analysis (a detailed design report) to the UBO for review and approval. Refer to DCSM section 2.7.5.9.5 for detailed requirements.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.6.6 HVAC Systems Design

1. The primary manufacturer or model number for various types of mechanical equipment is specified in the DCSM. Provide a minimum of two additional equivalent manufacturers and model numbers for each primary manufacturer and model number listed.
2. Blacksburg campus design conditions: Indoor design conditions shall conform to current energy code. Winter outdoor design temperature shall be -10 °F; that is, all mechanical equipment shall be able to operate and provide the building heat at -10 °F without tripping on freeze stat. Design altitude shall be 2150 feet for all design calculations.
3. All capital renovations and new construction shall utilize central steam, condensate and chilled water utilities when available.
4. HVAC systems shall be selected based on the lowest life cycle cost as determined by a life cycle cost and energy analysis in accordance with DCSM section 1.4.3.
5. Provide for replacement of the largest piece of equipment without removing permanent walls or roof, large items of equipment, or equipment essential to the principal on-going day-to-day building use. Removable louvers are acceptable.
6. Locate filter boxes and other maintainable equipment outside of electrical rooms, telecommunication/data rooms, elevator machine rooms, operating rooms, and other critical areas so that items can be serviced without disrupting operations in the room or releasing contaminants into the space.
7. Locate humidifiers, fan coil units, terminal boxes, and other equipment containing water above hallways. Avoid locating these items above electrical rooms, telecommunication/data rooms, elevator machine rooms, operating rooms, or critical areas.
8. Equipment mounting stands shall be constructed of steel. Wood stands are not acceptable.
9. The mechanical A/E shall lay out zones with a reset schedule in mind.
   a. All perimeter heating in capital projects must be zoned.
   b. Renovation projects shall not remove existing perimeter heat without approval from VT Engineering.
10. Provide standby or redundant equipment, cycled or alternating lead-lag sequence for critical needs (e.g., standby compressors on refrigeration for food storage).

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

11. All fire dampers shall be accessible via removable ceiling tiles or 24-inch by 24-inch access doors. Fire damper access points shall be marked on the ceilings or access doors. Access doors shall be provided in hard ceilings.
12. Use dual independent refrigeration circuits on HVAC equipment where available, particularly when serving critical areas such as IT closets, animal holding/vivariums or other critical research.
    a. Areas that house critical research and are temperature sensitive must have dual dedicated independent mechanical systems. Campus and/or building systems can be used as a backup to the dedicated primary systems.
13. Air handling equipment installed above a ceiling, or anywhere an overflow may cause damage, shall have a safety shut-off device.
    a. Air handling equipment with cooling coils shall have a water level detection device (UL 508) that will shut off the chilled water valve if the drain is blocked. The unit fan shall not be turned off by the device.
    b. The water level detection device shall be in the primary drain pan on the equipment or in the overflow line. An auxiliary drain pan shall not be installed. An alarm signal shall be sent through the BAS.
14. Existing hydronic systems shall be evaluated. If necessary, filtration shall be provided using sidebar submicron filtration; this is not applicable for chilled water.
15. Hard-piped expansion loops are the preferred method of controlling thermal piping expansion. Provide guides and anchors to direct expansion toward the loops. Other expansion compensation methods must be approved by VT Engineering.
16. All air handlers shall be set high enough to allow for the full depth of drip legs and steam traps as well as condensate traps for chilled water coils and shall be high enough to not interfere with housekeeping pads and base rails. Show elevations of air handling units on drawings.
17. Any new 100% outside air system shall include an approved heat recovery method.
18. The A/E shall coordinate the space needs for all the trades. Access space for maintenance, installation, and service areas shall be indicated on drawings with dashed or faded outlines.
19. Where mechanical ventilation is provided for occupied areas, dedicated outside air shall be supplied directly to the air handler without consideration of the natural ventilation allowance in section 402.2 of the Virginia Mechanical Code. Exceptions to this requirement must be approved by Environmental Health and Safety and CPIF Engineering Services.

2.6.6.1 Air Conditioning

1. If available, campus chilled water utility shall be used as the cooling medium for all new buildings on campus. If the central chilled water utility is not available, the building shall be designed to cool with a central chilled water system.
2. For projects in an existing building, if sufficient capacity is available in an existing chilled water system, chilled water shall be used as the cooling medium for any new or renovated spaces.
3. Direct exchange systems:
   a. Direct exchange systems may be used for server rooms, NI&S closets, electrical rooms or critical research spaces. Installation of a backup cooling-only VAV shall be considered for critical applications.
   b. Direct exchange systems may be used for cooling in buildings that do not have a central chilled water system or central HVAC.
   c. Other uses for direct exchange systems are prohibited without prior approval by the University.

2.6.6.2 Process Cooling Equipment

1. Process cooling is defined as anything other than “comfort cooling” (including all water-cooled condensers).
2. Process cooling requirements shall be addressed by a dedicated process cooling system.
3. Process cooling shall not be achieved using the building chilled water system, the campus chilled water system, or the building domestic water system. Exceptions to this shall require an approved design waiver per DSCM section 1.3.5 and shall be limited by the following requirements:
   a. The process cooling must have an isolation heat exchanger and be downstream of the building pump or have an independent pump.
   b. Domestic water shall not be used as a primary source of cooling. Domestic water for labs or industrial water can be used as a back-up on critical systems.
   c. A standalone chiller or other air-cooled device may be used if the heat is exhausted or it is determined that it is not exceeding the heat load calculated for the space.

2.6.6.3 Central/Local Chilled Water Plants

1. Utilize semi-hermetic compressors rather than hermetic compressors for all HVAC/refrigerant equipment larger than 10 nominal tons where available.

2. Provide minimum 5-year parts and labor warranty on HVAC compressors 5 tons and less and a 10-year parts and labor warranty on HVAC compressors more than 5 tons.
3. Any new or renovated building containing more than one chiller shall have a variable-primary chilled water pumping system.

2.6.6.4 Mechanical Rooms

The A/E shall, in the earliest stages of design development, be responsible for establishing and/or verifying programmatic requirements for mechanical rooms.

1. A minimum of one mechanical room per building must have direct access to the outdoors. The minimum door size is two standard 3' x 7' doors with walk-in access.
2. In phased projects, mechanical rooms shall be sized to include equipment for all the phases.
3. Mechanical rooms shall have a floor drain.
4. Mechanical rooms shall have sufficient space for a full air handler installation and shall meet code for accessibility to equipment without removal of other equipment.

2.6.6.5 Mechanical Access and Service Spaces

1. Provide adequate safe access and the manufacturer’s recommended working clearances for all equipment.
2. Provide access doors for all maintenance items above inaccessible ceilings and into inaccessible walls. If necessary, fire-rated access doors shall be used to preserve wall fire rating.
3. Air handling units, zone control devices, such as VAV boxes, mixing boxes, reheat coils, etc., shall also be located to provide unobstructed access to filters, manual valves, zone control devices and automatic control equipment.
4. Access to ducted fan coil units on occupied floors shall be from corridors, rather than through offices, classrooms, laboratory ceilings, or other occupied spaces.
5. All buildings shall contain storage space for a minimum of one complete change of air filters for all HVAC equipment. The storage space shall be dry and (preferably) accessible from the loading dock or service entrance.
6. Accessible doors to crawl spaces shall be located as close as possible to mechanical equipment under floor.

7. In atriums or other multi-story open-to-roof areas, maintenance and accessibility shall be a consideration when mounting fans, lights and other equipment above the floor.
8. Provide adequate roof access (stairs or elevator) wherever serviceable equipment is roof mounted. Ladders to roof hatches are not acceptable.

2.7 Code Compliance/Working Design Phase

2.7.1 Submittal Requirements

Provide a completed submittal requirements checklist for working drawings in the design package.

Working drawings shall be complete, coordinated, and ready for approval to bid. The working drawings including the specifications shall bear a uniform date. The drawings shall consist of architectural and engineering drawings in such detail as to show clearly the work to be performed. These drawings shall be planned to produce a set of plans with all disciplines coordinated to describe the work required. Architectural and engineering details shall be included on the drawings with cross-references on both the plan and the detail sheets designating specifically the location to which the particular detail applies. Do not include details which do not apply to the particular project.

2.7.1.1 Code Compliance Documents

HECO-4, HECO-5, and HECO-6 form usage is dependent on the type of project delivery method. These forms are generally used for Design-Bid-Build projects, but do not correlate with Design-Bid or CM at Risk delivery methods. For Design-Build, submit the DGS-30-471 request form. For CM at Risk, submit the DGS-30-456 request form.

2.7.2 Capital Project Requirements

The A/E shall visit the site as necessary to ascertain pertinent local and site conditions. Based on the preliminary plans (Design Development Documents) including the review and the value engineering comments and resolution thereof, the A/E shall prepare the working drawings and specifications. The working drawings shall set forth in detail the requirements for the construction of the entire project and include the applicable bidding information. The A/E shall assist in the preparation of the bidding forms, the Special Conditions of the Contract and the Contract Between Owner and Contractor, CO-9.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Specifications and drawings for any type of built-in equipment must be submitted with the working drawings for the building, whether or not such equipment is to be procured under another contract, in order that such work can be coordinated and bid on at the same time.

If any change from the information submitted at the preliminary design relating to the mix or amount of space is made, the University shall submit the revised information including justification, legislative approval, or other documentation related to the change.

The A/E shall submit 90% working drawings including draft technical specifications for review by the University.

The A/E shall include on the working drawings and in the specifications all necessary information to describe the components for the fire-resistive rated construction assemblies and fire protection systems needed to provide the necessary fire integrity of the structure for compliance with all applicable governing Codes.

2.7.3 Cost Estimate Requirements

The A/E shall provide the following as part of the cost estimate submission for the working drawings design phase:

1. Provide a final and detailed cost estimate based on the working drawings and specifications in conformance with the requirements of DCSM section 2.2.
    a. Submit electronic and hard copies of a signed Building Cost Summary form and supporting documents.
    b. Prepare the estimate using the systems format.
    c. Provide a full and accurate description of each system in the estimate.
    d. Provide quotations for all items of substantial quantity or cost. Price quotations labeled as “estimated prices” shall be reasonable expectations of the price a Contractor will be expected to pay.
    e. Separate estimates must be prepared for each additive bid item included in the documents and shall be in the proper format.
    f. Estimates that do not conform to these formats and information requirements will be returned for revision.
2. Advise the University of any adjustments to previous statements of estimated construction cost.
3. If the data varies significantly from that shown on the preliminary design phase cost estimate, attach an explanation to the working drawing cost estimate.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.7.4 Code Compliance Narrative Requirements

Completed code compliance narrative checklists shall be submitted for the project. The UBO may waive the requirement for the code compliance narrative based on the size and scope of the project. Coordinate with the VT PM.

2.7.5 Drawing Requirements

Working drawings shall be prepared in accordance with the requirements in the DCSM and the working drawings requirements checklists. Completed working drawings requirements checklists shall be submitted with the design package. Apply the general requirements working drawings checklist to all project drawings.

2.7.5.1 Permits and Utilities

The A/E shall assist the University in filing the required documents for approval of authorities having jurisdiction over the project. If the Contractor will be required to interface with, coordinate with, or obtain inspection or approvals from any local authority or utility, the requirements and the name and address of such entity shall be shown in the documents.

2.7.5.2 Calculations

Calculations must be organized, indexed, numbered and submitted for each discipline involved. Design calculations shall identify assumptions, considerations and factors involved in the design and support the design shown on the plans and specifications. The A/E shall be responsible for storing the complete set of calculations.

2.7.5.2.1 Structural Calculations

Calculations for every structural member are not required. Structural calculations for members representative of the various types of structural elements should be submitted. If submitted, computer printouts shall clearly indicate the individual member being analyzed or shall be accompanied by diagrams labeled with member numbers corresponding with the printout.

2.7.5.3 Record Drawings and Specifications

The A/E shall prepare record drawings showing the as-built conditions, locations and dimensions based on the Contractor’s as-built set of drawings and specifications, and other data furnished by the Contractor to the A/E. The record drawings shall reflect the actual equipment installed on the project instead of the basis of design equipment.

The record drawings shall include actual location and depth of piping and utilities as well as all other changes specifically known to the A/E. These record drawings shall also include the depths of foundations in the construction (pilings, caissons, or rammed AGG, etc.). Record documents shall be provided to the University in electronic PDF and AutoCAD (DWG) formats, in addition to any other physical format required by the University.

2.7.5.4 Concrete

2.7.5.4.1 Cast-in-Place Concrete

The documents shall provide sufficient details with data on the various configurations or conditions of the concrete and reinforcing steel to facilitate bidding and shop drawing preparation. Details shall include, but not be limited to, rebar size, location and spacing, location and lengths of splices, and required embedment lengths and cover. Typical details with tabular information are acceptable with special sections and details shown as needed. Clearly indicate that the design of formwork and shoring required for construction are the responsibility of the Contractor. The documents may require that the design of the formwork and shoring be performed by a licensed professional engineer and that the design responsibility shall rest with the Contractor and his engineer.

2.7.5.4.2 Cast-in-Place Post-tensioned Concrete

The documents may require that the post-tensioning system be engineered by the Contractor. Clearly indicate all design, loading and performance criteria as well as all pertinent design assumptions. Contractor is required to provide calculations and shop drawings for the post-tensioning system sealed by a licensed professional engineer. The A/E shall review these submittals for conformance with the design requirements.

2.7.5.4.3 Precast Concrete (Non-prestressed)

The documents may require the Contractor to provide these components as an engineered system. Clearly indicate the layout and configuration of the units as well as the complete performance requirements. The Contractor shall be required to provide calculations and shop drawings of the units sealed by a licensed professional engineer. The A/E shall review these submittals for conformance with the design requirements.

2.7.5.4.4 Precast, Prestressed Concrete

The documents may require the Contractor to provide these components as an engineered system. Clearly indicate the layout and configuration of the units as well as the complete performance requirements. Contractor is required to provide calculations and shop drawings of the units sealed by a licensed professional engineer. The A/E shall review these submittals for conformance with the design requirements.

2.7.5.5 Acoustical Treatment

Where acoustical ceilings are provided in conjunction with thermal insulation beneath vented attic spaces, under certain types of roof decks, careful attention should be given to furnishing adequate details on the contract drawings. Such features as support of insulation over flush-mounted light fixtures, conduit, acoustical units, and suspension system components and around heating, air conditioning, and other utilities shall be covered by the details. Appropriate specification shall be included in the project manual to cover the installation of insulation over the suspension system, light fixtures, and other ceiling penetrations. See DCSM section 5.15.5.1 for more details on acoustical tile ceilings.

2.7.5.6 Structural Drawings

For structural drawings, the plans, details and specifications shall completely define the structural system and special conditions for the project.

2.7.5.7 Special Requirements

2.7.5.7.1 Pre-engineered Metal Buildings

The documents may require that pre-engineered metal structures be provided by the Contractor as engineered systems. All design and performance criteria must be indicated in the documents. The supporting structure for the engineered system shall be detailed on the drawings with the assumed reactions from the engineered system indicated. The Contractor shall be required to provide calculations and shop drawings for these systems prepared by a Virginia licensed professional engineer. The A/E shall review these submittals for conformance with the design requirements.

2.7.5.7.2 Structural Steel

The documents shall provide complete details of the configuration of the structural steel and of any non-standard connections. The detailing of standard connections shown in AISC's Manuals of Steel Construction, Allowable Stress Design and Load and Resistance Factor Design, may be left to the Contractor. If this is done, the documents must clearly indicate all design loads and other criteria required for the development of connection details. The A/E shall review the shop drawings and verify design adequacy of fabricator detailed connections. The Contractor shall not be required to provide a licensed professional engineer for the design of these connections.

2.7.5.7.3 Steel Joists and Joist Girders

For non-standard loading conditions, the documents may require that the components be provided by the Contractor as an engineered system. In this case, clearly indicate all loading and design criteria. The Contractor shall be required to provide calculations and shop drawings for these components prepared by a licensed professional engineer. The A/E shall review these submittals for conformance with the design requirements.

2.7.5.7.4 Prefabricated Wood Components

The documents may require that prefabricated wood components such as glue laminated structural members and trusses, metal plate fabricated wood trusses, and similar shop fabricated wood structural systems be provided by the Contractor as engineered systems. All design and performance criteria must be indicated in the documents. The Contractor shall be required to provide calculations and shop drawings for these systems prepared by a licensed professional engineer. The A/E shall review these submittals for conformance with the design requirements.

2.7.5.8 Openings

Include a complete door schedule. The door schedule should assign a separate number for each opening and provide the information required by the working drawings openings checklist. The use of standard door nomenclature, SDI 106, to indicate designs (e.g., "F, L, G, GL, etc." in lieu of "A, B, C, etc."), is recommended.

2.7.5.9 Fire Protection and Fire Safety Systems

2.7.5.9.1 Fire Suppression Systems – Sprinklers/Standpipes

Changes to the design during the construction phase of the project shall be submitted to the UBO for review and approval. It is the responsibility of the A/E to provide a project-specific design. Performance criteria do not meet the intent of this section.

1. Shop Drawings Review
   Shop drawings (working plans, product data and calculations) are to be reviewed by the A/E of record for compliance to the project contract documents and the code. At the conclusion of the shop drawing review, the A/E of record shall:
   a. Verify the UL listings and classifications for the materials, components and equipment provided for this project result in a code compliant fire suppression system.
   b. Provide a "sealed" statement, attached to the reviewed shop drawings indicating that the fire suppression shop drawings (working plans, product data and calculations) satisfy the requirements of the project contract documents and the code (cite the applicable NFPA Sections).
   c. Provide the regional SFMO a copy(s) of the approved complete fire suppression shop drawings.
   d. Refer to DCSM section 3.10.2 for additional requirements.
2. Validation of the Fire Suppression Systems
   Fire suppression systems are to be acceptance tested in accordance with the requirements of the code. The regional SFMO shall observe the installed fire suppression system and witness the fire suppression system performance tests. The A/E and Contractor shall certify that the fire suppression system is complete.

2.7.5.9.2 Fire Suppression Systems – Alternate Automatic Systems

Changes to the design during the construction phase of the project shall be submitted to the UBO for review and approval. It is the responsibility of the A/E to provide a project-specific design. Performance criteria do not meet the intent of this section.

Alternate automatic systems include wet-chemical systems (NFPA 17A), dry-chemical systems (NFPA 17), foam systems (NFPA 11 and NFPA 16), carbon dioxide systems (NFPA 12A) and clean agent systems (NFPA 2001). Halon systems shall not be used in the design of new fire extinguishing systems in state owned buildings.

Commercial cooking suppression systems shall either be: a pre-engineered automatic dry and wet chemical extinguishing systems tested in accordance with UL 300, and labeled and listed for the intended applications, or developed in accordance with one of the above-referenced NFPA standards.

1. Shop Drawings Review
   Shop Drawings (working plans, product data and calculations) are to be reviewed by the A/E of record for compliance to the project contract documents and the code. At the conclusion of the shop drawing review, the A/E of record shall:
   a. Verify the UL listings and classifications for the materials, components, and equipment provided for this project result in a code compliant fire suppression system.
   b. Provide a “sealed” statement, attached to the reviewed shop drawings indicating that the fire suppression shop drawings (working plans, product data and calculations) satisfy the requirements of the project contract documents and the code (cite the applicable NFPA Sections).
   c. Provide the regional SFMO a copy(s) of the approved complete fire suppression shop drawings.
   d. See DCSM section 3.10.2 for additional requirements.
2. Validation of the Fire Suppression Systems
   Fire suppression systems are to be acceptance tested in accordance with the requirements of the code. The regional SFMO shall observe the installed fire suppression system and witness the fire suppression system performance tests. The A/E and Contractor shall certify that the fire suppression system is complete.

2.7.5.9.3 Fire Pumps

Changes to the design during the construction phase of the project shall be submitted to the UBO for review and approval. It is the responsibility of the A/E to provide a project-specific design. Performance criteria do not meet the intent of this section.

1. Application of Fire Pumps in Fire Suppression Systems
   A fire sprinkler/standpipe suppression System is to provide a reasonable degree of protection for life and property from fire based on sound

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

engineering principles, test data, and field experience. One key component of the system is a reliable water supply of acceptable volume and pressure. The connection of the fire suppression system to a public water supply that is of acceptable volume and pressure is considered to be the most "reliable water supply." Where the building characteristics are such that the water supply requirements of the designed fire suppression system cannot be provided by the available water supply then the incorporation of an automatically controlled fire pump into the fire suppression system, compliant with NFPA 20 *Standard for the Installation of Stationary Pumps for Fire Protection*, shall result in an "acceptable water supply." Sound engineering principles are to be incorporated into the design of the fire suppression system to result in the most reliable and acceptable water supply for the project.

2. Electrical Requirements
   Fire pump electrical components and systems shall comply with the National Electric Code (NFPA 70) section(s) on fire pumps. The power for fire pumps shall be from a service which is both electrically and mechanically separate from the remainder of a building's power supply.
3. Emergency Electrical Systems
   Fire pumps are considered to be an emergency system and shall comply with the additional electrical requirements of the National Electric Code (NFPA 70) section on emergency power where any of the following condition(s) occurs:
   a. The building is more than 75 feet in height.
   b. The building has a total assembly design occupant load that exceeds 1,000 people.
   c. The building is designated as an Emergency Shelter (VCC Section 1604.5).
   d. Electric motor driven fire pumps are used and the height of the structure is beyond the capacity of the fire department apparatus.
4. Existing Fire Pumps
   Where an existing fire pump is to be used in the project, its performance and condition is to be established and validated. This is to be accomplished by submitting a copy of the recent report of the fire pump inspection, testing, and maintenance, compliant with the *Virginia Statewide Fire Prevention Code: Fire Pumps – Testing and Maintenance*. This section requires that fire pumps be inspected, tested, and maintained in accordance with NFPA 25. The current edition of NFPA 25

defines the parameters for the report. The performance and condition of the fire pump is to be validated on an annual basis.

5. Shop Drawings Review
   Shop drawings (product data, sketches and certified shop test pump curves) are to be reviewed by the A/E of record for compliance to the project contract documents and the code. At the conclusion of the shop drawing review, the A/E of record shall:
   a. Verify the UL listings and classifications for the materials, components, and equipment provided for this project result in a code compliant fire pump system.
   b. Provide a “sealed” statement, attached to the reviewed shop drawings indicating that the fire pump shop drawings (product data, sketches and certified shop test pump curves) satisfy the requirements of the project contract documents, the VCC and NFPA 20.
   c. Provide the regional SFMO a copy(s) of the approved fire pump shop drawings.
   d. See DCSM section 3.10.2 for additional information.
6. Validation of the Fire Pump
   The fire pump(s) is to be acceptance tested in accordance with the requirements of the code. The regional SFMO shall observe the installed fire pump and ancillary components and shall witness the fire pump performance tests. The A/E and Contractor shall certify that the fire pump installation is complete.

2.7.5.9.4 Fire Detection and Fire Alarm Systems

The A/E shall provide complete project-specific drawings and specifications that define a code compliant fire alarm system. User’s programmatic requirements which may supplement or provide additional levels of protection above the minimum requirements of the code shall be included in the design. Changes to the design during the construction phase of the project shall be submitted to the UBO for review and approval. The A/E shall assure that code compliant fire alarm Systems(s) are provided through the review of the fire alarm shop drawings and the observation of the progress and quality of the work. The A/E shall confirm that the fire alarm system(s) is complete and code compliant. It is the responsibility of the A/E to provide a project-specific design. Performance criteria do not meet the intent of this section.

1. Shop Drawings Review
   Shop drawings (working plans, product data and calculations) are to be reviewed by the A/E of record for compliance to the project contract documents and the code. At the conclusion of the shop drawing review, the A/E of record shall:
   a. Verify the UL listings and classifications for the materials, components, and equipment provided for this project result in a code compliant fire alarm system.
   b. Provide a "sealed" statement, attached to the reviewed shop drawings indicating that the fire alarm shop drawings (working plans, product data and calculations) satisfy the requirements of the project contract documents and the code (cite the applicable NFPA).
   c. Provide the regional SFMO a copy(s) of the approved complete fire alarm shop drawings.
   d. See DCSM section 3.10.2 for additional requirements.
2. Validation of the Fire Alarm Systems:
   Fire alarm systems are to be acceptance tested in accordance with the requirements of the code. The regional SFMO shall observe the installed fire alarm system and witness the fire alarm system performance tests. The A/E and Contractor shall certify that the fire alarm system is complete.

2.7.5.9.5 Smoke Control Systems

Changes to the design during the construction phase of the project shall be submitted to the UBO for review and approval. The A/E shall assure that a code compliant smoke control system is provided through the review of shop drawings and the observation of the progress and quality of the work. The A/E shall confirm that the smoke control system is complete and code compliant.

The VCC defines 3 methods of smoke control: 1) Pressurization Method, 2) Airflow Design Method, and 3) Exhaust Method. Large enclosed volumes, such as atriums, shall be permitted to utilize the Exhaust Methods. Smoke control systems using the Exhaust Method shall be designed in accordance with one of the five design approaches defined in NFPA 92B. The UBO's approval is required for the use of any of these methods within a project.

When the preliminary Rational Analysis is accepted by the UBO, complete and submit the final Rational Analysis documents with the Working Drawing design documents to the UBO for review and approval.

1. Rational Analysis:
   Provide conceptual floor plans which identify the locations of the major components, pertinent calculations, sequence of operation and any other information that may assist in the evaluation of the methods are to be included in the documents submitted to the UBO. It is the responsibility of the A/E to provide a project-specific design. Performance criteria do not meet the intent of this section.
2. Validation of the Smoke Control System(s)
   The smoke control system(s) are to be acceptance tested in accordance with the requirements of the code. The regional SFMO shall observe the installed components of the smoke control system(s) and witness the smoke control system performance tests. The A/E and Contractor shall certify that the smoke control system is complete prior to acceptance testing by the UBO.

2.7.5.9.6 Access Control Systems

Shop drawings shall be submitted to the UBO for work elements including electric strikes, electric latches, electric locks, magnetic locks and other electronic controls (card keys, access buttons, proximity sensors, etc.), even if used as an overlay on mechanical door hardware. Other security measures including cameras, contact switches or other security items which do not affect means of egress are not required to be included.

2.7.5.9.7 Applied Fire-Resistant Materials

The A/E shall provide complete project-specific drawings and specifications that result in code compliant fire-resistive construction through the use of applied fire-resistant materials. Applied fire-resistant materials include spray-applied fire-resistant materials, fire-resistant mastics and intumescent coatings. The A/E shall determine which members are required to be fireproofed and indicate the minimum thickness of the applied fire-resistant materials to be applied. Changes to the design during the construction phase of the project shall be submitted to the UBO for review and approval. The A/E shall assure that code compliant fire-resistive construction is provided through the review of the applied fire-resistant material shop drawings and the observation of the progress and quality of the work. The A/E shall confirm that the fire-resistive construction is complete and code compliant.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

1. Removal and Replacement of Sprayed-on Material
   Agencies and/or their A/E shall contact the UBO early in the design phase to verify the original purpose of the fireproofing material to be removed or replaced and what, if anything, must be done to restore the fire resistance characteristics. Submit plans and specifications to the UBO which will include any bidding documents, addenda or change orders which may relate to the fire resistance characteristics of the existing structure. Include the date(s) of construction, original and present uses, height in floors and feet, whether sprinkled and any other information that may assist the UBO in his determination.
2. Shop Drawings Review
   Shop drawings (working plans, product data and calculations) are to be reviewed by the A/E of record for compliance to the project contract documents and the code. At the conclusion of the shop drawing review, the A/E of record shall:
   a. Verify the UL design assemblies and for the materials, and components provided for this project result in code compliant fire-resistive construction.
   b. Provide a “sealed” statement, attached to the reviewed shop drawings indicating that the sprayed-on fireproofing shop drawings (working plans, product data, and calculations) satisfy the requirements of the project contract documents and the code.
   c. Provide the regional SFMO a copy(s) of the approved complete shop drawings.
   d. See DCSM section 3.10.2 for additional requirements.
3. Validation of Sprayed-on Fireproofing Assemblies
   Applied fire-resistant material assemblies are to be acceptance tested in accordance with the requirements of the code and the requirements defined herein. The regional SFMO shall observe the installed fireproofing assemblies. The independent testing laboratory reports shall clearly show the location of the tests and test results. The A/E and Contractor shall certify that the sprayed-on fireproofing assemblies are complete. Copies of the reports shall be sent through the A/E to the VT PM. The VT PM will submit the reports to the SFMO and the UBO.
4. Validation Testing Requirements
   All applied fireproofing shall be tested after installation according to ASTM E605, ASTM E736, ANSI/UL 263 and ANSI/UL 1709, latest editions.

The minimum location and number of tests of the applied fireproofing shall conform to the requirements below:

a. For thickness on floor sections: One out of every four bays or similar units shall be inspected, but in no case shall a bay or unit exceed 2,500 sq. ft. Each bay or unit selected shall be divided into quarters. In each quarter, a 12-inch square shall be selected for taking thickness measurements. The thickness shall be determined by taking the average of at least ten individual symmetrical thickness measurements within the 12-inch square. Where more than one thickness is required by design, a similar procedure shall be followed for each of the required thicknesses.
b. For thickness on beams and columns: Beam and column thickness measurements shall be taken within each bay or similar unit in which floor insulation thickness measurements are made. Four sets of random measurements shall be taken for each bay or unit.
c. For density: Samples for density determination shall be taken for each 10,000 sq. ft. of pre-selected floor area, but in no case shall there be less than two per floor.
d. For bond strength: Samples for cohesion/adhesion shall be taken on thoroughly dried material adjoining test sections used for thickness and density determinations. There shall be one test for beams and one test for decks for each 10,000 sq. ft. of pre-selected floor area, but in no case shall there be less than two tests per floor.

2.7.5.10 Project-Specific Specifications

Specification sections shall be written/edited to apply specifically to the project and shall not include materials, standards, requirements or data not pertaining to the project. Specifications shall conform to the requirements and standards listed in DCSM section 1.5.4.

2.7.5.11 Rock Excavation

See DCSM section 7.10.6 for requirements. Provide estimated quantities of rock excavation on the Bid Form.

2.7.5.12 General Notes for Contractor Parking and Traffic

Parking and traffic requirements during construction shall be provided to the Contractor and shall be included in the general notes of the drawing submittal. Contractor parking and traffic on campus is managed with the following requirements. Refer to the latest version of the Parking and Traffic Operational

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Manual provided by Transportation Services for permit information and requirements.

1. Contractors shall abide by all traffic regulations at Virginia Tech. Parking on the Virginia Tech campus is regulated for all vehicles. Virginia Tech Parking Services strictly enforces the parking regulations that are posted on the VT Transportation Services web pages. Violations of parking regulations may result in parking tickets, wheel booting, or vehicle towing.
2. Construction sites must maintain the flow of all traffic on and adjacent to the project site (including roads, trails, sidewalks, etc.). All traffic and mobility type (vehicle, bike, pedestrian, etc.) disruptions shall be coordinated through the VT PM with Virginia Tech Parking Services (540-231-3200) and the VT Transportation Planning Engineer. Disruptions shall require a minimum notice of three weeks by submission of a detailed and clear plan and the submission of a traffic disruption request. Traffic disruption requests may be found at the VT Campus Closures Map Viewer website. Use the "Submit Construction/Road Closure Request" link at the top of the web page to submit a request.
3. No significant activities causing disruption to university functions shall be planned at the construction site during home football games, university graduation, or other large-scale events. To determine the impact to the University, projects should work through their VT PM.
4. The contract shall include the contractor parking statement.
5. Parking at the construction site:
    a. Parking within the construction fencing of a capital project is allowed without restriction. Company and private vehicles may be parked inside the fence without a permit. The Contractor shall make all efforts to keep construction parking within the fenced area.
    b. Parking onsite after the project is deemed substantially complete and the construction fence is removed requires written approval by the University and/or an appropriate parking permit (Turf permit).
    c. An automated access gate shall be considered when controlling access.
6. Parking in the contractor parking lot:
    a. If additional contractor parking is needed, coordinate early with Parking Services (540-231-3200). The University will designate a parking lot on campus for use by contractors.
    b. The designated contractor lot will be the only lot on campus in which contractor parking is allowed.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. The University encourages contractor carpooling from the designated contractor lot to the project site on a daily basis to reduce the overall volume of traffic around and within the project area.
d. Parking in the designated contractor lot requires the purchase of a Contractor/Vendor permit from Parking Services. These rates may change on an annual basis at the discretion of Parking Services.
e. The University, at its discretion, reserves the right to change the designated contractor lot to any other lot on campus during the term of the contract.
f. The hours of use of the designated contractor lot are generally reserved for normal daytime hours of work (7 a.m. to 10 p.m., Monday-Friday). The potential need for occasional night work is recognized and accepted, providing the lot is not used for overnight storage of vehicles. At no time will the lot be used to store equipment or industrial vehicles.
g. Occasionally the lot must be completely vacated for special activities such as graduation or football game parking. Parking Services will inform the CC department in advance of the special events dates and notices will be posted at the entrance to the lot. Vehicles left in the lot on these occasions are subject to being towed at the violator's expense

7. The University is not tolerant of contractor parking outside the fenced project site at any time, except at a pre-approved contractor parking lot location. Construction equipment and material is only authorized within the fenced project site and is not allowed elsewhere on the main campus of Virginia Tech. If the site does not support sufficient space for material laydown then the contractor must locate an off-campus site at the contractor's expense.
8. Deliveries that cannot be accommodated within the staging area may be briefly off-loaded in the roadway only with prior coordination Virginia Tech Parking Services and the Transportation Engineer in OUP at least five working days in advance.

2.7.5.13 Electrical

2.7.5.13.1 Electrical Coordination Analyses Review

1. The A/E shall review the delegated design of the electrical coordination analyses for compliance with NEC and the approved permit documents. Refer to DCSM section for 2.6.1.3 for delegated design.

2. The A/E and delegated design professional shall collaborate and ensure that the design demonstrates equipment and a system that complies with the NEC and applicable codes and standards.
3. Changes required to the approved permit documents to provide a code compliant system shall be made at no cost to the University.
4. The A/E shall submit the final electrical coordination analyses design to the UBO for review.
5. Electrical coordination analyses shall:
    a. Utilize applicable industry standards and application data including IEEE, ANSI and NEMA.
    b. Utilize an industry standard software package specifically designed for performing these analyses.
    c. Group time-current curves (TCC) into code required and non-code required sets for ease of review. The TCCs shall be labeled with the same nomenclature as the permitted documents.
6. The electrical coordination analyses submittal shall be indexed and contain individual, tabbed sections. The tabbed sections shall contain the information as outlined in this document including the following as a minimum:
    a. State project code
    b. Project name
    c. Firm name, address, phone number; and the dated and signed seal of the registered Professional Engineer who performed the electrical coordination analyses
    d. Date when the electrical coordination analyses was completed
    e. Method used to perform the electrical coordination analyses
    f. Short-circuit analysis with protective device evaluation
    g. Protective device coordination analysis
    h. Arc flash analysis
    i. Input data
    j. One-line diagram used as the basis of the model
7. The electrical coordination analyses shall include ground fault protection coordination and recommended device settings for the devices provided with ground fault protection. Ground fault protection settings shall be coordinated with phase current device settings.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.7.5.13.2 In-Building Emergency Communications Systems

When an in-building emergency communications system is required, the scope of work shall include the design of a complete and functioning system.

1. Provide floor plans for each floor indicating locations for in-building emergency communications infrastructure.
2. The design shall include a rebroadcasting agreement signed by the FCC License holder authorizing the system.
3. The design shall identify components to be provided by the locality.
4. If delegated design of the system is specified, the design shop drawings shall be reviewed and approved by the A/E. Refer to DCSM section 2.6.1.3 for delegated design. The delegated design shall be sealed by a Virginia Professional Engineer or a design technician with an FCC License.

2.7.5.14 Submission

The A/E shall prepare and submit working drawings and specifications for the University to submit to the various review agencies for approval as pertinent to the project (see DCSM section 1.5.1).

2.7.5.15 Time for Completion

With this submission, the A/E shall furnish the University with an estimate of the time for constructing the project and include such in the appropriate paragraph of the bid form.

2.7.6 Plan Changes

1. When changes are made to approved plans, incorporate any revised sheets (i.e., slip sheets) into discipline sets and the complete plan set.
2. Submit a complete set for each discipline affected by the plan changes that includes all revisions (as one PDF file per discipline) and a complete plan set that includes all revised sheets.
3. Updates for sheet labeling, hyperlinks, and bookmarks shall be provided for the submitted sets. A/Es shall follow the requirements listed in the working drawings submittal requirements checklist.
4. Provide a comprehensive list of all revised sheets.
5. All submissions of plan changes shall be provided to the VT PM. The VT PM will distribute the revised sets and list of revised sheets to the UBO and the appropriate departments in accordance with their current policies and procedures.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.8 Computer-Aided Drafting and Design (CADD) Standards

These standards are issued to promote the development of drawings suitable for use at Virginia Tech. All design, construction, and record drawings submitted to Virginia Tech shall follow the DCSM. Primary A/E firms shall enforce these standards with their sub A/E firms. Each of the following sections contains the most essential criteria for developing drawings for use in the Virginia Tech CADD environment.

2.8.1 Submittal Requirements

The following documentation shall be delivered to Virginia Tech at the specified project milestones for new construction and renovation projects. All submissions shall include a completed CADD Quality Assurance Checklist.

1. Design – Schematic/Preliminary/Working Drawings
   The A/E shall provide a complete set of Review Documents in AutoCAD DWG and PDF formats. During the preliminary and design phases of the project, various Virginia Tech departments which review the design may use the DWG and PDF files to provide feedback and questions on the design.
2. Bid Documents
   AutoCAD drawings in both DWG and PDF format and all specifications in PDF format shall be submitted to the VT PM for posting prior to the pre-construction meeting or start of the project.
3. Floor Plan Drawings
   a. At the start of construction, the A/E shall submit space management floor plan drawings in AutoCAD format for Space Data review; submit the files through the VT PM. At substantial completion, the A/E shall submit updated AutoCAD as-built drawings for the use in managing the facility. See DCSM section 2.3.2.
   b. For construction projects involving multiple buildings or structures, space management floor plan drawings shall be provided at the beginning of construction and at substantial completion for each structure.
4. Record Drawings
   The documents shall contain the as-built information on the project and shall include all AutoCAD drawings in both DWG and PDF formats and all specifications, manuals, etc., in PDF format.

See the VT Design Standard Forms Library for the CADD Quality Assurance Checklist form. Depending on the size and scope of the project, certain AutoCAD drawings may not be required. Coordinate specific requirements with the VT PM and Space Data.

2.8.2 Record Documents File Submittal

Each electronic drawing set submittal shall include the following items upon delivery to Virginia Tech:

1. An index containing filenames and sheet numbers for each submittal. The index ensures the completeness of the drawing set and assists in archival procedures.
2. The Record Documents Submitted form available from the VT Design Standards Forms Library.
3. All field survey data.
4. Copies of the original Contractor redline plans and specifications.
5. The signature and seal of a professional engineer and the clear marking of "Record Drawings" for all record drawings, including civil and site record drawings, in accordance with the A/E contract.

2.8.3 Quality Assurance/Quality Control (QA/QC)

Virginia Tech will check rooms and floors for accuracy. See DCSM sections 2.3 and 2.4.12 for the standards. If the delivered data or floor plans are not in accordance with the DCSM, then the Contractor shall update drawings or deliverables as needed at no additional charge.

2.8.4 Drawing Files

Each drawing filename shall follow the naming convention described in DCSM section 2.3.2.

Drawing submissions shall include three file types:

1. AutoCAD – Virginia Tech will accept files from AutoCAD versions released within the past five years. Files shall be in DWG format only.
2. Revit – Virginia Tech will accept files for the current Revit release or up to five years prior to the current version of the software.
3. PDF – Include PDF files with all AutoCAD and Revit files.

2.8.5 AutoCAD Drawings

Prior to delivery to Virginia Tech, AutoCAD files containing multiple drawing sheets shall be broken down into separate drawings containing single sheets. AutoCAD files submitted to Virginia Tech shall contain only one drawing and one title block per file. See DCSM section 2.3.2 for floor plan drawing requirements.

2.8.5.1 General

1. All survey tasks shall refer to and comply with the National Center for Education Statistics Postsecondary Education Facilities Inventory and Classification Manual (FICM) guidelines.
2. Survey data shall be included in the AutoCAD drawings and placed on the appropriate layers (see DCSM section 2.8.5.2). Survey data collected and used in designing the project shall be submitted as a text file(s) (e.g., ASCII files).
3. Primary drawing entities are lines and arcs.
   a. Blocks shall only be used for hinged doors and plumbing fixtures.
   b. Polylines shall only be used on layers “GROSS” and “ROOMS” for area mapping.

2.8.5.2 Layers

The Virginia Tech layering standards are based on the National CAD Standards (NCS) and the AIA CAD Standards (AIA), latest edition, Layering Guidelines.

All AutoCAD drawings submitted to Virginia Tech shall follow the NCS/AIA layering standards.

1. Only the minimum number of layers necessary to adequately separate entities shall be used in each drawing. The number of layers contained in each drawing will vary depending on the scope and complexity of the drawing.
2. All AutoCAD drawings shall be purged of empty, unused, or non-essential drawing data prior to submittal to Virginia Tech. This includes all unused layers, linetypes, blocks, fonts and entities. Each drawing shall be purged of unused layers prior to submittal.
3. AutoCAD drawings shall not contain any frozen layers. All unused entities on frozen layers should be erased and the empty layers purged.
4. AutoCAD drawings shall not contain multiple overlaid lines or lines with multiple segments unless the overlaid lines or adjacent line segments are assigned to different layers.

2.8.5.3 Entity Properties

AutoCAD entities shall be created following these standards:
1. Entity colors shall be defined by layer, not by entity.
2. Blocks shall be defined (created) on layer 0 (zero).
3. All attributes shall be defined on layer 0 (zero).

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.8.5.4 Drawing Requirements

1. Walls – lines on layer “FLOOR”, color 7 (White)
   a. For interior walls, the lines shall be broken and trimmed at each wall intersection and not be continuous through perpendicular or angled walls.
   b. Phantom walls (lines with linetype of “DASHED” and drawing LTScale of 30) may be used to delineate major room use differences, major hallway direction changes, and other space differentiations.
   c. Phantom walls shall be drawn in doorways with no physical door located at the wall thickness midpoint.
2. Identify floor elevation changes including steps, ramps, tiers, etc. – lines on layer “STAIRS”, color 7 (white); with elevation arrows on layer “TEXT”, color 6 (magenta)
3. Doors – blocks on layer “DOOR”, color 1 (red)
   a. Hinged doors – blocks
      i. Door
      ii. Swing direction
      iii. Door size is based upon width of clear opening between door jambs
   b. Sliding doors – lines
      i. Door (simple line) slightly offset
      ii. Door size is based upon width of clear opening
4. Windows – single lines on layer “WINDOW”, color 5 (blue)
   a. Three lines drawn at the front, middle, and back of wall or frame thickness indicates window glazing is present
   b. Window size is based upon width of clear opening
5. Casework – single lines on layer “CASEWORK”, color 3 (green)
   a. Built-in casework resting on the floor including lab benches, fixed counters, etc. (simple lines)
   b. Mobile/movable benches – use “DASHED” linetype
6. Plumbing fixtures – blocks on layer “PLUMBING”, color 6 (magenta) including built-in sinks, toilets, shower stalls, bathtubs, water fountains, etc.
7. Toilet partitions – lines on layer “TPART”, color 3 (green)
8. Elevators – lines on layer “ELEVATOR”, color 7 (white). Include elevator carriage on the ELEVATOR layer only, not elevator shaft walls.
9. Space identification – text on layer “TEXT”, color 6 (magenta).

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Table 2-2. FLOORDWG Layer Properties

Name	Color	Linetype	Lineweight	Plot Style	Description
0	15	CONTINUOUS	Default	Color_15	
CASEWORK	green	CONTINUOUS	Default	Color_3	Built-in floor casework including lab benches and counters; lines
DOOR	red	CONTINUOUS	Default	Color_1	Doors; blocks of single line and arc showing door swing
ELEVATOR	white	CONTINUOUS	Default	Color_7	Elevator carriage; lines
FLOOR	white	CONTINUOUS	Default	Color_7	Walls; lines, arcs, and circles
PLUMBING	magenta	CONTINUOUS	Default	Color_6	Plumbing fixtures including toilets, sinks, etc.; blocks
STAIRS	white	CONTINUOUS	Default	Color_7	Stairs; lines
TEXT	magenta	CONTINUOUS	Default	Color_6	Text – room numbers are 1'3"; stair directions (UP/DN) are 1'0"; centered as possible (Text angles are either 0 degrees or 90 degrees; style is "STANDARD"; font is "simplex") Directional arrows – arrow points are lines 1'0" long and 45-degree angle from shaft line
TPART	green	CONTINUOUS	Default	Color_3	Toilet partitions; lines
WINDOW	blue	CONTINUOUS	Default	Color_5	Windows; lines
ROOMS	green	CONTINUOUS	Default	Color_3	Closed polylines: one for each interior space
GROSS	yellow	CONTINUOUS	Default	Color_2	Two closed polylines: 1) Exterior gross area; 2) Interior gross area These two polylines border the exterior wall(s) of the building

2.8.5.5 Polylines Drafting

1. All polylines shall be closed by the use of the "close" <c> command.
2. All exterior gross polylines shall be drawn in model space (not paper space).
3. All polyline widths shall be set to (0).

2.8.5.5.1 Gross Polylines

1. Exterior and interior gross polylines shall be located on the "GROSS" layer.
2. Assign color 2 – yellow to gross polylines.

2.8.5.5.1.1 Exterior Gross Polylines

1. The exterior gross polylines shall be drawn to the exterior surface of the exterior wall of the building.
2. The exterior gross polylines shall not include patios, exterior stairs, or roof areas.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2.8.5.5.1.2 Interior Gross Polylines

The interior gross polylines shall be drawn to the interior surface of the exterior wall of the building including attached columns.

2.8.5.5.2 Room Polylines

1. The room polylines shall be drawn to the interior wall surface of each room/space. In the case of an elevator, the polylines shall be drawn to the surface of the interior wall, not to the surface of the elevator carriage.
2. All spaces (rooms, chases, corridors, bathrooms, kitchens, lobbies, closets, etc.) shall have a room polyline.
3. The room polylines shall not include any door threshold areas for entrances with doors.
4. The room polylines shall include one-half of any door threshold areas for entrances without doors so that the threshold is completely accounted for by the two adjacent room polylines.
5. The room polylines shall be located on the “ROOMS” layer.
6. Assign color 3 – green to room polylines.

2.8.5.6 Title Block Information

All title blocks used in AutoCAD drawings submitted to Virginia Tech shall contain the following information:

1. Original issue date – This date shall not change once the drawing has been issued.
2. Sheet number.
3. Title – The description of the drawing and location information. Location information shall include all building names, building numbers, floor level, and room numbers as applicable.
4. Revision history, if applicable.
5. Drawing phase – Drawings submitted as record drawings shall clearly be marked as such.
6. Virginia Tech project number, if applicable.
7. A/E/C – The consultant responsible for producing the drawings shall be clearly identified.
8. Contractor – Record drawings shall clearly indicate the General Contractor.

2.8.5.7 External References – Xrefs

External references (Xrefs) in drawing sets shall conform to the following requirements:

1. Bind Xrefs to the drawings before they are submitted to Virginia Tech.
2. AutoCAD drawings submitted to Virginia Tech shall not contain any attached Xrefs.

2.8.5.8 Referenced Image Files

Virginia Tech will not accept any referenced images (JPGs, BMPs, PNGs, etc.). All images included in a drawing shall be inserted into the drawing as an OLE object.

2.8.5.9 AutoCAD Drawing Support Files

AutoCAD fonts, linetypes, and hatch patterns in drawing sets shall conform to the following requirements:

1. Only native AutoCAD or AutoCAD Land Desktop fonts, linetypes, and hatch patterns or the CAD symbology provided by the NCS shall be acceptable.
2. Custom fonts, linetypes, and hatch patterns, including those provided by third party software, are not acceptable and shall not be used.
3. Only these TrueType fonts are acceptable: Arial, Courier New, and Times New Roman.
4. Postscript fonts shall not be used.

2.9 Document Retention

The University is responsible for assembling, maintaining and retaining the record construction documents for university buildings. This includes documentation of all renovations, remodels and additions.

These documents shall be provided to the University electronically in PDF format. The University may also request additional copies of the record documents in other formats at its discretion.

The record documents include the record drawings of the as-built plans, specifications, maps, submittals, shop drawings, and other pertinent documents. These documents shall be retained until the building is removed from the state inventory. At that time the University shall contact the state archivist at the Library of Virginia to determine the disposition of the documents. The University is responsible for records retention in accordance with the applicable Library of Virginia records retention policy.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 3 – SAFETY AND SECURITY

Safety and security equipment as described in this chapter cannot be removed from the project requirements as a result of Value Engineering.

3.1 Fall Protection

Passive or active fall protection systems must be installed on roofs and other locations such as mezzanines where the fall distance to the next lower level is greater than 30 inches whenever feasible.

Passive fall protection shall be provided on exterior grounds where one grade is more than 30 inches above an adjacent grade and they are connected by a vertical or near-vertical slope. Landscaping shall not be permitted to guard a fall hazard area unless approved by EHS.

Where mechanical equipment is installed on roofs, it should be located inside penthouses, behind screens, within a parapet wall of sufficient height, or behind permanent guardrails, when possible. If mechanical equipment is not located behind or within an enclosure, and is located within 15 feet of an unguarded edge, the edge shall be guarded in accordance with 304.10 of the Virginia Mechanical Code.

1. Passive fall protection systems
    a. Parapet wall height at least 39″ from the walking/working surface
    b. OSHA-compliant guardrails
        i. Top rail: 42″ +/- 3″ from ground/walking surface and withstands 200 lb. of force applied in an outward and downward direction.
        ii. Mid-rail: approximately halfway between top rail and ground (about 21″) from ground/walking surface and withstands 150 lb. of force applied in an outward and downward direction.
            1. If vertical, intermediate members (e.g., balusters) are installed between the top rail and walking/working surface, they shall not be more than 19″ apart.
            2. Other structural members, such as additional mid-rails or architectural panels, shall not have an opening more than 19″ apart.
        iii. Toe-boards installed where materials can fall off of the elevated walking/working surface onto personnel below. They should be 3-1/2″ in height, and no more than 1/4″ above the walking/working surface, and withstand 50 lb. of force applied in an outward direction.
    c. Standard guardrails
        i. Penetrating (roof): Permanently mounted

- ii. Non-penetrating (roof): Free-standing
- d. Low-profile (reduced visibility) guardrails (setback, curved)
  - i. Penetrating (roof): Permanently mounted
  - ii. Non-penetrating (roof): Free-standing
- e. Collapsible guardrails
  - i. Penetrating (roof): Permanently mounted
  - ii. Non-penetrating (roof): Free-standing
- f. Temporary guardrails
  - i. Penetrating (roof), install or store as needed: Permanently mounted, low-profile base plates installed on roof, temporarily add rails when accessing roof
  - ii. Non-penetrating (roof), install or store as needed
    1. Clamp to parapet wall
    2. Install base or mount to wall or short parapets
    3. Free-standing

2. Active fall protection systems
   - a. Where passive fall protection systems are not feasible, permanent anchor points that are specifically designed for fall arrest and meet OSHA requirements shall be provided.
     - i. Bollards or anchor points designed to withstand 5,000 lb. per attached person
     - ii. Travel restraint systems with 100% tie-off
     - iii. Horizontal life lines
   - b. Where permanent anchor points are not feasible, mobile anchor points as approved by CPIF and EHS shall be provided.
     - i. Designed for permanent, long-term installation
     - ii. Designed for temporary, short-term use
3. Skylights shall be sufficiently guarded in accordance with 29 CFR 1910.28(b)(3)(i).

3.1.1 Elevated Walking/Working Surface Access

1. Stairway and door access to roofs and other elevated working or accessible storage surfaces is preferred over fixed ladders, roof hatches, or temporary means of access (e.g., extension ladders).
2. Handrails shall be provided for stairways per Table D2 of 29 CFR 1910.28(b)(11).
3. Handrails shall be provided for exterior stairs associated with walkways in accordance with 1910.28(b)(11), or the VCC, whichever is more restrictive.
4. Roof hatches shall have guardrails on each side.
   - a. A self-closing swing gate shall be provided at the access point.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   b. Grab-rails shall be provided at the roof level if they are not integral with the roof hatch system.
5. Mezzanines shall have the designated load rating posted. Mezzanines shall have guardrails and swing gates for fall protection.
6. Fixed ladders
   a. New fixed ladders, that extend more than 24 feet above a lower level, must have a personal fall arrest system or a ladder safety system installed.
   b. Ladder Safety Systems selected shall be consistent with existing systems installed on campus, or as approved by Engineering Services and EHS.
   c. Cages or wells are no longer permitted on new installations after November 19, 2018, or on existing installations after November 18, 2036.
   d. Fixed ladders must have a swing gate or be offset at the point of access to prevent falls.

3.1.2 Floors/Ramps

Flooring must have a dynamic coefficient of friction (DCOF) of at least 0.42. Some applications may require a higher DCOF depending on use, expected traffic and wear, contaminants, maintenance, and manufacturer guidelines. The use of floor coatings to achieve this coefficient of friction is permitted, but not preferred.

Entryway walk-off systems shall be provided at all regularly used, exterior-to-interior entrances and entrances from covered parking garages. Walk-off carpet tiles or recessed mat/grate systems are preferred in lieu of removable roll-out mats.

3.2 Safety Equipment Not Required by Code

Safety equipment, including fire detection, fire alarm, and fire suppression systems, which are not required by code, but are provided at the University's option in buildings and structures shall be installed in accordance with the code and shall operate as designed. Work that is planned as a complete system, but requires phased construction to provide a complete system is acceptable. It is also acceptable to provide non-required, fully functional "partial systems" to certain areas (e.g., storage spaces) which will improve safety. However, incomplete systems which are not designed in accordance with the code, non-functional systems, and abandoned life safety systems are not acceptable because such systems may be perceived as code-compliant systems and may result in life safety or fire hazards to adjacent areas.

3.2.1 Fan Guarding

To prevent access to fan blades, all industrial ventilation fans shall have guards with openings that are 0.5-inch wide or less.

3.3 Emergency Aid Specialties

Install a sufficient number of automatic external defibrillators (AEDs) to provide a 3-minute response time. Place AEDs in central locations in buildings.

Provide AEDs (typically one per floor) to:

1. Service public areas such as lobbies, hallways, entryways, high visibility pedestrian collection points, areas of high pedestrian concentration, areas of frequent large populations;
2. Be visible to the pedestrian public by locating cabinets in line of sight paths;
3. Be equipped with signage adequate to reasonably alert the public of AED locations;
4. Be placed in areas where service technicians can gain access without specialized permissions, access cards, or in restricted research areas without prior approval of the VT Rescue Squad; and
5. Be placed on walls or contained within a recessed cabinet without potential to be covered by furniture, wall decorations, or equipment.

The location of defibrillators shall be coordinated and approved by Virginia Tech Rescue Squad.

AEDs purchased for Virginia Tech shall be the Zoll AED 3 model automatic external defibrillator. The product package shall include the AED, battery, pads (universal or separate adult and pediatric sets), a quick response AED prep kit, a wall-mounted protective cabinet with alarm, and wall signage.

3.4 Exterior Access

A Knox Box shall be placed on the exterior of the building. The Knox Box shall be Knox-Vault (Series 4400, P/N 4441, silver finish, recess mount, 6″ depth with a dual lock key). Mount unit 6 feet above finish grade and locate near the building's front entrance, typically by the fire panel. The exact location shall be determined by the fire department. The Knox Box should have the appropriate keys inside upon completion and opening of the building. Knox Boxes may be furnished by Virginia Tech.

For Blacksburg campus locations, one lock shall be keyed to CPIF and the other to the Blacksburg Volunteer Fire Department.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3.5 Doors and Windows

Doors and windows have the following safety requirements:

1. Exterior doors, stairwell doors, and hallway doors:
   a. All egress double doors shall not have the potential to be chained. When viewing from the outside, the left-hand door shall not have a handle, only the right side may have a handle. On the inside, panic/push bars shall have no gap behind (between bar and glass, or bar and door).
   b. These doors should provide unfettered egress, but should also make it not possible to lock them from the outside.
   c. The inside should have push bars (not handles). The outside should have only one of the two door sets with handles to open (alleviates the chaining of handle to handle). The locks should be set to the store room function.
   d. In addition, caution should be used that nothing else in the area of the doors provides a means of locking/chaining them from the outside or inside.
2. All interior classroom doors, conference rooms, and offices shall have a manual lock on the inside.
3. Interior glass:
   a. Interior glass that would allow access to classroom or office space shall be covered with an impact-resistant coating. This would include large windows viewing into occupied spaces from corridors, as well as windows on access doors that could be broken out to access interior locking mechanisms.
   b. The coating or window film selection should meet the requirements set in ANSI Z97.1-2015 standard.
   c. Interior window shades are recommended for interior glass walls for securing in place. Open view and open concept areas separated by glass limit occupant ability to secure in place during a campus incident.

3.6 Exterior Lighting

1. OUP and VTPD shall be consulted on the design and color temperature of all exterior lighting.
   a. Exterior lamps shall be LED.
   b. Neon and/or cold cathode lighting systems are not permitted for use in exterior lighting systems.
2. Exterior light sources should be of a white source.
   a. The color rendering index (CRI) is important for normal pedestrians and the natural and perceived surveillance of the building.

   b. In addition, any future plans for surveillance cameras shall require white light sources for color imaging (i.e., color video surveillance cameras require a much higher CRI).
   c. The CRI of white sources goes from 80 up.
3. Where outdoor light fixtures are provided, shielded outdoor light fixtures shall meet one of the following requirements:
   a. Fixtures shall be fully shielded so that no light rays are emitted by the installed fixture above the horizontal plane.
   b. Fixtures shall be constructed so that no more than two percent of the total luminaire lumens in the zone of 90 to 180 degrees vertical angle is permitted, if the related output of the luminaire is greater than 3200 lumens.
4. With exterior lighting, the lighting recommendations for pathways and parking lots are referenced in the ANSI/IES RP-8-18 standard. Parking lot area lighting and sidewalk area lighting shall be addressed to ensure sufficient lighting to meet the recommendations. Coordinate parking lot lighting requirements with the Virginia Tech Police Department (VTPD) and the VT PM.
5. For roadway and parking lot signage and pedestrian “Hokie” lighting, see DCSM sections 4.5 and 4.8.14.7.

3.7 Electronic Safety and Security

3.7.1 Access Control

Electronic access (Hokie Passport) is required on all of the exterior doors. Infrastructure should be included regardless. See DCSM section 5.7.4 for requirements for electronic door access control.

3.7.2 Video Surveillance

1. Buildings shall have all necessary infrastructure and exterior features for the placement of surveillance cameras. All sides of buildings shall be included in the surveillance camera design layout. Exterior camera placement typically includes rooftop locations to provide maximum coverage of the area under surveillance.
2. Exact locations of surveillance cameras shall be coordinated with and approval obtained from VTPD and the specialty contractor for cameras. Coverage required for sites and the placement of cameras will vary. The vendor shall provide assistance during the design phase.
3. For exterior camera placement, the A/E shall incorporate the following:
   a. Provide 360-degree exterior coverage.
   b. Provide coverage of crosswalks, intersections, and major roadways. Complement existing coverage.

c. Provide coverage of areas with higher concentrations of people (common areas and areas with enough space for people to gather together).
d. Provide coverage of ingress and egress points from a lower viewing angle; typical placement would be above a portal or on the side of a building.
e. Provide coverage of high value assets.
f. Provide coverage of loading dock areas for asset protection and intrusion prevention.

4. Exterior camera placements can be supplemented with cameras mounted on new blue light phone placements, if those are part of the project.
5. For interior camera placement, the A/E shall incorporate the following:
   a. Provide coverage of areas with higher concentrations of people (common areas and areas with enough space for people to gather together).
   b. Provide coverage of high value assets.
   c. A security camera shall be installed in all elevator cabs.
6. The infrastructure for surveillance cameras shall be installed in the hallways and stairwells for future camera installations.

3.8 Communications

When required by the current adopted version of the VUSBC, all occupiable structures shall have a distributed antenna system (DAS) as needed in the building for police, fire, and rescue personnel and it shall be monitored by the fire alarm system.

Regardless of whether a DAS is required per code, the A/E shall design a complete system for the building during the schematic and preliminary design phases. This should include, at a minimum, the locations of the interior and exterior antennas, major cable pathways, interior amplifier(s), and battery backup(s). Coordinate locations and design elements with the VT PM and the distributed antenna system vendor as part of the design.

For emergency preparedness signage, provide ADA-compliant locations and install 2″ × 2″ posters under plexiglass. This signage will be provided by the Office of Emergency Management (OEM). OEM signage locations shall be considered when laying out floor plans.

3.8.1 Mass Notification System

1. Emergency notification system: The location of message boards and/or addressable fire annunciator system shall be approved and closely coordinated with the OEM. Emergency message boards should be located in both classrooms and common spaces. The Contractor shall provide and install conduit and power t

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

o the approved locations. Virginia Tech Network Infrastructure & Services (NI&S) shall provide the data cable and message boards.

2. Fire alarm annunciators with public address systems/speakers are required.
3. VT Alert message boards: In buildings with annunciators capable of providing VT Alerts, message boards are to be located in suitable common spaces providing redundant delivery of emergency messages. Coordinate message board locations with VTPD and the VT PM.

3.8.2 Emergency Telephone and Enclosures

1. A number of "push-to-talk" emergency phones may be located within the project limits. Infrastructure shall be designed to provide for emergency phone usage.
2. It is recommended that emergency callbox(s) be placed outside of the building.
3. The number and location of the phones is determined by OEM and the VTPD. The physical requirements for the infrastructure to support the phones are found in the following specifications and the drawing below.
4. For placement of blue boxes (interior emergency phones), the A/E shall incorporate the following:
   a. Each floor shall have emergency phones. Exact number depends on floor plan and floor square footage and shall be coordinated with the VT PM and VTPD.
   b. Phones shall be located along paths of egress to exits and stairwells. Longer floors or hallways may require additional boxes.
   c. Phones shall be visible, but not located in areas where heavy traffic would lead to accidental activation.
   d. Exact locations for phones shall be coordinated with and approval obtained from VTPD.
5. For placement of blue light phones (exterior emergency phones), the A/E shall incorporate the following:
   a. Phones shall be placed in projects to supplement the overall deployment. The A/E shall review the campus map for placement locations.
   b. Phones shall be located in primary travel paths for pedestrians.
   c. All new phone installations shall include camera placement capability.
6. Any emergency phones removed during a construction project shall be replaced as close as possible to the original location. Changes to the location or quantity of emergency phones within the structure should be approved by OEM and VTPD.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

7. Equipment and materials used shall be standard components that are manufactured and available for purchase as standard replacement parts as long as the product is commercially available from the manufacturer.

3.8.2.1 Quality Assurance

1. All tower installation, configurations, setup, program and related work shall be performed by electronic technicians thoroughly trained by the manufacturer in the installation and service of the equipment provided.
2. The tower shall be warrantied against any defects in material and workmanship under normal use for a period of five years from date of installation, provided that manufacturer receives a completed "installation certification" certifying the date on which the system has been installed. An installation certification card shall be enclosed with every unit. In the event that no installation certification is received by manufacturer, the five years will commence on the date of shipment by the manufacturer.
3. The blue light and faceplate light shall be warrantied against any defects in material and workmanship under normal use for a period of 24 months from date of installation, provided that manufacturer receives a completed "installation certification" certifying the date on which the system has been installed. An installation certification card shall be enclosed with every unit. In the event that no installation certification is received by manufacturer, the 24 months will commence on the date of shipment by the manufacturer.

3.8.2.2 Certifications and Standards

1. The tower as an assembly shall be certified to UL Standard 60950-1. The basis of design for the tower shall be Talk-A-Phone model: ETP-MT.
2. The included LED blue light (the basis of design for the LED blue light shall be Talk-A-Phone model: ETP-EL or ETP-EL12/24) shall be certified to:
   a. UL Standard 1598
   b. CSA Standard C22.2 No. 250.0

3.8.2.3 Products

The tower shall consist of a highly vandal-resistant free-standing steel emergency phone tower mount with an integrated flashing LED blue light. Have an integrated LED faceplate light, mounted directly above the phone faceplate.

3.8.2.3.1 Hardware

1. The tower shall:
   a. Be constructed of 0.25″ thick steel and weigh approximately 300 lb.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

b. Measure:
    i. Tower only: 10″ W × 8″ D × 108″ H, with a 0.5″ radius on each corner.
    ii. Tower and blue light: 10″ W × 8″ D × 114″ H.
c. Utilize a high-gloss, multi-coat, corrosion-inhibitive coating that shall be applied to withstand prolonged exposure to hard environments.
    i. Tower shall be sandblasted to SSPC-SP 6 standards before a 2-3 mil layer of rust-inhibitive primer is applied.
    ii. Tower shall be hand sanded for smoothness before a second 2-3 mil layer of primer is applied.
    iii. Tower shall have a 2-3 mil layer of dark bronze color coat applied.
    iv. Tower shall have a 1-2 mil layer of clear coat applied.

2. The tower base plate shall:
    a. Be 2.0″ above the tower base.
    b. Be constructed of 0.75″ thick A36 structural steel.
    c. Have a 4″ diameter center hole for wiring access.
    d. Have four 1″ holes for anchor bolt attachment.
3. The tower wiring access opening shall:
    a. Measure 9″ H × 6.75″ W.
    b. Be located 15″ above the base of the tower.
    c. Have a flush cover plate that shall:
        i. Be constructed of 0.25″ thick steel.
        ii. Be held in place by two 1/4″-20 countersunk, tamper-resistant spanner screws.
4. The tower shall have an opening in the front to accommodate flush mounting an emergency phone. The phone opening shall:
    a. Measure 10″ H × 6.75″ W.
    b. Have six self-clinching #10-24 stainless steel threaded nuts to mount the emergency phone.
5. Directly below the tower phone opening, the tower shall have a section with a 30-degree downward slope from rear to front, spanning the depth of the phone opening to the full tower depth.
6. The tower shall have the word “EMERGENCY” emblazoned on all four sides in 3.25″ high reflective white letters. Custom lettering, sizes and colors are available.
7. The tower blue light shall:
    a. Be mounted at the top of the tower with three #10-24 tamper-resistant spanner screws.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

b. Have a polycarbonate refractor lens assembly with a prismatic pattern to increase visibility at greater distances.

3.8.2.3.2 Functionality

1. Blue Light
   a. The LED blue light shall remain lit at all times.
   b. The blue light shall automatically flash 78 times per minute when triggered by the emergency phone.
   c. The blue light shall have an illumination rating of 209 lumens (peak).
   d. The blue light shall retain 70% of its initial output intensity after 50,000 hours of operation.
2. Faceplate Light
   a. The faceplate light shall remain lit at all times.
   b. The faceplate light shall have a concealed, ultra-bright LED design.
   c. The faceplate light LEDs shall have no less than 50,000-hour lifetime.

3.8.2.3.3 Power Requirements

The tower shall be powered by one of the following power sources:
1. 12 VDC – Nominal: 9 watts
2. 24 VDC – Nominal: 9 watts
3. 24 VAC – Nominal: 9 watts
4. 120 VAC – Nominal: 9 watts

3.8.2.3.4 Manufactured Units

The basis of design for the tower shall be a Talk-A-Phone ETP-MT emergency telephone tower to match existing equipment specified by VTPD and OUP.

3.8.2.4 Installation

1. The Contractor shall carefully follow instructions in documentation provided by the manufacturer to ensure all steps have been taken to provide a reliable, easy-to-operate system.
2. All equipment shall be tested and configured in accordance with instructions provided by the manufacturer prior to installation.
3. The tower mounting shall be per manufacturer's specification.
4. Provide and install all necessary conduit pathway and infrastructure as noted in the drawing attached.
5. Telecommunications cabling to be installed by NI&S under separate contract.

6. Power to the telephone tower is to be provided by the Contractor under separate contract. Contractor shall consult tower manufacturer's recommendations for power requirements.
7. Conduit pathways including service/pull boxes locations are to be designed by the Contractor during site plan coordination.
8. Conduit pathway shall be installed in accordance with the conduit pathway installation detail in the VT Design Standard Detail Library.

3.9 Laboratory Emergency Safety Appliances

For additional laboratory design requirements, see DCSM section 5.18.

1. Eyewashes
   a. Unobstructed access to an eyewash within 10 seconds is required in every laboratory where corrosive substances are present as is stated in 29 CFR 1910.151(c). Unobstructed is defined for this purpose as not being inside or outside of a door that can be locked or that would otherwise inhibit access, such as a door with an inward swing or one without a crash bar. Unobstructed also means that no stairs, step-ups, etc., will need to be traversed in order to get to the eyewash or safety shower.
   b. The design and installation of all eyewashes must meet ANSI Z358.1-2014. Counter-mounted eyewashes must be installed within 6 inches of the front of the counter for hands free access.
   c. Portable eyewash stations are not allowed without EHS review and approval.
   d. Every new or renovated laboratory must include a plumbed eyewash installation.
   e. Standalone eyewash stations or combination eyewash/shower stations must be plumbed to a drain in order to facilitate use and weekly testing (flushing) of the eyewash.
2. Safety showers
   a. Where the potential for contact with corrosive materials exists, a safety shower must be installed within 10 unobstructed seconds.
   b. Safety showers must be installed in accordance with ANSI Z358.1. Where new buildings are designed or labs are renovated, ANSI Z358.1-2009 requires a water-mixing valve for tempered or a tepid supply of rinsing fluid.
   c. Any new building with more than 15 safety showers in it shall utilize a central tepid water system with dedicated mixing valves and circulating pumps. Individual mixing valves at each shower in this situation are not an acceptable alternative.

3. Flow rates for all new eyewashes and showers shall be tested as part of the renovation or construction process. Flow rate data shall be provided to EHS prior to project turnover.
4. Flow rates for eyewashes and safety showers shall conform to a functional test involving the fixture(s) on the floor that is farthest from the water supply. In accordance with ANSI standard Z358.1, flow rates for all new construction and major renovations shall be measured at 20 GPM. Existing eyewashes and safety showers shall have a minimum flow rate of 12 GPM.
5. See DCSM section 6.6.8 for floor drain requirements
6. Portable fire extinguishers: A portable fire extinguisher, suitable for use in the laboratory and around chemicals used therein, must be mounted in each laboratory. At minimum, a 10-pound ABC extinguisher will be required. Signage must also be displayed at the extinguishers. See DCSM section 3.10.5 for fire extinguisher cabinet requirements.

3.10 FIRE PROTECTION SYSTEMS

Provide the information required in the fire systems drawing checklists for each design phase submittal. The requirements pertain to all projects which are constructed on state property, regardless of funding source.

3.10.1 Fire Safety Systems

The design of fire suppression systems (sprinkler systems/standpipes, alternate automatic suppression systems, fire pumps), fire detection and fire alarm systems, smoke control systems, access control systems and applied fire-resistant materials shall comply with the submittal requirements outlined in DCSM section 2.7.5.9 and the fire systems checklists for each design phase submittal. The requirements pertain to all projects which are constructed on state property, regardless of funding source.

3.10.2 Fire Safety Review of Shop Drawings

Shop drawings for the following building systems shall be reviewed and approved prior to the work being installed:

1. Fire suppression systems (sprinklers/standpipes, alternate automatic suppression systems, fire pumps): shop drawings prepared by a certified engineering technician, NICET Level III or IV, reviewed and approved as indicated below.

2. Fire detection and fire alarm systems: shop drawings prepared by a certified engineering technician, NICET Level III or IV, reviewed and approved as indicated below.
3. Smoke control systems designed by the licensed engineer, shop drawings reviewed and approved by the A/E of record, then reviewed and approved by the UBO.
4. Applied fire-resistant materials: product data and details prepared by the Contractor, as may be required by specific projects.
5. Access control must be coordinated with fire systems by the A/E.

The licensed professional engineer is responsible for the overall design of the fire protection systems, evaluating the building-specific conditions and preparing the analysis, calculations, design, and documents. When complete, the final documents display the signed, dated seal of the responsible professional engineer. Refer to DCSM section 2.7.5.9.

The certified engineering technician, certified to NICET Level III or IV, prepares the working plans as defined by NFPA 13, supplemental calculations, and material submittals based upon the engineer's design, for the engineer's review and approval. The professional engineer does not affix his/her professional seal to the shop drawings.

3.10.2.1 A/E Shop Drawing Final Approval

When the design of fire suppression, fire detection and fire alarm, smoke control, access control systems or applied fire-resistant materials provided in the initial working drawings submittal is determined to be complete and code compliant by the UBO, then the building permit shall stipulate that the shop drawings and submittal data shall be reviewed and approved by the A/E of record.

The A/E shall include a stipulation on the working drawings and in the technical specification that the Contractor shall bid and install the fire protection system as shown in the documents. Designs modified from the UBO-approved working drawings, shall be submitted to the UBO for review and approval as described in DCSM section 3.10.2.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3.10.3 Protection During Construction

In renovation projects where the building is to remain occupied during construction, the following measures shall be included in the Contract Documents:

All existing fire protection systems shall remain operational during construction. If temporary shutdown is necessary, the system shall be returned to operational condition as soon as possible and no later than the end of each working day prior to the Contractor leaving the job site. The Contractor is to notify the SFMO prior to any necessary shutdowns. Any necessary shutdowns shall not affect other areas not involved with this construction project.

All operational standpipes are to be maintained at all times.

Sprinkler systems in areas being renovated shall be operational when the Contractor leaves the site each day. A fire watch shall be provided at all times that a sprinkler system is inactive.

3.10.4 Spray Fireproofing Design and Specification

3.10.4.1 General

1. Final Construction Documents shall clearly show locations, rating and type of spray fireproofing on the drawings, on typical and special details, and in the specifications.
2. The spray fireproofing applicator shall be qualified and/or licensed on the manufacturer product.
3. Proof of qualification and/or licensure shall be submitted to the University.
4. At the intersection of structural steel members with different thicknesses of spray fireproofing, provide spray fireproofing equal to the greater thickness on all members for a distance of 2′ minimum from the intersection of the members.
5. Spray fireproofing shall meet or exceed the fire rating on all clips, hangers, light gauge framing, support sleeves and other attachments covered at the area of attachment to a structural member.
6. Mark new spray fireproofing with fire rating and material type in all accessible locations at 16′ intervals.

3.10.4.2 Testing Requirements

All spray fireproofing shall be tested after installation according to manufacturer’s requirements.

The University shall arrange and pay for services for field and laboratory tests and reports. The Contractor shall schedule the tests while the material is accessible. If additional tests are required as a result of non-compliance with the specifications, the additional tests and reports shall be paid for by the Contractor.

3.10.4.3 Removal and Replacement

The A/E, in consultation with the University, shall verify early in the design phase with the UBO the original purpose of any fireproofing material to be removed or replaced and what, if anything, must be done to restore the fire-resistive characteristics.

Plans and specifications shall be submitted to the UBO, including any final construction documents, amendments/addenda, or change orders which may relate to the fire-resistive characteristics of the structure. On every submittal, indicate construction date, original and present uses, height in floors and feet, whether the building is sprinklered, and any other information that may assist the UBO in his/her determination.

If sprayed-on ACM is to be replaced, copies of the specifications for the intended replacement material shall be submitted to the UBO for review.

Independent testing laboratory reports shall be sent through the A/E to the UBO.

3.10.4.4 Identification of Spray-Applied Fire-Resistive Materials (SFRM)

New and replaced SFRM material shall be identified at 16′ intervals in accessible locations with label providing the following information:

1. Fire-rated assembly design number from listing agency.
2. Hourly rating.
3. Material type and designation.

3.10.5 Fire Extinguisher Cabinets

1. Fire extinguisher cabinets shall be incorporated into all projects. All fire extinguishers shall be installed in red, code-acceptable cabinets.
2. Fire extinguisher cabinet doors shall not be equipped with any type of lock. Only roller latches, or something providing an equivalent level of function shall be used. Access without a key is required for extinguisher inspection.

3. Fire extinguisher cabinets that are located in hallways or would be considered a protruding object per ADA requirements shall be either semi-recessed or fully recessed.

3.10.6 Fire Extinguishers

Contract specifications shall identify the extinguisher type and size, and note that the extinguishers shall be provided, inspected and appropriately tagged with the inspection date, and installed by the Contractor.

In general, all fire extinguishers shall be serviceable, 10-pound ABC type unless there is a special hazard present. If there is a special hazard present, then the fire extinguisher shall be listed for that specific hazard.

Permanent fire hoses are not acceptable for installation on campus.

3.10.7 Fire Alarm Systems

3.10.7.1 Overview

This section provides Virginia Tech's standards for the design and installation of fire alarm systems and equipment in new construction, retrofit of new systems into existing buildings, and modifications to existing systems. All new university buildings shall be equipped with a fire alarm system with voice alarm capabilities meeting or exceeding these standards and applicable codes.

Over the years, Virginia Tech has developed a technologically advanced campus-wide fire alarm system through the standardization and integration of each new individual building system. These standards require that each new system installed by or for Virginia Tech within the boundaries of Montgomery County have the proper technology to be fully compatible with the campus fire alarm network and that each be fully integrated as a node on the same, thereby providing the level of fire protection the University desires.

In applying these standards to the design of a new system, designers are expected to follow everything listed without exception.

To determine the level of protection appropriate for a given type of building, several risk factors were considered. These were:

1. Building size – both the height and total area.
2. Building use – how the building is used and what hazards are present.
3. Occupant load – number of people occupying the building.
4. Type of construction – combustible, non-combustible, fire protected, etc.
5. Sprinkler protection – whether or not the building will be sprinklered.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

A voice fire alarm system provides a public address function by use of the control panel microphone. This can effectively be used to communicate to all of the building's occupants for any type of emergency, even when building evacuation is not needed.

3.10.7.2 Design Phase Procedural Requirements

1. In designing Virginia Tech fire alarm systems, nothing in these standards shall be construed to allow anything less than full compliance with minimum legal requirements of the applicable codes and standards as established in the current edition of the VUSBC. Any discrepancies found should be brought to the immediate attention of the University.
2. The latest adopted edition of NFPA 72 shall be used for all new fire alarm systems. A code modification may be required from the UBO for required systems where the referenced edition in the VUSBC is not the most recent edition. The modification request is the responsibility of the University.
3. The communications protocol for the campus fire alarm network is proprietary to Johnson Controls. No other manufacturer's equipment can be properly integrated into the network, and provide the two-way communication needed for monitoring and control of the existing systems. Therefore, all fire alarm equipment shall be listed as compatible with Johnson Controls. All suppression release (including kitchen grease hoods and server rooms) shall be by Johnson Controls.
4. As part of their service to the University, Johnson Controls provides a high level of engineering support to the A/E for the design of our new systems. The A/E is required to contact the Roanoke branch office of Johnson Controls for their assistance for every project. We rely heavily on input by Johnson Controls to assure compliance with codes and university standards, and for proper integration of new systems into the campus network. The A/E shall send Johnson Controls a copy of the set of preliminary design documents submitted to the University's internal review team.
5. Johnson Controls shall assist the A/E and the University by:
    a. Providing Johnson Controls specifications to the A/E for their use.
    b. Meeting with A/E and University to go over basic system design issues.
    c. Reviewing working drawing design documents to assure system equipment is properly specified, and located within the building in compliance with codes and university standards.
    d. Analyzing existing equipment impacted by any new installation to ensure that it can work properly with the new equipment.

   e. Inspecting and testing new systems to help assure that the complete system is installed properly and performs in a manner compliant with code. Johnson Controls will send the CAD drawing files they have prepared showing final device locations to EHS.
6. Provisions need to be made to update the campus fire alarm network when new systems are added. The TrueSite Workstation (TSW) in the Fire Protection Manager's office, the TSW in the Student Affairs Fire Protection maintenance office, and the appropriate Network Display Units necessary for sending the signals to the Central Station monitoring, must be reprogrammed to include building address, point label, etc., as needed to add the new system to the network.
7. The University's room numbering must be used to program the labels for the points in the control panel, and not the construction document numbers.

3.10.7.3 General Design Standards

1. All equipment shall be manufactured by Johnson Controls.
2. Control and Annunciator Panels
   a. All displays and annunciators shall be touchscreen alarm displays.
   b. Location of control panel – The fire alarm control panel (FACP) shall be located at the primary entry point to be used by the local fire department or in an electrical room. If the FACP is located in an electrical room, a remote command center shall be provided at the primary entry point to be used by the local fire department. The University will provide this information to the A/E after consultation with the local fire department.
   c. Remote annunciator panels shall only be used where two or more fire department response points are clearly identified. Otherwise, the main control panel or remote command center is all that is needed.
   d. The FACP shall be used to control pre-action sprinkler systems. The panel must be UL listed or FM approved for this function.
   e. Maximum mounting height of FACP shall be 75 inches above finished floor to the top of the 4100 panel.
   f. Max limitation on power supplies – The design load placed on the power supply shall not exceed sixty percent of the power supply capacity.
   g. Individual signal circuits shall not exceed sixty percent of the card capacity. For voice systems this assumes that all speakers are tapped at their maximum wattage, which is currently 2 watts.

h. Location of secondary panels – All secondary panels for the fire alarm system shall be located either in electrical closets or in public spaces where they are readily accessible.
i. All batteries associated with the fire alarm system shall be no more than three months old (based on the date code on the battery) at the time of system acceptance.
j. Batteries serving the FACP but installed in separate cabinets shall be located adjacent to the FACP and no higher than 3 feet above the floor.
k. Emergency power – Where a generator is present, the FACP and all secondary panels shall be tied to the emergency circuit, and batteries shall also be provided, sized per NFPA 72 requirements. Where there is no generator, batteries shall be provided and sized per NFPA 72 requirements as the secondary power source.
l. If smoke control or stairwell pressurization systems are being installed, the FACP shall provide a manual means of activating and disabling these systems. Switches shall be clearly labeled as to the specific system they control.
m. If a building has stairwell pressurization fans and has emergency power generators, pressurization fans shall be on emergency power.
n. Degree of point reporting – All initiating devices shall be reported individually to the TSW and NDUs.
o. Network node – The panel shall be configured as a node on the campus Johnson Controls 4190 fire alarm network.

3. Initiating Devices
   a. Location of pull stations – Locations for pull stations shall be per code and pull stations shall be provided as if the building were not equipped throughout with an automatic sprinkler system. The exceptions in the code shall not be used. All pull stations must be listed for the environmental conditions for the area of installation.
   b. All pull stations shall be single action.
   c. Addressable initiating devices – All devices shall be addressable-type devices. All initiating devices must be listed for the environmental conditions for the area of installation.
   d. Duct detectors – Unless required by code, are not to be installed on any air handling equipment. When duct detectors are installed the detector must be accessible for maintenance and a remote LED shall be placed on a wall or ceiling in public area where it will be readily visible and will not be obstructed by furniture, and shall be located as close as possible to

the air handling unit (AHU). Signage shall be provided indicating the AHU served. Do not provide test switches.

e. For locations with an installed smoke or heat detector that would be affected by adverse environmental conditions or where maintenance on the detector would be problematic, aspirating early warning smoke detectors shall be used as an alternative to spot detectors.
f. Heat detectors and combination smoke/heat detectors:
   i. Install a combination smoke/heat detector in the following locations:
      1. Mechanical rooms
      2. Sprinkler riser rooms
      3. Areas deemed necessary by the VT PM and VT Engineering during the preliminary design phase, such as areas with water pipes (domestic or fire sprinkler).
   ii. Heat detectors and combination smoke/heat detectors shall be programmed to provide a non-latching supervisory trouble signal for low temperatures at 40 °F.
      1. The supervisory trouble signal shall be programmed to report the low temperature reading.
      2. The signal shall be programmed to clear when temperatures rise above the 40 °F threshold.

4. Notification Devices
   a. Strobes shall be installed in conformance with NFPA 72. Strobes must be listed for the environmental conditions for the area of installation.
   b. Ceiling mounted strobes are acceptable.
   c. Location of strobes – All public spaces listed above for detection; and also, classrooms, bathrooms, laboratories, assembly spaces, conference rooms, shops with high ambient noise levels, mechanical rooms and other areas as required by the VUSBC. Placement shall be made with consideration of ambient light levels.
   d. Synchronization of strobes – Strobes shall be synchronized and all strobes shall be the addressable type.
   e. A/V unit mounting heights are dictated by the requirements for the strobe, not the speaker.
   f. All speakers shall be tapped at their maximum capacity, which is currently 2 watts.
   g. Ceiling mounted speakers are preferred.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. Circuits and wiring
   a. Class B circuits shall be used.
   b. Conduit vs. cable – For new construction, wire in conduit or EMT that is dedicated to the fire alarm system shall be used. For retrofit installations, the use of cable will be acceptable, but it must be installed in locations where it will be protected by building construction (above ceilings, in cable trays, chases, within walls, etc.) as long as the installation complies with the NEC.
   c. Conduit shall be a minimum of 3/4-inch.
   d. No conduit or EMT shall be run in or below slabs.
   e. Wiremold may be used in retrofit installations, but only when it is in the project's scope.
   f. All wire routed underground shall be listed for direct burial and be installed in conduit.
6. Interface with other fire protection systems and VT Alerts
   a. Mass Notification – To ensure the emergency notification to all members of the university community, the equipment necessary to connect to the university emergency communication system (VT Alerts) shall be provided and installed to the building fire alarm panel. This will include two Ethernet ports installed in the building fire alarm panel.
   b. Where the building contains other fire related systems, such as sprinklers, hood suppression, fire door hold-open devices, etc., these systems shall be connected to the new FACP and monitored for alarms, trouble, or supervisory conditions.
   c. The A/E shall coordinate the sprinkler and fire alarm design to help assure that the number of flow, tamper, and pressure switches are identified as accurately as possible in the working drawing design.
   d. Where a fire pump is present, a "pump running" condition shall be treated as a supervisory condition, and not an alarm.
   e. Where dry-pipe valves are installed in buildings not normally occupied, where loss of heat in the room could go undetected, a means for monitoring the temperature of the sprinkler riser room shall be installed and programmed to provide a supervisory signal to the fire alarm panel.
   f. A supervised tamper switch is required on all exterior post indicator valves on fire protection water supply lines. These valves are typically installed 40 feet from the building, which will require underground circuit be provided to the switch.

   g. Every tamper and flow switch shall be individually addressed, regardless of their proximity to other devices.
7. Miscellaneous
   a. Consideration shall be given to any room within the building that may be subject to wash-down cleaning.
   b. Devices shall be listed for conditions.

3.10.7.4 Building-Specific Design Standards

1. Definitions of University Building Categories
   a. Class 1 – Academic, administrative, assembly and research buildings (multi-story with elevator), or otherwise classified as such as needed to address specific safety concerns
   b. Class 2 – Residential buildings, all dormitories, and special purpose housing
2. Class 1 Building Specifications
   a. Panel model – 4100ES or the latest version of this level of panel. Note that at present, the 4100ES is the only panel listed for use as a panel to control fire suppression systems, such as pre-action sprinkler systems. When a building has a pre-action sprinkler system in it, the 4100ES must be used.
   b. Type of audible devices – All notification audible devices shall be speakers.
   c. Addressable audible devices – When addressable speakers become available from Johnson Controls, they are to be used.
   d. Addressable strobes – Strobes shall be the addressable type.
   e. Level of automatic detection – For non-sprinklered buildings, public area smoke detection shall be provided. This will include areas such as lobbies, hallways, reception areas, areas above every floor landing in all stairwells, elevator lobbies, and similar spaces. Auditoriums shall be addressed on a case-by-case basis with University consultation.
   f. Specific areas that require heat detection in non-sprinklered buildings – mechanical equipment rooms; attics and crawl spaces built with combustible construction; chemical storage rooms, shop areas used for welding, woodworking, painting, etc.; or any other area with a hazard that warrants heat detection as determined by the University.
   g. Specific areas that require smoke detection in non-sprinklered buildings – NI&S communication closets; large electrical rooms containing either distribution transformers or switchgear;

transformer vaults; at the FACP; storage rooms which are greater than 100 square feet, open into a space without smoke detection, and are neither sprinklered or enclosed by fire-rated construction.

h. Laboratories involving hazardous operations must be evaluated for the need for automatic detection (either heat or smoke) on a case-by-case basis.
i. Specific areas that require smoke detection in sprinklered buildings – elevator lobbies, transformer vaults, NI&S communication closets, at the FACP.
j. Elevator machine rooms – In general, smoke detectors shall be installed in these rooms, however, if the ambient conditions in the room are such that a smoke detector would result in nuisance alarms, another appropriate detector may be used with the university's concurrence.

3. Class 2 Building Specifications
   a. All provisions for Class 1 systems shall apply, unless otherwise modified here.
   b. All sleeping rooms shall be equipped with system smoke detectors with addressable speakers programmed to function as a single station detector. This will satisfy the code requirement for single station detectors. If the detector is still in an alarm condition at the end of 60 seconds, the system shall sound a general alarm.
   c. All detectors within a suite shall be programmed to operate the addressable speakers simultaneously.
   d. In addition to the public spaces listed for Class I buildings, strobes shall be installed in all suite living rooms, and in all bedrooms designed specifically to accommodate the disabled. Strobes shall be 110 candelas in these bedrooms.
   e. Heat detectors shall be installed in all residence hall student lounge kitchen areas and in locations where steam may be present.
   f. All pull stations shall be equipped with alarmed covers to prevent vandalism. The basis of design for pull station covers shall be Lexan Stopper II.

3.10.7.5 Acceptance Testing and Warranty Period

1. As part of the final inspection and systems test, Johnson Controls will verify the candela rating of every strobe in its installed location, to ensure that the installing contractor has installed these devices per contract documents,

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

and per code. A copy of this report shall be provided to the University Fire Protection Manager.

2. Johnson Controls will measure the sound level and clarity of the alarm signal, in all areas of the building, to assure that the installed system produces the signal volume as required by code. All intervening room doors shall be shut during the test. A copy of this report shall be provided to the University Fire Protection Manager.
3. Johnson Controls will provide the University with a written statement verifying the successful completion of all required tests. This document will be required at the time of substantial completion, before a Certificate of Occupancy can be obtained for the building. A copy must also be provided to the SFMO.
4. During the one-year warranty period, one complete system test shall be provided and included as part of the initial purchase of the system. The test shall be performed during the eleventh month and shall be scheduled in coordination with the University Fire Protection Manager.
5. Any time the fire alarm system is inspected and/or tested, a copy of the inspection/test report shall be provided to the University Fire Protection Manager.

3.10.8 Fire Suppression Systems

3.10.8.1 General Duty Valves for Water-Based Fire Suppression Systems

1. Sprinkler system control valves shall only be installed in corridors, stairwells, mechanical rooms, fire pump rooms and sprinkler valve rooms. The control valves shall be accessible with the use of no more than a six-foot stepladder.
2. Provide minimum of 24″ × 24″ access door for valves located above inaccessible ceiling types.
3. Control valves shall not be installed, above or below ceilings in classrooms, offices, conference rooms or any dormitory living quarters.
4. Drain valves shall only be installed in corridors, stairwells, mechanical rooms, fire pump rooms and sprinkler valve rooms and shall be easily accessible. The drain valves shall be accessible with the use of no more than a six-foot stepladder.
5. Drain valves shall not be installed, above or below ceilings, in classrooms, offices, conference rooms or in dormitory living quarters, or in any area requiring entry through a classroom, office, conference room or any dormitory living.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6. All drain valves discharge shall be piped to a drain capable of handling the discharge at full flow or to the exterior of the building.
   a. Concrete splash blocks shall be installed below all sprinkler auxiliary drains. Splash blocks shall be placed with a slope draining away from the building and shall prevent erosion. Confirm placement with SID.
7. Inspector test valves (ITVs) shall only be installed in mechanical rooms, corridors, stairwells, fire pump rooms, sprinkler valve rooms and housekeeping closets and shall be easily accessible. The ITVs shall be accessible with the use of no more than a six-foot stepladder.
8. Inspector test valves shall not be installed, above or below ceilings, in classrooms, offices, conference rooms or in dormitory living quarters or in any area requiring entry through a classroom, office, conference room or any dormitory living quarters.
9. Inspector test valves discharge shall be piped to a drain capable of handling the discharge at full flow or to the exterior of the building.

3.10.8.2 Identification for Fire Suppression Piping and Equipment

1. Each control valve shall be supplied with signage indicating the area of the building that is served by the valve.
2. At all locations that inspector test valves or control valves are concealed above ceilings or behind access doors, a sign shall be provided on the ceiling below the valve or on the access door indicating the location of the valve.
3. Specifications shall indicate that following the completed installation, Virginia Tech Facilities Fire Protection Manager and their independent consultant will inspect and test all components of the installed sprinkler systems prior to final inspection and acceptance by the SFMO and report any deficiencies to the VT PM, the UBO and the SFMO.

3.10.8.3 Water-Based Fire Suppression Systems

1. In residential buildings, all control valves that are located in spaces accessible by the occupants of the building shall be provided with lockable tamper prevention devices and locks that shall be specified by the University.
2. In residential buildings, each fire department hose valve shall be provided with a lockable tamper prevention device and a lock.
3. No sprinkler heads from any manufacturer which incorporate a rubber O-ring shall be permitted to be installed in university buildings.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4. The stock of spare fire sprinklers shall correspond and the quantity be in proportion to the types and temperature ratings of the sprinklers in the property.
5. In residential buildings, provide concealed-type sprinkler heads in all occupiable rooms.

3.10.8.4 Fire Suppression Hose Valves

In addition to building code requirements, in buildings where the floor level of the highest story is located more than 24 feet above the lowest level of fire department access, all stairways that have an exterior exit shall be provided with standpipes and fire department hose valves on each intermediate level.

3.10.8.5 Fire Suppression Sprinkler Systems

1. Sprinkler system piping shall be steel; no plastic pipe shall be used.
2. In buildings with sprinklers, fire pumps and/or standpipes, separate water service for fire protection shall be provided, and shall not be through the domestic metered water service.
3. A digital set of as-built sprinkler system plans in AutoCAD format (see DCSM section 2.8.5) shall be provided to the VT PM and shall include information for every individual sprinkler head location which identifies the manufacturer, model, temperature rating and date of manufacture for the head that was actually installed. In addition, a digital summary shall also be provided to the VT PM which lists all the individual types of heads installed for the whole building, and the total number installed of each type. It is the responsibility of the sprinkler contractor to verify in the field that the inventory accurately represents the heads that were actually installed. Reliance solely on the approved shop drawings is not acceptable.

3.10.8.6 Dry-Pipe Sprinkler Systems

All dry sprinkler system piping shall be nitrogen-filled black steel pipes for dry-pipe sprinkler systems.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 4 – SITE DEVELOPMENT

4.1 GIS AND SURVEYING

1. Surveys and locations shall be tied to the Virginia Tech Campus Control Network and the Virginia State Plane Coordinate System NAD 83, NAVD 88. For a map of campus control points, visit Campus Survey Monuments.
2. A minimum of two survey control points of semi-permanent material such as rebar or iron pipe oriented to this system shall be established at the project location. The bearing and distance from at least one of the project control points to the Virginia Tech control monuments used shall be labeled.
3. Layer definitions shall adhere to the National CAD Standard for layers collected in the survey.
4. The survey plat or map shall bear:
   a. the name, address, telephone number, and signature of the professional land surveyor,
   b. the surveyor's official Commonwealth of Virginia seal and registration number,
   c. the date the survey was completed, and
   d. the dates of all revisions.
5. The survey plat or map shall:
   a. include a convenient, clearly indicated scale,
   b. include a graphic scale, shown in feet,
   c. show a north arrow,
   d. provide a legend (or other means) on the face of the plat or map to identify symbols or abbreviations used, and
   e. accurately present supplementary or exaggerated diagrams on the plat or map, if necessary for clarity.
6. Sources of information shall always be provided and shall include Virginia 811 markings (with the Virginia 811 ticket number), field observations, as-built records, etc., as applicable to the site.
7. Plans and surveys shall be delivered as a digital file of the location surveys in AutoCAD DWG and DXF formats. Virginia Tech will accept files for the current AutoCAD release or up to five years prior to the current version of the software.
8. Plans and surveys shall be delivered with an ESRI Shapefile (minimum SHP, SHX, DBF, and XML components). The file shall include the completed sections 1 through 7 from the current Metadata Minimum Standards, developed by the Federal Geospatial Data Committee. Anyone submitting metadata can contact the GIS team at gis-space-g@vt.edu with any questions about metadata requirements.

9. Survey points shall be delivered as a comma delimited text or CSV file. The file shall contain the Northing, Easting, Elevation, and Description of the points.
10. Electronic documents shall be delivered to the Plans Library at planslibrary@vt.edu or as directed by the VT PM.

4.1.1 Surface Location and Topographic Survey

Submittals shall include all applicable items in this section on the survey or in the recorded data.

1. Titles and Designations
   a. The identifying titles of all recorded plats, filed maps, right-of-way maps, or similar documents that the survey represents, wholly or in part, shall be shown with their
      i. appropriate recording data,
      ii. map numbers, and
      iii. the lot, block, and section numbers or letters of the surveyed premises.
   b. For non-platted adjoining land, the names and recording data identifying adjoining owners of record, as they appear, shall be shown.
   c. For platted adjoining land, the recording data of the subdivision plat shall be shown. The survey shall indicate platted setback or building restriction lines which have been recorded in subdivision plats or which appear in a Record Document.
   d. Flood zone designation with proper annotation based on federal Flood Insurance Rate Maps or the state or local equivalent shall be shown by scaled map location and graphic plotting only.
2. Monuments, Elevations, and Contours
   a. All evidence of monuments shall be shown and noted to indicate which were found and which were placed.
   b. Elevations for manholes rims, inlets, inverts, curb/gutter, and pavement elevations shall be to one-hundredth of one foot (0.01′). Spot elevation shall be at 25′ intervals on curb/gutter and pavement. These are minimum values, and closer spacing may be needed to satisfy the accuracy of the data.
   c. Elevations for ground shots, water lines, steam lines, and duct banks shall be to one-tenth of one foot (0.1′). Spot elevation shall be at 50′ intervals for ground shots. These are minimum values, and closer spacing may be needed to satisfy the accuracy of the data
   d. For contours, the error shall not exceed one-half contour interval.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Natural Features
   Ponds, lakes, springs, or rivers bordering on or running through the premises being surveyed shall be shown.
4. Structures and Access Routes
   a. The location of all buildings upon the lot or parcel shall be shown and their locations defined by measurements perpendicular to the boundaries.
      i. If there are no buildings erected on the property being surveyed, the plat or map shall bear the statement, "No buildings."
      ii. Proper street numbers shall be shown where available.
      iii. Show the exterior dimensions of all buildings at ground level and the square footage of the exterior footprint of all buildings at ground level.
   b. The character and location of all walls, buildings, fences, and other visible improvements within five feet of each side of the boundary lines shall be noted.
   c. Driveways and alleys on or crossing the property shall be shown.
      i. Where there is evidence of use by other than the occupants of the property, the surveyor shall indicate that on the plat or map.
      ii. Where driveways or alleys on adjoining properties encroach, in whole or in part, on the property being surveyed, the surveyor shall indicate that on the plat or map with appropriate measurements.
   d. Parking areas and, if striped, the striping and the type (handicapped, motorcycle, regular, etc.), and number of parking spaces shall be shown.
   e. Indication of access to a public way such as curb cuts and driveways shall be shown.
5. Roadways
   a. The measured and recorded distances from corners of parcels surveyed to the nearest right-of-way lines of streets, together with recovered lot corners and evidence of lot corners, shall be noted.
   b. The distances to the nearest intersecting street shall be indicated and verified. Names and widths of streets and highways abutting the property surveyed and widths of rights of way shall be given.
   c. A vicinity map showing the property surveyed in reference to nearby highway(s) or major street intersection(s) shall be provided.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6. Easements
   Easements of record shall be shown, both those burdening and those benefiting the property surveyed, indicating recording information.
   a. If such an easement cannot be located, a note to this effect shall be included.
   b. Observable evidence of easements and/or servitudes of all kinds shall be located and noted. These may include easements created by roads or rights-of-way; water courses or drains; telephone, telegraph, or electric lines; and water, sewer, oil or gas pipelines on or across the surveyed property and on adjoining properties if they appear to affect the surveyed property.
   c. If the surveyor has knowledge of any such easements and/or servitudes, not observable at the time the present survey is made, the lack of observable evidence shall be noted.
   d. Surface indications, if any, of underground easements and/or servitudes shall also be shown.
7. Utilities
   Show the location of utilities existing on or serving the surveyed property as determined by:
   a. Observed evidence, observed evidence together with plans and markings provided by client, utility companies, Virginia 811, and other appropriate sources (with reference as to the source of information);
   b. railroad tracks and sidings, manholes, catch basins, valve vaults or other surface indications of subterranean uses; and
   c. wires and cables (including their function) crossing the surveyed premises, all poles on or within ten feet of the surveyed premises, and the dimensions of overhangs affecting the surveyed premises.
8. Land Use
   a. As accurately as the evidence permits, the location of cemeteries and burial grounds shall be shown. These locations may be disclosed in the process of researching title to the premises or observed in the process of performing the field work for the survey.
   b. Locate and note observable evidence of the site being used as a solid waste dump, sump, or sanitary landfill.

4.1.2 Subsurface Utility Location

1. Notify the university surveyor before the installation of all underground utilities or when existing utilities are exposed.

2. Horizontal accuracy shall be within one-tenth of one foot (0.1′) and vertical accuracy shall be within one-hundredth of one foot (0.01′).
3. The subsurface location survey data and mapping shall be continuous throughout the project.
4. Utilities to be located and data to be collected shall include these items:
   a. Steam tunnel and lines
      i. Location and elevation of the tunnel and manholes
      ii. Location and diameter of direct-buried steam and condensate lines
   b. Water lines (domestic, chilled & hot water)
      i. Location, material type, size, and elevation at the top-installed water lines
      ii. Location and material type of valves and a valve type designations
      iii. Location and material type of all fittings at horizontal and vertical bends
   c. Electric and communication utilities
      i. Location and elevation of the duct bank top and bottom invert
      ii. Location of top, diameter, and material type of direct-buried electric and communication conduits
      iii. Location of top, size, and material type of junction boxes, vaults, and other appurtenances
   d. Storm sewer
      i. Location of manhole rims and inlets with invert elevations
      ii. Identification of offsets, pipe sizes, material types, and the direction of the flow for each offset
      iii. Location of pipe reducers and tie-ins not within a storm structure
   e. Sanitary sewer
      i. Location and elevation of manholes with inverts of all pipes entering and leaving the structure
   f. Existing utilities
      i. Location and elevation of any existing utilities exposed during the excavation of trenches for new utilities
      ii. Digital photograph of the crossing of the existing and new utilities

4.2 Landscaping

1. The project A/E shall retain a landscape architect to provide the University with a complete landscape plan, details, and specifications to be included in the project bid documents, as well as a cost estimate.

2. The A/E landscape architect shall develop plans in conjunction with the University Landscape Architect. The University Landscape Architect, University Arborist, and VT Grounds Manager will collaborate on the design and development of the landscape.
3. Final stabilization and landscaping in all stormwater Best Management Practices (BMPs) shall be the responsibility of the Contractor in compliance with the VTAS&S.
4. All tree planting, removal, and maintenance shall meet standards set by ANSI Z133.1 Safety Standard and ANSI A300 Tree Performance Standards.
5. The USDA Plant Hardiness Zone Map should be used as a guide in the selection of plantings. Marginally hardy species are discouraged.

4.2.1 Landscape Planning Process

1. Follow the Appendix I: Approved Plant and Tree Lists during the development of the landscape plan. Any deviation from the lists requires approval from the University Arborist and the University Landscape Architect prior to plan submittal.
2. The A/E landscape architect must consult with the University Landscape Architect throughout the landscape planning process and as follows:
   a. Survey the existing trees on the site with the University Arborist.
   b. Consult the VT Campus Master Plan and Appendix A: Campus Design Principles for the discussion of landscape guidelines prior to meeting with the University Landscape Architect.
   c. Conduct preliminary landscape planning meeting to discuss process and site issues influencing development of the landscape plan.
   d. Coordinate plant selection.
   e. Coordinate landscape planning with building stakeholders with assistance from the University Landscape Architect.
   f. Provide full landscape plans and specifications.
   g. Review landscape specifications with the University Landscape Architect.

4.2.2 Landscape Implementation

1. Landscape installation will be managed (procurement, installation, and final inspection) by CPIF using plans and specifications provided by the project A/E. CPIF landscape installation will commence after the Contractor responsibilities are fulfilled and the work is inspected and approved by ESC inspectors.
2. Contractor responsibilities include the following items:
   a. Staging area soil restoration work

   b. Topsoil spreading and fine grading
   c. Furnishing, installing, and maintaining (watering) of sod until the sod is fully rooted
      i. Sod shall be sufficient to stabilize the site.
      ii. Sod shall be protected from damage during the rooting process using warning signs and temporary perimeter controls.
   d. Furnishing, installing, and maintaining (watering) seeded areas until the grass is established. Seeded areas that have grown enough to be mowed twice are considered established. See DCSM section 4.3.2 for seeding mixes and process for installation.
3. CPIF responsibilities include the following items:
   a. Installation of mulch on the site prior to sign-off by ESC inspectors
   b. Edging of plant beds (shrub and groundcover beds) and application of a minimum of 3 inches of mulch to plant beds
4. For projects where the landscape installation is in the Contractor's scope of work the following shall apply:
   a. The A/E landscape architect must conduct a preconstruction meeting with the landscape subcontractor.
   b. Provide, at a minimum, an inspection of plant materials prior to installation, one or more inspections during landscape installation, and a final landscape inspection/punch list.
   c. The University Landscape Architect and VT Grounds shall be included in plant material inspection prior to installation and in the final landscape inspection/punch list.
   d. Final landscape installation acceptance shall be by the University Landscape Architect.
5. For projects where landscape installation is managed by VT Grounds, CPIF will manage all preconstruction and inspection activities.

4.2.3 Landscape Design Considerations

1. Landscaping (and the future growth of landscaping) shall not impact transportation site distance and shall be avoided within sight lines from 3 to 7 feet above the paved traffic route. See DCSM section 3.1 for restrictions on using landscaping as fall protection.
2. Maintenance resources on campus are very limited. The landscape must be designed with this in mind.
3. A landscape of predominantly long-lived shade trees with accents of flowering and evergreen trees is preferred.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4. To simplify maintenance, shrubs should be planted in masses, avoiding complicated or “fussy” multi-species arrangements while serving a specific function (screening, traffic control, non-mowable slope cover, etc.).
5. Perennial beds should be severely limited and focused on high visibility areas such as main building entries.
6. Complicated, multi-species ground cover and perennial beds, ornamental grasses, etc., are not long-term landscape features and should not be included in the landscape plan. Use of ornamental grasses for the campus core should be limited and must be approved by Virginia Tech during design. Lawn is an acceptable cover for embankments that are less than 3:1 slope.
7. Bioretention planting outside of the treatment area shall be shrub-based with plants selected based on tolerance to flooding and drought and adaptability to the current bioretention soil specification.
8. Embankments:
   a. No trees shall be planted on a BMP embankment.
   b. Embankments with slopes greater than 3:1 shall be planned with consideration for the maintenance of the area.

4.2.4 Tree Protection and Preservation Procedures

For tree protection procedures, see the tree protection detail in the VT Design Standard Detail Library. Coordinate trees to be removed with the University Arborist.

For risk assessment and tree inspection procedures, contact the University Arborist office for copies of the VT Tree Risk Assessment Procedure and VT Tree Inspection Procedure.

4.2.4.1 Preservation During Design Phase

Construction, renovation, and development shall not occur within specified tree protection zones.

On the site survey map, identify all trees that may be impacted (above and below ground) by construction equipment, cut and fill activities, utility corridors, proposed walks and roads, and potential construction staging areas. All trees that will remain and the tree protection zones for those trees shall be indicated on the site plans.

If trees are grouped in a forest or woodlot, then only the location of the woodlot and any trees greater than 15 inches in diameter at 4.5 feet above grade (the diameter at breast height or DBH) should be identified.

4.2.4.1.1 Low Priority for Preservation

1. Small trees (less than 5 inches DBH) that will likely be impacted by construction activities.
2. Larger trees with relatively low landscape value. Examples include but are not limited to, trees with poor form, trees of undesirable species, or trees with inadequate space to accommodate current or future growth even if the site is ameliorated, as determined by the University Arborist office.

4.2.4.1.2 High Priority for Preservation

1. Larger trees (greater than 5 inches DBH) of desirable species with fair to good form, good health, and room to continue to grow, as determined by the University Arborist office.
2. Trees that were planted as memorials, commencement trees, or commemorative trees.

4.2.4.2 Construction Site Location

Avoid locating the general construction site around high priority trees where possible.

1. Plan all construction activities including new utility corridors, staging areas, new sidewalks, and new roads for a minimum clearance of 25 feet away from the base of trees, and not within the critical root zone as determined by the University Arborist. Greater distances are desirable.
2. High priority trees should receive more consideration than low priority trees in planning corridors, staging areas, walks, and roads.

4.3 PLANTING

The University Landscape Architect shall be consulted on all planting-related project components. The University Arborist shall be consulted on all tree planting-related project components. See the VT Design Standard Detail Library for planting and tree protection details. The use of sod is recommended on all disturbed areas. Areas of focus include, but are not limited to:

1. Planting preparation
   a. Soil Profile Rebuilding: This specification sheet is provided through the VT Urban Forestry website.
   b. Mulching
   c. Planting soil mix
   d. Planting beds

2. Turf and grasses
    a. Hydro-mulching
    b. Seeding
    c. Sodding
3. Plants
    a. Groundcovers
    b. Plants and bulbs
    c. Shrubs
    d. Trees
4. Planting accessories
    a. Landscape edging
    b. Tree grates
    c. Silva cells
5. Transplanting
    a. Groundcover
    b. Plant and bulb
    c. Shrub
    d. Tree

4.3.1 Topsoil

Topsoil shall consist of friable surface soil, sandy clay loam, obtained from well-drained areas, free from objects larger than 1-1/2 inches maximum dimension, and free of subsoil, roots, grass, other foreign matter, hazardous or toxic substances, and deleterious material that may be harmful to plant growth or may hinder grading, planting, or maintenance.

Composition shall be in general accordance with ASTM D5268:

1. Gravel-sized fraction: Maximum 5 percent by weight retained on a No. 10 sieve.
2. Sand-sized fraction: Minimum 20 to 60 percent passing No. 10 sieve.
3. Silt and clay-sized fraction: Minimum 35 to 70 percent.
4. Organic matter: Minimum 1.5 percent by dry weight as determined in accordance with ASTM D2974.
5. pH: Range 5.5 to 7.0.

Test topsoil at Virginia Tech Soil Testing Lab and follow amendment recommendations for landscape plants.

4.3.2 Seed Mixes, Rates, and Installation Processes

4.3.2.1 Seed Materials and Topsoil

1. Seed Mixes:
   a. Spring and fall seasons (March 1-May 15 and August 15-November 1): New crop, blue tag certified. Mix to consist of: 15% Kentucky Bluegrass (mix of 3 varieties) and 85% Turf Type Tall Fescue (mix of 3 varieties). Percentages determined by weight.
   b. Summer seeding (May 15-August 15): New crop, blue tag certified. Mix to consist of: 15% Kentucky Bluegrass (mix of 3 varieties), 80% Turf Type Tall Fescue (mix of 3 varieties), and 5% German Millet. Percentages determined by weight.
   c. Winter seeding (November 1-March 1): New crop, blue tag certified. Mix to consist of: 15% Kentucky Bluegrass (mix of 3 varieties), 80% Turf Type Tall Fescue (mix of 3 varieties), and 5% Annual Rye. Percentages determined by weight.
2. Hydroseeding fertilizer: 20-20-20 soluble.
3. Straw: Clean oat or wheat straw well-seasoned before bailing, free from mature seed-bearing stalks or prohibited or noxious weeds.
4. Test topsoil at the Virginia Tech Soil Testing Lab and follow recommendations for landscape plants.

4.3.2.2 Seeding Process

1. Grade seed bed to a smooth, free-draining, even surface with a loose, fine, texture.
2. Remove stones over 1″ in any dimension, sticks, roots, rubbish, and extraneous matter from graded seed bed.
3. Seed immediately after preparation of bed.
4. Seed areas within contract limits and any areas outside contract limits disturbed as a result of construction operations.
5. Apply seed with a rotary or drop type distributor. Install seed evenly by sowing equal quantities in two directions, at right angles to each other. Apply seed at 8 lb./1000 sq. ft. or 340 lb./acre.
6. Incorporate seed into top 1/8″ of soil and roll.
7. Seeded area mulching:
   a. Blown straw tacked with a light coating of hydromulch is preferred.
   b. Place straw or fiber mulch on seeded areas within 24 hours after seeding, in a continuous blanket, and at the rate of 2-1/2 tons per acre, or 2 bales

per 1,000 square feet of area. The Contractor will be asked to remove any straw clumps left on the seeded area.
c. A mechanical blower may be used for straw mulch application when acceptable to OUP and VT Grounds. Coordinate through the VT PM.
d. For areas requiring an erosion control blanket (e.g., slopes exceeding 4:1), provide a straw fiber mat with a single polypropylene netting sewn with degradable thread. The mat thickness shall be approximately 0.45″ and all components of the mat shall photodegrade in approximately 45 days. The basis of design is EroNet DS75.

8. Seeded area protection:
   a. It is the Contractor's responsibility to protect seeded areas from various types of traffic (vehicles, bikes, pedestrians, etc.). Seeded areas should be identified with signs and isolated using a form of temporary perimeter control.
   b. No construction traffic will be permitted on seeded areas. Any seeded area disturbed by the Contractor must be re-tilled to 4″ depth and re-seeded.

4.3.3 Sod

1. Sod shall be a locally grown blend of fescue and bluegrass (85% fescue/15% bluegrass).
2. Apply sod to topsoil surfaces prepared in equal manner to seeded areas.
3. Install sod within similar timeframe as seeding.
4. Water sod sufficiently to maintain moist root zone soil until establishment.
5. Sod installation may be extended in to summer months with understanding that Contractor will be required to adequately water until establishment.

4.3.4 Topsoil Preparation

1. Spread topsoil to 4″ minimum depth after subsoil preparation.
2. Compact topsoil to 80% Standard Proctor.

4.3.5 Staging Area Restoration

Staging areas to receive landscaping in any form (lawn, trees, shrubs, etc.) must be restored using the specifications provided in the Soil Profile Rebuilding document located on the VT Soil Profile Rebuilding website.

4.3.6 Lawn Restoration

Lawn restoration shall be performed as a one-time action at project closeout.

On existing lawns where substantial (greater than 50%) turf remains within the construction fencing, rake, aerate (twice in opposite directions), fertilize and overseed as noted above at 5 pounds per 1000 square feet. Straw is not required on overseeded lawns.

Provide fertilizer, seed, and soil amendments as specified for new lawns and as required to provide a satisfactorily reconditioned lawn. Provide topsoil as required to fill low areas and meet new finished grades.

4.4 Tree Planting and Care

4.4.1 Purpose

The purpose of the Virginia Tech tree planting and care standards is to identify the policies, procedures, and practices that are used in establishing, protecting, maintaining, and removing trees on the Virginia Tech campus. This document shall serve as a source for designers, contractors, and Virginia Tech faculty and staff to reference when planning or implementing activities on Virginia Tech properties that may impact tree assets. The overall goal of the standards is to ensure a safe, attractive, and sustainable campus urban forest.

The specific objectives of the standards are:

1. Ensure proper species selection, high-quality nursery stock acquisition, and installation compliant with industry standards.
2. Promote appropriate species diversity, tree age distribution, and urban canopy structure for campus urban forest sustainability.
3. Protect and conserve high-value campus trees during development, construction, and renovation projects.
4. Promote tree health, structure, and safety by implementing ANSI standards and ISA’s best management practices when maintaining the campus urban forest.
5. Ensure that trees are reasonably replaced when there is mortality due to weather, pest infestations, injury, construction, or development displacement.
6. Encourage campus community members to respect and value the campus urban forest.

All tree planting and tree care on Virginia Tech property shall conform to ANSI A300 standards and ANSI Z133 safety standards. All trees planted on Virginia Tech property shall conform to ANSI Z60.1 standards.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.4.2 Responsible Department

The Virginia Tech University Arborist office, located within the CPIF and under the direction of the VPCPIF, is responsible for the development of the Virginia Tech tree planting and care standards and for managing natural tree assets on campus.

4.4.3 Campus Tree Advisory Committee

The campus tree advisory committee is formally known as the Arboretum Committee and is comprised of faculty and staff from many plant-related programs within the university and the town of Blacksburg, VA. The committee meets biannually or as needed and provides important input into the care and improvement of the campus landscape.

4.4.4 Plant Selection, Diversity Requirements, and Planting Stock Standards

As the campus is used as a teaching lab and a resilient canopy is a priority, increasing the diversity of tree species is extremely important. Diversity thresholds of 5% of any one species, 10% of any one genus, and 15% of any family should be implemented during planting projects; this practice will ensure adequate diversity as tree populations are installed.

Small, mostly ornamental, tree species should be limited on new planting projects to no more than 10% of the population installed. However, species selection must be dictated by site conditions, available planting stock, and expected changes in the climate. See Appendix I: Approved Plant and Tree Lists.

All planting projects shall specify bare root or balled and burlapped planting stock. Container grown trees will not be approved by the University Arborist office. Planting stock shall not be specified at sizes greater than 2.5-inch caliper.

4.4.5 Planting Specifications

Planting shall consist of excavating all planting holes, planting, and maintaining new trees of the type designated on the Virginia Tech Core Campus Approved Tree List (see Appendix I: Approved Plant and Tree Lists). All work shall be in accordance with these specifications and to the satisfaction of the University Arborist office.

It is the responsibility of the installer to notify all owners and operators of underground facilities and have all utilities located and marked before work occurs.

Once work begins, the installer takes full responsibility for the planting locations. All excavated materials that are not backfilled into the planting hole shall be removed from the site and disposed of properly. The area shall be safe and secure throughout the job and at the end of the workday.

Site characteristics, such as overhead utilities, existing vegetation, and infrastructure items (e.g., curbs and sidewalks) shall be considered prior to tree design and installation. Trees that grow taller than 25 feet should not be planted directly under utility lines. When possible, the tree leader shall be offset from power lines. Where subsurface obstructions (e.g., vaults, utilities, or sprinklers) are encountered during excavation and restrict the planting of a tree, the installer shall restore the disturbed area to its original condition. If damage is done to an underground obstruction, it is the responsibility of the installer to restore the site to its original condition. A new planting location will be designated if conditions permit.

Trees shall be transported and handled with care to ensure adequate protection against injury and desiccation. When transported in closed vehicles, plants shall receive adequate ventilation to prevent sweating. When transported in open vehicles, plants shall be protected by tarps or other suitable cover material. Balled and burlapped trees shall be set on the ground and balls covered with soil. Until planted, all materials shall be properly maintained and kept adequately watered. Installers are liable for any damage to property caused by planting operations and related work. All disturbed areas shall be restored to their original condition.

Traffic shall not be disrupted at any time during planting operations, unless VT Parking and Transportation has permitted the disruption. Work shall not be performed on opposite sides of the street at the same time.

4.4.5.1 Planting Seasons

All planting steps shall be performed and shall conclude within the same planting season. Planting stock shall be dug at the nursery in the dormant season (November-March) and retained temporarily in holding yards. Planting stock shall be delivered to the site directly before installation. Stock shall not be held or stored beyond the planting season. No planting is permitted in the summer. Any off-season planting must be approved by the University Arborist office.

4.4.5.2 Installation

Remove all materials from the planting hole for the full length and width of the planting hole to the depth of the tree’s root ball. For excavation of a lawn strip that is not restricted by hardscape, excavate an area at least three times the diameter of the root ball. If the lawn strip is restricted by hardscape on two sides, excavate a planting hole parallel to the hardscape that is three times the diameter of the root ball. Extreme care shall be taken to avoid excavation to a depth greater than required. The subgrade below the root ball shall be tamped slightly to prevent settlement. All ropes, stones, etc., shall be removed from the planting site before backfilling. All excavated materials remaining above grade after tree installation shall be removed from the site and disposed of in an acceptable manner.

Place balled and burlapped material in the prepared planting hole by lifting and carrying it by the root ball so that the ball will not be loosened. Set the tree straight and in the center of the pit. All trees shall sit, after settlement, with the base of the trunk and the beginning of the roots, known as the "trunk flare", level with the site soil grade. If the top of the root ball is not consistent with this area, the depth of the planting site should be adjusted by adding or removing soil below the root ball to make the trunk flare level with the sidewalk grade.

Cut and remove rope and wire from the root ball. All rope, wire, twine, burlap, and other materials shall be removed and not backfilled into the hole. Backfill shall be loose and friable and clumped; this will reduce air pockets and settling. Soil shall be firmed as the hole is backfilled but not compacted. All planting holes shall be filled with the backfill and made level with existing conditions. Cultivate and rake over finished planting areas leaving them in a clean condition. At no time should soil or mulch be mounded to cover the trunk of the tree. The trunk flare shall always be visible. The final soil level shall be flush with the surrounding soil grade to prevent a potential tripping hazard.

4.4.5.3 Staking and Tree Wrap

All staking shall be done during the planting operation and shall be maintained throughout the first year of the 2-year guarantee period. After the first year, the stakes shall be removed. Stakes shall be of seasoned hardwood, preferably oak, and shall show no sign of cracking or decay.

Stakes shall be cut evenly so they are the same height. All trees shall be supported by two five-foot-long stakes. The diameter at the mid-point of the tree stake shall not be less than 2 inches. Stakes shall be placed outside of the root ball, driven 30 inches into the ground, and fastened to the tree with a suitable length of 3/4" wide, flat, woven polypropylene material (i.e., arbor tie).

Unless otherwise directed, trees shall be staked as shown on the plans and in accordance with these specifications. Stakes shall be set parallel to curbs. Trees shall stand plumb after staking. Stakes and arbor tie shall be removed at the end of the first year of the 2-year guarantee period, unless otherwise directed by the University Arborist office. At the time the stakes are removed, any holes left by the stakes shall be filled.

No tree trunks shall be wrapped. Remove all nursery tags and protective wrapping. No material shall be left that may girdle the stem.

4.4.5.4 Pruning

Pruning shall be done in accordance with ANSI A300 Part 1 Standard Practices for structural pruning. Pruning before and for two years after planting shall be limited to the removal of dead, broken, or diseased branches. All diseased branches and all dead branches shall be removed. Any branch which may be partly dead, yet has a healthy lateral branch at least one third the diameter of the parent branch shall be pruned back to the healthy lateral branch.

All stubs or improper cuts resulting from former pruning shall be removed. All cuts shall be cleanly made with sharp and sterile tools as close to the parent trunk or limb as possible without disturbing the branch bark ridge or callus collar. Any existing nails, spikes, wire, plastic, or other materials found driven into or fastened to the trunk or branches shall be removed or, if approved by the University Arborist, they shall be cut flush in a manner to permit complete sealing over.

4.4.5.5 Watering

At the time of planting, the soil around each tree shall be thoroughly saturated with at least 20 gallons of potable water. Care shall be taken to avoid compacting the backfill or eroding the planting hole. Water shall not be applied in a manner which damages plants, stakes, or adjacent areas. Each tree bed shall be watered evenly in a manner which does not erode the soil or mulch. Watering shall not cause uprooting or exposure of plant roots to the air.

4.4.5.6 Mulching

Bark mulch, arborist chips, or coarse woody debris shall be applied as a ground cover to the surface of all planting beds at the time of planting and again after the tree stakes have been removed, one year after planting.

Mulch shall be applied to a uniform depth of 3 inches and shall be distributed to create a smooth, level cover over the exposed soil. A gap of approximately

2 inches should be left between the mulch and the trunk of the tree to avoid mounding above the trunk flare.

4.4.6 Installation Maintenance

4.4.6.1 Watering

Watering shall take place throughout the two-year guarantee period, at a rate of at least 20 gallons at approximately two-week intervals from May 15 to October 31. The frequency of watering may increase or decrease based on weather conditions, the resulting soil water content, other physical factors, or at the request of the University Arborist office.

Water shall not be applied in a manner which damages plants, stakes, or adjacent areas. Each tree bed shall be watered evenly in a manner which does not erode soil or mulch. Watering shall not cause uprooting or exposure of the plant's roots to the air. Damages resulting from these operations shall be immediately repaired at the expense of the installer.

4.4.6.2 Other Maintenance Activities

All newly planted trees shall be maintained by the installer until 2 years after the final inspection by the University Arborist office. Maintenance for the trees shall include weeding, cultivating, edging, pruning, adjustment, and timely removal of stakes and arbor tie (one year after tree installation).

Maintenance for the planting area shall include the repair of minor washouts, mulching, soil replacement, and any other horticultural operations necessary for proper growth of all trees and for keeping the entire planting area neat in appearance. All planting areas shall be cultivated and weeded with hoes or other appropriate tools within the period from May 15 to October 31, and such cultivating and weeding shall be repeated at least every 3 weeks. Under no conditions shall weeds be allowed to attain more than 6 inches of growth.

4.4.6.3 Guarantee Period

All trees must be guaranteed for 2 years. All installers shall provide a guarantee for the trees planted.

4.4.6.4 Tree Replacement

Any tree planted as dead or, in the opinion of University Arborist office, planted in an unhealthy or unsightly condition prior to final acceptance shall be replaced immediately, or in the next planting season, if a seasonal delay is necessary. Such trees include those that have lost the natural shape due to dead branches,

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

excessive pruning, inadequate or improper maintenance, or have been damaged through actions or negligence by the Contractor or subcontractor.

There shall be a 2-year guarantee on trees commencing after the final inspection by the University Arborist office. Where dead trees have been identified, whether due to natural causes, improper actions, or negligence, the dead material along with stakes and arbor ties shall be removed within 30 days of notification. When necessary, topsoil, grass seed, or appropriate paving material shall be added to the pit at the time of tree removal to eliminate potential tripping hazards. Photos shall be submitted to the University Arborist office showing the proper removal of trees. A renewed approval is required for any replanting during the planting season.

4.4.7 Campus Arboriculture Practices

4.4.7.1 Pruning Schedule

The maintenance pruning schedule shall be dictated by tree species, age, condition, function, and location.

1. Trees classified as young in the Virginia Tech Tree Inventory shall receive structural pruning every 4 years or more frequently as needed.
2. Trees classified as immature in the Virginia Tech Tree Inventory shall receive structural pruning every 4 years or more frequently as needed.
3. Trees classified as mature in the Virginia Tech Tree Inventory shall receive maintenance pruning every 5 years to remove dead, diseased, dying, and defective branches from the crown or to resolve any tree and human conflicts. Some mature trees may require more frequent maintenance and shall be assessed as needed.
4. Trees adjacent to roadways, walkways, signs, buildings, and street lights should be inspected annually for safety and clearance issues. Maintenance pruning should be scheduled as necessary.

4.4.7.2 Pruning Practices

To encourage the development of a strong, healthy tree, the following guidelines shall be followed when pruning.

4.4.7.2.1 General

1. Pruning shall not be conducted without a clear objective.
2. Prune first for safety, next for health, and finally for aesthetics.

3. When removing branches, the pruning cut shall not damage the branch bark ridge and branch collar.
4. Internode (heading) cuts should not be used except in storm response and crown restoration procedures.
5. Branch reduction or thinning should be used to achieve pruning objectives rather than making large (greater than 8 inches in diameter) branch removal cuts.

4.4.7.2.2 Dead Wood Pruning

1. Pruning shall be performed to remove dead, diseased, dying, and compromised branches; this practice reduces risk, promotes health, and improves appearance.
2. Large branches shall be removed with the aid of ropes and rigging equipment to minimize the risk of tree injury from falling debris.
3. Some dead wood may be retained in low occupancy areas for the benefit of wildlife and to aid in education and outreach.

4.4.7.2.3 Thinning

1. Thinning shall be performed to reduce the density of branches which increases light penetration, improves visibility, and decreases wind load.
2. Assess how a tree will be pruned from the top down.
3. Branches with strong, U-shaped angles of attachment shall be favored. Remove branches with weak, V-shaped angles of attachment and the included bark.
4. Evenly space lateral branches on the main stem of young trees.
5. Remove any branches that rub or cross another branch.
6. Ensure that lateral branches are no more than one-half to three-quarters of the diameter of the main stem to discourage the development of co-dominant stems.
7. Do not remove more than one-quarter of the living crown of a tree at one time. If it is necessary to remove more, do it over successive years.

4.4.7.2.4 Raising

1. Raising shall be performed to provide vertical clearance from thoroughfares, around signs and street lights, and near structures.
2. Always maintain live branches on at least two-thirds of a tree's total height. Removing too many lower branches will hinder the development of a strong main stem.
3. Remove basal sprouts and vigorous epicormic sprouts.

4.4.7.2.5 Reduction

1. Reduction shall be performed to decrease the overall height of a tree, to decrease the length of an individual branch, or to reduce the size of a tree's crown.
2. Use reduction pruning only when absolutely necessary. Make the pruning cut at a lateral branch that is a least one-third the diameter of the stem to be removed.
3. If it is necessary to remove more than half of the foliage from a branch, remove the entire branch.

4.4.7.2.6 Topping of Trees

Topping, heading, hat-racking, or any other form of damaging crown- or branch-reduction pruning shall not be permitted except in emergency situations or while executing a crown restoration practice.

4.4.7.3 Cultural Practices

4.4.7.3.1 Mulching

For tree mulching, apply mulch to a depth no greater than 3 inches; care shall be taken to prevent mulching around the root collar. Mulch shall be applied every two years for trees up to approximately 6 inches in diameter. Periodically, drip lines of larger trees, tree stands, and high-value trees are mulched extensively with coarse wood chips.

4.4.7.3.2 Fertilization and Pest Management

There is no regular tree fertilization beyond the treatment received as a result of fall lawn fertilization. Specimen or high-value trees may receive prescription fertilization when severe nutrient deficiencies are diagnosed.

Trees are treated for pest problems as needed. There is an extensive Dutch elm disease treatment program on campus. There is some regular treatment of hemlocks on campus for hemlock wooly adelgid and ash trees for the emerald ash borer.

4.4.7.4 Tree Removals

Live trees are generally removed to reduce risk to the public, property, and services. Rarely does tree removal occur to improve the quality of the landscape.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Trees may be removed after assessment by the University Arborist office, which will consult with and seek consensus from the Arboretum Committee.

When the University Arborist office and the Arboretum Committee cannot reach a consensus, an independent assessment by a consulting arborist may be required and submitted to the committee for review.

4.4.7.5 Storm Response and Recovery

Storm response and recovery are generally accomplished in-house. In a crisis, the first priority is to remove tree debris that blocks campus thoroughfares, disrupts campus operations, or poses a high or imminent risk to the campus community. Once these critical needs are addressed, a prioritized recovery plan is implemented during which seriously damaged trees are systematically removed and other impacted trees are pruned to restore their health and structure while reducing risk.

As the tree planting budget permits, lost trees are strategically replaced to restore the structure and function of the campus urban forest in a reasonable time frame. During storm response and recovery, needs for trees requiring specialized equipment or skills not available in-house are addressed by an outside contractor.

4.4.7.6 Destruction of Trees

Whether partial or complete, any damage or destruction of trees, shrubs, or other growth on University property without prior approval is unlawful and is a misdemeanor (*Code of Virginia* § 18.2-140). If damage or destruction of trees is anticipated, prior approval for those actions shall be obtained from the University Arborist. If damage or destruction of shrubs or other growth is anticipated, prior approval for those actions shall be obtained from VT Grounds.

4.5 Exterior Signage

1. The exterior signage standards are provided in Appendix F: Campus Wayfinding Guidelines. The following applies to these standards:
   a. The product components specified in the standards shall be used to the exclusion of all others.
   b. Requirements on the use of the university mark:
      i. The standards show a mark that has been discontinued from use. When a mark is needed, signage shall feature the new mark.
      ii. OUP shall be consulted on the presence of a university mark on signage packages.

iii. The university mark is no longer being placed at the base of the B.1 signs.

c. Several updates to the exterior sign standards are available as details in the VT Design Standard Detail Library.

2. Mechanical fastening shall be used for exterior signage.

4.6 Exterior Improvements

4.6.1 Exterior Site Furnishings

OUP shall be consulted on all exterior metal fixtures and furnishings. All fixtures and furnishings shall be finished with a dark bronze powder coat to match campus standards unless an alternate color and/or finish is approved by OUP.

Approved powder coat manufacturers and colors include:

1. Tiger Drylac Roman Bronze Matte (39/60060)
2. Sherwin-Williams custom color formula

Table 4-1. Sherwin-Williams Custom Color Formula

BAC COLORANT	OZ	32	64	128
B1 – Black	4	57	-	-
Y3 – Deep Gold	2	2	-	-
R2 – Maroon	-	27	-	-
W1 – White	-	36	-	-

3. Benjamin Moore custom color formula

Table 4-2. Benjamin Moore Custom Color Formula

HP29-4X		
Y3	2x	14.5000
S1	5x	13.7500
W1	2x	22.0000
R3	1x	2.1250

Refer to Appendix D: Site Furnishing Guide. OUP must review furniture/equipment plans and requests to use specialty or higher-end furniture.

4.6.1.1 Handrails

1. For posts set in concrete, furnish matching sleeve or inserts not less than 5 inches long. Aluminum handrails are acceptable; steel handrails must be powder coated. Provide positive drainage where handrails are set into sidewalks.
2. When using stainless steel railing system all mechanical fasteners used in the assembly of the railing system shall be manufactured from stainless steel.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.6.1.2 Storage

Prefabricated storage sheds shall not be placed on campus, nor shall shipping containers be placed for use as storage facilities. Existing storage sheds may remain but shall not be improved (except for ordinary maintenance and repair). These structures shall be removed at the end of their useful life. Any existing shipping containers shall be removed as soon as feasibly possible.

4.6.1.3 Site Seating

Stadium Seating – The University does not generally endorse stadium seating in the campus landscape. Such seating arrangements, as traditionally composed, do not meet the university standards for Universal access. However, Accessible variations are possible and should be discussed with OUP early in the site design process. Approvals from OUP, the UBO, and the Office for Equity and Accessibility are required before implementing designs using stadium seating in the campus landscape.

4.6.2 Paving and Curbs

Accessibility related improvements (ramps, curb cuts, walks, crossings, etc.) must follow the ADA Standards for Accessible Design related to Title II facilities.

In general, pavement repair shall follow Accessibility requirements and the standard shown in the pavement repair detail in the VT Design Standard Detail Library and in VDOT standards.

4.6.2.1 Concrete Paving and Walks

1. Sidewalks shall follow the concrete walk and slab detail in the VT Design Standard Detail Library.
2. All non-pigmented concrete walks and slab-on-grade shall be class A3 concrete specified with 3 lb./cu. yd. polypropylene macro fiber reinforcement.
    a. Fiber shall be incorporated into the concrete at the plant (prior to delivery). Fiber shall be Euclid Tuf-Strand ES or equal.
    b. Standard concrete walks shall have a minimum thickness of 6 inches and a minimum walk radius of 6 feet.
    c. Concrete walks designed for vehicle traffic (e.g., trash truck access) shall have a minimum thickness of 8 inches and a minimum radius of 15 feet.
3. Plans must show expansion and control joint patterns with maximum control joint spacing equaling the width of the walk.

4. Control joints shall be tooled or saw cut to one-quarter of the concrete thickness, followed with a 'V' chaser blade to chamfer joint. Saw cut within 24 hours of finishing.
5. All adjacent pours and new-to-old work tie-ins must be doweled at a minimum of 3-foot on-center.
6. Concrete walks designed for vehicle traffic shall have a curb edge (concrete or other approved material) and sidewalk corners. Lawn adjacent to the curb should be graded to match the top of the curb.
7. Color and finish:
    a. Use of exposed aggregate and colored concrete is encouraged to reduce glare and add interest to concrete surfaces.
    b. Concrete surfaces shall receive medium weight broom finish.
    c. Exterior concrete shall not be painted or stained.

4.6.2.2 Unit Paving

1. Precast Concrete Unit Paving – paver standard basis of design is Techo-Bloc Blu, 60 mm (pedestrian) or 80 mm (vehicular), with the acceptable colors of Champlain Grey, Shale Grey, and 5% Onyx Black in larger areas.
2. OUP shall also be consulted on the use of porous paving materials.

4.6.2.3 Asphalt Walks

1. Standard asphalt is intended for non-vehicular use only such as bike paths.
2. Heavy asphalt is intended for vehicular use such as parking lots and access drives.
3. Thickness of aggregate base, asphalt sub-base and wearing surface are based on expected vehicle loads.
4. Service access paths shall have a curb edge (concrete or other approved material).

4.6.2.4 Curbing

1. Site curbing shall match VDOT standards. Specify CG-2, CG-6, CG-3, etc., on the plans.
2. Other materials are acceptable such as granite, or precast concrete in limited use where warranted by design intent.

4.6.3 Bollards

The basis of design shall be the MaxiForce Collapsible Bollard model #MCSP-SS2-U or approved equal. The finish shall be powder coated steel and where possible the co lor shall match the campus standard dark bronze. See DCSM section 4.6.1 for approved manufacturers and color formulas.

4.6.4 Exterior Stairs

1. See the VT Design Standard Detail Library for the handrail detail for exterior steps.
2. All handrail and guardrail powder coats shall match the campus standard dark bronze. See DCSM section 4.6.1 for approved manufacturers and color formulas.
3. All exterior steps shall be a minimum of two risers. Single riser steps are not permitted.
4. All exterior steps shall be designed to follow the formula: tread depth + (2 × riser height) = 26 or 27 inches.
5. Riser height must be between 6 to 7 inches.
6. Cheek walls are preferred for exterior steps.
7. Metal stair nosings are not acceptable.
8. The leading edge (intersection of the tread and riser) of stairways shall be perpendicular to the direction of travel. Stairways with the direction of travel at an angle to the leading edge of the stairway are not acceptable.

4.6.5 Retaining Walls

OUP shall be consulted on the design of:

1. Precast or cast-in-place concrete retaining walls
2. Hokie Stone retaining walls
3. Gabion walls (cannot be used in Campus Core)

4.6.6 Fences and Gates

1. Decorative metal fence and gates: include decorative metal guardrail detail shown in VT Design Standard Detail Library.
2. Wood fence and gates: These are generally not acceptable in the core campus; when needed, use VDOT 4-Board fence detail.
3. Green screen: These are generally not accepted in high-visibility areas of the core campus, but where appropriate, fences shall be constructed of 2-inch × 6-inch sized 6-gauge mesh with 2-inch or 2.5-inch sized 16-gauge square posts spaced 96.5 inches on-center (max) and finished with a dark bronze colored powder coat to match campus standards. See DCSM section 4.6.1 for approved manufacturers and color formulas. Fence height can range from 4 to 8 feet tall. Green screens must be planted.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.6.7 Building Edge

Tan river stone size #3/4 on woven landscape fabric shall be used.

Separate from lawn and landscape areas with heavy gauge metal edging.

4.6.8 Irrigation

Campus landscapes generally are not irrigated by automatic irrigation system. Inclusion of an automatic irrigation system requires discussion with CPIF Buildings and Grounds.

Freeze resistant wall hydrants should be placed on buildings on each façade at approximately 100-foot spacing and shown on the planting plan.

For landscapes where water access is required in the landscape, freeze resistant boxed ground hydrants may be used.

4.6.9 Exterior Screening

OUP shall be consulted on all screening requirements on buildings and in the campus landscape. Elements requiring screening include, but are not limited to, all mechanical/electrical/plumbing infrastructure and network infrastructure visible from the exterior of a building. These elements should be installed in a discreet location on the structure.

4.7 Stormwater Design

The standards in this section apply for projects regulated by SID. For projects not regulated by SID, the VSMP regulations shall apply.

4.7.1 References

Except where more stringent requirements are presented in the DCSM, stormwater management control shall comply with stated requirements.

1. Stormwater Hydrology shall comply with state requirements. The primary design references are:
   a. VDOT Drainage Manual
   b. Virginia Stormwater Management Handbook (VSWMH)
   c. Virginia Stormwater Best Management Practice (BMP) Clearinghouse
2. Open Channels shall comply with VDOT and DEQ requirements. The primary design references are the latest editions of the following:
   a. VDOT Drainage Manual
   b. VDOT Road and Bridge Standards
   c. Virginia Erosion and Sediment Control Handbook (VESCH)

   d. Hydraulic Engineering Circular Number 15 (HEC-15), Design of Roadside Channels with Flexible Linings
3. Culverts shall comply with VDOT requirements. The primary design reference is the VDOT Drainage Manual. Other appropriate references include the latest editions of the following:
   a. VDOT Road and Bridge Standards
   b. VDOT Road and Bridge Specifications
   c. VESCH
   d. VDOT Instructional and Informational Memorandum IIM-LD-121.15, Allowable Pipe Criteria for Culverts and Storm Sewers
   e. Federal Highway Administration (FHWA) Hydraulic Design of Highway Culverts HDS No. 5, Pub. No. FHWA-HIF-12-026
   f. FHWA Debris Control Structures Evaluation and Countermeasures HEC No. 9, Pub. No. FHWA-IF-04-016
   g. FHWA Culvert Design for Aquatic Organism Passage HEC No. 2, Pub. No. FHWA-HIF-11-008
4. Storm drainage systems shall comply with VDOT and DEQ requirements. The primary design reference is the VDOT Drainage Manual. Other appropriate references include:
   a. VDOT Road and Bridge Standards
   b. VDOT Road and Bridge Specifications
   c. VESCH
5. Design and construction of stormwater detention facilities shall comply with VDOT and DEQ requirements. The primary design references are:
   a. VSWMH
   b. VDOT Drainage Manual
   c. VESCH
   d. VDOT Standards
   e. Virginia Stormwater BMP Clearinghouse
6. Energy dissipators shall comply with VDOT and other state requirements. The primary design references are the VDOT Drainage Manual and the VESCH. Other appropriate references include:
   a. VDOT Road and Bridge Standards
   b. VDOT Road and Bridge Specifications
   c. VSWMH
   d. FHWA Design of Riprap Revetment HEC No. 11 (Pub. No. FHWA-IP-89-016 1989/2000)

e. FHWA Hydraulic Design of Energy Dissipators for Culverts and Channels HEC No. 14 (Pub. No. FHWA-EPD-86-110 Sept. 1983 and FHWA-IF-00-02 2000)
f. U.S. Dept. of the Interior – Bureau of Reclamation: Hydraulic Design of Stilling Basins and Energy Dissipators (Engineering Monograph No. 25)
g. U.S. Dept. of the Interior – Bureau of Reclamation: Design of Small Canal Structures

7. Stormwater quality best management practices shall comply with DEQ requirements. The primary design reference is the Virginia Stormwater BMP Clearinghouse.

4.7.2 Stormwater Hydrology

Stormwater hydrology defines the means and methods to calculate stormwater runoff from a designated area. This section documents the hydrologic practices used to establish design flows necessary to prepare the required stormwater peak flow and storage calculations.

4.7.2.1 Storm Drainage System Design Frequencies

Design frequencies shall be selected consistent with good engineering practice and regulatory requirements. The design frequency requirements in this section are minimum standards. Specific conditions may dictate that less frequent design frequencies should be used.

Storm drainage systems consist of open channels, culverts, and storm drains. Designs shall be based on the following minimum design storm frequencies:

Table 4-3. Minimum Design Storm Frequencies

Type of System	Frequency
Open Channels: Flood Protection	10-year
Open Channels: Channel Protection	2-year
Culverts	10-year
Storm Drains	10-year

Additionally, all storm drainage designs for open channels, culverts, and storm drains shall be checked for the 100-year flow condition where there is the possibility of downstream flooding, overtopping primary roads, experiencing significant economic loss, or catastrophic failure. Where justified by the consequences of failure, the minimum design recurrence interval shall be increased.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.7.2.2 Stormwater Management Facilities

Certain stormwater management facilities temporarily store a portion of stormwater runoff to mitigate increases in stormwater runoff peak flows and volumes due to the effects of land development.

4.7.2.3 New Development

Channel protection and flood protection shall be addressed in accordance with the criteria set forth in the Virginia Stormwater Management Program (VSMP) Regulations.

4.7.2.4 Time of Concentration (T_c) and Travel Time (T_t)

4.7.2.4.1 General

Travel Time (T_t) is the time it takes runoff to travel from one location to another in a watershed. Travel Time is a component of Time of Concentration (T_c), which is the time for runoff to travel from the most hydraulically distant point in the watershed to the outfall. The Time of Concentration is computed by summing all the travel times for consecutive components of the drainage conveyance system. Travel Time and Time of Concentration generally consist of three flow types – overland flow, shallow concentrated flow, and open channel flow. The following methods shall be used to determine the flow and velocity for the various conditions; however, the results shall be reviewed for reasonableness, and the results shall be revised if needed to provide a reasonable velocity and flow time that will best represent the study area.

When designing a drainage system, the Time of Concentration is not necessarily the same before and after land disturbing activities have been completed. Therefore, the travel time path shall be reflective of the actual conditions both before and after the land disturbing activities. When using TR-55 calculations, if T_c is less than 6 minutes, then a value of 6 minutes shall be used. Whereas, if T_c is greater than or equal to 6 minutes, then the calculated value shall be used. When using the Rational Method, if a T_c is less than 5 minutes, then a value of 5 minutes shall be used. Whereas, if T_c is greater than or equal to 5 minutes, then the calculated value shall be used.

In some cases, runoff from a portion of the drainage area that is highly impervious may result in a greater peak discharge than would occur if the entire drainage area were considered. In this case, adjustments shall be made to the drainage area by disregarding those areas where the travel time is too long to add substantially to the peak discharge.

To prevent small drainage areas from skewing the time of concentration calculation results, when establishing subdrainage areas for analysis, the largest subdrainage area shall be no greater than 5 times the area of the smallest subdrainage area.

4.7.2.4.2 Overland (Sheet) Flow

Overland flow is flow that occurs at the upper end of a watershed, where flow is not concentrated and there are no channels. The length of overland flow shall be reflective of actual conditions and shall normally be no greater than 100 feet.

4.7.2.4.3 Shallow Concentrated Flow

Shallow concentrated flow is the flow that occurs when minor rivulets form just downstream from the overland flow. The maximum allowable length for shallow concentrated flow shall be 1000 feet.

4.7.2.4.4 Open Channel Flow

Open channel flow occurs where stormwater flow converges in gullies, ditches, and natural or man-made conveyances.

4.7.2.4.5 Pipe Flow

Pipe flow is the flow that occurs through culverts and storm drains. Use full-flow pipe velocities, unless it can be shown that the pipe will operate at partially full conditions. If it can be shown that the pipe will operate at a partially full condition, then the partially full pipe velocity may be used.

Design of culverts is presented in DCSM section 4.7.4. Design of storm drain systems is presented in DCSM section 4.7.5.

4.7.2.5 Hydrologic Methods

4.7.2.5.1 General

There are a variety of widely used hydrologic methodologies. Each has its strengths and weaknesses. In the interest of standardizing hydrologic calculations, the following methodologies will be used for all projects, unless a variance is granted. A variance will only be granted if it may be demonstrated that good engineering practice dictates the use of another method.

4.7.2.5.2 Peak Discharge Methods for Design of Storm Drainage Systems

The Rational Method may be used to design storm drainage systems for drainage areas up to 20 acres.

The Soil Conservation Service (SCS) Method may be used for drainage areas up to 10 square miles.

For drainage areas greater than 10 square miles, calculations shall be performed using at least two separate methods as described in the VDOT Drainage Manual (SCS Method, regression equations, and/or stream gage data). The design peak flow shall be selected based on a professional evaluation of the results of the various methods.

4.7.2.5.3 Hydrograph Methods for Design of Stormwater Management Facilities

The SCS method must be used to design stormwater management facilities.

4.7.2.6 Methodologies

Following is an abbreviated discussion of each method. Refer to the VDOT Drainage Manual for a more complete discussion of the Rational Method and the VSWMH for a more complete discussion of the SCS Method.

4.7.2.6.1 Rational Method

4.7.2.6.1.1 General

The Rational Method is expressed as: $Q = C_f \times C \times I \times A$
Where:

Q = Peak flow rate of runoff, cubic feet per second (cfs)
C_f = Saturation factor
C = Runoff coefficient representing a ratio of runoff to rainfall (dimensionless) (See VESCH Table 5-2 below.)
I = Average rainfall intensity for a duration equal to the time of concentration for a selected return period (in/h)
A = Drainage area contributing to the design location, acres (ac)

Table 4-4. VESCH Table 5-2: Values of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, average, 2-7%	0.10-0.15
		Sandy soil, steep, 7%	0.15-0.20
		Heavy soil, flat, 2%	0.13-0.17
		Heavy soil, average, 2-7%	0.18-0.22
		Heavy soil, steep, 7%	0.25-0.35
Residential:		Agricultural land:	
Single-family areas	0.30-0.50	Bare packed soil	
Multi units, detached	0.40-0.60	• Smooth	0.30-0.60
Multi units, attached	0.60-0.75	• Rough	0.20-0.50
Suburban	0.25-0.40	Cultivated rows	
		• Heavy soil, no crop	0.30-0.60
		• Heavy soil, with crop	0.20-0.50
		• Sandy soil, no crop	0.20-0.40
		• Sandy soil, with crop	0.10-0.25
		Pasture	
		• Heavy soil	0.15-0.45
		• Sandy soil	0.05-0.25
		Woodlands	0.05-0.25
Industrial:		Streets:	
Light areas	0.50-0.80	Asphaltic	0.70-0.95
Heavy areas	0.60-0.90	Concrete	0.80-0.95
		Brick	0.70-0.85
Parks, cemeteries	0.10-0.25	Unimproved areas	0.10-0.30
Playgrounds	0.20-0.35	Drives and walks	0.75-0.85
Railroad yard areas	0.20-0.40	Roofs	0.75-0.95

Note: The designer must use judgement to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest C values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned the highest C values.

4.7.2.6.1.2 Saturation Factor

The saturation factor (C_f) is an adjustment factor for modifying the runoff coefficient (C) for storms that are less frequent than a 10-year recurrence interval. The product of C_f and C should not be greater than 1.0. Where the product of C_f and C is greater than 1.0, use 1.0.

Table 4-5. Saturation Factor

Recurrence Interval (Years)	C_f
2,5, and 10	1.0
25	1.1
50	1.2
100	1.25

4.7.2.6.1.3 Runoff Coefficient

The runoff coefficient (C) is a variable of the Rational Method that requires significant judgment and understanding for proper selection.

As the slope of the drainage basin increases, the selected C-value (from VESCH Table 5-2) should also increase as follows:
1. The lower range of C-values should be used where the majority of the slopes are less than 2 percent.
2. The average range of C-values should be used where the majority of slopes are from 2 to 5 percent.
3. The higher range of C-values should be used where the majority of the slopes are greater than 5 percent.

The C-value selection should be based on the soil type as follows:
1. The lower range C-values should be used in sandy and other more pervious soils
2. The higher range of C-values should be used in clayey and other less pervious soils.

It is often necessary to develop composite C-values based on the different land uses and other factors in a drainage basin. The composite C-value must be representative of the drainage basin. Averaging the C-values for mixed pervious/impervious watersheds may underestimate the peak flow rate.

4.7.2.6.1.4 Average Rainfall Intensity

Rainfall intensity (I) shall be determined by utilizing the National Oceanic and Atmospheric Administration (NOAA) Atlas 14.

4.7.2.6.1.5 Drainage Area

Drainage area (A) is measured in acres and is determined from evaluating a topographic map of the area.

4.7.2.6.2 SCS Method

4.7.2.6.2.1 General

The SCS Method may be used for computing peak flow rates and generating hydrographs for storms of selected return frequencies. This approach takes into account the time distribution of the rainfall, the initial rainfall losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm.

4.7.2.6.2.2 24-Hour Rainfall and Distribution

The 24-hour rainfall is determined by consulting NOAA Atlas 14.

4.7.2.6.2.3 Curve Number

The SCS method uses a combination of soil conditions and land use (ground cover) to assign a runoff factor to an area. These runoff factors, or runoff curve numbers (CN), indicate the runoff potential of an area. The CN requires significant judgment and understanding for proper selection.

When calculating existing rates of runoff (pre-construction), assume that all cover types are in good hydrologic condition.

Hydrologic soils groups include types A, B, C, and D, with Type A being the most permeable and Type D the least permeable. Soil maps for Virginia may be obtained by referring to the http://soils.usda.gov.

4.7.2.6.2.4 Drainage Area

Drainage areas for each sub-basin should be identified on an appropriate topographic map. The United States Geological Survey (USGS) quadrangle maps are often appropriate to delineate drainage areas that extend beyond the site development area.

4.7.2.6.2.5 Elevation – Storage Relationship

When runoff hydrographs are being routed through a stormwater management facility, the relationship between the elevation (or depth) of stored water in the facility and storage volume needs to be known and input into the calculation. Often this information is obtained by determining the pond area bounded by contour lines on a grading plan. Enough data pairs (elevation – storage) must be provided to properly model conditions.

4.7.2.6.2.6 Elevation – Discharge Relationship

When runoff hydrographs are being routed through a stormwater management facility, the relationship between the elevation (or depth) of stored water in the facility and the discharge rate from the facility needs to be known and input into the calculation. The development of this relationship requires an understanding of the design conditions and underlying hydraulic principles. The hydraulic principles and equations governing the discharge rate will often change several times at varying elevations, based on the flow control and conveyance structures. These include weir flow, orifice flow, culvert inlet control, culvert outlet control, open channel flow, and possible effects from downstream tailwater.

4.7.2.7 Pre-development Site Conditions

Pre-development hydrologic calculations for land disturbing activities shall consider the site conditions that exist at the time that plans for the land development are submitted to SID. Where phased development or plan approval occurs (preliminary grading, demolition, etc.), the existing conditions at the time prior to the first item being submitted shall establish the pre-development conditions.

For the purposes of computing pre-development runoff, all pervious lands on the site shall be assumed to be in good hydrologic condition, regardless of conditions existing at the time of computation.

4.7.2.8 Drainage Area Analysis

When determining the stormwater management requirements for quantity control, an analysis of the pre- and post-development site conditions must be conducted. The drainage area analysis shall reflect the ultimate development conditions of the property where the land disturbing activity is being conducted.

To prevent the undersizing of stormwater management components, upstream property conditions in the entire watershed shall be considered in the drainage area analysis. Improvements to stream channels and conveyance systems shall be analyzed based on the ultimate development conditions. Design of drainage infrastructure shall be based on proposed development and the associated density of impervious areas.

When a site contains or is divided by multiple drainage areas, the downstream receiving channel for each area must be analyzed in accordance with the VSMP regulations.

The downstream limits of analysis and channel adequacy shall be determined in accordance with the VSMP regulations.

4.7.3 Open Channel Design Methodology

Open channels are man-made ditches, channels, as well as natural channels, that are used to convey stormwater runoff. This section defines the criteria and restrictions to be used in designing open channels.

Grass Channels are a type of water quality BMP with design requirements beyond those of the typical open channel. The design specifications for Grass Channels can be found on the Virginia Stormwater BMP Clearinghouse.

4.7.3.1 Open Channels

Open channels are classified as either major channels or minor channels. The base design storm for storm drainage systems are the 2- and 10-year, 24-hour storm events, for velocity and capacity. However, the entire system must be capable of handling a 100-year, 24-hour design storm.

4.7.3.2 Design Flow

Design flow for open channels is contained in DCSM section 4.7.3. Design flows for open channels must be contained within the channel with adequate freeboard from the top of the bank to the peak water surface elevation. See DCSM section 4.7.3.9 for adequate freeboard requirements for capacity calculations.

Capacity calculations shall be made at the flattest section of the channel.

4.7.3.3 Hydrology

See DCSM section 4.7.2 for the methodology used to determine peak flows for a given design frequency.

4.7.3.4 Channel Hydraulics

Open channel design will be based on Manning's Equation for open channel flow:
$Q = A \times 1.49/n \times R^{2/3} \times S^{1/2}$
Where:

- Q = Flow rate in the open channel (cfs)
- A = Cross-sectional area of the flow in the channel (sq. ft.)
- R = Hydraulic radius, A/wetted perimeter (ft.)
- S = Channel slope (ft./ft.)
- n = Channel roughness coefficient (See VDOT Table: Appendix 7D-1 below.)

Figure 4-1. VDOT Table: Values of Roughness

Appendix 7D-1 **Values of Roughness Coefficient n (Uniform Flow)**

Type of Channel and Description	Minimum	Normal	Maximum
LINED CHANNELS (Selected linings)			
a. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Gunite, good section	0.016	0.019	0.023
b. Asphalt			
1. Smooth	0.013	0.013	-
2. Rough	0.016	0.016	-
c. Riprap (st'd VDOT sizes)*			
1. Class 1A	0.033	0.038	-
2. Class 1	0.035	0.040	-
3. Class 2	0.037	0.042	-
4. Class 3	0.039	0.045	-
5. Type I	0.041	0.047	-
6. Type II	0.044	0.050	-
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
5. Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
1. Minor streams (top width at flood stage <100 ft)			
a. Streams on Plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones/weeds	0.030	0.035	0.040
3. Clean, winding, some pools/shoals	0.033	0.040	0.045
4. Same as above, but some weeds/stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080

* Rev 7/09

4.7.3.5 Channel Velocity

The lining of open channels with drainage areas of five acres or less shall be designed to withstand the erosive effects of a 2-year storm. The final design shall be consistent with velocity limitations for the selected channel lining, as presented in the table below.

Open channels associated with dam embankment spillways or other structures where catastrophic failure could result from a lining failure may be required to be designed to withstand a more severe storm event.

Where open channels receive flow from storm drains, culverts, or other open channels, or in other areas where channel velocity may cause scouring or erosion, outlet protection or energy dissipation may be necessary to reduce the potential for severe erosion. For the design of energy dissipation devices, see DCSM section 4.7.7.

Velocity calculations shall be made at the steepest section the channel. The VDOT Drainage Manual provides the following table for maximum velocity based on channel lining selection.

Table 4-6. Maximum Velocity Based on Channel Linings

Channel Lining	Maximum Velocity (Design Storm)	
	Erosion Resistant Soils[1]	Easily Erodible Soils[2]
Vegetative-Lined Channels		
Tall Fescue Grass Mixtures	5 fps	3 fps
Kentucky Bluegrass	5 fps	3 fps
Annual and Perennial Rye	4 fps	3 fps
Sod	4 fps	3 fps
Geosynthetic-Lined Channels		
VDOT EC-2	4 fps	
VDOT EC-3, Type A	7 fps	
VDOT EC-3, Type B	10 fps	
Other	Per Manufacturer Recommendations	
Riprap	Dependent on stone size and thickness, see VDOT Drainage Manual for design of riprap	
Concrete	None	

[1] Erosion resistant soils include those with a high clay content and high plasticity, silty clay, sandy clay, and clay.
[2] Easily erodible soils include those with a high content of fine sand or silty, lower plasticity or non-plasticity, sand, silt, sandy loam, and silty loam with an erodibility factor (K) greater than 0.35.

4.7.3.6 Channel Slope

Generally, the slope of an open channel shall be established by the site topography. Open channels must be graded to drain with no standing water following a rain event. The minimum allowable grade shall be 2 percent for vegetative lined and riprap-lined open channels and 1 percent for a concrete open channel.

The maximum allowable grade for a stormwater channel shall be dependent on the channel lining materials and its ability to withstand erosion during the design storm.

4.7.3.7 Cross-Sectional Area

Open channel cross-sectional area shall be designed based on site restrictions and channel capacity required. Acceptable cross-sectional area options include:

1. Vee
   a. For design aids, see the VDOT Drainage Manual and the VESCH.
   b. The maximum side slope of a vee-shape open channel is 3-horizontal to 1-vertical for natural or vegetated channels and is 2-horizontal to 1-vertical for riprap, concrete, or as approved by SID.
2. Parabolic
   For design aids, see the VDOT Drainage Manual and the VESCH.
3. Trapezoidal
   a. For design aids, see the VDOT Drainage Manual and the VESCH.
   b. The maximum side slope of a trapezoidal-shape open channel is 3-horizontal to 1-vertical for natural or vegetated channels and is 2-horizontal to 1-vertical for all other linings engineered to be stable at this slope.
4. Rectangular
   a. Rectangular channels shall only be allowed where site restrictions prevent the installation of a vee, parabolic, or trapezoidal channel.
   b. The requirements for rectangular channels apply to any open channel with side slopes greater than 2-horizontal to 1-vertical and include the following:
      i. Rectangular channels must either be constructed of concrete or gabions.
      ii. An approved safety barrier must be placed on both sides for the length of the rectangular channel, where the channel is more than 3 feet deep.
      iii. Care must be taken to ensure that energy dissipation is placed at the outfall of the rectangular channel to prevent erosion at the discharge point.

4.7.3.8 Channel Lining

An open channel lining shall be designed based on the cross section, slope, and channel velocity requirements. The design may be based on a consideration of

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

either permissive velocity or tractive force as described in the VDOT Drainage Manual.

The preferred method for analyzing channel linings is to compare the maximum permissible velocity for the channel lining, listed in the table in DCSM section 4.7.3.5, to the design velocity computed using Manning's equation to verify the selected lining is adequate. As an alternative, the selected lining may be analyzed using the Tractive Force Method in the VDOT Drainage Manual. This method analyzes critical shear loading on the open channel bottom and side slopes. The permissible tractive force for various soils is located in the Appendix of the VDOT Drainage Manual.

Open channels may have different lining materials in different channel reaches based on velocity and potential erosion conditions. Care must be exercised to avoid erosion at open channel transition points.

The open channel lining will have an impact on the design capacity in the form of the roughness coefficient. Allowable open channel linings include the following:

4.7.3.8.1 Natural

To the extent possible, natural channels shall be preserved.

To determine the permissible velocities in natural channels, based on soil conditions, use permissible velocities based on soil conditions published in the VDOT Drainage Manual. If the design storm velocity exceeds the permissible velocity, a natural channel cannot convey the stormwater runoff without modifying the discharge flow conditions or improving the natural channel.

4.7.3.8.2 Vegetative-Lined

Vegetated or grass-lined channels include man-made channels lined with established vegetation. These channels usually include a geosynthetic mat for channel stabilization for design flow velocities.

The type of grass allowable for vegetative-lined open channels is dependent on the slope of the channel and the peak calculated velocity. See the table in DCSM section 4.7.3.5 for the maximum permissible velocities for various channel linings.

A permanent channel stabilization geosynthetic mat should be considered for all vegetated channels. There is a wide variety of geosynthetic stabilization mat options from various manufacturers. The geosynthetic mat selected should be adequate for the slope and design flow velocities calculated for the channel. Where appropriate, VDOT Road and Bridge Standard EC-2 or EC-3 may be used.

Where a permanent geosynthetic mat is used to provide channel stabilization, information on the proposed mat, in the form of the manufacturer's catalog information, shall be submitted as a part of the stormwater management plan. The catalog information shall include the manufacturer's recommendations for maximum allowable velocity. Design drawings must state that the geosynthetic stabilization mat shall be installed in strict accordance with the manufacturer's recommendations.

Where a permanent channel stabilization geosynthetic is not used, a temporary geosynthetic lining designed to provide a measure of the bed/bottom and bank stability until such time as a reasonably stable and mature stand of vegetation is established shall be provided.

4.7.3.8.3 Riprap-Lined

The use of vegetated and geosynthetic-lined open channels for mild-sloped open channels and concrete for steep-sloped open channels is encouraged. Riprap-lined channels will not be acceptable where vegetated or geosynthetic-lined open channels are feasible. However, where design flow velocities exceed the erosive capability of a natural or vegetative-lined channel, riprap may be used as a channel lining in areas where erosion is a concern. For an extended length of high velocity channel, consideration should be given to using a concrete channel rather than riprap.

Use of riprap-lined channels requires pre-approval from SID.

Where riprap is approved by SID, it shall meet VESCH Specification 3.19, VDOT Standards, and VDOT Specifications.

4.7.3.8.4 Concrete-Lined

Concrete shall be considered where design velocities dictate or where there is a need to provide the maximum level of erosion protection.

4.7.3.9 Freeboard Requirements

Open channels shall have a minimum of 6″ of freeboard above the calculated water surface elevation for the design peak flow, unless the flow is supercritical. Where the flow is supercritical, a minimum of 12″ of freeboard is required.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Flow is supercritical when: $V / (32.2 \times H)^{0.5} > 1$

Where:

V = Velocity (fps)

H = Depth of flow (ft.)

At channel bends and curves, the freeboard shall be measured from the calculated water surface elevation, including the increased depth due to the superelevation of the water surface.

4.7.3.10 Calculation of Depth of Flow at Bends and Curves

Increases in the depth of flow occur at bends and curves due to the superelevation of the water surface. Superelevation of the water surface at bends and curves is calculated, using the VDOT Drainage Manual, by:

$\Delta Z = V^2 / (32.2 \times r_c) \times (r_o - r_i)$

Where:

ΔZ =Difference in water surface elevation between the concave and convex banks (ft.)

V = Average velocity (ft./sec.)

r_c = Radius of the center of the stream at the bend (ft.)

r_o = Radius of the outside bank of the stream at the bend (ft.)

r_i = Radius of the inside bank of the stream at the bend (ft.)

The increase in the normal stream flow depth at the outer bank of an open channel bend is one-half of ΔZ.

4.7.3.11 Environmental Considerations and Aquatic Organism Protection

Construction or modifications to open channels shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits, such as United States Army Corps of Engineers (USACE) and DEQ wetland permits, DEQ Virginia Pollutant Discharge Elimination System (VPDES) permits, etc., prior to obtaining SID approval.

4.7.3.12 Maintenance Requirements

The Operator/Contractor is responsible for maintenance of open channels until the termination of land disturbance as described in the VTAS&S. Maintenance includes periodically pruning or mowing vegetation and removing debris.

No one shall fill, modify, or construct structural modifications that impair or restrict flow in open channels.

Sterrett Facilities Complex
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Blacksburg, Virginia 24061

4.7.4 Culverts

A culvert is a single run of storm drain pipe that conveys water or stormwater under a road, railway, embankment, sidewalk, or other open channel obstruction. A culvert typically connects two open channels, but it may connect an open channel to a storm drain.

Proper culvert design must consider many factors including:
1. Design Flow
2. Inlet conditions (flow approach conditions, allowable headwater, culvert inlet configuration)
3. Culvert conditions (pipe roughness, pipe slope, diameter and length)
4. Tailwater depth
5. Buoyancy potential
6. Environmental considerations and effects on aquatic life
7. Design loads and service life of the pipe material

Refer to the VDOT Drainage Manual for a more thorough discussion of these items. For the design of stormwater inlets and storm drains, see DCSM section 4.7.5.

4.7.4.1 Design Methodology and Criteria

4.7.4.1.1 Computational Methods

Computations may be manual or by computer program.

Manual computations use design equations and nomographs. Results are documented on VDOT's Design Form LD-269.

There are a number of computer programs available to design culverts. Any of these computer programs will be acceptable if their methodologies are based on the same equations and nomographs accepted by VDOT, and if they provide the same documentation of inputs, assumptions, and output as are contained on VDOT's Design Form LD-269.

4.7.4.1.2 Design Flow Methodology

See DCSM section 4.7.2 for methodology used to determine design flows. Generally, culverts shall be designed based on the peak flow (steady state), ignoring the effects of temporary upstream storage.

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4.7.4.1.3 Culvert Hydraulics

4.7.4.1.3.1 Design Flow

Culverts shall be designed in accordance with the VDOT Drainage Manual, latest edition.

Compliance with the National Flood Insurance Program (NFIP) is necessary for all locations where construction will encroach on a 100-year floodplain. The Town of Blacksburg administers the NFIP on the Virginia Tech main campus, in accordance with the Commonwealth of Virginia Executive Order 45.

In addition, the 100-year peak flow (without the addition of the obstruction allowance) shall be routed through all culverts, determining the headwater depth behind the culvert with road overtopping, to ensure that buildings and other structures are not flooded and that adjacent roadways and adjacent properties do not suffer significantly increased damage during the 100-year storm event. Storage impacts of water behind the culvert may be considered in the calculation but is not required.

4.7.4.1.3.2 Allowable Headwater

The allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design condition, as measured from the culvert inlet invert.

The allowable headwater depth shall be limited by the following conditions:

1. Headwater does not cause upstream property damage;
2. Headwater does not increase the 100-year flood elevation, as mapped by NFIP;
3. During a design storm event, the water surface shall be a minimum of 18 inches below the shoulder of the road at the point where the culvert crosses, or the low point of the road grade where the water would overtop the road;
4. Headwater depth shall not exceed 1.5 times the diameter or height of the culvert barrel;
5. Headwater depth shall not be such that stormwater flows to other ditches or terrain, which permit the flow to divert around the culvert.
6. In most instances, the roadway overtopping may be treated as a broad crested weir.

7. The maximum overtopping depths during a 100-year storm event for various street classifications are as follows:

Table 4-7. Maximum Overtopping Depths During a 100-Year Storm Event

Classification	Max Depth at Crown	Max. Velocity
Local/Collector	1 ft.	6 fps
Arterial/Highway	No Overflow	No Overflow

4.7.4.1.3.3 Tailwater Conditions

Tailwater is the water into which a culvert outfall discharges. Culvert design shall be based on tailwater conditions that could reasonably be anticipated during the design condition.

1. If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert may establish the design tailwater depth at the upstream culvert.
2. If the culvert discharges into a lake, pond, stream, or other body of water, the maximum water elevation of the body of water during the design storm may establish the design tailwater elevation at the upstream culvert.

4.7.4.1.3.4 Inlet and Outlet Control

Culvert hydraulic design shall consider both inlet and outlet control conditions. For a culvert operating under inlet control, the headwater elevation is governed by the inlet geometry. For an outlet control culvert, the inlet geometry, barrel characteristics and tailwater elevation all impact the headwater elevation.

Minimum culvert performance is determined by analyzing both inlet and outlet control for a given flow and using the highest resulting headwater.

1. Inlet Control
    a. The following factors are considered when calculating inlet control headwater:
        i. Inlet Area – cross-sectional area of the culvert entrance face
        ii. Inlet Edge – projecting, mitered, headwall, or beveled edges are common
        iii. Inlet Shape – rectangular, circular, elliptical, or arch are common

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

b. Nomographs for calculating headwater and flow capacity are found in the VDOT Drainage Manual.

2. Outlet Control
   a. The following factors are considered when calculating outlet control headwater:
      i. Manning's Roughness (n) – based on barrel material
      ii. Barrel Area – cross section perpendicular to the flow
      iii. Barrel Length
      iv. Barrel Slope
      v. Tailwater Elevation
   b. Outlet control affects the hydraulic grade line of the flow through the culvert. To calculate the hydraulic grade line, reference the equations for velocity, velocity head, entrance losses, friction losses, and exit losses contained in the VDOT Drainage Manual.
3. For nomographs, cross sections, and pipe materials, see the VDOT Drainage Manual.

4.7.4.1.3.5 Culvert Velocity

1. Outlet velocity must be checked to assure that excessive erosion and scour problems will not occur.
2. Culvert outlet protection shall be provided in accordance with the standards and specifications for Outlet Protection and Riprap in the VESCH.
3. Culverts under roadways shall be provided with end sections or endwalls in accordance with the outlet protection requirements of the VDOT Drainage Manual.
4. Where a special design is needed to reduce outlet velocity, it shall be designed in accordance with VDOT standards.
5. The minimum velocity in a culvert barrel must be adequate to prevent siltation at low flow rates. At a minimum this velocity shall be 3 feet per second for a 2-year storm event.

4.7.4.1.4 Structural Design

All culverts shall be designed to withstand a HS-20 highway loading, unless it crosses under a railroad, in which case the culvert shall be designed for railroad loads. The structural design shall consider the depth of cover, trench width and condition, bedding type, backfill material, and compaction.

4.7.4.1.5 Materials

Culverts in public easements or rights-of-way shall be constructed of materials based on the following:

1. Culverts under a roadway in the right-of-way shall be VDOT approved materials.
2. Culverts under sidewalks, trails, etc., shall be reinforced concrete pipe (RCP) or high-density polyethylene (HDPE).

4.7.4.1.6 Culvert Sizing and Cover

The minimum culvert size shall be 18-inch diameter.

Culverts shall meet all cover conditions required. Where the site conditions preclude the use of a single culvert barrel to meet the design flow conditions, multiple barrel culverts are acceptable.

The maximum length of a culvert shall be 300 feet. A culvert longer than 300 feet shall have manholes or junction boxes and shall fall under the requirements of DCSM section 4.7.5.

4.7.4.1.7 End Conditions

Headwalls and end sections shall normally be required on inlets and outlets, as described below.

4.7.4.1.7.1 Prefabricated End Sections

Prefabricated end sections, or flared end sections, provide for a better flow path, improving the design flow and headwater conditions.

Prefabricated end sections shall be provided for culverts from 18 to 36 inches in diameter, except:

1. Where culvert alignment exceeds 20 feet in vertical elevation change or culvert slope exceeds a 2:1 slope, a standard concrete headwall shall be provided instead of a prefabricated end section.
2. Where a concrete headwall is provided.

4.7.4.1.7.2 Concrete Headwalls and Structures

Precast concrete headwalls shall be provided at all culvert inlets and outlets, unless other end conditions are allowed, as stated above. Precast concrete headwalls shall meet the requirements of the VDOT Road and Bridge Standards and VDOT Road and Bridge Specifications.

Wingwalls may be required in conjunction with headwalls. Culvert pipes 48″ or larger in diameter shall have concrete wingwalls. Wingwalls are generally used where the culvert is skewed to the normal channel flow or where the side slopes of the channel or roadway are unstable. Wingwalls shall meet the requirements of the VDOT Standards and VDOT Specifications. Wingwalls shall be set at an angle between 30 degrees and 60 degrees from the headwall.

Concrete aprons may be used at the entrance or the exit of a culvert. Aprons are typically used where high velocities or headwater conditions may cause erosion upstream or downstream of the culvert. An apron shall not protrude above the normal stream bed elevation.

Special design concrete slab end treatment, per VDOT Standards, may be used as a concrete end section.

4.7.4.1.8 Multiple Barrel Culverts

Multiple barrel culverts shall be allowed where single culverts cannot handle the design flow while meeting the required cover or headwater condition requirements. The design of multiple barrels should avoid the need for excessive widening of the upstream or downstream receiving channels.

The minimum spacing between culverts in a multiple barrel culvert design shall be that required to provide adequate lateral support and allow proper compaction of bedding material under the pipe haunches.

4.7.4.1.9 Culvert Skew

Where possible, culverts shall be installed parallel to the flow path. The maximum allowable skew shall be 45 degrees as measured from the line perpendicular to the roadway centerline.

4.7.4.1.10 Buoyancy

Verify that the culvert pipe, end sections, and concrete endwall structures will not fail under hydrostatic uplift conditions.

The buoyancy force consists of the weight of water displaced by the pipe and the fill material that is over the pipe (below the headwater depth). The force resisting buoyancy includes the weight of the pipe, weight of the water within the pipe, and the weight of fill material over the pipe.

Buoyancy is more likely to be a problem where:
1. Lightweight pipe is used

2. The pipe is on a steep slope (usually inlet control with the pipe flowing partially full)
3. There is little weight on the end of the pipe (flat embankment slopes, minimum cover, and/or no endwalls)
4. High headwater depths (HW/D>1.0)

Suitable cover, footings, or anchor blocks may be required to ensure the culvert's integrity during design conditions.

4.7.4.1.11 Debris and Trash Racks

In general, trash racks or debris deflectors shall not be used where other site modifications may be made to prevent excessive trash or debris from entering the culvert. However, they may be required at specific locations by SID where large amounts of storm debris may be anticipated.

4.7.4.2 Installation

All culvert pipe, headwalls, end sections, outlets, and other peripheral structures shall be installed in accordance with VDOT requirements and the manufacturer's recommendations. The characteristics of the trench, bedding, and pipe material all impact the structural strength of the pipe system. The installed culvert conditions shall comply with the design assumptions and calculations.

4.7.4.2.1 Bedding Material

Bedding material and installation shall comply with the requirements of the VDOT Specifications.

4.7.4.2.2 Backfill

Backfill shall be suitable material and shall be placed and compacted in accordance with VDOT Specifications.

A minimum of 12″ of backfill shall be placed over the top of a HDPE or corrugated metal pipe (CMP) culvert prior to placing pavement or other surface treatment.

4.7.4.3 Environmental Considerations and Aquatic Organism Protection

Where compatible with good hydraulic engineering, a culvert shall be located in "dry" conditions. Where this is not possible, the culvert shall be located to minimize impacts to streams or wetlands.

When a culvert is set in a perennial stream, the invert of the culvert shall be set below the normal flow line of the stream as required in the VDOT Drainage Manual. The grade of the culvert shall not exceed the grade of the natural stream in that section.

Where construction requires environmental permits, the applicant shall be responsible for obtaining all necessary environmental permits and complying with their requirements.

4.7.4.4 Maintenance Requirements

The Operator is responsible for maintenance of culverts until the termination of land disturbance as described in the VTAS&S.

4.7.5 Storm Drains

A storm drainage system consists of two or more interconnected pipes and one or more structures designed to intercept and convey stormwater runoff from specific storm event without surcharge. Storm drains collect and transport stormwater from a site primarily through the use of a closed pipe network. For the stormwater to be efficiently handled in a storm drain, the site must also have an efficient way to collect stormwater runoff and have it enter into the piped network. Once in the storm drain, the stormwater is routed to a discharge outfall.

Storm drainage systems include:

1. Inlets
2. Storm drain piping and structures that convey stormwater runoff to the outfall

This section defines criteria and restrictions that shall be used in designing and constructing storm drains. See the VDOT Drainage Manual for more in-depth information.

Profiles for all storm drains 12 inches in diameter and greater shall be provided on the site plans.

4.7.5.1 Design Methodology and Criteria

4.7.5.1.1 Computational Methods

Computations may be manual or by computer program.

Manual computations use design equations and nomographs. Results may be documented on VDOT work sheets.

1. Form LD-204, Stormwater Inlet Computations
2. Form LD-229, Storm Drain Design Computations

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Form LD-347, Hydraulic Grade Line Computations

There are a number of computer programs available to design storm drainage systems. Any of these computer programs will be acceptable if their methodologies are based on the same equations and nomographs accepted by VDOT, and if they provide the same documentation of inputs, assumptions, and output as are contained on VDOT's work sheets.

Computational methods are explained in detail, including comprehensive design examples, in the VDOT Drainage Manual.

4.7.5.1.2 Hydrology

See DCSM section 4.7.2 for the methodology used to determine design flows. Calculations establishing the design flow shall be submitted with the Stormwater Management Plan. Design flows shall be based on the ultimate build-out of the project, or of the campus precinct in accordance with the Virginia Tech Stormwater Management Master Plan.

4.7.5.1.3 Design Flows

Inlets shall be designed for 10-year storm frequencies and intensities consistent with the VDOT Drainage Manual.

Storm drains shall be designed in accordance with DCSM section 4.7.2.

4.7.5.1.4 Measures to Convey Stormwater Runoff to Inlets

4.7.5.1.4.1 Curb and Gutter

Curb and gutter at the edge of pavements may be used to collect stormwater runoff from roadways. Curbing captures stormwater runoff and directs it to stormwater collection inlets while protecting adjacent properties from flooding and erosion due to sheet flow runoff from the impervious roadways.

A curb and gutter forms a triangular conveyance channel. When a storm occurs, the runoff from the road creates a spread of water from the curb. The curb and gutter must be designed to convey this flow and with associated drainage structures prevent the spread onto the roadway from impacting traffic. The spread width of flow is determined by using nomographs. For curb and gutter flow, a Manning's n value of 0.015 is used in the computational analysis.

Curb and gutter dimensions and design shall meet VDOT Standards.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.7.5.1.4.2 Open Channels

Open channels may be used to collect site drainage and convey it to a storm drain inlet. Design requirements for open channels are covered in DCSM section 4.7.3.

4.7.5.1.5 Storm Drain Inlets

4.7.5.1.5.1 General

Storm drain inlets are used to collect stormwater runoff from roads, sidewalks, or low elevations during storm events and provide a method for conveying the stormwater into the storm drain system. This is usually accomplished by placing storm drain inlets at regular intervals or at key locations to intercept flows and control the stormwater spread width. The design criteria for limiting the spread of water on travel lanes is found in the VDOT Drainage Manual.

There are several different types of storm drain inlets that can be used to meet this purpose, and the designer shall choose the proper inlet structure based upon site conditions and design conditions to maximize the drainage efficiencies.

1. Curb
2. Grate
3. Slotted Drain/Trench
4. Combination

Stormwater management plans shall include a contour plan with sufficient contours shown to ensure positive drainage to an inlet. Inlet Volume Capacity Calculations are required with the Stormwater Management Plan submittal.

4.7.5.1.5.2 Curb Inlets

Curb inlets are vertical openings in the curb covered by a top slab. These inlets can convey large quantities of water, but also allow for large amounts of debris to enter the storm drain system.

Curb inlets shall be used to the maximum extent possible for pavement drainage.

4.7.5.1.5.3 Grate Inlets

Grate inlets are horizontal grates that are usually used in depressed medians or in other areas of low elevations. Grate inlets are often referred to as drop inlets or DIs. Grate inlets shall be pedestrian rated when installed in paved areas. Where they are used in pavement, inlet grates shall be bicycle safe.

4.7.5.1.5.4 Combination Inlets

Combination inlets combine both the vertical opening used by curb inlets and the horizontal grate used by grate inlets. These inlets are often used when the inlet chamber is required to be under the gutter or street pavement away from the sidewalk or other utilities. Combination inlets shall be avoided where possible. Where they are used, they must have bicycle-safe grates.

4.7.5.1.5.5 Trench Drain Inlets

Trench drain inlets are cast-in-place or precast concrete trenches covered by a grate that are used to intercept sheet flow.

4.7.5.1.5.6 Inlet Locations

Inlets shall be located to meet the design requirements of the VDOT Drainage Manual for maximum spread width. In addition, inlets shall be provided, regardless of contributing drainage area, as follows:
1. At sag points in the gutter grade.
2. Either side of sag point inlet (flanking inlets).
3. Upstream of median breaks, crosswalks, and street intersections.
4. Immediately upstream and downstream of bridges.
5. On side streets at intersections, where flow is approaching the main line.
6. Behind curbs, shoulders, or sidewalks to drain low areas or intercept concentrated flow.
7. At 1% cross slope upstream of cross slope reversals.
8. At any low elevation in the grade.

Inlets installed in pathways likely to be used by pedestrians or bicyclists shall be a pedestrian rated grate.

4.7.5.1.5.7 Access

All inlets shall have a removable grate or manhole cover to allow access for clean out.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.7.5.1.5.8 Inlet Capacities

The capacities of each inlet type are contained in the VDOT Drainage Manual. Capacities are determined from equations or nomographs that are contained within the VDOT Drainage Manual. Documentation of inlet capacity shall be made on VDOT Form LD-204, Stormwater Inlet Computations or computer modeling output.

4.7.5.1.5.9 Separation of Pipes

Where two or more storm drains enter a concrete structure at or near the same elevation, a 6″ minimum horizontal clearance must be maintained between the pipes. Additional clearance between pipes shall be provided if required to protect the structural integrity of the structure.

4.7.5.1.6 Storm Drain Pipes

4.7.5.1.6.1 Flow Capacity

Based on the size and slope of the storm drain, the design capacity for a pipe flowing full can be determined using Manning’s equation.
$Q = A \times 1.49/n \times R^{2/3} \times S^{1/2}$
Where:

- Q = Flow in the pipe (cfs)
- A = Cross-sectional area of the pipe (sq. ft.)
- R = Hydraulic radius; for circular pipe flowing full, R = diameter/4 (ft.)
- S = Storm drain slope (ft./ft.)
- n = Pipe roughness coefficient

The design flow capacity of a storm drain shall comply with the design frequencies set forth in the VDOT Drainage Manual. In a roadway underpass, or depressed section, where ponded water can only be removed through the storm drain system, a 100-year frequency storm event shall be used to design the storm drain at the sag point.

4.7.5.1.6.2 Storm Drain Slope

To deter the settling of debris and sediment in the storm drain pipe, the pipe shall be designed to ensure positive slope and maintain a minimum velocity of 3 feet per second during a 2-year frequency storm.

The maximum pipe velocity in any storm drain shall be 20 feet per second during a 10-year frequency storm to prevent excessive abrasion of the pipe and erosion at the discharge. If the pipe velocity exceeds 15 feet per second during a 10-year frequency storm, a reinforced concrete storm drain pipe is required.

Storm drains shall be sloped to meet the velocity requirement set in this chapter. Slopes greater than 16% shall be avoided if possible. If unavoidable, drop structures shall be utilized in steeper terrain. In addition, storm drains with slopes steeper than 16% must have anchor blocks for support.

4.7.5.1.6.3 Pipe Size

The minimum recommended conduit size for storm drainage pipe is 15-inch diameter or its equivalent for non-circular shapes. Where necessary, it will be permissible to use a 12-inch diameter pipe for laterals or initial pipe runs of 50 feet or less. Pipe size shall not be reduced along the direction of the flow, except as required for proper operation of stormwater management facilities.

4.7.5.1.6.4 Access

Regardless of pipe size, a cleanout access point, either an inlet, manhole, or junction box shall be provided at a maximum of every 300 feet of pipe.

4.7.5.1.6.5 Watertight Joints

The use of watertight joints is encouraged to prevent infiltration of groundwater, and potential pollutants carried by contaminated groundwater, and to prevent settlement problems from occurring due to soil materials washing into storm drains.

SID reserves the right to require the use of watertight joints in the following locations:

1. Culverts and storm drains under pavement, sidewalks, or concrete structures
2. Through stormwater “hotspots”
3. In areas where groundwater may be contaminated by pollutants
4. On steep slopes
5. Culverts

The following land uses and activities are designated as stormwater hotspots:

1. Vehicle salvage yards and recycling facilities
2. Vehicle fueling stations
3. Vehicle service and maintenance facilities

4. Vehicle and equipment cleaning facilities
5. Fleet storage areas (bus, truck, etc.)
6. Industrial sites (for SIC codes contact Virginia DEQ)
7. Marinas (service and maintenance areas)
8. Outdoor liquid container storage
9. Outdoor loading and unloading facilities
10. Public works storage areas
11. Facilities that generate or store hazardous materials
12. Commercial container nursery
13. Golf courses
14. Chemical storage
15. Dry cleaning operations

4.7.5.1.7 Determination of Hydraulic Grade Line

The hydraulic grade line represents the free water surface elevation of water in a pipe system. Where the hydraulic grade line is above the top of a pipe, the pipe is flowing under pressure. The hydraulic grade line in a manhole or other structure is the elevation to which water will rise.

Hydraulic grade lines shall be calculated and evaluated for all storm drains. The hydraulic grade line shall be calculated using VDOT methods and equations that are fully described in the VDOT Drainage Manual. Calculations shall be documented on VDOT Form LD-347, Hydraulic Grade Line Computations, or computer modelling output. The output shall be in the form of profiles showing the HGL in relation to the pipe and structures.

The hydraulic grade line shall not exceed any critical elevation during the design storm. Critical elevations include rising above the ground elevation at inlets or other structures, or reaching an elevation where storm flow could back up to cause flooding damage.

The calculation of the hydraulic grade line begins at the system outfall and proceeds upstream to each structure in the system. The calculation is based on the principal of conservation of energy as shown below and includes major and minor energy losses: $HGL_{us} = HGL_{ds} + H_f + H_m$
Where:

HGL_{us} = Elevation of hydraulic grade line at the upstream structure
HGL_{ds} = Elevation of hydraulic grade line at the downstream structure
H_f = Pipe friction loss
H_m = Summation of minor head losses (junctions, bends, etc.)

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Major head losses are attributable to friction losses within the pipe. Minor head losses include losses from:

1. Junctions
2. Exits
3. Entrances
4. Bends in Pipes
5. Access holes
6. Conflict pipes
7. Plunging flow
8. Expansions and contractions
9. Appurtenances such as weirs, diverters, valves and meters

4.7.5.1.7.1 Outfall Conditions

The hydraulic grade line starts at the system outfall. At this point the hydraulic grade line shall be the actual tailwater elevation or the elevation of 0.8 times the diameter of the outlet pipe, whichever is higher. If the system discharges into a detention or retention pond, the hydraulic grade shall start at the 10-year water surface elevation.

4.7.5.1.7.2 Pipe Friction Losses

The friction slope is the energy slope for that run of pipe. The friction slope is determined by inserting pipe information and design flow into Manning's equation and solving for S (slope). The total friction head loss in the run of pipe is the friction slope multiplied by the length of the run.

Where the hydraulic grade line falls below the crown of the pipe, the elevation of normal flow is the hydraulic grade line.

4.7.5.1.7.3 Junction Losses

Junction head losses are the summation of entrance (H_i), exit (H_o), and bend losses (H_Δ). When calculating junction losses, it is important to use actual flow velocities. If pipes are flowing partially full, then partially full velocities are used.

1. Entrance (expansion) losses
   Entrance loss at a junction is given by:
   $H_i = K_e (V_i^2 / 2g)$
   Where:
   H_i = Entrance head loss
   K_e = Entrance loss coefficient. K_e = 0.35

V_i= Velocity in the inlet pipe. Where more than one inlet pipe is present, use the velocity from the pipe that has the greatest momentum (Q*V)
g = Gravitational acceleration constant, 32.2 ft./sq. sec.

2. Exit (contraction) losses
   Exit loss at a junction is given by:
   $H_o = K_o\ (V_o^2 / 2g)$
   Where:
   H_o = Exit head loss
   K_o = Exit loss coefficient. $K_o = 0.25$, except that $K_o = 0.3$ when computing the loss leaving the initial inlet
   V_o = Velocity in the outlet pipe
   g = Gravitational acceleration constant, 32.2 ft./sq. sec.

3. Bend losses
   a. Bend losses at a junction are dependent on the angle between the inlet and outlet pipes. If the inlet and outlet pipe are in line with one another (no bend), the angle is 0 degrees and there is no bend loss. As the angle increases towards 90 degrees, the bend loss increases. Storm drain systems should not be designed with bend angles greater than 90 degrees. Where more than one pipe enters a junction at an angle, the H_Δ should be figured on all bends and the largest one used as the bend loss.
   b. The bend loss is given by: $H_\Delta = K\ (V_i^2 / 2g)$
      Where:
      H_Δ = Head loss at bend
      K = Bend loss coefficient. K is determined by consulting Figure 9-9 in the VDOT Drainage Manual.
      V_i = Velocity in the inlet pipe.
      g = Gravitational acceleration constant, 32.2 ft./sq. sec.

4. Plunging losses
   Where surface inlet inflow is 20 percent or more of the total flow through a junction, or when a lateral pipe enters a junction with its invert elevation above the crown of the outgoing pipe and the flow in the lateral pipe is 20 percent or more of the total flow through the junction, the total head loss from the structure ($H_i + H_o + H_\Delta$) shall be multiplied by 1.3 (increased by 30 percent). This adjustment is cumulative with the adjustment for plunging losses.

5. Inlet shaping
   Inlet shaping refers to how the invert is shaped to provide smooth flow through the structure and is required in all manholes and inlets. When VDOT Standard IS-1, inlet shaping, is used in a structure, the total head loss from the structure ($H_i + H_o + H_\Delta$) shall be multiplied by 0.5 (decreased by 50 percent). This adjustment is cumulative with the adjustment for inlet shaping.

4.7.5.1.8 100-Year Conditions

Where there is the possibility of building structures flooding, conditions during the 100-year storm shall be analyzed to verify that all existing and proposed structures do not flood. Flow from the 100-year storm may be carried overland as well as by the storm drain system.

4.7.5.1.9 Materials

4.7.5.1.9.1 Structures

All stormwater structures (inlets, manholes, and junction boxes) located in public easements or rights-of-way shall be precast or cast-in-place concrete. All structures, frames, grates, and covers shall be in accordance with VDOT Standards and VDOT Specifications.

4.7.5.1.9.2 Storm Drain Pipe

Storm drain pipe in roadways shall be constructed of RCP. Storm drain pipe in sidewalks, trails, etc., shall be constructed of RCP or HDPE. CMP shall not be allowed.

4.7.5.1.10 Structural Design

All inlet structures, frames and grates; and pipes shall be designed to withstand a HS-20 loading, unless a pipe crosses a railroad, in which case the pipe shall be designed for railroad loads. The structural design shall consider the depth of cover, trench width and condition, bedding type, backfill material, and compaction.

4.7.5.2 Installation

All inlets, pipes, and associated structures shall be installed in accordance with VDOT Specifications and the manufacturer's recommendations. The characteristics of the trench, bedding, and pipe material all impact the structural strength of the pipe system. The installed pipe conditions shall comply with the design assumptions and calculations.

4.7.5.2.1 Bedding Material

Bedding material and installation shall comply with the requirements of the VDOT Specifications.

4.7.5.2.2 Backfill

Backfill shall be suitable material and shall be placed and compacted in accordance with the VDOT Specifications.

Before passage of equipment, a minimum of 12 inches of cover shall be placed over the top of a storm drain pipe prior to placement of pavement or other surface treatment. Additional depth of cover shall be provided if recommended by the manufacturer.

4.7.5.2.3 Separation of Utilities

Where storm drains cross other utilities, at least 1 foot of vertical separation shall be provided. Where 1 foot of vertical separation cannot be provided, special provisions shall be made in the bedding and backfill to avoid settlement that could cause point loadings on the storm drain or other utility.

Waterlines and sewer lines shall not pass through a storm drain inlet or manhole.

4.7.5.3 Environmental Impacts

Construction or modifications to storm drains shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits.

4.7.5.4 Erosion Protection at Outfalls

Erosion protection at storm drain outlets shall be provided in accordance with the outlet protection standards contained in the VESCH and the VDOT Drainage Manual.

4.7.5.5 Maintenance Requirements

The Contractor is responsible for maintenance of storm drains until the termination of land disturbance as described in the VTAS&S.

4.7.6 Stormwater Detention

Stormwater detention facilities are a means of attenuating increases in peak flow rates caused by land development. In addition to providing flood control, stormwater detention facilities can protect downstream channels from increases in erosion and may provide a measure of water quality treatment. This chapter addresses general requirements for detention facilities as they relate to attenuating peak flow rates.

When a storm event occurs, stormwater runoff enters the detention facility. The outlet structure allows a portion of the stormwater runoff to discharge from the facility, while the remainder of the stormwater runoff is temporarily stored. After the end of the storm, water continues to discharge from the facility until it is empty or the permanent pool elevation is reached.

Stormwater detention facilities, as listed in Virginia Stormwater BMP Clearinghouse and DEQ Stormwater Regulations, include:

1. Proposed facilities (under Part IIB)
    a. Bioretention (including urban bioretention)
    b. Constructed wetlands
    c. Wet ponds
    d. Extended detention ponds
    e. Underground detention facilities
2. State existing facilities (under Part IIC)
    a. Detention basin
    b. Enhanced extended detention basin

An underground detention facility consists of pipes or manufactured underground chambers used to temporarily store stormwater runoff following a storm event, discharging it at a controlled rate through a hydraulic outlet structure to a downstream conveyance system. An underground detention facility is dry during non-rainfall periods.

In addition to detention, the design requirements specified by this chapter shall apply to ponds created as amenities, research ponds, and farm ponds.

4.7.6.1 Design Methodology and Criteria

4.7.6.1.1 Hydrology

See DCSM section 4.7.2 for methodology used to determine design flows.

4.7.6.1.2 Design Flows and Storage Volumes

To properly design stormwater detention facilities, a flow routing program shall be used with an appropriate elevation-storage-discharge relationship for the design storm events.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.7.6.1.3 Detention Facility Locations

Stormwater detention facilities should not be constructed within a Federal Emergency Management Agency (FEMA) designated 100-year floodplain. If this is unavoidable, the facility shall comply with all applicable regulations under the National Flood Insurance Program, 44 CFR 59.

The following factors shall be addressed when siting a stormwater detention facility:
1. Geotechnical conditions, including soil conditions
2. Karst topography
3. Groundwater levels
4. Existing and proposed utilities
5. Aesthetic impacts on surrounding properties
6. Environmental impacts, including wetlands

Stormwater basins shall be located to minimize the aesthetic impacts to adjacent properties. Basins shall be set back from property lines a distance equal to the minimum width of the applicable required Source in accordance with Virginia Stormwater BMP Clearinghouse Specification No. 15.

Locate stormwater detention facilities to avoid collecting significant amounts of drainage from offsite areas.

All stormwater management basins shall be lined with either a clay liner or an impermeable HDPE liner.

4.7.6.1.4 Detention Basin Grading

Stormwater basins shall be graded to blend into the surrounding topography with the following conditions:
1. Basin side slopes shall be no steeper than 3H:1V.
2. Provisions shall be made for the long-term maintenance of basin slopes and periodic access for maintenance of the outlet structure and emergency spillway and removal of accumulated sediment and debris.
3. The maximum allowable depth of a stormwater detention basin shall be 15 feet, as measured from the top of the embankment to the lowest point in the basin.
4. The bottom of the basin shall be designed so that the entire bottom of the Extended Detention Basin is sloped at 1 percent to facilitate positive drainage to the outlet structure.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

In addition to the above requirements, the following standards of practice should be used when designing a stormwater basin, to the extent possible:

1. In order to prevent short-circuiting of a stormwater basin's sediment storage areas, the length-to-width ratio of the basin should be a minimum of 2:1, with the flow entering the basin as far from the outlet structure as possible. A 3:1 ratio is desired where possible.
2. To minimize cut and fill, the long dimension of a stormwater basin should run parallel to the contours.

4.7.6.1.5 Embankments and Emergency Spillways

Embankments and emergency spillways shall be designed in accordance with the Earthen Embankment and Vegetated Emergency Spillway specifications on the Virginia Stormwater BMP Clearinghouse. A geotechnical study for the embankment and basin is required.

4.7.6.1.6 Outlet Structures and Release Rates

4.7.6.1.6.1 Stormwater Release Rates

Stormwater detention facilities shall be designed with an outlet structure to control the release rate of stormwater being held in the facility. Design release rates shall meet the requirements set forth in DCSM section 4.7.6.

Research ponds, farm ponds and ponds created as amenities shall be exempt from release rate requirements.

4.7.6.1.6.2 Outlet Structure Criteria

Outlet structures generally include a principal spillway and an emergency spillway. An outlet structure may take the form of combinations of risers, pipes, weirs, or orifices. The principal spillway is intended to release flow from the design storm events at the necessary controlled rate, without allowing flow to enter the emergency spillway. The sizing of the outlet structure shall be based on the results of the hydrologic routing calculations or model. Due to the tendency of clogging, the minimum orifice diameter shall be 3 inches. A basin drain shall be installed to allow for dewatering.

Outlets from stormwater detention facilities shall be designed to function without manual, electrical, or mechanical controls.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Where necessary, energy dissipaters shall be placed at the outfall to provide a non-erosive velocity from the facility to a channel. See DCSM section 4.7.7 for the design of outfall protection.

Where a stormwater basin with an earthen embankment does not have an emergency spillway, the principal spillway shall be sized to safely pass the flow from the 100-year storm without overtopping the embankment. In addition, the minimum diameter of the primary spillway inlet shall be 24 inches.

Freeboard for detention basin facilities are as follows:

1. With emergency spillway: 1′ of freeboard for basins that have an emergency spillway that is measured from the calculated design water surface elevation to the top of the embankment; or
2. Without emergency spillway: 2′ of freeboard for basins that do not have an emergency spillway that is measured from the calculated design water surface elevation to the top of the embankment.

Where a stormwater basin has an outfall with an emergency spillway, the outfall shall be sized to safely pass the flow from the 10-year storm and the emergency spillway shall be sized to safely pass the 100-year storm. For a stormwater basin that does not have an emergency spillway, the outfall shall be sized to safely pass the flow from the 100-year storm.

For examples of design calculations of outlet structure orifices and weirs, see the VDOT Drainage Manual.

All riser structures shall be cast-in-place, precast concrete, or PVC unless a substitute material has been approved by SID. Standards for riser structures may be found in the VDOT Standards. Riser buoyancy calculations are required.

Outlet pipes shall be reinforced concrete pipe with rubber gasket watertight joints, shall have appropriate seepage control, and shall be installed on a concrete cradle from the toe of the pipe to the riser for the entire length of the outfall pipe. Concrete cradle shall be in accordance with the requirements of the VDOT Standards.

4.7.6.1.7 Landscaping

Stormwater basin embankments shall be stabilized. Plant selection and installation shall be in accordance with the standards of the Virginia Stormwater BMP Clearinghouse specifications. Trees and shrubs shall not be planted within a stormwater detention basin, nor on a stormwater basin berm, dam, or emergency spillway.

Native plants will be used to the maximum extent possible.

4.7.6.1.8 Underground Detention

4.7.6.1.8.1 Materials

All materials used in underground detention facilities shall be corrosion-resistant, consisting of reinforced concrete, corrugated HDPE pipe, or similar approved material.

4.7.6.1.8.2 Slope

Underground detention facilities shall be sloped to drain at a minimum floor slope of 1 percent.

4.7.6.1.8.3 Capacity

Underground detention facilities and other storm drainage system and facility components shall be sized such that the 100-year design storm may be routed through the drainage system and facilities with no damage to the surface property.

4.7.6.1.8.4 Accessibility and Maintainability

All underground detention facilities shall be designed to be readily accessible for periodic inspection and maintenance from the surface without the need to perform confined space entry.

Providing pre-treatment to remove sediments before or at the entrance of the underground detention facility to improve water quality and/or improve maintainability shall be included to the maximum extent practicable in the design.

4.7.6.1.9 Trash Racks

Outlet structures shall be equipped with an appropriate trash rack. The trash rack shall be in accordance with the VSWMH.

4.7.6.2 Environmental Impacts

Environmental impacts shall be carefully considered when designing stormwater detention facilities. Stormwater detention facilities shall be designed in accordance with MS-14. Proposing basins in low-lying areas with potentially environmentally sensitive areas requires careful consideration, coordination, approval, and permitting with SID and state and federal agencies to evaluate the suitability of constructing in these areas. Environmentally sensitive areas include, but are not limited to wetlands, shallow marshes, jurisdictional waters, natural watercourses, wildlife habitat, etc., and may be protected by state and/or federal laws. With careful planning, it may be possible to incorporate wetland mitigation into the basin design.

Construction of stormwater basins or modifications to existing basins shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits, such as U.S. Army Corps of Engineers and Virginia DEQ wetland permits, Virginia DEQ VPDES permits, etc., and providing SID with the permit documentation prior to beginning construction.

Detention facilities may be coordinated with a Virginia Tech regional stormwater management plan or the Virginia Tech Stormwater Management Master Plan.

4.7.7 Energy Dissipation

Outlet protection for culverts, storm drains, BMP outlets, and steep open channels is essential to prevent high velocity flows from eroding downstream channels and damaging drainage structures. Erosion problems at culverts or at the outlets of detention basins are a common occurrence. Determination of the flow conditions, scour potential, and channel erosion resistance shall be standard procedure for all designs.

Outlet protection can be a channel lining, structure, or flow barrier designed to lower excessive flow velocities and prevent erosion and scour.

Outlet protection shall be employed whenever the velocity of flow at a pipe or open channel outlet exceeds the erosive velocity of the immediate downstream reach.

Energy dissipation may take the form of the following:

1. Erosion control stone outlet protection.
2. Erosion control stone-lined channels
3. Riprap outlet basins
4. Concrete baffled outlets

4.7.7.1 Design Methodology and Criteria

4.7.7.1.1 Outlet Velocity

Where the outlet velocity from culverts, storm drain outfalls, or open channels is high, and channel or pipe modifications cannot adequately reduce the velocity, energy dissipation may be necessary. See the VDOT Drainage Manual and/or the VESCH for methodologies to determine design outlet velocities from open channels, culverts, and storm drains.

4.7.7.1.2 Erosion Control Stone

The most common form of energy dissipation is the use of erosion control stone at the outlet. Protection is provided primarily by having sufficient length and flare to dissipate energy by expanding the flow. The outlet velocities are computed for the 10-year discharge.

Where a pipe discharges into a channel, the apron shall extend across the channel bottom and shall extend up the bank to a depth of one foot above the maximum tailwater depth from the design storm event. The dimensional requirements of the erosion control stone apron shall be determined using the graphical curves in the VESCH.

Generally, the use of erosion control stone for energy dissipation is limited to a maximum velocity of 19 feet per second. Alternative means of energy dissipation shall be required where the discharge velocity is greater than 19 feet per second. Alternative means include riprap stilling basins or concrete baffled outlets. The use of alternative means of energy dissipation requires the approval of VDOT when located in a VDOT right-of-way.

4.7.7.1.3 Riprap Basins

A riprap outlet basin is a depressed area of riprap placed at the outlet of a high velocity culvert, storm drain or open channel. The riprap reduces the exit velocity by expanding the flow over the riprap length and width and forming a hydraulic jump.

For the design of riprap basins, refer to the VDOT Drainage Manual. Dissipator geometry may also be computed using the “Energy Dissipator” module that is available in the computer program FHWA HY8, Culvert Analysis.

4.7.7.1.4 Baffled Outlets

A baffled outlet usually consists of a concrete box structure with a vertical hanging concrete baffle and an end sill. Several variations of concrete baffled outlets have been published by VDOT and other state and local transportation and stormwater management agencies. Baffled outlets are usually used when very high exit velocities exist at piped or channel transitions. Baffled outlets function by dissipating energy through impact of

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

the water hitting the baffle and through the resulting turbulence. A tailwater depth is not required for adequate energy dissipation, but will help smooth the outlet flow.

This type of outlet protection may be used with outlet velocities up to 50 feet per second.

Baffled outlets are not included in the state guidance handbooks. Hydraulic design procedures for baffled outlets may be found in the U.S. Department of Interior, Bureau of Reclamation, Design of Small Canal Structures, 1978.

4.7.7.1.5 Additional Energy Dissipators

For additional energy dissipators, refer to FHWA HEC No 14, Hydraulic Design of Energy Dissipators for Culverts and Channels.

4.7.7.2 Installation Requirements

Energy dissipators shall be installed and constructed according to all applicable FHWA, VDOT, and state requirements and recommendations.

4.7.7.3 Environmental Impacts

Construction or modifications to energy dissipation structures shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits, such as U.S. Army Corps of Engineers permits, Virginia DEQ wetland permits, etc.

4.7.7.4 Maintenance Requirements

The Operator/Contractor is responsible for maintenance of energy dissipation structures in accordance with VESCH standards until the termination of land disturbance as described in the VTAS&S.

4.7.8 Stormwater Pollutant Removal Practices

A wide variety of BMPs and general development strategies may be utilized to remove environmentally harmful pollutants from stormwater runoff. Allowable BMPs are listed on the Virginia Stormwater BMP Clearinghouse.

4.7.8.1 Stormwater Quality Requirements

Stormwater runoff generated from land disturbing activities shall be treated through best management practices designed to remove pollutants from the stormwater. The required pollutant removal shall be dependent on the land cover conditions.

For most projects, the BMPs will be designed to remove phosphorus from the stormwater runoff. Generally, when a BMP is efficient in removing phosphorus from the stormwater runoff, it is assumed that easier to remove pollutants such as heavy metals and total suspended solids have also been adequately removed.

When a site drains to more than one hydrologic unit code (HUC), the pollutant load reduction requirements shall be applied independently within each HUC, unless reductions are achieved in accordance with a comprehensive stormwater management plan.

Where appropriate, additional pollutants may be required to be removed from the stormwater runoff based on the presence of stormwater hotspots (land use activities that generate highly contaminated runoff, as determined by SID). See DCSM section 4.7.5.1.6.5. These pollutants may include the following:

1. Total suspended solids in areas with highly erodible soils
2. Total petroleum hydrocarbons (TPH) at fueling stations or areas with fuel-contaminated soil
3. Heavy metals in areas with contaminated soils
4. High temperature runoff

Land disturbing activities shall also comply with all additional water quality requirements as indicated in the VTAS&S, current version.

Proposed Common Plan developments shall apply stormwater quality management criteria to the land development project as a whole. Individual projects in Common Plan developments shall not be considered separate land development projects in regards to water quality. Hydrologic parameters shall reflect the ultimate land development and shall be used in all engineering calculations.

Where stormwater quality requirements must be implemented, stormwater runoff must flow through appropriate BMPs before the water is discharged from the site.

4.7.8.2 Stormwater Quality Calculations

To meet the requirements of the VSMP regulations, the Virginia Runoff Reduction Method (VRRM) will be utilized to verify compliance. The VRRM water quality compliance worksheet is available on the DEQ website. This worksheet must be submitted in the Stormwater Management Plan. The average one-year rainfall depth shall be 43 inches.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.7.8.3 Manufactured BMP Systems

A manufactured BMP system is a structural measure that is specifically designed and sized by a manufacturer to intercept stormwater runoff and prevent the transfer of pollutants downstream. Use of manufactured BMPs will only be allowed if the device is approved and listed on the Virginia Stormwater BMP Clearinghouse.

4.8 UTILITIES

Future subterranean utility improvements should be buried at a sufficient depth (typically 30 inches) to allow for regrading of nearby slopes without requiring relocation of the improvement. Grading operations shall not result in utilities being buried at an unreasonable depth without prior approval from Mechanical Utilities.

4.8.1 Manholes and Structures

4.8.1.1 References

The following ASTM standards provide specifications for this section:
A48 – Standard Specification for Gray Iron Castings
C443 – Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets
C478 – Standard Specification for Circular Precast Reinforced Concrete Manhole Sections

4.8.1.2 Materials

1. General – Concrete manholes and utility structures shall be of precast construction. All concrete shall be rodded or vibrated to minimize honeycombing and assume water tightness. Items delivered and installed at the site shall be structurally sound and free from cracks or major surface blemishes.
2. Precast concrete manholes:
   a. Precast manhole shall conform to ASTM C478 and the standard details referred to on the plans.
   b. Minimum inside diameter shall be 48 inches unless noted on plans with minimum of 5-inch thick walls. All manholes shall have monolithic bases except as shown on the plans.
3. Manhole steps: Plastic coated steps only shall be provided in all manholes and shall be on 12-inch minimum centers. Steps shall conform to OSHA requirements for manhole step detail.

4. Pipe:
    a. Provision for indicated storm drainage pipe connections shall be made by means approved in VDOT Specification 302.
    b. Sanitary sewer pipe connections shall be made with flexible watertight rubber connector fastened to the pipe with a stainless steel band. Connector shall be in accordance with ASTM C923.
    c. All lines shall be grouted into place.
5. Frames and covers: Frames and covers shall be of cast iron conforming to ASTM A48 for Class 30 Gray Iron and shall conform to VDOT (or watertight where indicated on plans) manhole cover and frame detail.
6. Concrete: Concrete used for shaping of manholes, channels, sidewalk, and miscellaneous work shall meet requirements of VDOT Type A3 or C1.
7. Inlet structures: Curb opening and grate opening inlets shall be provided as shown on the plans and shall conform to VDOT Specification 302. All inlets shall be precast and shall conform to the VDOT Road and Bridge Standards.
8. Steam manhole:
    a. Steam manholes shall be designed with sump pumps.
    b. Steam manholes shall be designed with a drip leg that runs to a flash tank with a steam trap.
9. Steam tunnel junction box: Junction box shall be VDOT modified JB-1.
10. Precast steam tunnel: Shall be VDOT Standard BCS-DT single box culvert. Laying lengths shall be 72″ with dove-tail joints. Inside dimensions shall be 6′ × 6′.
11. Invert shaping: Unless shown otherwise on the plans, all inverts shall be shaped according to VDOT Standard IS-1, or invert shaping shown on the manhole detail.
12. Sanitary sewer drop manhole: A drop stack is required when the difference between invert-in and invert-out of the pipes is 2 feet or greater.

4.8.1.3 Execution

1. Installation
    a. Manholes: The subgrade and bedding for the monolithic base for the precast manhole shall be prepared similar to that for pipe. Invert shaping is required for all sanitary sewer manholes and for storm manholes where noted. The invert channels shall be formed with concrete as shown on the VDOT Standard Details MH-1 and MH-4 and shall be smooth and semicircular in shape, conforming to the inside of the adjacent sewer section. Changes in direction of flow shall be made with a smooth curve o

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

f as large a radius as the size of the manhole will permit. The floor of the manhole outside of the channels shall be smooth and shall slope toward the channels not less than 2 inches per foot, nor more than 4 inches per foot.

b. Sanitary sewer manhole joints: Joints shall be a double ring of butyl rubber rope caulk to form a watertight seal. Manhole frames, covers, and hatches shall also be set on a double ring of butyl rubber rope caulk. When leveling is required manhole frames shall be set level on a full bed of mortar to the proper grade prior to the application of the butyl caulk. Under no circumstances shall manholes or other structures be left in an incomplete condition such that surface water could enter into the sewer line.

c. Steam tunnel:
    i. Reinforced concrete inverted “U” tunnel: Conduit foundation slab shall be minimum 4000 psi concrete reinforced with four #4 rebar spaced equally from edges. Tunnel top shall be a minimum of 5000 psi concrete. The rebar shall be set a minimum of 1.5 inches above the bottom of the trenches. No portion of the concrete base cross section shall be less than 6 inches thick. A 1-3/4 inch × 5-5/8 inch internal drain shall be provided throughout all runs. Slab surfaces shall be seeded straight and to proper grade and pitched uniformly to drainage points. The foundation slabs and drain shall extend through the building and manhole walls. Bedding for the foundation slab shall be shown on the plans.

    A mastic sealant shall be used at all base joints. The sealant shall be three-quarters of an inch in thickness. After installation of conduit, all exterior joints shall be sealed with grout to a smooth finish with no rough spots to cut the waterproofing membrane.

    After all joints are sealed with grout and smoothed, a heavy coat of underground asphalt sealing compound shall be applied to all joints. A waterproofing membrane shall be installed over the entire conduit system. The membrane shall be 30-mil neoprene lining. At all separations of the lining a 6-inch overlay shall be used and sealed with a mastic sealant to a waterproof seal. The entire conduit system shall be made waterproof.

    ii. Walkthrough steam tunnel: Walkthrough steam tunnel shall be precast single box culvert in accordance with VDOT Standard BCS-DT, and shall be 6′ × 6′ interior. Bedding shall be 6 inches of VDOT #26 stone. A double ring of butyl rubber caulk shall be used at all joints. Waterproofing shall be as stated under reinforced concrete inverted "U" tunnel.

2. Tests
   a. Manhole vacuum testing: Unless otherwise approved by the A/E, manholes shall be tested by the vacuum method. Manholes shall be tested after assembly and after backfilling. The Contractor is encouraged to test the manhole prior to backfilling. Stub-outs, manhole boots and pipe plugs shall be secured to prevent movement while the vacuum is drawn. Installation and operation of vacuum equipment and indicating devices shall be in accordance with equipment specifications for which performance information has been provided by the manufacturer and approved by the Health Department. A measured vacuum of 10 inches of mercury shall be established in the manhole. The time for the vacuum to drop to 9 inches of mercury shall be recorded.
   b. The Construction Field Representative (CFR) shall observe manhole testing.
   c. Acceptance standards for leakage shall be established from the elapsed time for a negative pressure change from 10 to 9 inches of mercury. The maximum allowable leakage rate for a four-foot diameter manhole shall be in accordance with the following:

Table 4-8. Maximum Allowable Leakage Rate

Manhole Depth	Minimum Elapsed Time for a Pressure Change of 1 inch Mercury (inHg)
10 feet or less	60 seconds
> 10 feet, but < 15 feet	75 seconds
> 15 feet, but < 25 feet	90 seconds

   d. For manholes 5 feet in diameter, add an additional 15 seconds and for manholes 6 feet in diameter, add an additional 30 seconds to the time requirements.
   e. If the manhole fails the test necessary repairs shall be made and the vacuum test and repairs shall be repeated until the manhole passes the test or the manhole shall be tested in accordance with the standard exfiltration test and rated accordingly.
   f. If a manhole joint mastic is completely pulled out during the vacuum test the manhole shall be disassembled and the mastic replaced.
   g. It is not necessary to test storm drainage manholes.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.8.2 Domestic Water Utility Distribution Piping

1. Water line materials:
   a. C151 – Ductile iron pipe, centrifugally cast in metal molds or sand lined molds. For water or other liquids.
   b. C900 – Polyvinyl chloride (PVC) pressure pipe, 4 inches through 12 inches for water.
   c. C905 – PVC water transmission pipe, 14 inches through 36 inches.
   d. Class SDR 9 – High density polyethylene (HDPE) pressure pipe, maximum pressure of 200 psi, with CTS end connections and brass compression fittings.
   e. Copper pipe shall not be buried underground. Pipe shall be transitioned from copper to a different material inside the building.
2. Water main: At the Contractor's option, water lines 4 inches and larger shall be one of the following:
   a. Polyvinyl chloride pipe: All PVC pipe shall meet or exceed the following requirements:
      i. All pipe and fitting shall be made from PVC components as defined in ASTM D1784 and AWWA C 900.
      ii. Pipe shall have a minimum 4:1 safety factor at its recommended maximum working pressure.
      iii. Standard laying length of pipe shall be 20 feet.
      iv. PVC pipe shall be SDR-18, Class 150.
      v. Joints shall be push-on type; the basis of design shall be Ring-Tite or equivalent with rubber rings conforming to ASTM D3139 and ASTM F477.
      vi. Lubricant: Lubricant for joints shall be that supplied by the manufacturer of the pipe being used. If PVC pipe is used, the lubricant for PVC pipe shall be used at joints with valves, fittings, hydrants, or other pipe materials. With PVC pipe, no lubricant harmful to polyvinyl chloride plastic shall be used.
   b. Ductile iron pipe: All ductile iron pipe (DIP) for sewer or water installation shall meet or exceed the following requirements:
      i. Pipe shall be the diameter shown on the drawings.
      ii. Pipe shall be Class 350 in accordance with AWWA C150.
      iii. Pipe shall be cast in accordance with AWWA C151.
      iv. Pipe shall be cement-lined in accordance with AWWA C104.
3. Water lines 3″ and larger shall be ductile iron and shall meet the following requirements:

   a. Pipe shall be the diameter shown on the drawings.
   b. Pipe shall be Class 350 in accordance with AWWA C150.
   c. Pipe shall be cast in accordance with AWWA C151.
   d. Pipe shall be cement-lined in accordance with AWWA C104.
4. Water lines 2″ and smaller shall be Class SDR 9 HDPE pressure pipe.
5. All water lines shall have a #12 AWG solid copper tracer wire attached to the line. The tracer wire shall be brought into the valve box with enough slack to allow removal of the end of the wire for connection to tracing equipment.
6. There shall be no gripper gaskets on restraining joints.
7. Hot water supply and return (HWS and HWR) in manholes and/or tunnels
   a. 2-1/2″ and larger:
      i. Pipe – ASTM A53B, Type E, galvanized, electric resistance welded, Schedule STD.
      ii. Fittings – ASTM A234 Grade WPB/ANSI B16.9, Schedule STD, seamless, galvanized.
      iii. Flanges – Class 150, galvanized.
   b. Special considerations:
      i. After wire brushing the final pass and while the pipe is hot, apply zinc spray. The basis of design for zinc spray shall be ThermaCote Galvanize.
      ii. Provide chlorine for cleaning piping and flush per local regulations. Test prior to putting in service per local regulations.
8. Reduced pressure zone assemblies (RPZ valves) shall be used on domestic water lines for backflow prevention. RPZ systems shall consist of two parallel backflow preventers to accommodate servicing. All RPZ valves will be selected and purchased by Facilities Ops Mechanical Services who will be reimbursed from the project funds. Special purpose backflow prevention devices shall be decided based on the best fit for the purpose and application.
   a. The basis of design for piping 2″ and smaller is Zurn Wilkins model 975XL.
   b. The basis of design for piping 2-1/2″ and larger is Zurn Wilkins model 375A.

4.8.3 Water Valves

1. Valve boxes: Adjustable cast iron boxes of suitable diameter, length, and design shall be furnished and installed for all buried valves excluding post-indicator valves. Boxes shall be three-piece screw type, with #6 round base (#8 for 8″ valves). Valve boxes shall be in accordance with VDOT Road and Bridge Standards, Detail VB-1.
2. Valve installation:

a. Valve stems shall be oriented for accessibility.
b. Valves shall be installed so no forces are transmitted to the valve through the piping or valve boxes.
c. Flushing: All valves and appurtenances shall be flushed clear of all foreign material after installation.
d. Field test all valves and appurtenances for proper operation, proper adjustments, binding, scrapings, and other defects. Check all valves and boxes for high quality.
e. A valve box shall be provided for every valve. The valve box shall not transmit shock or stress to the valve and shall be centered and plumb over the wrench nut of the valve, with the box cover flush with the surface of the finished grade or as directed by the engineer.
f. Water pipe lines shall be protected against joint pulling or thrust damage by suitable mechanical joint restraint devices at all joints, fittings, and all other critical points. Mechanical joint restraint shall be incorporated in the design of the follower gland and shall include a restraining mechanism which, when actuated, imparts multiple wedging action against the pipe, increasing its resistance as the pressure Increased. Flexibility of the joint shall be maintained after the burial. Glands shall be manufactured of ductile iron conforming to ASTM A536-80. Restraining devices shall be of ductile iron heat treated to a minimum hardness of 370 BHN. Dimensions of the gland shall be such that it can be used with the standardized mechanical joint bell and tee-head bolts conforming to ANSI/AWWA A21.11/C111 and ANSI/AWWA A21.53/C153 of latest revision. Twist-off nuts, sized same as tee-head bolts shall be used to insure proper actuating of restraining devices. The mechanical joint restraint shall have a working pressure of at least 235 psi with a minimum safety factor of 2:11. The basis of design for the grip ring shall be Romac Industries, Inc. and Romac style 611 for bell joints.

4.8.3.1 Domestic Water Valves

Gate valves: For domestic water, valves shall be cast iron body, resilient seated with reinforced rubber seat ring or permanently bonded disc, and machined seating surface, brass or bronze non-rising stems, and shall comply with AWWA C509. All valves shall have right-hand threads.

A post indicator valve shall be installed on all buildings that are fully sprinkled. The post indicator valve shall be a resilient seal valve (NRS), open left. The basis of design for the post indicator shall be Mueller or approved equal.

4.8.3.2 Chilled Water Valves

Gate valves: For chilled water lines, valves shall be cast iron body, resilient seated with reinforced rubber seat ring or permanently bonded disc, and machined seating surface, and brass or bronze non-rising stems. All valves shall have right-hand threads.

4.8.4 Water Utility Metering

1. Water meters up to 2″ shall be:
   a. Zenner (performance) Multi-Jet type Magnetic Drive cold water meter Nitro1 with encoder-type register with Itron quick connect, or
   b. Badger Meter Recordall Disc Series positive displacement meter with HR-E High Resolution Encoder, or
   c. Mueller Systems 500 Series Magnetic Drive Positive Displacement Disc meter with Mueller Systems ME-8 encoder.
2. Water meters 2″ and larger shall be:
   a. Zenner (performance) Bronze Turbine Meter with encoder-type register with Itron quick connect, or
   b. Badger Meter Recordall Turbo Series direct coupled turbine meter with HR-E High Resolution Encoder, or
   c. Mueller Systems Hersey HbMAG electromagnetic flowmeter with integral register and an Itron 100W Endpoint (ERT) module with an Itron in-line connector cable.
3. Encoder types shall be specific to the water meter selected:
   a. Zenner (performance) meters shall have an Itron 100W Encoder with an inline connector, part #ERW-0771-202, Utility ID#181 for Virginia Tech.
   b. Badger meters shall have a Badger HR-E High Resolution Encoder with an in-line connecter.
   c. Mueller Systems 500 Series meters shall have a Mueller Encoder Eight (ME-8) with an in-line connector. Mueller Systems Hersey HbMAG meters shall have an Itron 100W Endpoint (ERT) module with an Itron in-line connector cable.
4. A water meter with a bypass is required for all new buildings.

4.8.5 Fire Hydrant

The basis of design for the fire hydrant shall be Mueller Super Centurion 4-1/2″ pumper connection and two 2-1/2″ hose nozzles, or equal approved by the University.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.8.6 Field Quality Control

4.8.6.1 Testing Water Lines Excluding the Fire Line

Test pressures shall be 150 psi unless otherwise noted. Testing shall begin on the first valved section of line within ten days after its completion. The pressure and leakage tests shall be conducted concurrently for a duration of two hours.

Leakage shall be defined as the quantity of water that must be supplied into the valved pipe section to maintain pressure within 5 psi of the specified test pressure. The allowable leakage shall not exceed the values given in table labeled Allowable Leakage per 1,000 Feet of Pipeline.

The valved section of the pipe under consideration shall be slowly filled with water and brought to the specified pressure by means of a pump. Before supplying the specified test pressure, all air shall be expelled from the pipe. The Contractor shall supply taps for expelling air. Testing shall not begin until at least seven days after the last concrete anchor has been poured on the section of line being tested (if high early concrete is used, two days). The CFR shall observe all leakage tests.

If the pipe fails to meet test requirements, all leaks shall be repaired and defective pipe repaired or replaced at the Contractor's expense. The test shall be repeated until satisfactory results are obtained. The Contractor shall be charged for all retests at the normal rates for inspection services.

Table 4-9. Allowable Leakage by Pipeline Length

Allowable Leakage per 1,000 Feet (305 m) of Pipeline (gph)												
Average Test Pressure	Pipe Size											
psi	2	3	4	6	8	10	12	14	16	18	20	24
200	0.21	0.32	0.43	0.64	0.85	1.06	1.28	1.48	1.70	1.91	2.12	2.55
175	0.20	0.30	0.40	0.59	0.80	0.99	1.19	1.39	1.59	1.79	1.98	2.38
150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

If the pipeline under test contains sections of various diameters, the allowable leakage will be the sum of the computed leakage for each size.

4.8.6.2 Testing Fire Line

1. Flushing of piping: Underground mains and lead-in connections to system risers shall be flushed thoroughly before connection is made to system piping in order to remove foreign materials which may have entered the

underground main during the course of the installation or which may have been present in existing piping. The minimum rate of flow shall not be less than the water demand rate of the system, which is determined by the system design, or not less than that necessary to provide a velocity of 10 feet per second (3 m/sec.), whichever is greater. For all systems, the flushing operations shall be continued for a sufficient time to ensure thorough cleaning. When planning the flushing operations, consideration shall be given to disposal of the water issuing from the test outlets.

2. Hydrostatic test requirements: All new private fire service mains shall be tested hydrostatically at not less than 200 psi (13.8 bar) pressure for two hours. The amount of leakage in piping shall be measured at the specified test pressure by pumping from a calibrated container. For new pipe, there shall be no allowable leakage at the joints.

   The CFR shall observe all leakage tests and flushing operations. If the pipe fails to meet test requirements, all leaks shall be repaired and defective pipe repaired or replaced at the Contractor's expense. The test shall be repeated until satisfactory results are obtained. The Contractor shall be charged for all retests at the normal rates for inspection services.

4.8.7 Sanitary Sewer Piping

At the Contractor's option, sewer pipe shall be one of the following materials, unless otherwise shown on the plans:

1. Polyvinyl chloride pipe: All PVC shall be PVC SDR 35 or PVC schedule 40.
2. Ductile iron pipe: All DIP shall meet or exceed the requirements of AWWA C104, C150, and Cl5l.

For procedures for testing non-pressure plastic pipe sewer lines, the Contractor shall follow the latest version or revision of ASTM F 1417-11a(2019).

4.8.8 Chilled Water Distribution

Bypass chilled water control valves on campus chilled water utility connections shall be linear globe valves sized for proper authority.

4.8.8.1 Underground Piping

1. Pipe material shall be PVC pressure pipe AWWA C900/C905, DR14 rated for 305 psi working pressure for sizes 4″ through 12″, DR18 rated for 235 psi working pressure for sizes 14″ through 30″, and DR21 rated for 200 psi for 36″.

2. The system design maximum pressure shall be 150 psi and the hydro test pressure shall be 200 psi.
3. The basis of design for pipe joints shall be push joint with mechanical restraints equal to EBAA Series 1900 or Series 2800. Restraints shall be ASTM A536 ductile iron and designed for use with AWWA C900/C905 piping. Restraints shall be coated with a corrosion protective coating for direct burial use. Pressure rating of the restraint and fasteners shall be equal to or greater than that of the pressure rating of the piping system. All bolts and nuts shall be low alloy steel with corrosion protective coating.
4. Pipe fittings shall be ductile iron mechanical joint type manufactured in accordance with the latest revisions of AWWA C110/A21.10 and AWWA C111/A21.11 and rated for 250 psi working pressure. AWWA C153 compact fittings are not allowed.
    a. Pipe fittings shall be designed to provide positive restraint against end-wise separation due to thrust through the use of mechanical restraints. The basis of design for pipe fittings shall be EBAA Iron Series 2000PV or equal. The pressure rating shall be a minimum of 250 psi. All restraints shall be provided with a factory-applied corrosion protective coating.
    b. All bolts and nuts shall be low alloy steel with corrosion protective coating.
    c. All gaskets shall be SBR.
    d. Piping connection at point of entry to structures shall be made with a factory flange on the underground piping and not a set screw-type (e.g., Uni-Flange product) or gripping wedge-type (e.g., Megaflange product) flange or flange adapter.
5. All chilled water lines shall have a #12 AWG solid copper tracer wire attached to the line. The tracer wire shall be brought into the valve box with enough slack to allow removal of the end of the wire for connection to tracing equipment.
6. Concrete supports shall not be placed behind saddles for taps.

4.8.8.2 Direct Buried Butterfly Valves

1. Valves shall conform to latest revision of AWWA C504. Valves shall be tight closing and rubber-seated. Valves shall be bubble-tight at the rated pressure in either direction, and shall be suitable for throttling service and operation after long periods of inactivity. Valves shall be rated for 200 psi non-shock working pressure-minimum. Valves shall be designed for direct buried application.

2. Valves shall be cast iron body ASTM A126B, Class B, restrained mechanical joint (AWWA C151/ANSI 21.11) or flanged (ANSI B16.1) ends. Valves shall be furnished complete with joint accessories (bolts, nuts, gaskets and glands).
3. The resilient seat shall be capable of mechanical adjustment in the field and field replacement.
4. Valves shall be hydrostatically and leak tested in accordance with AWWA C504.
5. Valves shall be complete with grease-packed buried service gear operator and shaft extensions with centering disk located on shaft to within one foot of finished grade and soil pipe.

4.8.9 Steam Distribution Tunnel

Steam vaults shall be ventilated.

4.8.9.1 Precast Materials

1. Concrete shall conform to ASTM C478 and as follows:
   a. Compressive strength: 5000 psi minimum at 28 days.
   b. Air content: 4% minimum.
   c. Cementitious materials: Minimum of 564 lb./cu. yd.
   d. Course aggregates: ASTM C33. Sound, crushed, angular granitic stone only. Smooth or rounded stone shall not be used.
   e. Fine aggregates: ASTM C33. Free from organic impurities.
   f. Chemical admixtures: ASTM C494. Calcium chloride or admixtures containing calcium chloride shall not be used.
   g. Air Entraining Admixtures: ASTM C260.
2. Reinforcing steel shall be ASTM A615 Grade 60 deformed bar, ASTM A82 wire, or ASTM A185 welded wire fabric.
3. All reinforcing steel used in underground steam system structures including but not limited to manholes, precast tunnel covers, tunnel slab, etc., shall be galvanized.
4. Lift loops shall be ASTM A416 steel strand. Lifting loops made from deformed bars shall not be allowed.

4.8.9.2 Precast Components

1. Lifting inserts, holes, and devices shall comply with OSHA Standard 1926.704. Lift holes and inserts shall be sized for precision fit with lift devices and shall not penetrate through structure wall. Lifting devices shall be provided by precast manufacturer.

2. Joints shall be sealed internally between tongue and groove and additionally around external perimeter of the joint.
3. Components shall be designed in accordance with ACI, ASTM C890.
4. Rectangular subgrade components shall be designed and manufactured in conformance with ASTM C913.

4.8.9.3 Waterproofing

1. Waterproofing for this section shall apply to all underground structures, precast and poured-in-place.
2. Provide a multilayer waterproofing sheet membrane system rated for buried service.
3. The waterproofing membrane shall have the following minimum properties:

Table 4-10. Minimum Properties for Waterproofing Membrane

Puncture Resistance	169 lb., FTMS 101B
Tensile Strength	4000 psi
Elongation	700%
Resistance to Hydrostatic Head	150 ft. – zero leakage
Coefficient of Permeability	2.7×10^{-13} $cm^3/cm^2/sec$
Packaging	4′ × 24′ rolls
Thickness	170-200 mil

4. The waterproofing membrane shall be protected from backfill by a layer of non-woven polypropylene or as recommended by the membrane manufacturer. Unless recommended otherwise by the membrane manufacturer, the protective layer shall have an approximate weight of one-half pound per square yard.

4.8.10 Steam (LPS and HPS), Condensate, and Pumped Condensate Valves

1. All valves used in steam service shall be marked as rated for steam use. Manufacturers: Kitz, Powell, Crane, Edwards, Milwaukee, Williams, Adams, Zwick, Yarway, or approved other.
2. Gate valves
   a. Valves 2″ and smaller – steel body, rising stem, threaded ends, solid wedge, stainless steel trim, OS&Y malleable iron hand-wheel.
   b. Valves 2-1/2″ and larger – steel body, rising stem, flanged ends, OS&Y, bolted bonnet, 13% Cr steel wedge, hard-faced, stainless steel trim, stainless steel

stem, malleable or ductile iron hand-wheel, designed in accordance with ASME B16.34.

c. Provide all valves with removable insulating blankets.
d. Valves and gaskets shall use no components containing asbestos.

3. Triple offset valves (high pressure steam service)
    a. Triple offset valves are only to be used where gate valve use would otherwise result in excessive sizing of manholes or access. Unless there is a significant cost savings.
    b. Valves 12" and larger – Class 300, quarter turn, metal to metal seated, incorporating "inclined conical" geometry creating a torque seating operation. Valves shall provide bi-directional bubble tight shut off and be designed in accordance with ANSI/ASME B16.34 and B31.3.
    c. Valve bodies shall be double flanged, cast steel, able to withstand induced pipe loads without distortion and effect on the movement of the disc. Valves shall be complete with blow out proof stem.
    d. Valve disc shall be 316 stainless steel. Disc attachment to the shaft shall be by means of parallel keys. Disk to shaft attachment by use of pins is not allowed.
    e. The valve shaft shall provide adequate strength to operate the valve at full rated design conditions. Shaft shall be one piece. A thrust bearing shall be provided to absorb thrust in both directions and provide blowout protection. The shaft diameter shall be reduced at the actuator connection so as to put the weakest point outside the valve above the packing.
    f. The seal ring shall consist of laminations of 316 SS and graphite. The seal ring shall be secured by means of a retainer to insure no movement or flexing. Retainer bolting on internal rotating parts is not allowed. No leakage behind the seat ring is allowed.
    g. The packing gland shall be provided with a minimum of four studs for precision adjustment and compression of the packing. Packing shall consist of a minimum of five packing rings suited for the pressure and temperature rating of the valve.
    h. Valves will incorporate solid metal, press fit shaft bearings which are sealed from the ingress of particulates or contaminants. Sufficient differential hardness between the shaft and bearing surfaces shall be provided to insure smooth, non-galling rotation.
    i. Valve actuators shall be provided with self-locking gears. The actuator mounting bracket shall be rigidly pinned to the body and centered by machined register between bracket and body.

   j. Valves shall be tested in accordance with ASME Bl6.34-1996 and API598-1996. Valves shall be factory tested for seat leakage from both sides of the disc. Provide test certifications with each valve.
   k. Valve machined surfaces shall be protected with anticorrosive coatings prior to shipment.
   l. All steam and condensate valves shall be provided with removable insulating blankets.
4. Ball valves (condensate only)
   a. Valves 6″ and smaller: ASTM A216 WCB steel body, flanged, stainless steel ball, full port, PTFE seat, stainless steel stem, two-piece construction, ANSI Class 150, Apollo 88A-200 series, Milwaukee F20CS150 series, NIBCO F-515-CS-F-66-FS series or Kitz 150SCTBZM (C) or approved equal.
   b. Valves 8″ and larger: gate valves as specified above, provide Class 150 for condensate valves in lieu of Class 300 for steam.
   c. Provide rotary hand wheel operators with gear actuators and with adjustable position stop and position indicators. Size hand wheel operators with no higher than 40 lb. rim pull at full valve pressure rating.
   d. Provide valve neck extensions with sufficient length to allow for insulation where insulation blanket.
   e. All steam and condensate valves shall be provided with removable insulating blankets.
5. Check valves
   a. Valves 2-1/2″ and smaller: A 105 forged carbon steel body, horizontal globe, threaded ends, series 400 stainless steel renewable disc and seat, ANSI Class 600.
   b. Provide check valves at steam condensate lines at outlet of all traps. Install check valve between trap and gate valve.
6. Globe valves
   a. Valves 2″ cast steel, flanged, union bonnet, stainless steel plug disc and seat rings, malleable iron hand-wheel, Class 300, conforming to ASME B16.34, Powell Fig. 3031 or equal.
   b. Install 2″ globe valves in bypass lines around each main steam valve. Position valve handle accessible and locate valve in bypass such that it will not interfere with operation or maintenance of the main steam valve.
7. Drain valves
   a. Gate valve for steam or ball valves for condensate as specified above. Provide drain valves on each side of steam valves. Provide drain valve on

condensate on each side of take offs from main. Drain valves shall be provided with short threaded nipple and cap.

b. Provide drain valves at all low points of piping systems for complete drainage of systems.

8. Steam pressure reducing valves shall have tight seal shutoffs. The basis of design is Fisher.

4.8.11 Steam Pipe and Fittings

4.8.11.1 General

1. Description
    a. Use only new material, free of defects, rust and scale, and guarantee for services intended.
    b. Use material meeting the latest revision of ASTM specifications as listed in this specification.
    c. Follow local codes if they require other types of pipe or joints.
    d. Use only long radius elbows having a centerline radius of 1.5 pipe diameters unless otherwise indicated.
    e. Manufacturer, pressure class, size and heat code of each fitting and flange shall be permanently identified on its body in accordance with MSS SP-25.
    f. Where size for a pipe segment is not indicated, the pipe segment size shall be equal to the largest pipe segment to which it is connected. Transition to smaller size shall occur on the side of fitting where smaller size is indicated.
    g. Unless otherwise indicated, fittings and accessories connected to pipe shall be of the same material as the pipe.
    h. Unless otherwise indicated, construct piping for highest pressures and temperatures in respective system in accordance with the latest revision of the applicable sections of the ASME Code for Pressure Piping, ANSI/ASME B31.1, including the following: B31.1 Power Piping (All Piping).
2. Pipe welding:
    a. Welding shall be done using only the following processes:
        i. Shielded metal arc welding (SMAW)
        ii. Gas tungsten arc welding (GTAW)
        iii. Gas metal arc welding (GMAW)
        iv. Flux cored arc welding (FCAW)
        v. Submerged arc welding (SAW)

b. Unless otherwise stated, fabrication, installation, inspection, examination and testing shall be in accordance with ASME B31.1, as applicable.
c. Backing rings (chill rings) or consumable inserts are not allowed.

3. Weld examination procedures:
   a. 100% of the steam and condensate field welds on underground piping installed under this contract will be inspected and tested by non-destructive examination. Weld inspection will be paid for by the University with project funds using a third-party testing agency.
   b. Approximately 10% of the welds on steam and condensate pipes in manholes and tunnels installed under this contract will be inspected and tested by non-destructive examination. Weld inspections will be paid for by the University with project funds using a third-party testing agency. Coordinate weld inspections with the VT PM.
   c. Any failure of a weld will require re-inspection of the failed weld at the Contractor's expense. The piping vendor shall test each factory weld and provide weld reports during construction when pipe is delivered to the Contractor.
   d. All tests shall be performed by an AWS-CWI (American Welding Society Certified Welding Inspector) selected and contracted by the University.
   e. All steam and condensate butt welds to be tested as specified above, shall be tested by means of radiography or ultrasound. The criterion for pass/fail of this test will be as defined in the latest edition of the ASME B31.1 Power Piping code.
   f. 10% of steam and condensate socket weld connections shall be tested by means of dye penetrate, magnetic particle analysis, radiography, or ultrasound by University's testing agency and paid for by the University with project funds. The criterion for pass/fail of this test will be as defined in the latest edition of the ASME B31.1 Power Piping code.
   g. Prior to pipe joint fit-up, the firm providing the testing services shall determine if the area of radiography exposure is:
      i. Completely inside the construction fence or tunnel.
      ii. Beyond the construction fence and not impacting adjacent buildings.
      iii. Beyond the construction fence and impacting adjacent buildings.
      iv. If the area of radiography exposure is determined to impact areas outside of the construction fence, contact the VT PM for coordination of signage, barricades, and monitoring.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

h. In the rare occurrence where radiography cannot be used to test a weld due to site restrictions the weld may be visually inspected by an AWS-certified welding inspector provided that all the following conditions are met.
   i. The VT PM and A/E must agree that a radiographic test cannot be reasonably achieved.
   ii. The pipe joint fit-up must be inspected prior to welding by an AWS-CWI.
   iii. All welding passes must be inspected by an AWS-CWI including the root pass, hot pass, and all fill and cover passes.
   iv. If any of these steps are bypassed, and radiography cannot be utilized to verify the joint integrity, then the joint will be rejected outright and it will be replaced at the Contractor’s expense. The replacement joint will be subject to the same testing requirements.
   v. All initial testing will be funded by the University through the project funds.
   vi. All repairs and re-examination of repaired welds will be at the Contractors expense.

4. Welder qualifications:
   a. Each welder and welding operator must qualify by passing the required procedure test before performing any project welds. Submit a copy of the manufacturer's record of welder or welding operator qualification tests as required by Section IX of the ASME Boiler and Pressure Vessel Code for all welding procedures to be performed by the welding operator.
   b. Qualification tests for each welder shall be the responsibility of the Contractor. Welder qualifications must be current. If qualification test is more than 6 months old, provide record of welding continuity for each welder.
   c. Record of welding continuity is intended to show that welder has performed welding at least every 6 months since the date that welder qualification test was passed for the submitted welding procedure specification.
   d. Record of welding continuity shall include, at a minimum, the following:
      i. Welder's employer name and address
      ii. Date welder qualification test was passed
      iii. Dates indicating welding continuity

   e. Welders shall be qualified as required by B31.1, as applicable. In addition, there shall be an independent witness of welder tests. That witness shall be a representative of an independent testing laboratory, or the UBO's/Engineer's Inspector, or a consultant approved by American Welding Society Certified Welding Inspector.
   f. Test segment shall be 2″ nominal pipe size with wall thickness within range of WPS for each pipe material specified in this Section. Test position shall be arranged in “6G position.” In addition to above test requirement, welding operator shall perform test on coupons which qualify for all piping sizes and wall thickness used on this project.
   g. Engineer reserves the right to test work of any welder employed on project, at Contractor's expense. If the work of the welder is found to be unsatisfactory, the welder shall be prevented from doing further welding on project.
5. Weld record:
   For all welding within the scope of ASME B31.1 Power Piping, submit to Engineer for approval and administrative procedure for recording, locating, monitoring, and maintaining the quality of all welds to be performed on the project. This quality control document record shall include but not be limited to: drawings and schedules identifying location of each weld by individual number, identification of welder who performed each weld by individual welder's name, stamp number, date, and WPS used.
6. Pipe certification:
   a. Certification is required for all pipe within the scope of ANSI/ASME B31.1. Submit certification papers, as outlined below, within 30 days of delivery of pipe to project site.
   b. Type E or S pipe: Furnish manufacturer's mill certificates (material test report) including dimensions, heat numbers, chemical analysis and tensile test results for pipe shipped to project site.

4.8.11.2 Products

1. High pressure steam (HPS) in manholes and/or tunnels
   a. Pipe 2″ and smaller:
      i. Pipe – ASTM A53B or ASTM A106B, Type S, black steel, seamless, Schedule 80.
      ii. Fittings – ASTM Al05/ANSI B16.11, 3000 lb. forged steel, socket weld.
      iii. Flanges – Class 300, refer to unions and flanges in this section.

b. Pipe 2-1/2" and larger:
    i. Pipe – ASTM A53B or ASTM A106B, Grade B, Type E or S, black steel, ERW or seamless, Schedule 40.
    ii. Fittings – ASTM A234 Grade WPB/ANSI B16.9, Schedule Standard, seamless, carbon steel butt weld fittings.
    iii. Flanges – Class 300, refer to unions and flanges in this section.

2. Condensate (CPD), high pressure condensate (HPC), and high pressure return (HPR) in manholes and/or tunnels
    a. Pipe 2" and smaller:
        i. Pipe – ASTM A53B or ASTM A106B, Type S, black steel, seamless, Schedule 80.
        ii. Fittings – ASTM A105/ANSI B16.11, Grade 2, 3000 lb. forged steel, socket weld.
    b. Pipe 2-1/2" and larger:
        i. Pipe – ASTM A53B or ASTM A106B, Grade B, Type E or S, black steel, ERW or seamless, Schedule 80. Extra heavy is not allowed.
        ii. Fittings – ASTM A234 Grade WPB/ANSI B16.9, Schedule 80, seamless, carbon steel butt weld fittings. Standard weight or extra heavy is not allowed.
        iii. Flanges – Class 150, refer to unions and flanges in this section.
3. HPS, CPD, and HPR for direct-bury underground
    Direct-bury underground steam pipe shall only be used for laterals from the steam main to serve a single building. Direct-bury steam pipe shall not be used for steam mains. Direct-bury underground steam pipe shall not be used in any circumstance when crossing an active roadway.
    a. General:
        i. All underground steam and condensate shall be engineered drainable, dryable type. Contractor fabricated piping and fittings are not allowed. No metal components shall be exposed to earth.
        ii. The high-pressure piping design shall be based on 125 PSIG superheated steam at 600 °F. The condensate piping line shall be based on 125 PSIG at 250 °F.
        iii. All straight sections, fittings, anchors and other accessories shall be factory prefabricated to job dimensions, and designed to minimize the number of field welds. The design shall be computer analyzed by the piping system manufacturer to determine stresses and movements of the service pipe and to ensure that the system design is in strict conformance with ANSI B31.1 latest edition, and

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

stamped by a registered professional engineer licensed in the state of Virginia. The analysis shall include piping and structures inside the manholes.

iv. For projects with direct-buried underground piping the piping manufacturer shall provide on-site technical assistance during installation of the piping for the minimum days stated below. The factory representative shall be a factory trained technician to witness requirements outlined in the installation portion of this standard.
   1. Projects with less than 100 linear feet of piping – minimum of 5 days
   2. Projects with 100 linear feet or more of piping – minimum of 15 days

v. All underground piping shall have a #12 AWG solid copper tracer wire attached to pipes and extended into vaults, tunnels, or manholes.

b. Pipe support guides:
   i. Piping shall be spaced and supported at a maximum of 10-foot intervals in conduit by insulating support-guides and to permit pipe to expand and contract freely without stress or wear on pipe or insulation as well as provide for drainage and free air circulation.
   ii. All sleeve type expansion joints shall employ piping guides to insure proper pipe alignment.

c. Expansion loops, moment guided, ells, and tees.
   i. Prefabricated ells, loops, and tees to be provided shall consist of pipe, insulation, and conduit conforming to the same pipe and welding specifications as specified before herein for straight runs. Tees, anchors, elbows and other fittings shall be factory connected and prefabricated to straight sections whenever shipping requirements permit. All fittings shall be designed with adequate space to account for pipe expansion.
   ii. Expansion loops to be of proper design in accordance with stress limits indicated by ASME Code for pressure piping, District Heating Section. Install loop piping in conduit suitably oversized to accommodate the calculated pipe expansion without damaging the insulation.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

iii. The piping system may be designed with both expansion loops and expansion joints. The piping system shall be designed to accommodate each type of expansion system by including moment guides as required for the piping system to function properly in conjunction with expansion joints.

iv. Cold springing or pre-stressing piping as a means for control of expansion in any portion of the steam system is not allowed.

d. Anchors:

i. All anchors on the steam line shall be designed to thermally isolate the carrier pipe from the anchor plate based on design conditions, to insure interface temperature on anchor plate to 200 °F. All steel anchor plates shall be isolated from the soil with a double layer of high ratio shrink wrap capable of withstanding 200 °F. temperature. The pre-engineered pipe manufacture shall submit design engineering calculations with submittal on temperature interface. All anchor plate thickness shall be designed to accommodate the thermal expansion forces based on the design conditions. The new piping system may be designed with a combination of both expansion loops and expansion joints. Each anchor shall be designed to withstand the forces imposed by either means of expansion control.

ii. Concrete block to be cast over plate and conduit and to be large enough for firm anchorage into undisturbed trench sidewalls and/or bottom. Concrete block to be at least 36″ in length and extend minimum of 12″ beyond entire anchor plate. The piping vendor shall provide detailed instructions to Contractor for oversized anchors due to expansion joints. The Contractor shall provide oversized anchors as detailed by the piping vendor.

e. End seals and gland seals:

i. Terminal ends of conduits inside manholes shall be equipped with end seals consisting of steel bulk head plate welded to pipe and conduit. Where there is no anchor within 5′-0″ of terminal end, conduits shall be equipped with gland seals to end of conduit. End seals or gland seals to be equipped with drain and vent consisting of packed stuffing box and gland follower mounted on steel plate welded to end of conduit. Ends seals or gland seals to be equipped with drain and vent openings located diametrically opposite on vertical centerline of mounting plane and to be shipped to job site with plugs in place. Terminate conduits 4″ beyond inside face of manhole or building walls to protect any exposed piping insulation from damp-wall condensation.

ii. All end and gland seals shall be reinforced with 24″ long galvanized steel sleeve at the sealing surface to prevent compression of the outer jacket and insulation from modular wall sealing devices. The protection sleeve shall be minimum 6-gauge thickness and shall be outside of the HDPE jacket. Where the galvanized steel sleeve stops on the outside of the manhole, the sleeve shall be shrink wrapped to the HDPE jacket and sealed water tight.

iii. All end seals and gland seals inside manholes, shall be thermally isolated based on design conditions to ensure that the outer steel conduit is maintained below 200 °F. The pre-insulated pipe manufacturer shall submit engineering design calculations on the temperature interface at the terminations.

f. Field joints:
All field joints shall consist of field installed mineral wool insulation banded with stainless steel bands on the carrier pipe, field applied 10-gauge connector sleeve on the inner conduit, field applied foam insulation, polyethylene heat shrink wrap and split HDPE jacket at a minimum. All field joint materials and methods shall be provided by and approved by the piping manufacturer.

g. Service pipe (steam carrier pipe):
Internal piping for all pipe sizes shall be ASTM A106B, Schedule Standard, Type S, seamless, carbon steel. All joints shall be butt-welded. Straight sections shall be supplied in 40-foot or random lengths with 6″ of piping exposed at each end for field joint fabrication where possible. Fittings shall be ASTM A234 Grade WPB/ANSI B16.9, Schedule Standard, seamless, carbon steel butt weld fittings.

h. Service pipe (condensate carrier pipe):
Internal piping for all pipe sizes shall be ASTM A106B, Schedule 80, Type S, seamless, carbon steel. All joints shall be butt-welded. Straight sections shall be supplied in 40-foot sections or random lengths with 6″ of piping exposed at each end for field joint fabrication where possible. Fittings shall be ASTM A234 Grade WPB/ANSI B16.9, Schedule 80, seamless, carbon steel butt weld fittings.

i. Service pipe insulation:
Insulation shall be mineral wool insulation fabricated in half or V-Groove insulation sections. The insulation shall be secured to the pipe by stainless steel bands. Insulation thickness shall be as specified herein with a thermal conductivity of not more than 0.33 at 200 °F mean temperature. The insulation shall be installed such that joints are staggered preventing a continuous joint between the carrier pipe and the inner conduit.

j. Inner conduit:
Use 10 gauge for conduits 26 inches and smaller and use 6 gauge for conduits above 26 inches. All conduit shall be either electric resistance welded pipe conforming to ASTM A-135 or electric fusion welded pipe conforming to ASTM A-139. Conduit shall be finished in prime coat finish. Where field welds and connections are made, Contractor shall field install prime coat finish.

k. Inner conduit insulation and outer jacket:
   i. Conduit insulation shall be factory-applied polyurethane foam, having density of 2.0 to 3.0 pounds per cubic foot for all straight lengths and fittings. The insulation thickness shall be 1″ minimum. The urethane foam shall meet ASTM C591 with the following minimum characteristic K factor equal to 0.14, density of 2 pounds per cubic foot and a closed cell content of 90% to 95%.
   ii. The outer jacket shall be HDPE with a minimum wall thickness of 150 mil.

l. System description:
   i. The underground conduit system shall consist of the following at a minimum:

Table 4-11. Underground Conduit System Minimums

Carrier Pipe	Insulation (Mineral Wool)	Nominal Outer Conduit
12″ HPS	4.5″	26″
8″ CPD	1.5″	14″
1″ HPR	1.0″	6″

   ii. All piping inner conduit shall be insulated with 0.75″ polyurethane foam insulation with HDPE outer jacket as specified above.

m. Manufacturer: Rovanco Piping Systems model Insul 800, Thermacor Process Inc. model Duo-Therm 505, or PERMA-PIPE model MULTI-THERM 500.

4. Unions and Flanges
    a. Unions: 2″ and smaller: Forged steel, ASTM A106 Grade 2, ASME B16.11, socket weld, 3000 lb. WOG with steel to steel seats.
    b. Flanges:
        i. 2″ and larger: ASTM A105, ANSI B16.5, hot forged steel, welding neck pattern. Slip-on patterns are not allowed. Bore dimension of welding neck flange shall match inside diameter of connected pipe.
        ii. Use raised face flanges for mating with other raised face flanges with self-centering flat ring gaskets. Use flat face for mating other flat face flanges with full face gaskets.
        iii. Flange pressure class indicated in respective piping service is minimum required. Mating flange pressure class shall match pressure class of device connected to such as valves and piping specialties.
    c. Flange gaskets:
        i. Gasket material to be asbestos free and suitable for pressure temperatures and fluid of piping system. Non-metallic gaskets shall be in accordance with ANSI/ASME B16.21 and ASTM F104. Unless otherwise indicated or recommended by manufacturer, gaskets shall be 1/16-inch thick.
        ii. Service temperature (250 °F thru 800 °F) – Basis of design is Flexitallic Style CG, Flexible graphite filler, 304 SS winding, carbon steel centering ring, and 0.175-inch thick. Acceptable manufacturers are Flexitallic, Garlock, and Lamas.
    d. Bolting:
        i. Bolts, bolt studs, nuts and washers shall have zinc plated finish. All bolts, bolt studs, nuts and washers in contact with soil shall be stainless steel.
        ii. Thread shall be in accordance with ANSI/ASME B1.1, Class 2A tolerance for external threads and Class 2B tolerance for internal threads. Threads shall be coarse-thread series except that alloy steel bolting 1-1/8″ and larger in diameter shall be 8 pitch thread series.
        iii. Threaded rods are not allowed as fastening elements.
        iv. For all service temperatures, use alloy steel bolts or stud bolts conforming to ASTM A193, Grade B7 or B16, with nuts conforming to ASTM A194, Grade 2H.

v. No stainless steel bolts to be used for above ground steam applications.

4.8.11.3 Execution

1. General
   a. Remove foreign materials before erection. Ream ends of piping to remove burrs.
   b. Install piping parallel to existing tunnel or new manhole walls and at such locations as to not obstruct access or egress. Install piping to allow adequate service space for equipment and piping specialties. Install vertical piping plumb. Where interferences develop in field, offset or reroute piping as required to clear such interferences. In all cases, consult drawings for exact location of ladders, or access openings or other details before installing piping.
   c. Provide anchors and expansion loops so that piping may expand and contract without damage to itself, equipment or other structures.
   d. Mitered elbows, welded branch connections, notched tees and “orange peel” reducers are not acceptable. Unless specifically indicated, reducing flanges and reducing bushings are not acceptable.
   e. Unless otherwise indicated, use fittings as specified in DCSM section 4.8.11.2 for elbows, tees, reducers, etc.
   f. Basis of design for fittings shall be Weldolets and Sockolets (as appropriate for outlet size). Weldolets with outlet size 2-1/2 to 4 inches and Sockolets with outlet size 2 inches and smaller may be used for branch takeoff up to one-half diameter of main. Manufactured tees shall be used where a takeoff is greater than 6 inches. Use Sockolets where socket weld fittings are specified. Materials of Weldolets and Sockolets shall match the piping material.
   g. Install drains throughout systems to permit complete drainage of entire system. This includes, but is not limited to, all low points, bases of all risers and at each branch take-off.
   h. Install all valves and piping specialties, including items furnished by others, as specified and/or detailed.
   i. For piping within the scope of ANSI/ASME B31.1 Power Piping, transfer piping material specification and “Heat Number” to each segment of pipe prior to cutting.
   j. Concrete supports shall not be placed behind saddles for taps.

2. Welded Pipe Joints
   a. Inspect pipe and pipe fittings for roundness before they are fit-up or set in place.
   b. Properly clean and prepare pipe base material before fit-up. Verify joint land and bevel.
   c. Preheat pipe base material as required by the welding procedure specification. Temperature of pipe material must be a minimum of 60 °F before welding.
   d. Properly align and adjust joint as required by welding procedure and thickness of material. Verify tolerances after tacking sequencing.
   e. Use weld material diameter as procedurally required for type and thickness of work being done.
   f. Properly store all welding materials.
   g. Clean all tacks before welding out. Remove all slag after each pass by grinding to avoid slag inclusion.
   h. Weld reinforcement shall be in accordance with Chapter V of ANSI/ASME B31.1.
   i. Brush each weld free of rust and paint with rust resistant product that matches piping surface color.
   j. For piping within the scope of ANSI/ASME B31.1, each weld shall be permanently marked by welder performing the weld. Each welder shall sign and date the field welding log record for all welds performed by the welder as indicated in DCSM section 4.8.11.1.
   k. No chill rings shall be allowed.
3. Flanged Joints
   a. Clean flange surfaces and align flange surfaces parallel.
   b. Gaskets shall fit concentrically without modification or centering so compression is equally distributed over entire gasket surface.
   c. Lubricate bolts and run nuts down by hand.
   d. By using a torque wrench and considering the type of lubricant being used, tighten nuts in the proper sequence so the gasket is compressed evenly and to the appropriate torque specified by the bolt manufacturer.
4. HPS, HPC, and HPR
   a. Pitch main downs at 1-1/4″ per 10′-0″ in direction of steam/condensate flow unless noted otherwise. Install drip traps at each rise and at horizontal termination of each steam main. Unless otherwise indicated, use eccentric fittings for changes in horizontal pipe sizes with fittings

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

installed for proper condensate drainage (bottom of pipe straight). Concentric fittings may be used for changes in vertical pipe sizes.

b. For steam branch connection and run outs, use side or top 45-degree connection to main.
c. For condensate branch connection to condensate main, use side or top 45-degree connection to main.
d. For condensate connection from steam main, use bottom connection to main.
e. In the event that the insulation and interior carrier pipe of the pre-engineered direct buried piping is subjected to flooding or is exposed to water, the Contractor shall provide dew point monitoring system, air compressors, desiccant dryers and other materials and equipment required for drying of the piping insulation prior to activation of the steam line. Air injected into the line for drying shall have a dew point of not more than -20 °F. All drying activities shall be approved and directed by the piping manufacturer.

5. Condensate Pumped Discharge (CPD)
   a. Pitch mains down at 1-1/4″ per 10′-0″ in direction of flow unless otherwise noted. In limited space situations and where specifically indicated on drawings, horizontal lines may be run dead level. Where two separate pump discharge mains join together, provide check valve in each line before tee. Provide gate valve between check valve and tee for line isolation in an accessible location.
   b. In the event that the insulation and interior carrier pipe of the pre-engineered direct buried piping is subjected to flooding or is exposed to water, the Contractor shall provide dew point monitoring system, air compressors, desiccant dryers and other materials and equipment required for drying of the piping insulation prior to activation of the condensate line. Air injected into the line for drying shall have a dewpoint of not more than -20 °F. All drying activities shall be approved and directed by the piping manufacturer.
6. Piping System Pressure Tests
   a. Pneumatic testing procedures and safety measures are required per the contract.
   b. Steam systems:
      i. Coordinate pressure tests with the A/E and the VT PM at least 3 working days in advance of its occurrence and conduct tests in presence of the A/E and/or the university representative.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ii. Conduct hydrostatic (hydro) test for carrier piping with test medium of water unless specifically indicated.
iii. Conduct a pneumatic test for the inner conduit with test medium of air unless specifically indicated.
iv. If leaks are found, repair with new materials and repeat test.
v. Pressure tests may be made of isolated portions of piping systems to facilitate general progress of installation. Any revisions made in piping systems require retesting of affected portions of piping systems.
vi. No systems shall be insulated until it has been successfully tested. If required for additional pressure load under test, provide temporary restraints at expansion joints or isolate them during test. Minimum test time to be 4 hours plus such additional time as may be necessary to conduct examination for leakage.
vii. No pressure drop shall occur during test period. Any pressure drop during test period indicates leakage.
viii. Provide pumps, appropriately scaled and calibrated, gauges, instruments, test equipment, temporary piping and personnel required for tests and provide removal of test equipment and draining of pipes after tests have been successfully conducted.
ix. For hydrostatic tests, remove air from piping being tested by means of air vents or loosening of flanges. Measure and record test pressure at high point in system. Where test pressure at high point in system causes excessive pressure at low point in system, due to static head, portions of piping system may be isolated and tested separately to avoid undue pressure. However, every portion of the piping system must be tested at the specified minimum test pressure.
x. Pneumatic test for outer casing shall be performed using a medium of dry air using desiccant dryers or nitrogen as recommended by the pipe manufacturer. During the pressure test, each weld on the outer casing shall be soap bubble tested using a water/dishwashing liquid mix. Each joint shall be coated with the mix and visually inspected to insure no leaks.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. Conduct pressure tests with parameters indicated below:

Table 4-12. Pressure Test Parameters

System	Test Pressure	Remark
HPS and CPD Inner conduit	15 PSIG	PNEU
HPS and CPD	225 PSIG	HYDRO

7. Flushing and Cleaning of Steam and Condensate System
   a. Contractor shall visually inspect internal portion of each length of pipe during installation. Remove all dirt and foreign matter prior to installing additional lengths.
   b. Pull a pig through each pipe, max length of pull is 100 feet. This will require leaving the piping open at the ends for access for the pig. TIG weld root passes on piping connections to prevent slag buildup in final connections.
   c. Fill piping with water and conduct the specified hydrostatic pressure testing and completely drain system to system low point(s).
   d. Use a portable pumping apparatus for continuous 24-hour minimum circulation of cold-water detergent. The basis of design for detergent shall be Nalco 2567 cleaner or similar. Flush detergent clear with continuous draining and raw water fill for additional 12 hours or until all cleaner is removed from system. Replace strainers and reconnect all apparatus bypassed.
   e. Sectionalize system to obtain minimum velocity of 4 fps flow velocity or as otherwise recommended by chemical provider. Provide temporary piping to connect dead-end headers at boiler and connection points as necessary. Flush bottoms of risers.
   f. Provide temporary piping or hose to bypass any component, which may be damaged, unless acceptable means of protection are provided and subsequent inspection of hide-out areas takes place.
   g. All cleaning and flushing shall be performed such that all debris will be pulled or flushed downhill.
   h. Contractor shall provide access at all low points through valves, tees, flanges, etc., to facilitate the cleaning and flushing process. If temporary fittings or piping is required it shall be provided by the Contractor and removed by the Contractor after successful cleaning.
   i. After flushing and cleaning is completed, Contractor shall provide necessary pipe and fittings required to complete the piping system. Each

cleaned section of piping shall be capped and protected to keep mud, debris, water, etc., from entering the piping. If a piping section is left open or unprotected, or is found to be contaminated, it shall be re-cleaned prior to being filled and activated at no cost to the University.

j. Contractor shall provide all water for flushing and cleaning. Coordinate rental of fire hydrant meters with the local fire department, or the utility owner.
k. Contractor shall provide all temporary piping from water source to piping system and shall provide means for conducting cleaning water from underground piping system to the appropriate sewer (pumps, piping, hoses, tanks, etc.). Contractor to remove all temporary piping, pumps, hoses, etc., from site immediately after flushing has been completed.

4.8.12 Steam Piping Specialties

1. Pipeline strainer
    a. Manufacturers: Mueller Steam Specialty, Hoffman, Armstrong, Illinois, or approved equal.
    b. Steam and condensate system
        i. Pipe 2 inches and smaller – full pipeline size, “Y” type, Class 300, steel, socket weld ends with removable screen caps. Screen caps to have socket weld blowdown connection.
        ii. Pipe 2-1/2 inches and larger – full pipeline size, “Y” type, Class 300, steel, weld ends. Furnish strainer with bolted screen retainer and off-center socket weld blowdown connection.
        iii. Steam service screens – constructed of Monel with 20 mesh or 1/32″ diameter perforations for sizes through 2 inches, and 3/64″ or 0.045″ diameter perforations for sizes over 2 inches. Net area of screen to be at least 4 times that of connected pipe.
        iv. Installation – Install in the horizontal position, not in the down position.
    c. Provide drain valve at each strainer blowdown connection with hose threaded adapter and cap. Valve size to be same as blowdown connection size.
    d. Install strainers in steam system at inlet to steam traps and pressure reducing valves.
    e. Orient strainers so that full screen flow is achieved and not blocked by condensate accumulation.
    f. Install drain valve in each blow-off connection.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. Steam traps
    a. Manufacturers: Spirax/Sarco, Nicholson (Illinois), Armstrong, Hoffman, or Watson McDaniel.
    b. Trap bodies and trim shall be suitable for pressure classification with which they are used, but not less than 250 PSIG working pressure.
    c. Traps shall have side inlet and side outlet connections to allow for complete maintenance of the trap trim without removing it from the piping system. Traps shall have threaded end connections.
    d. Unless otherwise indicated, size traps as scheduled. Minimum trap size is 3/4″ for all types.
    e. Do not insulate thermostatic traps.
    f. Inverted bucket traps: Cast iron body with renewable cover, stainless steel bucket, and stainless steel valve mechanism assembly.
    g. Install steam traps at locations where end-of-main drips are required. Provide steam main drip/traps at intervals not to exceed 400 feet and anywhere a low spot is created.
    h. Install traps to gravity flow to trap in accordance with trap manufacturer's guidelines.
    i. Unless specifically shown, do not lift condensate from discharge of any trap without written permission of VT PM.
    j. Support traps weighing over 25 pounds independently of connecting piping.
    k. High pressure condensate shall not be put directly into low pressure or pumped condensate lines.
3. Pressure gauges (low pressure steam, high pressure steam, pumped condensate)
    a. Manufacturers: Ashcroft, U.S. Gauge, Marsh, Taylor, Trerice, Marshalltown, or Weiss equal to Trerice 700 Series.
    b. Minimum 4″ diameter, liquid filled, 304 stainless steel case, glass window, bronze tube, brass socket, stainless steel movement, 1-1/4″ NPT connection.
    c. Gauge accuracy shall be 1.0% full scale.

d. Reading range of gauges shall be:

Table 4-13. Gauge Scale Range

Service	Scale Range
Low Pressure Steam	30" mercury vacuum to 30 PSIG
High Pressure Steam	0 to 200 PSIG
Pumped Condensate	0 to 160 PSIG

e. Coil siphons: 1/4-inch or 1/2-inch size, matching gauge pipe size, 1000 PSIG WP. Material shall match gauge pipe material.
f. Gauge piping: All gauge piping shall be Schedule 40 black steel, 3/8-inch minimum size.
g. Gauge valve: Provide gate valves for steam, condensate and pumped condensate. Gauge valves shall be in accordance with the gauge valve detail in the VT Design Standard Detail Library.

4. Expansion devices
   a. Expansion joints (slip type):
      i. Manufacturers: Advanced Thermal Systems Type TP2, ADSCO Type RJ, Yarway Type W, or Hyspan equal to Advanced Thermal Systems Type TP2.
      ii. Slip type expansion joints to permit injection of self-lubricating packing under full line pressure. Internal and external guides to be integral with stuffing box. Provide outward limit stop to prevent disengagement of slip from body in event of main anchor failure.
      iii. Joints to be constructed from A-53 Grade B, schedule 80, seamless carbon steel pipe with 150# flanged end connections. Slip joint to be ground and polished to 16 RMS roughness and then plated with 1 mil of hard chrome applied over 1 mil of crack-free hard chrome. Internal and external guide surfaces in contact with chrome plated slip to have flexible nonmetallic low friction inserts to prevent scoring or binding of slip (metal inserts are not allowed). Guide inserts shall be rated for 600 °F.
      iv. Packing ram cylinders shall be a minimum of 2" diameter having internal acme thread and integral stainless steel shutoff valve. Packing ram cylinders shall be welded to joint, threaded connections are not allowed. Stuffing box shall be fully packed with self-lubricating flake graphite injectable packing and reinforced graphite ring packing. Area of packing in contact with slip to be minimum of 15

times nominal pipe size. Injectable packing shall be asbestos free and rated for 1000 °F.

v. Design joints for working temperature and pressure suitable for application, but not less than 150 PSIG, and continuous operating temperature of 600 °F.
vi. Furnish minimum of 0.80 cubic inches spare injectable packing in plug form for each packing cylinder of each expansion joint.
vii. Provide insulating blankets rated for 550 °F and damp and salt exposure conditions. Blankets shall have inner and outer protective cover and designed to allow for service of the packing cylinders without removal of the blanket. Insulating blankets shall be manufactured by the joint manufacturer. Field made insulation blankets are not allowed.
viii. Expansion joints shall be provided with a minimum 5-year leak free warranty.
ix. Contractor shall be responsible for pre-compressing joints to allow for difference between installation temperature and minimum design temperature.
x. Anchors and guides shall be installed per the project documents and per the manufacturers guidelines prior to conducting piping system pressure tests or putting joints into service. Anchors shall be designed for cracked concrete.

5. Pipeline strainers
   a. Provide drain valve at each strainer blowdown connection with hose threaded adapter and cap. Valve size to be same as blowdown connection size.
   b. Install strainers in steam system at inlet to steam traps and pressure reducing valves.
   c. Orient strainers so that full screen flow is achieved and not blocked by condensate accumulation.
   d. Install drain valve in each blow-off connection.

4.8.13 Steam Distribution Pipe Insulation

1. This section applies to pipe installed in a steam tunnel.
2. Manufacturers: Owens-Coming, Pittsburgh Coming, Schuller International (Manville), Knauf or Manson similar to product indicated except where product of another manufacturer is specifically identified for special type of insulation.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Insulation:
   a. Fire retardant, moisture and mildew resistant, vermin proof, and suitable to receive jackets, adhesives and coatings as indicated.
   b. Glass fiber insulation, where indicated, shall be of inert inorganic material, non-corrosive to mechanical surfaces.
   c. Insulating cement shall have a dry density of no more than 38 lb./cu. ft. and thermal conductivity of 0.63 at 400 °F mean temperature.
   d. Filling and finishing cement shall have a dry density of no more than 24 lb./cu. ft. and thermal conductivity of 0.74 at 500 °F mean temperature.
   e. Type G insulation (cellular glass): 100% cellular glass cells with no organic material, noncombustible, 0.00 perm-inch permeability, 8.5 lb./cu. ft. average density, compression strength l00 psi, and thermal conductivity of not more than 0.36 at 50 °F mean temperature. The basis of design shall be Pittsburgh Corning FOAMGLAS or approved equal.
   f. Type M insulation (mineral wool pipe covering): Mineral fiber pre-molded pipe insulation, in accordance with ASTM C-547, Type ll, Grade A, nominal 8 lb./cu. ft. density, water resistant, non-wicking, suitable for continuous temperature through 1200 °F, thermal conductivity not more than 0.31 at 200 °F and 0.41 at 400 °F mean temperature, Fibrex Coreplus 1200, Roxul1200, or IIG MinWool-1200.
4. Jackets
   a. Jackets puncture resistance based on ASTM-D-781 test methods. Vapor barriers perm ratings based on ASTM E-96 procedure A.
   b. Type A-1 jacket:
      i. Factory fabricated 0.016-inch thick, ASTM B209, Type 3003 embossed aluminum jacket, complete with integral longitudinal Pittsburgh Z-Lock seam.
      ii. Fitting covers to be factory fabricated from not lighter than 0.024-inch thick, Type 3003 aluminum.
   c. Type P-1 jacket: Heavy-duty fire retardant material with glass fiber reinforcing and self-sealing lap. Jacket shall have neat, white Kraft finish suitable for painting, with beach puncture resistance of 50 units minimum. Vapor barrier shall be 0.0005" aluminum foil adhered to inner surface of jacket. Permeance shall not exceed 0.02 perm. Cover jacket with 30# builders felt. Builders felt shall be secured every 18 inches with stainless steel wire or stainless steel bands.

5. Metal bands and wires
    a. Aluminum bands to be 0.5″ × 0.020″ up to 48″ O.D. and 0.75″ × 0.020″ over 48″ O.D.
    b. Stainless steel bands to be 0.5″ × 0.015″.
    c. Stainless steel wires to be 16 gauge.
6. Removable insulating blankets
    a. Custom designed removable, reusable, flexible, blanket thermal insulation system.
    b. Acceptable manufacturers: Thermal Energy Products, Inc., Advanced Thermal Corp., and Remco Technology, Inc.
    c. Removable insulation system shall be custom designed for each individual item to provide close contour fit. Overlapping seams and gaps are not acceptable.
    d. Removable insulation shall be designed to overlap adjoining pipe insulation by 2 inches.
    e. Insulation: Minimum 2″ thick, 2.4 lb./cu. ft. density, 1000 °F thermal insulating wool.
    f. Interior and exterior fabric: 17.5 oz./sq. yd. silicone rubber coated fiberglass cloth.
    g. Securement: Blanket seams shall be closed with buckle and strap assembly (D-ring closure).
    h. Identification tagging: Label each removable insulation device with 304 stainless steel tag with raised letters.
7. Execution

    Applications: Provide insulation and jackets as indicated in the following schedule. The schedule applies to both exposed and concealed applications unless noted otherwise:

Table 4-14. Steam Distribution Pipe Insulation and Jackets

Service	Jacket Type	Insulation Type	Insulation Thickness According to Pipe Size		
			1″ to 2″	3″ to 4″	5″ and Larger
HPS and CPD in Manholes	A-1	G	2-1/2″	3″	3″
HPS in Existing Tunnel	P-1	M	2-1/2″	3″	3″
CPD and HPR in Existing Tunnel	P-1	M	1-1/2″	2″	3″
HPR in Manholes	A-1	G	1-1/2″	-	-
HWS and HWR in Existing Tunnel	P-1	M	N/A	1-1/2″	2″

8. Installation – General
    a. Install all products with good workmanship, with smooth and even surfaces. Use full length factory furnished material where possible. Does not use scrap piecing.
    b. Apply insulation only on clean, dry surfaces, after all rust and scale have been removed and testing of systems has been completed. Do not insulate any section of system which must be pressure tested until after it has been successfully tested. Any removal and reinstallation to correct system defects, prior to end of guarantee period shall be accomplished at no expense to University.
    c. Install insulating materials with necessary joints and terminations, to permit easy access and removal of equipment sections where inspection or frequent service or repair is required, and to allow for expansion.
    d. Provide beveled terminations at all name plates and un-insulated fittings.
    e. Make longitudinal joints in jackets, where possible, facing toward wall or ceiling.
    f. Apply insulation to each pipe individually. Common insulation applied for adjacent pipes will not be accepted.
    g. Unless otherwise indicated, pipe insulation shall be continuous through not-rated walls and floors.
9. Type G insulation (cellular glass): Install cellular glass in strict accordance with manufacturer instructions.
10. Type A-1 jacket:
    a. Unless otherwise indicated, install shields (A-1 jacket) around all insulated pipe and fittings within manholes and tunnels. Seal water and vapor tight at terminations.
    b. Longitudinal overlap shall be at least 2″ wide with vapor barrier sealant.
    c. Secure jacketing with 3/4-inch wide, 0.020-inch stainless steel or aluminum strapping and wing seals on maximum 18-inch centers.
11. Piping, valve, and fitting insulation
    a. Install removable insulating jackets on the following devices:
        i. All steam valves 4″ size and larger
        ii. All condensate valves 4″ size and larger.
    b. Apply insulation to pipe, and fittings with butt joints and longitudinal seams closed tightly. Valves and expansion joints shall have removable insulation blankets as specified.
    c. Laps on factory-applied jackets shall be 2″ minimum width firmly cemented with lap adhesive, or be pressure sealing-type lap.

d. Where terminations of pipe insulation are required, insulation shall have tapered ends, built up and finished as specified for fittings.

4.8.14 Electrical Utilities

4.8.14.1 Typical Outdoor Pad Mounted Construction Standards

This standard is for use concerning areas where outdoor pad mounted equipment is acceptable. The following standards will apply for the electrical service installation based upon the size of the service installation.

4.8.14.1.1 Small Size – Electrical Service

1. Defined:
   a. There is one transformer.
   b. There is NOT a secondary connection cabinet.
   c. There are less than 6 secondary conductors per phase.
   d. Secondary conductors are not longer than 125 feet.
2. General-A/E Requirements:
   a. At the pad mounted transformer location, the Virginia Tech Electrical Service (VTES) requires a high voltage primary selective switch. The switch will be an S&C PMH-9 source automatic transfer switch or S&C PMH-9 manual switch depending on building needs. VTES requires 8 feet minimum of working space on the switch and fuse compartment sides and 3 feet of working space on the control sides of the switch. Refer to the drawing of a typical PMH-9 switch pad layout in the VTES details located in the VT Design Standard Detail Library.
   b. VTES requires 8 feet minimum of working space on the front of the transformer. Refer to the drawing of a typical transformer pad layout in the VTES details located in the VT Design Standard Detail Library. Working space provided through gates or double door openings is acceptable to VTES. If working space is through a gate, the gate shall be provided with hasp mechanism for a padlock supplied by VTES. Gates on double doors shall swing clear of working space if access for other personnel, such as generator maintenance, is needed to the area. More than one gate may need to be provided with the appropriate lock/keying for other personnel besides VTES.
   c. Utility metering will be at the transformer location. Metering at a dedicated transformer can be done in the transformer secondary compartment if the installation is six or less 500 MCM copper, (or 600 MCM aluminum), or smaller conductors per phase in the building

service and the conductors must not be longer than 125 feet. This requirement excludes any conductors for site lighting and temporary service referenced below.

d. A/E is responsible for VTES equipment layout, pads, and required clear working space around VTES provided equipment. Crane or line truck access for VTES equipment shall be identified and reserved in VTES equipment layout plan. The maximum equipment weight is based on line truck capabilities. Consult VTES to determine the current equipment capabilities.
e. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S. The permitted site plan shall include the route from the existing primary distribution system to the location of the new service equipment.

3. Contractor Requirements:
   a. If a contractor has been selected and approved by VTES to build the electrical installation, this section describes the requirements for that construction.
   b. The Contractor is responsible for bringing the secondary concrete encased service duct bank and conductors from the building back to the transformer location.
   c. The Contractor is also responsible for the high voltage switch pad and transformer pad, including conduit install per VTES layout drawing. Coordination between the Contractor and VTES is required. Contact VTES for specific pad details, conduit routing, and required sizes.
   d. The transformer and high voltage switch pads shall have a fiberglass box pad installed in conjunction with the concrete pads. The fiberglass pads create a well under the transformer and high voltage switch. The fiberglass box pads will be provided by VTES for contractor installation. Box pads shall be VTES field coordinated with the Contractor during pad construction. The top of the fiberglass box pads shall be level and flush with the top of the concrete pad.
   e. The high voltage switch shall have two ground rods in opposite corners inside the switch well. Refer to the switch pad layout detail in the VTES details located in the VT Design Standard Detail Library.
   f. The transformer pad shall have a ground rod located in the high voltage compartment area. Refer to the transformer pad layout detail in the VTES details located in the VT Design Standard Detail Library.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

g. The Contractor shall provide and install a service to be used to serve future temporary functions or events in the transformer service area. One 2-inch Schedule 40 PVC conduit with service conductors from the transformer's low voltage compartment to a 200-amp fused disconnect shall be provided. The electrical disconnect shall be rated as NEMA 3R for outdoor installations and can be located on a wall or rack. The conduit shall be provided and installed by the Contractor. Conduit shall be capped to prevent debris from entering conduit until electrical install has been completed.
h. The Contractor is responsible for all conduits used with metering and SCADA related to installations particularly at the transformer and switch pads. See conduit requirements and drawings in the VTES details located in the VT Design Standard Detail Library. Consult VTES with any questions on specific requirements.
i. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts. All conduits shall have caps placed on the conduits, but not glued, prior to pouring concrete. Conduits shall be free of foreign objects including gravel and concrete. VTES may require a validation of clean conduit through the use of pulling a mandrel through the conduit as needed. Pull strings shall be installed in conduits.
j. The Contractor shall be responsible for all hardscape and landscaping remediation along the primary duct bank path.
k. The Contractor is responsible for all installation and usage charges for temporary power associated with the project. Estimates are provided per each request.
l. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S. The permitted site shall include the route from the existing primary distribution system to the location of the new service equipment.

4. VTES Requirements:
   a. All primary work, primary conductors, primary duct bank, high voltage switch, transformer, and metering are normally provided and installed by VTES and shall be paid for by the project. See DCSM section 4.8.14.5 for more information.
   b. Termination of the contractor-installed secondary feeder conductors on the transformer will be completed by VTES. The Contractor shall

install the secondary cables and VTES will terminate the cables at the transformer's secondary compartment.

4.8.14.1.2 Large Size – Electrical Service

1. Defined:
    a. At least one transformer.
    b. At least one secondary connection cabinet.
    c. There are more than 6 secondary conductors per phase.
    d. Secondary conductors may be longer than 125 feet.
2. General-A/E Requirements:
    a. At the pad mounted transformer location, VTES requires a high voltage primary selective switch. The basis of design for transfer switches shall be S&C Electric Company products. The switch will be an S&C PMH-9 source automatic transfer switch or S&C PMH-9 manual switch depending on the building needs. VTES requires 8 feet minimum of working space on the switch and fuse compartment sides and 3 feet of working space on the control sides of the switch. Refer to the drawing of a typical PMH-9 switch pad layout in the VTES details located in the VT Design Standard Detail Library. An S&C Vista switch is an acceptable alternative. Vista switches may require venting. Consult with VTES prior to installation.
    b. VTES also requires 8 feet minimum of working space on the front of the transformer. Working space provided through gates or double door openings is acceptable to VTES. If working space is through a gate, the gate shall be provided with a hasp mechanism for a padlock supplied by VTES. Gates on double doors shall swing clear of working space if access for other personnel, such as generator maintenance, is needed to the area. More than one gate may need to be provided with the appropriate lock/keying for other personnel besides VTES.
    c. Secondary connection and metering cabinets located adjacent to the transformer are needed if there are multiple metered services provided from the transformer. If a service requires more than 6 conductors per phase, (excludes site lighting service and temporary service conductors) then secondary connection and metering cabinets are also needed. The secondary connection cabinet is 42″ W × 42″ D × 53″ H. Metering will be installed at or near this secondary cabinet location. VTES requires 5-1/2 feet of working space on the two sides of the cabinet that has doors. Refer to the typical

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

layout drawings in the VTES details located in the VT Design Standard Detail Library.

d. A/E is responsible for VTES equipment layout, pads, and required clear working space around VTES provided equipment. Crane access for VTES equipment shall be identified and reserved in the VTES equipment layout plan.
e. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S and shall be the responsibility of the project. The permitted site plan shall include the route from the existing primary distribution system to the location of the new service equipment.

3. Contractor Requirements:
    a. The Contractor is responsible for bringing the secondary concrete encased service duct bank and conductors from the building back to the secondary connection cabinet location.
    b. Should site logistics or other concerns cause the project team to desire the Contractor to perform portions of the primary duct bank installation work, VTES will entertain this option.
    c. The Contractor is responsible for the high voltage switch pad, transformer pad, and secondary connection cabinet pad. Coordination between the Contractor and VTES is required. Contact VTES for specific pad details.
    d. The transformer, secondary connection cabinet, and high voltage switch pads shall have a fiberglass box pad installed in conjunction with the concrete pads. The fiberglass pads create a well under the transformer, secondary connection cabinet, and high voltage switch. The fiberglass box pads will be provided by VTES for contractor installation. Box pads shall be VTES field coordinated with the Contractor during pad construction. The top of the fiberglass box pads shall be level with the top of the concrete pads.
    e. The transformer pad shall have a ground rod located in the high voltage compartment area. Refer to the drawing of typical transformer pad layout in the VTES details located in the VT Design Standard Detail Library.
    f. The secondary connection cabinet pad shall have a ground rod located inside the cabinet area. Refer to the drawing of typical pad layout in the VTES details located in the VT Design Standard Detail Library.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

g. The high voltage switch shall have two ground rods in opposite corners inside the switch.
h. The Contractor shall provide and install a service to be used to serve future temporary functions or events in the transformer service area. One 2-inch Schedule 40 PVC conduit with service conductors from the transformer's low voltage compartment to a 200-amp fused disconnect shall be provided. The electrical disconnect shall be rated as NEMA 3R for outdoor installations and can be located on a wall or rack. The conduit shall be provided and installed by the Contractor. Conduit shall be capped to prevent debris from entering conduit until electrical install has been completed.
i. The Contractor is responsible for all conduits for metering and SCADA in the transformer and switch pads. See conduit requirements in the VTES details located in the VT Design Standard Detail Library.
j. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts. All conduits shall have caps placed on the conduits, but not glued, prior to pouring concrete. Caps prevent debris from entering the conduits. All conduits shall also have pull strings attached.
k. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts.
l. The Contractor shall be responsible for all hardscape and landscaping remediation along the primary duct bank path.
m. The Contractor is responsible for all installation and usage charges for temporary power associated with the project.
n. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S. The permitted site shall include the route from the existing primary distribution system to the location of the new service equipment.

4. VTES Requirements:
   a. All primary feeder work, primary conductors, primary duct bank, high voltage switch, transformer, metering, and secondary connection cabinet are normally provided by VTES and paid for by the project.
   b. VTES will provide conductors from the transformer to the secondary connection cabinet and terminate the secondary conductors on the utility transformer end and all conductors in the secondary connection cabinet.

   c. All metering equipment including the meter, current transformers (CTs), and potential transformers (PTs) will be provided and installed by VTES.
5. Conduit Requirements for Pad Mounted Service Transformer, Related Metering, and SCADA:
   a. The Contractor shall provide one 1-1/2-inch Schedule 40 PVC conduit from the transformer secondary compartment, (or secondary connection cabinet if used), to the meter location for metering. The meter location shall be within 30 conduit feet of the transformer, (or secondary connection cabinet if used), the motor location must be readily accessible to the transformer and secondary cabinet to facilitate testing. The meter can be wall or rack mounted. For 480-volt services, the PTs will be mounted in an aluminum 24″ L × 24″ W × 10″ D and NEMA 3R rated junction box under the meter.
   b. The Contractor shall provide one 1-inch Schedule 40 PVC conduit from the high voltage switch to the meter location for SCADA controls. For an automatic source transfer switch this shall be from the control compartment. For a manual switch this shall turn up just outside one of the fuse compartments with a second conduit stubbed into the switch well. Utilize a NEMA 3R junction box to join the two conduits into a complete raceway. Refer to the drawing of typical pad layout in the VTES details located in the VT Design Standard Detail Library.
   c. If a lighting pedestal/control is installed, one 1-inch conduit shall be extended from the SCADA location to the lighting pedestal. Refer to the drawing of typical pad layout in the VTES details located in the VT Design Standard Detail Library.
   d. The primary duct bank installed by VTES will have one 2-inch conduit for SCADA communication that will extend to the meter location.
   e. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts. All conduits will be capped but the cap will not be glued prior to pouring concrete.
6. Exceptions for Outdoor Pad Mounted Construction Standards for Small Scope Projects
   a. New small services including but not limited to traffic lights and steam tunnel service as well as services installed in farm areas and

services installed from existing transformers must be coordinated with VTES.

b. Concrete pads for the high voltage switch and transformer shall be installed by VTES or the Contractor depending on the scope of the project.
c. All 3-phase services up to 200 amps and 240-volt single phase service up to 400 amps will be metered with socket-based meters.
d. PTs and CTs are required for all 480-volt services. Metering shall be located near the transformer or near the load.
e. Depending on the scope of the project, VTES or the Contractor may provide and install service conduit and conductors.
f. If VTES determines that concrete encased secondary duct bank from the transformer to the service entrance equipment is required, then it shall be provided and installed by the Contractor.
g. If a switch or transformer is required, VTES requires 8 feet minimum of working space on the switch compartment sides of this switch, 8 feet minimum on the fuse compartment sides and 3 feet of working space on the control sides. VTES requires 8 feet minimum of working space on the front of the transformer. Refer to the drawing of typical transformer pad layout in the VTES details located in the VT Design Standard Detail Library. Working space provided through gates or double door openings is acceptable to VTES. If working space is through a gate, the gate shall be provided with hasp mechanism for a padlock supplied by VTES. If access for other personnel is needed to the area, such as generator maintenance, provide another gate with appropriate lock and keying.

4.8.14.2 Outdoor Below Ground Vault Construction Standards

If an outdoor below ground vault is provided, the requirements and installation will be similar to the pad mount standards with the following additions.

1. General-A/E Requirements
    a. The bottom of the vault must be above the floodplain.
    b. There shall be a low point well and sump pump with associated drain piping, power, and float controls. Sump pump shall be wired to an emergency circuit.
    c. Access at grade level, if the vault is built into a bank with a door through the wall, or a stairwell is preferred.

d. If ladder access is required then a safety railing around the entrance is required. If the top of the ladder is flush with grade, engineered hand holds or retractable ladder extensions are required.
e. Natural or mechanical ventilation shall be provided to maintain a 40 °C maximum ambient for the equipment. If access is via ladder, mechanical ventilation will be required with local control at the point of entry.
f. A minimum of one light shall be on the building emergency circuit with a switch at the point of entry. If there is minimal natural lighting available when the door is closed then lighting shall be provided to meet the NEC.
g. Metering shall be wall mounted.
h. Provisions shall be made for a 48″ H × 36″ W × 12″ D clear wall space for mounting VTES-supplied SCADA and metering equipment. We require a minimum of a 36-inch clear working space in front of the SCADA and metering equipment, for a total of 48-inch depth space from wall.

2. Contractor Requirements
   a. At least two ground rods shall be installed in opposite corners of the vault.
   b. Construction of vault will be by the Contractor and shall include conduits for metering, SCADA, lighting, 120-volt receptacle, and sump pump circuit.
   c. VTES requires at least one receptacle to be fed from the building emergency circuit in the SCADA/meter area. If the building emergency circuit is not available, a normal power fed receptacle is acceptable. Label the receptacle and identify the source of power.
   d. VTES must approve drawings for any outdoor below grade vaults prior to construction. Consult with VTES as needed.

4.8.14.3 Indoor Vault Construction Standards

For areas where the transformer will be located in the building the following sections will apply for the electric service installation.

4.8.14.3.1 Manhole and Duct Bank

1. General-A/E Requirements
   a. All duct banks shall be inspected by VTES before the Contractor pours concrete.
   b. The concrete encased duct bank will contain four 5- or 6-inch conduits for the primary. Please note that older legacy duct bank connections may require four 4-inch conduits. However, 5- or 6-inch conduits are typically preferred. Refer to the drawing of a typical duct bank layout

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

in the VTES details located in the VT Design Standard Detail Library. Consult with VTES to determine the proper size for the installation location. The conduits will extend from the manhole to the appropriate compartments of the high voltage switch.

c. A secondary duct bank will contain two 6-inch conduits. The ducts shall extend from the manhole to an area outside but adjacent to the low voltage compartment of the transformer. Refer to the drawing of a typical duct bank layout in the VTES details located in the VT Design Standard Detail Library.
d. The Contractor shall provide and install a minimum 8 ft. by 8 ft. by 6-1/2 ft. high (inside dimensions) manhole within 10 feet of the outside of the building. Refer to the drawing of a typical manhole layout in the VTES details located in the VT Design Standard Detail Library.
e. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S. The permitted site shall include the route from the existing primary distribution system to the location of the new service equipment.

2. Contractor Requirements
   a. VTES will typically build all concrete encased duct bank for the primary cables. However, in cases where VTES has authorized a Contractor to build concrete encased duct bank, the following requirements shall be achieved. All duct bank construction must be approved by VTES prior to any build activities through the use of complete drawings supplied by the Contractor and/or A/E firm. In such cases, the following general requirements would need to be met. Other requirements may also be noted after the drawing review. Refer to the drawing of a typical duct bank layout in the VTES details located in the VT Design Standard Detail Library.
   b. The Contractor shall provide and install a minimum 8 ft. by 8 ft. by 6-1/2 ft. high (inside dimensions) manhole within 10 feet of the outside of the building per VTES standards.
   c. The Contractor shall provide and install a concrete encased duct bank from the manhole into the room, (vault), in the building containing the high voltage switch and transformer.
   d. VTES is responsible for installation of the primary cable and termination on the transformer and on the load break elbows in the manhole. If a Contractor has been authorized to install cabling, VTES

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

power line worker(s) must be present during the installation. Consult with VTES prior to construction.

e. The concrete encased duct bank will contain four 5- or 6-inch conduits for primary as determined by VTES. The conduits will extend from the manhole to the appropriate compartments of the high voltage switch.
f. The duct bank will also contain one 2-inch conduit for SCADA communications that will extend from the manhole to the SCADA cabinet.
g. The secondary duct bank shall also contain ducts of the size and number needed for a conductor equivalent to the building secondary service size. These ducts will extend from the manhole to an area outside but adjacent to the low voltage compartment of the transformer.
h. There shall also be one 2-inch duct from the manhole to a temporary service disconnect (see DCSM section 4.8.14.3.6).
i. All ducts shall have pull strings installed.
j. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts. All conduits shall be capped, but not glued prior to pouring concrete.
k. All duct banks shall be inspected by VTES before the Contractor pours concrete. All conduits must be free of foreign objects. VTES may require and specify a mandrel pull to be witnessed by VTES personnel to avoid foreign objects in the conduit.
l. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S. The permitted site shall include the route from the existing primary distribution system to the location of the new service equipment.

3. VTES Requirements:
   a. VTES will provide duct bank and primary conductors to the manhole outside the building.
   b. The manhole must have a ground installed in opposing corners of the manhole per VTES standards. Refer to the drawing of a typical manhole layout in the VTES details located in the VT Design Standard Detail Library.
   c. VTES will provide load break junction points in the manhole. A four-way junction is the minimum requirement. Larger junctions may be required, consult with VTES.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

d. VTES will also require cable racking per VTES standards. Consult with VTES for further details.
e. VTES will also provide and install the utility metering as further described below. See DCSM section 4.8.14.5 for more information.

4.8.14.3.2 Vault

A vault shall be provided and is the responsibility of the Contractor as part of the project:

1. Sufficient site to accommodate medium voltage switch, transformer, metering, SCADA equipment, and associated clear working space.
2. Ventilation sufficient to maintain a maximum 40 °C temperature on a day with maximum 30 °C outdoor temperature while the transformer is operating at full FA loading. Ventilation controls shall be at the point of personnel entry and fed from the building emergency circuit.
3. A minimum of one light shall be on the building emergency circuit. The light switch shall be at the point of entry.
4. At least one receptacle in the SCADA/meter area shall be on the building emergency circuit.
5. The basis of design for keyed access from the exterior of the building shall be Best Lock. VTES Best Lock is preferred because VTES personnel will not have building keys. Consult with VTES and the VT key shop on the lock series.
6. VTES requires an 8-foot minimum working space in front of the switch and transformer compartments that contain high voltage terminations or that would have exposed live parts when doors are open. VTES will accept a portion of this working space being available through double doors or rollup doors in the vault wall. Refer to the drawing of typical switch and transformer pad layouts in the VTES details located in the VT Design Standard Detail Library.

4.8.14.3.3 Medium Voltage Switch Requirements

The medium voltage switch shall meet the following specifications:

General-A/E Requirements

1. The switch shall be a utility grade switch with visible break. Vacuum circuit breakers that require racking out to witness the visible break are not acceptable. Commercial grade medium voltage interrupter switches meeting IEEE C37.22 are not acceptable due to the limitations of mechanical and electrical endurance capabilities.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. The medium voltage switch shall be a primary selective switch. Manual or automatic operation of the switch will depend on the needs and requirements of the building.
3. Preferred switching shall be an air insulated load break style switch.
4. Transformer protection provided by this switch shall be fusing or vacuum interrupters. The basis of design for fusing shall be S&C SMU-20 power fuses or McGraw Edison type NX current limiting fuses with clip mounting, (mounting code 5 up to 30 amps, mounting code 6 for 50 through 100 amps), to match fusing stocked by VTES. Type NX fusing may also be used on transformers up to and including 1500 kVA. Vacuum interrupters shall have TCC curves which simulate these fuses.
5. Source-transfer switches driven by stored-energy operators are preferred.
6. Switches shall have de-couplers to permit exercising of the switch operators without affecting the positions of the switches.
7. One 24 VDC rated auxiliary contact to indicate the position of each switch shall be provided.
8. An empty 2-inch conduit from the compartment containing the terminal connection for the auxiliary contacts shall be extended to the SCADA/meter area and into the SCADA cabinet.
9. All medium voltage switch compartments shall have a ground rod installed in the equipment pad.
10. For automatic source transfer switches, the transfer from one source to the other shall be accomplished in no more than 10 cycles plus any relay time delay for coordination. The transfer control shall be totally self-contained for programmed control of all switching functions associated with the automatic source transfer. Voltage sensors for sensing and control power shall be integral to the switchgear. The transfer control shall contain a “ready” indicator and corresponding auxiliary contact indicating that all controls and switches are ready for a transfer if a loss of source was sensed by the control.
11. The basis of design for source transfer switches and source transfer controls shall be S&C Electric Company products. For automatic operation, the switch shall be an S&C PMH-9 source transfer switch. Source transfer controls shall be S&C Micro-AT source transfer control. For manual operation, the switch shall be an S&C PMH-9 switch. An S&C Vista switch is an acceptable alternative. Vista switches may require venting. Consult with VTES prior to installation.

12. VTES requires 8 feet minimum of working space on the switch compartment sides of this switch and 3 feet of working space on the control sides. Working space provided through double door openings is acceptable to VTES. Refer to the drawing of a typical switch pad layout in the VTES details located in the VT Design Standard Detail Library.

4.8.14.3.4 Indoor Building Transformer Requirements

The building transformer will be a dry-type vacuum pressure impregnated (VPI) or a cast coil transformer with the following specifications:

General-A/E Requirements

1. Applicable standards: IEEE/ANSI C57.12.01, IEEE/ANSI C57.12.50, IEEE/ANSI C57.12.91
2. The transformer shall be UL listed
3. kVA rating and FA rating shall equal the building service size needs
4. Frequency: 60 Hz
5. Impedance: 5.75%
6. Windings: Aluminum or copper
7. Primary voltage: 12.47 kV
8. Primary taps: Two 2.5% FCAN and two 2.5% FCBN
9. Primary connection: Delta
10. Primary termination: Air terminal chamber, (Standard ANSI Segment 2, or Segment 1 or 3 acceptable), for cable termination. Close coupling with the primary switch is not acceptable.
11. Secondary voltage: 208 or 480 (as needed)
12. Secondary connection: Grounded wye
13. Secondary termination: Air terminal chamber, (Standard ANSI Segment 4), for cable termination or close coupled with low voltage switchgear via flexible leads.
14. Application location: Indoor NEMA 1
15. Sound level: Standard
16. Winding temperature rise: 80 °C
17. Insulation system: 220 °C
18. Primary BIL: 95 kV minimum
19. Secondary BIL: 20 kV minimum
20. Forced air rating: AA/FA or AA/FFA
21. Digital three phase temperature monitor for fan control to provide local control and indication of temperatures and alarms with additional alarm output contacts for connection to utility SCADA system.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

22. Surge arrestors: 15 kV distribution class arrestors shall be provided at the transformer high voltage terminals.
23. Provide IEEE/ANSI impulse testing in addition to standard tests.
24. VTES and the VT PM shall be provided with test reports including all standard IEEE/ANSI specified tests, impulse test, and loss evaluation.
25. The transformer pad shall have a ground rod located in the high voltage compartment area.

4.8.14.3.5 Utility Metering and SCADA Requirements

1. Provide utility metering compartment located ahead of the main service overcurrent device. All compartments containing unmetered conductors shall be lockable or sealable.
2. All bus shall be designed to withstand available fault currents.
3. The bus and current transformer mountings shall be designed so that each of the current transformers may be withdrawn from its mounting position directly through the access panel without disturbing any other current transformer or bus.
4. Provide IR type inspection windows in the compartment. Windows shall provide broadband transmission to support short, mid, and long wave IR cameras as well as visual inspections. Position windows so all CTs are visible from at least one window.
5. Provide metering accuracy CTs on all three phases, with polarity clearly marked. CTs shall have a 5-amp secondary and a primary rating equal to 50% of the transformer FA current rating. If this is not a standard CT rating then the next higher standard CT rating shall be used. CTs shall have a minimum rating factor of 2.0 at 30 °C. CT shall have a minimum 0.3B-0.5 accuracy and burden rating. CT shall have a CT manufacturer supplied shorting device as part of the CT. The shorting device shall be covered and capable of being sealed with a seal wire. This shorting terminal shall be accessible when the metering compartment is open. The CT shall be ABB type CLC or equivalent. All CTs that are not ABB shall be evaluated by VTES.
6. Provide CT mounting so rating information is visible from the IR inspection windows.
7. Provide phase to ground metering potentials for all three phases. Metering potentials shall be fused. For 480-volt services, provide metering accuracy PTs from phase to ground on all three phases. PTs shall have a ratio of 288:120 and a thermal rating of 500 VA at 30 °C and

an accuracy rating of 0.3Y. The PTs shall be ABB type PPM or equivalent. All PTs that are not ABB shall be evaluated by VTES.

8. VTES will provide and install the utility meter, meter enclosure, and cabling from the utility metering compartment to the meter. Contractor is to provide a single 1-1/2-inch conduit from the utility metering compartment to the area where the meter is mounted.
9. The meter location shall be within 30 conduit feet of the metering compartment to facilitate testing.
10. Provisions shall be made for clear wall space to accommodate 48″ H × 36″ W × 12″ D VTES-supplied SCADA and metering equipment. VTES requires a minimum of a 36-inch clear working space in front of the SCADA and metering equipment with a total of 48 inches total depth off the wall.
11. SCADA and metering conduits from the outside primary duct bank and from the medium voltage switch will also terminate at the SCADA and metering cabinet location.

4.8.14.3.6 Additional Service for Temporary Functions

The Contractor shall provide and install a service to be used to serve future temporary functions or events outside the building. A 200-amp fused disconnect suitable for use as service equipment, one 2-inch Schedule 40 PVC conduit, and service conductors from the transformer's low voltage compartment to the disconnect shall be provided and installed by the Contractor. Disconnect shall be rated as NEMA 3R, if located outdoors. Duct from the fused disconnect shall extend outside the building to the manhole nearest the building, and marked "VTES". Disconnect shall be labeled "VTES" and the working voltage shall be identified.

4.8.14.4 Primary Service Standards

For areas where the service will be at primary rated voltage, (12.47 kV), the following will apply for the electric service installation, (chiller plants and other similarly large services where a substation circuit is normally dedicated to the service).

4.8.14.4.1 Manhole and Duct Bank

1. General-A/E Requirements and Contractor Requirements
   a. The Contractor shall provide and install a minimum 8 ft. by 8 ft. by 6-1/2 ft. high (inside dimensions) manhole within 10 feet of the outside of the building, for VTES use only. Refer to the drawing of a

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

typical manhole layout in the VTES details located in the VT Design Standard Detail Library.

b. Electrical duct bank shall not be installed under site improvements (stairs, generators, etc.) to the maximum extent practical.
c. The Contractor will provide and install a concrete encased duct bank from the manhole into the 15 kV switchgear in the building.
d. The duct bank will contain at least two 6-inch conduits for primary. They will extend from the manhole to the appropriate compartments of the high voltage switch. Refer to the drawing of a typical duct bank layout in the VTES details located in the VT Design Standard Detail Library.
e. The duct bank will also contain one 2-inch conduit for SCADA communications that will extend from the manhole to the meter location and into the SCADA cabinet.
f. All ducts shall have pull strings installed. All conduits will be capped, but not glued prior to pouring concrete. All ducts shall have documented mandrel pulls completed prior to installing pull strings.
g. Conduits shall be inspected by VTES prior to the Contractor pouring concrete.
h. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S and shall be performed by the Contractor. The permitted site shall include the route from the existing primary distribution system to the location of the new service equipment.

2. VTES Requirements
   a. VTES will provide duct bank from the VTES system to the contractor-installed manhole outside the building.
   b. VTES will provide and terminate primary conductors on the high voltage switchgear.
   c. VTES will also provide and install the utility metering.

4.8.14.4.2 Equipment Room Requirements (Project Responsibility)

General-A/E Requirements and Contractor Requirements
The equipment room shall be provided with the following, and is the responsibility of the project:

1. Ventilation sufficient to maintain a maximum 40 °C temperature on a day with maximum 30 °C outdoor temperature while the transformer is operating at full FA loading with local control at the point of entry.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. A minimum of one light in the switchgear area shall be on the building emergency circuit.
3. At least one receptacle in the SCADA/meter area shall be on the building emergency circuit. The receptacle shall be labelled to identify the source of power (e.g., PANEL W CBR).
4. Room height shall be at least 2 feet greater than the transformer height and 4 feet greater than the switch height to support jacking and rigging.
5. Provision shall be made for an access path (doors, removable louvers, hallways, etc.) that would be required for the replacement of the switch and transformer. The access path must be wider than the transformer and/or switch (whichever is greater). Do not impede access paths to the equipment. Do not impede door swings. Proper clearance and escape pulls shall be maintained. Consult VTES as needed.
6. Where practical, all medium voltage equipment shall be physically separated (fencing with locking or non-locking gates or equivalent) from low voltage (below 600 volt) equipment per the NEC. At a minimum, yellow caution floor tape floor shall be applied to the floor to identify areas around medium voltage equipment. Warning signs shall be placed to denote this area in addition to the NEC required warning signs on the equipment. If permanent fencing is not installed, temporary fencing shall be provided for use to screen off the area when medium voltage maintenance work is occurring.

4.8.14.4.3 Medium Voltage Switchgear Requirements

A medium voltage circuit breaker shall be used as the service entrance equipment when dual services are required for reliability and maintenance. Typically, three medium voltage circuit breakers in a main-tie-main configuration shall be provided. Manual or automatic operation for transfer between services by these breakers will depend on the needs and requirements of the building. Other options for reliability and maintenance may also be considered by VTES.

The medium voltage circuit breaker shall have the following specifications:

1. Breaker shall have a racking-type draw-out mechanism provided with remote racking capability.
2. Auxiliary contacts to indicate the position of each breaker shall be provided. An empty 1-inch conduit from each compartment containing the terminal connection for the auxiliary contacts shall be extended to the SCADA/meter area and to the SCADA cabinet.

3. All breaker compartments shall have a bonded ground installed in the equipment pad.

4.8.14.4.4 Building Transformer Requirements

VTES will provide the transformer and will be responsible for the primary side of the transformer. The primary side of the transformer will be fully cabled, terminated, and connected by VTES.

Responsibility for the transformer secondary cabling will be split between VTES and the project. VTES will complete the transformer secondary terminations and connections. This work is completed at the transformer only and does not include either the building gear or the building electrical panels.

The secondary cable costs and the secondary cable pull-in shall be the responsibility of the project.

The building transformer(s) will be a cast coil transformer with the following specifications:

1. Applicable Standards: IEEE/ANSI C57.12.01, IEEE/ANSI C57.12.91
2. The transformer shall be UL listed
3. kVA Rating and FA rating shall equal the building service size
4. Frequency: 60 Hz
5. Impedance: 5.75%
6. Windings: Aluminum or copper
7. Primary Voltage: 12.47 kV
8. Primary Taps: two 2.5% FCAN and two 2.5% FCBAN
9. Primary Connection: Delta
10. Secondary Voltage: as needed
11. Secondary Connection: Grounded Wye
12. Application Location: Indoor NEMA 1
13. Sound Level: Standard
14. Winding Temperature Rise: 80 °C
15. Insulation system: 220 °C
16. Primary BIL: 95 kV minimum
17. Secondary BIL: 20 kV minimum
18. Forced Air Rating: AA/FA or AA/FFA
19. Digital three phase temperature monitor for fan control to provide local control and indication of temperatures and alarms with additional alarm output contacts for connection to utility SCADA system.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

20. Surge arrestors: 15 kV distribution class arrestors shall be provided at the transformer high voltage terminals.
21. Provide IEEE/ANSI impulse testing in addition to standard tests.
22. VTES and the VT PM shall be provided with test reports including all standard IEEE/ANSI specified tests, impulse test, and loss evaluation.
23. The transformer pad shall have a ground rod located in the high voltage compartment area.

4.8.14.4.5 Utility Metering and SCADA Requirements

1. General A/E Requirements and Contractor Requirements
   a. Contractor is to provide 1-1/2-inch conduit from the instrument transformer metering compartment to the area where the meter is mounted.
   b. The meter location shall be within 30 conduit feet of the metering compartment to facilitate testing.
   c. Wall space provisions shall be made for a 48″ H × 36″ W × 12″ D cabinet(s) for mounting VTES-supplied SCADA and metering equipment. VTES requires a minimum of 36 inches of clear working space in front of the SCADA and metering equipment as well as 48 inches of total working depth. SCADA cabinet shall be mounted at 80 inches from the top of the cabinet to the finished grade.
   d. SCADA and metering conduits from the outside duct bank and from the high voltage breakers shall terminate at the SCADA and metering cabinet(s) location.
   e. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts. All conduits shall be capped, but not glued. Pull strings shall be installed into each conduit.
2. The following shall apply to the metering instrument transformers:
   a. PTs and CTs shall be provided for utility metering. Provide test reports for these instrument transformers.
   b. Provide metering accuracy CTs on all three phases. CTs shall have a 5-amp secondary and a primary rating equal to the transformer FA current rating. If this is not a standard CT rating then the next higher standard CT rating shall be used. CT shall have a minimum 0.15B-0.5 accuracy and burden rating. CT leads shall terminate on a shorting-type terminal block. The terminal block shall be located in a

compartment that is user accessible without being exposed to primary voltage.

c. Provide phase to ground metering potentials for all three phases. Metering potentials shall be fused. PTs shall have a ratio of 60:1, a BIL of 95 kV, and a minimum thermal rating of 500 VA at 55 °C including a minimum accuracy rating of 0.3Y.
d. CTs shall not be used for any other function than VTES metering.
e. PTs may be used for other functions if those functions are separately fused and do not affect PT accuracy. VTES prefers to not use PTs for other functions. Consult with VTES prior to using.

4.8.14.5 Primary Duct Bank and Manhole Work

1. VTES will provide and install the utility meter, meter enclosure, and cabling from the instrument transformer metering compartment to the meter.
2. VTES will normally install concrete encased primary duct bank at a depth to the top of the duct bank of 30 inches below finished grade. Finished grade must be established before work may commence.
3. The number of cells in the duct bank will vary based on the requirements of the project and considerations of future construction in the area. The minimum number of cells will normally be two 4-inch and one 2-inch conduits.
4. If due to site logistics or other concerns the project team desires that the Contractor provides excavation for the primary duct bank facilities, VTES may consider this. VTES would normally perform construction of the duct bank and placement of manholes. In limited selected cases, VTES may elect to have the project install the primary duct bank facilities. If a contract crew other than VTES has been selected to construct a duct bank then VTES must be allowed ample time to review. Specifications from the A/E for the project. Duct banks shall be built to VTES specifications. In addition, a VTES employee(s) will observe and follow the progress of the construction. The A/E shall only use VTES specifications and specified materials for primary duct bank facilities. All materials shall be declared by A/E and approved by VTES prior to construction.
5. VTES will not allow contractors to enter or work on existing duct bank or manholes with energized 12 kV circuits.
6. Manholes provided and installed by VTES for most distribution circuits are 9′ × 9′ × 7.5′ high for outside dimensions (8′ × 8′ × 6.5′, inside dimensions). For main line 1000 MCM conductors, the manholes are 13′ × 9′ × 7.5′ high

outside to allow room for splicing the larger conductors. Smaller manholes will not be approved by VTES for 1000 MCM conductors. In addition, pull pipes must be installed. Consult with VTES as needed.

7. VTES or the project contractor can remove hardscape as specified on the construction documents as necessary in order to install primary duct bank.
8. Replacement of hardscape and landscaping is the responsibility of the project.
9. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S and shall be performed by the Contractor. The permitted site shall include the route from the existing primary distribution system to the location of the new service equipment.

4.8.14.6 Temporary Construction Service

The Contractor is responsible for applying for temporary service at the VTES office at 601 Energy Drive in Blacksburg, VA. The Contractor is responsible for all charges for electrical energy consumption used by the temporary facilities. Temporary electric service will be provided by VTES from the nearest facilities with the required capacity. VTES will provide the metering for temporary services. Charges to the Contractor for temporary facilities will be actual installation cost and estimated removal cost.

4.8.14.7 Roadway, Parking Lot, and Pedestrian Hokie Lighting

4.8.14.7.1 Light Pole and Fixture Installation

1. Contractor Requirements:
   a. The Contractor is responsible for providing and installing the concrete light pole bases and conduit with pull strings interconnecting. See the pole base detail in the VTES details located in the VT Design Standard Detail Library.
   b. The feeds for the site lighting shall be brought back to the transformer location and terminate in the site lighting flip top enclosures.
2. VTES Requirements:
   a. VTES provides and installs the poles, fixtures, controllers, and wiring.
   b. VTES provides labor for termination of wiring.

4.8.14.7.2 Roadway and Parking Lot Lighting Details

1. Roadway and larger parking lots are lighted using 30-foot aluminum poles and a typical cobra head-type fixture. New installations use a

70-watt or 140-watt LED cutoff fixture depending upon the project. The 30-foot cobra head lights have a multi-tap ballast (120/208/240/277 volts) or a 480-volt ballast. New installations with LED have a preferred voltage of 208 or 240 volts. The roadway fixture standard arm length is 6 feet, but up to 12 feet can be accommodated. If there is roadway or extensive parking lot lighting, separate metering may be required from the building service.

2. VTES maintains roadway, parking lot, and sidewalk pedestrian lighting. Since lighting on the campus is a safety and security issue and VTES receives after hour calls about lighting outages, any temporary or rerouting of lighting circuits shall be done by VTES. Doing so ensures VTES is aware of the routing and the condition of lighting circuits. Because lighting circuits often extend beyond the project limit, changes to circuits on the project site can affect lighting outside the projects defined boundaries. Coordination between the project, VTES, and the Contractor are required for site lighting changes.

4.8.14.7.3 Pedestrian Hokie Lights

General-A/E Requirements: Hokie pedestrian lights are a 10-foot post-top styled pole. New installations are 50-watt LED lamps. Older Hokie installations are a 100-watt metal halide or high-pressure sodium fixture. Typical Hokie light spacing along sidewalks is 70 to 80 feet with lights placed at or near intersections. The Hokie fixtures are typically installed on 120-volt circuits, but the LED lamps are rated for 120-277 volts. A small step-down dry-type transformer shall be used if supplied from a 480-volt system. Hokie lights are normally metered as part of the building service.

4.8.14.7.4 Led Lamp Color Rating

1. A 4000 K LED color temperature has been the standard to maintain uniformity across the campus. This matches well with the metal halide lights that are still being used.
2. Exceptions to Hokie or cobra head installations must be approved by OUP and VTPD.

4.8.14.7.5 Light Pole and Fixture Demolition

Contractor Requirements: The Contractor will remove concrete bases and abandon lighting conduit.

VTES Requirements: VTES will remove the poles and fixtures.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.8.14.7.6 Site Lighting Power Source Configuration

Consult with VTES for site lighting details.

4.8.14.7.7 Outdoor Transformer Installation

1. Contractor Requirements:
    a. The Contractor is responsible for supplying a NEMA 3R fused disconnect near the lighting controls that serves as the service disconnect for the site lighting, with one 2-inch conduit from the building transformer (or secondary connection cabinet if used) to the disconnect. One 2-inch conduit from the disconnect to the control pedestal shall be installed. Additionally, one 2-inch conduit from the lighting controls pedestal to the first light pole shall be installed.
    b. All conduit stub-ups shall be plumb and conduit shall be spaced sufficiently to allow installation of couplings and locknuts. All conduits shall be capped, but not glued. All conduits shall have pull strings installed.
2. VTES Requirements:
    a. VTES provides an outdoor pedestal mounted cabinet (27-inch wide, 18-inch deep, 30-inch tall and 50-inch tall when open) with a separate service from the transformer (or secondary cabinet) for lighting controls.
    b. VTES shall provide, install, and terminate conductors for this service and provide and install the lighting controls. This allows VTES crews to maintain the lighting without needing access to the building and eliminates VTES's need for building keys.

4.8.14.7.8 Indoor Transformer Installation

1. Contractor Requirements:
    a. For indoor or below ground vault-type transformer installations, the Contractor shall provide a photocell lighting controller/contactor in a wall mounted junction box in the vault with a separate service from the transformer.
    b. The photocell shall be exterior mounted, accessible, and shall be provided as well as installed by the Contractor. A 1-inch conduit shall be installed from the photocell to the lighting controller.
    c. The Contractor is responsible for supplying a NEMA 3R fused disconnect near the lighting controls that serves as the service disconnect for the site lighting, with one 2-inch conduit from the

building transformer, (or secondary connection cabinet if used), to the disconnect. One 2-inch conduit from the disconnect to the control pedestal shall be installed. Additionally, one 2-inch conduit from the lighting controls pedestal to the first light pole shall be installed.

2. VTES Requirements:
   VTES shall provide, install, and terminate conductors for this service. This allows VTES crews to maintain the lighting without needing access to the building and limits VTES's need for other building keys.

4.8.14.7.9 General Site Lighting Requirements

1. Minimum conduit size shall be 2-inch Schedule 40 PVC from the lighting controls to the first pole in the circuit and 1-1/2-inch Schedule 40 PVC for all lighting circuits beyond the first pole. Minimum conduit cover depth is 24 inches under paved areas and 18 inches otherwise. A 5/8-inch ground rod shall be placed in the concrete base so the ground rod stubs up 5 inches inside the base of the light. At least one conduit shall be stubbed out of each light base as a spare for future use.
2. See the light base detail in the VTES details located in the VT Design Standard Detail Library.
3. All hardscapes shall have conduits installed for crossing prior to concrete pour.
4. All hardscape and landscaping remediation are the responsibility of the project.

4.8.14.7.10 Lighted Building Sign

The lighted building sign can either be supplied from the building or from the nearest site lighting circuit. If the building is supplied from the site lighting, the sign shall be supplied from the nearest “Hokie” light with a 3/4-inch Schedule 40 PVC conduit. If the light is an existing “Hokie” light, VTES will remove the pole, drill the concrete base for the 3/4-inch conduit, stub out the conduit for contractor extension, and re-install the “Hokie” pole. VTES prefers lighted building signs to be supplied from the building service panel on a dedicated breaker.

Contractor Requirements: Contractor will extend the 3/4-inch conduit from pole base to sign and leave a pull string in the empty conduit.

VTES Requirements: VTES will provide wiring and connect to the site lighting circuit.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.8.14.8 Utility Manhole and Duct Bank Specifications

4.8.14.8.1 Manholes

1. Furnish and install precast concrete manholes as indicated on the drawings and specified hereinafter. The basis of deign shall be equal to the model 880MH as manufactured by Smith Midland of Midland, Virginia. Please note that 1000 MCM cable installations require larger manholes (13′ × 9′ × 7.5′); see DCSM section 4.8.14.5.
2. Manholes shall have minimum inside dimensions of 8′ W × 8′ L × 6.5′ H. Provide one manhole opening in the top center of the manhole with a diameter of 36″. There shall be “knockout” duct windows on all sides to allow for the installation of the duct as detailed on the drawings and for any future installation.
3. Provide manhole reinforced to support highway truck traffic and conform to the Construction Materials Testing Institute Bridge Loading Specification No. H-20. Construction shall also conform to ASTM C857 and C858 pertaining to underground precast concrete utility structures.
4. Each manhole shall be equipped with pulling irons in the bottom near each side wall. Pulling irons shall be seven-strand 1/2-inch diameter steel rope with yield strength of 2709 kips or equivalent. Exposed portion shall be totally encapsulated in durable non-hydroscopic plastic material.
5. Manhole cover shall say “Electric” and shall be at least 30 inches in diameter, however 36 inches is preferred.
6. Manhole covers and collars for manholes shall be level with the finished grade. Furnish and install precast riser rings between manhole top and manhole cover collar as required for leveling with finished grade. Collars shall be securely fastened to the manhole vault per manufacturer’s instructions.

4.8.14.8.2 Manhole Installation

1. Install manholes as indicated in the VTES Details located in the VT Design Standard Detail Library.
2. The hole to receive a manhole shall be dug to the proper depth to receive the manhole and cover plus 8 inches of crushed stone, (21A or 21B), in the bottom of hole. Manholes shall be set in place and inspected prior to backfilling. Stabilize and level the bottom of the manhole excavation with 8 inches of crushed stone. The excavation bottom should be level to

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

within 1 inch side-to-side and end to end. VTES may require re-installation of the manhole vault if the installation is not level.

3. The excavation to receive the manhole shall be a minimum of 6″ clear of manhole side in order to allow adequate backfilling and tamping of the earth fill along its side.
4. Place black mastic sealant strips, (provided from manufacturer), in the groove on the top of the wall prior to installing top to provide a water tight installation. VTES will require re-installation if mastic was not used.
5. Cover requirements: Install the manhole at least one foot below finished grade and no more than three feet below finished grade.
6. Install two 6-inch pull pipes into opposing faces of each manhole, per the manhole pull pipe detail in the VTES Details located in the VT Design Standard Detail Library. Coordinate installation with VTES. Install locating beacons in the ends of each pull pipe, under the 6-inch PVC conduit cap and below the surface.

4.8.14.8.3 Duct Bank Conduit and Associated Material

1. All underground conduit runs shall be standard 20-foot length utility Type EB-20 PVC conduit rated for encased burial and shall be encased in concrete. The latest edition of NEMA TC 6 and 8 PVC plastic utilities duct for underground installations standards shall apply. 10-foot lengths are not acceptable.
2. Duct shall be suitable for use with 90 °C rated conductors.
3. Use Schedule 40 PVC where exposed above ground or stubbed up poles.
4. Standard warning tape shall be 4-mil polyethylene, 3-inch wide warning tape, red with black letters, imprinted with “CAUTION BURIED ELECTRIC CABLE BELOW”.
5. All ducts entering manholes shall be fitted with end bells. Concrete flow through bases and spacers for ducts shall be used.
6. Duct spacers shall maintain a 2-inch separation between ducts and are required every 6-1/2 to 7 feet (three sets per 20-foot length). Duct spacers shall be PVC. The basis of design for duct spacers shall be from GS Industries of Bassett’s Underground Products base and intermediate spacer system or VTES approved equivalent are acceptable. Duct spacers shall meet VTES specifications. Otherwise, the duct bank may need to be rebuilt. Consult with VTES as needed.
7. As noted in duct bank installation details, #4 rebar shall be installed (see DCSM section 4.8.14.8.4).

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.8.14.8.4 Duct Bank Installation

1. Work with extreme care near existing ducts, conduits, cables, and other utilities to avoid damaging them.
2. Cut the trenches neatly and uniformly. The walls of the trench may be used to form the side walls of the duct bank provided that the soil is self-supporting and the concrete envelope can be poured without soil inclusions. Forms are required where the soil is not self-supporting or in areas that have been dug wider than the normal trench.
3. Required depth of conduit from final grade to the top of the conduit in the conduit bank is 36″ for primary, minimum. Less cover requires VTES review.
4. Provide one #4 rebar running longitudinal with the duct bank in each top and bottom corner approximately 3 inches from the edge of the concrete envelope. Provide one additional #4 rebar in the bottom for each additional foot of duct bank width over 1.5 feet. Additional rebar is to be evenly spaced across the width of the duct bank. Secure rebar with tie wire at every duct spacer. Rebar lengths shall overlap 2 feet minimum at the ends of the rebar (joints).
5. Reinforcing bars shall be used to stabilize the duct and spacers when the concrete is poured. These prevent the duct bank from “floating” up in the concrete. Drive #4 reinforcing bars through the inside edges of the duct spacers and at least 6 inches into the trench bottom, securing with tie wire. The top row of conduit shall be secured to the duct spacers with tie wire or a #4 rebar across the top shall be added and secured to the side stabilizing rebar with tie wire.
6. All bends shall be long sweep. The preference is to “bow” the conduit in long sweeps instead of installing conduit bend fittings. Where fittings or heated bending of conduit are required, the minimum radius shall be 60 inches. Maximum total bends per run between manholes and pads shall be the equivalent of three bends at 90 degrees. As-built drawings shall show the size and location of any fittings or heated bends used. VTES must approve all drawings prior to construction.
7. Couple the ducts with proper PVC couplings. All couplings shall be glued prior to concrete encasement.
8. Unless indicated otherwise on the drawings, all conduit shall enter manholes at a 90-degree angle. Conduit shall enter the manhole window on the outermost sides of the window, (not in the middle). Conduits shall

enter at the bottom windows of the manhole unless noted otherwise on the attached drawings.

9. Conduit runs that continue straight through a manhole shall enter and exit directly opposite each other, (no elevation or lateral changes), unless indicated otherwise on the drawings. Conduit runs that turn 90 degrees through the manhole shall be arranged so conduits enter and exit on diagonally opposite corners rather than the near corners. This facilitates pulling and racking of cable.
10. Concrete encasement: Provide a minimum of 3 inches of concrete on top and 3 inches on each side of duct in the duct bank. Vibration of the concrete during pouring will be required to ensure encapsulation of all the duct in the duct bank. Concrete shall be 4000 psi.
11. Refer to the typical duct bank detail in the VTES details located in the VT Design Standard Detail Library for a typical 15 kV duct bank installation and concrete encasement requirements.
12. After the concrete encased duct has sufficiently cured, the trench shall be backfilled and compacted to grade with earth. The standard warning tape shall be installed 12 inches above the duct bank during the backfilling. Contractor shall notify the VT PM and VT GIS for survey of installed duct bank.
13. Keep ducts clean of earth, sand, or gravel during construction, and seal with tapered plugs upon completion of each portion of the work.
14. Upon completion of the conduit installation or installation of direct buried ducts, a standard flexible mandrel shall be pulled through each duct to loosen particles of earth, sand, or foreign material left in the line. The mandrel shall not be less than 6 inches long, and shall have a diameter of no less than 1/2-inch less than the inside diameter of the duct. Mandrel pulls shall be witnessed by VTES, prior to pouring concrete.
15. After the mandrel pull, a pull rope shall be installed in each conduit. It shall be plastic with 200-pound minimum tensile strength.
16. Duct and Conduit capping: Cap the ducts and conduits at building entrances, and at outdoor terminations for equipment, with a suitable preformed conduit cap to prevent the entrance of dirt and contaminants.
17. Connections to Existing Manholes: Due to energized conductors, the Contractor shall not enter existing manholes. Stop the duct bank 20 feet outside the existing manhole leaving 2 feet of duct and rebar exposed (not concreted) and cap/plug the ducts.

18. VTES will connect the duct bank to existing manholes. When VTES has completed the duct bank connection, the contractor shall complete the concrete encasement of duct bank.
19. Partially Completed Duct Banks: During construction, wherever a construction joint is necessary in a duct bank, prevent debris such as mud and dirt from entering ducts by providing suitable conduit plugs. Fit concrete envelope of a partially completed duct bank with reinforcing steel extending a minimum of 2 feet back into the envelope and a minimum of 2 feet beyond the end of the envelope.
20. VTES shall specify the number, size, and configuration of ducts.
21. A VTES representative shall be present during the duct bank installation to inspect and review the quality of the installation. If poor workmanship is identified during duct bank installation, the VTES representative will notify the VT PM and the UBO, either of whom has the authority to stop work. The duct bank deficiency will be corrected before normal installation continues. Duct bank of deficient quality shall not be accepted and will be rebuilt.

4.8.14.9 Primary Relocation Work

Relocation of Primary Conductors:

1. VTES will perform any relocation of primary duct bank or other primary facilities required by the project. Requirements will be handled on a case-by-case basis and will be based upon VTES specifications. Consult with VTES as needed.
2. Routing or locations must be coordinated with VTES, OUP, and CC. The proposed layout shall be provided to VTES for development of any duct bank and pad requirements.
3. Any required ESC Plan shall be part of the project documents and in accordance with the VTAS&S and shall be the responsibility of the project.
4. Any hardscape or landscaping repair is the responsibility of the project.
5. A finished grade must be established prior to starting the project.

4.9 Transportation

Transportation and traffic as used in the DCSM and any DCSM checklists shall refer to vehicles, bicycles, transit, and pedestrians, and any other forms of mobility. Project designs shall follow the Virginia Tech Parking & Transportation Master Plan, the Campus Master Plan, the DCSM, the transportation details in the VT Design Standard Detail Library, and the design phase checklists. All plans shall be reviewed by OUP.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

The transportation and parking sections in the design phase checklists provide a guide for the A/E to use during design to ensure that common problems are addressed.

4.9.1 Applicable Standards

Except when more stringent requirements are stated in the DCSM, the transportation details in the VT Design Standard Detail Library, or the design phase checklists, all design and construction for transportation and traffic shall comply with the latest adopted editions of the standards listed.

1. Transportation signage including exterior signage, exterior signage for traffic control, and materials standards and mounting methods for signage shall comply with:
   a. DCSM Appendix F: Campus Wayfinding Guidelines
   b. VDOT
   c. VT Parking & Transportation Master Plan
   d. Virginia Tech Campus Master Plan
   e. Federal Highway Administration (FHWA) Manual on Uniform Traffic Control Devices (MUTCD)
2. Road design and construction including site distances, turning radii, curb and gutter, guardrail, crosswalks, and asphalt pavement repair shall comply with:
   a. VDOT
   b. FHWA MUTCD
   c. ADA Standards for Accessible Design
3. Parking design and construction including curbing and Accessibility requirements shall comply with:
   a. VDOT
   b. ADA Standards for Accessible Design
   c. VT Parking & Transportation Master Plan
   d. Virginia Tech Campus Master Plan
4. Alternate transportation design and construction, including trail design and provisions for bicycles employing racks, shelters, corrals, and parking, shall comply with:
   a. VDOT
   b. VT Bicycle Parking Master Plan
   c. VT Parking & Transportation Master Plan
   d. Virginia Tech Campus Master Plan
   e. American Association of State Highway and Transportation Officials (AASHTO)

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4.9.2 Accessibility Requirements

Plans shall comply with the ADA Accessibility standards in the ADA Standards for Accessible Design and the following requirements:

1. All projects that renovate or alter Accessible facilities shall provide an adequate number of parking spaces for physically disabled people. The number of parking spaces shall be calculated to comply with the ADA Standards for Accessible Design.
2. Parallel ADA parking spaces shall be avoided if possible.
3. Striped-out areas next to ADA parking shall be 8′6″ × 18′.
4. Locate the Accessible parking spaces to minimize the distance to Accessible exits, routes to Accessible buildings, and exposure to crossing traffic.
5. Accessible parking spaces shall be located close to the nearest Accessible entrance on an Accessible route and no more than 250 feet from the Accessible entrance.
6. ADA parking signs should follow the standard in the VT Design Standard Detail Library.
7. Detectable warning surfaces (truncated domes) for crosswalks shall comply with the ADA Standards for Accessible Design.
8. All crosswalk slopes shall meet ADA standards.

4.9.3 Alternate Transportation Requirements

The need for and quantity of bike racks, bike shelters, and bike corrals shall follow the DCSM and the VT Bicycle Parking Master Plan. The locations of bike racks shall be reviewed and approved by OUP and VT Alternative Transportation.

Trails shall have a paved width of 10 feet and grass shoulders shall be 3 feet wide.

4.9.3.1 Bicycle Parking Calculations

Virginia Tech integrates the Association of Pedestrian & Bicycle Professionals (APBP) Bicycle Parking Guidelines and LEED standards to determine the number of covered and uncovered bicycle loops required for buildings. Calculations for the number of bicycle loops (each loop accommodates two bicycles) are based on the user groups and number of people in a zone.

The APBP guidelines define how to program and distribute bicycle parking for a large building with several use groups. In some cases, a small cluster of buildings may share a set of desire lines and may be analyzed as a single large building. Virginia Tech has divided the campus into 49 zones to collectively address the parking needs of a cluster of buildings in each zone. LEED standards are used to determine the number of covered loops required for a zone.

Covered racks shall be provided in increments of eight loops and there shall be no fewer than eight loops per building, where covered racks are required. When the required number of loops is between multiples of eight, the number shall be rounded up to the nearest multiple. Bicycle rack covers are encouraged for all high-use areas and shall be considered based on demand. Covered racks are only required for buildings with office, class/lab, and residential stations. Covered racks are a subset of the total number of racks.

Terms used for bicycle parking calculations:

- Total loops – Combined number of uncovered and covered loops.
- User groups – Users are categorized by office stations, class/lab stations, residential stations, and dining seats.
- Persons – Number of individuals in a user group.
- Bicycle % – Percentage of the number of persons within a user group who are expected to access the zone by bicycle. Covered parking is not a user group but it does have a bicycle % requirement for the calculation of total loops.
- # Bicycles – Number of bicycles for a user group, calculated as the number of persons multiplied by the bicycle percentage.
- Required loops – Number of uncovered, inverted rack loops needed, calculated by dividing the number of bicycles by two.
- Existing loops – Number of uncovered, inverted rack loops already installed in the zone.
- Differential – Number of existing loops minus the number of required loops.
- Covered loops – A subset of the total number of loops and required for the office, class/lab, and residential stations user groups.
- Required covered loops – Number of covered, inverted rack loops needed, calculated by dividing the number of bicycles by two.
- Existing covered loops – Number of covered, inverted rack loops already installed in the zone.

Required bicycle percentages (bicycle %) for total loops:

- Office stations: 5%
- Class/Lab stations: 10%
- Residential stations: 20%
- Dining seats: 10%
- Covered parking: 15%

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Required bicycle percentages (bicycle %) for covered loops:

- Office stations: 5%
- Class/Lab stations: 5%
- Residential stations: 15%

Calculations:

- # Bicycles = Persons × Bicycle %
- Required loops = # Bicycles / 2

Calculations for required uncovered loops and required covered loops use the associated bicycle percentages. For office stations, the bicycle percentage for uncovered and covered is the same; therefore, 100% of the total number of loops for office stations must be covered. For class/lab stations, 50% of the total number of loops must be covered. For residential stations, 75% of the total number of loops must be covered.

Table 4-15. University Zone Bicycle Parking Calculation Example

USER GROUP	PERSONS	BICYCLE %	# BICYCLES	REQUIRED TOTAL LOOPS	EXISTING UNCOVERED LOOPS	COVERED LOOP % OF TOTAL LOOPS	REQUIRED COVERED LOOPS	EXISTING COVERED LOOPS	COVERED LOOP DIFFERENTIAL	TOTAL LOOP DIFFERENTIAL
Office Stations	100	5%	5	2.5		100%	2.5			
Class/Lab Stations	100	10%	10	5		50%	2.5			
Dining Seats	100	10%	10	5		0%				
Residential Stations	100	20%	20	10		75%	7.5			
TOTAL	400		45	22.5	20		16	0	-16	-2.5

4.9.4 Traffic Signage

1. All signs related to transportation are to be approved by the Virginia Tech Transportation Planning Engineer.
2. All parking signage should be purchased through the Virginia Tech Sign Shop.

4.9.5 Roads and Routes

1. All transportation routes shall be designed for the largest vehicles expected to access the site via that route (e.g., garbage trucks, recycling trucks, delivery trucks, fire trucks).
2. The A/E and the Contractor shall provide smooth transitions between all proposed and existing grades including asphalt, landscaping, concrete, etc.

3. The proposed curb radii shall be large enough for all traffic including tractor trailers, transit, and emergency vehicles. Turning movements and paths of the largest vehicle shall be shown on plans.
4. Fire truck turning movements should follow the standard in the VT Design Standard Detail Library.

4.9.6 Crosswalks

1. Crosswalks shall follow continental style crosswalk standards, use continental style pavement markings, and cross roads perpendicular to the vehicle traffic flow. Standard crosswalks shall follow the detail in the VT Design Standard Detail Library.
2. Crosswalk thermoplastic should be at least 6 feet wide and the width should be increased for areas with higher pedestrian volume.
3. Crosswalk lighting and design shall follow the standards in the VT Design Standard Detail Library.
   a. The basis of design for the pole shall be HAPCO part no: HAP30971P30 – 20′ Decorative Alum Pole Hokie Brown w/ 8′ Single Arm for Over Head Tear Drop Fixture. See the crosswalk light standard in the VT Design Standard Detail Library.
   b. The basis of design for the luminaire shall be HAPCO part no: HAP80911P30 – Adjustable Luminaire Adapter for Antiques Lighting SB33 Fixture. See the crosswalk light standard in the VT Design Standard Detail Library.
4. Crosswalks shall follow the requirements in DCSM section 4.9.2.

4.9.7 Barriers

When roadway guardrail is needed, timber wooden guardrail equal to the Blue Ridge Parkway type should be used. See the standard in the VT Design Standard Detail Library.

4.9.8 Parking Requirements

4.9.8.1 General

Loss of existing parking spaces shall be minimized. Total number of parking spaces lost shall be shown on plans at each plan review stage. Reduction of parking spaces shall be incorporated into the project budget. Replacement parking will be billed to the project. There will be no charge for parking spaces restored at the conclusion of the project.

Parking configurations and aisles widths shall be designed to provide adequate maneuvering and safe circulation for all vehicles. Consideration shall be given to

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

increasing the sizes of spaces and aisles for short duration parking or high turnover areas. Protection of columns, walls and posts with parking signage shall be considered by the use of wheel stops, bollards, or guard rails of contrasting color.

4.9.8.2 Minimum Standards for Parking

The following minimum parking space dimensions are standards for use in the design of parking decks, parking garages, and parking lots.

1. Stalls in parking decks, parking lots, and garages utilizing self-parking:
   a. For standard cars, maintain a minimum width of 8′6″, a minimum length of 18 feet, and a minimum area of 153 sq. ft.
   b. For Accessible spaces, refer to the ADA Standards for Accessible Design requirements and DSCM section 4.9.2.
   c. Typical parking spaces should follow the standard in the VT Design Standard Detail Library.
2. Parking spaces shall be delineated by 4-inch striping.
3. Wheel stops shall be avoided if possible.
4. VDOT standard curbing is preferred in parking areas. If that is not feasible, then wheel stops should be used. Follow the parking wheel stops standard in the VT Design Standard Detail Library.

4.9.8.3 Parking Space Planning

Requirements for the minimum number of parking spaces shall apply to all new buildings, additions and changes in use or occupancy. Buildings which undergo major renovations shall comply to the greatest extent possible. Planning for Accessible parking spaces shall comply with the ADA Standards for Accessible Design and DCSM section 4.9.2.

Service vehicle parking spaces shall be included. Project-specific requirements shall be coordinated with Parking Services via the VT PM.

Parking plans may be developed for an entire campus, facility, or complex to address the total parking spaces available for all buildings and their associated use groups. Where insufficient parking is provided on site, the parking plan shall address the availability of offsite parking for the occupants and guests to the building or facility.

For purposes of calculating employees or students, their number is equal to the number of workstations or the maximum number of employees or students in a shift. For mixed use occupancies, the total number of parking spaces shall be

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

allocated proportionally to the individual groups which the parking lot or structure is intended to serve.

4.9.9 Electric Vehicle Charging Stations

Virginia Tech welcomes the use of electric vehicles (EV) on campus to support the Virginia Tech Climate Action Commitment and the Electric Vehicle Master Plan. Installation of electric vehicle charging stations (EVCS) shall be reviewed with the A/E and the VT project team in pre-design meetings for new construction.

A minimum of one Accessible EVCS space shall be provided at a single location where there are 20 or fewer EVCS spaces. If a location has more than 20 EVCS spaces, then additional Accessible EVCS spaces shall be provided at a 1:20 ratio.

Installation shall follow the requirements of the manufacturer including electrical, communication (cellular), and mounting requirements.

1. Equipment
    a. EVCS shall be dual-port stations for use with adjacent or tandem parking spots.
    b. Charging ports shall meet the SAE J1772 plug standard for EV and plug-in hybrid vehicles.
2. Electrical
    a. The A/E shall evaluate the electrical infrastructure planned for the site to coordinate the power demand and location for EVCS.
    b. Conduit installed to support the EVCS shall be sized to allow for future expansion.
3. Placement
    a. Locations for EVCS shall receive sufficient cellular signal for data collection and metering. If cellular signals are insufficient, the A/E shall provide a design for ensuring connectivity for the EVCS.
    b. The A/E shall consider the use of protective bollards or wheel blocks where appropriate for mounting the EVCS. Installation should be behind a curb where possible.
    c. Signage shall be provided to limit parking for EV while charging only.
    d. Installations of EVCS shall not block existing Accessible ramps or pathways.

4. Project-specific items
   Several aspects of EVCS cannot be generalized. If a new project will include EVCS, these items shall be decided for each new project:
   a. Mounting type – Pedestal mount installations are used for parking lot and most building exterior locations. Wall mount installations may be used if parking space is available adjacent to a structure or building envelope.
   b. Charger level – Level 1 or Level 2 will be used for most installations. If Level 3 chargers are being considered, electrical infrastructure and conduit may require upgrades beyond what is minimally needed for Level 1 or Level 2.
   c. If the site has the potential for future expansion of the new EVCS, then the infrastructure and surroundings shall be planned to allow for that possibility.
   d. The proximity to or the use of high-value parking spaces for the EVCS shall be planned in coordination with Parking Services.

4.10 Site Grading

1. The Contractor shall bring the site to final grade and full stabilization to comply with the VTAS&S.
2. Prior to grading, topsoil should be stripped and stockpiled for reuse where feasible.
3. Slopes designated as mowable lawn may not exceed 3:1 slope.
4. Planted areas shall have a maximum slope of 2:1 with approved soil holding landscape material.
5. Paved areas should be graded to positively drain (1% min. for concrete and asphalt, 2% for unit pavers and other materials) but within the specifications outlined in the ADA Standards for Accessible Design.
6. Lawns should be graded to minimum slope of 2% to achieve positive drainage.
7. Grading for project should seek to balance cut and fill on-site.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 5 – BUILDING

5.1 Energy Efficient Design

The A/E shall use the current accepted version of ASHRAE Standard 90.1 and this section for energy efficient design.

5.1.1 Energy Metering

5.1.1.1 Electricity (Digital Energy Meters)

1. Application
   Substations and building primary switchgear shall have power quality meters. Building submeters shall have energy meters. All meters shall have a local display of demand and totalized consumption.
2. Connectivity
   a. All installations shall be digitally integrated into the Building Automation System (BAS) via MODBUS/IP or BACnet/IP protocols or be directly accessible over the university Ethernet for energy management use. At a minimum, apparent power, reactive power, real power, and energy shall be mapped to the BAS/data management system. Consumption reading in the BAS/data management shall match the meter's local display.
   b. The contractor shall be responsible for proper installation of the meter and for enabling energy consumption calculations during construction before the service is turned on. Temporary meters for construction use will be supplied by the VTES metering department without connection to the BAS and will be read monthly.
3. Approved Meters:
   a. Power quality meters:
      i. Square D CM4000, PM870, or equivalent
      ii. ION 7650/7550 series
      iii. GE PQM II series
   b. The basis of design for energy meters shall be:
      i. Square D energy meter or equivalent
      ii. ION 6200 series

5.1.1.2 Chilled Water and Heating Hot Water

1. Application
   a. Transit-time ultrasonic flowmeters may be used on all pipe types and shall be used for services greater than 6 inches or where a service outage

is not possible or cost effective. Services at or below 6 inches may use in-line electromagnetic flowmeters. Either meter type shall be suitable for the application and in accordance with the guidelines herein.

b. For existing buildings, meter technology and size selection shall be based upon actual volumetric flow rate in the pipes, the allowed permanent pressure loss, and the minimum straight run availability. Minimum and maximum flows in the pipes shall be estimated using the design cooling load data, pump curves or field measurements.
c. A calibrated pair of temperature sensors for energy meters shall be installed in thermo wells on the specific chilled water supply and return lines measured by the meter.
d. For design documentation and meter submittal package shall include tabulated values of the min/max flow in the line and the allowed maximum pressure drop across the meter.
e. All meters shall provide a turndown ratio of 50:1 or more.
f. All meters shall provide an accuracy of 1.0% or less for the whole range of volumetric flows supported by the meter.
g. All non-BAS meters shall have the ability to measure the volumetric flow rate and calculate instantaneous and totalized cooling and/or heating demand.

2. Ultrasonic Flowmeters
   a. Ultrasonic clamp-on flow measurement system designed for non-intrusive external to pipe measurement of water and wastewater media. The system shall utilize a transit time ultrasonic principle of measurement mounted on the customer pipe from which the volume flow rate can be derived. Ultrasonic flowmeter shall be suitable for flow velocities 0-33 fps.
   b. The flow measuring system shall consist of a clamp-on sensor pair(s), sensor holders, sensor cables, transmitter, transducer coupling pads, mounting clamps/straps, and installation aids.
   c. The sensors shall be selectable for pipe diameters in the range of 2 inches to 160 inches (DN 50 to 4000) and meet the application requirements.
   d. The transmitter shall integrate, control, and allow setup of the measurement system.
   e. The flow measuring system shall automatically adjust its nominal operating frequency within an available frequency band, so as to optimize

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

the actual operational frequency in respect of pipe material, wall thickness, liner (if present), and fluid condition.

f. The flow measuring system shall retain all setup parameters and accumulated measurements internally in non-volatile memory.

3. Electromagnetic Flowmeters
   a. Electromagnetic flowmeters shall be for permanent installations both above and below ground. The meters shall utilize bipolar pulse DC coil excitation to measure voltage induced by the flow of conductive liquid through a magnetic flux. The voltage shall be linearly proportional to flow velocity from 0.033 to 33 feet per second.
   b. The flowmeter shall be a flanged sensor which complies with AWWA C751 and transmitter which may be mounted integral (compact) to the sensor or remote with interconnecting cables up to 650 feet in length.
   c. The flow metering system shall be microprocessor-based and possess a non-volatile memory to store the sensor calibration and transmitter setup information. The electronics shall be interchangeable for meters sized for 1 to 90 inches.
   d. The sensor shall consist of a stainless steel flow tube with ANSI B16.5 or AWWA C207 carbon steel or stainless steel flanges. The flanges shall be Class 150 for 24" and smaller.
   e. The sensor liner and electrode material shall be chosen to be compatible with the process fluid. All fluids require a minimum conductivity of 5μS/cm (20μS/cm for deionized water).
   f. The sensor tube shall be lined with polyurethane, hard rubber, or PTFE in accordance with NSF-61 based upon the size of the flowmeter and the process media conditions.
   g. The external sensor housing shall enclose the coil assemblies and internal wiring. The materials shall be designed and constructed to prevent moisture ingress and promote corrosion resistance.
   h. The transmitter shall be a three-stage microprocessor controller mounted integrally or remotely as specified in the instrument schedule or drawings. The transmitter shall incorporate a universal 100-240 VAC/ 18-30 VDC power supply. The transmitter housing will carry a NEMA 4X rating and shall be constructed to prevent moisture ingress, promote corrosion resistance, and be impervious to saline environments.
4. Installation
   a. All meter design and installation shall be as recommended by the manufacturer's installation and operation manual.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

b. If meters are installed in the mechanical rooms, they shall have a converter and a local display mounted in the same room. When meters are installed on the lines in the tunnels or crawl spaces which are not easily accessible, these meters shall have a remote converter mounted in the nearest mechanical room. The manufacturer's specification must be met for maximum allowable distances between the sensor (meter) and the convertor.
c. Flowmeters shall have 15 unobstructed pipe diameters of straight pipe upstream and 5 pipe diameters downstream unless specified otherwise by the manufacturer.
d. The Commissioning Agent shall verify the meter for accuracy in measurement using appropriate means and methods over the expected minimum and maximum range of the meter.

5. Connectivity
All installations shall be digitally integrated into the BAS via MODBUS/IP or BACnet/IP protocols or be directly accessible over the university Ethernet. Totalization, flow and Btu rates, and diagnostic data shall be mapped into the BAS or a data management platform. Where needed, meters shall calculate and display energy consumption without BAS/data management support. Totalization values in the BAS/data management shall match the meter's local display.
6. Approved Meters and Associated Devices
The basis of design for chilled and hot water flowmeters shall be equivalent to:
a. Endress+Hauser Proline Prosonic Flow 91W or 93W
b. Endress+Hauser Proline Promag W 400 Series

5.1.1.3 Steam

1. Application
a. Meters shall be an inline flowmeter which utilizes a dual D/P technology. The meter body and element shall be made from 316SS. The flowmeter shall consist of a toroidal nozzle design and a pitot-style sensing element. The meter body shall have an integral port for an optional RTD. The measuring station shall be rated up to 600# ANSI depending on the application conditions and the sensor specified.
b. The steam meter must be able to be used in limited straight run piping configurations. The straight run is to be integral to the meter. The stabilization and linearization of the velocity profile shall be within the

throat of the nozzle thus eliminating the need for any upstream run. Where possible straight pipe runs shall be included for better access to and clearance for meter.

c. The accuracy of the flow element shall be within +/- 1.0% for the whole range of volumetric flows supported by the meter over a maximum flow turndown of up to 50:1. Certified test data from independent flow laboratories shall be provided as verification. The repeatability of the flow element shall be +/- 0.075% of actual value over the entire flow range.
d. A metering flow computer shall be used to process and correct the flowmeter signal to usable and specified outputs. The flow computer shall include an alphanumeric display to display measured parameters in easy to understand formats. Other features of the flow computer shall include:
    i. Internal communication card option that supports: BACnet IP, BACnet MS/TP, Metasys N2, Modbus TCP, AB Ethernet/IP, AB DF1, and LonWorks
    ii. Liquid, gas, steam, and heat flow equations including differential pressure steam meters
    iii. Menu selectable hardware and software features
    iv. Isolated pulse and analog outputs
e. A flow calculation is required to determine the DP and verification of the operating limits.
f. For existing buildings, meter technology and size selection shall be based upon the actual steam load in the building and the properties of steam. The following parameters have to be estimated or measured for every location prior to meter selection:
    i. Steam quality (saturated vs superheated)
    ii. Steam pressure (PSIG)
    iii. Steam temperature (°F)
    iv. Steam volumetric flow min and max (cu. ft./sec.)
    v. Steam velocity min and max (ft./sec.)
    vi. Turndown ratio = Vmax / Vmin
g. For new designs, engineering design documentation and meter submittal package shall include tabulated values for the above parameters and the maximum allowed pressure loss.

2. Installation
    a. If meters are installed in the mechanical rooms, they shall have a converter and a local display mounted in the same room. When meters are installed in tunnels or crawl spaces which are not easily accessible or when the environment in those locations is harsh, meters shall have remote electronics located in the nearest mechanical room. The manufacturer's specifications must be met for a maximum allowable distance between the sensor (meter) and the convertor.
    b. In the instances when there is a need to install a meter of smaller diameter compared to the diameter of the line, the section of the pipe of a required length shall be downsized using two eccentric reducers to avoid condensate accumulation in the pipe.
    c. In the instances when minimum straight pipe run requirements are not met, upstream flow straighteners shall be utilized.
    d. Install meter displays such that readouts can be viewed from an appropriate angle.
    e. All meters shall have ability to calculate the instantaneous and totalized volumetric, mass, and Btu flow rate of steam.
    f. The Commissioning Agent shall verify the meter for accuracy in measurement using appropriate means and methods over the expected minimum and maximum range of the meter.
3. Connectivity
    a. All installations shall be digitally integrated into the specified network via MODBUS/IP or BACnet/IP protocols or be directly accessible over the university Ethernet. Totalization, flow and Btu rates, and diagnostic data shall be mapped into the BAS or a data management platform. Steam meters shall calculate and display energy or mass flow rate demand and total consumption without BAS/data management support.
    b. The contractor shall be responsible for proper installation of the meter and for enabling energy consumption calculations during construction before the service is turned on, unless ordered by the Office of Energy Management (OEM).
4. Approved Meters and Associated Devices
    a. The basis of design for steam flowmeters shall be Veris Accelabar or Veris Verabar by Armstrong International, Inc.
    b. The basis of design for flow computers shall be Kessler-Ellis Products (KEP) ES749.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. Low Pressure Steam
   Care shall be exercised while selecting meters for low pressure steam applications. Steam meters shall be selected in the way to avoid excessive permanent pressure loss across the meter which is accomplished by selecting meters with low minimum velocity requirement. The permanent pressure drop across the meter shall not exceed 1 psi at the design flow conditions.

5.2 Thermal and Moisture Protection

5.2.1 Waterproofing and Drainage for Subsurface Structures

No state buildings for human or equipment occupancy shall be designed with building systems (such as ductwork) or basement floor levels below the water table. Varying degrees of subsurface water content require the following minimum waterproofing and drainage techniques.

5.2.2 Soils with Little or No Obvious Water Content

1. Waterproof walls and provide any suitable waterproofing protection board.
2. Provide perforated-type drainage pipe with gravel surrounding.
3. Backfill with suitable material that has some porosity.

5.2.3 Damp to Wet Soils with No Obvious Water Source

1. Waterproof walls and provide protection board. Note: If geotechnical type drainage board is used, protection board may not be required.
2. Provide perforated type drainage pipe and (if necessary) surround with full height gravel to the underside of the impervious soil or material. An approved geotechnical-type drainage board may be used in lieu of the full height gravel at the Contractor’s option.
3. Provide impervious soil or material at finish grade.

5.2.4 Walls or Floors Below the Groundwater Table

Delete the lowest floor or space below the highest calculated groundwater table possible, or raise the level of the lowest top of floor structure above the top of the highest calculated groundwater table possible, and follow the waterproofing techniques listed above.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.3 Concrete

1. All exposed vertical concrete edges are to be 3/4″ chamfered and 1/2″ round over flatwork.
2. All control joints shall be sawcut.
3. LEED documentation shall be included in the shop drawing submission as required by LEED approach for project.
4. Reinforcing bars shall be placed at re-entrant corners, slab penetrations, and embedded assemblies to restrain concrete cracking.
5. Slab-on-grade floors in buildings shall have a minimum thickness of 4 inches.
6. Hardener treatment is required for all interior floors subject to heavy, impact, and/or rolling loads.
7. A sealer is required for all interior floors. Verify sealers, hardeners, and additives are compatible with curing and finish floor requirements.
8. Slip resistant surfacing (having a DCOF of 0.42 or better) shall be specified for all ramps, stair treads, and landings when not covered with flooring materials. The method and details of providing a slip resistant surface shall be indicated in the construction documents (e.g., broom finish, exposed aggregate, or coating).
9. Building interior concrete surfaces to be painted shall not receive a rubbed finish.
10. All defects, form irregularities or honeycomb shall be repaired immediately upon form removal.
11. Anything attached to flatwork shall be epoxy-anchored. Mechanical anchors are not acceptable. The intent is to prevent concrete from cracking due to water getting into perimeter of the fastener holes. This is for fasteners that are not loaded in tension.
12. Epoxy anchors shall not be used for overhead installations or members that are loaded in constant tension.
13. Cement shall conform to the requirements of:
    a. Portland Cement: ASTM C150/C150M, Type I/II
    b. Blended Cement: ASTM C595/C595M, Type IL

5.3.1 Architectural Concrete

OUP shall be consulted on the selection of all exterior materials, including precast architectural concrete.

1. Architectural precast concrete is specified under this section for color consistency of the exposed exterior surfaces. The architectural precast concrete design mix produced by the following manufacturer is to establish an “or equal” design standard and not a required proprietary product.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. The color produced by the following mix design is to be the standard precast color and finish for new construction unless otherwise noted by OUP.
3. OUP may require a different color/finish if a match of existing precast concrete, cast stone, or limestone is to be part of the work, such as for an addition to an existing building.
4. Submittals: Prior to construction of the project mock-up wall, submit 12″ × 12″ architectural precast concrete sample(s) for preliminary color and finish design approval by OUP. The approved sample will be the basis for the color and finish of the precast sample(s) to be installed in the mock-up wall.
5. The basis of design for architectural precast concrete shall be:
   a. Manufacturer: American Stone, Virginia LLC, Ladysmith, Virginia
   b. Mix design based on sample #3168A (exact proportions are subject to adjustment to obtain color and finish):

Table 5-1. Architectural Precast Concrete Mix Design Based on Sample #3168A

Reference	Material	Source	Quantity (lb./cu. yd.)
ASTM C33	Texas #7 Gravel	Lafarge	1678
ASTM C33	Texas C33 Sand	Lafarge	1570
ASTM C150	White Cement	Federal	658
ASTM C979-82	Yellow 50908 Pigment	Davis	10
ASTM C494	Sika 4100 water reducer	Sika	39 oz. +/-
ASTM C260	Sika AEA-14 air entrainment	Sika	5% +/- 1.5%
POTABLE	Water		263 +/-

   c. As an alternative to using the above referenced mix design supplier may match a physical precast sample provided by OUP.

5.4 Exterior Walls

OUP shall be consulted on the selection of all exterior materials, including synthetic wood paneling. This also includes structures not attached to buildings (e.g., handrails). When metals are used, zinc is the preferred material. The use of metal panel in mechanical screening shall include articulation and refinement to break down scale.

5.4.1 Fire Walls: Abutting New Construction to Existing Structures

When an addition is needed adjacent to an existing state-owned building, and the existing building cannot accommodate the additional height and area limitations due to its construction type and Use Group, as an alternative to a traditional fire wall, Chapter 7 of the VCC now recognizes that two exterior building walls may be designed to function as a "double fire wall," as defined in NFPA 221. Consideration shall be given to the structural stability and fire resistance of the exterior walls and door openings. Where door openings are provided, portals or vestibules designed to comply with NFPA 221 are acceptable.

5.4.2 NFPA 285 Acceptance Criteria in Exterior Walls

For the use of Exception No. 3 to section 2603.5.5 in the 2018 edition of the VCC, contact the UBO.

5.4.3 Intersection of Fire Resistance Rated Wall Assemblies with Lesser-Rated and Non-Rated Wall Assemblies

The 2018 VCC provides limited guidance for addressing how Fire Barriers (VCC 707), Fire Partitions (VCC 708), and Smoke Barriers (VCC 709) intersect with lesser-rated and non-rated exterior walls. At these conditions, the UBO applies and enforces the following requirements:

1. The gypsum board manufacturer(s) included in the listed fire resistance rated wall assemblies typically provide partition priority legends and installation details to address these conditions as well as instructions on how corners and tees are to be constructed. The UBO considers the manufacturer's installation instructions to be a critical component for achieving a compliant fire resistance rated fire barrier, fire partition, or smoke barrier assembly. To the extent possible, the manufacturer's instructions shall be incorporated into the Working Drawings.
2. The VCC sections for fire barriers, fire partitions, and smoke barriers do not require the exterior walls of the separated fire compartments to be fire resistance rated. The rationale for this is based on fire exposure from outside of the building (not within the building). As a result, these sections do not adequately address the potential for in-building horizontal fire spread from one fire compartment to another where the interior wall assembly intersects with the exterior wall. The UBO applies the following requirement to address this concern: where the fire barrier, fire partition, or smoke barrier assembly intersects and terminates at a lesser-rated or non-rated exterior stud wall, the assembly shall extend in its entirety to the inside face of the exterior wall sheathing.
3. As an alternative, VCC section 707.9 Voids at Intersections or 715.4.2 Exterior Curtain Wall/Vertical Fire Barrier Intersections may be applied, whereby the fire resistance rated wall assembly terminates at the interior wall sheathing of the exterior wall. In this arrangement, the intersecting stud cavities within the

exterior wall shall be completely filled with an approved material, such as mineral wool. Conditions may vary from project to project, so consult with the UBO to determine the correct application of this alternate approach.

The following documentation for the design of fire-resistance-rated wall assemblies shall be provided at a minimum:

1. Define the listed fire-resistance-rated wall assembly.
2. Define the respective listed head-of-wall and bottom-of-wall joint systems.
3. Provide the basis-of-design gypsum board manufacturer's partition priority legend and related standard details for the proposed construction.
4. Include copies of the listings for the proposed fire-resistance-rated wall assemblies and joint systems in their entirety on the working drawings (see DCSM section 2.7.5.9 and the fire systems working drawings checklist).

5.4.4 Masonry/Hokie Stone

Unit masonry (e.g., brick, concrete masonry units, or faux stone) is typically not an acceptable exterior cladding material, in-particular for the campus core. OUP shall be consulted on all applications of Hokie Stone. In addition to the traditional Hokie Stone veneer, this includes all non-standard uses such as Grade B stone or polished stone.

1. Hokie Stone shall not be used for any horizontal surfaces.
2. Granite and slate shall not be used for pedestrian surfaces.
3. Weep holes shall be cellular vent type similar to Heckman No. 85.
4. For guide specifications on the use of Hokie Stone materials, applications, installation, execution, and accessories, refer to Appendix G: Hokie Stone Masonry Guide Specifications.
5. The UBO will conduct daily inspections of Hokie Stone during installation.

5.4.5 Wall Details

1. All parapet walls up to a 4′-0″ height above roofing shall be flashed continuous from coping to roofing.
2. Fiberglass batt insulation shall be installed in such a manner as to eliminate exposed fiberglass in areas needing to be accessed for inspections and/or maintenance. Designs shall encapsulate fiberglass using foil or pre-applied backing, plastic, or gypsum board covering. Open-facing insulation is not allowed.
3. Fire caulking shall be from an approved manufacturer. Approved manufacturers include:
    a. Hilti, Inc.

   b. 3M Fire Protection Products
   c. Dow
4. Exterior joint sealant in building elements shall be a silicon product. Approved manufacturers include:
   a. Henry
   b. Grace
   c. Meadows
5. All through wall flashing shall be 16-ounce minimum copper or stainless steel. If stainless steel flashing is used, it shall be Type 304 stainless steel, meeting the requirements of ASTM A666, and shall be minimum of 0.018 inch (0.4572 mm) thick. Other metal or vinyl flashing shall not be used. All coping flashing shall be through wall type.
6. All flashing corners shall be pre-fabricated, or field fabricated with welded or soldered seams.
7. All vapor barriers shall be applied and protected per manufacturer's instructions.

5.5 Roofing

5.5.1 Roofing Policy and Technical Standards

The provisions of this section shall govern the design of low-slope (roof slope less than 2:12), flexible membrane (built-up and single-ply) roofs. This section also governs the design of metal roofing systems to be used on university buildings.

This section provides criteria and qualifications for selecting full-time roof inspectors (DCSM section 8.3.4) and roof consultant/inspection services providers (DCSM section 8.3.5). It also provides criteria for non-destructive evaluation (NDE) roofing surveys and criteria for drawings to accompany NDE surveys (DCSM section 5.5.3).

New or reroofing project working drawings and specifications shall be prepared by a licensed Virginia A/E. Procurement of these professional services is covered in the VT CPSM.

Assuming roofs are equal in other respects, low-slope roofs that shed water are more desirable than flat roofs that do not; and steep roofs are more desirable than low-slope roofs. Economy, aesthetics, constructability and compatibility are valid considerations in evaluation and design of roof systems.

The A/E shall include form DGS-30-326, "Special Requirements for Low Slope Roofing Membranes," in the front end of the specifications and reference it in the

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

low slope roofing membrane specifications. The A/E is responsible for selection and specification of the roofing membrane.

5.5.2 General

OUP shall be consulted on all roofing materials and roofing accessories. These include, but are not limited to:

1. Slate roof shingles – intent is to match historical samples in color, size, distribution, etc.
2. Standing seam metal roof – generally not an acceptable roofing material, especially for the campus core
3. Roof accessories and trim – copper or dark bronze coloration preferred (but subject to review).
4. Roof accessories and trim – if required; avoid residential looking gutters and downspouts

5.5.2.1 Pre-roofing Conference

A pre-roofing conference is required and shall be included in the Specifications as part of DGS-30-326, "Special Requirements for Low Slope Roofing Membranes." The conference shall be held before ordering roofing materials.

Representatives of the University (including the roofing inspector), A/E, General Contractor, roofing contractor, deck contractor, mechanical contractor, and roofing manufacturer shall attend.

Review of plans, specifications, flashing details, work scheduling, and workmanship standards is required. Problems and discrepancies shall be resolved.

A written record of proceedings shall be prepared and made part of the job record.

5.5.2.2 Guarantees

Guarantees and warranties for new construction or reroofing are included in the Specifications as part of DGS-30-326, "Special Requirements for Low Slope Roofing Membranes." Additional requirements, warranty period length, or University-approved waivers/exceptions may be specified by the A/E in the roofing specifications. Identify the DGS form section being modified in the roofing specification.

5.5.2.2.1 Roofing Contractor's Guarantee

Provide the following roofing contractor's guarantee on the General Contractor Guarantee form:

"The roofing contractor shall guarantee materials and workmanship associated with the roofing, flashings, and sheet metal work incidental to the work required under the roofing subcontract, against defect due to faulty materials or workmanship for a period of two years from the Final Completion Date of the entire project. It is understood and agreed by all parties hereto that the responsibility of the roofing contractor under this guarantee form or any contract document, shall be in accordance with the roofing contractor's limited guarantee."

5.5.2.2.2 Owner's Agreement

Provide the following Owner's Agreement on the Contractor Guarantee form:

"The University agrees, from the Final Completion Date of the entire project, to maintain the roof in accordance with the manufacturer's written requirements and also agrees to avoid damage to the roof surface by any parties under its control working or walking on the roof. The University recognizes its responsibility to inspect the roof semiannually."

5.5.2.2.3 Contractor's Guarantee for New Construction

The Contractor shall furnish, as a minimum, a manufacturer's 20-year total system material and labor warranty/guarantee with no monetary limitations (NDL, no dollar limit) from the Final Completion Date of the entire project. The contractor shall provide a workmanship warranty agreeing to maintain the entire roof system(s) in a completely watertight condition at no cost to the University for two years from the Final Completion Date of the entire project. Sheet metal flashing incidental to the roofing shall be covered under the manufacturer's warranty.

Exception: Roofs less than 5,000 sq. ft. in area and roofs on utility or unoccupied structures shall have a minimum 10-year total system warranty.

5.5.2.2.4 Contractor's Guarantee for Reroofing

The Contractor shall furnish, as a minimum, a manufacturer's 20-year total system material and labor warranty/guarantee with no monetary limitations (NDL, no dollar limit). The contractor shall provide a workmanship warranty agreeing to maintain the entire roof system(s) in a completely watertight condition at no cost to the University for two years from date of final acceptance. Sheet metal flashing incidental to the roofing shall be covered under the manufacturer's warranty.

Exception: Roofs less than 5,000 sq. ft. in area and roofs on utility or unoccupied structures shall have a minimum 10-year total system warranty.

5.5.2.3 NRCA Roofing Manual

Use the latest edition of the NRCA Manual as a guide in preparing plans and specifications for all new roofing projects and for reroofing projects to the extent practicable unless:

1. The NCRA Manual conflicts with provisions of this document, or
2. The A/E obtains approval from the University to use different details and provisions.

5.5.2.4 Bidding Roofing Systems

Specifications shall include bids for only one type of roofing system. For the purpose of bidding, KEE, NPB, PVC and TPO shall be considered one roofing system. Single-ply and multi-ply roofing systems shall not be bid as alternates.

5.5.2.5 Materials Certification

1. Materials Certifications shall be included in the Specifications as part of DGS-30-326, "Special Requirements for Low Slope Roofing Membranes," that the materials shall be labeled with ASTM certification numbers or other specified product certifications or the Contractor shall give to the A/E the roofing manufacturers certification that the roofing materials being furnished comply with specified ASTM and approved standards.
2. The owner's full-time roof inspector shall verify the materials received are as specified and in accordance with A/E approved shop drawings before roofing materials may be installed.

5.5.2.6 System Evaluation

The A/E responsible for roofing design shall evaluate and specify the roofing system(s) for:

1. Fire resistance rating
2. Wind uplift resistance (including roof system and sheet metal flashing components)
3. Warranty
4. Tear resistance

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. Attachment
6. Resistance to harmful local chemicals
7. Membrane compatibility with insulation
8. Type of membrane seams and joints

5.5.2.7 Single-Ply Membrane (SPM) Specifications

1. Specify SPM completely with latest listed ASTM and performance criteria.
2. SPM, if specified with either manufacturer or brand-name products, shall be specified with three manufacturers and three equivalent products.
3. The single-ply membrane manufacturer's representative shall check installation procedures at start-up and inspect the completed membrane installation.

5.5.3 Non-destructive Evaluation Roofing Surveys

A non-destructive evaluation (NDE) survey uses infrared, nuclear, impedance moisture, electronic field vector mapping or electronic leak detection to locate unacceptable moisture within a roofing system.

An NDE survey is mandatory before a newly constructed roof may be accepted. Depending on the size and condition of an existing roof, a survey may or may not be required before the repair or replacement of a roof. The following outlines requirements for NDE surveys:

1. Equipment, subject to the University's approval, shall be equal to the following:
   a. Infrared: A camera designed for the intended application and capable of taking thermograms. Instrument sensitivity shall permit recognition of areas of wet insulation as small as 6 inches on a side.
   b. Nuclear: A nuclear hydrogen detection (NHD) meter used for the measurements of reflected neutrons that can be linked to the presence of water in the roofing system
   c. Impedance moisture survey: Scanner designed to detect and evaluate non-destructively comparative moisture conditions within roofing and waterproofing.
   d. Electronic field vector mapping (EFVM) or electronic leak detection: Generator and receiver designed for the intended membrane leak detection used for roofing and waterproofing.
2. Operators of equipment shall be certified in the equipment used and licensed as required for by the survey protocol.

3. Surveys
    a. Infrared: Provide a complete survey of the roof or roofs. Outline all anomalies on the roof. Provide a thermogram showing the outlines and daylight photographs of all anomalies. Survey inspection procedures, reports, etc., shall be conducted in accordance with the requirements and procedures in ASTM C1153, "Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging," except as otherwise noted in this section.
    b. Nuclear: Provide a grid, comprising 5′ × 5′ grid unit, to completely cover the roof or roofs. Mark each grid intersection with spray paint. Take readings at the inter-sections and record them on a roof plan. Provide daylight photographs of area of anomalies. Survey inspection procedure, reports, etc., shall be conducted in accordance with the requirements and procedures of ANSI/SPRI/RCI NT-1, "Detection and Location of Latent Moisture in Building Systems by Nuclear Radioisotopic Thermalization," except as otherwise noted in this section.
    c. Impedance moisture survey: Provide a complete survey of all roof or waterproofing areas. Mark, number, and photograph all anomalies on the membrane surface. After field testing is complete submit a report with all anomalies located on a roof plan. Photographs of each anomaly shall be included in the report. Mapping shall be done in accordance with standard practices over the entire roof surface. Survey inspection procedures, reports, etc., shall be conducted in accordance with the requirements and procedures of ASTM D7954, "Practice for Moisture Surveying of Roofing and Waterproofing Systems using Non-destructive, Electrical Impedance Scan," except as otherwise noted in this section.
    d. Special surveys using electrical conductance measurement methods to locate leaks in roofing systems – electronic leak detection or electronic field vector mapping (EFVM): This system may be used on roof areas where full time roof inspector has noted that there is no detrimental moisture observed in the roof system during the daily observations. Provide a complete survey of roof or waterproofing areas as directed. Mark, number, and photograph all anomalies on the membrane surface. After field testing is complete submit a report with all anomalies located on a roof plan. Photographs of each anomaly shall be included in the report. Survey inspection procedures, reports, etc., shall be conducted in accordance with the requirements and procedures of ASTM D7877, "Standard Guide for Electronic Leak Detection methods for Detecting and Locating Leaks in

Waterproof Membranes," except as otherwise noted in DCSM section 5.5. Roof cores shall be taken at all leaks to determine the extent of damage by the leak if roof insulation is below the roof membrane and above the deck. Roof cores may be omitted if the roof inspector is to be present to observe the roof contractor's repair of the roof leak by opening roof and removing wet insulation. Wet insulation is determined in the field by the roof inspector. Fees for the roof inspector and retesting shall be paid by the contractor by change order to the contract. For electronic leak detection, test the roof area on an area by area basis not to exceed 5,000 sq. ft. Readings taken with the receiver shall be done on a 24″ × 24″ grid pattern.

4. Core samples
   Because NDE surveys are not able to measure moisture in roofs directly (nuclear equipment responds to hydrogen emissions, infrared to heat changes), core samples to measure actual moisture content must be taken from surveyed roofs and correlated with NDE readings (see the exception below for roofs with no anomalies). The samples shall be taken as follows:
   a. One is required on roofs showing no anomalies.
   b. On all other roofs a minimum of one dry and one wet core shall be taken from each roof surveyed where anomalies are present. Additional cores are not required if the consultant can show that moisture is not causing detected anomalies. The consultant shall identify such anomalies and explain their cause in a written report to the University.
   c. As many cores as needed should be taken to verify non-destructive testing data results, but no more than five cores shall be taken from any roof area except as noted in the test protocol.
   d. Exception: If no anomalies are shown by the survey equipment and the University's full-time roof inspector was present on the site during all roofing applications and had not noted any roofing applications where moisture was present in the form of rain, dew, mist or entrapped moisture, the requirement for a minimum of one roof core into a newly installed assembly may be waived by the University.
5. Gravimetric analysis
   a. As soon as possible after samples are taken, core should be sealed in air tight containers and taken to a laboratory for analysis.
   b. Analyze samples gravimetrically per ASTM D1864 to determine percent of moisture in any required core sample taken from new roofs and, unless waived for justifiable reasons, from existing roofs.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. Identify all materials in the cores – surfacing, membrane (and number of plies), insulation, vapor barriers, adhesives, etc.

6. Moisture conditions
   a. The surveyor shall correlate survey reading results with actual moisture conditions determined by core samples gravimetrically analyzed. The correlation shall be shown or tabulated on the drawings.
7. Report
   a. The consultant shall submit a written report explaining the problems.
   b. Reports for existing roofs shall:
      i. Identify and describe all anomalies.
      ii. Identify and describe any visual survey defects that may be harmful to the roof.
      iii. Give the causes for each anomaly and defect.
      iv. Recommend alternate courses of corrective action for defects and anomalies harmful to the roof.
      v. Provide the cost estimate for correcting the defects and anomalies.
   c. Reports for new roofs where a design professional is providing construction administration services shall:
      i. Identify and describe all anomalies.
      ii. Identify and describe any visual survey defects that may be harmful to the roof.
      iii. Give the causes for each anomaly and defect.
8. Drawings
   The consultant shall prepare drawings that include the following as a minimum:
   a. Plans shall show all roofs surveyed.
   b. State identification, title, date, and use of the building.
   c. Name, address and phone number of VT PM.
   d. Make, model and serial number of equipment used.
   e. Name of operator and data analyst.
   f. The survey technique used.
   g. Condition of the roof surface at the time of the survey.
   h. Date, time and weather conditions at the time of the survey.
   i. Description of the roofing and waterproofing assembly.
   j. Provide an orientation north arrow and drawing scale
   k. Indicate the area of each roof and approximate overall dimensions
   l. All existing features, equipment, and roof penetrations of whatever nature (such as vents, stacks, drains, hatches, skylights, screens, railings, mechanical equipment, etc.) shall be accurately indicated and identified.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

m. Show and explain all roofing defects and anomalies.
n. Delineate, for an infrared survey, moisture anomalies with contour lines; for a nuclear survey, show all grid point readings and define areas having unacceptable moisture by contour lines. Indicate where core samples were taken. Correlate nuclear grid point readings and infrared contour changes to percent of moisture. Dimension areas recommended for removal and locate them with respect to fixed identify-able features (such as parapets).
o. Provide at least one detail section showing roof construction where core samples were taken; more if there are differences in construction from core to core. Identify surfacing material, membrane product, insulation type and thickness, vapor barrier if used, and deck construction.
p. A statement shall be made of the basis for the unacceptable moisture content levels established for each material present. See survey protocols.
q. Other information as required or listed in the survey protocol.

5.5.4 Reroofing

5.5.4.1 Roof Survey for Reroofing

Before reroofing a facility or making major repairs, the University shall procure a roof survey performed by an experienced and qualified inspection service. See qualifications for a roof consultant/inspection services provider in DCSM section 8.3.5. The roof survey shall use NDE moisture detection methods indicated in DCSM section 5.5.3. For roof repairs or replacement where asbestos materials may be present, an asbestos survey shall be performed and the findings reported in writing.

5.5.4.1.1 Exception

For roofs that are very small or that have reached an advanced stage of deterioration and where a roof survey does not appear cost effective, the University may request a waiver of the roof condition survey after determining the conditions by visual inspection. The request must be accompanied by a roof plan sketch with features noted, a written description of the problems cross-referenced to the plan, an approximate area of the roof, and photographs showing the conditions which support the request. An asbestos assessment is required.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.5.4.2 Reroofing Requirements

If complete reroofing is required for over 25% of the roof area in a calendar year:

1. Provide secondary (emergency) roof drains in accordance with the requirements for new construction.
2. Provide guarantees for new construction
3. Provide insulation in the roof covering assembly in accordance with the requirements for new construction.

5.5.4.3 Reroofing – Secondary (Emergency) Roof Drains in Reroofing Projects

If secondary (emergency) roof drains are not a part of the existing construction, then secondary roof drains shall be provided as part of reroofing work. Structural calculations shall be submitted that demonstrate that the structure is adequate to sustain the accumulated water up to the elevation of the secondary roof drains in accordance with ASCE 7, section 8.5. Scuppers are permitted.

5.5.5 Roof Load

The minimum design superimposed load for flat roofs and roofs with a slope of less than 4 inches per foot shall be as indicated on the follows. Generally, roofs in areas in and west of the Blue Ridge Mountains and the indicated areas of Northern Virginia shall be designed for a minimum design superimposed load of 30 pounds per square foot. Indicated areas east of the Blue Ridge Mountains shall have a minimum design roof superimposed load of 20 pounds per square foot for roof design. Greater live, snow, and/or combination loads shall be used where local experience, calculations, drifting or other conditions dictate.

5.5.5.1 Addition of Loads to Existing Structures

Prior to mounting any antennae, microwave dishes, HVAC equipment or other items on the roof of an existing building, the adequacy of the structural framing to support the additional live, dead, wind, and lateral loads shall be verified by a licensed structural engineer. Consideration must be given to deflection from the added load(s), to potential for vibration, to potential for ponding water and to the consequences of overturning moments on stressed attachments and construction.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.5.6 Low-Slope Membrane Roofing

The following requirements are generally applicable to all low-slope roofs. Contractor-specific requirements for the items listed below are included in the Specifications as part of DGS-30-326, "Special Requirements for Low Slope Roofing Membranes."

5.5.6.1 Roof Slope

1. All new roofs shall slope 1/4″ per foot, minimum, to drains.
2. Dead level valleys are unacceptable. Roof cricket valleys shall slope a minimum of 1/8″ per foot unless impractical.
3. No ponding for any amount of time on new roofs is permitted.

5.5.6.2 Wind Uplift

Roof assemblies shall be designed to resist the uplift loads as calculated using the current VCC edition of ASCE 7 for field, perimeter, and corner conditions. Low slope membrane edge systems, except gutters, shall be designed and installed for wind resistance in accordance with ANSI/SPRI ES-1.

For additional information on wind design see the following:

1. Factory Mutual (FM) P7825
2. Factory Mutual (FM) Property Loss Prevention Data Sheet 1-29
3. Factory Mutual (FM) Property Loss Prevention Data Sheet 1-28
4. Single-Ply Roofing Institute (SPRI) SPRI RP-4 Wind Design Standard for Ballasted Single-ply Roofing Systems

5.5.6.3 Insulation

Unless otherwise required to comply with a manufacturer's roofing system or by University-approved waiver, insulation shall be as follows, except as noted:

1. C or R (per inch) factor
2. Two layers, if thickness permits
3. Staggered joints
4. Roof insulation securement shall be specified in the roofing specifications. Mechanically fasten the first layer to metal deck. Cold applied adhesives and/or low-rise foam products are acceptable for the attachment of the first layer to concrete decks, and for attachment of the individual insulation layers to each other contingent upon meeting FM I-90 wind uplift rating and the specified roofing material manufacturer's warranty.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. Compatible insulation: The A/E shall assure the University that the specified type of insulation has been investigated and is entirely compatible with contiguous, specified roofing materials.

5.5.6.4 Rooftop Equipment

1. See DCSM section 3.1 for safety requirements if rooftop equipment is required.
2. Comply with NRCA Roofing Manual recommendations including minimum height of equipment above the roof membrane when equipment is supported above the roof surface.
3. Design clearances and details for easy re-roofing.
4. Provide prefabricated walks to and around equipment that requires servicing; walks must not block roof drainage.
5. Install equipment and conduit in coordination with the roof manufacturer or installer such that placement does not degrade or negatively interact with the roof.

5.5.6.5 Approved Applicator

The roofing and base flashing applicator shall be approved by the materials manufacturer.

5.5.6.6 Roof Protection

1. Before moving equipment or materials over a roof, the University, General Contractor, roofing contractor, and any of their agents must inspect and document the roof conditions and protect the roof from damage during and following roofing work.
2. Movement of equipment and materials without roof protection shall be cause for the University, General Contractor, roofing contractor, or A/E to stop work until protection is provided and any damage is corrected.
3. The University's roofing inspector shall record all such violations.

5.5.6.7 Acceptable Low-Slope Roofing Membranes

1. Roofs with slopes less than 4-in-12 pitch shall be black EPDM membrane with a minimum thickness of 60 mm.
2. Ballasted systems are not acceptable for new construction.
3. Existing ballast systems shall be replaced with black EPDM with a minimum thickness of 60 mm.
4. All membrane roofs shall have a minimum of 20-year NDL warranty.
5. Mechanically fastened systems are not acceptable.

6. Service walkways shall be a minimum of 24-inches wide and appropriately located to service all rooftop equipment from the roof access point.
7. EPDM membrane shall be obtained from an approved manufacturer. Approved manufacturers include:
   a. Carlisle
   b. Firestone
   c. Versico

5.5.6.8 Plaza Decks

Plaza decks, when constructed over occupied spaces, are considered to be roofs and shall use roofing membranes as indicated in DCSM section 5.5.6.7. Where plaza decks are accessible to personnel, implement the fall protection safety requirements in DCSM section 3.1.

5.5.7 Shingles

1. Natural slate shingles
   a. Shall have a minimum thickness of 1/4-inch.
   b. Have a unit weight of not more than 900 pounds per square.
   c. The basis of design for the color shall be Buckingham Black Slate or similar, as approved by OUP.
   d. The length shall be 18 inches.
   e. The width shall be 12 inches.
   f. Shall match existing shingles if a renovation project where the entire roof is not replaced.
2. Simulated slate shingles
   a. Shall have a minimum thickness of 1/4-inch tapered.
   b. The basis of design for the color shall be EcoStar Majestic Slate or similar, as approved by OUP.
   c. The butt shape shall be a standard square cut.
   d. The length shall be 18 inches.
   e. The width shall be 12 inches.
3. Synthetic slate shall be considered as an alternative to natural slate, with materials to be reviewed and approved by the University. Synthetic slate installation shall require a random mixture of similar dark colors to eliminate a homogeneous appearance.

5.5.8 Standing Seam Metal Roofing Panels

1. Size: nominal 16-inch coverage
2. Seam height shall be a minimum of 1-1/2 inches with a maximum of 2 inches.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. The panels shall be mechanically seamed for double locked side lap.
4. The use of stiffening ribs is acceptable.
5. All standing seam metal roofing shall be manufactured domestically.

5.5.9 Vegetative Roofs

Design considerations for vegetative roofs shall be based on the depth of soil required for the plantings. Selection of the type of roofing, the plantings and system components, the leak-detection requirements, the warranties, and the continuing maintenance will derive from the soil depth.

The A/E shall consult with OUP, Buildings and Grounds, and the university stakeholder throughout the design of the vegetative roof system to develop a solution that balances creativity with long-term maintenance requirements and limitations. The design shall acknowledge the following requirements:

1. Vegetative roofs with a soil depth greater than 4" shall require a fluid-applied asphalt waterproofing system.
2. Vegetative roofs with membrane roofing shall include a leak-detection system.
3. Membrane roofing systems shall have a 20-year warranty for 60-mil applications and a 30-year warranty for 90-mil applications.
4. Vegetative roof systems shall include a 5-year service agreement for the plant material and system components.

5.6 Roof Drainage, Equipment, and Accessories

5.6.1 Gutters and Downspouts

1. For copper gutters and downspouts, there shall be a minimum of 16 oz./sq. ft. of copper.
2. All gutters shall have positive drainage to downspouts. Additional downspouts shall be added to maintain positive drainage in all gutters.
3. Downspouts shall tie directly to the underground storm drainage system.
4. Round profile downspouts are preferred.

5.6.2 Snow Guards

1. Snow guards are to be provided over all entrances with roofs that have a slope of 6-in-12 or greater.
2. OUP shall be consulted on the final snow guard selection.
3. Snow guards shall be mechanically fastened. The use of adhesively fastened snow guards is prohibited.
4. For renovations, consider structure strength before adding snow guards.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.6.3 Rooftop Safety

Fall protection systems shall be permanently installed in new construction. Retrofit fall protection systems shall be installed in all roof replacement projects. See DCSM section 3.1 for more information.

5.6.4 Roof Hatches

1. Roof hatches are to be insulated to the same standard as the subject roof and provided with a hasp for a padlock.
2. Provide roof hatches with a hold-open mechanism.
3. Spring-loaded roof hatches are not acceptable.
4. Alternating tread devices to access hatches are not acceptable.
5. See DCSM section 3.1.1 for safety requirements for roof hatches.

5.7 Doors and Windows

5.7.1 Interior Doors

1. Wood interior doors shall be a five-ply, solid core construction with a minimum size of 3′-0″ × 7′-0″ × 1-3/4″ and have lifetime warranty. All doors shall comply with the ADA Standards for Accessible Design and ANSI 117 requirements.
2. Wood interior doors shall have application-specific HPDL or wood veneer faces approved by the University and applied by the door manufacturer. Doors shall have 3 mm PVC impact edge on stiles in a face-complementing color, and 1 mm black PVC clean edge on top and bottom rails.
3. Doors into and within laboratory spaces shall be fire-rated with factory-installed, clear-glazed vision panels. EHS should approve any exceptions for windowless doors for laboratories.
4. When used, vision panels shall be clear glazed for classrooms and stair doors, and factory installed.
5. Power operators shall be electro-mechanical. The basis of design manufacturer is Stanley.

5.7.2 Exterior Doors

1. OUP shall be consulted on all openings. These include, but are not limited to:
    a. Wood doors – Units selected should match color and grain of historic wood doors
    b. Door hardware – Certain spaces (e.g., lactation rooms) have specific door hardware needs. Include discussion of specialty spaces in keying conference and note special access control needs in door schedule.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. At least one door for each set of entry doors shall be power operated. The left-hand leaf, as viewed from the exterior, shall be the power operated door. Prevailing wind must be considered in the selection of which door shall be power operated; exception to the above left-hand preference shall be taken if the prevailing wind will interfere with proper operation.
   a. Operators shall be electro-mechanical. The basis of design manufacturer is Stanley.
   b. Power operated egress doors shall have an electronic strike or latch to allow power operation during times the building is locked. Power actuated exit devices shall not be used.
   c. Radio controlled remote actuators shall be wall or post mounted. Post mounting shall be the manufacturer's unit unless otherwise directed by the University. Placement of the actuator must be in a fully accessible and visible location.
3. Exterior door electronic power operators shall have auxiliary contacts to allow for card reader and proximity reader activation of the openers.
4. Every exterior door opening shall be prewired for an electronic access control reader that is coordinated with the access control plan.
5. Every exterior door opening shall be provided with a door position switch which will allow remote monitoring and alarming capabilities.
6. All door hardware shall be provided with hex nuts and through bolts.
7. The basis of design for all exit devices shall be Von Duprin 33A/99 series.
8. Provide all exit device trims with forged brass, full escutcheon. Lever trims shall be "breakaway type" with substantial resistance to rotation when locked but allowing the vandalized lever to drop to a vertical, 90 degrees, position when more than 35 pounds of torque is applied.
9. Provide concealed vertical cable exit devices when necessary.
10. All exits not managed by Hokie Passport shall be provided with a deadlatching (deadlocking) latchbolt feature for security and/or for future addition of alarm kits and/or other electrical requirements.
11. The basis of design for all exterior door hinges shall be Select continuous geared hinges #SL14 HD.

5.7.2.1 Double/Pairs of Doors

Pairs of doors, whether dissimilar or similar in size, shall adhere to the following standards:

1. Door opening viewed from the exterior/secure side, the right door shall be defined as the "Primary" door and the left side door shall be defined as the "Secondary" door.
2. No hardware trim is permitted on the exterior/outside of "Secondary" doors.
3. Door hardware shall not be provided and installed in a manner that would allow two doors to be zip-tied, chained, cabled, or any other method of being secured together.
4. Any door designed with a glass lite that creates a gap between the back of an exit device's mechanism case (tube/channel) shall be filled-in.

5.7.3 Door Hardware

1. The basis of design for all locks and latches shall be Best 9 K3 series X15D lever design to accept Cormax 7 pin core.
2. The University Key Shop shall provide all cores and keys that are to be paid for through the project and not the Contractor. A/E and/or Contractor shall provide an approved door and hardware schedule to the University Key Shop.
3. The basis of design for deadbolts shall be Best 82T series to accept Cormax 7 pin core.
4. The basis of design for all interior locks in residence halls shall be networked electronic locks Schlage AD400 series. Networked locks to be installed using wireless infrastructure.
5. The basis of design for networked locks shall be Schlage AD400CY70MTK x RHO x BD x 626 with Virginia Tech custom key with university standard CBORD CS Gold Access Control System.
6. The basis of design for all removable mullions shall be lockable/key removable Von Duprin #KR4954/KR9954.
7. The basis of design for all door closers shall be cast iron cylinder with forged forearms and parallel arms with non-ferrous full covers, LCN 4040XP series.
8. The use of floor closers and concealed closers is prohibited.
9. The basis of design for low energy operators shall be LCN 9500 Senior Swing equipped with an electric strike or electric latch retraction.
10. The basis of design for all electric power transfers shall be Von Duprin EPT10.
11. The basis of design for all electric strikes shall be Von Duprin 6000/6300/6400 series.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.7.4 Electronic Door Access Control

This section provides guidelines for the A/E specification on electronic safety. These items are to be coordinated to meet the other requirements in the DCSM. The A/E shall schedule a meeting through the VT PM with the Hokie Passport Office, VTPD, and building occupants.

5.7.4.1 Selection of Electronic Door Hardware

Selection of electronic door hardware will vary depending on many factors, including building code, facility design and construction, architectural style, and safety.

While situations vary, the following general guidelines shall be followed when specifying electronic hardware:

1. Function shall be fail secure.
    a. Hardware provides free mechanical egress
    b. No connection is required to building fire alarm system
    c. Note that certain safety or fire code provisions may dictate the use of failsafe hardware and interconnection with the building fire alarm system for specific doors. These exceptions must be approved by the UBO.
2. Electrified locks, electric strikes, and electric trim shall be either 12 VDC or 24 VDC.
    a. The University will provide filtered and regulated 12 VDC or 24 VDC to power electric strikes, locks, and trims.
    b. Separate power supplies shall not be provided with the hardware.
    c. Up to 16 low current strikes or trim devices can be operated from a single filtered power supply.
3. Electric latch retraction devices:
    a. These typically require a manufacturer-specific power supply. The high in-rush current dictates conductor size and maximum cable length to power supply.
        i. Maximum cable length may dictate installation of the power supply near the door.
        ii. The power supply must be accessible.
        iii. Where possible, mount the power supply in the access control closet.
    b. Power supplies require 120-volt AC cord and plug connection
    c. Specify hardware which includes battery backup integral to power supply

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4. ADA doors with automatic operators shall be equipped with electric strike or electric latch retraction device.
   a. If pulls are desired on both leaves of double doors, both leaves shall receive electronic hardware (i.e., both doors unlock/unlatch on card swipe).
   b. If electric hardware is not desired on both leaves, the inactive leaf shall not be equipped with an exterior pull.
   c. Double doors with a single active leaf and one inactive leaf must be configured to ensure positive latching of the inactive leaf whenever the active leaf is closed and latched. The preferred solution is to equip the inactive leaf with automatic flush bolt(s) and door coordinator.
   d. Magnetic locks are discouraged due to increased safety concerns (connection to fire system, local physical bypass switch, etc.) and must be approved by the UBO.

In addition to standard electronic hardware which can be activated/controlled via relay contact closure or application of power, the basis of design shall be the following specialty products that are integrated with and fully configurable through CS Gold:

1. Schlage AD-300 networked wired locks
2. Schlage AD-400 networked wireless locks
   a. Note: The Schlage AD-400 is currently the only wireless lock approved for use with CS Gold.
   b. PIMs should be programmed for Dynamic Control Switching (DCS) to reduce PIM to lock communications failure.

These specialty hardware options require far less door and frame preparation than standard hardwired installations, and can in some instances significantly reduce installation costs.

We recommend the Schlage AD series locks not be used on exterior doors because they are not as resistant to weather as the wired options.

5.7.4.2 Infrastructure

Infrastructure for electronic access control projects shall be provided by the A/E and shall include:

1. A dedicated location for installation of access controls
   a. Preference is for a dedicated room/closet with:
      i. Locking door with electronic hardware and card reader

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ii. A minimum of 16 square feet of available wall surface area shall be provided for buildings with 1 to 30 doors; buildings with 31 or more doors will require a minimum of 32 square feet. Any doors that are near this area will swing outward and away from this area.
iii. Controlled temperature and humidity
iv. Minimum two each dedicated 120-volt 20-amp quad receptacle on emergency circuit with generator backup (if available). Facilities with large numbers of controlled doors or extensive use of latch retraction devices may require additional circuits or outlets.
v. Network (data) drop
vi. Open paths/sleeves to pull cable from controls to door locations

b. Accommodation can be made for a less secure space, as long as access to the space is restricted (i.e., no general public) and meets the other requirements noted above.

2. Cable Path
   a. A closed and secure cable path (conduit, flex) from accessible ceiling to points of termination within the door and door frame. Sample sketches are located in the door access details located in the VT Design Standard Detail Library. These are representative sketches intended to convey preferred routes for cable and typical installation details for various components and local conditions. In addition to these line drawings, the points below shall be verified during design and construction.
   b. In many instances access control cables use the same cable paths as NI&S network cables. Conduits, risers, and cable trays must be sized or added to accommodate the access control cables and not interfere with the NI&S network.
      i. AC power shall not be run in the same conduit or junction box as low voltage access control cable.
      ii. Proximity infrared (PIR) sensors are no longer installed unless specifically required.
      iii. Junction boxes shown in the sample sketches may be omitted if the following conditions are met:
         1. Obtain prior written approval by the VT PM.
         2. Individual conduits can be stubbed above doors in a concealed but accessible ceiling.
         3. Conduits are grouped in one location (no more than 12 inches between outermost conduits) to allow for splitting of the composite access control cable bundle and routing of the

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

individual component cables to their points of termination within door and frame.

iv. Conduit routed to door frame shall have the minimum number of wide radius bends required to reach the desired location. In no instance shall bends exceed 180 degrees without an intermediate (and accessible) junction box or pull "L". Minimum conduit size to accommodate composite cable is 1 inch.

v. Pull strings shall be installed from junction box (or stub-out above ceiling) to point of termination in all conduits.

vi. Grouted frames shall be equipped with mortar boxes around electric hinges, electric power transfers, electric strikes, door contacts, etc.

vii. Use of factory installed raceway within hollow metal frames is encouraged.

viii. Where ADA operators are installed:
   1. A minimum of one ADA push button must be hardwired to the ADA operator.
   2. Card reader shall be installed adjacent to the ADA push button, and may share a common conduit run.
   3. ADA operators must be integrated with the access control system to allow access with valid credentials.
   4. Four more 18 AWG conductors are needed to be run to each ADA door to integrate the actuator with the access control system.
   5. Egress will always be allowed.

5.7.4.3 Installation Responsibilities

Power supplies for latch retraction hardware shall be provided by hardware supplier. The University provides the following components and services with respect to access control projects:

1. Squadron access control modules
2. Enclosure for Squadron controls (where required)
3. Card readers – with weather shields and reader splice boxes if applicable
4. Installation services through separate contract shall include mounting and connecting:
   a. Squadron panels
   b. University-provided power supplies
   c. Card readers

   d. Request-to-exit devices
   e. Termination of cabling to electrified hardware provided by the General Contractor

Note that, if desired, door contacts may be prepped and provided by door supplier.

5.7.5 Locksets and Access Control

1. Locksets shall be cylindrical locksets, Series 4000, Grade 1 (ANSI A156.2), 93K lever handle with through bolted trim; round rose; and varying in size between 2-9/16" to 3-3/8" or the largest available size.
2. The basis of design for locksets shall be locksets complete with a combined core and must accept a Best 7-pin interchangeable core, no substitutes. Contractor to work through the VT PM with the University Key Shop to determine how to combinate cores and cut keys.
3. The University Key Shop personnel shall accomplish the final keying and installation of cores. Construction cores may be installed by the contractor during construction, but must be removed prior to beneficial occupancy. The University Key Shop shall have a copy of all construction keys.

5.7.6 Exterior Windows

1. OUP shall be consulted on all openings. These include, but are not limited to:
   a. Windows for punched openings (especially in historic, legacy, or contributing-legacy buildings as identified in the campus master plan) –Use one of the thermally-broken windows selected by OUP as a basis of design.
   b. Stick-built fenestration systems – Generally not an acceptable exterior fenestration system, especially for the campus core and at historic, legacy, or contributing-legacy structures.
2. Exterior glazing shall be insulating glass units meeting the following characteristics and performance criteria:
   a. Passive solar Low-E insulating-glass units with argon gas interspace content.
   b. Outdoor light and indoor light shall be Class 1 (clear) float glass, annealed of kind FT (fully tempered) as specified.
   c. Low-E coating shall be pyrolytic on the second and third surface.
   d. Visible light transmittance shall be 37 percent minimum.
   e. Winter nighttime U-factor shall be 0.38 maximum.
   f. Solar heat gain coefficient shall be 0.55 maximum.
3. Metal windows and storefront shall have thermal break frames and insulating glass.

4. Operable sash: Unless impractical, it is recommended that operable windows be provided in areas that can create effective cross-ventilation in the building if required due to failure of HVAC system. Operable sashes shall be provided with lockable operators. Operable windows in residence halls shall have window screens and first floor windows shall have safety screens.

5.7.7 Horizontal Louver Blinds

Blinds for student rooms in residence halls are 1″ mini blinds in a white color.

5.7.8 Window Shades

1. Window shades in residence halls include:
    a. For common areas, roller shades with a 3% openness in a neutral color. The control should be placed on the right side.
    b. For apartments, black out shades in a neutral color.
2. Window shades in education and general (E&G) buildings are typically:
    a. Roller shades (manual or motorized) with a 3% to 5% openness in a neutral color. Consult OUP for project-specific requirements.

5.7.9 Safety

For more information about safety with doors and windows, refer to DCSM section 3.5.

5.8 Structure

5.8.1 Grouting

The selection of zero or low VOC mortars, grout, and sealants will help to eliminate indoor air quality problems. All floors and wet walls shall receive an epoxy grout. Avoid the use of white and light-colored grouts.

5.8.2 Gypsum Board Assemblies

For residence halls, gypsum wall board shall be impact resistant sheetrock and light orange peel spray finish shall be applied. The light orange peel spray finish is not required for the interiors of faculty and staff apartments or inaccessible areas (e.g., high ceilings).

The Contractor shall provide mock-ups (see DCSM section 1.7.1).

5.9 Design and Finish Criteria

5.9.1 Finish Carpentry

1. Avoid depletion of natural resources by specifying wood species from sustainable sources, such as Forest Stewardship Council (FSC) Certified Wood or regionally harvested wood from abundant species. Avoid use of exported or exotic species such as mahogany that are limited in supply or not sustainably harvested. Products shall be free of urea-formaldehyde binders, copper, and arsenic.
2. Casework may be wood or clad with a plastic laminate.
3. Wood trim is acceptable in certain areas and may be requested if trying to match existing conditions.

5.9.2 Acoustics

1. Acoustics must be a consideration in all university projects. Acceptable forms of acoustic treatment include but are not limited to:
   a. Flooring
   b. Vertical panels
   c. Ceiling treatment
   d. Lighting
2. Classroom A/V, a team within the Office of the University Registrar, shall be consulted on acoustical considerations for future learning space projects.
3. Classrooms should receive acoustical considerations in order to provide an unimpeded learning environment. Consider acoustic standards and reasonably adhere to guidelines set in ANSI/ASA S12.60 Part 1: Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools. Examples include, but are not limited to, the following items (ANSI/ASA S12.60 standard citations in parentheses below):
   a. (5.2.1.1) Unoccupied, furnished learning spaces must not:
      i. Exceed 35 dB (A weighted)/ 55 dB (C weighted)
      ii. Surpass the maximum permitted reverberation times for sound pressure levels (SPL) in octave bands with mid band frequencies of 500, 1000, and 2000 Hz:
         1. Smaller classrooms: 0.6 seconds
         2. Larger rooms: 0.7 seconds
   b. (5.2.2.1) Must comply with HVAC SPL regulations based on type and class.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. (5.5.1) Classroom audio distribution systems, if installed, shall not be used as a substitute for achieving the acoustical design requirements of this standard.
d. (Annex A) Proper testing should be conducted post construction to confirm compliance.

5.10 Partitions

5.10.1 General

1. Metal stud wall framing shall be designed using the Steel Stud Manufacturers Association (SSMA) Product Technical Guide.
2. The structural design of framing members shall be designed for the appropriate loads. The minimum size necessary for the strength and serviceability shall be indicated on the construction documents. Upsizing of members for economy of scale shall be indicated by the fabricator, not the A/E. A member utilizing less than 75% of the proposed member's available strength shall be justified by calculations.

5.10.2 Fire-Rated Assemblies and Fire Stopping

Specify fire-rated plywood for NI&S rooms as blocking. Coordinate with NI&S for locations. Fire-rated plywood logos shall not be painted over and shall remain visible. Plexiglass may be placed over the fire-rated plywood logo.

5.10.3 Blocking and Miscellaneous Carpentry

1. Fire-rated wood blocking shall be provided where required.
2. Residential bathroom cabinetry shall be plywood with finish approved by Student Affairs.

5.11 Interior Signage

1. The product components specified in Appendix E: Interior Signage Standards Manual shall be used to the exclusion of all others.
2. Interior room numbering signs shall match the final room numbering on the drawings. The A/E shall utilize Virginia Tech standard permanent room numbering on the floor plans during the preliminary design review phase. See DCSM section 2.3.1 for room numbering standards.
3. Signage, including donor recognition and electronic signage, shall be identified by the A/E on floor plans and elevations as required for coordinating lighting, power and finishes.
4. Sign installation shall be appropriate for the surface receiving the signage.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

a. Sign mounting on completely smooth interior surfaces such as drywall and glass may be accomplished using double-sided tape.
b. Mechanical fastening shall be used for signage placed on any textured or non-flat surface. These surfaces include but are not limited to the following:
   i. Concrete masonry units (or blocks), brick, or Hokie Stone
   ii. Plastered or skim-coated surfaces

5.12 Lighting

5.12.1 Specifications

1. OUP shall be consulted on the color temperature of interior lighting.
2. Engineering Services shall be consulted on lighting controls for E&G buildings.
3. LED lighting is required for all new and renovation projects.
4. No lighting fixtures shall be specified for which the manufacturer will require a minimum order for the purchase of replacements. Non-catalog and custom lighting fixtures are to be economically justified and avoided whenever possible.
5. Locate light fixture schedule on drawings. Schedule shall contain a description of the fixture, not simply a model number.
6. Use of dimming systems is required for conference rooms, auditoriums and very large classrooms. The dimming range shall be 100% to 1%.
7. All components shall be standard products in production in the USA for a minimum of 5 years. Daylight harvesting systems specification shall also require job specific installation instructions and wiring diagrams for use during installation. Record as-built drawings indicating any changes for these systems shall also be provided upon project completion.
8. Lighting systems installed shall not exceed allowable watts per square foot based on the latest International Energy Conservation Code (IECC) adopted by the Commonwealth of Virginia.
9. Lighting average illumination in footcandles (or lux) shall be as recommended by the latest Illuminating Engineering Society (IES) publication.
10. The halogen MR16 lamp is not allowed; however, the LED MR16 is acceptable.
11. A minimum of two support wires shall be provided per lay-in fixture on the diagonal unless additional support is necessary due to seismic consideration.
12. Light fixtures shall be supported per the manufacturer’s recommendation.
13. Stairwell light fixtures shall be wall mounted above landing floors at a maximum of 8 feet above the finished floor.
14. LED downlights provided shall have replaceable drivers that are easily accessible.

15. LED lighting: Use UL listed 120 or 277 V luminaires with the following performance characteristics:
    a. Minimum lumen efficacy:
        i. 100 lumens/watt for general lighting
        ii. 75 lumens/watt for accent and display lighting, down lighting, and special purpose lighting.
    b. Correlated color temperature:
        i. 4000 K for classrooms and labs
        ii. 3500 K for general lighting and down lighting
        iii. 2700 K for accent and display lighting.
    c. Color rendering index: 90 or better.
    d. LED design life: Not less than 50,000 hours.
    e. Driver system design life: Not less than the LED design life.
    f. Power factor: 0.9 or better.
    g. Design ambient temperatures: 95 °F
    h. Fixture efficacies shall improve the above listed requirements.

5.12.2 Emergency and Exit Lighting

1. Emergency lighting and exit signs shall be provided through the use of fixtures on emergency generator or dedicated battery backups.
2. Connect emergency lights to generator if available. Do not provide battery backup emergency lights if a generator is available.
3. Virginia Tech requires the use of LED lighted exit signs with a typical lamp life of 10 years minimum. Utilize chevron directional indicators when required. Only red lettered exit signs will be used.
4. Coordinate building egress lighting with site lighting such that egress lighting is provided to the public way during power outages.
5. In addition to code requirements, emergency lighting shall be provided in laboratories, classrooms, chemical storage rooms, and chemical receiving areas.

5.13 Toilet, Bath, and Laundry Accessories

1. All new construction and renovation of restroom facilities shall include wall-mounted, high-efficiency hand dryers and at least one “no touch” paper towel dispenser in each restroom.
2. All new construction and renovation of restroom facilities shall include wall mounted soap dispensers that are installed within 5 feet of the sink. Sink mounted dispensers shall not be installed.

3. All consumable dispensers (e.g., soap dispensers, paper towels, and toilet tissue) shall be coordinated with the current vendor.
4. Handwashing areas shall accommodate a minimum soap dispenser size of 12″ H × 7″ W × 5″ D and a minimum paper towel dispenser size of 15″ H × 13″ W × 10″ D.
5. Restroom stalls shall accommodate a minimum toilet paper dispenser size of 12″ H × 21″ W × 5″ D.
6. Accessibility-compliant grab bars shall be stainless steel.
7. Provide wall-mounted shelving in restrooms to accommodate books, backpacks, etc.
8. Mirrors shall be vandal-proof with stainless steel frame.
9. Student rooms in residence halls shall have stainless steel medicine cabinets.

5.14 Interior Stairways

Metal and wood stairways, treads, nosings, and railings are acceptable. Rubber stair treads are acceptable.

The leading edge (intersection of the tread and riser) of stairways shall be perpendicular to the direction of travel. Stairways with the direction of travel at an angle to the leading edge of the stairway are not acceptable.

See DCSM section 3.1.1 for fall protection requirements regarding handrails for stairways.

5.15 Interior Finishes

OUP shall be consulted on:

1. Exposed ceilings – Areas shall be uniformly painted; piping and other mechanical or plumbing systems shall be aligned in orderly and uniform way at right angles.
2. Resilient tile flooring
3. Carpet tile
4. Interior painting – Lobby and front-of-house public areas shall use colors consistent with the University's branding guidelines. The intent of the color restriction is to avoid short-term trends that will quickly appear out-of-date.

5.15.1 General Finishes

1. The preliminary selection of interior finish materials shall take place during the design development phase. Informal discussions of finish materials appropriate to the intended project use shall precede a formal interior design presentation of interior finish boards by the A/E consultant’s interior designer with design

input and approval from CC and OUP. Virginia Tech must then approve the color selections of all finishes.

2. The interior finish boards and the interior finish binder set shall include representative samples of adequate size to visualize colors and patterns. Particular attention shall be given to finishes in public spaces. The finish boards shall be labeled and keyed sufficient to cross-reference to a floor plan presentation and finish legend for easy reference. Templates for the boards and the binders will be provided by CC.
3. Interior finish selections shall be high quality, durable materials, with a strong preference for Virginia based and/or regional manufacturers. Specialty or higher end finishes may be acceptable for public spaces as deemed appropriate during the informal discussions in design development.
4. Avoid imported materials. Avoid custom materials and choose from manufacturers' standard offerings as future replacement or matching is an unnecessary premium in cost.

5.15.2 Wall Finishes

1. General: The use of wallcovering and wall panels provides a durable, cleanable surface that adds aesthetic and/or acoustical properties. Wallcoverings shall not be used in areas that are subject to moisture and shall be used economically.
2. Design considerations: The use of wallcovering and wall panels manufactured with high recycled post-consumer and/or post-industrial content is encouraged. The selection of zero or low volatile organic compound (VOC) primers and adhesives will help eliminate indoor air quality problems.
3. Products: Suitable selections include, but are not limited to:
    a. Vinyl wallcovering with a mostly smooth surface for scrubbing purposes
    b. Acoustical wall panels may be wood, laminate, or fabric
    c. Tile and tile grout
        i. Zero or low VOC mortars, grout, and sealants shall be used.
        ii. Epoxy grout shall be used in all kitchens and restrooms/showers.
4. Wall tile may be ceramic, porcelain, or glass.
5. A variety of tile sizes may be used.
6. All tile patterns must follow manufacturer guidelines. For example, large format tiles (12″ × 24″ and above) must be installed in a 1/3 offset and grout joints typically 1/8″ according to TCNA recommendations.

5.15.3 Painting and Coating – Interior Painting

1. Volatile organic compounds (VOCs): Products used shall not emit VOCs as defined by the EPA, measured by weight in grams/liter and listed herein:
   a. Semigloss and gloss – 0 to 50 grams/liter VOC – low VOC paint
   b. Eggshell – 0 to 5 grams/liter VOC – zero VOC paint
2. Formulation: do not use products that contain formaldehyde, halogenated solvents, aromatic solvents, or heavy metals.
3. Acceptable manufacturers meeting the above specifications include:
   a. Benjamin Moore & Co.
   b. The Sherwin-Williams Company
   c. PPG Architectural Finishes, Inc.
4. Paint all interior and exterior exposed conduit, boxes, and supports except in electrical rooms, mechanical rooms, and janitor closets.
5. Additional residence hall painting requirements:
   a. All walls shall be primed with latex primer and shall be back rolled with a 1/2-inch nap roller.
   b. Room paint shall be in accordance with this section and shall be white semigloss latex and shall be back rolled with a 1/2-inch nap roller.
   c. All paint shall be applied with one coat primer and two coats of finish as a minimum or to cover as needed for colors.
   d. All accent wall paint colors shall be latex and shall be back rolled with a 1/2-inch nap roller.

5.15.4 Floor Finishes

1. Discuss finish requirements with VT Housekeeping during the selection process.
2. Flooring requirements for resident halls:
   a. Student rooms – luxury vinyl tile (LVT)
   b. Laundry room – vinyl composition tile (VCT) or monolithic seamless floor
   c. Cove base – 4-inch rubber; color is application specific.
3. Design considerations: The use of flooring manufactured with high recycled post-consumer and/or post-industrial content is encouraged. The selection of zero or low VOC primers, adhesives, and sealants will help to eliminate indoor air quality problems.
4. See DCSM section 5.18 for laboratory design guidelines.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.15.4.1 Floor Tile

1. Floor tile shall be a through-color/color body product. All products shall be top quality, easy to clean and maintain, and have a DCOF of at least 0.42. Some applications may require a higher DCOF depending on use, expected traffic and wear, contaminants, maintenance, and manufacturer guidelines. Install a coordinating cove tile base where possible.
2. A variety of tile sizes may be used; however, a 6″ × 6″ or smaller size must be used on floors that slope to a drain.
3. All tile patterns must follow manufacturer guidelines. For example, large format tiles (12″ × 24″ and above) must be installed in a 1/3 offset and grout joints typically 1/8″ according to TCNA recommendations.
4. Floor leveling compound is one way to accommodate an uneven existing subfloor. Alternately, choose a smaller scale or flexible floor finish.

5.15.4.2 Resilient Flooring

The use of resilient flooring provides an economical solution for flooring in a variety of areas, including but not limited to, corridors, work rooms, copy rooms, offices, and classrooms. Resilient flooring for laboratories shall meet project criteria for chemical resistance and maintainability. When resilient flooring is used in restrooms or food service areas it shall be properly protected/sealed to ensure it is waterproof.

1. Products include but are not limited to:
    a. Luxury vinyl tile (LVT) or sheet flooring: See DCSM section 5.15.4.3 for further requirements.
    b. Rubber flooring
    c. Vinyl composite tile
    d. Linoleum
    e. Rubber base: Specify rubber cove base, 4 inches high. Avoid the use of preformed interior and exterior corners.
2. Resilient stair treads, risers, and nosings are acceptable.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5.15.4.3 Resilient Tile Flooring

1. Products:
   a. LVT shall meet the following minimum requirements:

Table 5-2. Minimum Requirements of LVT

Construction (Plank and Tile)	Luxury Vinyl Plank or Tile with Micro Bevel Edges
Overall Thickness (Plank and Tile)	0.098 inches (2.5 mm)
Wear Layer Thickness (Plank and Tile)	20 mil
Finish Layer	Urethane aluminum oxide topcoat cured by ultraviolet process with minimum 10-year warranty
Static Load Limit	750 psi
Specification (ASTM 1700)	Class 3, Type B
Heat Stability (ASTM F-1514)	Passes
Stain Chemical Stability (ASTM F-925)	Passes
HUD/FHA Requirements	Exceeds
Flooring Radiant Panel (ASTM E-648)	≥ 0.45 watts/cm², Passes (Class 1)
NBS Smoke Chamber (ASTM E-662)	<450 – Passes

   b. Flooring shall meet composition, size, thickness, squareness, flexibility, dimensional stability, and resistance to chemicals requirements of ASTM F 1700, "Standard Specification for Solid Vinyl Tile," Class III, Type B – Embossed Surface.
2. Accessories:
   a. For patching, smoothing, and leveling monolithic subfloors (concrete, terrazzo, quarry tile, ceramic tile, and certain metals), provide Portland cement-based underlayment. No gypsum products.
   b. For sealing joints between the top of wall base or integral cove cap and irregular wall surfaces such as masonry, provide plastic filler applied according to the manufacturer's recommendations.
   c. Provide transition/reducing strips tapered to meet abutting materials.
   d. Provide threshold of thickness and width as shown on the drawings.
   e. Provide resilient edge strips of width shown on the drawings, of equal gauge to the flooring, homogenous vinyl or rubber composition, tapered or bullnose edge, with color to match or contrast with the flooring, or as selected by the architect from standard colors available.
   f. Provide metal edge strips of width shown on the drawings and of required thickness to protect exposed edges of the flooring. Provide units of maximum available length to minimize the number of joints. Use butt-type metal edge strips for concealed anchorage, or overlap-type metal

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

edge strips for exposed anchorage. Unless otherwise shown, provide strips made of extruded aluminum with a mill finish.

3. Quality assurance:
   a. Examine subfloors prior to installation to determine that surfaces are smooth and free from cracks, hole, ridges, and other defects that might prevent adhesive bond or impair durability or appearance of the flooring material.
   b. Inspect subfloors prior to installation to determine that surfaces are free from curing, sealing, parting and hardening compounds; residual adhesives; adhesive removers; and other foreign materials that might prevent adhesive bond. Visually inspect for evidence of moisture, alkaline salts, carbonation, dusting, mold, or mildew.
   c. Report conditions contrary to contract requirements that would prevent a proper installation. Do not proceed with the installation until unsatisfactory conditions have been corrected.
   d. Failure to call attention to defects or imperfections will be construed as acceptance and approval of the subfloor. Installation indicates acceptance of substrates with regard to conditions existing at the time of installation.
4. Finishing of floors: The A/E shall consult with VT Housekeeping and OUP about the design and specify if the Contractor is to finish the floors.
5. Extra stock: Furnish 5% additional yardage of each resilient floor type required; extra yardage is over and above any overage provided by manufacturer. Normal manufacturing overage not to exceed 10% for under 1,000 yards. Not to exceed 5% for over 1,000 yards. Consult with the VT PM to determine the required quantity of attic stock and determine where it will be stored. Deliver uncut extra stock in clearly marked dust-proof packages prior to commencement of work and store where directed.
6. Warranties: All LVT shall have a minimum warranty of 10 years.

5.15.4.4 Carpet Tile

The use of carpet provides an economical solution for flooring in a variety of areas, including but not limited to offices, conference rooms, and classrooms. Specify top quality aesthetically pleasing products, with characteristics of cleanability and acoustical properties. Color selections shall minimize the showing of dust and/or footprints. Avoid very light, very dark, or solid color carpeting. Avoid the use of cut pile carpeting, instead selecting loop or cut and loop combination for increased durability. High quality carpet is a long lasting, durable product that is easy to maintain over its lifetime. The use of carpet tiles allows damaged or stained tiles to be replaced individually.

1. Products:
   a. Carpet shall meet the following minimum requirements:

Table 5-3. Minimum Requirements for Carpet

Construction	Tufted – Loop or Cut/Loop (non-ortho phthalate construction)
Face Fiber	1. Type 6,6 Nylon preferred, but not required, in heavy traffic areas. The basis of design for Type 6,6 nylon carpet shall be STAINMASTER Antron. 2. Type 6 Nylon for lesser trafficked areas 3. Fibers will contain a soil and stain resistance
Dye Method	Solution/Yarn dyed
Gauge	5/64 preferred, minimum of 1/12 required
Stitches Per Inch	9 or more
Density	5,000 or higher
Primary Backing	100% woven synthetic
Recycled Content	At least 15% pre-consumer
Size	Modular, tile, sizes vary
Static Control	< 3.0 kV when tested under AATCC 134
Flammability	1. DOC-FF-1-70 Pill Test: Passes 2. Floor Radiant Panel: Meets NFPA Class 1 when tested per ASTM-E-648 glue down 3. NBS Smoke Chamber: Less than 450 Flaming Mode. Per ASTM-E-662
Color Fastness	1. Lightfastness: AATCC 16E-1982 – Dark color: Gray scale rating of 4 or better after 160 standard fading hours as compared to AATCC gray scale for evaluation change in color 2. Ozone and gas: AATCC 129-1981 – Rating 3 or better per color AATCC transference scale
Moisture Barrier	1. Passes Moisture Impact at 10,000 cycles 2. Passes British Spill Test
Indoor Air Quality	Manufacturer must demonstrate that carpet is certified under the CRI Green Label Plus Program
NSF 140 Certification	SCS Sustainable Choice Gold

   b. Pattern and Color: Understanding the importance of pattern and color for aesthetics, as well as appearance retention and maintainability, OUP reserves the right to reject any product or manufacturer based solely on pattern and color considerations.
2. Quality assurance:
   a. Dimensions shown on drawings are approximate. It is the flooring contractor's responsibility to verify all dimensions and job site conditions; order sufficient yardage to fully carpet areas as indicated and to fill overage requirements as specified. No substitutions shall be

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

permitted to make up for any shortage of material in overage or in carpet to be installed.

b. Flooring contractor shall be totally responsible for the accuracy of his measurements of total yardage, individual floor yardage, and dye lot yardage requirements; no additional compensation shall be allowed for shortage of materials.
c. Dye lots: All carpet of the same type in continuous areas shall be from the same dye lots. Transition from one dye lot to another shall be detailed on shop drawings and approved by OUP.
d. Inspect surfaces to receive carpet and verify that all such work is complete to the point where this installation may properly commence. In the event of a discrepancy, notify construction manager. Do not proceed with the installation in areas of discrepancy until all such discrepancies have been fully resolved. Start of carpet installation indicates acceptance of subfloor conditions and full responsibility for completed work.

3. Extra stock: Furnish 5% additional square yardage of each carpet type required for renovations and verify the amount of additional square yardage required with the VT PM for capital projects. Extra square yardage is over and above any overage provided by manufacturer. Normal manufacturing overage is not to exceed 10% for under 1,000 square yards and not to exceed 5% for over 1,000 square yards. Consult with the VT PM to determine the required quantity of attic stock and determine where it will be stored. Deliver uncut extra stock in clearly marked dust-proof packages prior to commencement of work and store where directed.
4. Warranties:
   a. All carpet tile shall have a limited commercial lifetime warranty. The warranty should protect against product failure covering all costs including freight, labor, and material for the following:
      i. Edge ravel
      ii. Back delamination
      iii. Superior tuft bind in high traffic environments, wet or dry
      iv. Static protection as stated above
      v. Moisture barrier – Pre-coat and backing
      vi. Wear – No more than 10% of face tarn loss
      vii. Adhesive failure
   b. Cationic stain resistance – Stain resistance properties must be permanent and not removable by commercial cleanings or abrasive wear. Under GSA requirements, stain resistant carpets must score no less than

8.0 (10.0 is the best) on the AATCC Red 40 stain scale. Test sample must first be exposed to 100 revolutions on the Taber Abrader (1,000-gram weight per H-18 wheel) and then abraded area must be stain tested using AATCC Test Method 175. Topical stain resistance treatments will not be acceptable. Stain resistant properties must be inherent and warranted for fifteen years.

   c. Bleach resistance – Carpet products will resist color loss from diluted bleach applications for a period of fifteen years from the date of original installation. Diluted bleach applications are defined as spills or splashes on the carpet of diluted bleach solutions (10% or less) of the type normally used for cleaning or disinfecting purposes.

5. Environmental attributes – LEED criteria
   a. Carpets should be selected to help the project achieve the goal LEED status.
   b. Carpets and adhesives must meet the low emitting materials standards as outlined in the USGBC LEED criteria.
   c. End of life reclamation: It is preferred that carpet tile have an existing methodology actively in place for landfill diversion.
6. Accessories:
   a. Adhesives: Waterproof, non-flammable carpet adhesive recommended and approved by carpet manufacturer in writing for compatibility with carpet backing; have no calculated VOCs, be non-flammable, and meet the criteria of the CRI Green Label Plus certification program. Safety data sheets (SDS) and samples are required on product used. Adhesive must have lifetime bond warranty from manufacturer.
   b. Miscellaneous materials: As recommended and approved in writing by the manufacturer of carpet, and selected by the flooring contractor to meet project circumstance and requirements.

5.15.4.5 Rugs and Mats

Recessed walk-off mats or grates shall be provided at all primary entrances to buildings. Primary preference is to use walk-off carpet.

5.15.5 Ceiling Finishes

Ceilings may be exposed, have acoustic properties, contain decorative elements, and be constructed of gypsum wallboard (GWB).

5.15.5.1 Acoustical Tile Ceilings

1. Suspension systems shall have exposed tee profile fabricated of hot galvanized steel with baked on painted finish. All spaces using acoustical ceiling tile (ACT) must have a minimum NRC rating of 0.70 and a minimum CAC rating of 35, unless otherwise approved by OUP. Approved manufacturers include, but are not limited to:
   a. Armstrong
   b. USG
   c. CertainTeed
2. Products:
   a. ACT standard 2′ × 2′ × 5/8″ Tegular (on a project-by-project basis 2′ × 4′ × 5/8″ – discuss with OUP and Engineering Services), mineral fiber panels, for use in offices, classrooms, conference rooms and corridors.
   b. ACT specialty 2′ × 2′ × 5/8″ Tegular (on a project-by-project basis 2′ × 4′ × 5/8″ – discuss with OUP and Engineering Services) for use in wet areas and laboratories to resist moisture, steam and chemicals.
   c. Suspended grid: Heavy duty (HD) or intermediate duty (ID) exposed tee grid system with 15/16″ standard grid dimension or 9/16″ narrow grid dimension. Specify fire-rated grid if required.
3. Thin line grid shall not be used on campus.

5.16 FURNISHINGS

5.16.1 Common Work Results for Furnishings

1. Furniture shall meet ANSI/BIFMA standards.
2. Universal Design shall be considered in the following aspects when selecting furniture:
   a. Equitable use – The design is useful and marketable to people with diverse abilities.
      i. Provide the same means of use for all users; identical whenever possible; equivalent when not.
      ii. Avoid segregating or stigmatizing any users.
      iii. Provisions for privacy, security, and safety should be equally available to all users.
      iv. Make the design appealing to all users.
   b. Flexibility in use – The design accommodates a wide range of individual preferences and abilities.
      i. Accommodate right- or left-handed access and use.

c. Simple and intuitive use – The design is easy to use and understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
    i. Eliminate unnecessary complexity.
    ii. Be consistent with user expectations and intuition.
d. Perceptible information – The design communicates necessary information effectively to the user, regardless of ambient conditions of the user's sensory abilities.
    i. Maximize "legibility" of essential information.
    ii. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).
    iii. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.
e. Tolerance for error – The design minimizes hazards and the adverse consequences of accidental or unintended actions.
    i. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
    ii. Provide fail safe features.
f. Low physical effort – The design can be used efficiently and comfortably and with a minimum of fatigue.
    i. Specify furnishings which allow user to maintain a neutral body position.
    ii. Use reasonable operating forces.
    iii. Minimize sustained physical effort.
g. Size and space for approach and use – The design provides the appropriate size and space needed for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.
    i. Provide a clear line of sight to important elements for any seated or standing user.
    ii. Make reach to all components comfortable for any seated or standing user.
    iii. Accommodate variations in hand and grip size.
    iv. Provide adequate space and infrastructure for the use of assistive devices or personal assistance.

3. During the preliminary design phase, furniture and equipment plans are submitted to demonstrate the functional use of space. Virginia Tech's design review process includes review and input on these floor plans by OUP and the e

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

nd user. These plans shall be used as the basis for locating receptacles, switches, data outlets, lighting, etc., during the remainder of the design process.

4. Based upon the above referenced floor plans, the A/E shall provide outline specifications and a budget cost estimate reflecting appropriate vendor pricing (discounts, freight, delivery, installation) for Virginia Tech's use.
5. The A/E contract may be amended to include professional interior design services related to furniture selection and procurement or Virginia Tech may enter into a separate interior design contract defined by the VT CPSM.
6. The design and procurement process will be thoroughly defined for project. Under the terms of the interior design contract particular attention shall be given to furnishings in public spaces.
7. All furniture plans shall be labeled and keyed sufficiently to cross-reference to specifications and procurement documents for easy reference.
8. Plan layouts and furniture selections with respect to maximizing daylight and access to views for all building occupants. Consider lower panels and glazed panels for systems workstations. Avoid the use of panels that are 80 inches or higher that may obstruct adequate air flow and daylight penetration.
9. Furniture items selected shall emit zero or very low amounts of VOCs to eliminate problems associated with off-gassing and indoor air quality. Fabrics shall be flame retardant.
10. Furniture and upholstery selections shall include the following design strategies wherever possible:
    a. Post-consumer and/or post-industrial recycled content.
    b. Products with a minimum 10-year warranty; greater than 15 years is preferred.
    c. Materials that have been extracted locally or regionally. Furniture selections shall be high quality, durable items that are manufactured within a 500-mile radius of the project site, with a preference for manufacturers with established environmental policies in place.
    d. Certified wood products or sustainable species from abundant, local sources.
    e. Rapidly renewable materials (such as straw, wheat, sunflower board).
    f. Energy efficient task lighting.
    g. Products/materials free of formaldehyde, halogen, heavy metals, polyvinyl chloride, chlorine, plasticizers, antimony, harmful dyes, and topical treatments.
    h. Products/materials that are safely disposable, recyclable, or biodegradable.

i. Fabrics that are durable, minimum 80,000 double rubs, 100,000 preferred.
j. Fabrics that are antibacterial and easy to clean.
k. The basis of design to provide permanent stain protection for fabrics shall be Nanotex finish or equal. Equivalent stain protection shall ensure that spills bead and roll off preventing stain from absorbing into the fabric. The finish shall be applied at molecular level, adhered to fibers of the fabric and last the lifetime of the fabric.
l. The use of leather should be avoided. If the use of leather is approved by the University, specify only vegetable tanned leather.

5.16.2 Casework

Casework may be wood, wood veneer, or clad in a plastic laminate (preferred). Acceptable countertops products include metal, plastic laminate (P-LAM), glass, stone, solid surface, and quartz.

5.16.3 Storage Specialties

1. All residence halls shall have a key cabinet with a minimum of 32 keys located somewhere in the common areas of the first floor of the building. Consult with Student Affairs on project-specific key cabinet requirements.
2. Housekeeping supervisor’s office closets shall have a key cabinet installed with the following requirements:
   a. Cabinet shall be constructed of a minimum of 20-gauge steel.
   b. Finish shall be baked on enamel, or an equal approved by University Operations.
   c. Hinge shall be concealed.
   d. Lock type shall be keyed.
   e. Minimum size shall be 12″ × 12″ × 2″.
3. Housekeeping closets shall have a minimum footprint of 8′ × 5′.
4. Housekeeping equipment closets shall be located on the main or first floor. Equipment closets shall have double doors and a footprint of 12′ × 8′.
5. In addition, housekeeping closets and housekeeping equipment closets shall have:
   a. A floor sink, 30″ × 30″ size, that meets the requirements in DCSM section 6.6.6.8. The sink should be located in the corner of the closet, if possible.
   b. Supply shelves located on at least two walls. Shelves shall be at least 12″ deep.
   c. A closet organizer and tool holder.
   d. At least 4 GFCI electrical outlets.

e. A personal locker.
f. Wall space to accommodate a cleaning solution dispensing system. The basis of design shall be Diversey J-Fill.
g. Floor space to store equipment.

5.16.4 Whiteboards

All whiteboards should have a board finish that resists residue or "ghost marks" on the surface after markings have been erased (ceramic steel or equivalent).

Mobile whiteboards should be two-sided and have casters are designed to roll smoothly over carpeted and non-carpeted level floor surfaces. Casters should have a locking mechanism to secure the markerboard in place.

Whiteboards should have the option for a magnetic surface.

OUP will provide requirements for frame finishes and colors for the whiteboards.

5.16.5 Dry Erase Coating

1. Volatile organic compounds (VOCs): Low volatile organic compound (VOC) content of less than 50 grams per liter to meet Green Seal standards for paints and coatings.
2. Durable, long-lasting surface with 10,000+ scrub cycles and excellent stain removal.
3. Class A rated for fire safety in accordance with ASTM E-84; classified as insignificant flammability hazard by the Hazardous Material Identification System.
4. Level 5 finish required.
5. 10-year warranty minimum.

5.16.6 Residential Furnishings

5.16.6.1 Residential Kitchen Appliances

For residence halls: The basis of design for kitchen appliances shall be GE or equal and ADA Accessible.

5.16.6.2 Desks and Bedroom Furnishings

Examples below are presented for guidance only. Actual furniture will be selected by project. Consult with Student Affairs about furnishings for resident rooms during project design.

1. Virginia Correctional Enterprises (VCE):
   a. Period bed ends with springs – Item #3195020000, 36″ × 80″

b. Period loft kits – Item #319502loft
c. Right hand desk – Laminate top oak wood drawer item #311002traw, 30″ H × 40″ D × 43″ W
d. Left hand desk – Laminate top oak wood drawer item #311002law, 30″ H × 40″ D × 43″ W
e. Dressers – Upper quad item #317202-vtaw, 38″ H × 23″ D × 29″ W
f. Wardrobe: Item #31605020002, 35.5″ H × 40″ W × 25″ D, with two drawers at the bottom

2. Sauder Education, desk chair – Sauder Trey chair Item #VT 33912, 36″ H × 27″ D × 24″ W

5.16.6.3 Metal Lockers

Lockers should be 12″ wide at full height, metal with a louver door, and include a shelf and hooks.

5.17 Equipment

5.17.1 Foodservice Equipment

For dining halls, kitchen design firms shall be selected by Student Affairs for non-capital renovation projects.

5.17.2 Foodservice Storage Equipment

Specify water cooled units and remote compressors when possible. Consider maintenance access in the design.

5.18 Laboratory Design

5.18.1 Scope

The following requirements apply to all new laboratory design and construction as well as all laboratory renovations at Virginia Tech. In this context, a laboratory is defined as a space where chemical, biological, or radiological materials are used for research, teaching, or analytical services.

5.18.2 Laboratory Access and Egress Issues

1. Means of egress
NFPA 45 section 5.4, 2015 and/or OSHA 1910.37 require more than one means of egress be provided where high-hazard research operations (explosion hazards, compressed gas cylinder use, etc.) are anticipated. Clear access to each means of egress must be assured by the design of the research space. However, EHS

recommends every laboratory using any hazardous chemicals be designed with more than one means of egress.

2. Flow of traffic
   When labs are designed or renovated, the flow of traffic toward the means of egress must take a path of "diminishing hazards," i.e., the hazard presented by the anticipated research operations must diminish in the direction of egress travel. For this reason, lab seating, desks, computer stations and lounge areas shall be located closest to the means of egress, while fume hoods, chemical storage and bench top chemical work stations shall be located farthest from the means of egress (OSHA 1910.37(a)).
3. Aisles
   Major aisles shall provide a minimum width of 5 feet to allow for the passage of personnel and equipment safely down the aisles. Major aisles must align in the direction of egress travel. All other aisles shall provide a minimum width of 36 inches unless a greater width can be anticipated from the character of the research that is to be conducted. Consider ADA requirements as part of laboratory design.

5.18.3 Laboratory Safety Equipment

See DCSM section 3.9 for information about laboratory safety equipment.

5.18.4 Building Systems

1. Design strategy: The A/E shall ascertain the character of research and operations that are to be conducted in the area. Where emergency power is required, the A/E shall investigate alarm systems to alert during power failure.
   a. Special consideration shall be given to areas where general surface decontamination will be performed using sprayed disinfectants and/or water, where large sources of water will be present (e.g., aquatics and fisheries), and where a higher potential for electric shock may be present. In such areas, ground-fault circuit interrupters and wiring methods approved for damp/wet locations shall be provided as appropriate.
   b. Bulk chemical storage and dispensing areas shall be designed in accordance with Article 500 of the NEC as either Class I Division 1 or 2 as appropriate for the intended use. A ground bar shall be provided in dispensing areas to facilitate grounding to eliminate electrostatic discharge during dispensing operations.
   c. Consideration shall be given to providing emergency power for critical research equipment (very low temperature freezers, equipment that

protects valuable specimens, hazardous exhaust systems, etc.) as practical within the constraints of the existing building systems and budget. Coordinate with VT PM on project-specific requirements.

d. If the laboratory operations, require access to significant amounts of refrigeration or below 0 °C materials storage, the A/E should consider dedicated low temperature storage rooms or coolers. Emergency power shall be provided these storage areas.
e. Copper piping for vacuum and compressed gas distribution systems shall be purged with nitrogen. An oxygen-free nitrogen flow through the pipe shall be provided during brazing.

2. Cutoff Switches: Consideration shall be given to providing wall-mounted emergency stop switches in research areas where high-power or high-amperage research operations will be conducted on live electrical systems. Such switches shall be strategically located so that they are readily accessible to the occupants of the space. A lockable disconnect shall be provided in the immediate vicinity of fixed equipment that will be installed if such equipment incorporates multiple sources of energy.

5.18.5 Laboratory Ventilation

1. Ventilation and air balancing:
   a. For new buildings, air balancing for hoods must be done at the same time as the other mechanical ventilation systems in the building.
   b. Where lab activities involve the use of chemicals, air balance shall be designed to ensure a negative pressure relation between the lab and existing corridors, offices, break rooms and other support spaces.
      i. There is one exception to this rule. Bio-safety laboratories may require a positive pressure or equivalent pressure, but these instances must have other containment in place to ensure that airborne pathogens are not allowed to escape into non-lab spaces.
2. Laboratory ventilation systems (supply air – velocity and entry into labs):
   a. Supply system design shall comply with the latest adopted version of NFPA 45, Standard on Fire Protection for Laboratories Using Chemicals.
   b. For lab spaces, operable windows cannot be relied upon to meet outside air requirements provided by the mechanical code.
   c. Supply air must be tempered and delivered at a velocity that will not create occupant discomfort.
   d. Supply air diffusers and grilles must be placed a minimum of 4 feet from the face of any fume hood to prevent losses from the fume hood due to

turbulent flow. Where this is not practicable, the diffusers or grilles must have directional flow to minimize air loss/spilling from the hood face.
   e. Operable windows are not permitted in lab spaces with fume hoods or where lab air change rates are required for occupant safety.
   f. Transfer ducts are not permitted in laboratory spaces.
3. Recirculation of laboratory room air: No laboratory exhaust-air, or air that is potentially contaminated with chemicals or airborne radioisotopes may be mixed and recirculated to non-laboratory spaces.
4. Continuous ventilation of chemical labs: All labs that utilize chemicals must be constantly ventilated. This is also true for chemical storerooms, compressed gas storerooms, and central storerooms that are utilized as shipping/receiving areas for chemicals.
5. The installation of oxygen sensors is required when large quantities of cylinders containing inert gases or containers containing cryogenic liquid are planned for storage in enclosed spaces where there is the potential to reduce oxygen levels below 19.5%.
6. Energy saving set-backs:
   a. Where the design strategy will use a lower minimum ventilation rate during unoccupied periods, the set-back level may not be lower than six air changes per hour unless approval from EHS is obtained. In order to utilize such a system, occupancy sensors which provide full lab coverage must be provided that will bring the ventilation back up to the "occupied laboratory" ventilation rate immediately.
   b. Occupancy sensors shall be ceiling-mounted, hardwired, and utilizing dual technology. In addition, the sensor(s) shall provide complete lab floor coverage at desktop activity (i.e., small movement) and fail in the occupied state (component failure or loss of power).
   c. Maximum ventilation rates are to be established during the design and commissioning processes and be the greater of that required for cooling/heating loads or make-up air to maintain desired lab offsets.
   d. Laboratory air controllers for both supply and exhaust air terminal devices shall have the capability to accurately control to a minimum setpoint equivalent to four air changes per hour, in the event this lower value is approved or allowed in the future.
   e. Laboratory ventilation systems are to be designed in accordance with Classification of Laboratory Ventilation Design Levels, ASHRAE TC 9.10 2018 or current edition. It is incumbent upon the project design team to invest in an understanding of not only the immediate program goals for laboratory

spaces but also the long-term needs for program flexibility. Such discussions shall involve members of the project planning committee, Facilities Services, and EHS.

f. Energy setbacks that allow a reduction in hood face velocity rates to less than 60 feet per minute (linear feet per minute) are not allowed.
g. Energy setbacks that allow a reduction in hood face velocity rates to between 60 LFM and 80 LFM are not allowed except when occupancy sensors, installed and confirmed to provide full lab coverage, are used to establish unoccupied modes for the lab. In addition, fume hoods must be rated and tested to contain vapors at the proposed reduced face velocity. It also must be confirmed that the unoccupied ventilation level does not reduce ventilation levels to fewer than 6 air changes per hour. Reductions to fewer than 6 air changes per hour require approval from EHS.
h. Proximity sensors (those mounted to the face of the hood) are not allowed nor are face velocity setpoint reductions in an occupied lab.

5.18.6 Laboratory Exhaust

5.18.6.1 Exhaust Design

1. Auxiliary supplied air hoods are not to be used unless special energy conditions or design circumstances exist and can only be used with the approval of EHS.
2. Commingling or mixing of general laboratory exhaust and exhaust directly from fume hoods is allowable as long as it is accomplished in compliance with any applicable building and life safety codes.
3. Exhaust stack discharges: Dispersion modeling shall be conducted when required by ASHRAE TC 9.10, or as directed by the University, and exhaust stack discharge shall be in accordance with ASHRAE Handbook – HVAC Applications and ANSI/AIHA Z.9.5, current editions. Exhaust stack discharge shall be at least 3,000 feet per minute except as allowed by ANSI/AIHA Z9.5 and when approved by EHS.
4. Require appropriate weatherproof caution labels attached to outlet end of exhaust duct systems where warning of dangerous chemical fumes will be necessary for the protection of workmen in the vicinity.
5. Duct lines and duct risers shall be constructed of stainless steel when used for fume hood exhaust or a combination of fume hood exhaust and general laboratory room exhaust.
   a. The duct shall be round 316 stainless steel ductwork with welded seams and flanged or welded connections. The stainless steel ductwork shall be

run from the point of collection at hood connections to the main riser for that portion of the building.

   b. Ductwork and duct risers used only for general laboratory room exhaust may be constructed from coated or suitable anti-corrosion materials. Ductwork shall be run from the room exhaust grilles to the main riser for that portion of the building.
   c. If the general laboratory room exhaust will be joined with fume hood exhaust, the ductwork and risers from that point of connection to the exhaust discharge shall be constructed of stainless steel.

6. No heat recovery wheels (or any other technology which does not completely separate the exhaust and intake airstreams) will be considered for energy recovery building exhausts which handle fume hood exhaust, whether combined or not.
7. Variable air volume control dampers controlling the exhaust flow from fume hoods and general room exhaust shall fail OPEN upon loss of control power or control air.
8. In the event of a loss of power to the building, provisions need to be made by the Engineer to maintain negative pressure without causing excessive negative pressure in necessary lab spaces while allowing occupants safe egress of building and protect the mechanical equipment from nuisance freezing events. Coordinate specific requirements with EHS through the VT PM.
9. Regardless of the type of fan used the vendor shall certify dispersion performance of all fume hood and hazardous exhaust systems based on as-built conditions (with the system running in a controlled mode and design conditions too).
10. All laboratory exhaust air ducts shall be pressure tested, documented, and results submitted to the VT PM.

5.18.6.2 Chemical Fume Hoods

Laboratory fume hoods are ventilated enclosures designed to provide a safe working area for laboratory activities involving hazardous materials, generated fumes, aerosols, gases, and particulate matter. To operate satisfactorily, air is removed from this enclosure at an optimum face velocity. Require velocities measurable at the maximum face area of the hood, with maximum allowances for hood, filter, and appurtenance static pressure losses within the specified limits.

1. Chemical fume hood exhaust
    a. No fume hood may exhaust out of windows, through side-mounted louvers or other building orifices until reaching the roof.
    b. Laboratory exhaust containing chemicals must be under negative pressure to the point of discharge at the roof.
2. Chemical fume hood exhaust fans
    a. All new exhaust stacks for fume hood exhaust shall be a high plume dilution-type laboratory exhaust fan.
    b. All laboratory fans shall be direct drive. Belt driven fans are not permitted.
3. Fume hood testing
    a. All hoods shall be ASHRAE 110 factory-tested before installation.
    b. All newly installed, renovated, or relocated hoods shall be commissioned to ensure proper operation prior to use by laboratory personnel. All hoods shall be ASHRAE 110 as-installed tested before use. Tracer gas containment tests shall be conducted per ANSI Z9.5-2012.
    c. Face velocity shall be verified for all hoods installed during commissioning and a sticker shall be placed on the front of the hood frame before the hoods can be used by lab occupants.
    d. EHS must be notified of all new hood installations and all commissioning chemical fume hood testing reports shall be provided to EHS.
4. Minimum airflow velocity requirements: Face velocity must be in the 80 to 120 LFM range at the safe operating sash height as set by the manufacturer unless permission for other velocities is approved by EHS.
5. Certification: A label of certification must be placed on each hood by the authority having jurisdiction before occupation of all new labs or before use of all newly installed hoods.
6. For energy setbacks, see DCSM section 5.18.5.

5.18.6.3 Chemical Fume Hood Design

1. General
    a. All equipment shall be installed per manufacturer's recommendations.
    b. Chemical fume hoods and its associated ductwork and fans shall be selected for each application with consideration of the actual and potential use in mind.
    c. Submittals for all chemical fume hoods and bio-safety cabinets shall be provided to EHS for approval prior to purchase of equipment.
2. Automatic sash closure devices are not permitted.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Hoods used with flammable materials: Hoods and ductwork associated with work involving flammable materials shall be constructed completely from non-combustible materials. A lip shall be present inside of the hood to prevent the escape of material in case of spill.
4. Toxic gas cabinets: Gas cabinets for toxic or highly toxic gas cylinder storage shall comply with Chapter 50 of the Virginia Statewide Fire Prevention Code regardless of the quantity of gas stored or used.
5. Perchloric hoods: Perchloric hoods are required when perchloric acid of any concentration is heated or when solutions of greater than 72% perchloric acid are used. Perchloric hoods shall be constructed to allow for a wash-down of the ductwork. This system shall be designed to activate automatically, periodically, and manually. The ductwork for perchloric hoods shall not be manifolded and must exhaust directly to the roof.
6. Hydrofluoric acid use in fume hoods shall be restricted to use in chemical fume hoods specifically designed for hydrofluoric acid resistance. Resistant hoods shall have polycarbonate sashes (Lexan or equivalent) to prevent fogging and etching of the sash. Perchloric hoods are not adequate for this purpose.
7. Radioisotope hoods: Radioisotope hoods shall be constructed so that the surfaces are seamless and impermeable to solvents. Where the radioisotope use requires that the exhaust be filtered before being discharged, the filters shall be positioned for ease of access. The VT EHS Radiation Safety Officer must approve all radioisotope hoods.
8. Fume hood flow-rate alarms
    a. Every new fume hood installation shall have an audible and visual alarm, warning of unsafe airflow and/or to indicate to the user when the airflow deviates from the set point.
    b. The alarm shall be readily visible to the user during use of the fume hood.
    c. The design of the alarm should ensure that only authorized persons are able to adjust the set point.
    d. For new buildings and capital renovations and where feasible on non-capital renovations, the alarm shall remain functional in the event of loss of main electrical power. Alarms shall be connected to a backup generator; battery back-ups are not allowed.
9. Fume hood location: No lab design or lab renovation shall allow for fume hoods to be located within 10 feet of egress doors from the area except as permitted by EHS. Where hoods are located within 10 feet of an egress door,

a secondary means of egress must be provided in a path of diminishing hazard unless otherwise permitted by EHS.

10. Fume hood diversity
    a. Fume hood diversity, as used in ventilation design, refers to designing and operating a system (such as hoods on a plenum) at a lesser capacity than the sum of the existing parts (hoods) when running at peak demand. There may be opportunities to design research buildings to accommodate less than 100% diversity. Each of these design strategies must be visited on an individual basis.
    b. Where the building or renovation is designed for the academic lab rather than the research lab, 100% diversity should be considered. This subject shall be visited early in the design and construction planning meetings/process.

5.18.6.4 Other Laboratory Exhaust Devices

1. Local exhaust ventilation
    a. In general, the design of canopy hoods and related local exhaust systems shall comply with *Industrial Ventilation, A Manual of Recommended Practice*, current edition, American Conference of Governmental Industrial Hygienists, or another accepted industry standard.
    b. Canopy hoods shall not be used to control exposure to chemical, dust or fume hazards unless such processes are enclosed and employee exposure will not occur. Canopy hoods may be used to control the release of heated gases or vapors which do not present objectionable odors, health risks, or exposure issues of concern. The hood design and capture velocity must be sufficient to capture the contaminants. Testing of these hoods to ensure performance must be performed and documented.
    c. Local exhaust ventilation systems incorporating snorkels, flanged openings and similar intake openings may be used where it is inefficient or impractical to use a conventional fume hood. These must be installed per manufacturer specifications. Where used, these hoods must be tested for exhaust capacity and the results documented during commissioning.
2. Ductless fume hoods
    Ductless fume hoods shall not be used unless reviewed and approved by EHS. Where unknown chemical quantities, materials, or flammable liquid and/or volatiles in large quantities are used in the laboratory, the ductless hood will be prohibited.

5.18.7 Chemical Storage

1. Flammable storage cabinets
   a. Cabinet design
      i. Flammable storage cabinets must have approval by a nationally recognized testing laboratory such as UL.
      ii. Flammable storage cabinets may be under counter, installed under the fume hood, or free standing.
   b. Venting cabinets
      i. If the cabinet is vented to a local exhaust system, the system must be designed to accommodate this additional volume of exhaust air. The material used to ventilate the cabinet must be non-combustible and a fume hood cannot be the method of ventilation for cabinets that are not integral to the fume hood. Chemical cabinets built into the base of fume hoods may be vented directly to the hood.
      ii. When venting chemical cabinets, the venting material must be of equal or greater fire resistance than the cabinet itself – regardless if the cabinet is used for flammable storage. Exhaust from chemical storage cabinets may not be mixed via (plenum) ductwork with flammable storage exhaust ventilation until the vent lines have reached the major ventilation duct.
      iii. When a flammable cabinet is ducted and exhausted directly to a hazardous exhaust system, a flash-back arrestor must be installed at the exhaust bung.
2. Chemical storage cabinets
   a. Chemical storage cabinets must have approval by a nationally recognized testing laboratory such as UL. The cabinets may be fixed under fume hoods, counter mount or free standing.
   b. Shelving must be of a chemically resistant material.
3. Chemical storage rooms
   Where an entire room is dedicated to chemical storage, special considerations must be taken for the worst-case scenario. The following specifications are for a typical flammable storage room:
   a. The room must be sprinkler protected.
   b. The room must have floor dikes and sealed drains, where applicable. The dikes must be of sufficient depth to capture any foreseeable spills.
   c. Floor seams must be sealed. It is preferred that monolithic construction with seals from wall to floor is used in all chemical storerooms. Floor sealant shall be installed as an integral cove base and shall extend 4″ above the floor.

4. Waste accumulation areas
    a. EHS prohibits the designation of waste accumulation rooms or areas in new designs.
    b. Designs shall include consideration for an area within each lab for placement of active and storage of full waste accumulation containers.

5.18.8 Laboratory Furnishing

1. Lab Shelving and Benchtops
    a. Shelving and benchtops in chemical laboratories must be chemically impervious, and of fire-resistant construction. Wooden shelves shall not be used where chemicals may be stored unless coated with a chemically resistant, fire-resistant surface. Chairs used in laboratory work must be covered with a non-porous material that is chemically resistant and can be easily cleaned.
    b. Shelving for radioisotope labs must be impervious to reagent spills and joints must be sealed. Stainless steel or black epoxy resin shelving materials are preferred.
    c. Shelving must provide adequate containment to prevent accidental tipping or spilling of stored materials. Where shelves are located in open lab-spaces, this would include such designs as lips on shelves, and dividers on shelves that face two separate aisles.
    d. Shelving and benchtops are to be designed to allow easy access by personnel.
2. Flooring
    a. All lab facilities are to be designed to facilitate cleaning and decontamination. Carpeting shall not be installed in laboratories.
    b. Wet labs must have chemical resistant covered flooring.
    c. Moderate and high-risk facilities must have floors that are designed to be easily cleaned and that are impervious to reagent spills. These floors must be seamless, sealed seamed, or of monolithic construction with curved floor-to-wall junctures to facilitate cleaning. Wet chemistry labs, as well as all radioisotope labs and biosafety level 2 (BSL-2) facilities, shall be defined as moderate or high-risk facilities.

5.18.9 Biosafety Laboratory Design

1. Laboratory doors must be self-closing and have locks.
2. Each laboratory must have a sink for hand washing. The sink may be manually, hands-free, or automatically operated. It should be located near the exit door.

3. An eyewash station shall be readily available in each laboratory.
4. The laboratory must be designed so that it can be easily cleaned and decontaminated. Carpets and rugs in laboratories are not permitted.
5. Laboratory furniture must be capable of supporting anticipated loads and uses.
6. Spaces between benches, cabinets, and equipment should be accessible for cleaning.
   a. Bench tops must be impervious to water and resistant to heat, organic solvents, acids, alkalis, and other chemicals.
   b. Chairs for laboratory work must be covered with a non-porous material that can be easily cleaned and decontaminated with appropriate disinfectant.
7. If biosafety cabinets (BSCs) are required for work, they must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. BSCs should be located away from doors, windows that can be opened, heavily traveled laboratory areas, and other possible airflow disruptions. All biosafety cabinets must be installed per manufacturer's instructions.
8. Any ducted biosafety cabinets shall be approved prior to initiating the design.
9. If a central vacuum line is installed it must be protected with high efficiency particulate air (HEPA) filters, or their equivalent which are placed between the laboratory and the pump. These filters may be installed in each lab.
10. An eyewash station must be readily available.
11. Mechanical ventilation systems must provide an inward flow of air without recirculation to spaces outside of the laboratory. The lab spaces must be under negative pressure with respect to the surrounding hallways or common areas.
12. HEPA filtered exhaust air from a Class II, Type A2 biosafety cabinet can be safely recirculated back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations. BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or a direct (hard) connection. Provisions to assure proper safety cabinet performance and air system operation must be verified. Use of Class II, Type B2 biosafety cabinets can cause problems with building HVAC balancing and must be approved by EHS prior to installation.
13. A method for decontaminating all biological wastes must be available in the facility (e.g., autoclave, chemical disinfection, incineration, or other validated decontamination method).
14. Any design/construction of a biosafety level 3 (BSL-3) laboratory must consult with the university biosafety officer in the early phases of design.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 6 – BUILDING SERVICES

6.1 Building Services General

6.1.1 Physical Hosting of Computer Servers

The A/E shall coordinate with the VT PM and NI&S.

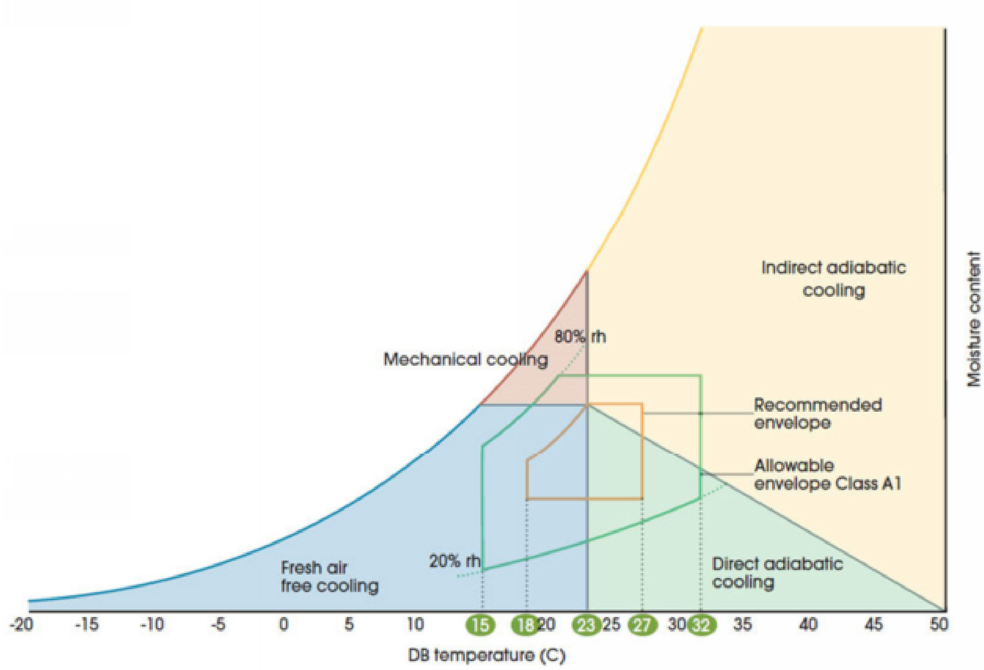
1. Physical security
    a. Servers should be locked away from physical access/ingress points
        i. Strong doors and walls
        ii. Check the door hinges
            1. Are hinge pins on the outside?
            2. Easily removable?
    b. Should only be accessible by authorized personnel
    c. Use auditable entry methods (bio-reader, token, or cards). Do not use lock-and-key or combination.
    d. Security cameras
        i. Entrances/exits
        ii. Interior of room: equipment may be difficult in complex or large room
    e. Environmental alarms (see also 2.a.iv., below)
        i. Temperature
        ii. Dampness/humidity
        iii. Unauthorized access (particularly remote rooms)
    f. Are there guards or trained personnel after-hours?
    g. Other points of entry
        i. Windows (may also provide visibility to on-screen data)
        ii. Walls with drop ceilings
        iii. Space under raised floor
    h. Server monitoring
        i. OS server management software
        ii. “Lights-out” controllers: these can reduce physical access requirements
2. Environmental security:
    a. See ASHRAE TC 9.9 guidelines
        i. Generally allowable from 59 °F to 89.6 °F with 20-80% relative humidity
        ii. Recommended from 64 °F to 80 °F
        iii. Non-condensing environment

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

iv. Consider using ambient (outside) air to save on infrastructure costs (Figure 6-1).

v. Continuous environmental monitoring
   1. Temp/humidity
   2. Liquid/moisture
   3. Room or cabinet opening

Figure 6-1. Use of Ambient Air Cooling



b. Redundancy
   i. Multiple HVAC units
   ii. Power loss protection; uninterruptible power supplies (UPS) and generators

c. Consider airflow (for large/dense installations)
   i. Aisles and under floor should be clear
   ii. Heat containment
   iii. Maintenance impediments; ensure clearance for
      1. Cabinet doors
      2. Cable management

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

iv. Source of cold air: check orientation/fan direction
  1. Often desired to mount network equipment in the back of cabinets
  2. Ensure air flow is not interrupted

v. Direction of hot air
  1. Blanking panels in racks to prevent wrap-around air
  2. Non-cabinet-mounted/rack-mounted equipment allows wrap-around air flow

3. Electrical security:
   a. Document limits; understand requirements for operation
      i. Branch circuits
      ii. Panels
      iii. Power distribution units
   b. Filtering – surge arrestors/protectors; often built-in to UPS
   c. Short-term power outages
      i. Uninterruptible power supplies
         1. Check volt-amperes (VA; apparent power) vs. watts
         2. Most UPS are rated in VAs
         3. Wattage output is less
         4. Most server power supplies are power factor corrected (i.e., documented in watts)
      ii. Double-conversion UPS vs. standby
         1. Double-conversion = always using DC inverted output
            (a) Cleaner power
            (b) More power consumption
         2. Standby = inverter only kicks in when incoming power is abnormal
      iii. Maintenance
         1. Test or service regularly; quarterly ignition testing/semi-annual load testing
         2. Schedule battery replacements or consider fly-wheels
   d. Long-term power outages
      i. Generators are necessary for mission critical applications and services
         1. Maintenance and testing similar to UPS
         2. UPS should be plugged into a generator-backed outlet
         3. Can room HVAC be handled as well?
      ii. Automated transfer switches
         1. How long can the generator carry a full load?

2. What's the UPS run-time?

e. Multiple power inputs
   i. Many servers can have multiple power supplies. Most designs balance power input load between all available circuits on both the utility side and the UPS/generator side.
   ii. What happens if something fails?
      1. Power supply? All of that server's load goes to the other(s).
      2. Circuit? All connected loads may re-balance.
      3. UPS? If two UPS, can either one handle the load if the other fails?
   iii. N+1 designs
      1. Have 3 or more power supplies
      2. How many are needed to keep the server(s) running?
      3. Plan UPS, circuits accordingly
f. How much power do servers use?
   i. At startup/during nominal load/at peak load
   ii. Use metered power strips, if possible. This will allow for assessment and measurement.
   iii. Document actuals and compare with factory ratings

4. General/human safety:
   a. Fire suppression
      i. Gaseous agent: environmental and availability issues
      ii. No overhead standing water: usually a factor of cost; is equipment and data being protected worth the expense of non-sprinkler system?
   b. Emergency power-off (EPO): only required in certain circumstances
   c. Emergency lighting
   d. Exit plan

6.1.2 Facility Control Systems

The University relies on control systems for several critical operations. Any new equipment must be compatible with these systems, using the same communications and programming languages.

These systems are listed below:

1. The Building Automation System (BAS)
   The campus-wide BAS is controlled by a Siemens building automation control system. The campus BAS controls all HVAC systems in the buildings and is networked back to the central BAS servers in the Sterrett Complex. VT uses this system to control, monitor, schedule equipment, diagnose mechanical issues, etc. The BAS system will control the chilled water in the buildings which are

supplied from a central plant to include building pumps, bypass valves, bridge valves, etc. The BAS will monitor the campus loop differential pressure at each building and communicate those readings to the central plant control system. In buildings with their own chillers, the BAS will only control the secondary loops including secondary pumps, secondary bypass valves, etc.

2. Central chilled water plant controls system
   The central chilled water plants are controlled through a Trane chilled water control system. The Trane controls system integrates seamlessly with the chillers on campus.

6.2 Commissioning Requirements

The Commissioning Agent shall verify the completeness and full functionality of designs, submittals, and construction.

With the cooperation of the Contractor, the Commissioning Agent shall develop the training agenda and methods for the operation and maintenance of all major equipment and controls.

Prior to approval of project closeout, the Contractor shall be responsible for the satisfactory completion of applicable commissioning items within this section and DCSM sections 1.8 and 7.4.

1. Energy Metering
   The Commissioning Agent shall coordinate with the Contractor for energy metering and shall verify meters in accordance with DCSM sections 5.1.1.2 and 5.1.1.3. Calibration certificates for electrical meters shall be made available for review prior to the start of testing.
2. MEP Systems
   a. Scope of work: The MEP equipment and systems defined in the project documents shall be commissioned.
   b. Work included in MEP commissioning:
      i. MEP equipment installation and operation verification
      ii. MEP system and equipment startup testing, adjusting, and calibration
      iii. MEP systems functional performance testing
   c. Sample forms and reports: Provide adequately detailed sample forms, checklists, and report formats for all commissioning inspections, tests, and reports.

d. Functional test procedures:
    i. The Commissioning Agent shall provide adequately detailed test procedures for all pre-functional and functional commissioning performance tests and inspections.
    ii. The same procedure and equipment used in the balance and testing procedure for exhaust and make-up air for the entire building and each device in the system shall be used on balancing and functional testing for commissioning.
e. Testing and re-testing: All tests that fail due to improper Contractor work or preparation shall be rescheduled. All costs of re-testing will be borne by the Contractor.
f. Demonstration and training:
    i. The Commissioning Agent shall provide a project walk-through, instruction, and start-up by the Contractor and a factory technical representative, where appropriate.
    ii. Instructions and training shall be videotaped with professional quality for future reference.

3. Elevators
    a. Prior to Virginia Tech's acceptance of the installation, an inspection must be performed and acceptance tests must be witnessed by an independent elevator inspector to verify conformance of elevators with code requirements.
    b. Virginia Tech shall employ the services of the independent elevator inspector. Virginia Tech requires three weeks notification prior to testing in order to schedule the inspector.
    c. Any deficiencies shall be corrected by the Contractor at no cost to Virginia Tech. Any re-inspection deemed necessary due to non-compliance issues will be billed to the Contractor.
4. Laboratory Systems
    Commissioning testing and verification for all laboratory exhaust devices and ventilation systems shall follow the requirements in DCSM section 5.18.

6.3 Building Automation System

6.3.1 General Notes

1. The A/E shall coordinate specific project requirements with the VT PM and with VT Instrumentation, Controls, and Metering (ICM).
2. All materials shall be new, the best of their respective kinds, without imperfections or blemishes, and shall not be damaged in any way, and shall consist of the manufacturer's latest proven technology that is compatible with

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

the existing building controls infrastructure at the time of equipment submittal. Used equipment shall not be used in any way for the permanent installation except where drawings or specs specifically allow existing materials to remain in place.

3. The installation of all equipment shall be in strict accordance with manufacturer's instructions and installation manual. All equipment shall be rated for the intended use.
4. The University reserves the right to make changes to the BAS during the warranty period. Such changes do not constitute a waiver of warranty. The installer shall warrant parts and installation work regardless of any such changes made by the University, unless the installer provides clear and indisputable evidence that a specific problem is the result of such changes to the BAS. Any disagreement between the University and the installer on such matters shall be subject to resolution through the contract 'disputes' clause.

6.3.2 Required Submittals

1. Project specifications shall have detailed instructions on owner training. A/E shall define which systems need training, how much training is needed, and how the training should be delivered, including videography of training if requested by Virginia Tech.
2. Project specifications shall have detailed instructions to make clear the expectations of the BAS vendor. These specifications shall require the BAS vendor to provide the following information in their submittal package:
   a. Describe system operation, functions and control techniques.
   b. Migration strategies to protect owner's investment in BAS system. This includes detailing existing-to-remain controls and the compatibility for all controllers in the building to seamlessly communicate.
   c. Technical data to support the information on the hardware and software proposed for this solution including any integrated systems and/or solutions.
   d. Integration information from third-party controllers including manufacturer passwords, Modbus or BACnet point maps, instance numbers is the responsibility of the BAS contractor. BAS contractors must gather this information and provide along with their submittal.
   e. Line-by-line specification conformance statement.
   f. Provide submittals for fast-track items that need to be approved and released to meet the schedule of the project.
   g. Valve schedule and product data

   h. Damper schedule and product data
   i. Mounting and wiring diagrams for factory-installed control components
   j. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices
   k. Wiring diagrams: Power, signal, and control wiring. Detail the wiring of the control devices and the panels. Show point-to-point wiring from field devices to the control panel. Show point-to-point wiring of hardwired interlocks. Show a ladder diagram or schematic of wiring internal to the panels, including numbered terminals. Clearly designate wiring that is done at a factory, at a panel shop or in the field.
   l. Details of control panel faces, including panel size, control component layout, instrument layout, and labeling. The intent here is to ensure that panels are not overcrowded and allow sufficient room for future improvements.
   m. Schedule of valves, dampers and actuators including size, leakage, and flow characteristics. If dampers are furnished by other, submit a damper actuator schedule coordinating actuator sizes with the damper schedule.
   n. Written description of the sequence of operations.
   o. Network riser diagram showing wiring types, network protocols, locations of floor penetrations and number of control panels. Label control panels with network addresses and BACnet device instance numbers. Show all routers, switches, hubs and repeaters.
   p. Point list for each system controller including both inputs and outputs (I/O), point numbers, controlled device associated with each I/O point, and location of I/O device.
   q. Starter and variable frequency drive wiring details of all automatically controlled motors.
3. Product data: Include manufacturer's technical literature for each control device indicated, labeled with setting or adjustable range of control. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated. Submit a write-up of the application software that will be used on the operator workstation including revision level, functionality and software applications required to meet the specifications.
4. Submit BACnet protocol implementation conformance statements (PICS) for all direct digital controllers, software and other system components that will communicate on the BAS utilizing BACnet.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. After the BAS system components have been approved for construction, submit standard operator workstation graphics for approval. Electronically submit the graphics that the operator will use to view the systems, change setpoints, modify parameters and issue manual commands. Graphics must be approved by the ICM shop prior to final commissioning.
6. Project record documents including, at a minimum, as-built versions of shop drawings, O&M manual, startup, and commissioning reports. BAS record documents shall clearly convey the physical design of the system, network layouts, as well as materials and devices used therein. As-built shop drawings must be inclusive of all field changes to system configuration and sequences of operation.
   a. Each unique type of equipment shall have an equipment schematic showing hardware layout, a module or panel detail showing layout and connection, a bill of materials and a concise written sequence describing each mode of operation.
   b. A network diagram shall be provided for each project, indicating the physical layout, including the routing of network wire, as well as the location of each node and the equipment it serves. This diagram should include all BAS modules, as well as any network devices such as gateways, routers and third-party devices.
   c. A power riser, power layout, including electrical panel/circuit number.
   d. Record documents shall include equipment schedules detailing the specification and application of control valves, control dampers and any other equipment provided by the BAS contractor.
   e. All record documents are subject to the approval of the project management and/or A/E of record.
   f. Upon completion of the project, an electronic copy of the as-builts, in pdf format, shall be provided to the ICM department and stored on the BAS server in the as-builts folder (G:/ drive).
   g. The controls installer shall provide the University with all product line technical manuals and technical bulletins, including new and upgraded products, throughout the warranty period of the project.

6.3.3 Coordination with Other Trades

1. Power and raceways for the BAS system shall be procured in the most cost-effective method possible. BAS building level network panel locations shall be shown on the A/E contract documents. Power circuiting for these field panels

and conduit between field panels shall be included on the A/E contract documents.

2. The BAS vendor shall actively coordinate with the electrical contractor or any other contractors that are impacted by their work.

6.3.4 BAS Commissioning

1. It is imperative that the BAS contractor actively support commissioning activities that are critical to successful operation of the building once occupied.
2. Provide complete submittal package as described above with sequences of operations and BAS graphics.
3. Attend commissioning planning meetings .
4. Certify that instrumentation and control systems are installed according to the contract documents and complete all required checklists from the commissioning agent.
5. Certify that instrumentation and control systems have been completed and calibrated; are operating according to contract documents; and that pretest set points have been recorded prior to functional performance testing. Complete all required test checklist documents.
6. Test systems and intersystem performance after approval of test checklists for systems, subsystems, and equipment.
7. Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shut down, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
8. Verify each operating cycle after it has been running for a specified period and is operating in a steady-state condition.
9. Inspect and verify the position of each device and interlock identified on checklists. Sign off each item as acceptable or failed. Repeat this test for each operating cycle that applies to system being tested.
10. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.
11. Annotate checklist or data sheet when a deficiency is observed.
12. Verify proper responses of monitoring and control system controllers and sensors to include the following:
    a. For each controller or sensor, record the indicated monitoring and control system reading and the test instrument reading. If initial test indicates that the test reading is outside of the control range of the installed device, check calibration of the installed device and adjust as required. Retest malfunctioning devices and record results on checklist or data sheet.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   b. Report deficiencies and prepare an issues log entry.
13. Verify integrity of all control wiring to ensure continuity and freedom from shorts and grounds prior to commencing the startup and commissioning procedures.
14. Test all operating modes, interlocks, control responses, responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.
15. The BAS contractor is required to participate in seasonal post occupancy setpoint optimization for energy efficiency for a minimum of four seasons after acceptance. This shall include optimization of pressure setpoints, temperature setpoints, PID gains, and general review of system operation to identify equipment with unusual run times, unusual cycling, etc.

6.3.5 Access to the BAS

1. Access to the BAS shall be by approval only. The request shall be submitted to the ICM shop and ultimately approved by the Campus Energy Manager.
2. The system shall have the follow user access permissions at a minimum:
   a. Administrator
   b. Owner
   c. Power user
   d. Support user
   e. Read only
3. The BAS contractor shall be responsible for setting up user access permissions prior to project closeout. Virginia Tech will provide a list of users and their user access category so proper system access associated with the project is completed at the time the project is implemented and any access related issues are resolved prior to the end of commissioning activities.

6.3.6 Notification Management

1. The system shall have configurable alarming notification ability for different users. Virginia Tech will provide a list of users, their user access category, and desired alarm notification level so that this function is set up at the time the project is implemented and any alarming related issues are resolved prior to the end of commissioning activities.
2. See Appendix J: BAS Standards: Sequence of Operations for more detail on alarm reporting actions.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.3.7 Approved Products

1. One approved BAS vendor is Siemens. The new BAS shall utilize electronic sensing, microprocessor-based direct digital control, and electronic actuation of dampers, valves, and devices to perform control sequences and functions specified.
   a. All new capital projects shall utilize Desigo or other approved vendor as the BAS front-end.
   b. Non-capital projects consisting of less than 50% of the building shall be tied into the existing network residing on Insight. Renovation projects consisting of more than 50% of the building shall be migrated into the native front end of the newly installed controllers and include the migration of exiting, to remain, BAS infrastructure into this front end as well. In no instance shall there be two or more BAS systems within the same facility.
2. Energy metering
   a. Accuracy: +/- 0.2% FS
   b. Power meters shall have hardwired pulse and analog output capability for the kW demand output. Additional monitoring points shall be available via BACnet.
3. Lab controls
   a. Fume hood controllers, lab supply air valves, lab general exhaust air valves, and fume hood exhaust air valves shall be directly controlled by the BAS without an integration to a third party laboratory control valve system. Third-party lab controls are not acceptable.
4. Hydronic differential pressure transmitters
   a. Five-port manifold with remote transducer type (rather than integrated transducers). Each transducer shall include a 5-port manifold necessary to isolate, bleed, and test the individual sensor.
   b. Accuracy: +/- 0.25% FS
5. Space temperature and humidity sensors
   a. All space and humidity sensors shall be located at or near the door, the light switch, and at 60 inches to center. An exception shall be made when adjustable sensors are required by a LEED credit, and shall be mounted 44″ to center.
   b. Accuracy: Temperature +/- 0.4 °F
   c. Accuracy: Humidity +/- 2% (20-80% RH)
   d. Classrooms, offices, and other occupied spaces shall use a sensor with a setpoint adjust and occupied override functionality. Occupant override

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

functionality will be disabled during the commissioning process to allow for the 60-inch height requirement.

e. Non-display sensors shall be used in public spaces (hallways, bathrooms, etc.).
f. Include thermostat guards for obvious hazardous locations (gyms, mechanical rooms, etc.).

6. Damper actuators
   a. Dampers and actuators shall be designed to provide adequate airflow controllability at minimum flow and economizer situations.
   b. The basis of design for automatic control damper actuators serving central systems shall be Belimo. This includes central air handling units and central exhaust systems.
   c. The basis of design for automatic control damper actuators on terminal equipment shall be Siemens or Belimo. These systems include heat pumps, VAV boxes, fan coil units, unit ventilators, cabinet unit heaters, and other terminal systems serving rooms and common areas.
   d. The basis of design for control of all automatic damper actuators shall be Siemens or Belimo DDC controllers.
7. Control valves
   a. The basis of design for control valves shall be Siemens or Belimo. Control valves shall be provided by the BAS contractor but installed by the mechanical contractor.
   b. Terminal units shall use pressure independent control valves with testing ports sized for the designed flow rate for the coil. Actuators for terminal equipment coils shall be fully modulating. Floating point actuators are acceptable.
   c. In renovation applications where pressure independent valves are installed, existing balancing valves shall be removed, and manual isolation valves shall be included.
   d. Where pressure independent valves are not feasible, units shall use characterized control valves sized for the designed pressure drop across the coil. Actuators for terminal equipment coils shall be fully modulating. Floating point actuators are acceptable.
   e. Coils that are exposed to outside air or other freezing conditions shall have failsafe actuators. Hot water and steam valves shall fail open in most applications. Chilled water valves shall fail closed. Terminal equipment valves shall not require failsafe actuators.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

f. Energy valves with a built-in flowmeter shall be considered for central systems such as air handling units, chilled water systems, and hot water systems.
g. Automatic isolation valves shall be 2-position ball or butterfly valves where appropriate.
h. Control valves shall be selected with appropriate valve authority to provide adequate flow controllability with a minimum authority coefficient of 0.25, but no higher than 0.5.
i. High performance butterfly valves shall be considered for modulating applications larger than 3" in lieu of modulating globe valves.

8. Hydronic thermal energy meters
    a. Flowmeters for energy monitoring and utility billing shall be electromagnetic or ultrasonic flowmeters with matched temperature sensors. Hot tap kits shall be provided for insertion meters.
        i. Accuracy: +/- 0.5% full span
        ii. Range: Selected for each application based on anticipated flow.
    b. Hydronic flowmeters
    c. Flowmeters for central plant systems used for energy monitoring and control applications shall be insertion style electromagnetic flowmeters. Hot tap kits shall be provided.
        i. Accuracy: +/- 1.0% full span
        ii. Range: Selected for each application based on anticipated flow.
    d. Flowmeters for domestic water and make-up water applications shall be impellor style insertion flowmeters. Hot tap kits shall be provided.
        i. Accuracy: +/- 1.0% full span
        ii. Range: Selected for each application based on anticipated flow.
    e. Flowmeters shall be provided by the BAS contractor but installed by the mechanical contractor.
9. Airflow measurement stations
    a. Thermal dispersion style
        i. Accuracy: +/- 3% of full scale
        ii. Range: Selected for each application based on anticipated flow.
10. Air quality monitoring systems
    a. Space CO_2 sensor: Accuracy: +/- 50 ppm (0-2000 ppm) or +/- 30 ppm (400-1250 ppm)
    b. Space volatile organic compound (VOC): Accuracy +/- 100 ppm (0-2000 ppm)
    c. Duct CO_2 sensor: Accuracy: +/- 30 ppm (0-2000 ppm) or +/- 30ppm (400-1250 ppm)

   d. Duct VOC sensor: Accuracy: +/- 50 ppm (0-2000 ppm)
11. General metering requirements
    a. Thermal energy meters shall be provided with internal communication card that supports BACnet IP and BACnet MSTP. These should be tied directly to the BAS system controller.
    b. A hardwired connection to the BAS shall be provided for steam, chilled and hot water rate flow.

6.3.8 VT Point Naming Standard

1. All point names for the BAS shall follow the VT BAS point naming convention which follows the CSAL point naming convention.
2. All fully qualified point names, where applicable, shall include the respective building number, equipment/system identification number, and the appropriate point abbreviation, each separated by a period. For example, B0101.AH01.SAT would represent a supply air temperature associated with air handler one in building 101.
3. Terminal equipment controllers shall be named by the associated room number that they serve. For example, B0101.RM201.VAV would represent building 101, room 201, served by a variable air volume (VAV) terminal.
    a. Rooms that are served by multiple terminal equipment, will have the terminal equipment name RMXXX.VAV1, RMXXX.VAV2, etc.
    b. Terminal equipment that serves multiple rooms shall be named by the room number where the T-stat is located. Other rooms that are served by the terminal equipment shall be listed in the point descriptor.
4. Field panel naming convention: B0101 CAB 01
5. ALN naming convention: Sandy Hall – B0101

6.3.9 Graphics Standards

All BAS projects/renovations shall include new or updated graphics. These graphics will be created in accordance with the following:

1. A main menu for the building with graphic links to all associated system graphics. Include the energy dashboard with the building graphic.
2. One graphic per system (air handling system, exhaust system, hot water system, chilled water system, domestic hot water system, lighting system, energy metering, etc.) shall be included. Each graphic will specify the system’s location and what the system serves.
3. Individual terminal equipment will be associated with the correct standard application graphic.

4. Any lab or room with HVAC equipment that is more complex than a standard application graphic can support (e.g., multiple supply terminals, exhaust terminals, and fume hoods in a single lab) will have its own individual graphic with the correct equipment and points shown.
5. Detailed floor plan graphics shall be created. Floor plan graphics must show the following item:
   a. All terminal equipment (VAVs, FCUs, UHs, HPs, etc.) with associated equipment and T-stat locations.
   b. All field panel locations.
   c. The floor plan will also specify which AHU and exhaust system serves which space.
   d. Floor plan graphics shall show thermal mapping.
   e. Locations of field panels, terminal equipment, transformers, airflow stations, 2/3-down duct sensors, differential pressure sensors, and major equipment (chillers, AHUs, HWS, etc.) shall be shown.
6. All graphics shall be sized to fit the monitors in the ICM department.
7. Dashboarding – Energy meters and calculated energy values shall still be integrated into the BAS as described in Appendix J: BAS Standards: Sequence of Operations to assist with troubleshooting building issues.
8. Sequence of operation graphics – Provide a written “sequence of operation” graphic for every system to make it easy to read the logic for users that do not have the expertise to read the code embedded within the control system.

6.3.9.1 Building Level Graphics

The building level graphic shall include a high-quality picture of the building with quick links to the following at a minimum:

1. Main floor plan graphic and links to each floor plan
2. Primary equipment including all primary water systems and airside systems
3. Links to critical equipment

6.3.9.2 Floor Plan Graphics

The main floor plan graphic shall have either a floor plan overview with all zones shown and links to each floor plan, or a picture of the building with hotspots and links to each floor plan graphic.

Individual floor plans shall include the following at a minimum:

1. An architectural floor plan with all zones to scale. Publishing the scale is not necessary.
2. Room numbers and room names, if available.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Links to all primary equipment serving spaces in that floor plan. AHUs serving multiple spaces shall be color coded with the corresponding color highlighting areas served by the AHU.
4. Links to primary central equipment
5. Links to all other floor plans
6. Zones that are outside of their controlled setpoints shall be highlighted
7. Outside air temperature and humidity
8. All room temperatures shall be placed on the floor plan beside correct T-stat, where they can be dragged and dropped to pull up the individual room graphic.
9. T-stat icons on floor plans shall be blue; humidity icons shall be dark grey; and CO_2 icons shall be light grey. Terminal equipment shall be shown on the floor plan graphic as close to the actual location as possible.

Figure 6-2. Example Floor Plan with Equipment Locations and Sensors

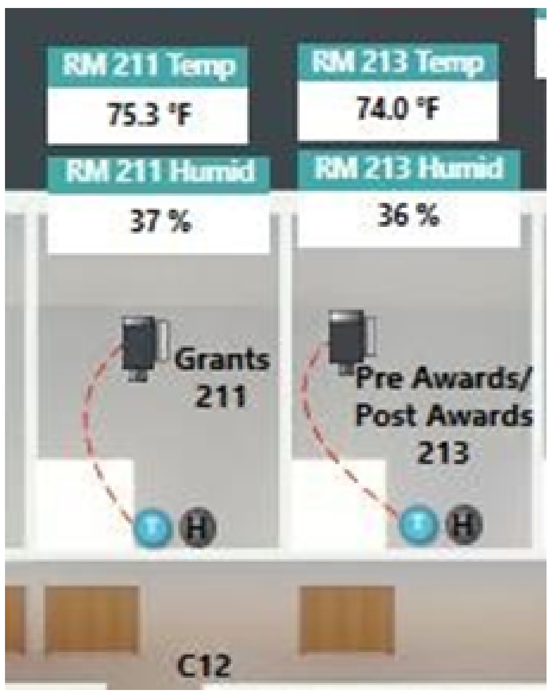


Figure 6-3. Example Floor Plan Graphic

6.3.9.3 Equipment Graphics

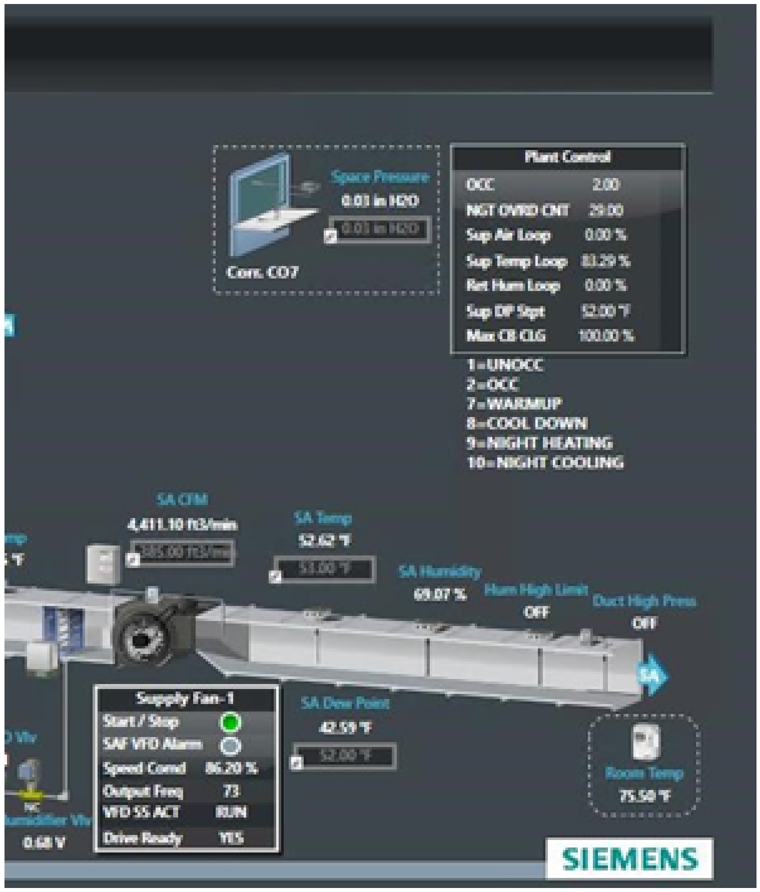
Individual floor plans shall include the following at a minimum:

1. Links to any parent equipment supplying air or water
2. Links to all other floor plans
3. Zones that are outside of their controlled setpoints shall be highlighted
4. Outside air temperature and humidity
5. All equipment graphics shall have a section designated to show system mode points and key performance indicators for the associated equipment. All HVAC equipment graphics shall show the building's primary broadcast outside air and humidity.
6. Points with the ability to be commanded (digital outputs, analog outputs, virtual setpoints, etc.) shall be indicated on the graphic as an editable text box or graphical control icon.
7. Monitoring points (digital inputs, analog inputs, etc.) shall be displayed for all physical inputs and any key calculated values (energy demand, etc.) along with the point name.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

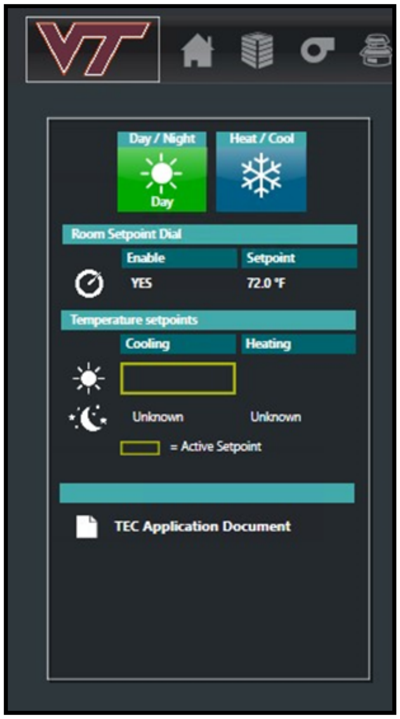
8. Points with source equipment like coil valves and supply ductwork shall show the incoming condition of that source (chilled water supply temperature, AHU-1 supply temperature, etc.) along with a link to the source equipment.
9. Include application notes and startup guide links on the graphic.

Figure 6-4. System Mode Points and Key Performance Indicators



Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Figure 6-5. Terminal Equipment Mode Points and Key Performance Indicators

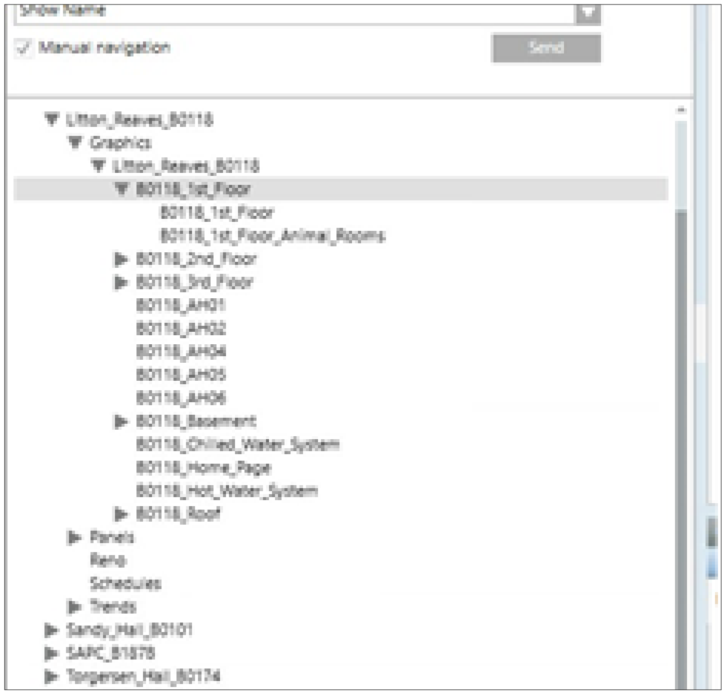


6.3.9.4 Geographic Trees

Building geographic trees shall be laid out with all zones included under their respective floor plans. Primary and central equipment shall reside at the building level as a peer to floor plans. Terminal equipment and single zones shall reside within their respective floor plans.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Figure 6-6. Geographic Tree Example



6.3.10 Third-Party Integration

1. The BAS vendor shall be responsible for directly connecting and controlling all HVAC equipment and associated systems with the building automation system. Equipment controls provided by the equipment manufacturer (i.e., “packaged control”) are not acceptable. Any exception shall require a design waiver per DCSM section 1.3.5.
2. All third-party integration, if approved, shall be accomplished via BACnet with native BACnet controls. Integration utilizing alternative protocols (non-BACnet such as Modbus, Lon, etc.) must have additional pre-approval from the VT ICM department.
3. Where a third-party interface is approved for the equipment control and sequencing, the interface shall be native BACnet as provided by the manufacturer.
4. Where a third-party interface is approved, the equipment provider shall provide a factory trained startup technician certified to configure the BACnet device.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. All BACnet instance numbers, network IDs, MAC addresses, and port numbers, shall be coordinated with the VT ICM department and requested during the wavier application.
6. Refer to required submittals section for point mapping information required for all equipment provided with third-party packaged controls.

6.3.11 BAS Network Configuration

1. Please contact the ICM Department for next available BACnet addresses and instance numbers.
2. Any IP address requests associated with the BAS shall be made through the ICM department.
3. BACnet broadcast management devices (BBMDs) are assigned by the ICM department. When a new network controller is connected to the BAS network, the BAS installer shall coordinate with the ICM department to configure any necessary BBMDs. Automatic management of the BBMDs shall be disabled.
4. All default/generic user accounts and passwords shall be changed prior to placing any controller online in the production environment. All device username and password information shall be turned over to the ICM department.

6.3.12 Trending and Reporting

Trends shall be enabled on all hard-wired points, setpoints, and calculated variables to record for a minimum of 48 hours. Points specified for historical archival shall be maintained for a minimum of 365 days. The A/E of record, commissioning authority, or other authority may request, with the owner's approval, historical trend archives longer than the minimum period. If a temporary server, or other field device is used, all historical trends shall be migrated to the final archive database.

1. Interval trending, unless otherwise specified, shall be in 15-minute intervals with 48 hours samples collected in the field panel.
2. Change of value (COV) trending shall be for binary (on/off) points and shall be for a minimum of 48 hours of data.

All critical equipment and spaces shall have scheduled reports created in coordination with VT Facilities BAS management and/or as listed in the job specification. Typical critical spaces include but are not limited to the following:

1. Vivariums (animal holding)
2. Critical labs (biosafety level)
3. Food storage (freezers and coolers)

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

All trend collections to the BAS front end shall be created in coordination with CPIF BAS management and/or as listed in the job specification.

6.3.13 Low Voltage and Communications Wiring

1. The wire basis of design is Anixter wire. Equivalent products may be used, provided their specifications meet or exceed the basis of design.
2. The term “control wiring” is defined to include the providing of wire, conduit, and miscellaneous materials as required for mounting and connecting.
3. All exposed control wiring and control wiring in the mechanical, electrical, telephone, and similar rooms shall be installed in conduit. All other wiring shall be installed neatly and inconspicuously above ceilings, anchored to the permanent building structure, with supports no more than 6 feet apart. Any exposed wiring shall be plenum-rated cable.
4. Critical safety interlocks, such as low temperature detection, high limit protectors, end switches, etc., shall be directly connected through wire, so as not to depend on any digital control system “sequence of operation” to perform their safety function. Contacts shall be provided so the safety can be monitored by the BAS. Low temperature detection and static pressure switch contacts shall be mechanically latching and only reset manually.
5. All Ethernet wiring shall be CAT6.
6. Competitive bidding on BAS control wiring is encouraged and does not need to be performed by the BAS vendor.

6.3.14 Control Panel Layout

1. Conventions:
   a. All line voltage wiring and connections must be protected behind covers and/or in raceways. Exposed line voltage circuitry is prohibited.
   b. Control wiring shall be neatly routed and terminated without excessive cable length. Wherever possible, control wiring should be concealed by wire duct.
2. Line voltage power:
   a. All control panels shall be served by emergency power circuits. Equipment connected to BAS controls may or may not be served by emergency power, but BAS controls shall be provided with emergency power.
   b. Control panels shall be served by dedicated emergency power circuits from the same source and service level provided to the equipment controlled. Low voltage control power for fume hoods must also be served by dedicated emergency power circuits. The control panel shall be labeled with the electrical panel name and circuit source.

c. All dampers within the air handlers and exhaust systems, including fire and smoke dampers, shall receive emergency power from the BAS system.
d. The BAS installer shall furnish and install any power supply surge protection, filters, etc., as necessary for proper operation and protection of all controllers. All control equipment must be tolerant of voltage variations 10% above or below scheduled nominal with no impact on hardware, software, communications, or data storage.
e. Unless extremely critical, UPS are not allowed. In the event of highly critical equipment/spaces (e.g., BSL3), UPS must be hybrid in nature. Critical UPS basis of design will be Sola S4K2UC or equivalent. A central, online UPS may be used in place of an individual UPS for BAS equipment.

3. Labeling:
   a. Panel layouts, network riser diagrams, and power riser diagrams shall be provided in each panel upon completion of the project.
   b. All wires and devices (filed panels, transformers, relays, etc.) in the control panel shall be labeled.
   c. The cabinet shall be clearly labeled on the outside.

6.4 Network Communications

6.4.1 Summary

VT Network Infrastructure and Services (NI&S) specifications are to be used for all new construction and major renovation projects.

1. Major renovation projects are defined as complete buildings, floors, or work group areas which require new telecommunication rooms and cabling to the new room(s).
2. Renovations that will require cabling to existing NI&S rooms may have materials or installation techniques that do not conform to these standards. These types of small renovations are considered outside the scope of this section and requests for these types of cabling projects must be submitted to NI&S Customer Support Services (CSS) at (540) 231-6460 or at nis-projects-g@vt.edu.

Network Infrastructure & Services, part of Virginia Tech's Information Technology organization, is responsible for installing, operating, managing and maintaining the university telephone, data, and CATV systems. The telecommunications cabling system described in this section will be utilized by NI&S to provision these services to the university. NI&S is responsible for the ongoing management and maintenance of university telecommunications cabling systems including adding,

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

removing and or relocating cabling as required to support the needs of the university as persons and departments relocate and/or their requirements change over time. NI&S is certified by the Siemon Company (Siemon) and Optical Cable Corporation (OCC) as required to perform this ongoing cable plant work without voiding the manufacturer's warranties provided by these companies.

The products and execution from this section are the accepted practices from NI&S and any products or execution outside this section shall require a design waiver per DCSM section 1.3.5.

Every effort has been made to use industry standard terminology throughout this section, but industry standard terminology is not used by all manufacturers and, in many cases, industry standard terminology does not exist. Contractor shall notify the VT PM and NI&S personnel to define terminology used in specifications if they believe any questions could arise.

This section is not intended to eliminate the need for a detailed review of a new project between the designers, the end users, and NI&S engineers. The best and most cost-efficient method for designing a building's telecommunications infrastructure is to have the A/E team, the VT PM, and the NI&S design representative meet with the future occupants of the building and discuss in detail the telecommunications needs for the buildings. These meetings help avoid unnecessary infrastructure being installed and necessary infrastructure being omitted; both of which drive up project costs. These meetings should occur after the schematic design drawings are released but before the end of preliminary design.

Drawings, contract forms, and conditions of the contract, including the Construction Manager/General Contractor (CM/GC) agreement, exhibits, and other VT DCSM sections, apply to this section.

All service activation requests, or modification of existing services, must be submitted by the requesting department to NI&S Customer Support Services (CSS) at (540) 231-6460 or at cssnis@vt.edu.

The Contractor shall review related project documents and report any and all concerns prior to installation.

In the event of a conflict or discrepancy between this section and other project-related documents, the Contractor shall submit a written request for clarification to NI&S for resolution.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.2 Requirements for Communications Projects

1. Refer to DCSM section 6.4.4 for the minimum qualifications for the Communications Contractor.
   a. Proof of the Communications Contractor's current enrollment in the Siemon Company Certified Installation (CI) program is required.
   b. Proof of the Communications Contractor's current enrollment in the OCC Certified Multimedia Design and Integration Specialist (MDIS) Program is required.
2. Contractors will provide pricing options for a complete Category 6 or a complete Category 6A structured cabling solution based on the requirements found in these standards. The VT PM and NI&S will coordinate with the building occupant's representative to determine the department's bandwidth requirements and will specify the applicable solution for each project.
   a. A complete structured cabling system, as described within these specifications, includes the following:
      i. Equipment rooms (ERs)/telecommunication rooms (TRs)
      ii. Copper and fiber backbone cabling and connectivity
      iii. Copper horizontal cabling (station cabling) and connectivity
      iv. Grounding and bonding of telecommunications pathways and equipment
      v. Labeling and testing
      vi. Firestopping
   b. A complete structured cabling system, as described within these specifications, does not include the following:
      i. Outside plant pathways and backbone cabling
      ii. Network electronics
      iii. Uninterrupted power supplies/power strips
3. Refer to DCSM section 6.4.4.8.6 for firestop requirements and refer to the architectural drawings for ratings of existing and new walls, floors, and other surfaces in the project area.

   The base bid for a project containing communications cabling is required to include all firestop installation and materials for all communication cabling in the project area.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.3 Operation and Maintenance of Communications Systems

6.4.3.1 Contract Administration

The Contractor shall carefully study and compare the contract documents and shall at once report to the VT PM and NI&S any error, inconsistency or omission identified. If the Contractor performs any construction activity knowing it involves a recognized error, inconsistency or omission in the contract documents without such notice, the Contractor shall assume appropriate responsibility for such performance and shall bear an appropriate amount of the attributable cost for correction.

The Contractor shall advise the VT PM and NI&S as early as possible of any product delays and minimum quantity requirements that may affect the project timeline. Should conflicts, discrepancies, deficiencies, or errors arise which require changes in the Contract Documents, immediately notify the VT PM and NI&S. Failure to do so shall be interpreted as the intention of the Contractor to supply all necessary labor and materials for the suitable completion of this work. Obtain written approval on necessary adjustments before the installation is started.

6.4.3.2 Project Management and Quality Assurance

1. The Contractor shall designate and identify a Project Manager to oversee the project work specified in this section and to attend all necessary project meetings as a representative of the Contractor. The Contractor's Project Manager shall have the authority to act for the Contractor, and all communications given to the Project Manager will be deemed to have been given to the Contractor.
2. The Contractor shall not begin construction on any project without written notice to proceed.
3. All additional costs must be approved in writing with a change order signed by the VT PM.

6.4.3.3 Job Supervision

1. Designate and identify job supervisor in advance.
2. Provide no more than one supervisor per job.
3. Provide one primary contact, one backup contact.
4. Maintain the following information on the job site:
   a. All project-related drawings including H-Link/portal identification information will be provided by NI&S (see DCSM section 6.4.10).

    b. All addenda
    c. Submittals
    d. All change orders
    e. Any inspection reports from NI&S and/or structured cabling system manufacturer
    f. Test results
    g. Schedule and outage logs
    h. As-built drawings set showing all changes
5. Assist NI&S and manufacturers' representatives in performing periodic inspections for evaluation and functional testing of communications subsystems or sections.
6. Assist NI&S and manufacturers' representatives in performing evaluation and functional testing of complete communications system(s).
7. Conduct an overall quality assurance program.
8. Apply and install materials, equipment, and specialties in accordance with manufacturer's written instructions. Conflicts between the manufacturer's instructions and these specifications shall be referred in writing to NI&S for resolution.
9. All products, components, devices, equipment and materials shall be new and unused, clean, free from defects, and free from damage and corrosion.
10. Installation and service shall be performed by manufacturer trained and certified personnel.

6.4.3.4 Submittals

1. The Contractor shall submit for review and approval by NI&S a complete list of all materials, components, equipment, systems, and products proposed. Any requests for substitutions must be submitted with complete product data.
2. Product submittals shall show, as a minimum, the following:
    a. Manufacturer, color, complete model and part number
    b. Dimensions
    c. Complete technical specifications and performance data
    d. Any other pertinent information necessary to determine adequacy for the intended application
3. When not provided by the project A/E, the Contractor shall submit for review and approval by NI&S a complete set of shop drawings detailing the Contractor's design plans for each specification section. Shop drawings must include an overall site plan with any outside plant telecommunications

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

pathways shown, exterior and/or interior cable pathway details (including quantity and sizes), room construction plans (including wall and rack details, equipment elevations, grounding systems, conduit pathways, etc.), copper and fiber backbone cabling plans, work area outlet details (including outlet labeling plans).

4. Two sets each of hard copy and electronic shop drawings are required to be submitted to NI&S via the VT PM.
5. Generate shop drawings using the VT CADD standards in DCSM section 2.8.

6.4.3.5 Substitutions

Requests to substitute for specified items or previously approved materials or equipment shall be submitted by the Contractor to the VT PM and NI&S for review. Substitution requests shall include all required submittals and shall be complete with reasons for substitutions and savings which will accrue to the project if substitutes are approved. Substitutes will be considered only if equal or superior to those specified and do not void specified cable system manufacturer's warranties.

6.4.3.6 Statement of Warranty

The Contractor shall provide statements of warranty based on both the structured cabling and fiber optic system manufacturers' performance warranties as well as the Contractor's parts and labor warranty.

6.4.3.7 Periodic Field Observation Reports

NI&S and cabling systems manufacturers' warranty representatives will conduct site visits as required to monitor the progress and quality of the workmanship, the work environment, as well as the surrounding facility. Any item found by NI&S and/or the cabling system representatives to be deficient will be documented in a periodic field observation report.

The Contractor shall take appropriate action to immediately correct and rectify any items deemed to not meet plans and specifications by NI&S and/or the cabling systems manufacturers' warranty representative. The Contractor shall not wait for a hard copy of the periodic field observation report if the action required to rectify the situation is communicated to them.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.3.8 Inspections and Tests

The Contractor has requirements for inspections and testing. The Contractor shall:

1. Furnish, without additional charge, all test equipment with up-to-date calibration, instruments, facilities, labor, and material needed to perform safe and convenient inspection and testing.
2. Submit to NI&S a complete project schedule and timeline, including installation, inspection, and testing for each project area prior to beginning work, so that interim inspections can be conducted as work progresses. NI&S shall not be obligated to inform the Contractor of its intent to inspect job sites while work is in progress.
3. Perform pre-testing of the installed telecommunications systems to determine compliance and notify NI&S personnel when the system is ready for final inspection and testing.
4. The Contractor shall leave all work uncovered for a minimum of five business days from the date of a notification to NI&S of a request for inspection. Overhead work shall not be covered up or enclosed until inspected by NI&S personnel or other proper authorities. Should any work be covered up or enclosed before such inspection, it shall be uncovered, inspected, and after approval, restored by the Contractor to finished condition at no additional cost to the project.
5. Replace or correct, without charge, any material or any workmanship found by NI&S not to conform to the specifications, unless NI&S consents to accept such material or workmanship with appropriate adjustment in price. All work that is determined to be unsatisfactory shall be corrected immediately. The Contractor shall promptly segregate and remove rejected material from the premises. The Contractor will pay the additional cost of any test or inspection of the replaced material or corrected workmanship.
6. Submit final test results as described in this specification for review and acceptance by NI&S and the cabling systems manufacturers' warranty representatives.

6.4.3.9 Continuity of Services and Scheduling

The building may be in use during construction operations. Insofar as possible, the Contractor shall employ such methods or means as will not cause interruption of, or interference with, the owner's scheduled use of the building and will maintain existing systems in operation within all rooms outside of the scope of the project at all times.

1. For areas under renovation, coordinate all installation activities with the VT PM and other trades for renovations of architectural, mechanical, and/or electrical facilities. Insofar as possible, the Contractor shall employ such methods or means as will not cause interruption of, or interference with, the work of any other contractor.
2. Moving or removing any facility related to providing telecommunications services must be done under the supervision of NI&S so as not to cause interruption of the project work or of university operation.
3. Disruption of critical services will require after hour or weekend working constraints.
4. Existing communication services shall be interrupted only with consent from the VT PM and NI&S. An advance warning time of seven working days shall be given. Such interruptions shall be preceded by all possible preparations which will minimize down time to expedite that particular phase of the work pursuant to good workmanship. This shall be done during regular and/or premium time as approved by the VT PM without additional expense to the project.
5. Adjust work schedule within reason (weekly), as per direction of the VT PM, and coordinate with work or other trades in order to make portions of project available as soon as possible.
6. All expenses due to untimely or improperly coordinated work shall be the responsibility of the Contractor.

6.4.3.10 Use of Cable Prior to Acceptance

The Contractor shall permit the placement and installation by NI&S of cross-connects, patch cords, and/or equipment onto cable and terminations installed under this contract, prior to substantial completion of the contract as necessary. Such placement or installation shall not evidence completion of the work or portion thereof, nor signify NI&S acceptance of the work or portion thereof.

6.4.3.11 Final Acceptance and Work Closeout

1. Contractor shall inspect the entire telecommunications system installation to assure all work is completed and all systems are completely operational before calling for final inspection, testing and acceptance of work.
2. Punch list closeout:
   a. Notify NI&S when telecommunications work is ready for final inspection and punch list preparation.

   b. The Contractor shall submit for review and approval by NI&S a complete set of as-built drawings including:
      i. Cover with legends.
      ii. Site plan with outside plant building entrance conduits shown.
      iii. Riser diagrams showing conduit (include size and quantity), grounding, and all backbone cabling (multi-pair copper, multimode fiber, single-mode fiber and coaxial).
      iv. Floor plans with all outlet locations.
      v. Equipment room (ER) details with footprint, equipment rack layout, conduit locations, and wall design.
      vi. All additional TR details with footprint, equipment rack layout, conduit locations, and wall design.
      vii. Horizontal pathway details including paths for all cable tray and conduits. Details must include quantity and sizes of all horizontal pathways.
      viii. Details sheet with faceplates, wireless plates (surface box), wireless boxes, camera box, floor box, box assembly, etc.
   c. Generate as-built drawings using the VT CADD standards in DCSM section 2.8.
   d. Two sets each of hard copy and electronic as-built drawings are required.
3. After the successful installation inspections and functional testing by NI&S and the Contractor, NI&S will determine if there are any open issues or discrepancies and notify the Contractor via the VT PM. Upon completion or determined failure, NI&S will issue written notification to the Contractor as to the status of the installation acceptance.

6.4.4 Common Work Results for Communications

6.4.4.1 Related Documents

1. Design, manufacture, test, and install telecommunications cabling networks per manufacturer’s requirements and in accordance with NFPA-70 (latest adopted edition of the National Electrical Code), IEEE C2 (latest adopted edition of the NESC), state codes, local codes, requirements of authorities having jurisdiction, and particularly the following standards:
   a. ANSI/BICSI N1-2019, Installation Practices for Telecommunications and ICT Cabling and Related Cabling Infrastructure
   b. ANSI/TIA/EIA standards:
      i. ANSI/TIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises – Addendum 2, General Updates

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ii. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard, Part 1: General Requirements
iii. ANSI/TIA-568-C.2 – Commercial Building Telecommunications Cabling Standard, Part 2: Balanced Twisted Pair Cabling Components
iv. ANSI/TIA-568-C.3-1 – Optical Fiber Cabling Components Standard
v. ANSI/TIA-569-C – Commercial Building Standard for Telecommunications Pathways and Spaces
vi. ANSI-J-STD-607(B) – Commercial Building Grounding and Bonding Requirements for Telecommunications
vii. TIA-526-7-OFSTP-7 – Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant
viii. TIA-526-14-B-OFSTP-14-B – Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant
ix. ANSI/TIA-758(B) – Customer-Owned Outside Plant Telecommunications Cabling Standard

c. Install cabling in accordance with the most recent edition of BICSI publications:
   i. BICSI – Telecommunications Distribution Methods Manual
   ii. BICSI – Installation Transport Systems Information Manual
   iii. BICSI – Outside Plant Design Reference Manual
   iv. BICSI – Wireless Design Reference Manual

2. Federal, state, and local codes, rules, regulations, and ordinances governing the work, are as fully part of the specifications as if herein repeated or hereto attached. If the contractor should note items in the drawings or the specifications, construction of which would be code violations, promptly call them to the attention of the VT PM in writing. Where the requirements of the Virginia Tech specifications are more stringent than applicable codes, rules, regulations, and ordinances, the specifications shall apply.
3. Some differences exist between the standards listed above and the Virginia Tech specifications detailed in this document. These differences may include room construction specifications, work area outlet quantities and configurations, etc. Where differences occur, the specifications detailed herein shall apply unless not specifically allowed by code.
4. Maintain separate sets of redlined record drawings for the communications work that show the exact placement and identification of as-built system components. These are subject to weekly review by the VT PM.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. Provide communication room record drawings that indicate exact placement for all components (conduit, wireway, cable tray, backboards, equipment cabinets, equipment racks, cross-connect equipment, etc.).
6. Provide communication wiring and cabling record drawings and schedules that indicate exact placement, routing, and connection details for all components (twisted-pair cables, splices, cable cross-connect termination locations, enclosures, telecommunications outlets, and cross-connect jumpers, patch cords, etc.).
7. Cabling administration drawings: Show building floor plans with all telecommunications outlets identified including NI&S-provided outlet/cable designations for each location. Identify labeling convention and show labels for TRs and ERs, riser pathways and backbone cables, entrance pathways and termination panels/cabinets.

6.4.4.2 Scope of Work

1. Work includes, but is not limited to, the following:
    a. Placement of telecommunications room (TR) and equipment room (ER) hardware including equipment racks, cable routing hardware, copper and fiber termination equipment, and grounding and bonding.
    b. Placement of and additions to interior telecommunications pathways including conduit, cable tray, pull boxes, and metallic surface-mount raceway systems.
    c. Placement of and additions to exterior telecommunications pathways including building entrance conduit systems.
    d. Installation and termination of backbone cabling including multi-pair copper cabling, coaxial cabling, and single-mode and multimode fiber optic cabling.
    e. Installation and termination of horizontal cabling including copper unshielded twisted pair (UTP) cabling, and coaxial cabling.
    f. Testing, identification, and administration for the above telecommunications systems.
    g. Removal of existing horizontal cabling, terminations, and outlets in coordination with electrical contractor for removal of associated conduit in areas where renovations require demolition of existing telecommunications outlets.
2. All work shall be conducted in coordination with NI&S and other building trades.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. The work covered by this section consists of furnishing all materials, accessories, connectors, supports, equipment, tools, setup, preparation, labor, supervision, incidentals, transportation, storage, and related items and appurtenances, and performing all operations necessary to complete the telecommunications work as indicated in the project drawings and specified herein. It is the intent and purpose of this specification to have, upon completion of the project, a "turn-key" telecommunications system. This system shall be designed, built, coordinated and integrated with the existing telecommunications system and complete and operable in all respects to which, upon receiving activation orders from the building's occupants, NI&S can deploy network electronics to successfully integrate the cabling system into the campus network.
4. Completely install, connect, and test all systems, equipment, devices, etc., shown or noted or required to leave ready for satisfactory operation. Provide any minor items omitted from the design, but obviously necessary to accomplish the above intent.
5. All telecommunications designs for VT buildings on and off campus must be approved by NI&S for compliance to the Virginia Tech standards. Any design outside of these standards must be approved and include a written agreement for the design from NI&S.
6. Minimum composition requirements and/or installation methods for the following materials and work are included in this section:
    a. Cables
    b. Factory assembled products
    c. Compatibility of related equipment
    d. Special tools and kits
    e. Firestop and penetration seals
    f. Anchoring and supports
    g. Grounding and bonding
    h. Cutting and patching
    i. Concealment
    j. Equipment modification

6.4.4.3 Definitions

Every effort has been made to use industry standard terminology throughout this specification, but industry standard terminology is not used by all manufacturers and, in many cases, industry standard terminology does not

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

exist. Contractor shall notify the VT PM and NI&S personnel to define terminology used in specifications if they believe any questions could arise.

1. Approved/Approval – Written permission to use a material or system
2. Contractor – Telecommunications contractor performing work under DCSM section 6.4.
3. Engineer – Telecommunications engineer for DCSM section 6.4.
4. Equal/Equivalent – Equally acceptable as determined by NI&S
5. Final acceptance – NI&S acceptance of the project from Contractor
6. Furnish – Supply and deliver to installation location
7. Inspection – Visual observation or cable certification testing
8. Install – Mount and connect equipment and associated materials as required to make ready for use
9. Jack – Modular connector for station cabling medium (UTP copper, fiber, coax) at work-area outlet.
10. Outlet – Box and faceplate to accommodate up to six modular jacks at the work-area.
11. Pull-box – Box to be used for pull-through of cabling in a conduit run. Not to be used as a junction box.
12. Provide – Furnish and install complete with all details and ready for use
13. Relocate – Disassemble, disconnect, and transport equipment to new locations, then clean, test, and install ready for use
14. Replace – Remove and provide new item
15. Telecommunications – All work specified in DCSM section 6.4.

6.4.4.4 Contractor Qualifications

1. The Contractor shall at a minimum possess the following qualifications:
   a. Be in business a minimum of five years.
   b. Contractor shall demonstrate satisfaction of sound financial condition and can be adequately bonded and insured if the project deems necessary.
   c. Possess those licenses/permits required to perform telecommunications installations in the specified jurisdiction.
   d. Personnel knowledgeable in local, state, province and national codes and regulations. All work shall comply with the latest revision of the codes or regulations. When conflict exists between local or national codes or regulations, the most stringent codes or regulations shall be followed.
   e. Must possess current liability insurance certificates.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   f. Contractor must employ at least one current BICSI Registered Communications Distribution Designer (RCDD) having documented experienced with structured cabling design equivalent to the scope of work found in these specifications.
   g. Provide at least three references from customers where the type and size of installation provided in this specification was successfully completed within the past five years.
   h. Must have personnel proficient in the use of CAD and possess and operate CAD software using DWG or DXF format.
2. Required Contractor training:
   a. The Contractor shall be fully conversant and capable in the cabling of low voltage applications such as, but not limited to data, voice and imaging network systems. The Contractor shall at a minimum possess the following qualifications:
      i. Personnel trained and certified in the design, installation, and certification of the Siemon Cabling System for horizontal and backbone UTP copper cable distribution and the OCC system for backbone fiber riser distribution.
      ii. Personnel trained and certified in the design, installation, and certification of OCC fiber optic cabling and components through the OCC MDIS program.
      iii. Personnel trained in the installation of pathways and support for housing horizontal and backbone cabling.
   b. The Contractor shall show proof of current enrollment in the Siemon Cabling System's cabling partners program via an up-to-date certificate given after attending the CI training course or an online recertification class given every two years.
   c. The Contractor shall show proof of current enrollment in OCC's MDIS program.
3. Contractor responsibility:
   a. Contractor shall be obligated to exercise the highest standards of care in performing its obligations as defined in this request for proposal.
   b. Contractor acknowledges that NI&S will rely on contractor's expertise, ability and knowledge of the system being proposed and shall be obligated to exercise the highest standards of care in performing its obligation as defined in these specifications.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

4. Manufacturer quality and product substitutions:
   a. All telecommunications connecting hardware and cable must be made by an ISO 9001 certified manufacturer.
   b. All products must meet the technical requirements listed herein. Any products not meetings these requirements will not be considered.

6.4.4.5 Drawings and Specifications

1. It is the intention of these specifications and related project drawings to call for finished work, tested and ready for operation in complete accordance with all applicable codes, regulations, standards, and ordinances.
2. These specifications and the project drawings are complimentary, and what is called for in either of these shall be binding as though called for by both. Should any conflict arise between the drawings and specifications, such conflict shall be brought to the attention of the VT PM for resolution. If the Contractor fails to contact the VT PM in writing of any conflict between the specifications and the project drawings, the Contractor shall be subject to rework the area of conflict at the Contractor's cost.
3. Omissions from the specifications and/or project drawings or the incorrect description of details of work which are evidently necessary to carry out the intent of the specifications and project drawings, or which are customarily performed, shall not relieve the Contractor from performing such omitted or incorrectly described detail of the work.
4. The telecommunications and technology project drawings are diagrammatic and indicate general design, layout, and arrangement of equipment and various systems. Being diagrammatic, the drawings may not necessarily show all details such as pull boxes, conduit runs or sizes, etc., necessary for a complete and operable system. Unless detailed dimensioned drawings are included, exact locations are subject to approval of the VT PM.
5. The amount of varying types of telecommunication symbols should be kept to a minimum. A number should be placed next to each symbol to indicate the quantity of cables to be located at each data outlet box.
6. All telecommunications cables intended to be connected to the university network should be shown on the telecommunications drawings regardless if they are shown on A/V, security, etc., so that the cable plant infrastructure is clearly defined.
7. Do not scale project drawings for dimensions. Take all dimensions and measurements from the site and actual equipment to be furnished. All dimensions, measurements, and the location and existence of underground

equipment or facilities must be verified in the field since actual locations, distance, and elevations will be governed by actual field conditions. Contractor shall be responsible for all measurements taken from the field.

6.4.4.6 Examination of Project Site

1. Prior to any project work, examine the project site carefully including all project drawings showing existing systems and equipment. The Contractor shall make themselves fully informed of and shall identify all utility, state, and local requirements that will affect the telecommunications work at the project site.
2. It shall be the Contractor's responsibility to determine if the installation of the proposed systems will affect the operation or code compliance of existing systems. Only while under NI&S supervision, relocate, modify, or otherwise revise existing telecommunications systems as required to maintain operational integrity and code compliance.
3. The Contractor shall become familiar with the local conditions under which the work is to be performed and correlate the on-site observations with the requirements of the specifications and project drawings. No allowance will be made for claims of concealed conditions which the Contractor, in exercise or reasonable diligence in examination of the site, observed or should have observed.
4. Before ordering any materials or doing any project work, verify all measurements and be responsible for correctness of same. No extra charge or compensation will be allowed for duplicate work or material required because of unverified differences between actual dimensions and the measurements indicated on the project drawings. Any discrepancies found shall be submitted in writing to the VT PM for consideration before proceeding with the project work.

6.4.4.7 Workmanship, Warranty, and Support

1. Materials and workmanship shall meet or exceed industry standards and be fully guaranteed for one full year from final acceptance for each project. Cable integrity and associated terminations shall be thoroughly inspected, fully tested and guaranteed as free from defects, transpositions, opens/shorts, tight kinks, damaged jacket insulation, etc.
2. Furnish a written warranty to VT for a minimum of:
    a. One-year materials warranty on parts and labor to repair/replace defective telecommunications materials specified herein. This warranty

only applies to materials provided by Contractor and does not apply to materials provided by NI&S.

b. One-year installation workmanship warranty on parts and labor to resolve problems related to telecommunications system installation workmanship.
c. A minimum twenty-year manufacturer's performance warranty on parts and labor to repair/replace defective telecommunications cabling materials. The installer/contractor shall be certified by the following cabling systems manufacturers to provide the materials warranty.
    i. Siemon Cabling System (Siemon System 6 or 500 MHz Z-Max 6A cabling system warranty – dependent on category specified by project)
    ii. OCC Fiber Optic Systems

3. The appropriate cabling system manufacturer shall be responsible for and make good, without expense to VT, any and all defects in any part of either the Siemon or OCC related systems arising during this 20-year warranty period that are due to imperfect materials, appliances, improper installation, or poor workmanship.
    a. During the 20-year warranty period, provide all labor required to repair or replace defects in the telecommunications system, at no cost to VT.
    b. During the 20-year warranty period, provide new materials to repair or replace defects in the telecommunications system, at no cost to VT.

6.4.4.8 Materials

6.4.4.8.1 Equipment and Materials Minimum Requirements

1. All materials and equipment shall be new, free from defects, installed in accordance with manufacturer's current published recommendations in a neat manner and in accordance with standard practices of the industry.
2. All literature, installation manuals, warranty documentation, and un-used accessories included in equipment and material packaging shall be handed over to NI&S with notes identifying installed location.
3. Where no specific material, apparatus, or appliance is mentioned, any standard, first-class product made by reputable manufacturer regularly engaged in the production of such material may be used providing it conforms to the contract requirements and meets the approval of NI&S.
4. Materials shall have a flame spread rating of 25 or less and a smoke developed rating of 50 or less, in accordance with NFPA 255.

5. Materials shall meet or exceed the following minimum requirements:
   a. Where applicable, all materials and equipment shall bear the label and listing of UL. Application and installation of all listed equipment and materials shall be in accordance with such labeling and listing.
   b. Equipment shall meet all applicable FCC regulations.
   c. Electrical equipment and systems shall meet UL standards and requirements of the NEC. This listing requirement applies to the entire assembly. Any modifications to equipment to suit the intent of the specifications shall be performed in accordance with these requirements.
   d. The listing of a manufacturer as “acceptable” does not include acceptance of a standard or cataloged item of equipment. All equipment and systems must conform to the specifications herein and meet the quality of the specified item.
   e. Materials and equipment shall bear the manufacturer’s name or trademark and model/serial number permanently marked.

6.4.4.8.2 Cables

1. All telecommunications cabling inside the building shall be UL listed and marked type CM, CMR, CMP, CATV, CATVR, or CATVP and shall be installed in accordance with NEC articles 300-22(C)(2), 800-49, 800-50, 800-51, 800-52, 800-53, and 820. The substitutions listed in articles 800.154 and 820.154 shall be permitted.
2. All fiber optic cable inside the building shall be UL listed and marked type OFN, OFNR, or OFNP and shall be installed in accordance with NEC articles 300-22, 770-49, 770-50, 770-51, 770-52, and 770-53.

6.4.4.8.3 Factory Assembled Products

Manufacturers of equipment assemblies that include components made by others shall assume complete responsibility for the final assembled unit.

1. All components of an assembled unit need not be products of the same manufacturer.
2. Constituent parts, which are alike, shall be the product of a single manufacturer.
3. Components shall be compatible with each other and with the total assembly for intended service.

4. Contractor shall guarantee performance of assemblies of components and shall repair or replace elements of the assemblies as required to deliver the specified performance of the complete assembly.

6.4.4.8.4 Compatibility of Related Equipment

Equipment and materials installed shall be compatible in all respects with other items being furnished and with existing items so that a complete and fully operational system will result.

6.4.4.8.5 Special Tools and Kits

The Contractor shall furnish any special installation equipment, tools, or kits necessary to properly complete the telecommunications system installation. This may include, but is not limited to, tools for pulling, splicing, terminating, testing, assembly, and adjustment for cables, communication devices, stands for cable reels, cable winches, etc.

6.4.4.8.6 Firestops and Penetration Seal Materials

1. Use qualified systems to firestop through penetrations in fire-rated walls and floors for pipes, cables, conduits, ducts, inner-ducts, and cable trays.
2. Firestopping for openings through fire and smoke-rated walls and floor assemblies shall be listed or classified by an approved independent testing laboratory for "Through-Penetration Firestop Systems." The system shall meet the requirements of "Fire Tests of Through-Penetration Firestops" designated by ASTM E814.
3. Inside all conduits, the firestop system shall consist of a dielectric, water-resistant, non-hardening, permanently pliable/re-enterable putty along with appropriate damming or backer materials (where required). The sealant must be capable of being removed and reinstalled and must adhere to all penetrants and common construction materials and shall be capable of allowing normal cable movement without being displaced.
4. Foam sealant shall meet all fire test and hose stream test requirements of ASTM E-119-73 and shall be UL classified as a wall opening protective device.
5. Provide devices/systems fire tested by a third party according to ASTM E814 (or UL 1479) tested under positive pressure.
6. Provide only material combinations that are qualified by independent agencies based on the material's performance when tested in a particular configuration.

7. Match the thickness (and/or depth) of firestop materials to that recommended by the manufacturer.
8. Per the UBO, all firestop material must be red in color.
9. Thickness of materials must be established by formal ASTM E814 or UL 1479 tests.
10. The basis of design for firestop for fire-rated floors and walls shall be:
    a. Hilti firestop systems
    b. 3M fire protection
    c. Others as approved by the VT PM and NI&S

6.4.4.8.7 Anchoring Materials and Supports

1. Metal bars, plates, channel, tubing, etc., shall conform to ASTM standards:
    a. Steel plates, shapes, bars, and grating – ASTM A36
    b. Cold-formed steel tubing – ASTM A500
    c. Hot-rolled steel tubing – ASTM A501
    d. Steel pipe – ASTM A53, schedule 40, welded
2. Metal fasteners shall be zinc-coated.
3. Anchoring materials:
    a. Structural steel
    b. Steel channel – galvanized or painted
    c. Unistrut

6.4.4.8.8 Grounding and Bonding Materials

1. Compression connectors
2. Bonding conductor: 6 AWG minimum copper
3. All grounding equipment shall be UL listed for that purpose.

6.4.4.9 Execution

6.4.4.9.1 General Installation Requirements

1. The approximate locations of existing and new telecommunications outlets, cabling and equipment will be indicated on the project drawings; however, the drawings are not intended to give complete and accurate information. Contractor is responsible to field verify existing outlets and cabling prior to submitting quote. Determine the exact location after thoroughly examining the general building plans and by actual measurements before and during construction, subject to the approval of the VT PM and NI&S.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. Before construction work commences, visit the site and identify the exact routing for all horizontal pathways and equipment placement. Verify all dimensions, locating the work and its relation to existing work, all existing conditions and their relation to the work, and all man-made obstructions and conditions, etc., affecting the completion and proper execution of the work as indicated in the project drawings and specifications.
3. If core drills are required, the exact core locations shall be identified and coordinated with the VT PM, the UBO, and the EHS Asbestos Operations and Maintenance Program as necessary. Where required for inspection, Contractor shall retain removed cores and label with location information where the core was removed. Refer to the VT PM and the UBO for all coring requirements.
4. All equipment locations shall be coordinated with the VT PM, other trades and existing conditions to eliminate interference with required clearances for equipment maintenance and inspections.
5. Coordinate work with the VT PM, other trades and existing conditions to determine exact routing of cable, cable tray, hangers, conduit, etc., before fabrication and installation.
6. Install telecommunications cabling and equipment to facilitate maintenance and repair or replacement of equipment components. Provide easy, safe and code mandated clearances at equipment racks and enclosures, and other equipment requiring maintenance and operation. Coordinate with NI&S exact location and mounting height of all equipment in finished areas, such as equipment racks and termination equipment. As much as practical, connect equipment for ease of disconnecting, with a minimum of interference with other installations.
7. Coordinate ordering and installation of all materials with long lead times or having major impact on work by other trades so as not to delay the job or impact the schedule.
8. Set all equipment to accurate line and grade, level all equipment and align all equipment components. All work shall be installed level and plumb, parallel and perpendicular to other building systems and components.
9. Provide all scaffolding, rigging, hoisting and services necessary for delivery, installation, and erection of materials, equipment, and apparatus furnished into the premises. These items shall be removed

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

from premises when no longer required. The use of university supplies and equipment is prohibited.

6.4.4.9.2 Workmanship

All labor must be thoroughly competent and skilled, and all work shall be executed in strict accordance with the best practice of the trades.

1. Good workmanship and appearance shall be considered of equal importance with telecommunications operation.
2. Lack of quality workmanship shall be considered sufficient reason for rejection of a system in part or in its entirety.
3. Carefully lay out all work in advance and install in a neat and workmanlike manner in accordance with recognized good practices and standards.
4. Provide workmen who are skilled in their craft and a competent Project Manager who will be on the job at all times.

6.4.4.9.3 Cables

1. Backbone and horizontal telecommunications cabling shall be placed in separate dedicated conduit pathways. Cable trays may be shared however trays shall be clearly divided between backbone and horizontal cabling. Backbone cabling must be installed prior to horizontal cables.
2. Telecommunications pathways shall be dedicated for use for NI&S voice, data and CATV cabling.
3. Horizontal cabling for other services will be allowed within the NI&S pathways per the following guidelines and acceptance of written approval from NI&S. NI&S must understand and accept the services to be used on the horizontal cabling as to not create interference with other services within the pathways. NI&S will be the sole owner of the horizontal cabling with jacks on both ends that will be installed and tested to the TIA standards on category 6 cable or better with the Siemon standard cabling. Other terminations and systems can be reviewed by NI&S but all horizontal cabling for other services must be approved in writing from NI&S.
4. All horizontal cabling terminating within a single faceplate must be routed to and terminated in the same ER or TR.
5. Consolidation points and multi-user telecommunications outlet assembly (MUTOA) configurations for horizontal cabling are not currently supported by NI&S and will not be permitted.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.4.9.4 Cutting and Patching

1. Provide all cutting, patching, and core drilling, etc., as necessary for telecommunications work. Locate holes and outlets to be drilled and coordinate with work of other trades. Obtain approval of the VT PM and the UBO prior to cutting or core drilling holes in structural members.
2. Cut and drill from both sides of walls and/or floors to eliminate splaying.
3. Patch adjacent existing work disturbed by installation of new work including insulation, walls and wall covering, ceiling and floor covering and other finished surfaces. Patch openings and damaged areas equal to existing surface finish.
4. Cut openings in prefabricated construction units in accordance with manufacturer's instructions.
5. All openings shall be carefully caulked or grouted as required. Spare conduits shall be tightly capped.
6. All cutting in the building construction made necessary to admit work, repair defective materials, defective workmanship, or by neglect of the Contractor to properly anticipate requirements, shall be done in accordance with these specifications with no additional cost to the project. Patching shall be complete in every detail. Actual work involved in these repairs shall be done by skilled craftsmen in the trades involved.
7. Provide and maintain temporary partitions or dust barriers adequate to prevent the spread of dust and dirt to finished areas as required by the VT PM.

6.4.4.9.5 Concealment

Use existing conduit and cable trays where possible and practicable. Conceal all project work above ceilings and in walls, below slabs, and elsewhere throughout building. If concealment is impossible or impracticable, notify the VT PM and NI&S before starting that part of the work and install only after approval.

6.4.4.9.6 Equipment Modification

Where existing equipment is to be modified, Contractor shall furnish materials and labor as necessary to modify or add to the equipment. Modifications shall be done neatly with factory parts and assemblies approved for the application. Modification shall in no way jeopardize the compliance of existing equipment with any governing codes and regulations.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.4.9.7 Firestops and Penetration Seals

1. All new and pre-existing conduit and sleeve openings used for the project shall be waterproofed or fireproofed upon cable placement through such passageways in compliance with the Virginia Statewide Building Code and UBO standards regardless of the installation of cabling or left void.
2. Patch all openings remaining around and inside all new and pre-existing conduit sleeves and cable penetrations to maintain the integrity of any fire-rated wall, floor, ceiling, etc.
3. The manufacturer's installation standards shall be closely followed (minimum depth of material, use of ceramic fiber, procedures, etc.).
4. Brick, concrete, and concrete blocks walls:
   a. Provide metallic sleeving systems for routing of cables through these surfaces.
   b. Ensure that sleeve extends from the front and back of the wall only far enough to attach the required bushing or collar.
   c. Secure sleeves in place according to manufacturer's specifications.
   d. Provide firestop seal between sleeve and wall, but do not use firestopping material to support or secure sleeve.
   e. Firestop ends of sleeving or inner-duct after installation of cable, without exception.
5. Floor openings:
   a. Install firestop materials to stop openings between sleeving (or other supporting material) and core.
   b. When coring through concrete flooring, use boots and packing materials to fashion core before installing firestopping materials.
   c. If rectangular openings exist in concrete floors, use steel sleeving to fashion opening before installing firestopping materials.
   d. Firestop openings in all un-used telecommunications designated slots, sleeves or ducts.
   e. Firestop openings in slots, sleeves or ducts after installation of cable, without exception.
6. Cable trays: All new cable tray pathways penetrating fire-rated walls should be fully closed with Hilti CFS-BL firestop bricks or equivalent firestopping system approved NI&S and UBO.
   a. Install the system according to the manufacturer's instructions.
   b. Firestop materials must be easily removable if required to provide for installation of cable.

7. Fire-rated gypsum walls:
    a. Sleeve all penetrations of gypsum walls used for cable routing if cable is not in continuous conduit with Hilti Speed Sleeve product or equivalent firestopping system approved NI&S and UBO.
    b. Firestop seal between sleeve, conduit, or inner-duct and wall on both sides of the wall.
    c. Use qualified firestop systems to seal penetrations in gypsum wallboard assemblies.
    d. Verify that penetration conditions fall within the following firestop system parameters:
        i. Hourly rating
        ii. Opening size
        iii. Annular space
    e. Install the firestop system symmetrically on both sides of the wall.
    f. Install the materials according to manufacturer-tested methods.
8. Other firestopping:
    a. Firestop through penetrations according to the guidelines for the basic construction of the two outermost layers of the combination wall.
    b. Firestop load-bearing stud walls that are part of combination walls by enclosing (i.e., boxing) the penetration in the cavity.
    c. Firestop partial penetrations according to the recommendations for the type of wall being penetrated.
    d. Firestop any penetrations which violate the fire-rating integrity of vertical shafts.
    e. Firestop openings around outlet boxes installed in fire-rated walls, on both sides.
9. Firestop installation methods:
    a. Use drop cloths to protect other surfaces when installing.
    b. Firestop completely around each cable individually – do not firestop bundles of cables.
    c. If using putty around a vertical penetration, use putty to build flooring of seal, fill with fiber or rock wool to required thickness, then top with putty according to manufacturer's specifications.
    d. The methods used shall incorporate qualities that permit the easy removal or addition of conduits or cables without drilling or use of special tools.

e. The product shall adhere to itself to allow repairs to be made with the same material and to permit the vibration, expansion and/or contraction of any items passing through the penetration without cracking, crumbling, and resulting reduction in fire rating.

10. The installed firestop system shall meet the requirements of “Fire Tests of Through-Penetration Firestops” designated by ASTM E814.
11. Seal all foundation penetrating conduits and all service entrance conduits and sleeves to eliminate the intrusion of moisture and gases into the building. This requirement also includes spare conduits.
12. Spare conduits shall be plugged with removable approved, fire-rated plugs.
13. All service entrance conduits through the building shall be sealed or resealed upon cable placement with a removable waterproof duct seal.
14. The firestop system shall be submitted to the VT PM prior to starting construction with a list or map of each location and system number used for the project. Inspections and approval of installed firestop systems or areas in which firestop material was or should be used will be at the discretion of the VT PM and the UBO.

6.4.4.9.8 Anchoring Methods

1. Anchor and brace all cabling, material, and equipment installed under this section as required by all codes, regulations, and standards. Provide required supports, beams, angles, hangers, rods, bases, braces, straps, struts, and other items to properly support project work. Supports shall meet the approval of the VT PM.
2. Supports shall be fabricated from structural steel, steel channel, or Unistrut, rigidly bolted or welded to present a neat appearance.
3. Fastenings and supports shall be adequate to support loads with ample safety factors.
4. Fasten hanger rods, conduit clamps, outlet boxes, and pull boxes to building structure.
5. Use toggle bolts, spider-type expansion anchors, or hollow wall fasteners in hollow masonry, plaster, or gypsum board partitions and walls.
6. Use lead expansion shields or expansion anchors or preset inserts in solid masonry walls.
7. Use self-drilling anchors or lead expansion anchor on concrete surfaces.
8. Use sheet metal screws in sheet metal studs.
9. Use wood screws in wood construction.

10. In precast structures, use cast-in inserts wherever possible. Expansion anchors can be used with caution, but only with prior approval.
11. In cast-in-place concrete, use expansion anchors, preset inserts, or self-drilling masonry anchors.
12. Use lead expansion anchors or preset inserts on metal surfaces.
13. Do not fasten supports to piping, ceiling support wires, ductwork, mechanical equipment or conduit.
14. Do not drill structural steel members.
15. Any anchoring must be able to be unsecured and removed should relocation be required.
16. Where necessary and with approval from the VT PM, modify studs, add studs, add framing, or otherwise reinforce studs in metal stud walls and partitions as required to suit project work. If necessary in stud walls provide special supports from floor to structure above.
17. Support surface mounted cabinets, enclosures and panel boards with a minimum of four anchors.
18. On exterior concrete walls below grade, provide 1" steel channel stand-offs for cabinets and raceways.
19. Use stud bridges at top and bottom of cabinets and enclosures that are flush mounted on hollow drywall walls.
20. For precast panels/planks and metal decks, support communication work as determined by manufacturer and the VT PM.

6.4.4.9.9 Grounding and Bonding

1. Bond all new metallic cable shields and metallic supporting structures, in all equipment rooms and service entrances, including racks, frames, protectors and cabinets to the telecommunications grounding busbar, according to the manufacturer's specifications and as described in DCSM section 6.4.7.
2. Do not make connections between the telecommunications busbar system and building electrical grounds, or other types of connections, without approval by the VT PM.
3. Bond metallic surfaces of telecommunications hardware with #6 AWG grounding wire as straight as possible to the ground source.
4. Ensure that the grounding system is physically secured.
5. All grounding conductors leaving the ERs and TRs shall be in a separate conduit from all communication cabling.

6. All grounding items shall be installed in complete compliance with the NEC.

6.4.5 Pathways for Communications Systems

6.4.5.1 Scope of Work

Provide all services labor, materials, tools, and equipment required for the complete and proper installation of interior telecommunications pathways as called for in these specifications and related drawings.

This section includes minimum requirements and installation methods for the following:

1. EMT conduit and cable tray systems
2. Surface metal raceway systems
3. Telecommunications outlet boxes

6.4.5.2 Quality Assurance

1. All installation work for the new interior telecommunications pathways shall be performed in a neat and workmanlike manner. All methods of construction that are not specifically described or indicated shall be subject to the control of the VT PM.
2. Equipment and materials shall be of the quality and manufacture indicated. The equipment specified is based on the acceptable manufacturers listed. Where "approved equal" is stated, equipment shall be equivalent in every way to that of the equipment specified and subject to approval of the VT PM based on submittals provided.
3. Materials and work specified herein shall comply with the applicable requirements of:
   a. ANSI/NFPA 70 – National Electrical Code including, but not limited to, the following:
      i. Article 250 – Grounding
      ii. Article 300 – Wiring Methods
      iii. Article 314 – Outlet, Device, Pull, and Junction Boxes; Conduit Bodies; Fittings; and Manholes
      iv. Article 342 – Intermediate Metal Conduit: Type IMC
      v. Article 358 – Electrical Metallic Tubing: Type EMT
      vi. Article 386 – Surface Metal Raceways
      vii. Article 392 – Cable Trays
      viii. Article 770 – Optical Fiber Cables and Raceways

b. ANSI/TIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises – Addendum 2, General Updates
c. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard
d. ANSI/TIA-569-B – Commercial Building Standard for Telecommunications Pathways and Spaces, including applicable addendum
e. ANSI/TIA-607 – Commercial Building Grounding and Bonding Requirements for Telecommunications
f. BICSI Telecommunications Distribution Methods Manual

6.4.5.3 Submittals

As-built drawings as required per DCSM section 6.4.3.

6.4.5.4 Materials

6.4.5.4.1 EMT Conduit, Outlet Boxes, and Cable Tray Systems

1. Electrical metallic tubing (EMT): Electro-galvanized steel tubing 1″ and larger diameter per project requirements:
   a. Conduit joint couplings and connectors – steel double set screw indenter fittings.
   b. Insulated metallic bushings for 1″ and larger conduit.
   c. Insulated metallic bushings with grounding lugs as required.
   d. Conduit sweeps – minimum 10 times the conduit inside diameter.
   e. Include required conduit straps, and hangers, heavy-duty malleable iron or steel.
   f. Perforated pipe strap, j-hooks, bridle rings, or wire hangers are not permitted without approval.
   g. LB fittings and plastic fittings are not permitted.
   h. Conduits connecting one outlet box to another outlet box are not permitted.
2. Conduits feeding surface metal raceways shall be sized to allow for no greater than 40% fill when horizontal station cables supporting the raceway outlets are installed.
3. The standard outlet box shall consist of a nominal 4″ × 4″ × 2-1/4″ metal box, with a 4″ × 4″ drywall ring with mounting holes for a double gang faceplate.
4. If a standard 4″ × 4″ × 2-1/4″ metal box is not feasible, NI&S must approve the substitute in order to ensure compatibility with NI&S-

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

supplied hardware, compliance with standards, and life cycle maintainability.

5. Emergency phones – internal
   a. A number of "push-to-talk" emergency phones may be located on each floor of a building. The number and location of the phones is determined by OEM and VTPD.
   b. The physical requirements for the infrastructure to support the phones are a flush mount 4″ × 4″ back box with a minimum 2-1/4″ depth. One 1-inch conduit shall be routed from the back box to within 12 inches of the nearest cable tray or homerun to the nearest communications room.
   c. The mounting height should meet ADA requirements (coordinate with the VT PM for final box elevation). The back-box faceplate mounting hole pattern shall be designed to accept the Viking 1600A push-to-talk device without the use of additional mounting equipment.
6. Pull boxes:
   a. Minimum 14-gauge galvanized steel with screw fastened cover and trim for flush or surface mounting as required for project. Dimensions as required for project.
   b. Box extensions are prohibited for new construction.
   c. Box extensions are permitted on remodel work to extend existing installations.
7. Metal flex conduit (1″) and deep cut-in boxes for outlets in existing walls for remodel projects only.
8. Mule tape: Use polyester or aramid line with a minimum pull tensile strength of 200 pounds for installing backbone cable in riser conduits. Contractor shall install and secure mule tape in all telecommunications conduits for future cabling installations.
9. Poly line: Use poly pull line with a minimum pull tensile strength of 200 pounds for installing station cabling in horizontal pathways. Contractor shall install and secure poly lines in all horizontal telecommunications pathways for future cabling installations.
10. Cable trays in ceiling areas:
    a. Welded wire mesh cable system sized to accommodate all necessary project cabling and future growth.
    b. Include components, and compatible fittings designed and manufactured by the cable tray manufacturer as required for a fully installed electrically continuous system.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. Include support kits, brackets, threaded rod hangers, lateral threaded rod braces, and other anchors and supports as required as specified in DCSM section 6.4.4.

6.4.5.4.2 Surface Metal Raceway Systems (SMRS)

1. Include all parts and components (base and cover, compatible fittings, insulated bushings, and supports) designed and manufactured by the raceway manufacturer as required for a complete installation.
2. Where raceways will support work area outlets, provide appropriate adapters which will accept NI&S standard modular outlet jacks.
3. Where power and communications cabling must be run within the same raceway Contractor shall provide and install a solid metallic separation device manufactured specifically for the installed raceway system.

6.4.5.5 Execution

6.4.5.5.1 Inspection

1. Examine areas and conditions under which the new interior telecommunications pathways are to be installed. Provide notification, in writing, of conditions detrimental to proper completion of the work.
2. Verify field measurements and pathway routing conditions are as shown on project drawings. Provide notification, in writing, of conditions deviating from drawings.
3. Beginning of telecommunications pathway installation indicates Contractor acceptance of existing conditions.

6.4.5.5.2 Inside Cable Tray Installation

1. Cable trays provide critical cable management and allow access to horizontal wiring, which is essential for initial installation and future growth. Cable tray systems shall originate in the ER/TR and extend the entire length of the main hallways. Cable trays shall form part of a continuous cable pathway connected to the serving ER/TR.
2. Cable tray capacity shall be determined by the number of telecommunications outlets that will be served. Larger cable trays should be used in areas that have high-density telecommunications requirements. The dimensions of the cable tray may vary to accommodate the space available as long as the required capacity is maintained. Capacity requirements shall be specified by NI&S. Cable

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

trays shall not be filled greater than the NEC maximum fill for the tray selected.

3. The size of the cable tray may be incrementally decreased the further it extends away from the ER/TR, depending on the specific requirements of the areas being
4. There must be at least 3 inches of clear space above the cable tray for access; a clear space of 6 inches is preferable.
5. All telecommunications cable trays shall have a minimum of 5-inch clearance from any sort of light fixtures.
6. No conduits, pipes, wires, threaded rod, grounding hardware or any other obstruction may penetrate the interior area of the tray where the cables are to be routed.
7. All screws, bolts, etc., used to connect the sections of tray must be installed so that they do not obstruct the installation of the cabling.
8. Cable trays are to be installed at the same elevation within the ceiling throughout the building floor.

6.4.5.5.3 Inside Conduit Installation

1. The electrical contractor will provide clean, dry and debris free conduits, to be used solely by NI&S to provision telecommunications services.
2. Conduits shall either be continuous “home-run” from the telecommunications outlet box to the equipment room, or shall be run from the outlet box and stubbed out within one foot of a cable tray that runs continuously to the equipment room. In the case of a renovation where there is no cable tray available, the conduit for the outlet box should be routed to an accessible ceiling area in the corridor.
3. The standard station-cable conduit size is 1-inch diameter minimum. The 1-inch diameter minimum may be increased depending upon the size and number of cables to be installed. Minimum conduit diameter shall be determined by NI&S based on the quantity and size of cable required.
4. Perform installation of routing hardware as specified in DCSM section 6.4.4 including anchoring and supports, grounding and bonding, firestop, etc. Use anchors for attachment to surface. Use of adhesives is prohibited.
5. The contractor shall install threaded bushings on all conduit ends.
6. The maximum conduit length is 30 meters (100 feet) between pull boxes or pull points, with no more than two 90-degree bends between pull boxes or pull points.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

7. No unnecessary junction boxes, troughs, etc., will be installed in the conduit pathway between the outlet box and either the cable tray or the telecommunications equipment room. And the conduits are to be installed in the most direct route from the outlet box to either the cable tray or the telecommunications equipment room.
8. All conduit bends shall be sweeps with minimum bend radii as specified in the appropriate standards. There shall be no hard 90-degree bends.
9. The contractor shall provide a pull string (minimum pull strength of 200 pounds) in each conduit. Pull strings must be tied off at both ends of the conduit to prevent loss of the pull string.
10. All conduits from a room must be run to the same cable tray or equipment room. If there is more than one cable tray adjacent to a room, the conduits from a room cannot be “split” between the trays.

6.4.5.5.4 Surface Metal Raceway Installation

1. Place new surface metal raceway systems as shown on the project drawings.
2. Perform installation of routing hardware as specified in DCSM section 6.4.4 including anchoring and supports, grounding and bonding, firestop, etc. Use anchors for attachment to surface. Use of adhesives is prohibited.
3. Collector/distribution surface raceway shall be 25 +/- 5 feet between pull boxes. Surface raceway and boxes shall be upsized per fill in area.
4. Cut raceways square and ream ends to remove burs at raceway connections to outlets.
5. Install raceways parallel or perpendicular to building walls, floors and ceilings.
6. When installing through false ceiling, extend raceway above top of ceiling grid to a pull box feeder system or within 6 inches of the cable tray. Notch ceiling panel to size of raceway.
7. Coordinate raceway runs with other trades.
8. Ceiling tile shall be removed as necessary for the raceway installation and put back in place without damaging or dirtying any of the tiles or supporting framework. Ceiling tile shall be handled with clean hands so that no fingerprints or marks are left on the tiles. The contractor is responsible for the cost of repair or replacement of any damaged or dirtied tiles or ceiling hardware.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

9. Conduits feeding raceway shall be sized to accommodate the number of cables needed in the raceway and allow for future growth. Coordinate conduit sizing with NI&S.

6.4.5.5.5 Telecommunications Outlets

1. It is the responsibility of the VT PM to coordinate with the departments moving into the space(s), and with NI&S, to determine the location and number of telecommunications outlet boxes required in each space.
   a. Unless otherwise noted, outlet boxes shall be located as follows (dimensions are above finished floor to center line of boxes):
      i. Standard telecommunications outlets: 1′6″
      ii. Top of wall-mount telephone outlets: 4′0″
   b. All ADA standards shall be met when applicable.
   c. Adjust outlet box locations so that they will be symmetrically located and not interfere with other equipment.
   d. Where outlets of other types are adjacent, coordinate heights to be similar where possible.
   e. Where outlets are located on masonry walls, adjust box location to set in corner of block or brick.
   f. Back to back outlet boxes are not permitted. Separate boxes a minimum of 6 inches in standard walls and a minimum of 2 feet in acoustical walls.
   g. Where conflicts are noted for outlet box locations, coordinate with the VT PM and NI&S.
2. Support outlet boxes from building construction. Do not support from other installed systems (e.g., ceiling support wiring, conduit, or raceways).
3. Telecommunications outlet boxes that support devices for wireless access points and emergency notification boards will be part of the cabling design. The electrical contractor will install conduit from the outlet box to within one foot of the cable tray, or to the ER/TR.
   a. The wireless access point outlet boxes should be placed in locations designated by NI&S. The outlet boxes should be placed above accessible ceilings where possible. If a ceiling mount is not possible then the outlet boxes should be placed 12 inches below the ceiling in the locations designated by NI&S.
   b. Notification board outlet boxes should be placed in locations designated by OEM and VTPD. The outlet boxes should be placed

below the ceilings as close as possible to the reader board location as noted on the project drawings.

6.4.5.5.6 As-Built Drawings

Mark the project drawings with notations reflecting any variations from the base specifications and drawings including as-built conduit and cable tray routing.

Comply with construction drawing as-built requirements as described in DCSM section 6.4.3.

6.4.6 Exterior Underground Ducts and Raceways for Communications Systems

6.4.6.1 Scope of Work

Provide all services, labor, materials, tools, and equipment required for the complete and proper installation of exterior telecommunications pathways as called for in these specifications and related drawings.

This section includes minimum requirements and installation methods for the following:

1. Building entrance conduits.
2. ER/TR conduits extending from building entrance (where applicable).

6.4.6.2 Quality Assurance

1. All installation work for the new exterior telecommunications pathways shall be performed in a neat and workmanlike manner. All methods of construction that are not specifically described or indicated shall be subject to the control of the VT PM.
2. Equipment and materials shall be of the quality and manufacture indicated. The equipment specified is based on the acceptable manufacturers listed. Where “approved equal” is stated, equipment shall be equivalent in every way to that of the equipment specified and subject to approval of the VT PM and NI&S based on submittals provided.
3. Materials and work specified herein shall comply with the applicable requirements of:
    a. ANSI/NFPA 70 – National Electrical Code including, but not limited to, the following:
        i. Article 314 – Outlet, Device, Pull Boxes; Conduit Bodies; Fittings; and Manholes

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ii. Article 344 – Rigid Metal Conduit: Type RMC

b. IEEE/NESC – National Electrical Safety Code
c. NEMA standards including, but not limited to: NEMA, RN1, 1986 PVC Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
d. UL standards including, but not limited to: UL 6, 1981 Rigid Metal Electrical Conduit
e. ANSI C80.2-1983 – Specification for Rigid Steel Conduit, Enameled
f. ANSI/TIA-569-B – Commercial Building Standard for Telecommunications Pathways and Spaces
g. ANSI/TIA-607 – Commercial Building Grounding and Bonding Requirements for Telecommunications
h. ANSI/TIA-758-A – Customer Owned Outside Plant Telecommunications Cabling Standard (including all applicable addenda)
i. BICSI Telecommunications Distribution Methods Manual
j. BICSI Customer Owned Outside Plant Manual

6.4.6.3 Submittals

As-built drawings as required per DCSM section 6.4.3.

6.4.6.4 Materials

The conduit system is metallic conduit:

1. Galvanized rigid conduit (GRC) with PVC coating (for building entrances).
2. Intermediate metal conduit (IMC) or rigid steel conduit (for extending entrance conduit).

6.4.6.5 Execution

6.4.6.5.1 Conduit System Placement

1. Each building is required to have two diverse building entrances for survivability. Each building entrance must have a separate inside plant pathway to ER/TRs to be specified by NI&S. The location of these building entrances shall be determined in collaboration with NI&S and the VT PM.
2. Each building entrance shall consist of a minimum of two 4-inch conduits and two 2-inch conduits of IMC or rigid steel conduit extended a minimum of 10 feet from the foundation wall and into undisturbed soil. The exact size and number of conduits required depends on the requirements of the building being served and shall be specified by NI&S. These conduits are solely intended for the provisioning of

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

telecommunications services by NI&S. The use of these conduits is managed and documented solely by NI&S.

3. Additional conduit shall be provisioned as required to support other services (e.g., building control systems) that run over non-NI&S cable plant.
4. The conduit pathway within the building shall be continuous rigid or intermediate conduit in cases where the distance between the termination location and the building entrance is greater than 15 meters (49 feet).
5. All conduit bends will have a radius no less than 9 times the internal diameter of the conduit with a minimum radius of 36 inches.
6. No bends will be greater than 90 degrees.
7. No more than two 90-degree bends in a run between pulling points.

6.4.6.5.2 As-Built Drawings

Mark the project drawings with notations reflecting any variations from the base specifications and drawings including as-built conduit routing.

Comply with construction drawing as-built requirements as described in DCSM section 6.4.3.

6.4.7 Communications Equipment Room Fittings

6.4.7.1 Scope of Work

Provide all services, labor, materials, tools, and equipment required for the complete and proper installation of communications equipment within the ERs and TRs as called for in these specifications and related drawings.

This section includes minimum requirements and installation methods for the following:

1. Equipment racks and cable routing hardware
2. Copper termination equipment
3. Fiber termination equipment
4. Grounding and bonding

6.4.7.2 Quality Assurance

All installation work in the TRs and the ERs shall be performed in a neat and workmanlike manner. All methods of construction that are not specifically described or indicated shall be subject to the control of the VT PM.

Equipment and materials shall be of the quality and manufacture indicated. The equipment specified is based on the acceptable manufacturers listed. Where "approved equal" is stated, equipment shall be equivalent in every way to that of the equipment specified and subject to approval of NI&S based on submittals provided.

Materials and work specified herein shall comply with the applicable requirements of:

1. ANSI/NFPA 70 – National Electrical Code (NEC) Articles 250, 300, and 645
2. ANSI/TIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises- Addendum 2, General Updates
3. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard
4. ANSI/TIA-568-B.2 – Commercial Building Telecommunications Cabling Standard – Part 2: Balanced Twisted-Pair Cabling Components, including applicable addendum
5. ANSI/TIA-568-C.3 – Optical Fiber Cabling Components Standard
6. ANSI/TIA-569-C – Commercial Building Standard for Telecommunications Pathways and Spaces
7. ANSI/TIA-604 Series – Fiber Optic Connector Intermateability Standards
8. ANSI/TIA-607 – Commercial Building Grounding and Bonding Requirements for Telecommunications
9. BICSI Telecommunications Distribution Methods Manual

6.4.7.3 Architectural Requirements

1. New TRs and ERs shall be designed in compliance with the space, electrical, and environmental requirements of ANSI/TIA-569-C – Commercial Building Standard for Telecommunications Pathways and Spaces. Smaller spaces or enclosures shall not be acceptable without prior written approval from NI&S.
2. Any or all functions of a TR may be provided by an ER.
3. The ER and TRs shall be dedicated to the telecommunications function and related support facilities. For security purposes, non-NI&S systems shall not be co-located in the ER and TRs. The ER and TRs shall not be shared with electrical installations other than those supporting telecommunications. Equipment not related to the support of the ER or TRs (e.g., piping, HVAC systems, and pneumatic tubing) shall not be installed in, pass through, enter, or be stored in the ER or TRs.
4. ER and TR design, including location, should be developed in accordance with the security and disaster avoidance plans of the building.

6.4.7.4 Room Size and Spacing

1. There shall be a minimum of one TR per floor. Exceptions may be approved by NI&S where conditions warrant. Additional rooms shall be provided when:
   a. The floor area to be served exceeds 10,000 square feet or
   b. The horizontal cable distance from the ER/TR to the work area exceeds 90 meters (295 feet).
2. ER and TR room sizes: ER/TR size shall be determined by NI&S based on the size and program of the building.
   a. The minimum ER size is 10′ × 15′.
   b. The minimum TR size is 10′ × 10′.
3. Special purpose rooms, such as laboratories, computer rooms and certain instructional spaces, may have a varying density of communications outlets. The size of the ER/TR serving these rooms shall be sized accordingly, as determined by NI&S.

6.4.7.5 Location

1. Each ER/TR shall be located as close as practical to the center of the area served.
2. ER/TR doors shall open directly onto a hallway to facilitate the movement of large equipment and 24×7 maintenance access.
3. Access through ER/TRs to other areas of the building, including electrical vaults, shall not be permitted.
4. ER/TRs should be located away from sources of electromagnetic interference. Special attention shall be given to electrical power supply transformers, motors, generators, x-ray equipment, and radio/radar transmitters.
5. TRs on multiple floors should be stacked over/under the ER wherever practical and as close as possible to vertical stacks. Depending on building size, there may be multiple TRs per floor. Should this be required, there will need to be multiple TR stacks.
6. ER/TRs shall be located as close as practical to the location where the vertical backbone cable pathways rise throughout the building. This requirement reduces the length and quantity of the associated pathways.
7. The ER shall not be located below grade or below the 100-year floodplain unless preventive measures against water infiltration are employed.
8. ER/TRs shall be positioned such that the risk of water infiltration from in-building systems is minimized. Possible sources of such water infiltration

include domestic water supply and drains, fire sprinkler supplies, roof drains, HVAC condensation and drains.

9. ER/TRs shall be positioned away from sources of high quantities of airborne particulates (e.g., dust).

6.4.7.6 Power

1. Refer to DCSM section 6.8 for additional electrical power requirements.
2. A separate supply circuit serving the ER shall be provided and terminated in its own electrical panel in the ER. The electrical panel in the ER shall be sized to meet the projected power requirements of service to the ER and all TRs, and shall be used only to provide power to the ER/TRs.
3. Each TR shall have an electrical panel located in the TR that is fed from the electrical panel in the ER.
4. The electrical panel in the ER shall be connected to an emergency power system (generator).
5. Each ER and TR shall have two 30-amp 208-volt circuits terminated on L6-30R at rack location specified by NI&S. One circuit from ER or TR emergency panel and one from building utility power to provide redundancy on network equipment having dual power supplies.
6. Each equipment rack (ER and TR) will require one 20-amp 120-volt receptacle (5-20R) circuit originating from emergency panel in room.
7. Device boxes shall be extended to the top of each equipment rack via flexible conduit. Device boxes shall be mounted to a backplate which shall have accessible screws securing it to the rack location specified by NI&S.
8. In order to provide capacity for growth, in addition to circuits required for equipment racks, all new electrical panels for ER/TRs will also include:
   a. One 20-amp 120-volt single-pole circuit
   b. One 20-amp 208-volt double-pole circuit
   c. One 30-amp 208-volt 3-phase circuit
9. Each of these circuits will be landed (terminated) on the breaker and extended into individual 4-inch junction boxes located within 12 inches of the bottom of the panel. These junction boxes shall have blank covers with the panel and breaker information clearly marked.
10. In addition, identified and marked utility duplex outlets shall be placed at 6-foot intervals around the perimeter walls, at a height of 18 inches above the floor. Duplex utility outlets shall be provisioned on normal building power and not tied back to the electrical panel in the ER/TR.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.7.7 Equipment Bonding and Grounding

1. Grounding systems installed by or for NI&S are for NI&S use only; all other use is strictly prohibited.
2. All stranded grounding conductors shall be insulated and color-coded (green with yellow trace).
3. There shall be at least one grounding conductor, the telecommunications bonding backbone (TBB), for each riser stack. The TBB must be continuous and unbroken from the building central grounding point through each ER/TR in the stack. Minimum grounding conductor size is specified in the table below.
4. Virginia Tech requires that a terminal grounding bar (TGB) be installed in each ER and TR and tied to the TBB. For the TGB, the basis of design shall be a Panduit grounding bar (part number GB2B0312TPI-1) or equal. The TBB shall be tapped in each ER/TR and connected to the TGB in the ER/TR. Minimum grounding conductor size for the connection between the TGB and the TBB is specified in the table below.
5. All grounding conductor terminations shall be compression crimped (no threaded compression lugs).
6. In buildings with more than one TBB, the TBBs shall be bonded together at the top floor and at a minimum of every third floor in between. Minimum grounding conductor size is specified in the following table.
7. Minimum grounding conductor sizes are as follows:

Table 6-1. Minimum Grounding Conductor Sizes

Sizing of the Grounding Conductor Length in Linear Meters (Feet)	Size (AWG)
Less than 4 (13)	6
4-6 (14-20)	4
6-8 (21-26)	3
8-10 (27-33)	2
10-13 (34-41)	1
13-16 (42-52)	1/0
16-20 (53-66)	2/0
Greater than 20 (66)	3/0

8. Provide and install grounding strip kits for threaded rails on front left side of each equipment rack. Basis of design shall be Panduit RGS134 or equal.
9. Ground all equipment racks and building entrance protectors to the TGB using #6 ground conductor.

10. The Contractor shall install NI&S-provided labels on grounding conductors every 5 to 20 feet as required by the cable path.
11. The Contractor shall ground all metal cable trays by connecting them to the central building grounding point per applicable specifications.

6.4.7.8 Environmental Considerations

1. ER/TRs typically require cooling year-round due to the heat generated by telecommunications equipment. The HVAC system shall be capable of maintaining the temperature between 64 °F and 78 °F in each ER/TR, with relative non-condensing humidity maintained within the range of 30% to 50%.
2. Each ER/TR shall have its own thermostat controlling the temperature for that room. Thermostat will be hard wired (no battery powered remote thermostats).
3. In some cases, the ER/TR HVAC system(s) should be on the building emergency power system (as determined by NI&S).
4. A positive air pressure shall be maintained with a minimum of one air change per hour, or as required by applicable code.
5. Heat rejection specifications for each ER/TR is determined from the number of telecommunications outlets served by each particular room and the type of equipment used to provision services. Specific heat rejection values for ER and TRs shall be coordinated with NI&S.
6. The preferred location for a fan coil unit (FCU) is above the equipment room entry door to minimize the impact on the usable space within the equipment room.

6.4.7.9 Construction

1. A minimum of one wall shall be covered with 19 millimeters (3/4 inch) A-C plywood, void free, 2.4 meters (8 feet) high and securely fastened to the wall, capable of supporting attached equipment. Plywood shall be fire-rated (fire retardant) plywood. The location is to be coordinated with NI&S.
2. Lighting shall be a minimum of 500 lux (50 foot-candles) measured 1 meter (3 feet) above the finished floor, mounted 2600 millimeters (8.5 feet) minimum above finished floor.
   a. NI&S requires that at least two lighting fixtures be installed per ER/TR. These lights shall be installed in front and behind the telecommunication equipment rack(s). The location of the lighting fixtures is to be coordinated with NI&S.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   b. Lighting shall be controlled by one or more switches located near the entrance door(s) to the room. Dimmer switches shall not be used.
   c. At least one light per ER/TR shall be on the building emergency lighting circuit.
3. False ceiling shall not be provided.
4. For ER/TRs, the minimum clear height in the room shall be 2.4 meters (8 feet) without obstructions.
5. Door requirements:
   a. The door shall be a minimum of 0.9-meter (36 inches) wide, 2 meters (80 inches) high, without door sill, hinged to open outward (codes permitting) and fitted with a lock. The doors shall have a lever handle, store room lock, pick guard and shall be keyed to the next available core in the 102 series.
   b. The locks for the ER and TRs shall not be on the building master keys. These locks shall be incapable of remaining in an unlocked state when the key is removed.
   c. The door shall be equipped with an auto closing device. A door sweep shall be installed at the bottom of the door and shall be consistent with other door sweeps throughout the building.
   d. The fire rating of the door shall be consistent with the fire rating of the walls of the room.
   e. On outward opening doors, the hinges shall be of the anti-tampering type. These hinges shall be consistent with and match similar mechanisms throughout the building.
6. Floors and walls shall be finished with a static free treatment or sealed to minimize dust; finishes shall be light in color to enhance room lighting.
7. Floor loading capacity of ER/TRs shall be at least 50 lb./sq. ft. The A/E shall verify that concentrations of proposed equipment do not exceed the floor loading limit, which may require increasing the floor loading capacity in some cases.

6.4.7.10 Fire Protection

The contractor shall provide fire protection to the room as required by code.

Sprinkler heads, if required, shall be provided with wire cages to prevent accidental operation.

6.4.7.11 Pathways and Room Penetrations

1. The size and number of sleeves, conduits and/or cable trays used for riser and horizontal pathways depends on the requirements of the area served. The size and number of sleeves, conduits and/or cable trays required shall be specified by NI&S.
2. Sleeves or slots shall not be left open except during cable installation and shall be properly firestopped per applicable codes. The interior of all sleeves or slots shall be firestopped in the ER/TR by the Contractor after cable installation. Red firestopping material shall be used in all cases.
3. For any multi-story building, Contractor shall provide a schematic riser diagram depicting telecommunications infrastructure to include outside plant (OSP) main feed, OSP redundant feed, riser conduits (noting size and quantity), cable trays and transitions from cable trays to sleeves and a typical station cable conduit and outlet box.

6.4.7.12 Submittals

As-built drawings as required per DCSM section 6.4.3.

6.4.7.13 Materials

NI&S provides and installs the equipment and materials listed below.

6.4.7.13.1 Equipment and Materials Minimum Requirements

1. The basis of design for the floor-mount equipment rack is Ortronics Mighty Mo 6 #OR-MM6716.
   a. Rack height: 84″ high with 44 rack spaces (one rack space = 1-3/4″)
   b. EIA-310-D standard 5/8″-5/8″-1/2″ hole pattern
   c. EIA channel width of 16.25″ with double-sided 12/24 tapped screw holes
   d. Lightweight high strength aluminum construction with black finish
   e. Rack depth: 26.25″ deep base with four 3/4″ bolt down holes and equipped with hardware for permanent mounting on concrete floor
   f. Static capacity 1500 pounds.
   g. Bend radius control with integrated cable trough and waterfalls
   h. Rack installation kit
2. The basis of design for the vertical wire management is Ortronics vertical wire management cage #OR-MM6VML706.
   a. Cage dimensions: 77.18″ H × 6″ W × 6.13″ D

   b. Swing out latches allow for addition/deletion of cables without affecting adjacent cables
   c. Mounted on the front flange of Mighty Mo 6 racks when two or more are installed in a row, on a single rack or the end of a row
   d. Creates a 2-inch channel between racks for front to back routing of equipment cables and patch cords
   e. Includes all mounting brackets
3. The basis of design for the vertical grounding strip busbars for new install racks and cabinets is Panduit RGS134-1Y grounding strip for threaded rails.
   a. Provides clean bond to any rack mounted equipment regardless of whether or not equipment has an integrated grounding terminal
   b. Bonds full 45 RU per rack
   c. Comes in EIA universal mounting hole pattern
   d. Complies with U.S. and international grounding requirements
   e. Busbar installation kit
4. Cable tray:
   a. Cable tray shall be installed above the racks to facilitate routing of cables from room entrance conduits.
   b. The basis of design for the carbon steel wire mesh cable tray with electroplated zinc finish (2″ D × 12″ W × 10″ L) is Cablofil CF54/300EZ.
   c. Include support kits, brackets, splice kits, end caps, etc., as required for complete installation.
5. Plywood backboard: 3/4″ A-C fire-resistant or non-combustible plywood backboard, void free, 8′ high.
6. Category 6 compliant 1/2-D-Rings and D-Rings wall-mount nominal 2″, 4″, or 6″ as required.
7. Velcro cable ties for cable routing and management as required. The use of “tie-wraps” is prohibited without written authorization from NI&S.
8. Building entrance terminals:
   a. The basis of design is Circa BET 188B1-100-25.
      i. Includes 100-pair capacity
      ii. Includes 25′ stub in/110 block out
      iii. Accepts 5-pin surge protection modules
   b. The basis of design is circa surge protection modules 4B1S-300.
      i. Includes 5-pin solid-state protector module.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ii. Includes positive temperature coefficient (PTC) technology. Self-resetting current limiters which provide effective protection from "sneak current" faults.

9. The basis of design for the wiring block mount is the Siemon S210.
   a. The basis of design for the 19" field termination panel (tie to building entrance protector) is the Siemon S210.
   b. The basis of design for the 19" field termination panel (copper riser) is the Siemon S210-(XXX) – Use (XXX) to specify 128 or 292 pair panels sized per project.
   c. Standard 210 blocks shall possess the following characteristics:
      i. Be made of flame-retardant thermoplastic, with the base consisting of horizontal index strips for terminating up to 25 pairs of conductors.
      ii. Have detachable stand-off legs on the 128-pair base.
      iii. Contain access openings for rear to front cable routing to the point of termination.
      iv. Have termination strips on the base to be notched and divided into 5-pair increments.
      v. Have clear label holders with the appropriate colored inserts available for the wiring blocks. The insert labels provided with the product shall contain vertical lines spaced on 2-, 3-, 4- and 5-pair circuit sizes and shall not interfere with running, tracing or removing patch cords. Label holders must be capable of mounting between each row of connecting blocks.
      vi. Bases are attached to 19-inch panels for rack mounting with cable management hardware.
      vii. Have connecting blocks used for either the termination of cross-connect (jumper) wire or patch cords. All connecting blocks shall have color-coded tip and ring designation markers and be of single piece construction.
      viii. Have connecting blocks with a minimum of 200 re-terminations without signal degradation below standards compliance limit.
      ix. Support wire sizes of solid 22 to 26 AWG (0.64 to 0.40 mm), and 7-strand wires.
   d. Must be communications circuit accessory listed per UL 1863.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

e. Meet the following performance specifications:

Table 6-2. Wiring Block Mount Performance Specifications

Parameters	Performance @ 100 MHz
Insertion Loss	0.4 dB
NEXT	43.0 dB
FEXT	35.1 dB
Return Loss	20.0 dB

10. All Category 6 or 6A-termination panels shall facilitate cross-connection and inter-connection using modular patch cords and shall conform to EIA standard, 19-inch relay rack mounting requirements.
    a. The basis of design for the Cat 6 patch panel is Siemon Z6-PNL-24K.
        i. Includes 24 Z-MAX Panel outlets.
        ii. Made of lightweight, high strength steel with durable black finish in 24 port 1U configuration.
        iii. Panel outlets feature angled IDC contact pattern to exploit the widest outlet cross-section to minimize alien crosstalk.
        iv. Have a quick release lever that allows individual outlets to be easily removed even in tight installations.
        v. Have port identification numbers on the front of the panel.
        vi. Accommodate 24 ports for each rack mount space (one rack mount space [RMS] = 44.5 mm [1.75 inches]).
        vii. Come equipped with integrated rear wire management system.
        viii. Be provided with high visibility snap-on magnifying label holders that contain paper labels or Z-MAX icons for port identification.
    b. The basis of design for the Cat 6A shielded patch panel is Siemon Z6AS-PNL-24K.
        i. Includes 24 shielded Z-MAX panel outlets.
        ii. Made of lightweight, high strength steel with durable black finish in 24-port 1U configuration.
        iii. Panel outlets feature angled IDC contact pattern to exploit the widest outlet cross-section to minimize alien crosstalk.
        iv. Have a quick release lever that allows individual outlets to be easily removed even in tight installations.
        v. Have port identification numbers on the front of the panel.
        vi. Accommodate 24 ports for each rack mount space (one RMS = 44.5 mm [1.75 inches]).
        vii. Come equipped with integrated rear wire management system.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

viii. Be provided with high visibility snap-on magnifying label holders that contain paper labels or Z-MAX icons for port identification.

11. The basis of design for the rack mount optical fiber panel/enclosure is the rack-mount fiber cabinet by OCC #RTC2U6APB-RS2U2T, including one RS2U2T splice kit.
    a. The rack mount optical fiber panel/enclosure shall be constructed of all steel and equipped with either removable front and rear access to fibers or a sliding drawer to access fibers.
    b. The rack mount optical fiber panel/enclosures shall be available with locking capabilities for security.
    c. The rack mount optical fiber panel/enclosure shall be capable of terminating tight-buffered or loose tube optical fiber cable.
    d. The rack mount optical fiber panel/enclosure shall provide for bend radius control throughout the panel as well as storage space for slack cabling.
    e. The rack mount optical fiber panel/enclosure shall provide labeling space to facilitate port identification according to TIA 606A standards.
    f. The panel/enclosure shall meet or exceed the performance criteria per ANSI/TIA-568-C.3.
    g. The rack mount optical fiber panel/enclosure shall be equipped with optical fiber adapter panels and corresponding pre-terminated pigtail fiber optic assemblies.
12. Optical fiber adapter panels and pre-terminated pigtails:
    a. Field terminated fiber connectors will not be accepted. Factory polished pigtail assemblies for all fiber ends must be fusion sliced to the installed cabling.
    b. The multimode optical fiber adapter panels and pre-terminated pigtail fiber optic cable assemblies shall be configured with six dual port multimode SC adapters.
    c. The single-mode optical fiber adapter panels and pre-terminated pigtail fiber optic cable assemblies shall be configured with six dual port single-mode SC APC adapters.
    d. The basis of design for fiber adapter panels is OCC.
        i. OCC 6112DSC50G – adapter plate, 12-port, dual SC, 50 µm 10GbE multimode, composite sleeve
        ii. OCC 6112SMDSCAPC – adapter plate, 12-port, dual SC, single-mode, angled polish, ceramic sleeve

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

e. The basis of design for pre-terminated pigtails is OCC.
   i. OCC P5GSC12-3M – factory terminated pigtail assembly, 12-fiber 50 µm OM3 color-coded 900 µm multimode fiber stock, 3-meter lengths, pre-polished SC connectors
   ii. OCC P8SCAPC12-3M – factory terminated pigtail assembly, 12-fiber color-coded 900 µm single-mode fiber stock, 3-meter lengths, pre-polished SC APC connectors

6.4.7.13.2 Grounding and Bonding

1. Grounding wire: #4 and #6 AWG wire suitable for grounding application.
2. All connectors and clamps shall be compression type.
3. Terminals shall be solderless compression type, copper long-barrel NEMA two bolt.
4. Telecommunications bonding backbone (TBB): Minimum No. 6 AWG insulated copper conductor.
5. Telecommunications main grounding busbar (TMGB): Minimum 6.3 mm thick by 100 mm wide predrilled copper busbar with standard NEMA bolt hole sizing and spacing.
6. Telecommunications grounding busbar (TGB): Minimum 6 mm thick by 50 mm wide predrilled copper busbar with standard NEMA bolt hole sizing and spacing.
7. All grounding equipment shall be UL listed for that purpose.

6.4.7.14 Execution

6.4.7.14.1 Equipment Racks and Cable Routing Hardware in Telecommunications Rooms

1. The ERs and TRs may be equipped with some existing hardware, such as plywood backboards, grounding bus bars, equipment racks, ladder cable tray, horizontal and vertical cable management, and copper and fiber termination equipment. Existing hardware already in place will be shown on the project drawings.
2. Examine ERs, TRs, and verify conditions are as shown on project drawings. Provide notification in writing of conditions deviating from drawings or detrimental to proper completion of the work.
3. Beginning of installation in the ERs and TRs indicates contractor acceptance of existing conditions.

4. The quantity of equipment racks can vary based on the number of outlets being served by each ER/TR. At a minimum provide and install two racks per ER/TR in new construction projects.

   Some renovation projects or smaller new construction projects may require less than two racks or wall mount-type racks. Obtain approval from NI&S prior to construction for all equipment room designs which include these types of non-standard projects.

5. The contractor shall obtain NI&S approval of the proposed equipment rack layout prior to installation.
6. All equipment racks shall be securely anchored to the concrete floor using minimum 3/8-inch hardware or as specified by rack manufacturer.
7. Install new vertical wire managers on each side and between all equipment racks.
8. Install grounding strip on front left side of each equipment rack and bond to TMGB with a minimum No. 6 AWG insulated copper conductor.
9. Install new cable tray for cable routing in the ERs and TRs above the equipment racks. All cable tray shall be securely anchored to the walls with support kits and brackets as specified by manufacturer.
10. Install plywood backboard on the walls in the ERs and TRs as required for the project. All plywood backboard shall be securely anchored to the walls.
11. All new 4-pair unshielded twisted pair (UTP) cables shall be supported using only Category 6 compliant materials and equipment including cable tray, D-rings, and cable management hardware, and shall be manufactured to allow for installation of Category 6 cables without damaging or otherwise distorting the cable's jacket material. All cable management hardware shall allow for cables to be neatly dressed-out in the ERs and TRs.
12. Bend radius of the multi-pair copper cable shall not exceed 10 times the outside diameter of the cable during installation or at rest.
13. Place copper cables transitioning between the cable trays and cabinets or racks in a neat and orderly manner per NEC 318.11(b) requirements. Velcro tie-wrap shall be used for supporting multi-pair copper cables.
14. To reduce untwisting of pairs, maintain the twisted pair cable jacket as close as possible to the point of termination.
15. Multi-pair cable: Strip back only as much cable jacket as is minimally required to terminate on connecting hardware.

16. Use wiring block manufacturer's recommended tools with the proper-sized blades for all multi-pair copper punch downs.
17. Bend radius of the optic fiber cable shall not exceed 15 times the outside diameter of the cable during installation and 10 times the outside diameter during rest.
18. Each cable shall be individually attached to the respective splice enclosure by mechanical means. The cables strength member shall be securely attached the cable strain relief bracket in the enclosure.
19. Each fiber bundle shall be stripped upon entering the splice tray and the individual fibers routed in the splice tray.
20. Each cable shall be clearly labeled at the entrance to the splice enclosure. Cables labeled within the bundle shall not be acceptable.
21. A maximum of 12 strands of fiber shall be spliced in each tray
22. All spare strands shall be installed into spare splice trays.
23. Fiber slack shall be neatly coiled within the fiber splice tray or enclosure. No slack loops shall be allowed external to the fiber panel.
24. Firestop all sleeves and conduit openings after the cable installation is complete.
25. All building ERs and TRs require one wall-mount telephone outlet on the plywood backboard.
26. The contractor shall obtain NI&S approval of the proposed hardware equipment layout prior to installation.
27. NI&S standard rooms have copper termination equipment in the left side rack. Starting at the top with the building entrance tie cable 210 block (ER Only) and then the copper riser cable 210 blocks (TRs – top position). Install 210 horizontal cable management between each 210 block. Category 6 or 6A patch panels are installed below the 210 blocks.
28. Fiber optic panels are installed near the top of the right-side equipment rack leaving at least 4 RU space below backbone fiber panels for OSP fiber panels (installed by others). The remaining space in the right-side rack is reserved for network electronics.

6.4.7.14.2 Grounding and Bonding

1. Mount new telecommunications main grounding busbar (TMGB) on plywood backboard in main ER as shown on project drawings. The location for the TMGB shall be coordinated with the VT PM and NI&S.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. Mount new telecommunications grounding busbar (TGB) on plywood backboard in TRs as shown on project drawings. The location for the TGBs shall be coordinated with the VT PM and NI&S.
3. Install new TBB from the TMGB in the ER to the TGBs in the TRs as shown on project drawings. Connect the TBB to the TMGB and TGBs in accordance with TIA-607 and NEC. All grounding conductors leaving the ER and TRs shall be in a separate conduit from all communication cabling.
4. Bond all metallic surfaces of new racks, cable tray, and equipment in the TRs and ERs to the TGB or TMGB in the same room with #6 AWG grounding wire as straight as possible.
5. Bond all metallic raceways (conduit, cable tray, etc.) entering the TRs and ERs to the TGB or TMGB in the same room with #6 AWG grounding wire as straight as possible.
6. All grounding items shall be installed in complete compliance with the DCSM and NEC.

6.4.8 Backbone Cabling Requirements

6.4.8.1 Scope of Work

Provide all services labor, materials, tools, and equipment required for the complete and proper installation, splicing, and termination of new backbone cabling as called for in these specifications and related drawings.

This section includes minimum requirements and installation methods for the following:

1. Copper backbone cabling
2. Fiber optic backbone cabling
3. Fiber splices
4. Factory polished fiber pigtails
5. Coax backbone cabling

6.4.8.2 Quality Assurance

1. All backbone cabling installation, splicing, and termination shall be performed in a neat and workmanlike manner. All methods of construction that are not specifically described or indicated shall be subject to the control of NI&S.
2. Equipment and materials shall be of the quality and manufacture indicated. The equipment specified is based on the acceptable manufacturers listed. Where "approved equal" is stated, equipment shall be equivalent in every

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

way to that of the equipment specified and subject to approval of NI&S based on submittals provided.

3. Materials and work specified herein shall comply with the applicable requirements of:
   a. ANSI/NFPA 70 – National Electrical Code (NEC) Articles 250, 300, 645, and 770 (latest adopted edition of the National Electrical Code)
   b. IEEE/NESC – National Electrical Safety Code
   c. ANSI/TIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises – Addendum 2, General Updates
   d. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard
   e. ANSI/TIA/-568-C.2 – Commercial Building Telecommunications Cabling Standard, Part 2: Balanced Twisted Pair Cabling Components
   f. ANSI/TIA-568-C.3-1 – Optical Fiber Cabling Components Standard
   g. ANSI/TIA-569-C – Commercial Building Standard for Telecommunications Pathways and Spaces
   h. ANSI/TIA-598-C – Optical Fiber Cable Color Coding
   i. ANSI/TIA-604-3 – FOCIS 3 Fiber Optic Connector Intermateability Standard
   j. ANSI/TIA-606 – Administration Standard for Telecommunications Infrastructure of Commercial Buildings
   k. ANSI/TIA-607 – Commercial Building Grounding and Bonding Requirements for Telecommunications
   l. BICSI Telecommunications Distribution Methods Manual

6.4.8.3 Submittals

As-built drawings as required per DCSM section 6.4.3.

6.4.8.4 Materials

6.4.8.4.1 Inside Copper Backbone Cabling

1. Riser-rated non-plenum (CMR) category 3 UTP, 24 AWG (building entrance tie cable): 100 pair
2. Riser-rated non-plenum (CMR) category 3 UTP, 24 AWG (ER/TR tie cable), if required: 25 pair, 50 pair, or 100 pair
3. Riser-rated plenum (CMP) category 3 UTP, 24 AWG (ER/TR tie cable), if required: 25 pair, 50 pair, or 100 pair

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.4.8.4.2 Inside Fiber Optic Backbone Cabling

1. The basis of design for the cabling is OCC OC040210-05: Riser – indoor/outdoor subgrouping hybrid 8.3/125-micron, single-mode optical fiber and 50/125-micron, multimode optical fiber non-conductive riser (OFNR) tight-buffer bend tolerant cable.
   a. The indoor optical fiber cabling shall include 24 multimode and 24 single-mode 900-micron tight-buffered 250-micron fibers placed in a color-coded sub-unit bundles helically stranded with aramid strength elements.
   b. The indoor/outdoor optical fiber cabling shall meet or exceed the performance criteria found in ANSI/TIA-568-C.3 and be UL listed in accordance with NEC section 770.179(a).
   c. The indoor/outdoor optical fiber cables shall have sequential length markings printed on the cable jacket.
   d. Operating temperature: -40 °C to 85 °C
   e. Flex resistance: 2,000 cycles (TIA/EIA-455-104A)
   f. Crush resistance: 2,100 N/cm (TIA/EIA-455-41A)
   g. All single-mode and multimode fibers shall be pigtail spliced into a rack mounted
   h. Optical fiber enclosure. Field terminations will not be permitted.
   i. The loss of fiber shall not exceed 0.4 dB per kilometer @ 1550 nm and 0.5 dB per kilometer @ 1310 nm.
2. The basis of design for the cabling is OCC DX048KZDZ9QP: Plenum – indoor/outdoor subgrouping hybrid 8.3/125-micron, single-mode optical fiber and 50/125-micron, multimode optical fiber non-conductive plenum (OFNP) tight-buffer bend tolerant cable.
   a. The indoor optical fiber cables shall include 24 multimode and 24 single-mode 900-micron tight-buffered 250-micron fibers placed in a color-coded sub-unit bundles helically stranded with aramid strength elements.
   b. The indoor/outdoor optical fiber cables shall meet or exceed the performance criteria found in ANSI/TIA-568-C.3 and be UL listed in accordance with NEC section 770.179(a).
   c. The indoor/outdoor optical fiber cables shall have sequential length markings printed on the cable jacket.
   d. Operating temperature: -40 °C to 85 °C
   e. Impact resistance: 1,000 impacts (TIA/EIA-455-25A)
   f. Crush resistance: 1,500 N/cm (TIA/EIA-455-41A)

g. All single-mode and multimode fibers shall be pigtail spliced into a rack mounted optical fiber enclosure. Field terminations will not be permitted.
h. The loss of fiber shall not exceed 0.4 dB per kilometer @ 1550 nm and 0.5 dB per kilometer @ 1310 nm.

6.4.8.4.3 Inside Coaxial Backbone Cabling

1. The basis of design is CommScope 4564604 | F11SSV: Riser-rated non-plenum (CMR or CATVR) RG11 (Series 11), quad shield non-flooded cable capable of certification up to 1 GHz.
2. The basis of design is CommScope 4103304/10 | 2287K: Riser-rated plenum (CMP or CATVP) RG11 (Series 11), quad shield non-flooded cable capable of certification up to 1 GHz.
3. The basis of design for connectors used for terminations is Thomas & Betts F11 QS long shank hex-type crimp Series 11 connectors. Cables and connectors shall be capable of certification up to 1 GHz.

6.4.8.4.4 Coaxial Devices and Equipment

Provided and installed by NI&S after coaxial backbone cabling commissioning.

6.4.8.4.5 Backbone Cabling Installation Materials, Equipment, and Tools

1. Furnish all required materials, equipment, and tools necessary to properly complete the backbone cabling system installation including, but not limited to, tools for pulling, splicing, and terminating the cables, mounting hardware, cable ties, bolts, anchors, clamps, hangers, kits of consumables, lubricants, communication devices, stands for cable reels, cable winches, etc.
2. Mule tape – polyester or aramid fiber.

6.4.8.5 Execution

6.4.8.5.1 Inspection

1. Examine areas and conditions under which backbone cabling is to be installed. Provide notification, in writing, of conditions detrimental to proper completion of the work.
2. Verify field measurements and cable routing and termination conditions are as shown on drawings. Provide notification, in writing, of conditions deviating from drawings.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Beginning of backbone cabling installation indicates Contractor acceptance of existing conditions.

6.4.8.5.2 Copper UTP Building Entrance Tie and Backbone Cabling Installation

1. Perform all backbone cabling installation in conformance with manufacturer's installation guidelines.
2. Ensure that maximum pulling tensions of specified cables are not exceeded and cable bends maintain the proper radius during placement.
3. Failure to follow appropriate guidelines for cabling installation will require the Contractor to provide, in a timely fashion, the additional material and labor necessary to rectify the situation. This shall apply to any and all damages sustained to the cables during installation.
4. Field verify all cable measurements and install all backbone cables in such a matter as to avoid any and all mid-span splices. No mid-span splices are allowed except as specified and shown on project drawings.
5. Pull and secure new mule tape through all conduit while pulling new backbone cable.
6. The Contractor shall be responsible for all damage to the cable during placement.
7. Do not roll or store cable reels without an appropriate underlay.
8. All new copper backbone cables shall be attached to the cable pathway systems or plywood backboards with cable ties for strain relief.
9. Backbone telecommunications cabling shall be placed in dedicated pathways
10. Terminate cables so as not to pull tight on terminating equipment.
11. Ensure that all splice closures are properly sealed for protection of the cable and splices.
12. Neatly and permanently label all backbone cables with the cable number at both ends and at all splice locations.
13. Firestop all sleeves and conduit openings after the cable installation is complete.
14. Plug ends of conduit entering buildings with watertight conduit caulking compound after cable installation is complete to ensure foreign matter does not enter the buildings.
15. Test, label, and document the final backbone cable installation, including cable footages, on the as-built drawings.

6.4.8.5.3 Copper UTP Building Entrance Tie and Backbone Cable Terminations

1. Install copper UTP backbone cabling through conduit or other pathways as shown on the drawings.
2. Refer to project drawings for building specific pair count for backbone copper.
3. Terminate cable pairs on S210 connecting blocks in each ER and TR following the industry standard color code sequence.

6.4.8.5.4 Fiber Backbone Cabling

1. Cables shall be dressed and terminated in accordance with the recommendations made in ANSI/TIA-568-C.0 and/or ANSI/TIA-568-C.1, manufacturer's recommendations, and best industry practices.
2. Backbone cables shall be installed separately from horizontal distribution cables.
3. A plastic or nylon pull cord with a minimum test rating of 90 kg (200 lb.) shall be co-installed with all cable installed in any conduit.
4. Where cables are housed in conduits, the backbone and horizontal cables shall be installed in separate conduits.
5. Exposed cables must be OFNP rated if installed in an air return plenum. Riser-rated cables shall be installed in metallic conduit if installed in an air return plenum.
6. Where backbone cables and distribution cables are installed in a cable tray, backbone cables shall be installed first and bundled separately from the horizontal distribution cables.
7. Backbone cables spanning more than three floors shall be securely attached at the top of the cable run with a wire mesh grip and on alternating floors or as required by local codes.
8. Vertical runs of cables shall be supported to messenger strand, cable ladder, or other method to provide proper support for the weight of the cable.
9. Large bundles of cables and/or heavy cables shall be attached using metal clamps and/or metal banding to support the cables.
10. The cable's minimum bend radius and maximum pulling tension shall not be exceeded. Refer to manufacturer's requirements.
11. Each optical fiber cable shall be individually attached to the respective enclosure by mechanical means. The cables strength member shall be securely attached the cable strain relief bracket in the enclosure.

12. Each optical fiber cable shall be clearly labeled at the entrance to the enclosure. Cables labeled within the bundle shall not be acceptable.
13. Each fiber bundle shall be stripped upon entering the splice tray and the individual fibers routed in the splice tray.
14. A maximum of 12 strands of fiber shall be spliced in each tray.
15. All spare fiber strands shall be installed into spare splice trays.
16. Fiber slack shall be neatly coiled within the fiber splice tray or enclosure. No slack loops shall be allowed external to the fiber panel.
17. Perform fusion splicing of multimode fiber strands on SC APC factory polished pigtails with loss ≤ 0.02 dB at 850 nm.
18. Perform fusion splicing of single-mode fiber strands on SC APC factory polished pigtails with loss ≤ 0.05 dB at 1310 nm.
19. Terminate fiber strands on connectors and in termination equipment (shelves and panels) as specified in manufacturer's color code sequence.
20. Place "Caution Fiber" tags every 5 feet along the fiber cable route within the ER/TR.

6.4.8.5.5 Safety

The contractor must comply with VT regulations for asbestos, lead, and confined spaces.

6.4.8.5.6 As-Built Drawings

Mark the project drawings with notations reflecting actual cable lengths and any variations from the base specifications and drawings including as-built cable routing.

Comply with construction drawing as-built requirements as described in DCSM section 6.4.3.

6.4.9 Horizontal Cabling Requirements

6.4.9.1 Scope of Work

1. Provide all services, labor, materials, tools, and equipment required for the complete and proper installation and termination of new horizontal "station" cabling as called for in these specifications and related drawings.
2. The horizontal portion of the telecommunications cabling system extends from the work area telecommunications outlet to the termination in the TR or ER.

3. This section includes minimum requirements and installation methods for the following:
    a. Copper horizontal cabling
    b. Work area faceplates
    c. Copper modular jacks
    d. Coaxial horizontal (drop) cabling

6.4.9.2 Quality Assurance

1. All horizontal "station" cable installation and termination shall be performed in a neat and workmanlike manner. All methods of construction that are not specifically described or indicated shall be subject to the control of the VT PM and NI&S.
2. Equipment and materials shall be of the quality and manufacture indicated. The equipment specified is based on the acceptable manufacturers listed. Where "approved equal" is stated, equipment shall be equivalent in every way to that of the equipment specified and subject to approval of NI&S based on submittals provided.
3. Materials and work specified herein shall comply with the applicable requirements of:
    a. ANSI/NFPA 70 – National Electrical Code including, but not limited to, the following:
        i. Article 300 – Wiring Methods
        ii. Article 645 – Information Technology Equipment
        iii. Article 725 – Class 1, Class 2, and Class 3 Remote Control, Signaling, and Power-Limited Circuits
        iv. Article 770 – Optical Fiber Cables and Raceways
        v. Article 800 – Communications Circuits
    b. ANSI/TIA/EIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises – Addendum 2, General Updates
    c. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard
    d. ANSI/TIA-568-B.2 – Commercial Building Telecommunications Cabling Standard – Part 2: Balanced Twisted-Pair Cabling Components, including applicable addendum
    e. ANSI/TIA/EIA-568-C.3-1 – Optical Fiber Cabling Components Standard
    f. ANSI/TIA-569-C – Commercial Building Standard for Telecommunications Pathways and Spaces
    g. ANSI/TIA-604 Series – Fiber Optic Connector Intermateability Standard

h. ANSI/ICEA S-83-596 – Fiber Optic Premises Distribution Cable
i. BICSI Telecommunications Distribution Methods Manual

6.4.9.3 Submittals

As-built drawings as required per DCSM section 6.4.3.

6.4.9.4 Materials

6.4.9.4.1 Copper Horizontal Cabling

1. Category 6, 4-pair unshielded twisted pair (UTP) indoor cabling
   a. The basis of design is Siemon System 6 riser cable 9C6R4-E3-02-R(X)A, white sheath color. ("X" indicates payout system. Contractor may use REELEX or reel.)
   b. The basis of design is Siemon System 6 plenum cable 9C6P4-E3-06-R(X)A, blue sheath color. ("X" indicates payout system. Contractor may use REELEX or reel.)
   c. Riser- and plenum-rated cable characteristics and specification are as follows:
      i. Jacket features reverse sequential numbering.
      ii. Round jacket.
      iii. Center isolation member reduces NEXT loss by limiting pair-to-pair contact.
      iv. Be available in both 1000′ REELEX boxes and 1000′ reels.
      v. ISO/IEC 11801:2002 (Category 6), ANSI/TIA 568-C.2 – 2009, UL CMR/CMP, and CSA FT4/FT6 standards compliant.
      vi. Transmission performance verified by UL.
      vii. RoHS compliant.
      viii. Meet the following electrical specifications:

Table 6-3. Category 6 Copper Horizontal Cable Electrical Specifications

DC Resistance	< 9.38 Ω / 100 m
DC Resistance Unbalanced	5%
Mutual Capacitance	5.6 nF / 100 m
Capacitance Unbalanced	< 330 pF / 100 m
Characteristic Impedance (ohms)	1-100 MHz: 100 +/- 15% 100-520 MHz: 100 +/- 22%
NVP	CMP – 70% CMR – 65%
LCL	30-10Log(f/100) dB
Delay Skew	≤ 35 ns / 100 m

2. Category 6A, 4-pair foil over unshielded twisted pair (F/UTP) indoor cabling
   a. The basis of design is Siemon System 6A riser cable 9A6R4-A5-05-R1A, yellow sheath color (available payout system – reel).
   b. The basis of design is Siemon System 6A plenum cable 9A6P4-A5-06-R1A, blue sheath color (available payout system – reel).
   c. Riser- and plenum-rated cable characteristics and specification are as follows:
      i. Round cable jacket available in both CMR and CMP options with a nominal cable O.D. of less than or equal to 7.37 mm (0.290 inches).
      ii. Have a construction comprised of four pairs of 23 AWG solid bare copper conductors utilizing a center isolation member to maintain pair geometry for optimal NEXT performance.
      iii. Have a Mylar tape surrounding the cable pairs with a drain wire with an aluminum foil tape surrounding the drain wire.
      iv. Have a rip cord installed under the jacket for jacket removal.
      v. Be available in both 1000′ and 3000′ reels.
      vi. ISO/IEC 11801Ed 2.2, IEC 61156-5 Ed 2.0, ANSI/TIA 568-C.2, UL CMR/CMP and CSA FT4/FT6 standards compliant.
      vii. Transmission performance verified by UL.
      viii. RoHS compliant.
      ix. Meet the following electrical specifications:

Table 6-4. Category 6A Copper Horizontal Cable Electrical Specifications

DC Resistance	< 17.0 Ω / 100 m
DC Resistance Unbalanced	5%
Mutual Capacitance	5.6 nF / 100 m
Capacitance Unbalanced	< 330 pF / 100 m
Characteristic Impedance (ohms)	1 ≤ f ≤ 100: 100 +/- 15% 100 ≤ f ≤ 750: 100 +/- 22%
NVP	CMP – 72% CMR – 68%
LCL	30-10Log(f/100) dB
Delay Skew (ns)	≤ 45

6.4.9.4.2 Coaxial Horizontal Cabling and Connectors

Coaxial RG-6, quad-shield capable of certification up to 1 GHz.

1. The basis of design is General Cable C5889.41.02, inside rated (CM or CATV), white sheath color.

2. The basis of design is General Cable C3525.41.86, plenum rated (CMP or CATVP), white sheath color.
3. The basis of design for connectors used for terminations is Thomas & Betts Snap-N-Seal 360-degree true radial compression connectors. Hex-crimp connectors will not be accepted. Cable and connectors shall be capable of certification up to 1 GHz.

6.4.9.4.3 Work Area Faceplates

1. The basis of design is Siemon CT-8-FP-SS-L, double gang, stainless steel CT-style faceplate for Category 6 option.
   a. Allow couplers to be removed from the front of the faceplate.
   b. Allow UTP couplers to pass through faceplates even after termination.
   c. Have write-on designation labels for circuit identification together with a clear plastic cover.
   d. Easily removable designation label covers which can be removed without use of tools.
   e. Have optional modular furniture adapters available.
   f. Must be communications circuit accessory listed per UL 1863.
2. The basis of design is Siemon MX-FP-S-06-SS-L, double gang, stainless steel MAX-style faceplate for Category 6A option.
   a. Outlet to be 6-port double-gang configuration.
   b. Allow modules to be removed from the front of the faceplate.
   c. Allow UTP modules to pass through faceplates even after termination.
   d. Have write on designation labels for circuit identification together with a clear plastic cover.
   e. Feature easily removable designation label covers which can be removed without use of tools.
   f. Have optional modular furniture adapters available.
   g. Faceplate to be stainless steel versions with designation label option.
   h. Must be certified by UL to United States Standards.

6.4.9.4.4 Copper Modular Jacks

1. The basis of design is Category 6, 8-position, 8-conductor UTP outlet, Siemon CT6 Coupler CT-C6-XX. (The "XX" indicates outlet color. Coordinate with the A/E and VT PM prior to ordering for the project.)
   a. Be available in black, white, red, gray, yellow, blue, green, orange, ivory, bright white, light ivory and alpine white.
   b. Have available a gravity-feed (45 degree angled) design with angled shroud to protect connection and help control patch cord bend radius.

c. Utilizes TRI-BALANCE technology with optimized pair balance design and linear crosstalk response to address applications up to 250 MHz.
d. Have 310 style insulation displacement connectors with quadrant pair isolation and a Pyramid wire entry system.
e. Allow termination with a single conductor impact tool.
f. Modules should feature category markings on front and rear of outlet.
g. Be backwards compatible to allow lower performing categories of cables or connecting hardware to operate to their full capacity.
h. Have rear protective strain relief caps with side or rear entry, which can be installed onto cable before or after termination.
i. Support industry standards for T568A or T568B wiring options on each individual outlet.
j. Be removable from the front with the faceplate mounted in place.
k. Must have a hinged door option on angled version for areas having excessive airborne contaminants.
l. Provide color-coded snap-in icons available for circuit identification.
m. Be constructed of high impact, flame-retardant thermoplastic.
n. Allow for a minimum of 200 terminations without signal degradation below standards compliance limits.
o. Must be certified by UL to United States standards.

2. The basis of design is Category 6A, 8-position, 8-conductor F/UTP outlet, Siemon Z-Max shielded outlet Z6A-S(XX) (The “XX” indicates outlet color. Coordinate with the A/E and VT PM prior to ordering for project).
   a. Exceed category 6A component compliance through the frequency range of 1 to 250 MHz with usable bandwidth to 500 MHz.
   b. Provide full integration of cable shielding through the termination process of the outlet.
   c. Be available in black, white, red, gray, yellow, blue, green, orange, ivory, bright white, light ivory and alpine white.
   d. Universal design allows the same outlet to be mounted in flat or angled orientation.
   e. Basis of design for termination shall be a Siemon Z-tool to ensure fast and simple terminations.
   f. Have an available spring door allowing one handed operation.
   g. Have a lacing module that offers linear lacing and zero-cross termination, which eliminates pair crossing.
   h. Have available termination tool included with each box of 20 outlets.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

i. Be backwards compatible to allow lower performing categories of cables or connecting hardware to operate to their full capacity.
j. Support industry standards for T568A or T568B wiring options on each individual outlet.
k. Allow installation from the front or rear of the faceplate, and allow for the jack to pass through the faceplate without re-termination.
l. Provide color-coded, snap-in icons available for circuit identification.
m. Allow for a minimum of 5 terminations without signal degradation below standards compliance limits.
n. Have a bezel constructed of high impact, glass reinforced nylon.
o. Have, as an option, an outlet, which can be mounted into an IEC 60603-7 compliant opening (keystone).
p. Must be certified by UL to United States standards.

6.4.9.4.5 Installation Materials, Equipment, and Tools

Furnish all required materials, equipment, and tools necessary to properly complete the horizontal copper and CATV coaxial cabling system installation including, but not limited to, tools for pulling and terminating the cables, mounting hardware, Velcro cable ties (plastic tie wraps will not be accepted), bolts, anchors, clamps, hangers, kits of consumables, lubricants, communication devices, stands for cable reels, cable wenches, etc.

6.4.9.5 Execution

6.4.9.5.1 Inspection

1. Examine areas and conditions under which horizontal cable is to be installed. Provide notification, in writing, of conditions detrimental to proper completion of the work.
2. Verify cable routing and termination conditions are as shown on drawings. Provide notification, in writing, of conditions deviating from drawings.
3. Beginning of horizontal cable installation indicates Contractor acceptance of existing conditions.

6.4.9.5.2 Horizontal Cabling Installation

1. Install faceplates and copper jacks at each work area outlet location as indicated on the project drawings. Place the jacks in the faceplates beginning with position A and placing the copper jacks before the CATV coaxial adapter jacks. Place blank covers in the unused openings on each

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

faceplate. Faceplates shall be secured with mechanical fasteners. Adhesive fasteners shall not be allowed.

2. Unless otherwise noted on project drawings, each portal (station location) will be fed with one Cat 6 or Cat 6A cable as directed per project design.
3. Each wireless access point will be fed with two Cat 6 or Cat 6A cables as directed per project design.
4. Each message board will be fed with one Cat 6 or Cat 6A cable as directed per project design.
5. Each indoor emergency phone will be fed with one Cat 6 or Cat 6A cable as directed per project design.
6. Copper cabling to outdoor emergency phone locations will be provided by NI&S.
7. Install copper cable from each work area outlet location indicated on the drawings to the nearest TR or ER as indicated on the project drawings.
8. Perform all horizontal cable installation in conformance with manufacturer's installation guidelines.
9. Ensure that maximum pulling tensions of specified cables are not exceeded and cable bends maintain the proper radius during placement.
10. For outlet locations in walls, floor, and overhead, the horizontal cable distribution design uses conduit or surface raceway to the outlet location with conduit, surface raceway, and/or cable tray in the ceiling space to the TR or ER. Coordinate as necessary with electrical contractor for placement of horizontal cable pathways and outlet boxes.
11. Horizontal telecommunications cabling shall be placed in dedicated pathways separate from backbone and other cabling.
12. All horizontal cabling terminating within a single faceplate must be routed to and terminated in the same ER or TR.
13. Install new Poly line in all conduits while pulling in new horizontal cables.
14. Ceiling tile shall be removed as necessary for the cable installation and put back in place without damaging or dirtying any of the tiles or supporting framework. Ceiling tile shall be handled with clean hands so that no fingerprints or marks are left on the tiles. The contractor is responsible for the cost of repair or replacement of any damaged or dirtied tiles or ceiling hardware.
15. For cable penetration of ceiling tiles, the holes must be placed along the ceiling tile edge.

16. All cables in the ceiling space:
    a. Shall be supported in conduit or in the cable tray and shall not droop or hang outside of cable tray.
    b. Shall not be run “wild” (unsupported by conduit or cable tray) for distances greater than 6 inches.
    c. Shall not be attached to the suspended ceiling structure or laid directly on the ceiling grid as a means of support.
    d. Shall not be supported by or attached by any means to fire sprinkler heads or delivery systems, any environmental sensor, or the exterior of any conduit or raceway.
    e. Shall be routed at right angles to the electrical power circuits where the cable is not enclosed in conduit or in cable tray.
17. The total length of any horizontal station cable from the jack location to the equipment room termination panel shall not exceed 90 meters.
18. Maintain the following clearances from EMI sources:
    a. Unshielded power lines or equipment less than or equal to 5 kVA near cable in open or non-metal pathway: 12 inches.
    b. Unshielded power lines or equipment greater than 5 kVA near cable in open or non-metal pathway: 24 inches.
    c. Unshielded power lines or equipment less than or equal to 5 kVA near cable in grounded metal pathway: 6 inches.
    d. Unshielded power lines or equipment greater than 5 kVA near cable in grounded metal pathway: 12 inches.
    e. Power lines enclosed in grounded metal conduit less than or equal to 5 kVA near cable in grounded metal pathway: 3 inches.
    f. Power lines enclosed in grounded metal conduit greater than 5 kVA near cable in grounded metal pathway: 6 inches.
    g. Lighting fixtures near cable in open or non-metal pathway: 12 inches.
    h. Lighting fixtures near cable in grounded metal conduit: 6 inches.
    i. Motors or transformers near cable in non-metal pathway: 48 inches.
    j. Motors or transformers near cable in grounded metal pathway: 36 inches.
19. Manage slack to avoid excess cable or kinking.
20. Do not splice or bridge tap the cable.
21. All cables shall be tied and dressed neatly with a minimum bend radius of 10 times the cable diameter. Provide necessary hardware to maintain proper bend radius at corners.

22. All cables shall be firmly held in place. Fastenings and supports shall be adequate to support loads with ample safety factors.
23. Where cable ties or other fastening devices are utilized, the Contractor shall ensure that the cables are not deformed by over tightening. Mechanical cable tie installation tools are not allowed. The use of Velcro-type cable ties is required. Plastic ties will not be accepted.
24. Failure to follow appropriate guidelines for cable installation will require the Contractor to provide, in a timely fashion, the additional material and labor necessary to rectify the situation. This shall apply to any and all damages sustained to the cables during installation.
25. The Contractor shall be responsible for all damage to the cable during placement.
26. Cables with jackets that are chaffed or burned exposing internal conductor insulation or have any bare copper (shiners) shall be replaced.
27. Do not roll or store cable reels without an appropriate underlay.
28. Neatly and permanently label all horizontal cables with the cable number at both ends.
29. Firestop all sleeves and conduit openings after the cable installation is complete.
30. Test, label, and document final horizontal cable installation including outlet numbering on as-built drawings.
31. Remove existing cable and terminations that will no longer be used as specified and shown on project drawings. Coordinate as necessary with electrical contractor for removal of existing horizontal cable pathways and outlet boxes.

6.4.9.5.3 Copper Cable Termination

1. At the work area outlet and the jack panel in the ER/TR, terminate all pairs of each copper horizontal cable on the jack with TIA T568B pin-pair assignments.
2. All un-used Category 6 or Category 6A jack inserts packaged with the jack panels in the ER/TR are to be left in the manufacturer's original packaging and attached to the rack or wire manager for future cabling installations.
3. Terminate all pairs of each copper horizontal cable.
4. All cables shall be terminated so as not to pull tight on the terminating equipment.
5. Do not untwist cable pairs more than 0.5 inches when terminating.

6.4.9.5.4 Coaxial Horizontal Cabling

1. All drops are to be home-run from the nearest TR/ER to the face plate with no drop splitters or amplifiers to be used.
2. Drop connectors shall be compression type as listed in DCSM section 6.4.9.4. “Hex-crimp” connectors are not allowed.
3. Connector type is to be determined by the jacket material of the cable being terminated.

6.4.9.5.5 As-Built Drawings

Mark the project drawings with notations reflecting actual cable outlet numbering and any variations from the base specifications and drawings.

Comply with construction drawing as-built requirements in DCSM section 6.4.3.

6.4.10 Testing, Identification, and Administration

6.4.10.1 Scope of Work

1. Provide all services, labor, materials, tools, and equipment required for complete and proper testing, certification, identification, and administration of the installed telecommunications cabling as called for in these specifications and related drawings.
2. This section includes minimum requirements and installation methods for the following:
   a. Copper cable testing and testers
   b. Fiber optic cable testing and testers
   c. Labels and labeling
   d. Documentation
3. NI&S will provide the outlet numbers (H-Links) to the Contractor upon request. The Contractor must request this information at least four weeks prior to installing horizontal cabling. Requests for H-Links should be made through the VT PM.

6.4.10.2 Quality Assurance

1. All testing procedures and testers shall comply with applicable requirements of:
   a. ANSI/TIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises – Addendum 2, General Updates

   b. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard
   c. ANSI/TIA-568-B.2 – Commercial Building Telecommunications Cabling Standard – Part 2: Balanced Twisted-Pair Cabling Components, including applicable addendum
   d. ANSI/TIA/EIA-568-C.3-1 – Optical Fiber Cabling Components Standard
   e. TIA-455 Series – Fiber Optic Test Procedures
   f. TIA-526 Series – Optic Fiber Systems Test Procedures
   g. TSB 140-04 – Additional Guidelines for Field-Testing Length, Loss and Polarity of Optical Fiber Cabling Systems
2. Identification and administration work shall comply with applicable requirements of:
   a. ANSI/TIA-568-C.0-2 – Generic Telecommunications Cabling for Customer Premises – Addendum 2, General Updates
   b. ANSI/TIA-568-C.1 – Commercial Building Telecommunications Cabling Standard
   c. ANSI/TIA-568-B.2 – Commercial Building Telecommunications Cabling Standard – Part 2: Balanced Twisted-Pair Cabling Components, including applicable addendum
   d. ANSI/TIA-568-C.3-1 – Optical Fiber Cabling Components Standard
   e. ANSI/TIA-569-A – Commercial Building Standard for Telecommunications Pathways and Spaces
   f. ANSI/TIA-598-A – Optical Fiber Cable Color Coding
   g. ANSI/TIA-606 – Administration Standard for Telecommunications Infrastructure of Commercial Buildings
   h. BICSI Telecommunications Distribution Methods Manual

6.4.10.3 Submittals

Test reports and as-built drawings as required per DCSM section 6.4.3.

6.4.10.4 Materials

6.4.10.4.1 Multi-Pair Backbone Cabling and Category 6 Testing

1. All category 6 field-testing shall be performed by the Contractor with an approved level III balanced twisted-pair field test device.
2. All multi-pair UTP backbone cables shall be 100% tested by the Contractor for continuity.
3. Category 6 balanced twisted-pair horizontal cables shall be 100 percent tested according to ANSI/TIA/EIA-568-B.1. Test parameters include wire

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

map plus ScTP shield continuity (when present), length, NEXT loss (pair-to-pair), NEXT loss (power sum), ELFEXT loss (pair-to-pair), ELFEXT loss (power sum), return loss, insertion loss, propagation delay, and delay skew.

a. Test equipment criteria
   i. All balanced twisted-pair field testers shall be factory calibrated each calendar year by the field test equipment manufacturer as stipulated by the manuals provided with the field test unit. The calibration certificate shall be provided for review prior to the start of testing.
   ii. Autotest settings provided in the field tester for testing the installed cabling shall be set to the default parameters.
   iii. Test settings selected from options provided in the field testers shall be compatible with the installed cable under test.
b. Provide the following 4-connector guaranteed channel performance:

Table 6-5. Category 6 Testing 4-connector Channel Performance Requirement

Parameter	UTP Cat 6 Cable System Performance				
	100 MHz	200 MHz	250 MHz	350 MHz	550 MHz
Insertion Loss (dB)	19.6	28.7	32.6	36.1	51.3
NEXT Loss (dB)	47.3	42.8	41.3	40.1	36.2
PSNEXT Loss (dB)	45.3	40.8	39.3	38.1	34.2
ACR (dB)	27.7	14.1	8.8	4.0	-15.1
PSACR (dB)	25.7	12.1	6.8	2.0	-17.1
ACR-F (dB)	30.8	24.8	22.8	21.3	16.0
PS ACR-F (dB)	28.8	22.8	20.8	19.3	14.0
Return Loss (dB)	22.5	21.0	20.5	20.1	18.8
Propagation Delay (ns)	517.6	516.5	516.3	516.1	515.5
Delay Skew (ns)	≤ 35	≤ 35	≤ 35	≤ 35	≤ 35

6.4.10.4.2 Category 6A Testing

1. All 500 MHz category 6A field-testing shall be performed by the Contractor with an approved level 111e balanced twisted-pair field test device.
2. All multi-pair UTP backbone cables shall be 100% tested by the Contractor for continuity.
3. All 500 MHz Category 6A balanced twisted-pair horizontal and backbone cables shall be 100 percent tested according to ANSI/TIA/EIA-568-C.1. Test parameters include wire map plus F/UTP (ScTP) shield continuity (when present), length, NEXT loss (pair-to-pair), NEXT loss (power sum),

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ELFEXT loss (pair-to-pair), ELFEXT loss (power sum), return loss, insertion loss, propagation delay, and delay skew.

a. Test equipment criteria
    i. All balanced twisted-pair field testers shall be factory calibrated each calendar year by the field test equipment manufacturer as stipulated by the manuals provided with the field test unit. The calibration certificate shall be provided for review prior to the start of testing.
    ii. Autotest settings provided in the field tester for testing the installed cabling shall be set to the default parameters.
    iii. Test settings selected from options provided in the field testers shall be compatible with the installed cable under test.
b. Provide the following 4-connector guaranteed channel performance:

Table 6-6. Category 6A Testing 4-connector Channel Performance Requirement

Parameter	UTP Cat 6A Cable System Performance								
	100 MHz	200 MHz	250 MHz	300 MHz	400 MHz	500 MHz	550 MHz	625 MHz	700 MHz
Insertion Loss (dB)	19.8	29.0	32.8	36.4	43.0	48.9	51.8	55.8	62.3
NEXT Loss (dB)	44.3	39.8	38.3	37.1	35.3	33.8	33.2	32.4	31.2
PSNEXT Loss (dB)	42.3	37.8	36.3	35.1	33.3	31.8	31.2	30.4	29.2
ACR (dB)	24.5	10.8	5.5	.07	-7.8	-15.1	-18.6	-23.5	-31.1
PSACR (dB)	22.5	8.8	3.5	-1.3	-9.7	-17.1	-20.6	-25.5	-33.1
ACR-F (dB)	27.8	21.8	19.8	18.3	15.8	13.8	13.0	11.9	10.3
PS ACR-F (dB)	24.8	18.8	16.8	15.3	12.8	10.8	10.0	8.9	7.3
Return Loss (dB)	20.1	18	17.3	16.8	15.9	15.2	14.9	14.5	14.0
Propagation Delay (ns)	538.0	537.0	536.0	536.0	536.0	536.0	536.0	535.0	535.0
Delay Skew (ns)	≤ 45	≤ 45	≤ 45	≤ 45	≤ 45	≤ 45	≤ 45	≤ 45	≤ 45

6.4.10.4.3 Optical Fiber Cable Testers

1. Field test instruments for multimode fiber cabling shall meet the requirements of ANSI/TIA/EIAA-526-14-A.
2. Field test instruments for single-mode fiber cabling shall meet the requirements of ANSI/TIA/EIAA-526-7.
3. Multimode light source
    a. Meet the launch requirements of ANSI/TIA-455-78B achieved within the field test equipment or by use of an external mandrel wrap (as described in clause 6.4 of ANSI/TIA-568-C.0) with a Category 1 light source.
    b. Provide stabilized 850 nm and 1300 nm +/- 20 nm wavelength LED light source.
    c. Spectral width of sources shall be ≤ 50 nm of 850 nm wavelengths and ≤ 140 nm for 1300 nm wavelengths.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   d. Output of light source shall be 8 MW for 62.5 or 50 µm core optical fiber as appropriate.
   e. Output stability +/- 0.40 dB from 0 to 50 °C.
   f. Long term output stability +/- 0.10 dB at 25 °C.
   g. Connector types shall include SC.
4. Single-mode light source
   a. Provide stabilized 1310 nm and 1500 nm +/- 20 nm wavelength Laser light source.
   b. Output stability +/- 0.40 dB from 0 to 50 °C.
   c. Long term output stability +/- 0.10 dB at 25 °C.
   d. Connector types shall be SC APC.
5. Optical power meter
   a. Calibrated against National Institute of Standards and Technology (NIST) standard.
   b. Provide 850 nm, and 1300 nm +/- 20 nm selectable wavelength test capability.
   c. Measurement range from 10 to -60 dBm.
   d. Accuracy +/- 5% at 0 to -50 dBm.
   e. Accuracy +/- 10%, 10 to 0 dBm and -50 to -60 dBm.
   f. Resolution 0.01 dB.
   g. Connector types shall include SC.
6. Optical time domain reflectometer (OTDR)
   a. Dual selectable wavelength: 850/1300 nm for multimode.
   b. Dual selectable wavelength: 1310/1550 nm for single mode.
   c. Selectable cable index of refraction.
   d. Visual fault locator for continuity checks and dead zone fault location.
   e. Front display and printer connection for hard-copy documentation.
   f. Equipped with launch jumper cable of sufficient length to offset entry "dead zone."
7. Connector types shall include SC and SC APC.

6.4.10.4.4 Labels

1. Faceplate labels shall be printed and supplied by the Contractor with a Dymo electronic label maker 5000 or equivalent with prior approval from NI&S.
2. Labels for cable marking shall be vinyl substrate with a white printing area and a clear "tail" that self laminates the printed area when wrapped around the cable. If cable jacket is white, provide cable label with printing

area that is any other color than white, so that the labels are easily distinguishable.

3. Pre-printed labels shall meet legibility, defacement, exposure and adhesion requirements of UL 969.
4. Handwritten labels are not allowed.

6.4.10.5 Execution

6.4.10.5.1 Copper Cable Testing

1. Test 100% of installed backbone copper cabling for:
   a. Wire map
   b. Length
2. Perform the following permanent link tests for 100% of installed Category 6 and Category 6A horizontal cabling as described in ANSI/TIA-568-C.1, section 6.3 and ANSI/TIA-568-B.2, Annex E:
   a. Wire map
   b. Length
   c. Insertion loss
   d. Pair-to-pair NEXT loss
   e. Propagation delay
   f. Delay skew
3. Perform the following permanent link tests for 100% of installed Category 6 and Category 6A horizontal copper cabling as described in ANSI/TIA-568-C.0, section 6.3 and ANSI/TIA-568-B.2, Annex E:
   a. PSNEXT loss
   b. Pair-to-pair ELFEXT
   c. PSELFEXT
   d. Return loss
4. Cross-connects from horizontal to backbone cabling will not be in place for these tests.
5. The wire map test shall verify pair to pin termination at each end and check for connectivity errors. The wire map shall indicate the following for each of the eight conductors:
   a. Continuity to the remote end
   b. Shorts between any two or more conductors
   c. Reversed pairs
   d. Split pairs
   e. Transposed pairs
   f. Any other miswiring

6. The maximum length of the permanent link for horizontal cable shall be 90 meters. Shorten any cable runs as required at no additional cost to the project.
7. Replace and or repair cable and terminations as necessary to assure 100% passing performance specifications.
8. Final testing shall be scheduled and conducted in the presence of the NI&S and cable manufacturer's representative as specified in DCSM section 6.4.3.
9. Submit electronic and printed test results reports for each multi-pair backbone copper cable to NI&S (through the VT PM).
10. Submit electronic and printed test results reports for each copper cabling permanent link to both NI&S (through the VT PM) and horizontal copper system manufacturer per Siemon Structured Cabling System warranty requirements.

6.4.10.5.2 Optical Fiber Cable Testing

1. Test all installed fiber optic strands after splicing and termination with an optical time-domain reflectometer (OTDR) per TIA-455-61 and TSB-140:
    a. End-to-end bi-directional signature trace with fault finding, connection point reflections, fiber bend, pressure point locations, etc.
    b. One wavelength, 1300 nm, for multimode strands.
    c. One wavelength, 1550 nm, for single-mode strands.
    d. Multimode fiber connector losses ≤ 0.5 dB at 850 nm.
    e. Single-mode fiber connector losses ≤ 0.2 dB at 1310 nm.
    f. Multimode fiber splice losses ≤ 0.3 dB at 850 nm.
    g. Single-mode fiber splice losses ≤ 0.2 dB at 1310 nm.
    h. Localized attenuation shall not exceed 0.5 dB at any point.
2. Test link attenuation of all installed fiber optic strands after splicing and termination in accordance with ANSI/TIA-568-C.0, section 6.4 and Annex E, and TSB-140.
    a. One direction with an optical light source and an optical power meter.
    b. Test at two wavelengths to account for attenuation differences due to wavelength:
        i. Test at 850 nm and 1300 nm for multimode strands
        ii. Test at 1310 nm and 1550 nm for single-mode strands
    c. Test multimode strands in accordance with TIA-526-14-A, Method B, One Reference Jumper.

d. For multimode strands, wrap reference jumper around mandrel to remove high-order mode transient losses as specified in ANSI/TIA-568-C.0, section 6.4, Table 3.
e. Test single-mode strands in accordance with TIA-526-7, Method A.1, One Reference Jumper.
f. The total attenuation budget for each fiber cable length (end-to-end) shall equal the allowed attenuation for the fiber (0.2 dB per km times the length in km) plus the attenuation for each splice and connector. For example, a cable length of 3 km with 1 splice and 2 connectors would have an attenuation budget of 1.2 dB as shown here: (3 km × 0.2 dB/km) + (1 × 0.2 dB) + (2 × 0.2 dB) = 1.2 dB.

3. Fibers that are broken or damaged shall be replaced at no cost to VT and replaced fiber optic cables shall be re-tested.
4. Final testing shall be scheduled and conducted in the presence of the NI&S and cable manufacturer's representative as specified in DCSM section 6.4.3.
5. Submit electronic and printed OTDR test results reports for each fiber optic cable strand to both NI&S (through the VT PM) and fiber system manufacturer per OCC fiber warranty requirements.

6.4.10.5.3 Horizontal Cable Identification and Labeling

Neatly and permanently label all copper and fiber optic cables with the cable number at both ends within 2 inches of termination end.

NI&S provided standard outlet numbers (H-Links) are to be used for labeling faceplates, 210-blocks, patch panels, and fiber terminations.

6.4.10.5.4 As-Built Drawings

Mark the project drawings with notations reflecting any variations from the base specifications and drawings including as-built numbering for the outlets on the floor plans.

As-built drawings must include the NI&S provided H-Link outlet information as described in this section.

Comply with construction drawing as-built requirements as described in DCSM section 6.4.3.

6.4.11 Classroom A/V Services

In each assembly area where audible communication is integral to the use of the space, include modular assistive listening systems. For minor renovations, installing rack plates into lecterns may be considered. These plates should include a microphone input, audio output, and HDMI output connected to the space's audio-visual system. Consult the classroom audio-visual team, part of the Office of the University Registrar, for further information and coordination with other stakeholders (particularly the Office of Equity and Accessibility and Services for Students with Disabilities).

6.4.11.1 Classroom Design Standards

6.4.11.1.1 Small Classroom Standard (25-40 seats)

1. ADA-compliant lectern with space to securely house A/V equipment and a shelf for the document camera
2. Sources
    a. The basis of design shall be Cable Cubby (with at least one 120-volt outlet)
        i. A 12-foot HDMI cable to ensure enough distance to reach anywhere on the lectern or to an adjacent table and be wired into the rack
        ii. A 12-foot VGA cable to ensure enough distance to reach anywhere on the lectern or to an adjacent table and be wired into the rack
        iii. Space to add cables, if necessary (USB for lecture capture/web conferencing, Ethernet, USB-C, etc.)
    b. HD document camera
    c. Blu-ray player with clamping shelf; the basis of design for the clamping shelf shall be Middle Atlantic
    d. Wireless presentation solution; the basis of design shall be Crestron AirMedia
    e. Optional wall-mounted PTZ camera for lecture capture and web conferencing with USB conversion (landing on a USB hub with USB audio solution to provide a single USB output to the cable cubby)
3. Destination
    a. Ceiling-mounted laser WUXGA 5000 lumen (or better) projector
    b. A 16:10 electric projector screen (wall-mounted or ceiling-mounted depending on room)
    c. Optional wall-mounted 60″ monitor to be used as a confidence monitor or for student collaboration

4. Control system and midpoint distribution – the basis of design shall be Crestron and ID TECH products as listed below:
    a. Crestron series 3 processor (if not built into midpoint, e.g., DMPS)
    b. Crestron touch panel mounted with swivel mount table top kit (e.g., TSW-760)
    c. ID TECH WCR3227-512 magnetic card reader for access control
    d. Crestron midpoint (DM or NVX solution, typically DMPS for the smaller rooms)
    e. Optional button panel to control the 60″ monitor outside of class time
5. Audio
    a. Wireless lapel microphone
    b. Amplifier (70 V or 8 Ω, depending on room)
    c. Speakers (Ceiling mounted or surface mounted depending on room)
    d. Assisted listening system capability (installed or optional audio output for portable units)
    e. Optional ceiling mounted microphone system for lecture capture and web conferencing with USB conversion (landing on a USB hub with USB camera solution to provide a single USB output to the cable cubby)
6. Environment
    a. Non-ghosting whiteboards are preferred (as many as possible in most cases). See DCSM section 5.16.4 for whiteboard requirements.
    b. Optional cable pathways
        i. Floor box under the lectern with two 1-inch conduits for A/V stubbing out above the ceiling in the same room
        ii. Two 1-inch conduits stubbing out above the ceiling coming down to a 2-gang electrical box on the wall covered with a pass-through plate
        iii. Surface mount wiremold on the wall coming down and connecting to floor molding that ends under the lectern. The basis of design for the floor molding shall be Connectrac (or similar).
        iv. No disconnect plates
    c. Lectern power – 120-volt duplex building power for lectern located inside or beneath lectern needs to be on the same building phase as the projector and optional monitor

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

d. Projector power – 120-volt duplex building power located at the projector location to be on the same building phase as the lectern and optional monitor
e. Optional 120-volt duplex building power located at the monitor location to be on the same building phase as the lectern and projector
f. Power strip – 1RU mounted power strip with ten to twelve 20-amp outlets
g. Campus network connectivity provided at the lectern location (two ports)

6.4.11.1.2 Large Classroom Standard (above 40 seats)

1. ADA-compliant lectern or table with space to securely house A/V equipment and a shelf for the document camera
2. Optional equipment rack in a closet depending on room complexity
3. Sources
   a. The basis of design shall be Cable Cubby (with at least one 120-volt outlet)
      i. A 12-foot HDMI cable to ensure enough distance to reach anywhere on the lectern or to an adjacent table and be wired into the rack
      ii. A 12-foot VGA cable to ensure enough distance to reach anywhere on the lectern or to an adjacent table and be wired into the rack
      iii. Space to add cables if necessary (USB for lecture capture/web conferencing, Ethernet, USB-C, etc.)
   b. HD document camera
   c. Blu-ray player with clamping shelf; the basis of design for the clamping shelf shall be Middle Atlantic.
   d. Wireless presentation solution; the basis of design shall be Crestron AirMedia.
   e. Optional additional inputs from around the room depending on the room needs
   f. Optional wall-mounted PTZ camera for lecture capture and web conferencing with USB conversion (landing on a USB hub with USB audio solution to provide a single USB output to the cable cubby)
4. Destination
   a. Amount of destinations varies depending on room needs

   b. Ceiling-mounted laser WUXGA 6000 lumen (or better) projector depending on room needs
   c. Large 16:10 electric projector screens (wall-mounted or ceiling-mounted depending on room)
   d. Optional wall-mounted 60" monitor(s) to be used as a confidence monitor or for student collaboration.
5. Control system and midpoint distribution; the basis of design shall be Crestron and ID TECH products as listed below:
   a. Crestron series 3 processor (if not built into midpoint, e.g., DMPS)
   b. Crestron touch panel mounted with swivel mount table top kit (e.g., TSW-1060)
   c. ID TECH WCR3227-512 magnetic card reader for access control
   d. Crestron midpoint (DM or NVX solution, typically DM-MD solution for larger rooms)
   e. Optional button panel(s) to control the 60" monitor(s) outside of class time
6. Audio
   a. Audio DSP with USB output capabilities (landing on a USB hub with USB camera solution to provide a single USB output to the cable cubby)
   b. Wireless lapel microphone
   c. Wireless handheld microphone
   d. Amplifier (70 V or 8 Ω, depending on room)
   e. Speakers (ceiling-mounted or surface-mounted depending on room)
   f. Installed assisted listening system
   g. Optional ceiling mounted microphone system for lecture capture and web conferencing landing on the audio DSP
7. Environment
   a. Non-ghosting whiteboards are preferred (as many as possible in most cases). See DCSM section 5.16.4 for whiteboard requirements.
   b. Optional cable pathways
      i. Floor box under the lectern with two 1-inch conduits for A/V stubbing out above the ceiling in the same room
      ii. Two 1-inch conduits stubbing out above the ceiling coming down to a 2-gang electrical box on the wall covered with a pass-through plate
      iii. Surface mount wiremold on the wall coming down and connecting to floor molding that ends under the lectern. The

basis of design for the floor molding shall be Connectrac (or similar).

iv. No disconnect plates

c. Lectern power – 120-volt duplex building power for lectern/teaching table located inside or beneath lectern/teaching table needs to be on the same building phase as the projector locations(s), equipment closet equipment rack, and optional monitor(s)
d. Projector power – 120-volt duplex building power located at the projector location(s) needs to be on the same building phase as the lectern/teaching table, equipment closet equipment rack, and optional monitor(s)
e. Equipment closet power – 120-volt quad building power located at the equipment closet equipment rack location needs to be on the same building phase as the lectern/teaching table, projector location(s), and optional monitor(s)
f. Optional 120-volt duplex building power located at the monitor location(s) to be on the same building phase as the lectern/teaching table, equipment closet equipment rack, and projector locations(s)
g. Power strip – 1RU mounted power strip with ten to twelve 20-amp outlets located at lectern/teaching table
h. Vertically mounted power strips with an adequate amount of 20-amp outlets installed in the equipment rack
i. Campus network connectivity provided at the lectern location (two ports)
j. Campus network connectivity provided at the equipment closet equipment rack location (two ports)

6.4.11.2 Scope of Work

1. For renovations on classroom spaces assigned by the Registrar's Office (in-house)
   a. Choose rooms for renovation
   b. Engineer and design the system
   c. Create a signal flow diagram of the system
   d. Create an RFP for all the products within the system
   e. Review pricing from vendors and select the lowest price that best matches the RFP
   f. Receive, asset tag, and inventory everything that comes in

g. Schedule and install the equipment
    i. Install projector and screen
    ii. Install speakers
    iii. Install cabling pathways where necessary
    iv. Pull wiring point-to-point for the system
    v. Install equipment into lectern and wire
h. Commission the system
i. Program the system; the basis of design for in-house programming shall be Crestron.
    i. In-house Crestron programming
    ii. In-house GUI design
j. Monitor and maintain the system (VTEye)

2. For new construction of classroom spaces assigned by the Registrar's Office (Contractor)
    a. Work with A/E and A/V consultant on
        i. Classroom layout
        ii. Floor box and conduit locations
        iii. System design to match our current standards
        iv. Create an equipment list for all the product within the system
    b. Review pricing from vendors and select lowest price that best matches RFP
    c. Check in on the installation of the equipment
    d. Asset tag and inventory all the equipment
    e. Commission the system
    f. Program the system; the basis of design for in-house programming shall be Crestron.
        i. In-house Crestron programming
        ii. In-house GUI design
    g. Monitor and maintain the system (VTEye)
3. For classroom, lab, conference, or informal learning spaces that are not assigned through the Registrar's Office (in-house or contractor)
    a. Consult with the A/E, A/V consultant, and stakeholders on
        i. Classroom layout
        ii. Floor box and conduit locations
        iii. Recommend a system design to match our current standards
        iv. Help create an equipment list for all the product within the system
    b. If requested, review pricing with stakeholders from vendors and select lowest price that best matches RFP

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. If requested, check in on the installation of the equipment

6.5 Elevators

See DCSM section 6.2 for commissioning of elevators.

6.5.1 Applicable Code

1. ANSI A117.1 – Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People
2. ANSI/ASME A17.1 – Safety Code for Elevators and Escalators
   Virginia Tech's main campus is located in seismic zone 2 and therefore elevators are required to be provided with seismic protection. Confirm with the A/E for seismic zone requirements for projects not on Virginia Tech's main campus.
3. ANSI/UL 108 – Fire Tests of Door Assemblies

6.5.2 Alternate Conveyances

1. Escalators and moving walks shall not be installed in Virginia Tech facilities.
2. Wheelchair lifts shall not be installed in Virginia Tech facilities.

6.5.3 Contractor Requirements

1. The Contractor shall provide:
   a. Shop drawings for all elevator equipment.
   b. A letter from the elevator subcontractor certifying that the all components of the elevator system are compatible with each other and are appropriate for the application.
   c. A letter from the elevator manufacturer (on manufacturer's letterhead) verifying that the manufacturer acknowledges and will comply with all requirements of the specifications relative to repair and maintenance tools. Specifically, the letter shall include language that acknowledges the acceptance of the following:
      i. Any and all maintenance diagnostic tools, shop drawings, electrical schematic wiring diagrams, and any access codes and passwords required to perform any maintenance function over the life of the equipment such as diagnostics, adjustments, or parameter reprogramming shall be provided to the VT PM on the Date of Substantial Completion.
      ii. Tools may be handheld or built into the control system and shall function for the life of the equipment without the requirement to return them to the manufacturer.

iii. Complete product data manuals, operations and maintenance manuals, and maintenance training manuals including diagnostics instructions for troubleshooting the microprocessor system shall be provided to the VT PM.
iv. The University shall not be required to sign licensing agreements related to the use of maintenance or repair tools.

2. The Contractor shall select an elevator provider with:
   a. A full-service facility located within 100 miles of the installed elevator location, and
   b. The ability to respond to service calls within 2 hours.
3. The elevator subcontractor shall provide all signage as required by applicable codes. Signage shall be:
   a. Engraved in hall call stations and cab control stations
   b. Engraved in English and in Braille
   c. Mounted to meet ADA requirements

6.5.4 Elevator Type and Quantity

1. Buildings of 20,000 square feet or larger shall have at least two elevators.
   a. In research, lab, or dining facilities, one of these two elevators shall be of freight size and capacity.
   b. Residential buildings shall be provided with a minimum of two passenger elevators and one freight-sized elevator.
2. Service elevator cars shall be used instead of freight elevator cars.
3. If there is a penthouse in a building, it must be served by a freight-sized elevator with a service elevator car.
4. Access for ambulance stretchers shall be provided in plans for elevator service.
   a. All new, non-residential buildings provided with elevator service shall have at least one elevator sized and configured to accommodate an ambulance stretcher (84″ × 24″) in the horizontal position.
   b. New residence halls shall have all elevators configured to accommodate an ambulance stretcher.
   c. When existing elevators are replaced, the criteria for new construction shall be met where possible.

6.5.5 Mechanical, Electrical, and Communications

1. If emergency power is provided to the building, at least one elevator shall be on the emergency power circuit. If the building has more than one elevator, only

one elevator is required to be on emergency power but the other elevator(s) shall be provided with an emergency lowering system.

2. All electric motors installed on elevator or conveying equipment shall be premium efficiency.
3. The elevator controller shall be solid-state microprocessor based control system for dispatch and motor control.
4. Conduit for telephone wiring from the telephone backboard to the elevator controller shall be provided. Power for the elevator telephone shall be on an emergency circuit.
5. Elevator traveling cables shall be provided with an integral CAT 6 for the installation of security cameras.
6. Provide all elevators with remote monitoring capability through NI&S to elevator service monitoring company.
7. The elevator disconnect shall be located as close as possible to the non-hinged side of the elevator machine room door.

6.5.6 Elevator Pits, Equipment, and Machine Rooms

1. Protection from water damage in elevator pits shall be provided in plans for elevator service.
    a. Elevator pits shall have sump pumps and adequate drains to prevent the accumulation of water. Drains shall not be connected to building sewers.
    b. Water sensors shall be installed in elevator pits. The BAS will monitor water sensors, oil sensor and sump pump general alarm in elevator pits.
2. Provide disconnect switches according to DCSM section 6.8.2.4.
3. Cooling shall be provided for elevator machine rooms.
    a. The cooling design temperature for the air conditioning shall not to exceed 76 °F.
    b. For new buildings, elevator machine rooms shall be temperature-controlled spaces that provide proper operating temperatures and humidity levels for the elevator equipment provided.
    c. For renovation projects without existing mechanical cooling in the elevator machine room, air conditioning shall be added to the elevator cabinet.
    d. If an elevator is on the emergency generator, then the cooling equipment shall be served by the emergency generator also.
4. Electric Traction Elevators
    a. Traction elevators shall have machinery located overhead. Basement machines are prohibited.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   b. Traction elevators shall be installed where it is necessary to serve more than three stories.
5. Hydraulic Elevators
   a. Hydraulic elevator machine rooms shall be located adjacent to the elevator shaft.
   b. The jack cylinder shall be installed inside a PVC pipe and capped on the lower end.
   c. Install all elevator hydraulic piping above ground. Provide a shutoff valve in the machine room for maintenance purposes. All hydraulic piping for elevators shall be minimum Schedule 80 construction.
   d. Hydraulic elevators not on the emergency generator shall be provided with emergency battery backup elevator lowering devices such that in a power outage, the elevator will lower to the main landing and doors will open so that entrapped passengers can safely exit.
   e. Hydraulic elevators shall be installed to serve no more than three stories.
6. Elevator machine rooms shall not be used for access to roofs or other parts of the building unless elevator equipment is fenced or walled-in.

6.5.7 Cabs and Lobbies

1. Security cameras will be provided by VT for all elevator cabs (see DCSM section 6.4).
2. All elevators shall be provided with emergency lighting.
3. Cab overhead lights and cab operating panels shall be LED.
4. All buttons, hall call stations, light fixtures, car stations, position indicators, etc., shall be vandal-resistant.
5. All Phase I and Phase II fire service shall be keyed to barrel key EX-515.
6. In buildings with more than three stories, provide position indicators on each floor.
7. The basis of design for residence hall elevators shall be 5WL textured stainless steel cab interiors.
8. Protective pads shall be designed and supplied for all elevator cars.
9. In elevator lobbies, design un-switched “night lighting” luminaires at the entrance/exit of the elevator.

6.5.8 Warranty and Maintenance

1. Each elevator shall be provided with a 12-month warranty to begin on the Date of Substantial Completion.
2. The warranty shall include full maintenance services as described herein:

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

a. Maintenance shall be provided by skilled, competent employees of the elevator installer.
b. Maintenance shall continue for a period of 12 months following the Date of Substantial Completion and shall be at no additional cost to Virginia Tech.
c. Maintenance services to be included under this contract shall minimally include:
    i. Monthly preventive maintenance performed during normal working hours
    ii. Repair or replacement of worn or defective parts or components
    iii. Lubricating, cleaning, and adjusting as required for proper elevator operation in conformance with specified requirements
    iv. 24-hours-per-day, 7-days-per-week emergency callback service
    v. Performance of the annual test due during the 12-month service period

3. The only exclusions on the warranty shall be repairs or replacements due to misuse, abuse, accidents, or neglect caused by persons other than the elevator installer's personnel.
4. It is the intention of the University to obtain competitive bids for all maintenance and repair services and material for the elevator provided. Accordingly, the use of proprietary equipment or equipment requiring the use of any proprietary items throughout the life of the equipment is unacceptable. In addition, any special tools, prints, technical data, layouts, hardware, software, etc., required throughout the life of the equipment and which cannot be obtained from multiple suppliers, must be provided by the manufacturer to the University at the Date of Substantial Completion of the project.

6.5.9 Record Document Submittals

1. Provide all documents in both electronic and hardcopy form.
2. After the approval of all shop drawings, provide product data and two hardcopy sets of maintenance manuals. Maintenance manuals shall minimally include:
    a. Operating and maintenance instructions
    b. Schematic wiring diagrams
    c. Parts listing
    d. Recommended parts inventory listing
    e. Purchase source listing for major and critical components
    f. Emergency instructions.

6.6 Plumbing

6.6.1 Common Work Results for Plumbing

1. Backflow prevention devices shall be installed at the service connection of all new buildings. Backflow prevention devices (BFP) shall be installed inside the building. Provide two parallel BFPs at the service connection to allow servicing/testing of equipment without having to shut down the water service to the entire building. Minimum redundancy for each BFP is 50%.
2. There is an existing domestic hot water utility on campus that is fed from the power house. No new buildings shall connect to the existing utility. If a renovation is done to an existing building that is already connected to the utility, the domestic hot water service shall only be used with permission of the Engineering Services.
3. When designing a domestic hot water system for a new building or capital renovation, the energy source should be selected carefully. Assuming all options are available onsite, the energy source preference is as follows:
   a. Campus low-pressure campus steam (see DCSM section 6.6.5.4)
   b. Campus high-pressure campus steam (see DCSM section 6.6.5.4)
   c. Natural gas (see DCSM sections 6.6.5.5 and 6.6.5.6)
   d. Propane (see DCSM sections 6.6.5.5 and 6.6.5.6)
   e. Electricity (see DCSM section 6.6.5.7)
   f. If there is a system that has a significant daytime water heating demand, consider the use of solar thermal domestic water heating.
4. A central domestic hot water system is more efficient and easier to maintain than having many individual water heaters installed throughout a building. As such, designing a system with many individual heaters in lieu of a single hot water generation system can only be done with the approval of Engineering Services.
5. All domestic hot water systems shall be designed with hot water expansion tanks that are properly sized for the application.
6. To reduce the chance of legionella growing in domestic hot water storage tanks, any hot water tank or storage-type water heater shall be sized and set up for a minimum hot water storage temperature of 140 °F. A secondary mixing valve shall be used to ensure that the leaving hot water temperature to fixtures will never be above 120 °F. The secondary mixing valve shall be monitored and alarmed by the BAS.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

7. All central domestic hot water systems shall be designed with a hot water recirculation system. The recirculation pump shall have the ability to be scheduled via BAS system or with a timer. BAS scheduled is preferred.

6.6.2 Plumbing Equipment Insulation

1. Any plumbing equipment that will be insulated shall be insulated in a way that the equipment can be easily removed for maintenance without damaging the insulation. The basis of design shall be a custom insulation blanket by InsulTech or equal.
2. Large domestic hot water storage tanks shall be factory insulated with spray-on insulation when available.

6.6.3 Instrumentation and Control for Plumbing

See DCSM section 6.3 for BAS design standards.

6.6.4 Plumbing Piping

1. Pipes and pipe fittings:
    a. ABS piping is unacceptable.
    b. Do not install heating hot water or other similar service piping susceptible to freezing in overhanging soffit areas.
    c. On domestic water, mechanical systems, and vacuum lines, no sweat connection valves shall be used. Use only flanged or threaded valves. No threaded valves shall be larger than 2″.
    d. Allowable methods for connecting pipe in new construction include:
        i. Threaded
        ii. Flanges
        iii. Soldered (2″ pipe or smaller)
        iv. Brazed (pipe larger than 2″ and all vacuum lines)
        v. Welded
    e. Mechanically joined pipe, press-type connections, are allowed for post-construction repair projects only. They are not allowed for new construction.
    f. No mechanically formed tee connections or couplings shall be used on domestic water piping systems.
2. Valves:
    a. Include sufficient zone isolation/shutoff valves in domestic cold and hot water piping to allow maintenance and replacement of equipment without shutting down entire building.
    b. Install valves on every floor for all lines that penetrate floors from below.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. Install valves on all branch lines off of main lines.
d. Install valves on all lines at locations such that each floor can be isolated independent of main building.
e. Any fixture that mixes hot and cold domestic water shall not allow counter flow into the piping system from the fixture due to pressure differences. Must operate if one side is off or if difference is 1 to 80 PSIG.
f. Install control valves where they can be reached from the floor where possible, and ensure that the valves are accessible without obstructions.
g. Provide isolation valves for all individual wet labs and research spaces, accessible from outside the lab space.

3. Piping specialties – Pipe chases shall be provided in sufficient size to accommodate maintenance personnel (at least 3 feet wide). Do not locate pipe chases in housekeeping closets.
4. Copper pipe shall not be buried underground.

6.6.5 Domestic Water

6.6.5.1 Domestic Water Piping

1. Shutoff valves are required on each floor, on take-offs from all vertical risers, and at the connection to each piece of equipment.
2. Dielectric fittings shall be used with connecting piping of dissimilar metals. Brass fittings and dielectric nipples are acceptable fittings, but brass valves shall not be used as the dielectric connection.
3. Drain valves shall be installed in accessible locations at all low points in the piping system to permit drainage and servicing.
4. No iron pipe fittings (including galvanized) shall be used in any potable water system.
5. No more than four slip joints per fixture shall be permitted.
6. PEX piping is not approved for use in university buildings.

6.6.5.2 Domestic Water Packaged Booster Pump

1. A booster pump package shall be required if the utility cold water supply pressure cannot maintain 40 psi pressure at the highest fixture in the building.
2. If the booster pump is supplying the main domestic feed for a building and the maximum demand flowrate for the booster pump is 75 GPM or greater, the package shall have at least 2 pumps, each sized for a minimum of 60% of the demand flowrate.
3. Any booster pump package shall be installed with a manual bypass.

4. All packaged booster pumps shall be equipped with individual pump VFDs.
5. All booster pumps shall be installed with a bladder style hydro-pneumatic storage tank.
    a. If possible, install hydro-pneumatic tank at the high point of the system.
    b. Hydro-pneumatic tank shall be connected to the main system piping with the same size pipe as the tank connection; the pipe shall not be necked down to a smaller size.
    c. There shall be provisions in the piping connecting the hydro-pneumatic tank to main system piping that will allow the tank to be isolated from the system and drained of water while isolated.
6. All packages shall come factory equipped with a low-suction pressure safety and a way to communicate with the campus BAS.
7. All booster pumps shall be connected to emergency power.

6.6.5.3 Facility Potable-Water Storage Tanks

1. Internal epoxy coated tanks shall not be used.
2. If the A/E chooses to use a glass-lined tank, a double glass-lined coating shall be used if available.
3. If multiple tanks are being piped together to act as a single thermal mass, the tanks shall be piped in the 'reverse-return' method so that the piping pressure drop across all tanks is equalized.

6.6.5.4 Domestic Water Heat Exchangers

1. All heat exchangers for domestic water use shall be double-wall construction.
2. All heat exchangers for domestic water use shall be constructed of material suitable for domestic hot water use. Cast iron is not permitted.
3. Steam-to-water heat exchangers
    a. All steam-fired water heaters shall be provided with 1/3 – 2/3 steam control valves.
    b. Steam pressure serving a water heater's control valve shall not be greater than 15 PSIG.
    c. Select a heat exchanger with a fouling factor that is appropriate for the application.
    d. To avoid temperature overshoot, water heaters marketed as 'instantaneous' water heaters shall only be allowed for dump loads with little load modulation required. Water heaters for all other applications shall be 'semi-instantaneous' or 'storage' type.

   e. All steam-to-water water heaters shall be provided with steam control valves. Water heater designs that do not control steam flow and rely solely on a water tempering valve for temperature control are not allowed.
4. Water-to-water heat exchangers
   a. Water-to-water heat exchangers used for the primary water heater in a system shall be either brazed plate or plate-and-frame-type; shell-and-tube-type construction is only allowed for heat recovery/preheat applications.
   b. Plate-type heat exchangers shall be sized for a maximum pressure drop of 6 PSIG.
   c. Plate-and-frame heat exchangers shall be provided with enough carrier bar length to allow plate inspection and cleaning without having to remove the plates from the carrier bar.

6.6.5.5 Fuel-Fired Domestic Water Heaters

1. Propane shall only be used when natural gas is unavailable onsite and the system will be 100,000 Btu/h input or larger.
2. High-efficiency (condensing) water heaters shall be used whenever possible.
   a. All condensing water heaters shall be provided with acid-neutralizers per the manufacturer's instructions.
   b. Venting for condensing water heaters shall be sloped back to the water heater (minimum 1/8" per foot). If vent routing will not allow the whole vent to be sloped back to water heater, a tee with pigtail drain connection and separate acid neutralizer shall be installed at a point so that all vent can be sloped back to the water heater or the pigtail drain.
3. When multiple water heaters are located in a single space, individual vents shall be used in lieu of common venting.
4. Concentric vent kits are not allowed.
5. Water heaters shall be vented per the manufacturer's instructions using only the venting material(s) approved by the manufacturer.
   a. PVC is not an acceptable venting material and will not be allowed, even if the manufacturer has approved it for use.
   b. Because of its higher maximum temperature ratings, chlorinated polyvinyl chloride (CPVC) is an acceptable venting material.
6. All water heaters shall have some means of communicating with the BAS. At a minimum, water heaters shall be able to communicate status and alarm.

7. All gas-fired appliances shall have individual gas pressure regulators per the manufacturer's instructions.
8. Gas pipe serving water heaters shall be sized per the Fuel/Gas Code as well as the manufacturer's installation instructions.
    a. The gas pipe system shall be designed to supply gas to the water heater at a pressure that is within the equipment's operating range.
    b. If the water heater has a modulating gas valve, the supply gas pipe shall also be designed so that the gas pressure fluctuates only within the manufacturer's specified limits when operated between low and high fire.

6.6.5.6 Instantaneous, Tankless, Gas Domestic Water Heaters

1. Instantaneous water heaters shall be designed for commercial use; use of a residential product is prohibited.
2. Minimum heat exchanger warranty shall be 5 years.

6.6.5.7 Electric Domestic Water Heaters

1. In general, electric domestic water heaters shall only be used if steam, natural gas or propane is not available.
2. Acceptable applications for electric water heaters are:
    a. Small point-of-use (under sink) applications.
    b. Booster heater applications.
    c. Small systems (50 gallons or less storage).

6.6.5.8 Drinking Fountains

1. Specify wall or surface mounted, fully accessible drinking fountains in corridors; exact locations to be determined during design. Each fountain shall have its own compressor. Water shall not be cooled at another location.
2. A bottle filling attachment shall be provided at all drinking fountain locations. Locate a single bottle filling unit on each floor and a double unit on the main floor for ADA compliance.

6.6.6 Storm, Sanitary, and Chemical Waste Systems

A camera inspection of sub-slab sanitary waste systems shall be performed during the design phase for any building that is older than 20 years.

6.6.6.1 Facility Sanitary Sewerage

1. Extra heavy cast iron hub piping shall be used on all sanitary and storm sewer drains that are located under concrete floor slabs or under other inaccessible floor construction.

2. The use of PVC piping in under-floor slabs is prohibited.
3. All piping used below the slab shall be a minimum of 3 inches in diameter.

6.6.6.2 Sanitary Waste Piping Specialties

1. All mechanical rooms shall have a minimum of two floor drains per mechanical room.
   a. Floor drains for mechanical rooms shall have a minimum 4-inch inlet connection.
   b. All floor drains in mechanical rooms shall be piped in cast iron. Plastic pipe is prohibited.
2. All sanitary mains under slab shall be video-scoped to verify there is no standing water. This inspection shall happen after the slabs are poured and prior to the issue of a Change Order.
3. All restrooms shall have floor drains, centrally located with floor slightly sloped toward drain.
4. Acid resistant lines shall be used from laboratories to a point where waste water should dilute an accidental or unintentional acid release into the wastewater system.

6.6.6.3 Sanitary Sewerage Pumps

1. Any sanitary sump pump that is expected to have solid waste shall be designed to pass a minimum 2-inch sphere.
2. All sanitary sewerage pumps shall be provided as a duplex set with each pump sized for 100% of design.

6.6.6.3.1 Submersible Sewerage Pumps

1. Any submersible sump pump that is used for sanitary waste shall be provided with explosion proof motors and intrinsically-safe controls.
2. All submersible sewerage pumps shall be provided with removal rail systems.

6.6.6.3.2 Sewerage Pump Basins and Pits

1. Follow pump manufacturer’s recommendations for minimum sump water level, to ensure proper cooling of the pumps.
2. The pump basin depth should be sized to allow a minimum pump run-time of 90 seconds, and to have enough space for all floats below the invert.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.6.6.4 Facility Storm Drainage – Sump Pumps

Any submersible storm pump that serves a parking structure or any other location where flammable liquids can be introduced into the drainage shall be provided with an explosion proof motor and intrinsically-safe controls. All stormwater sump pumps shall be duplex.

6.6.6.5 Rainwater Reclamation Systems

1. Reclaimed rainwater will not be used in fixtures within a building without the approval of Engineering Services.
2. If a rainwater reclamation system is to be used, some form of disinfection (UV, chemical injection, etc.) must be used in conjunction with filtration prior to supplying the reclaimed water to fixtures.
3. Any rainwater reclamation system shall have an integrated municipal water backup with a backflow preventer.
4. All piping shall be labeled.

6.6.6.5.1 Facility Stormwater Retention Tanks for Rainwater Harvesting

See the VTAS&S for requirements.

6.6.6.6 Commercial Water Closets

Water closets shall be elongated vitreous china, wall hung, siphon jet, flush valve and trim for 1.28 gallons per flush (GPF), seat chair carrier, and chromium-plated nuts and washers.

1. Allowable manufacturers and models for regular use are:
   a. American Standard 2237.001
   b. Kohler K-4325
   c. Sloan ST-2059-A
   d. Toto CT708E
2. Allowable manufacturers and models for ADA use are:
   a. American Standard 3351.001
   b. Kohler K-4325
   c. Sloan ST-2059-A
   d. Toto CT708E

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.6.6.7 Commercial Urinals

1. Urinals shall be top spud water saver wash down type designed to flush between 0.5 and 1.0 GPF or less. The basis of design shall be Toto UT 104 or equal.
2. Waterless urinals shall not be used.

6.6.6.8 Commercial Sinks

1. Service sink shall be 24″ × 24″ (minimum size), floor-mounted, precast concrete or stone construction located at an 8-inch maximum height from floor to rim.
2. Housekeeping closets and housekeeping equipment closets shall have 30″ × 30″ floor sinks.
3. Separate hot and cold water utilities shall be provided. Mixing valves are not acceptable.
4. The faucet shall include a vacuum breaker, integral stops, a spout with pail hook and nose end, a top single brace, renewable units, and valve seats.

6.6.6.9 Commercial Showers

Install pressure compensating water saving shower heads on all showers at set at 2 GPM. Shower heads at less than 2 GPM must be approved by CPIF for functionality before installation.

6.6.6.10 Commercial Faucets, Supplies, and Trim

1. All faucets shall be fitted with pressure compensating flow controls in accordance with LEED standards.
2. Hot water supply to faucets shall be designed to provide hot water within 30 seconds of water flow. If this is not possible, then A/E shall consider adding a dedicated recirculating line for the faucet.
3. Touchless faucets shall be installed on at least one sink in each restroom for Accessibility where possible.
   a. The basis of design for touchless faucets shall be Toto Eco-Power auto sink sensor (or equal) that utilizes a hydro-powered turbine to charge the power supply and extend the battery life.
   b. Battery warranty for touchless faucets shall be a minimum of 10 years.
4. Sensor-type touchless automatic faucets shall not be installed in buildings for which the domestic hot water source is the central loop from the power plant due to large pressure variations. Two-handled faucets shall be installed

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

where touchless faucets cannot be used. Faucets shall be two-handled lever type on at least one lavatory for Accessibility.

5. Install touchless faucets on all lavatories in restrooms in new building projects and capital renovations in minimum quantities on renovation projects as follows (note at least one of the touchless fixtures shall be ADA Accessible):
    a. On one lavatory in restrooms with one to three lavatories.
    b. On two lavatories in restrooms with four to six lavatories.
    c. On three lavatories in restrooms with seven to ten lavatories.
6. Sensor-type faucets shall include the thermostatic mixing valve in the faucet control box. A single source faucet shall only be specified if pre-tempered water is provided to the unit. The thermostatic mixing valve shall be pressure compensated to adjust for different pressures in the hot and cold water lines.

6.6.6.11 Flush Valves and Flushometers

1. Water closet and urinal flush valves or flushometers shall be exposed, mounted on the fixture in the restroom, not in a chase. Valves shall be the manual piston type (not diaphragm type) mounted on water closets (1.6 GPF or 1.28 GPF) and urinals (1.0 GPF or 0.5 GPF). Valves should be adjustable to allow for slight increases or decreases in flow. The basis of design shall be Toto urinals or water closets as listed below.
    a. Toto TMU1NNC-12 or TMU1LN 12#CP manual urinals.
    b. TEV1GNC-12 or TEV 1 LN 12#CP automatic urinals.
    c. Water closet manual TMT1NNC-32 or TMT1LN#CP or automatic TETGNC-32 or TET1LN-32#CP.
2. Sensor operated automatic flush valves with manual override button. The basis of design for auto-flush, touchless valves shall be Toto Eco-Power sensor valve (or equal) battery powered device that utilizes a hydro-powered turbine to charge the power supply to extend battery life up to ten years.
3. Install the auto-flush, touchless valves on all water closets and urinals in new building projects and in minimum quantities on capital renovation projects as follows:
    a. On all Accessible water closets.
    b. On one water closet and one urinal each in restrooms with one to three fixtures.
    c. On two water closets and two urinals each in restrooms with four to six fixtures.

d. On three water closets and three urinals each in restrooms with seven to ten fixtures.

6.6.6.12 Laboratory Chemical Waste and Vent Piping

Separate acid-resistant sanitary systems shall not be provided for laboratory operations, nor shall an acid neutralization system be provided.

6.6.7 Piping Systems for Gases

6.6.7.1 General Service Compressed Air Systems

1. Provide all air compressors with mufflers.
2. Buildings that require laboratory air shall have a dedicated air compressor with redundancy and auto blowdown.

6.6.8 Emergency Shower and Eyewash Equipment

1. A floor drain is required in all spaces that have safety showers in new buildings.
2. Each shower and eyewash station shall have an isolation valve for service.

6.7 Heating, Ventilation, and Air Conditioning

6.7.1 General Design Requirements

1. Refer to DCSM section 2.6.6 for HVAC system design requirements.
2. Refer to DCSM section 6.6.1 for energy source preferences for heating systems.
3. Update all schedules to reflect the actual installed equipment for record drawings.
4. All mechanical equipment and components requiring maintenance and inspection shall be arranged in a manner to allow appropriate components to be accessed. All air handling units and fan coil units shall be located with provisions to service the following items, including but not limited to: changing filters, adjusting sheaves, lubricating bearings, motor service and replacement, belt replacements, and cleaning and pulling coils.

6.7.2 Motor Requirements

1. All motors used in VFD applications shall be “Inverter-Duty” rated according to NEMA MG 1 Part 31, “Requirements for Definite Purpose Inverter-Fed Polyphase Motors,” with minimum Class F temperature rise and Class H insulation. NEMA duty rating code on motor nameplate shall indicate “Inverter-Duty.”
2. All VFD controlled motors shall have grounding rings with a life expectancy of 200,000 hours. The basis of design for grounding rings shall be AEGIS.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. All VFDs shall be accessible from the outside of equipment. Maintenance staff shall not be required to enter an air handling unit to access VFDs.
   a. Exception: Outdoor equipment with dedicated maintenance vestibules can be used to house VFDs.
4. Outdoor-mounted VFDs are not preferred and should be avoided when possible. Use a NEMA 3R enclosure if installed outside.
5. Equipment with remote-mounted VFDs shall have signage indicating that the disconnect must be turned off and indicate the location of the disconnect. Provide lockout-tagout capability on disconnects.
6. Max speed for motors on VFDs shall be 60 Hz (including fans and pumps). Overspeeding of VFDs is not allowed.
7. One VFD shall be provided for each motor, including fan arrays. Multiple motors on a single VFD are prohibited.
8. For individual fans and pumps with no redundancy, the VFDs shall have a manual line voltage bypass that does not rely on any electronic controls within the VFD. If there is an N+1 arrangement, then a VFD bypass is not required. For fan arrays, a VFD is required for each; therefore, a bypass is not required.
9. All safeties for air handlers or pumps shall be wired to the circuit (e.g., freeze stats) of the VFD.
10. Electronically commutated motors (ECM) shall not be used on campus. If an ECM is approved through a design waiver, it may require a standby or replacement motor for each motor used.
11. Direct drive motors are preferred and shall be non-precision motors.

6.7.3 Sleeves and Sleeve Seals

Seals between the exterior and interior of the building shall use a modular link seal to prevent the infiltration of water.

6.7.4 Meters and Gauges (Inside the Building)

1. Provide a diaphragm-type differential pressure indicator for all serviceable filters and locate the indicator where it can be readily observed. Mark on the indicator the “clean” and “replace filter” points. Differential pressure indicator shall be 2% accurate, full scale.
2. Liquid-filled gauges are required for:
   a. Differential pressure across pumps, chillers, heat exchangers, and boilers.
   b. Pressure gauges on the condensate return line leaving the building to the utility tunnel and discharge condensate pumps.

3. Provide light-activated digital thermometers on the inlet and outlet of all heat exchangers, boilers, chillers, and air handling units.
4. See DCSM sections 5.1.1 and 4.8 for energy metering, utility tunnel metering, and gauging requirements, respectively.

6.7.5 Valves

6.7.5.1 General Valve Standards

1. Valves for major system components shall have locking handles. Major components include, but are not limited to chillers, boilers, heat exchangers, pumps, and air handling units.
2. Provide valves with locking handles on isolation valves of main utilities at the building entrance. Utilities include, but are not limited to, main domestic water, chilled water, hot water, and domestic hot water recirculation.
3. Provide valves with locking handles at floor level isolation valves of main utilities.
4. All branch lines shall have an isolation valve at the connection point of the main. Control valves shall not be used as the only means of isolation.
5. Isolation/shutoff valves shall be provided on piping entering and leaving (supply and return) on all HVAC equipment, including but not limited to: air handling units, fan coil units, VAV boxes and pumps.
6. Use threaded valves only. No soldered or brazed valves of any type shall be used, including but not limited to control valves, strainers, check valves, or balance valves.
7. Gasket materials for flange connections shall meet or exceed the temperature and pressure ratings for the system valves and be appropriate for the fluid being conveyed.
8. Manual valves with stems shall be installed with stems straight up but never lower than 90 degrees.
9. If actuated control steam valves cannot be mounted vertically, follow the manufacturer’s guidelines.
10. Valves shall have extended handles for proper operation without damage to pipe insulation.
11. Install chainwheels on operators for ball, butterfly, gate, and globe valves with 3-inch nominal pipe size (NPS) and larger and more than 7 feet above floor. Extend chains to 60 inches above finished floor and provide with security cable devices.
12. Install all valves in accordance with the manufacturer’s installation instructions.

13. Follow the manufacturer's recommended bolt pattern for flanged valves.

6.7.5.2 Hydronic System Valves

1. Valves sized 2-1/2 inches and smaller for shutoff service shall be ball valves with lever handles.
2. Ball valves shall be Class 150, full port, 2-piece, threaded with unions to aid in the removal of the valve.
3. Valves sized 3 inches and larger shall be butterfly valves. Provide 3-inch valves with 10-position lever lock handles. Valves sized 4 inches and larger shall have manual handle weatherproof worm gear and position indicator.
4. Resilient seated butterfly valves (RSBV), 2-inch to 20-inch size:
    a. RSBVs can be used in standard specifications for all applications in condenser water, chilled and hot water (excluding steam and condensate) and glycol/water solutions for shut off. Do not use RSBVs if the water temperature is 200 °F or greater.
    b. Manual butterfly valves shall be of the resilient seated design rated for 230 PSIG shutoff, bi-directional dead-end service with the downstream flange removed. Valves shall be full lug, compatible with ANSI 125/150 flanges. Valves shall be designed in accordance with MSS-SP 67 and ISO 5752. Valve design shall accommodate required insulation thickness.
    c. Performance and testing: Valves shall be individually tested at the factory to full-rated cold working pressure with zero leakage.
    d. Materials of construction and design shall be:
        i. Body: Cast iron, ductile iron, stainless steel, or carbon steel.
        ii. Disc: 316 stainless steel
        iii. Stem: 300 or 400 series stainless steel.
        iv. Seat: EPDM
        v. Packing: Buna-N with acetyl or polyester bushing.
5. High performance butterfly valves (HPBV) shall be used on building service entrance piping. Service entrance is defined as the entrance to a building from an underground distribution system or building branch connections to the mains of a centralized distribution system.
    a. HPBVs shall be double offset design.
    b. Double dead-end bi-directional zero leakage must exceed ANSI Class IV leakage standard.
    c. Valves shall meet ANSI B16.34, B16.10, and B16.5 Flange Drilling: MSS-SP68 "face-to-face" and API 609 (latest version) for blow-out proof stem retention.

d. Valves shall be full lug with extended neck to accommodate required insulation thickness.
e. Valves must provide double dead-end, bi-directional service with downstream flange removed at full-rated cold working pressure (ASME Class 150 = 285 PSIG).
f. The seat shall be designed to be bubble tight, bi-directional at 0 psi, high pressure, and under vacuum.
g. The valve identification plate shall be permanently attached in accordance with MSS-SP25 and ASME B16.34.
h. Materials of construction and design shall be:
   i. Body: ASTM A216, Grade WCB, carbon steel or stainless steel
   ii. Disc: ASTM A351, Grade CF8M, Type 316 SS
   iii. Stem: ASTM A564, Type 630, 17-4 PH SS
   iv. Disc pins: ASTM A564, Type 630, 17-4 PH SS
   v. Seat: RPTFE self-adjusting for both high- and low-pressure service
   vi. Stem bearings: 316 SS glass/Teflon-lined or 316 SS/BRZ/PTFE
   vii. Packing: PTFE adjustable with carbon fiber ring to provide constant compression and seal for full rating of valve or stainless steel rings
i. All valves shall be capable of automating without removing the valve from the line and without the use of brackets and actuator to valve shaft couplings.

6.7.5.3 Steam and Condensate Valves

1. Valves with non-rising stems shall have tags to show open or closed.
2. Gate valves for steam service shall be forged or cast steel bodies.
   a. Steam pressure 75 PSIG and lower: Class 150 valves
   b. Steam pressure greater than 75 PSIG: Class 300 valves
3. For additional gate valve requirements, see DCSM section 4.8.10.
4. Cast or forged steel body ball valves shall be used for steam condensate only. Valves sized 2 inches and smaller shall be rated for 150 PSIG at 365 °F steam.
5. Gate valves with steel bodies should be used on steam and ball or gate valves with steel bodies should be condensate gauges with the proper temperature and pressure rating.
6. Do not use cast iron, bronze, or brass valves on steam.

7. High performance butterfly valves (HPBV):
    a. HPBVs shall be double offset design for steam pressures less than 150 PSIG. HPBVs shall be triple offset design for steam pressures 150 PSIG and greater.
        i. Steam pressure 75 PSIG and below: Class 150 valves
        ii. Steam pressure greater than 75 PSIG: Class 300 valves
    b. Double dead-end bi-directional zero leakage must exceed ANSI Class IV leakage standard.
    c. Valves shall meet ANSI B16.34, B16.10, and B16.5 Flange Drilling: MSS-SP68 face-to-face dimensions; API 609 latest version for blow-out proof stem retention.
    d. Valves shall be full lug with extended neck to accommodate required insulation thickness.
    e. Valves must provide double dead-end, bi-directional service with downstream flange removed at full-rated cold working pressure (ASME Class 150 = 285 PSIG).
    f. The seat shall be designed to be bubble tight, bi-directional at 0 psi, high pressure, and under vacuum.
    g. The valve identification plate shall be permanently attached in accordance with MSS-SP25 and ASME B16.34.
    h. Materials of construction and design shall be:
        i. Body: ASTM A-216, Grade WCB, carbon steel or stainless steel
        ii. Disc: ASTM A351, Grade CF8M, Type 316 SS
        iii. Stem: ASTM A564 Type 630, 17-4 PH SS
        iv. Disc pins: ASTM A564 Type 630, 17-4 PH SS
        v. Seat: RPTFE self-adjusting for both high- and low-pressure service
        vi. Stem bearings: 316 SS glass/Teflon-lined or 316 SS/BRZ/PTFE
        vii. Packing: PTFE adjustable with carbon fiber ring to provide constant compression and seal for full rating of valve or stainless steel rings
    i. All valves shall be capable of automating without removing the valve from the line and without the use of brackets and actuator to valve shaft couplings.

6.7.6 Hangers and Supports

1. Metal pipe hangers: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. Provide thermal hanger shields on insulated piping.

6.7.7 Heat Tracing

1. Provide electric heat tracing for any fluid system without glycol that has the potential to freeze.
2. Provide all heat tracing with a controller that includes dry contacts that can provide an alarm to the building DDC system.
3. Follow the manufacturer's recommendations and installation requirements for heat tracing on flanges, valves, gauges, and other accessories.
4. The Contractor shall not insulate pipes before an inspection is performed by VT building commissioning.

6.7.8 Vibration Controls

1. Special attention shall be paid for sensitive areas such as low-noise criteria spaces; examples include equipment penthouses situated above occupied spaces.
2. All hanging equipment shall be provided with vibration isolation unless there is internal fan isolation in the unit.
3. Use duct silencers for noise control.
4. Use of interior duct liners are prohibited and shall not be used for noise control.

6.7.9 Identification

1. Use laminated plastic stick-on tags to identify equipment. Use wraparound labels or stencil to identify piping and ductwork.
2. Utilize standard placard to mark all major equipment. Tags shall include information like the following examples:
   a. Chillers – Unit Tag, Date Installed, Capacity (Tons), Chilled water Flow (GPM), Condenser Water Flow (GPM), Chilled Water Supply and Return Temperature (°F)
   b. Cooling Towers – Unit Tag, Date Installed, Capacity (Tons), Condenser Water Flow (GPM), Condenser Water Supply and Return Temperature (°F)
   c. Boilers – Unit Tag, Date Installed, Input Capacity (MBH), Output Capacity (MBH), Hot Water Flow (GPM), Hot Water Supply and Return Temperature (°F)
   d. Heat Exchangers – Unit Tag, Date Installed, Service (Building Heat), Capacity (MBH), Steam (PSIG), Hot Water Flow (GPM), Hot Water Supply and Return Temperature (°F)
   e. Air Handling Units – Unit Tag, Date Installed, Service (Classroom Wing A), Capacity (CFM @ ESP), Cooling (Tons), Heating (MBH)

   f. Rooftop Units – Unit Tag, Date Installed, Service (Classroom Wing B), Capacity (CFM @ ESP), Cooling (Tons), Heating (MBH)
   g. Fans – Unit Tag, Date Installed, Service (Room 201 Fume Hood), Capacity (CFM @ ESP).
   h. Terminal boxes – Unit Tag, Date Installed, Service (Room 101), Max Airflow (CFM), Min Airflow (CFM), Heating Capacity (MBH)
3. Tag all mechanical equipment to match the records documents.
4. Mark the location of air handlers, fan coil units, mixing boxes, duct access doors, and other items requiring maintenance and inspection that are above ceilings with identifying buttons.
5. Tag exhaust fans and associated fume hood(s) to facilitate maintenance.
6. Tag all valves and provide valve chart for each floor and in the main mechanical room.
7. Mark each with the name of service, direction of flow, and associated unit served where appropriate.
8. All systems handling hazardous materials must have appropriate marking and visual and/or audible alarms to protect building occupants and maintenance personnel. Coordinate alarming with building DDC system.
9. Mark air handling units with 3-inch letters and numbers.
10. All fire dampers, smoke dampers, and combination fire/smoke dampers shall be numbered and identified on chart in mechanical room. Provide damper location drawing to facilitate testing and inspection.

6.7.10 Testing, Adjusting, and Balancing

1. The testing, adjusting, and balancing (TAB) contractor shall be a subcontractor to the Contractor or the mechanical contractor. The Contractor or the mechanical contractor shall be responsible for all scheduling of the testing, adjusting, and balancing procedures.
2. The A/E shall recommend a TAB report prior to the start of construction for renovations where existing equipment will be utilized.
3. The A/E shall develop a test and balance procedure for exhaust and makeup air systems serving the entire building. Each device in the system (snorkels and hoods) shall be included, so the same procedure and equipment is used during both balancing and functional testing for the commissioning process. Any special devices needed for testing and balancing shall be furnished by the manufacturer and given to the University after completion of the project.
4. Balancing of HVAC systems should be done with clean filters in air handling unit equipment. TAB contractor shall be responsible for verification of filter

condition, type, size, and quantity as well as indicating that data in the final TAB report.

5. Verification of condensate traps on chilled water coils operation at 100% of air handler speed at simulated loaded filter conditions.
6. All adjustable sheaves shall be replaced with fixed after correct fan speed is determined and noted in balance report.

6.7.11 Insulation

6.7.11.1 Duct Insulation

1. The use of internal duct insulation (liner) is prohibited.
2. Duct insulation shall be by use of any of the following:
   a. Exterior applied duct wrap with vapor barrier for concealed locations.
   b. Factory fabricated double wall metal duct with solid metal inner wall and factory-applied interstitial insulation between walls.
   c. In addition to the interstitial insulation, double wall ductwork that is exposed to the weather shall have all joints externally insulated and jacketed with the same material as the exterior wall of the ductwork.
   d. Factory fabricated double wall metal duct with perforated metal inner wall and factory-applied interstitial insulation between walls. All perforated liners shall include a 3-mil thick Mylar film between inner liner and insulation. Perforated metal inner wall shall only be used where noise control is a concern.
   e. Use rigid exterior duct insulation for ductwork installed in exposed areas. Exposed ductwork in mechanical rooms shall be factory-applied all-service, vapor barrier jacket. In public areas, provide a paintable vapor barrier jacket.
3. All outside air ducts and supply ducts shall be insulated inside the building and return ducts shall be insulated where they may have heat loss due to temperature differences or are subject to condensation.
4. Provide rigid board insulation strips at duct supports to avoid compression of duct wrap.

6.7.11.2 Equipment Insulation

Double wall construction shall be specified for air handling units, fan coil units, variable air volume boxes, or other terminal boxes. Insulation shall be between the inner and outer walls. The inner wall shall be solid metal (not perforated) so that no insulation is exposed to the air stream.

6.7.11.3 Piping Insulation

1. Protective pipe shields shall be installed at the time of application of pipe insulation.
2. The basis of design for pipe insulation on piping with an operating temperature of 42 °F to 60 °F shall be cellular glass. The A/E will be responsible for determining the cause and correction of condensation on chilled water piping if it occurs.
   a. Insulation shall be 1-1/2 inches thick on pipes sized 2 inches through 4 inches.
   b. Insulation shall be a minimum of 2 inches thick to prevent condensation at 95% relative humidity in unconditioned spaces on pipe sizes greater than 4 inches.
3. The A/E shall determine thickness and type of insulation. Rubberized or flexible elastomeric-type insulation is not to be used on pipe sizes larger than 2 inches.
4. All piping operating under 80 °F shall be insulated (i.e., chilled beam systems).

6.7.12 Commissioning

See DCSM section 1.8 for Commissioning requirements.

6.7.13 Controls

1. See DCSM section 6.3 for BAS design standards.
2. All controls shall be Siemens or Siemens Apogee compatible. Third party software is not to be used. If the only controller is by another manufacturer then it will have a complete interface provided by equipment manufacturer. If BACnet is used a list of control points with read and write access will be provided.
3. All controls and operators will be provided by the controls contractor to be factory installed or field installed as noted in the bid documents. Controls shall be designated on the shop drawings or bid drawings for location and type.
4. The use of line voltage thermostats in any occupied or residential space is prohibited. Line voltage thermostats can be used in areas such as mechanical, electrical, and storage rooms if the voltage is 120 V or less.
5. All systems handling hazardous materials must have appropriate visual and/or audible alarms to protect building occupants and maintenance personnel.

6. Provide cooling coil condensate drain pan overflow switches. Provide cooling coil overflow drain pan alarm to BAS. Upon alarm, disable cooling but do not turn unit off.
7. Provide UV light safety cutoff switches at access doors.
8. A/E shall review the location of humidity sensors with the Instrument Controls and Metering (ICM) group.

6.7.14 Hydronic Piping

1. Hydronic piping and components shall be capable of withstanding the system working pressures and temperatures. Minimum design pressure shall be 150 PSIG.
2. Provide air vents at high points and end points in hydronic piping systems to easily bleed entrapped air.

6.7.15 Hydronic Piping Specialties

1. Triple duty valves shall not be used. Pumps shall be controlled by VFD or in constant speed applications, provide a dedicated balancing valve with a separate isolation valve and check valve.
2. All hydronic control valves must be able to close against system pressure.
3. Modulating control valves for terminal equipment shall be pressure independent.
4. All equipment used in the hydronic system shall be capable of operating correctly with pressures and flows that the system develops. Valves shall open and close fully without being heard in the occupied space, causing water hammer, or cavitation.
5. Control valves shall be sized for flow and pressure drop authority and not selected by line size with the exception of 2-way, 2-position valves used for isolation service.
6. Building-level closed-loop hydronic systems shall be provided with air separation equipment and expansion tanks.
7. Air separation equipment and expansion tanks for fluids from central systems will be provided at the heating or chiller plant.

6.7.16 Hydronic Pumps

1. All HVAC pumps shall be 100% duty, arranged in a lead/stand-by, parallel configuration.
2. Variable primary is the preferred system arrangement.
3. For variable speed applications, the system design shall include provisions to maintain minimum equipment flow rates at part-load conditions. This may be

achieved by providing some 3-way control valves near remote coils or with a dedicated 2-way minimum flow control valve. The 2-way minimum flow control valves shall be situated sufficiently away from the source equipment to provide the appropriate system volume to limit short cycling of equipment.

4. On variable primary systems with multiple pieces of generating equipment, provide motorized isolation valves to isolate flow through non-operating equipment.
5. For variable speed applications, variable frequency drives shall be wall mounted. ECM and motors with integral VFDs are not allowed.
6. Preferred pump type is base mounted, split-coupled arrangement. Provide start-up alignment for all split-coupled pumps after installation.
7. Applications utilizing in-line pumps shall be limited to 7.5 HP and smaller.
8. Double suction pumps shall be considered for any flow rates over 1,000 GPM.
9. The preferred pump speed is 1,750 RPM. A 3,500 RPM pump speed may be used for high head conditions where a 1,750 RPM pump selection is not appropriate. Do not use 1,150 RPM pump selections.
10. Pump model and horsepower shall be selected at the scheduled duty point. If the pump will be controlled by a variable frequency drive, provide the pump with the largest, non-overloading impeller trim for the selected horsepower rating.
11. Cooling coil condensate pumps, if used, shall include a building DDC system interface for monitoring.

6.7.17 Steam and Condensate Piping

1. All steam or condensate flanges, fittings, valves, and other equipment shall be 150 lb. rated or greater. Flanges, fittings, valves, and other equipment rated at 125 lb. are not allowed.
2. All piping, valves, and devices utilizing the campus steam shall be rated for minimum 500 °F and 1.5 times the working pressure. In buildings, all piping, valves and devices shall be rated for 400 °F and 1.5 times the working pressure.
3. Flange gaskets on high pressure steam shall be metal reinforced. Use Grade 8 bolts on all flanges.
4. Steam condensate return lines that have more than one steam trap connected to them shall be a minimum 1-1/4-inch or larger.
5. Steam and condensate piping shall not be run outside above grade or in unheated spaces.
6. High pressure steam condensate shall not be discharged into low pressure condensate lines. High pressure condensate shall be discharged to a vented flash tank with the outlet piped to a condensate return unit.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

7. Pitch all condensate a minimum of 1/4-inch per foot towards a drain point.
8. Pumped steam condensate shall not be mixed with gravity flow condensate.
9. For steam metering, see DCSM section 5.1.1 for energy efficiency guidelines.

6.7.18 Steam and Condensate Piping Specialties

6.7.18.1 Steam Traps

1. Steam pump traps are not permitted.
2. Steam traps on all HVAC equipment shall be 3/4-inch or larger, sized for the load plus a minimum safety factor of 2.0 or more depending on use.
3. All steam traps shall be gravity drained. All steam trap lines shall be sloped to the receiver; level piping or up-sloped piping is not permitted.
4. For steam traps serving drip legs on steam mains, steam traps lines may lift condensate for short runs only where the normal operating steam pressure provides enough lift. Avoid lifting condensate for long runs. When lifting condensate, provisions must be provided for start-up, otherwise gravity slope steam trap lines. End of line drip traps should be gravity flow for start-up drainage.
5. All steam traps shall be listed on a schedule by number, pipe size, load in pounds per hour, equipment served, type, max pressure, and differential pressure.
6. Use float and thermostatic-type steam traps for all modulating equipment.
7. If a single steam trap selection would result in a larger than a 2-inch inlet connection, provide two parallel steam traps in lieu of one large steam trap.
8. Do not install bypass lines on steam traps.
9. Provide isolation valves, unions, strainers, check valve, and test tee for all steam trap stations.

6.7.18.2 Flash Tanks

1. Flash tanks shall be vented to the building exterior without reducing the outlet pipe size, preferable to the roof. Flash tank vents shall not be combined with other vents operating at different pressures.
2. Do not connect flash tank vents to low pressure steam systems.
3. Do not use condensate pump receivers for flash steam.

6.7.18.3 Pressure Reducing Stations

1. Direct steam heating systems shall be designed for low pressure operation. Typically, coils and heating equipment shall be selected to operate at 5 PSIG or less steam pressure to meet required heating capacity. The system shall

be designed for operation at 10 PSIG with the relief set at 15 PSIG. These design conditions apply whether the steam source is the campus low pressure (nominal 10 PSIG) or the high pressure (nominal 80 PSIG) distribution system.

2. Steam pressure reducing valves shall be installed to reduce high pressure steam from 80 PSIG to the required utilization pressure as determined by the A/E.
3. Do not install bypass lines on steam reducing stations.

6.7.18.4 Relief Valves

1. Steam relief valves shall be piped to the roof without other equipment connections to the line.
2. Vents from steam relief valves and drip-pan elbows shall not be reduced in size and shall run full-size to the roof and discharged in a safe location.

6.7.19 Steam Condensate Pumps

1. Steam pressure-powered condensate pumps are preferred over electric pumps.
2. Steam pressure-powered pumps shall be used if it is determined that the high-pressure steam will provide enough discharge motive pressure to return condensate to power plant or pumping station. Care must be taken to ensure all condensate will gravity flow into the receiver.
3. Steam condensate pumps shall have isolation valves installed by the manufacturer on the suction side of each pump.

6.7.20 Refrigerant Systems

6.7.20.1 Refrigerants

All refrigerant types used on campus shall be approved by VT Engineering.

6.7.20.2 Refrigerant Equipment

1. For direct exchange systems (heat pipe systems), the total refrigerant charge shall be listed on the unit, including all connected refrigerant piping.
2. Installation shall be provided with necessary protective devices, including, but not limited to, electrical overload devices, low suction-pressure cutouts, oil traps, crankcase heaters, anti-cycling timers and head pressure control.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.7.20.3 Refrigerant Piping

1. Installations shall be complete with dryers, sight glasses, thermostatic expansion valves, and thermostatically controlled solenoid valves for pump-down operation (except for capillary tube units).
2. Suction lines shall be insulated. The need for defrosting is not limited to electrical units. In larger installations, hot gas defrost is required.
3. Main piping fittings for dryers, sight glasses, expansion valves and controls shall be flared joints.
4. All joints shall be brazed under a nitrogen purge.
5. Copper-to-copper joints shall be evacuated to 29.5 inches (water) gauge vacuum and held for at least 24 hours under this vacuum prior to charging the system with refrigerant.
6. Design relief piping as necessary to comply with code requirements.

6.7.21 Water Treatment

1. All heating hot water hydronic systems and standalone building chilled water systems shall include a pot feeder for adding water treatment chemicals. Coordinate with VT Engineering to determine the proper water quality requirements for new systems.
2. In individual buildings, only closed loop systems, such as secondary heating water and building generated chilled water, shall have chemical treatment.
3. Buildings with condenser water systems shall have chemical treatment.
4. Chemical treatment for fluids from central systems will be provided at the heating or chiller plant. VT Engineering maintains a water treatment contract for the campus chilled water loop. Any project that has additions or alterations to that utility shall coordinate those changes with VT Engineering.
5. The Contractor shall notify the VT PM when chemical treatment will take place and what type of chemicals are used to clean the piping systems and HVAC equipment. The Contractor shall furnish a written statement (or a form) that states who installed the chemicals, when the treatment was started, when the treatment was finished, and who removed the chemicals from the system.
6. After cleaning and chemically treating the HVAC system, the Contractor shall furnish to the VT PM in writing, the following information:
   a. Date of initial treatment
   b. Type of chemical(s) used for treatment
   c. Estimated date that further treatment or testing will be required

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.7.22 Metal Ducts

6.7.22.1 General

1. At a minimum, all ductwork shall be constructed to the SMACNA "HVAC Duct Construction Standards – Metal and Flexible" technical standard.
2. Supply, return, and general exhaust ductwork shall be G90.
3. Provide stainless steel or aluminum ductwork for systems exhausting moisture laden air.
4. For laboratory exhaust design, see DCSM section 5.18.6.1.
5. Ceiling return plenums shall not be used. All return air shall be ducted from the conditioned spaces back to air handling units.
6. Ductwork that is exposed to the weather shall be double wall, smooth inside and out, insulated, with flanged connections. Additionally, joints shall be insulated and jacketed with the same material as the exterior wall of the ductwork. The outer wall and joint insulation jacket shall be painted with weather resistant paint or be stainless steel. Thermal bridges are not allowed.
7. All supply, return, and exhaust ducts with a pressure class of 2-inch water gauge or higher shall be pressure tested and documented. Results shall be submitted to the VT PM.

6.7.22.2 Antimicrobial Coatings

1. Interior surfaces of the first 20 feet of supply air ducts downstream from an air handler shall be treated with an antimicrobial coating. UV lights can be used as a substitute for antimicrobial coating.
2. Acceptable antimicrobial treatments for interior surfaces of ductwork shall be as indicated below (proposed equals will be considered but must be specifically approved by the University):
   a. Foster 40-20
   b. Agion antimicrobial compound treatment for metal duct and equipment, blue coating; process as provided by Lindab, Inc.
   c. AVRON46 antimicrobial coating by SEMCO
3. Antimicrobial coatings shall be factory applied. Field-applied coatings are not acceptable.

6.7.22.3 Kitchen Exhaust Systems

1. Kitchen exhaust ductwork shall be tested per code and shall be internally washed down and tested for leakage prior to finishing walls or fire wrapping around the ductwork.

2. Grease duct access doors:
   a. All grease duct access doors shall be fabricated for 16-gauge or heavier steel and shall be UL approved.
   b. Access doors shall be manufactured with a high temperature gasket and shall be leakproof for water and grease.

6.7.23 Non-Metal Ducts

1. Flexible duct may be used only for short runs of 6 feet or less to air outlets.
2. Flexible duct shall be pulled tight, without any kinks, and supported with 2-inch wide banding to structure above to prevent any sagging.
3. A hard, round duct fitting shall be used in locations where the installation of flexible ductwork would result in more than two 90-degree turns.

6.7.24 Air Duct Accessories

1. Provide duct access doors for all items requiring maintenance or inspection. These items include but are not limited to: fire dampers, smoke dampers, combination/fire smoke dampers, and duct smoke detector sampling tubes.
2. Duct access doors:
   a. All duct access doors shall be fabricated from 24-gauge steel and shall meet SMACNA standards or better.
   b. Access doors shall have large cam locks or handles.
   c. Access doors sized 10 inches by 10 inches (or larger) shall have a minimum of 4 locks.
   d. Access doors sized 16 inches by 16 inches (or larger) shall have 8 locks. Unhinged access doors shall have a chain to secure the door when unlatched.
3. Provide motorized dampers for building relief air. Gravity backdraft dampers shall not be used for building relief.
4. Provide schedules of all fire dampers, smoke dampers, and combination fire/smoke dampers and access location.
5. Control dampers:
   a. Control dampers shall be opposed blade type. The basis of design for opposed blade dampers shall be Ruskin CD50 series or equal.
   b. Joints shall be tight and uniform width. Dampers shall be free of visible burrs and cuts.
   c. Supplier shall furnish construction details of all dampers.
   d. Dampers shall be aluminum construction. Damper frames shall be formed of 0.063-inch aluminum, mechanically joined. Blades shall be airfoil design of aluminum construction. Blades to have a nominal width of 6 inches with a

maximum width of 8 inches. Furnish dampers with jackshafts and locking quadrants.

e. The basis of design for damper seals shall be dampers provided with thermoplastic rubber blade seals and self-compressing stainless steel side seals. Linkage shall be 1/8-inch rolled steel, zinc plated, concealed in end channel frame. Blade pin shall be 3/8-inch square steel, zinc plated.
f. Dampers shall be capable of closing or opening against 1.5 times the static pressure of the unit

6.7.25 Fans

6.7.25.1 Axial Fans for Air Handlers

1. Fans shall be direct drive, Arrangement 4, with capacities and sizes as indicated on schedules.
2. Fan blade angle shall be manually adjustable from 0 degrees to a maximum of 32 degrees.
3. Fan blades shall be 356-T6, heat treated, high strength aluminum alloy, having a true airfoil section, and having both camber and twist. Each blade shall be sized for its diameter and shall not be cut down from longer blade sections.
4. The fan hub section shall be 356-T6, heat treated.
5. The impeller shall be placed on the inlet side of the fan, before the motor. Both motor and impeller shall be removable from the inlet side of the fan.
6. Casing shall be 3/8-inch thick hot rolled steel. Casing and end flanges shall be welded using continuous welds by ASME, Code IX, qualified welders. Certification shall be required upon request. Guide vanes shall be welded using continuous welds to a rigid motor base and the housing.
7. The fan shall be designed so that 1/3 of the housing is removable to permit motor and impeller replacement without removing ductwork. This section shall have bolting flanges welded using continuous welds along the casing.
8. Fan shall include extended copper motor grease leads or stainless steel braided. Provide pillow-block bearings with a 200,000-hour average life.
9. Fans shall include rigid walled extended electric leads to an externally mounted conduit box.
10. Horizontal mounting feet or clips or vertical mounting clips: inlet bell with safety screen, outlet cone, conventional type shall be provided, as required.
11. Fan shall be balanced to a maximum of 1 mil double amplitude, peak to peak, through the total pitch range of the fan.

12. Fan total efficiency shall not be less than 75% at design operating conditions and shall not vary more than +10% over the entire range of the design system curve.
13. After fabrication, fan shall be cleaned, primed, and coated with two coats of a synthetic polymer based, non-photo chemically reactive, industrial enamel.
14. Fans shall be manufactured by Joy, Woods, Greenheck, or approved equal.

6.7.25.2 Centrifugal HVAC Fans

1. All centrifugal fans shall be of the double width, double inlet type with backwardly inclined wheels with airfoil blades.
2. The fan wheels shall be of carbon steel, mounted on shafts having self-aligning greaseable lubricated pillow-block bearings with 200,000-hour average life.
3. The fan scroll and support system shall be of carbon steel, arrangement 3, Class II or better construction, continually welded seams.
4. The fan motor and fan assembly shall be factory mounted on a common base to allow constant belt tension with no relative motion between the fan and motor shafts. Fan and drive assembly shall be resiliently mounted, to isolate 90% of all vibration in all frequency ranges.
5. The fan units shall be balanced at the factory to not exceed 2.5 mil displacement in any axis when measured at the fan pillow block bearing. Additionally, the fans shall not pass through their first critical speed at any catalogued RPM.
6. The fan units shall have a factory-applied finish of the manufacturer's standard epoxy coating, two coats.
7. Each fan inlet shall have an inlet guard of 1-inch square stainless steel mesh.
8. Fan drives shall be fixed or adjustable. Guards shall be custom built, in accordance with OSHA Standards, and be partially and totally removable. Drives shall be fixed on all VFD controlled units.
9. Fan motors shall have TEFC enclosures.
10. Motor speed shall not exceed 1800 RPM.
11. Fans shall be manufactured by Greenheck, New York Blower, Twin City Blower, Chicago, Barry, or approved equal.

6.7.25.3 Plenum Fans Arrays

1. Direct-drive modular-plenum fans in a parallel array, using number of fans indicated on the drawings, arranged to provide equal air flow across the unit’s cross-section. The fans in each array shall be identical.

2. The fans operating in parallel shall meet the performance requirements scheduled. The fans shall be selected to have non-overloading design with self-limiting horsepower characteristics in the normal operation area.
3. Backdraft dampers: Each fan shall have a factory-mounted motor-operated low-leakage backdraft damper. Pressure losses across the dampers shall be included in the fan performance data and not considered to be included in the unit's scheduled pressure drop.
4. Airfoil wheel shall be single-width single-inlet (SWSI) construction with heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.
5. In multiple fan installations each fan shall have a VFD. Refer to DCSM section 6.7.2.
6. Direct drive fans shall be balanced to a maximum of 1 mil double amplitude, peak to peak, through the total pitch range of the fan.
7. Array support structure materials shall match interior casing material and have 6-inch minimum depth. Monorail or trolley system shall be provided to assist the removal of fan wheels and motors.

6.7.26 Air Terminal Units

1. Schedule terminal unit tag numbers to reference both floor location and air handler number it is served by. Example: Floor # – AHU# – VAV Box #.
2. All VAV boxes shall have reheat coils to maintain space temperatures.
3. For equipment insulation requirements, see DCSM section 6.7.11.2.
4. All terminal equipment (VAV) re-heat coils shall have modulating control valves.
5. Fan-powered VAV boxes in new construction and large Renovation projects are prohibited. Replacement of existing fan powered VAV boxes may be performed during maintenance or Renovation projects.

6.7.27 Diffusers, Registers, and Grilles

Size restroom grilles and diffusers according to State, Federal, and local codes for room size, air quality, etc. Provide Type 304 stainless steel or all aluminum (satin or brushed finish).

6.7.28 Fabric Air Distribution

Fabric duct shall be rigid frame supported. Color choices shall be approved by OUP.

6.7.29 Filtration

1. All air handling equipment, coils, and energy recovery devices shall be protected with filtration prior to the introduction of return or outside air.
2. Central station modular air handling units, custom air handling units, and energy recovery equipment filters shall be 90-95% efficient. This is typically achieved by using a 2-inch MERV-A 8 pleated or panel pre-filter and a 12-inch rigid box MERV-A 14 main filter. Main filter shall not be paper or less than 12-inch deep.
3. Do not use synthetic filters in locations where they are subject to exposure to UV systems.
4. Provide airtight, gasketed seals at all filter banks to eliminate by-pass air.
5. Provide 90% efficient, 2-inch MERV-A 13 filters for standard package equipment.
6. Fan coil units shall employ the highest MERV-A filter available.

6.7.30 Boilers

1. Heating boilers shall be provided when campus steam is not available and the calculated heating demand is greater than 100,00 Btu/h input or larger.
2. Propane shall only be used when natural gas is unavailable on-site.
3. Boilers shall have a minimum 5:1 turndown.
4. Provide three equally sized boilers at 50% of design load, if available.
5. High-efficiency condensing boilers shall be used whenever possible.
   a. All condensing boilers shall be provided with acid-neutralization kits.
   b. Venting for condensing boilers shall be sloped back to the water heater at a minimum of 1/8-inch per foot. If vent routing will not allow the entire vent to be sloped back to the boiler, provide an intermediate tee with pigtail drain connection and separate acid neutralization kit. The intermediate drain tee shall be installed at a point that allows the vent to be sloped back to the boiler primary vent drain.
6. When multiple boilers are in a single space, individual vents shall be used in lieu of common venting.
7. Condensing boilers shall be vented per the manufacturer's instructions using only AL249C or polypropylene venting materials as approved by the manufacturer.
   a. PVC and CPVC are not acceptable venting materials and will not be allowed, even if the manufacturer has approved them for use.
8. Sealed combustion ducting for condensing boilers shall be installed per the manufacturer's instructions using only AL249C, polypropylene, or CPVC materials as approved by the manufacturer.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

9. If using ducted fresh air for combustion, terminate the vent and intake in the same external pressure zone.
10. Concentric vent kits are not allowed.
11. All boilers shall have a means of communicating with the BAS. At a minimum, water heaters shall be able to communicate status and alarm.
12. On multiple unit installations, each boiler shall be controlled independently so that a failure of the primary controller does not interfere with the operation of the remaining boilers.
13. Provide UL-approved gas train assemblies.
14. All gas-fired appliances shall have individual gas pressure regulators per manufacturer's instructions. Gas regulators shall be vented to a safe location exterior to the building. Ventless regulators with vent limiters are not acceptable.
15. Gas piping serving boilers shall be sized per the Fuel Gas Code as well as the manufacturer's installation requirements.
    a. The gas piping system shall be designed to supply gas to the boiler at a pressure that is within the operating range of the equipment.
    b. If the boiler has a modulating gas valve, the supply gas piping shall also be designed so that the gas pressure fluctuates only within the manufacturer's specified limits when operated between low and high fire.

6.7.31 Heat Exchangers

6.7.31.1 Shell-and-Tube

1. Construction: Factory-fabricated with cast-iron flanged head bolted to steel shell; seamless copper tubes of diameter determined by manufacturer to meet service requirements; steel tube-sheets and baffles; and piping connections. Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1.
    a. Piping connections 2 inches NPS and smaller shall have threaded ends.
    b. Piping connections 2-1/2 inches and larger shall have flanged ends.
    c. Use low pressure steam on the shell side and hot water on the tube side.
2. Configuration: U-tube with removable bundle, unless otherwise noted on the drawings.
3. Support saddles: Fabricated of materials similar to the shell. Foot mount shall have provisions for anchoring support.
    a. Mounting height shall allow for proper gravity drainage of steam traps.
4. Provide vacuum breaker on all heat exchangers utilizing steam.

6.7.31.2 Gasketed Plate-and-Frame

1. Configuration: Freestanding assembly consisting of frame support, top and bottom carrying and guide bars, fixed and movable end plates, tie rods, individually removable plates, and one-piece gaskets.
2. Construction: Factory-fabricated with carbon-steel frame with anchors for supports and capacity to accommodate a minimum of 25 percent additional plates; painted carbon-steel, aluminum or stainless steel top and bottom carrying and guide bars; painted carbon-steel endplates; and stainless steel tie rods and nuts. Enclose plates in a solid aluminum or stainless steel removable shroud. Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 1.
   a. Piping connections 2 inches NPS and smaller shall have threaded ends.
   b. Piping connections 2-1/2 inches and larger shall have flanged ends.
   c. Use for liquid-to-liquid heat transfer.
3. Heat exchangers shall be selected and specified to AHRI certification.
4. Plate material: Type 304 stainless steel (0.024-inch thick before stamping).
5. Gasket materials: Glue-free EPDM rubber or other material suitable for service.

6.7.32 Packaged Rooftop Units

1. Packaged direct expansion (DX) rooftop units (RTUs) shall only be used in applications with a nominal capacity of 20 tons and less in locations where campus chilled water is not available, where a local building chiller is not feasible, and after approval by Virginia Tech. Units with a nominal capacity greater than 20 tons shall be custom design and shall follow the same general construction requirements for custom air handling units, DCSM section 6.7.39.2.
2. RTU fans shall be specified with standard motors designed to operate at mid-range speeds. Use of oversized fan motors is not allowed.
3. Avoid water coils and piping in rooftop air handling units.
4. Provide variable capacity scroll compressors with integral vibration isolators, internal overcurrent and over-temperature protection, and internal pressure relief.
5. Refrigerant condenser and reheat condenser coils shall be copper tube with mechanically bonded aluminum or copper fins. Coils shall be leak tested underwater with air and shall comply with ASHRAE 33 and AHRI 410.
6. Condenser fan assembly: Direct-drive propeller type with statically and dynamically balanced fan blades. Fan safety guards shall be steel with corrosion-resistant coating.

7. Safety controls: Compressor motor and condenser coil fan motor shall have low ambient lockout. Compressor motor shall have overcurrent protection.
8. Indirect-fired gas heaters
    a. Heat exchanger assembly: Factory-built assembly with stainless steel heat exchanger, electronically controlled electric spark ignition with flame sensor, stainless steel drain pan, and electronic modulating gas control valve. The assembly shall comply with NFPA 54 and bear the AGA approval label.
    b. Venting: Power vent with integral, motorized centrifugal fan interlocked with gas valve.
    c. Gas train: Single-body, regulated, redundant, 24 VAC gas valve assembly containing pilot solenoid valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff.
    d. Gas pressure regulator: Factory or field installed, sized by the manufacturer in coordination with the delivery pressure and the required connection pressure, and tagged and shipped with the unit.
9. Controls: Comply with DCSM section 6.7.13.

6.7.33 Water-Cooled Chillers

1. Where campus chilled water is not available, a water-cooled chiller(s) should be the basis of design.
2. Variable frequency drives and magnetic bearing machines should be considered on a life cycle basis.
3. All chillers shall be installed at a lower overall height than the cooling tower basin.

6.7.34 Cooling Towers

1. The design operating temperature for cooling towers shall be 78 °F wet bulb (WB).
2. The basis of design shall be crossflow, induced draft, open circuit cooling towers.
3. Casing and frame: Type 304 stainless steel, sealed watertight.
4. Gravity “hot water” distribution basin: Type 304 stainless steel non-pressurized design welded watertight with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated; plastic spray nozzles; and a single Class 150 flanged inlet connection with distribution piping and valves arranged to provide balanced flow within the cooling tower cell.
    a. Provide Weir dams.

5. Collection “cold water” basin: Type 304 stainless steel welded watertight with removable stainless steel strainer with anti-vortex hood and openings smaller than the nozzle orifices; overflow and drain connections; make-up water connection; Class 150 flanged outlet connection at bottom or side as indicated; removable equalization flume plate between adjacent cells of multiple cell towers; equalizer connection for field-installed equalizer piping; and PVC basin sweeper distribution piping and nozzles arranged to minimize sediment collection in the basin.
6. Collection basin water level control: Electronic water level controller in a NEMA 4 enclosure with a make-up water solenoid valve. The controls shall be solid-state with multiple stainless steel electrode probes for control of make-up water and low- and high-level alarms. The solenoid valve shall be slow-closing type with a stainless steel body that is controlled and powered through the level controller. The water stilling chamber shall be constructed of stainless steel, PVC, or fiber reinforced polyester (FRP).
7. Electric basin heater: Stainless steel electric immersion heaters installed in a threaded coupling on the side of the collection basin. Heaters shall be sized to maintain minimum 40 °F basin water temperature at -10 °F ambient temperature.
8. Fill: Factory-fabricated and installed PVC fill material conforming with ASTM E 84 with UV radiation inhibitors and suitable for water temperatures up to 120 °F in quantity and thickness required to meet performance requirements.
9. Drift eliminator: Factory-fabricated and installed PVC drift eliminator conforming to ASTM E 84 with UV radiation inhibitors in a multi-pass configuration designed and tested to reduce water carryover to 0.005% or less of the design water flow rate. The drift eliminator shall be separate and removable from the fill.
10. Air-intake louvers: Factory-fabricated and installed PVC louvers conforming to ASTM E 84 with UV radiation inhibitors and arranged to uniformly direct air into the cooling tower, to minimize air resistance and to prevent water from splashing out of the tower during all modes of operation. Louvers shall be separate and removable from the fill.
11. Propeller axial fan: Aluminum or galvanized steel hub and individually field-adjustable pitch aluminum blades that are factory installed and balanced. Fan shaft bearings shall be self-aligning ball or roller bearings with moisture-proof seals and premium moisture-resistant grease suitable for temperatures between -20 °F and 300 °F. Stack termination shall consist of wire-mesh galvanized steel screens complying with OSHA regulations.

12. Fan motor: NEMA premium efficiency, inverter-duty rated for variable torque, totally enclosed fan-cooled (TEFC) enclosure with epoxy or polyurethane finish, 1.15 service factor, and Class F insulated for cooling tower duty.
    a. Motor connection: The drive-to-motor connection shall be close-coupled to motor using a flexible coupling.
    b. Motor connection: The drive-to-motor connection shall be connected to motor located outside of the cooling tower casing by a full floating drive shaft.
    c. Gear drive: Right-angle gear-driven with 2.0 service factor based on motor nameplate horsepower, factory aligned, and complying with CTI Standard 111. Gear drive shall be capable of reduced speed down to 10% of full speed. Cast-iron housing with epoxy or polyurethane finish shall have beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds. The gear-drive shall be mounted directly to the fan hub, connected to motor so the motor shaft is in horizontal position, and able to operate both forward and in reverse. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized steel piping. Provide installation with oil-level sight glass.
        i. Bearing life L10A: 100,000 hours
        ii. Oil level switch: Oil level switch shall shut down the unit when it senses a low oil level.
13. Provide a vibration limit switch to shutdown fan and alarm BAS.
14. Maintenance personnel access components: Components shall be constructed of aluminum or stainless steel.
    a. Provide hinged access doors that operate from both sides.
    b. Provide external ladders and safety cages.
    c. Provide external platforms with handrails.
    d. Provide internal platforms with motor davits.

6.7.35 Air-Cooled Chillers

Air-cooled chillers shall be considered only for full load capacities of 100 tons or less and after approval by Virginia Tech.

6.7.36 Process Cooling Systems

1. Water-cooled condensing units using domestic, potable water on a single-pass cycle are prohibited.
2. Process cooling systems shall utilize standalone process chiller(s) and distribution piping or a plate-and-frame heat exchanger that utilizes campus

chilled water on the cold side and a standalone process cooling loop on the building side. Consider utilizing campus chilled water return for the source cooling water where process cooling loop temperatures allow.

6.7.37 Energy Recovery Equipment

1. See DCSM section 5.1 for energy efficiency design guidelines.
2. Energy recovery devices shall be protected with the same level of filtration indicated in the filter section. See DCSM section 6.7.29.
3. All lab systems shall use sensible heat-only heat recovery equipment.
4. Flat plate heat exchangers and refrigerant heat pipes are the preferred method of energy recovery.
5. Sensible, run-around type glycol heat recovery coils may be used.
6. Avoid using heat wheels for energy recovery systems.

6.7.38 Ventilation Systems

1. Ventilation: Outside air intakes shall not draw in exhaust air from adjacent systems, loading docks, parking lots, vehicular traffic areas, emergency generators, chemical storage, sewer manholes, plumbing vents, or other sources of contamination. Avoid locating inlets near the ground.
2. Overall building pressure shall be 0.03″ to 0.05″ W.C. positive in relation to the outside under occupied, unoccupied, and standby modes.
3. Transferred return air for ventilation (secondhand ventilation air) is unacceptable. Transfer ducts are not allowed.
   a. Exception: Transfer air shall be permitted when the transfer air provides make-up to toilet room exhaust fans, locker room exhaust fans, or other exhaust systems. Any transfer air to these spaces shall be Class 1 Air as defined in ASHRAE 62.1.
4. Ventilation systems shall be sized to provide necessary occupant outside air and make-up air for exhaust systems, and to provide overall building pressurization.

6.7.39 Air Handling Units

6.7.39.1 General

1. Modular air handling units can be used for interior applications only where the design airflow is 15,000 CFM or less. Units with a design airflow greater than 15,000 CFM or used in an exterior application shall be custom construction.

2. Rooftop air handlers shall be avoided whenever possible, except for special circumstances only after approval by Virginia Tech.
3. If rooftop air handlers are used, provide dunnage or framework to support the unit. Do not use roof curbs to minimize the potential of water leaks into the building. Dunnage or framework shall include steps and entry platforms for access. Duct penetrations into the buildings shall be made in a vertical wall, sealed watertight.
4. If rooftop air handlers are used, it is acceptable to use water for heating coils on a mixed air or heat recovery system, but it must be glycol treated to at least 33%. If humidifiers are used, they must have heat traced drains into the building drain that will always be above freezing not to a roof drain. Provide heat tracing for chilled water piping.
5. Air handling unit cabinets shall be sized such that chilled water coils shall have a face velocity of 450 FPM or less. The entire cooling coil section internal casing shall be stainless steel and extend for a minimum of 24 inches downstream of the coil.
6. Monorail beams: For custom units, each fan section shall include a structural I-beam monorail capable of lifting the fan motor(s) through the fan section access door on the primary service side of the unit.
7. Except in extraordinary circumstances as determined by the design A/E, air handling units which provide internal isolation for fan and motor assemblies shall not require external isolation.
8. Air handling units shall be of the horizontal draw-through (preferred) or blow-through type as shown on unit layout drawings. AHUs shall contain intake or mixing sections, air blenders, replaceable filter media, energy recovery coils as required, preheat coils, cooling coils, UV lights, re-heat coils if terminal heating is not provided, humidifiers, control dampers, access doors, and either vane axial, plenum or centrifugal fans in accordance with the equipment schedules data sheets.
9. Filters shall be the first section in 100% outside air handling units. For units with return air, the filters shall be the immediately following the mixing section.
10. The mixing box section on the air handler shall have an air blender. The air blender shall mix outside air with the return air to a resultant uniform temperature and velocity. The blender shall not allow temperature stratification under any condition or damper position. The blender shall be a static device with no moving parts, maintenance, or required adjustments. The blender shall have a known pressure drop and velocity that promotes

thorough mixing of the air streams. The blender shall have a maximum variance of 3 °F (top to bottom) downstream prior to entering the preheat coil.

11. Mixing boxes shall be the same for all air handling units. Mixing boxes shall be factory fabricated and have the same finish and insulation as the unit casing.
12. Steam is the preferred preheating media for air handling units with high outside air percentages. Hot water may be used if appropriate freeze protection is provided.
13. Steam coils used for air handling units shall have integral face and bypass. Vertical coils with modulating control valve(s) are preferred. Valves should be designed in a 1/3 – 2/3 configuration. Coils shall be selected at 5 PSIG or less. If the A/E specifies a two-position control valve, the controls contractor must install a valve capable of modulation.
14. All air handling units shall be designed and constructed so that the fan, filters, coils, humidifiers, dampers and access doors are supported from the AHU structure framework and not from the unit panels.
15. Air handlers shall have supply and return fans in AHU, not remotely mounted.
16. When humidifiers are to be used in an air handling unit, the humidifier section shall be the last in the air stream unless otherwise approved. The humidifier section may be ahead of the supply fan, but not ahead of any other coils. The entire humidifier section internal casing shall be stainless steel and extend for a minimum of 24 inches downstream of the distribution grid.
17. Refer to DCSM section 6.3 and section 6.7.13 for additional control requirements.
    a. Control sequence of operation and P&ID layout drawing to be provided to unit manufacturer for controls installation from the A/E or contractor.
    b. All control and instrument wiring shall be identified with a unique wire number.
    c. The unique wire number shall agree with the numbers indicated on the supplier's wiring diagrams.
    d. Control circuit wiring shall be permanently identified with wire markers applied within 1 inch of each terminal and splice.
18. Refer to DCSM section 6.7.42 for additional requirements regarding coils.
19. Refer to DCSM section 6.7.29 for additional requirements regarding filtration.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

a. If unit is run by the contractor during construction, the filters shall be installed and changed when the static pressure rises above 1 inch water gauge across the filter bank, unless the A/E of record gives a written statement to use a higher static pressure. If air is drawn from a different location than the unit filter bank, provide filtration equal to or exceeding the efficiency rating of the scheduled filtration for the unit

20. Refer to DCSM section 6.7.25 for additional requirements regarding fans.
    a. Provide Duro Dyne TDC/TDF model #MBX444 flexible connector, 10-inch wide by 1/16-inch thick for fan connections or equivalent.
21. Refer to DCSM section 6.7.24 for additional requirements regarding control dampers.
22. Refer to DCSM section 6.7.45 for additional requirements regarding humidifiers.
23. Factory cleaning
    a. The outside and particularly the inside of each air handling unit shall be thoroughly cleaned.
    b. Industrial grade cleaners can be used to remove construction dust. Any sheet metal mill finish, or grease can be removed with an environmentally safe and non-toxic commercial mixture of C9-C12 hydrocarbons and propanol.
    c. All proposed cleaning materials shall have contents identified and approved prior to use.
    d. Unit openings shall then be covered with sheet-metal. The unit shall be wrapped with 7-mil shrink wrap and heated to maintain unit cleanliness standards for shipping.
24. Warranty
    a. Air handling units shall be guaranteed free of defects, for a period of one year from owner acceptance and all components in the air handler are operational.
    b. All work and workmanship shall be done by highly trained professionals and their workmanship shall be guaranteed for a period of one year.
    c. The warranty of all components will be the manufacturer's standard warranties serviced by the air handling unit manufacturer. If the manufacturer will not warranty the unit from the completion date of the project, the Contractor shall provide warranty coverage for the full 12 months.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.7.39.2 Custom Air Handling Units

1. Custom air handling units shall be a factory assembled with the minimum number of modules as required for shipping and installation. Disassemble unit into modules at the factory and reassemble on site with the assistance of a factory authorized representative. All sections, service vestibules, doors, roofs, walls, and all other components shall be included in the factory assembled unit. Site build components are not allowed.
2. Casings for exterior units: Factory-fabricated and constructed self-supporting wall, roof and floor double-wall casing panels with a minimum of R-19 closed-cell injected-foam insulation within formed channel framing. The casing construction shall use phenolic resin thermal breaks, through-metal casing thermal breaks are not acceptable. Where these extrusions intersect, they will be continuously welded for strength and to form an airtight seal. All joints shall be air-tight and water-resistant sealed.
3. Casing roof for exterior units: The roof of outdoor units shall be pitched at a minimum 1/2-inch to 12-inch slope to one side of the unit.
4. Casings for interior units: Factory-fabricated and constructed self-supporting wall, roof and floor double-wall casing panels with closed-cell injected-foam insulation within formed channel framing. The casing construction shall use phenolic resin thermal breaks, through-metal casing thermal breaks are not acceptable. Where these extrusions intersect, they will be continuously welded for strength and to form an airtight seal. All joints shall be air-tight and water-resistant sealed. Casing roof to match wall construction.
5. Casing floor: Each section shall have a 2-inch tall lip at the perimeter to form a watertight pan. Walking surfaces of floor panels shall have a solid 3/16-inch thick checker-plate aluminum solid lining with watertight welded seams and reinforcements to support 300 pounds per sq. ft. live load. Floor insulation shall match casing walls. Outer skin to match exterior casing material.
6. Piping sleeves shall be provided for all pipes, instrument lines and conduit passing through the unit floor. These sleeves must be at least 2-inch tall and welded to form a watertight seal.
7. Casing performance:
   a. Leakage: Casing shall meet the AHRI 1350 casing air leakage rating CL1 with less than 3.5 cfm leakage per 100 sq. ft. at 10.0-inches water gauge positive or negative internal pressure.
   b. Deflection: Casing shall meet the AHRI 1350 casing deflection rating CD1 with less than 0.0033-inches (1/300) deflection per inch of span at

10.0 inches positive or negative internal pressure. Floor deflection shall not exceed 0.0625-inches at 10 inches internal pressure and 300 pound per sq. ft. live load.

8. Frame or base:
   a. Base shall be constructed from standard structural steel wide flange, channel, and angle sections of adequate size to prevent any deflection or sagging of unit housing, or internal components during lifting, shipping, unloading or operation. No preformed shapes or angles will be allowed in the base construction.
   b. When two or more units are stacked on top of each other, the structural integrity of the base unit(s) shall be sufficient to support the upper operating unit.
   c. Sealant shall be installed between panels at all joints, between panels and trim, and between panels and base channels to provide an airtight enclosure. Permanently flexible sealant recommended for this application by manufacturer.
   d. Access to all doors shall be provided by permanent walkway or steps.
9. Casing materials:
   a. Exterior: Aluminum, embossed, 16 gauge (0.050-inch thick) minimum with stainless steel screws.
   b. Interior: Aluminum, smooth, 18 gauge (0.040-inch thick) minimum with aluminum structure, except cooling coils and humidifier sections shall be 304 stainless steel, smooth, 20 gauge (0.038-inch thick) minimum.
   c. Casing finish: Factory-applied prime coat and thermosetting top-coat baked-on enamel.
   d. Casing sealant: All casing joints shall be sealed air-tight and water-resistant, including joints between panels and trim and panels and base channels. Sealants shall be non-sag, non-staining and permanently flexible.
   e. Casing performance: Manufacturer shall submit calculations for review to show the unit exterior will not condense moisture based on supply air temperature of 46 °F and outside ambient air temperature of 95 °F dry bulb (DB) / 78 °F wet bulb (WB).
   f. Casing fastening bolts, screws or rivets shall be 304 stainless steel.
   g. Units to be supplied with heavy duty, removable lifting lugs. Each section must have a minimum of four lifting lugs.
   h. Removable panels shall be installed and located to facilitate fan, coil, and any other major component removal. The removable panels shall be

constructed the same as an access door except that each removable panel shall be screwed in place on 6-inch centers.

10. Access doors:
    a. Access doors shall be 2-feet wide by 6-feet (minimum) high provided as walk-in access to each air handling unit section. Doors shall be wide enough to remove motors and all other replaceable unit components. Door frames shall be of welded, mitered extruded aluminum with a thermal break and welded at the corners. Door shall be made of insulated sandwich panel construction matching the unit casing.
    b. Doors shall have perimeter airtight double sealing replaceable gasket. Door sealing gaskets shall be neoprene, 3/4-inch wide by 5/16-inch thick sponge rubber.
    c. All doors shall be equipped with a 3-point latching system, which shall open from both sides of the door. The latches shall be wedge-level design with stainless steel quarter-turn handles. Doors shall be attached to the casing with a continuous stainless steel hinge. Handles shall be accessible without the use of a ladder.
    d. All doors shall be installed to open against the greater air pressure or with a second catch for the door.
    e. All doors, which leak or do not otherwise operate properly, shall be repaired or replaced at the manufacturer’s expense before being shipped.
    f. All doors shall have a 12-inch by 12-inch double pane, thermal reinforced safety glass viewing window. View panels shall be located on the accessible side of the air handler in each fan section and coil access section doors.
    g. Exterior units will have a 4-inch rain guard over each door and removable panel.
11. Design and assemble units to require only external connection of electrical power, chilled water, hot water, steam, drain piping, controls and ductwork.
    a. For motor power connections, provide a non-fused service disconnect switch on the exterior wall of the unit. Completely wire service disconnect, inside rigid metal conduit, back to motor junction box.
    b. VFD controls shall be accessible from outside of unit without opening doors of air handler.
    c. Condensate floor drain or drain pan shall be provided under the cooling coils and humidifier sections. Drains can be an integral part of the floor

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

system or outlet on side bottom of unit. Drain piping shall be extended 3 inches through the base steel and capped.
   d. Provide double-sloped floor drains at each coil section for wash down.
   e. Extend piping connections for each coil, or humidifier (if required) 3 inches through panel casing. Terminate piping full size with either a flange or a threaded connection and cap.
12. Factory install all internal electrical components, conduits, electrical conductors, junction boxes, control tubing and piping. Factory install casing penetrations, conduits, and junction boxes for field-installed control wiring and end devices. All conduits shall be rigid metal and shall be properly supported and securely attached to units.
13. Provide at least one 3/4-inch conduit, capped on both ends, between sections of the air handler for control wiring. This conduit shall be filled or plugged by the controls contractor after work is complete. Coordinate with controls contractor during manufacturing.
   a. As an option, the BAS manufacturer may provide controls equipment and wiring requirements for factory installation.
14. Test ports: Factory-fabricated test ports shall be provided at each component section for measurement and testing devices. Ports shall be 1-inch diameter with threaded cap. Ports shall be installed prior to pressure and leakage testing. Field drilled ports are not acceptable.
15. All conduits penetrating the unit casing shall be sealed airtight. After wire is pulled, conduit shall be sealed so that air cannot be transferred into or out of the unit through conduits. Seal conduit airtight at all filter racks.
16. Any sheet metal screws placed in unit casing for mounting tubing, conduit, etc., shall have a rubber washer.
17. Junction boxes or connectors should be provided at shipping split break points and electrical and pneumatic connections and shall be properly tagged for reconnection.
18. Fan sections:
   a. Bell-mouth transitions to fan intakes and outlets. Outlets should not be in the fan section near fan wheel.
   b. Fans shall include extended motor grease leads (stainless steel or stainless steel braided) and rigid-walled extended electric leads to an externally mounted conduit box.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

19. Intake hoods for external air handling units:
    a. Outside air intake hoods shall be fully welded 0.090-inch aluminum or 14-gauge 304 stainless steel. Bird screen shall be 1/2-inch X 0.051-inch aluminum hardware cloth and be contained within a removable frame.
    b. Hood design shall incorporate all structural supports to withstand a wind load of 100 mph.
    c. Louver shall be sized for the design CFM at a maximum of 850 feet per minute, face velocity based upon louver net free face area. Louver shall have less than 0.01 oz/sq. ft. of water penetration at full flow.
    d. The bottom of the intake shall be a minimum of 36 inches above the roof.
    e. The color shall match the external casing finish of the unit.
20. Electrical:
    a. Lighting and receptacles:
        i. Vapor-tight LED light fixtures, 1700 lumens minimum each, factory-installed in each fan, filter access, coil access and air mixing section. Air handling units, 12-foot and wider, shall have two equally spaced lights per section. All lights shall be factory-wired to a single switched junction box located on the casing's outside surface, adjacent to the supply air fan access door, and no higher than 48 inches above the floor of the unit. Service lights shall be factory-wired 120 volt.
        ii. Provide a GFCI receptacle under light switch at fan section door with a weatherproof self-closing cover.
        iii. Light switches and receptacles shall be approved for outdoor installation. The basis of design for light switches and receptacles shall be those rated for 20 A as manufactured by Hubbell or equivalent.
        iv. Conduit shall be 3/4-inch or larger for lights and power. All conduits shall be sealed outside and inside between air handler section to prevent air from passing from one section to another. This may need to be done after installing but should be on check list.
    b. Power: Install a non-fused disconnect switch, as required for complete and operable system.
    c. Wiring and conduits:
        i. All electrical wiring shall be installed in rigid metal conduit, minimum size of 3/4-inch. The use of flexible EMT is not permitted.
        ii. Use liquid tight flexible metal conduit at motors, transformers and any device subject to vibration and where rigid conduit is not

applicable; however, each length of flexible conduit shall not exceed 48 inches. The use of EMT is not permitted.

d. Wiring installation:
   i. All power, lighting, control, and instrumentation wiring shall be installed in rigid metal conduit.
   ii. Provide separate conduit systems for power, lighting, control, and instrumentation circuitry. Do not terminate power, lighting, control. and instrumentation circuitry on the same terminal blocks.
   iii. All conduit connections to boxes and fittings shall be supported not more than 12 inches from connection point. All conduit bends shall be supported not more than 12 inches from each change in direction.
   iv. Flexible conduit shall be used to connect conduits to motor. The maximum allowable length of flexible conduit shall be 4 feet.

21. The unit manufacturer shall provide a qualified supervisor to instruct and supervise the Contractor in the rigging, erecting, pre-operation checkout, and startup of each unit as necessary. The price for such services shall be indicated in the unit manufacturer's quote. The manufacturer's supervisor shall be a senior service technician trained in the startup of industrial HVAC systems.
22. Testing at job site:
    a. All units will be field tested by an independent TAB contractor after installation. Any deficiencies found at this time will be corrected at the cost of the unit manufacturer.
    b. Unit manufacturer shall provide a qualified service technician to be present at the job site when air handling units are tested by the TAB contractor. It is the responsibility of the unit manufacturer to see that all necessary corrections are made, and the units are performing in accordance with the specification. One day shall be provided in base bid for this work.
    c. Unit manufacturer shall provide a qualified technician to instruct the University's personnel on maintenance and operation of the air handling units for a minimum of one day after installation. If this is not done a refund for the service will be rendered.
    d. It is the responsibility of the unit manufacturer to coordinate with the VT PM to establish a schedule for the events previously described.

6.7.40 Computer Room Air Conditioning

Data centers and main distribution frame rooms shall be provided with HVAC systems that are specifically designed for these applications.

6.7.41 Ductless Mini-Split System

1. Independent distribution frame rooms and elevator machine rooms shall be conditioned with ductless mini-split systems.
2. Control thermostat shall be wall mounted and hardwired.

6.7.42 Coils

6.7.42.1 General

1. The coils shall be able to flow 15% above maximum total air flow without carryover of moisture. If carryover occurs stainless steel mist eliminators shall be installed by manufacturer. For cooling coil face velocity requirements, see DCSM section 6.7.39.1.
2. All coils shall be arranged with an 18-inch access section between adjacent coils to allow for inspection, cleaning of both coil faces, and the installation of leaving coil temperature sensors. Components shall not block access to coil section.
3. Any coil that has the possibility of collecting condensation shall have a drain pan.
4. The use of steel coils is prohibited.
5. Provide adequate freeze protection for all air handling equipment with high percentage of outside air.
    a. Provide coils that can be drained.
    b. Freezestats and other control devices shall not be used as the primary means of protection.
    c. Pumped hydronic preheat coils can be used for systems where the design mixed air temperature is above 35 °F at minimum air flow conditions.
6. Glycols and other heat transfer fluids shall only be used in limited systems such as heat recovery loops, in 100% or high percentage outside air systems for buildings that do not receive steam service, or thermal storage systems which serve only a single central station AHU. Use only after specific approval by the University.
    a. Use only propylene glycol. A 33% mixture is the preferred solution on campus. All glycol systems shall have a glycol makeup system.
7. Drain pans in air handling units shall be double layer insulated, double sloped and constructed of 16-gauge 304 stainless steel to allow for positive

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

drainage and eliminate the possibility of standing water. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

6.7.42.2 Hydronic Coils

1. Acceptable hydronic coil manufacturers:
   a. Aerofin
   b. Marlo
   c. Heatcraft
2. Tubes shall be round, seamless copper tubes, 5/8-inch O.D., arranged in counter flow pattern with respect to airflow. Bronze spring type turbulators shall be used at water velocities below 8 fps. Minimum tube thickness shall be 0.025-inch.
3. Fins shall be plate-type aluminum or copper. Fins shall be continuous across entire coil length. Maximum height for heating coils shall be up to 78-inch and up to 54 inches for cooling coils. Coils shall die-formed in multiple stages with full fin collars for maximum fin-tube contact and accurate spacing. Fins mechanically bonded to tubes. Fin spacing shall not be closer than 12 fins per inch.
4. Hydronic coils shall be factory leak tested to 315 PSIG (dry air) and rated for a minimum working pressure of 200 PSIG and minimum temperature of 325 °F. Coils are to be pressurized then completely submerged in water containing a wetting agent.
5. Headers shall be constructed from UNS 12200 seamless copper conforming to ASTM H55. Return and supply headers are located on the same side of the coil. Connections to be extended through panel wall unless coils are internally piped. Connections to be carbon steel or red brass.
6. Heating coil casings shall be continuously coated galvanized steel, stainless steel, or aluminum (as required).
   a. For end supports, and for top and bottom channels:
      i. Use a 16-gauge thickness with casings that are up to 33 inches wide.
      ii. Use a 14-gauge thickness with casings greater than 33 inches wide.
   b. Provide 16-gauge, continuously coated, galvanized steel center tube supports for casing widths greater than 48 inches.
      i. Include one center tube support for widths between 48 and 96 inches.
      ii. Include two or more center tube supports for widths over 96 inches.

7. Cooling coil casings shall be 304 stainless steel.
   a. Use a 16-gauge thickness for end supports and for top and bottom channels.
   b. Provide 16-gauge 304 stainless steel center tube supports for widths greater than 48 inches.
      i. Include one center tube support for widths between 48 and 96 inches.
      ii. Include two or more center tube supports for widths over 96 inches.

6.7.42.3 Cooling Coil Condensate

1. Cooling coil condensate drains shall be piped to sanitary drains. Condensate shall be indirectly discharged to a waste receptor with an air gap.
2. Cooling coil condensate lines shall have cleanouts which allow access of all branches of the condensate drain system.
3. All condensate drain pans shall double sloped toward the drain connection and include an overflow safety switch that will close the chilled water valve and alarm the building DDC system. The condensate drainpipe shall be stainless steel and welded into the deep end of the sloped drain pan.
4. Design shall include enough static height to achieve proper condensate trap operation and gravity drainage. Provisions to include base rails and housekeeping pads. Show an elevation on the drawings. Drain pans shall completely empty with no standing water when the AHU is in the off position and without overflow when running at full capacity.
5. Cooling coil condensate shall drain by gravity where possible. The use of cooling coil pumped condensate systems shall be minimized.
6. Cooling coil condensate lines shall be minimum 1-1/4 inches.
7. Cooling coil condensate lines shall be copper up to and including 1-1/2 inches. Condensate drain lines 2 inches and greater can us PVC.
8. Drain lines conveying cooling coil condensate from two or more units shall be a minimum 1-1/4 inches in diameter.
9. All above-ceiling units with chilled water coils shall include an auxiliary overflow pan.

6.7.42.4 Steam Coils

1. Vertical integral face and bypass steam coils shall have a tube thickness of 0.049-inch or heavier.

2. Design shall include enough static height to achieve proper steam trap operation and gravity drainage. Provisions shall be made to include base rails and housekeeping pads. Show an elevation on the drawings.
3. Fins shall be aluminum or copper plate fin type with full fin collars for accurate spacing and maximum fin-tube contact. Fin spacing shall not be closer than 10 fins per inch.
4. Headers shall have removable covers for repair of tubes at header.
5. Steam coils shall be factory leak tested to 315 PSIG (dry air) and rated for a minimum working pressure of 200 PSIG and minimum temperature of 400 °F. Coils are to be pressurized then completely submerged in water containing a wetting agent.

6.7.42.5 Refrigerant Coils

Refrigerant coils shall be factory tested to 450 PSIG (dry air) and rated for a minimum working pressure of 300 PSIG. Coils are to be pressurized then completely submerged in water containing a wetting agent.

6.7.43 Fan Coil Units

1. All terminal equipment fan coil unit (FCU) cooling and heating coils shall have modulating control valves.
2. Drain pans in fan coil units shall be double layer insulated, and double sloped to allow for positive drainage.

6.7.44 Finned-Tube Heaters

Finned-tube heaters shall have a pressure rating of at least 150 PSIG at 250 °F.

6.7.45 Steam Grid Humidifiers

1. Where space humidity is controlled, the design setpoint shall be 50% RH (+/- 5%) except for special circumstances only after approval by Virginia Tech.
2. For renovation projects with barrier wall construction, review humidification design setpoint with existing construction and perform a dew point analysis of existing walls.
3. Only direct steam injection shall be used with a minimum of 10 PSIG at the inlet of the control valve.
4. For steam humidifiers located in air handling units or in supply air ducts, the source of steam shall be the Central Campus Steam Plant where practical. Factors including the humidifier location relative to the steam lines, first cost operation and maintenance costs shall be considered in the selection of the humidifier. This requirement is for comfort humidity, not process.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

5. If source steam is site generated in a clean steam generator, the generator shall use pure water and be located within a mechanical room. Other types of humidifiers will be considered but must use a pure water and control possible bacterial growth. Untreated domestic water shall not be used. Humidifiers that have a reservoir for water that is heated and cycle for cleaning are not allowed.
6. Steam shall be piped through a separator and drained prior to injection. Dispersion tubes shall not spit water at any time during run cycle. The distribution manifold shall provide uniform distribution over its entire length and be jacketed by steam. A full-length stainless steel internal silencing screen shall be provided.
7. The separating chamber shall be of a volume and design that will discharge and remove all water droplets and all particulate matter larger than 3 microns when humidifier is operating at maximum capacity.
8. The control valve shall be capable of accepting a 0-10 volt DC signal. The metering valve shall be stainless steel, shall be integral within the body of the humidifier, and shall be jacketed by steam at supply pressure and temperature to prevent condensation. The stainless steel metering valve shall be a parabolic plug.
9. The humidifier shall be equipped with an interlocked temperature switch to prevent the humidifier from operating before startup condensate is drained.
10. Provide a two-position steam jacketing control valve to isolate the steam from the humidifier during the cooling season.
11. Provide high limit on steam humidifiers to prevent spraying liquid condensate into saturated air streams.
12. Steam humidifiers shall utilize float and thermostatic traps.

6.8 Electrical Systems

6.8.1 Common Work Results for Electrical

1. General Electrical drawings
    a. Provide a legend for all symbols and abbreviations used. Delete any symbols which are not used for the specific project.
    b. All spaces and rooms shall be labeled.
    c. New work shall be differentiated from that which exists. Include all existing equipment on the one-line/riser diagram that pertains to any new work on the one-line/riser diagram.
    d. For multi-level buildings, provide a floor plan for each level affected.
    e. Show panelboard, disconnect, starter, transformer, and equipment/appliance locations on floor plans.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   f. Light fixture schedule shall be provided on drawings. Show all lighting fixture types in the schedule. Show input watts per fixture for each fixture type.
2. Electrical Room drawings
   a. All electrical rooms or rooms containing new/renovated equipment (service entrance equipment, electrical panels, transformers, etc.) shall be drawn at a minimum of 1/4-inch scale.
   b. Show required clearances with faded dashed lines.
   c. All required door swings, and door hardware shall be noted and cross-referenced to architectural drawings if submitted as a set.
3. Electrical Details
   The following items require details to include all dimensions, materials, and location of construction to include distance above or below floor/finished grade:
   a. Duct bank
   b. Housekeeping/equipment pads
   c. Lighting switching – by tick marks, switch notation, or drawing notes. Lighting circuits are always required regardless of how the switching is indicated.
   d. Grounding detail for service entrance and individual transformers. Show grounding conductors, electrodes, and lighting protection system (where required); include sizes, materials, and associated conduits. Use of “per NEC” is not acceptable.
   e. Grounding riser diagram where generators, transfer switches, main-tie-main switchboards, or separately derived systems (aside from individual transformers) exist.
   f. Arc-flash warning labels as required by NEC 110.16. Refer to DCSM section 6.8.4.6 for requirements.
4. Electrical Calculations
   Provide the following calculations with the submittal of working drawings:
   a. COMCheck verification.
   b. Demand load for all switchboard, panelboards, and feeders to multiple loads in tabular form.
   c. Voltage drop calculations showing no more than 2% for feeders, and 2% for exterior branch circuits that feed lighting or equipment not mounted to the building.
   d. Photometrics of emergency lighting along the entire path of egress at same scale as floor plan included in working drawing submittal. NOTE: If egress paths are not indicated on the plan, it will be assumed that the lighting levels

for the entire room or area will need to meet the required illumination levels required by the VCC and IESNA.

e. All lighting and lighting calculations shall be provided in accordance with the latest edition of the IESNA Handbook, and applicable energy codes.
f. Lightning protection system calculation.
g. Provide a load analysis, calculation or evidence to show that the existing panels, gear and feeders are not overloaded.

5. Fire-Rated Assemblies
   a. All fire-rated walls shall be noted on power and lighting sheets. Fire rating shall match ratings indicated on architectural sheets.
   b. Provide a listed detail for all fire-rated penetrations.
6. Clearance Markings
   a. A 2″ wide yellow line shall be painted on all concrete floors in electrical rooms and closets indicating the electrical working space as defined by the NEC.
   b. The space dimensions shall be provided by the design professional on the contract drawings.
   c. Stencil “NO STORAGE – ELECTRICAL WORKING SPACE” in 2″ high, yellow letters centered in the space outlined area.
7. Mechanical Equipment
   a. Provide coordination between mechanical and electrical drawings for means of disconnect for all mechanical equipment. Where a means of disconnect must be provided by the electrical contractor, provide coordinated drawings specifying the location, means of support, and means of connection to the equipment. Locate disconnects as close as possible to equipment.
   b. Dashed or faded outlines shall be provided for all mechanical equipment on drawings. Provide notes as required to indicate clearances for maintenance, installation, or provisions for servicing. Coordinate with mechanical drawings.
   c. All mechanical equipment used to evacuate smoke, fumes, or provide heating in support of life safety equipment such as sprinkler pipes, shall be provided a circuit breaker locking device in the associated panelboard.
   d. Coordinate placement of lights around equipment such that working areas are illuminated.
8. 4-Wire Delta Systems
   a. No 4-wire delta systems are permitted to be used in new construction.
   b. Where 4-wire delta systems exist, they may be reused, but all elements of the system must be brought up to current standards when modified.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Modification includes disconnection, connections, and reconfiguring of any part of the system.

c. Provide labels, grounding, color coded conductors, etc., as required by the latest edition of the NEC as adopted by the State of Virginia.

9. Circuit and Equipment Designations
    a. All circuit designations shall be provided in such a manner that any drawing sheet may stand on their own for purpose of circuit designation. Circuits shall be provided with circuit numbers, conductor and conduit sizes as a minimum.
    b. All equipment designations shall be provided in such a manner that any drawing sheet may stand on its own for purpose of equipment designation.
    c. No references to index sheets shall be used for the purpose of identification of circuits or equipment.
10. One-Line Diagrams/Schedules
    a. Show fault currents at each panel, motor control center (MCC) and generator transfer switch affected by the project. Show the AIC rating of electrical equipment.
    b. Show size and type for all service and distribution equipment, transformers, panelboards, and major equipment as well as disconnect switches. For transformers, indicate kVA as well as primary and secondary voltages.
    c. Show all feeder sizes and types. Show type of conductor and raceway. Show all fuse and circuit breaker sizes, conduit and wire sizes, wireway and trough sizes.
    d. Show all grounding electrodes and their types. Size all grounding electrode conductors and equipment grounding conductors.
    e. Provide switchboard and panelboard schedules with fuse and breaker sizes, wire sizes, load in kVA, voltage, phase, size in amps, and AIC rating. Indicate if panel is MLO or MB.
    f. Disconnects-Show size and type as well as AIC rating.
    g. Show separation of emergency wiring and equipment from all other wiring. Label emergency branch, standby branch and normal branch.
11. Floor Boxes
    a. The installation of floor boxes shall be avoided where possible. If a floor box seems necessary, the A/E shall first consider if a poke-thru can be used in that location instead. If floor boxes must be used, then the floor boxes shall meet the following requirements:
        i. Only one type of floor box shall be used for all floor types in a building.
        ii. Floor boxes shall have replaceable covers.

iii. Floor boxes shall have knockouts from 3/4" to 2".
iv. Floor boxes covers shall open 180 degrees (covers shall lie flat on the floor when open).
v. Floor boxes shall use standard size faceplates and shall not require special parts.
vi. Modules in the floor box shall be replaceable from the top.

b. When floor boxes are used for a project, 10% excess of each type of floor box, cover, and faceplate shall be provided. Coordinate with the VT PM for storage of the floor box spare parts.

12. Points of Contact: All pertinent points of contact for construction efforts shall be documented in the drawings to include university representatives, construction managers, utilities, fire alarm, and communications contractors where known.
13. Dig Notice: Where digging is required as part of the construction effort, include "Contact Virginia 811 at 811, 1-800-552-7001, or http://www.va811.com no less than 72 hours prior to excavation and do not disturb the soil until dig ticket has been processed." on the working drawings.
14. Specifications: Provide complete specifications for electrical work.
15. Electrical Building Design
    a. Electrical closets and distribution shall be centrally located throughout the building.
    b. Access doors to crawl spaces shall be located as close as possible to electrical equipment under floor.
    c. Provide separate electrical and telecommunications closets. Housekeeping closets shall not be used to house electrical or telecommunications equipment.
    d. Provide Ethernet connection in all main electrical rooms.
    e. Each electrical room shall have 50% usable spare wall space for future growth.
    f. Provide one duplex receptacle for each floor level stair landing.
    g. USB recharging ports shall be added to lounges, student areas, and study areas.
    h. Corridor wall receptacles (primarily used for floor cleaning equipment) shall be circuited separate from interior office/classroom receptacles.
    i. Electrical wiring system shall be designed and installed with as much flexibility as practical and reasonable.
    j. MC cabling is not permitted.

k. In demolition associated with renovations, all wire shall be removed back to the panel board or source of power and all accessible conduit shall be removed.
l. In atriums or other multi-story open-to-roof areas, accessibility and maintenance shall be a consideration when mounting lights.
m. All spaces with mechanical equipment, including interstitial spaces shall maintain an evacuation route, clearly marked for egress.
n. See DCSM section 5.1 for energy efficiency guidelines.

6.8.2 Low Voltage

6.8.2.1 Operation and Maintenance of Low Voltage Electrical Distribution

The Contractor shall submit warranties and guarantees in one commercial quality, hardback binder sized to accommodate 8.5″ by 11″ pages, with a table of contents and two copies of each warranty or guarantee. Marked tabs shall separate warranties and guarantees in sections following the order of the specifications.

6.8.2.2 Low Voltage Electrical Power Conductors and Cables

1. For new construction or renovation projects, the use of MC cable is not permitted. Use of AC cable is not permitted. Use of BX cable is not permitted. Use of MI cable is not permitted. Flexible metal conduit (FMC) may be used per DCSM section 6.8.4.3.
2. Use of NM cable is not permitted except for R-5, individual dwelling unit.
3. All conductors shall be copper, 600 V, THHN/THWN with moisture resistant insulation.
    a. All power conductors shall be AWG #12 or larger.
    b. Minimum control wire shall be AWG #14 and minimum signal wire size no smaller than AWG #18.
    c. All AWG #12 and smaller wire shall be solid conductors and AWG #10 and larger wire shall be stranded.
    d. Exceptions can be made for UL factory-supplied cables.
4. All single conductor wire shall be in conduit.
5. Neutrals shall not be undersized.
6. No shared neutrals allowed.
7. Under-carpet electrical power systems are not allowed for capital projects or new construction.

8. Identification: Building system wiring shall be color coded as indicated in the following table of color codes by voltage.

Table 6-7. Color Code for Building System Wiring

208 V		
Neutral	-	White
Phase A	-	Black
Phase B	-	Red
Phase C	-	Blue
Ground	-	Green

480 V		
Neutral	-	Gray
Phase A	-	Yellow
Phase B	-	Brown
Phase C	-	Orange
Ground	-	Green

9. Busway:
   a. Include the following paragraph in specifications for busway systems: "The busway shall not be energized until the A/E has received and reviewed a letter from the Contractor and a Commonwealth of Virginia Licensed Professional Engineer provided by the Contractor, certifying that the installation was inspected and it was determined that the entire bus duct system has been properly installed in accordance with the bid documents, including approved shop drawings and/or manufacturer's instructions for this project."
   b. The certification of this work shall include the torqued pressure used to tighten bolts at all spliced joints in the busway system.

6.8.2.3 Low Voltage Distribution Transformers

1. Building supply transformers shall have copper windings. Transformers supplying individual equipment may be copper or aluminum.
2. Transformers supplying non-linear loads (computers, copiers, printers, etc.) shall be K-factor rated.
3. Transformers shall not be stacked.
4. The maximum size of a wall mounted transformer shall be 15 kVA.
5. Where it is necessary to mount a transformer above the floor, double doors to the space shall be provided.
6. Floor mounted transformers shall be installed on 4″ housekeeping pad.
7. Consider location of IT equipment when locating transformers.

6.8.2.4 Low Voltage Circuit Protective Devices

Provide disconnect switches, other than circuit breakers, to elevator main disconnect. Provide disconnect and shunt trip in the elevator mechanical room.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.8.3 Service and Distribution

6.8.3.1 Medium Voltage Electrical Distribution

Voltages greater than 600 volts shall be used for utility distribution only per NEC Article 328.

6.8.3.2 Switchboards and Panelboards

1. A laminated one-line diagram of normal and generator electrical system shall be posted in the main electrical room or in vicinity of distribution panel or switchboard.
2. Do not locate panelboards in housekeeping closets.
3. Panelboards shall be surface mount in rooms with hard ceilings.
4. Switchboards, switchgear and panelboards shall be provided complete with all mounting hardware for mounting any size breaker that the panel will accept.
5. For distribution and switchboards, breakers shall be plug-in type. Panelboards shall be bolt-on type.
6. Provide a minimum of one 60-amp, 30-pole 120/208 V, 3-phase panelboard per NI&S closet.
7. Provide a minimum of one 100-amp, 30-pole 120/208 V, 3-phase panelboard per laboratory closet.
8. Provide 40% spare breaker space in each new main distribution panel, main switchboard, and main switchgear for all new buildings. Provide 20% spare circuit breakers in each new panelboard. This also applies to new panels in existing buildings.
9. Panels and switchboards which utilize obsolete styles of breakers shall not be used to feed new equipment. Obsolete breakers include breakers no longer manufactured by the original equipment company or the original equipment company is no longer in business. VTES has first right of refusal for old breakers.
10. For new construction:
    a. Half-size breakers are not allowed.
    b. Tandem breakers are not allowed.
11. All panelboard indices shall identify all equipment served by each circuit (e.g., Rcpt – Rooms 111, 112, 115).
12. All spaces shall be fully bussed.
13. All busses shall be copper.

14. Wiring in gutter space shall be performed in a neat and workmanlike manner. Bends shall be made at 90 degrees whenever possible.
15. Panels shall only serve loads for the floor/level on which they are installed. Exceptions may be made for mezzanines, penthouses, rooftop units, etc.
16. For flush mounted panels, provide a 1″ empty conduit for every four spaces/spares. Extend to above ceiling. If panel is located on an upper floor, extend half of spare conduits above ceiling, half of spare conduits below floor into accessible space.
17. Exterior mounted panelboards, automatic transfer switches and switchboards shall be in fiberglass or stainless steel enclosures or have a roof over them. Architectural features should be considered when determining enclosure type.
18. When mounting exterior panelboards on channel, the channel shall be aluminum or stainless steel.
19. Series rating is not allowed.
20. Load centers will not be permitted.
21. Feed-through or sub feed-through are not allowed, with the exception of side-by-side panels.

6.8.3.3 Motor Control Centers

Use motor control centers when the total installed cost of the motor control center (MCC) will be less than individual starters, typically when there are more than three 480 V motor loads that require controllers. Avoid using MCCs for distribution switchgear when switchboards and panelboards are more economical. Locate MCCs in room containing motors served.

6.8.3.4 Wiring Devices

1. All wiring devices shall be industrial heavy duty specification grade, rated a minimum 20 A, 125 V.
2. Switches shall be rated a minimum of 125 V / 277 V.
3. Use side-wired devices; back-stabbing is not permitted.
4. Label all receptacles and switches with panel and circuit number.
5. Mounting Heights: note mounting heights on drawings. Devices include but are not limited to: heights for light switches, receptacles, plugmold, indicator lights, and card readers. (Note: all dimensions are from finished floor. Dimensions may be adjusted with architectural requirements as long as no code restriction is violated). Comply with the latest edition of ADA Standards for Accessible Design.

6.8.3.5 Fuses

Provide 10% spare fuses for each type used of 60 A or larger, minimum quantity of two. Coordinate delivery and storage location with VT PM and VTES.

6.8.3.6 Enclosed Switches and Circuit Breakers

Switches and disconnects (not to include wiring devices) shall be quick make, quick break type with lockout capability.

6.8.3.7 Variable Frequency Motor Controllers

1. See DCSM section 6.7.2 for common motor requirements for HVAC equipment.
2. See DCSM section 6.3 for BAS design standards.
3. All motor variable frequency controls shall meet IEEE recommended practices and requirements for harmonic control in electrical power systems. See IEEE Standard 519.
4. VFDs shall be pulse type (12 pulse where needed).
5. Maximum speed for motors on VFD shall be 60 Hz. Maximum speed for motors to not exceed its nameplate.
6. Avoid installing disconnect switch between VFDs and motors unless required by code. If required, provide auxiliary contacts to disable VFD.
7. VFDs installed more than 100 feet from their motor shall be provided with a harmonic filter. VFDs installed more than 125 feet from their motor shall use drive cables in addition to a harmonic filter.
8. The basis of design manufacturers shall be Square D and ABB.
9. All VFDs shall be provided with a manual type constant speed bypass circuit. The bypass circuit shall be provided in the drive enclosure.
10. Provide isolation transformers in a separate enclosure.
11. VFDs shall be provided with an input line reactor. Total impedance at the input terminals shall be no less than 5%.
12. Electrical output for VFDs shall not exceed 10% total harmonic distortion (THD).
13. VFD power supplies shall not be used for any external use. If 24 VDC is needed, an external power supply shall be added.
14. All VFDs shall have BACnet communications protocol available.
15. VFDs shall be clearly labeled with panel, circuit, and equipment designations.
16. All VFDs shall have an efficiency rating of 98% or higher at full load.
17. All VFDs shall be started-up and programmed by a factory certified technician for that manufacturer.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

18. Complete the VFD prestart-up checklist and provide to technician prior to factory start-up. See the VT Design Standard Forms Library for the Variable Frequency Drive Start-Up Checklist.

6.8.4 Building Electrical Systems

6.8.4.1 Grounding and Bonding for Electrical Systems

Along with every feeder and branch circuit, install a 600 V insulated copper wire as an equipment grounding conductor. Bond to every metal outlet box with a device, to all utilization equipment and land on the ground bar in the originating panel. Wire insulation shall be green or identified as required by applicable code.

6.8.4.2 Hangers and Supports for Electrical Systems

1. Utilize steel slotted channel where applicable for support system. For interior applications, use galvanized steel channel. For exterior systems or wet/damp rooms, utilize aluminum or stainless steel.
2. Utilize steel or iron hangers, clamps, etc.
3. Minimum hangar rod size for raceway supports is 1/4-inch.

6.8.4.3 Raceway and Boxes for Electrical Systems

1. Flexible metal conduit shall be used only for connections to lighting fixtures, vibrating equipment, where flexibility is required or where crossing an inaccessible ceiling, wall or chase. Whips to lighting fixtures may be 1/2-inch, maximum 6-foot length (whips shall be as short as practical, but no longer than 6 feet).
2. Provide liquid-tight flexible metal conduit in wet or damp locations. All other conduit systems shall be 3/4-inch minimum. Single-receptacle drops in existing walls may use 1/2-inch flex.
3. Conduit shall be utilized as follows at a minimum:
    a. Rigid galvanized conduit (RGC) where subject to damage or in exposed exterior locations. Utilize threaded fittings. Install as to be watertight.
    b. Rigid nonmetallic conduit (RNC) PVC schedule 40 below grade. Transition to RGC starting at the elbow before conduit emerges from below grade.
    c. Liquid tight flexible metallic conduit (LFMC), for equipment connections.
    d. Electrical metallic tubing (EMT) otherwise or where indicated.
4. All empty conduit shall have a 65-pound test polymer (or equivalent) pull string tied off at both ends.

5. For weather proof receptacle boxes, use metal in-use covers. Plastic covers are not acceptable.
6. Device cover plates shall be either stainless steel, nylon or unbreakable thermoplastic. For renovation work, match existing cover plate material and color.
7. No back-to-back boxes unless the spaces are separated by a low wall or framed opening.
8. Paint all conduit in wet locations, conduit in damp locations, and exposed conduit, boxes and supports except in electrical rooms, mechanical rooms and janitors closets.
9. Paint all exposed exterior conduit and boxes with two coats of paint unless fiberglass, aluminum or stainless steel.
10. For renovation projects, surface raceways shall be provided in finished areas only where raceway cannot be concealed. Surface raceway shall transition to EMT above finished ceiling.
11. All piping and conduit shall be run parallel and perpendicular to building structure (walls, ceiling, floors) and existing conduit.
12. Fire alarm conduit systems shall comply with DCSM section 3.10.7.
    a. All junction box covers in the fire alarm conduit system shall be painted red.
    b. A change in the location of any device or panel must be approved by the UBO as well as the engineer whose stamp appears on the fire alarm design drawings.

6.8.4.4 Underfloor Raceways

The use of underfloor raceways for electrical systems is not allowed.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.8.4.5 Identification for Electrical Systems

1. Panelboard designations:

Table 6-8. Panelboard Designations for Electrical Systems

Panel Type, Voltage, or Locator	Identifier Code
Mains	
Main Distribution Panel	MDP
Main Switchboard	MSB
Main Switchgear	MSG
Other Distribution and Branch Panels	
Emergency	E (if applicable)
Distribution Panel	DP (if applicable)
Voltage	LV or HV
Floor	B, 1, 2, etc.
Panel Identifier	A-Z
Sub-Panel Identifier	1, 2, 3, etc.

2. Examples of panelboard labelling:
   a. The third of three 480 V, emergency panels on the fourth floor would be designated EHV4C.
   b. The first panel for a 208 V panel on the first floor would be designated LV1A. This panel's first subpanel would be designated LV1A1.
   c. The first 208 V emergency distribution panel located in the basement would be designated as EDPLVB1.
3. For existing facilities, existing panelboard labeling plan shall be maintained and extended for all new panels.
4. Label all receptacles and utilization equipment with panel and circuit number.
5. Label all junction boxes with panel and circuit number.

6.8.4.6 Overcurrent Protective Device Coordination and Arc-Flash Studies

1. Final electrical installation shall include all arc flash labeling as required by NFPA 70E. Labels shall be on outside of equipment, not inside panel covers.
2. For new construction and capital projects, all calculations for labeling provided shall be submitted to the VT PM at project turnover. Provide labels listing limits of approach, incident energy, arc flash boundary, etc.
3. For renovation projects, match style of labels on the panel(s) feeding the new panel(s).

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.8.5 Power Generation

6.8.5.1 Facility Electrical Power Generating and Storing Equipment

1. Emergency Systems (NEC 700): All equipment, conductors, and conduits associated with emergency systems shall be clearly identified with drawing notation and physical labels. Emergency systems will be kept separate from all other systems as described in the NEC.
2. Legally Required Standby Systems (NEC 701): All equipment, conductors, and conduits associated with legally required standby systems shall be clearly identified with drawing notation and physical labels. Optional standby systems shall not share conduit and enclosures with other systems.
3. Optional Standby Systems (NEC 702): All equipment, conductors, and conduits associated with optional standby systems shall be clearly identified with drawing notation and physical labels. Label conduit at 10′ on center and at junction boxes.

6.8.5.2 Photovoltaic Collectors

1. Provide lightning protection on rooftop installation per DCSM section 6.8.6.
2. Consider direction of roof drainage when using ballasted systems.

6.8.5.3 Engine Generators

1. Generators shall be required for all new buildings that:
   a. Are 20,000 square feet or larger
   b. Have a maximum occupancy of 200 or more people
   c. Any building with sensitive or life-safety related equipment such as a research lab or a wood/metal shop
2. Generators rated 500 kW or less shall be natural gas. Generators rated above 500 kW shall be diesel. Fuel tanks shall not be located underground.
3. Specify a minimum 125 degree rise on the alternator.
4. Specify that engines will meet new source performance standards required by 40 CFR 60.
5. The A/E should note in specifications that the elevation of Blacksburg, Virginia, is 2,132 feet.
6. Provide generator with low coolant shutdown.
7. Generator manufacturer shall have a factory authorized full service facility located within 100 miles of generator installed location.
8. All access doors for generator enclosure shall be accessible without the use of a ladder; or, provide a catwalk.

9. Use the following noise control systems as appropriate to limit generator airborne noise to a maximum of 70 dB(A) measured at ground level exterior locations 50 feet in any direction from the center of the genset.
10. Roof mounted generators are prohibited.
11. All generators shall be exterior to buildings and come with weatherproof sound attenuated enclosures. Provide visual screening as approved by the VT University Architect.
12. The maximum speed of the engine shall not exceed 1800 rpm.
13. Diesel generators shall come with double wall fuel tanks, with a leak detection system.
14. Provide a remote annunciator at a location in the facility that is readily observable.
15. Multiple unit generator systems are not allowed.
16. The basis of design generator manufacturer shall be Caterpillar.

6.8.5.4 Transfer Switches

1. Transfer switch shall contain bypass isolation switch.
2. Transfer switch shall be open transition type.
3. Switch shall confirm phase synchronization prior to the transition.
4. Where the generator system is a “separately derived system” use 4-pole transfer equipment for three phase, 4-wire systems.

6.8.6 Lightning Protection

1. Lightning protection system requirements:
   a. The most recently adopted edition of NFPA 780 shall be used to evaluate lightning protection systems, and to determine if a system is required. For new facilities, roof replacements, and solar array installations the A/E shall evaluate the building to determine if a lightning protection system is required. A lightning protection system is not required where either:
      i. Ten times the Annual Threat of Occurrence (10 × Nd) is less than the Tolerable Lightning Frequency (NC), as calculated in the Simplified Risk Assessment (L.5) or
      ii. The Total Risk (R) is less than the maximum Tolerable Risk (RT), as calculated in the Detailed Risk Assessment, for each type of loss relevant to the structure (L.6).
   b. Provide a note on the project cover sheet or electrical cover sheet specifying the risk factors and specify if a lightning protection system is required. Risk evaluation documentation shall be included in calculations.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

2. Photovoltaic array installations shall be provided a minimum of a lightning arrestor either at the array or at the output of the inverter to protect downstream equipment regardless of the risk factor.
3. Lightning protection system labeling and certification:
    a. Initial certification or re-certification by inspection is required for all lightning protection systems which are installed or modified as part of a construction project. The inspection shall be performed by either:
        i. UL under the most recent edition of UL 96A: Standard for Installation Requirements for Lightning Protection Systems or
        ii. A Lightning Protection Institute certified inspector under the appropriate Lightning Protection Institute master certificate inspection.
    b. The inspection shall certify the final installation to obtain a master label for all elements to include the facility and services entering the facility.
    c. The installation Contractor shall provide a third party master label inspection to the VT PM prior to project close out. Should the Contractor not be able to obtain a complete master label, the VT PM shall provide the remaining certification at the Contractor's expense prior to issuance of a final Certificate of Use and Occupancy or Building Permit Close Out. These are typically part of UL 96A, Chapter 13. Planning and coordination of inspections shall be conducted during the design phase, and shall be coordinated with the VT PM.
4. Conceal all downleads including those at grade level.
5. Aluminum components may be used above grade. Copper components must be used below grade.

6.9 Electronic Monitoring and Controls

6.9.1 Electrical Power Monitoring

See DCSM section 5.1 for energy efficiency guidelines.

6.9.2 Lighting Control Devices

1. Wall mounted occupancy sensors shall be included in small rooms such as individual restrooms, one person offices, and small storage rooms like closets, supply rooms or recycling rooms, and areas of rescue assistance when possible. Dual technology ceiling mounted occupancy sensors shall be provided in conference rooms, corridors, and classrooms. Wall switches shall also be provided in conference rooms and classrooms such that lights may be controlled by switches when space is occupied.

2. Coordinate the location of wall mounted occupancy sensors with interior design so furnishings do not block sensors.
3. Exceptions to the above requirements are spaces where lighting is intended for 24-hour operation and spaces where an automatic shutoff would endanger the safety or security of the room or building occupant.
4. Adjust time-out settings for occupancy sensors to optimize energy saving, re-lamping cost, and user satisfaction. Manufacturer settings will vary; utilize the following settings or the closest option provided by the sensor:
   a. Classrooms, private offices, and restrooms: a time-out setting range of 10 to 15 minutes.
   b. Laboratories, shops and other hazardous areas: 2-hour time-out setting.
   c. Break rooms, storage rooms, copy machine rooms: 5-minute time-out setting.
   d. Conference rooms: a time-out setting range of 10 to 15 minutes.
   e. Corridors, lobbies: 5-minute time-out setting.
5. Dual level control
   a. Use dual-level light switching or dimmer control in areas 100 square feet and larger.
   b. Coordinate manual controls with automatic controls so that the manual control can reduce connected lighting load by at least 50 percent in a reasonably uniform illumination pattern.
6. The use of un-switched “night lighting” luminaires shall be as follows:
   a. In corridors, design luminaires at the entrance/exit to the corridor and at major corridor intersections. These luminaires may be part of the emergency lighting system. Residence hall corridors shall be un-switched and always on.
   b. In classrooms, do not locate luminaires near projection screens.
   c. See DCSM section 6.5.7 for use in elevator lobbies.
7. In spaces with more than one personnel entrance, design the lighting controls so all required manual control will be available at each entrance.
8. The basis of design manufacturer for university dimmers and lighting controls shall be Lutron.
9. For buildings greater than 5,000 square feet, provide means of automatic lighting shutoff for each area.
10. Provide time switches with astronomic time, automatic daylight savings time changeover, and battery backup.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

6.9.2.1 Means of Egress Illumination

Restrooms serving more than one occupant and all occupied rooms and spaces 300 square feet and larger shall be provided with normal power means of egress illumination in accordance with the VUSBC.

The means of egress shall be either a fixed means of egress path or the entire floor area of the room or space.

The room or space shall meet minimum normal power illumination levels at all times the space is occupied even with all light controls turned “OFF.” This shall not preclude the use of occupancy sensors to determine if the room or space is occupied.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 7 – CONSTRUCTION ACTIVITY

7.1 Pre-construction Meeting Requirements

The purpose of the pre-construction meeting is to clarify and discuss specifics related to the construction project. Participants in the project shall be clearly identified by their department or organization and their chain of authority.

Pre-construction meeting attendees and departmental discussion items may include the following:

1. UBO
   a. Required testing and inspections for the project (varies depending upon complexity and type of project)
   b. Procedures for requesting inspections
   c. Recommendations for avoiding issues that can slow construction progress
   d. Procedures for plan changes during construction
2. SID
   a. ESC requirements
   b. SWM requirements
   c. Stormwater record report requirements
   d. Inspections
   e. Responsible Land Disturber information
   f. Project and permit termination
3. OUP
   a. Mock-up inspection items (see DCSM section 1.7.1)
   b. Provide submittal log (see DCSM section 1.5). OUP to identify submittals that require review and comment.
   c. Protocol for historic restoration, salvage, and refurbished (where applicable)
4. CC
   a. Pay application procedure
   b. Schedule submission
   c. Capital Construction coordination meeting requirements
   d. Emergency contacts
   e. Procedures for shop drawings, and product and sample submittals
   f. Digital submittal process (RFI, ASI, ESI, etc.)
   g. Change order process
   h. Site access procedures
   i. Job site cleanliness
   j. Construction Field Representative roles and responsibilities

k. Third party inspectors
l. Shut down procedures (utility, road, sidewalk, etc.)
m. Acceptable campus procedures for personnel etiquette
n. Parking/eating requirements
o. Weather delays
p. Project close-out requirements and procedures

5. EHS
    a. Safety requirements for Contractors and subcontractors
    b. Site access requirements
    c. Program specific safety coordination
6. VTES/Utilities Distribution
    a. Requirements for A/E review of utility shop drawings
    b. Location and avoidance of buried utilities (see DCSM section 7.10)
    c. Department contact if any unmarked utilities are encountered or if any utilities are damaged during construction
    d. Coordination of utility shutdowns (see DCSM section 7.10)
    e. Verification that safety training requirements have been met
    f. Process for escorting construction personnel in substation areas and steam tunnels (see DCSM section 7.10)
    g. Safety training requirements
7. NI&S
    a. Periodic Field Observations requirement and stages of construction
    b. Safety standards and expectations from the Contractor for NI&S staff to be onsite

Coordinate project-specific pre-construction meeting attendee requirements with the VT PM.

7.2 Pre-installation Meeting/Inspection Requirements

1. Stormwater BMP pre-installation
2. Hokie Stone installation (see Appendix G: Hokie Stone Masonry Guide Specifications)
3. Landscape and hardscape installation (see DCSM section 4.2)
4. VTES/Utilities distribution
    a. Central utility connection inspections, in addition to the UBO inspections
    b. Cable splices or cable terminations at transformers

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

7.3 Progress Meetings

Meetings shall be held on a monthly basis (at a minimum) or as the project requires. The following items shall be addressed as part of the meeting:

1. Status of project drawings/specifications
2. Schedule status
3. Outstanding issues related to key building components or systems
4. Any changes in site limitations or work rules related to the project
5. Project budget status
6. Project savings opportunities

7.4 Contractor Responsibilities for Commissioning

1. VT will procure the Commissioning Agent on projects where commissioning services are required or deemed beneficial to the project. In a case where the Contractor is required to hire the Commissioning Agent, prior approval of the Commissioning Agent provider to be hired, as well as, associated project documentation is required by VT.
2. Contractors and subcontractors shall provide support to the Commissioning Agent in the form of cooperation, labor, materials, supplies, and assistance as required to facilitate the specified scope of the commissioning work. This includes support needed during the Commissioning Agent's testing, re-testing, inspections, and reports.
3. The Contractor shall provide all specified assistance for commissioning in a timely manner, at no extra cost to the University, and shall incorporate all commissioning activities and milestones into the overall Project Construction Schedule.
4. For fire damper installations, the fire damper installation contractor shall perform a full inspection prior to the commissioning of the fire dampers and another full inspection at or just prior to the 1-year anniversary of the fire damper commissioning.
5. For energy metering, the Contractor shall coordinate with the Commissioning Agent and shall be responsible for proper installation and operation of the meter and for enabling energy consumption calculations during construction before the service is engaged, unless instructed otherwise. See DCSM section 5.1 for energy efficient design.
6. Provide bound, indexed O&M manuals. Manuals shall be organized by systems and fully indexed by equipment type and must contain the original manufacturer's bulletins and manuals. Copies of manufacturer documents are not acceptable.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

7. University Training
    a. The Contractor shall provide the assistance, materials, and services required to conduct training in the operation and maintenance of all major equipment and controls.
    b. The Contractor shall cooperate with the Commissioning Agent in developing the training agenda and methods.
    c. A minimum of two weeks advance notice prior to the start date of any scheduled training event shall be provided to the departments receiving training.
8. Satisfactory completion and acceptance of all commissioning tests and reports shall be a condition for granting Final Completion of the project. All functional performance testing shall be completed in order to grant Substantial Completion of the project. See DCSM sections 1.8 and 6.2 for commissioning requirements.

7.5 Construction Safety

Contractors shall follow Federal, Commonwealth of Virginia, and VT construction safety requirements and shall bear all responsibility for employees under their control. Contractors shall provide appropriate safety training to employees and/or affirm that employees have received and understand the safety training required for the specific jobsite.

VT construction safety requirements are specified in Virginia Tech's Safety Requirements for Contractors and Subcontractors Program which is located on the EHS Contractor Safety Program website as the Contractor Safety Guide.

7.6 Construction Waste Management and Disposal

1. General: Responsible, thoughtful design can greatly reduce the amount of construction waste through the use of standard sizes for construction materials, minimization of applied finishes, and careful considerations for manufacturing methods.
2. Sustainable Considerations: The University's goal is to keep construction waste out of the landfill to the maximum extent practicable by emphasizing reuse and recycling. The diversion of waste materials shall be accomplished through salvage, reuse, and recycling as defined in the project specifications with diversion goals set in keeping with the USGBC's LEED standards and the VT CAC. Certain items may be taken to surplus to be sold by VT. Coordinate specific project requirements with the VT PM.
3. Materials to be considered for collection and waste diversion shall include:
    a. Land-clearing debris
    b. Clean or pallet wood

   c. Plywood, OSB, or particle board
   d. Concrete
   e. Hokie Stone waste (see Appendix G: Hokie Stone Masonry Guide Specifications)
   f. CMU or brick
   g. Unpainted gypsum drywall
   h. Metals (copper, aluminum, steel, etc.)
   i. Paint
   j. Carpet
   k. Acoustical ceiling tile
   l. Cardboard
   m. Mixed paper
   n. Commingled materials (plastic bottles, glass bottles, aluminum cans, etc.)
   o. Plastic containers (#1 through #7)
   p. Glass
4. Collection Containers: Contractors are responsible for providing and servicing containers for construction waste collection by the Montgomery Regional Solid Waste Authority (MRSWA). Virginia Tech is a jurisdictional member of MRSWA, and cardboard, mixed paper, commingled materials, plastic containers, glass, and metal can be recycled at their materials recovery facility. Contractors shall work with MRSWA for the disposition of construction materials they can receive, and they must make arrangements for the disposition of the remainder.
5. Reporting: Per the VT CAC, General Contractors shall maintain a record of all construction material recycled and placed in the local landfill, and provide data to the VT PM for inclusion in the Calendar Year Recycling Rate Report for Virginia Tech. This data is subsequently provided to the MRSWA for inclusion in the regional recycling rate report to the DEQ.
6. Hazardous waste, fluorescent bulbs and ballasts, and similar waste streams from renovation projects shall be handled as outlined in Virginia Tech's Safety Requirements for Contractors and Subcontractors Program. When practicable, it is recommended that TCLP testing be performed during the planning for the project so that hazardous waste determinations can be made in advance and incorporated into the design.

7.7 Construction Site Fencing

1. General
   a. Prior to initiating any on-site construction activities, the General Contractor shall erect a temporary construction fence as indicated in the contract documents. Prior to the start of installation, the contractor shall meet with the U

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

niversity and the A/E to discuss timing, work conditions, and pedestrian routing considering egress for neighboring buildings.

   b. If the fenced area contains fire hydrants, coordinate with the local fire department.
   c. The contractor shall contact Virginia 811 at 811, 1-800-552-7001, or http://www.va811.com before driving any posts for the fencing.
   d. Project signage shall be coordinated and approved by OUP prior to being posted on construction site fencing. Signage not requiring prior approval on construction site fencing includes:
      i. "No Trespassing" signs installed at 50-foot intervals
      ii. Safety related signs required by OSHA
      iii. Permit related documents as required by the DEQ, SID, and UBO
      iv. Visitor site entry rules as required by the contractor
   e. The contractor shall keep plant growth from around the base of the fence by either trimming or chemical treatment.
   f. Fence shall be maintained for the duration of the project and shall not be removed without the University's permission.
2. Fence design and materials
   a. The minimum height for all temporary fencing shall be 6 feet.
   b. The fencing shall be of galvanized 11.5 gauge chain link construction with a minimum of 1-5/8" outside diameter tubular steel posts and top rails.
   c. Surface mounted fence panels may be used with the approval of the University and are to be adequately braced to resist wind and ice loading and shall and shall be continuously connected to prevent access by the public.
   d. Privacy netting to screen construction activities shall be used on all "core campus" (bounded by Perry Street, Washington Street, West Campus Drive, and Kent/Stanger Streets) projects, or as specified in the contract documents.
   e. Privacy screen material shall be green polyethylene netting with a weave equal to the basis of design of U.S. Netting's Windscreen. Barbed wire shall not be used.
   f. Placement of fencing and privacy screen shall not reduce roadway and crosswalk sight distance below VDOT standards. Reference VDOT I&IM-TE-384.0 (or most recent) for crosswalk details.
3. Gates
   a. Limit entrance/exit to no more than two locations, unless otherwise approved by the University.
   b. Vehicular gates shall be located only where there are Construction Entrances in place per the DEQ.

   c. Gates shall be a minimum of 12 feet in width to allow access for emergency vehicles.
   d. Where other transportation authorities need to review gate locations and operation, communication with those authorities will be coordinated through the University.
   e. Gates shall be closed and locked at all times the site is not occupied, unless otherwise directed by the University where emergency vehicle passage through the site is needed to access existing occupied buildings.
4. Accessible design
   a. Alternate Accessible routes must be provided when construction fencing blocks established ADA paths.
   b. Signage must be placed at the entrance to the blocked ADA pathway and clearly indicate the alternate Accessible route. If the construction fencing blockage is obscured from line-of-sight at the beginning of an ADA pathway, additional signage shall be required to prevent hazards in re-routing of those requiring Accessible routes. Coordinate with the VT Office of Equity and Accessibility on placement of signage.

7.8 Traffic Impacts and Road Construction

7.8.1 Impacts to Traffic Routes

1. The Contractor shall develop and submit to the VT PM an access plan to address the following impacts:
   a. No vehicles shall obstruct ADA access aisles, park on walkways, or park on landscape or green spaces.
   b. Bike lanes shall be maintained. Alterations shall have proper signage.
   c. All transit stops and routes shall be maintained.
   d. All pedestrian routes shall be maintained.
2. All delivery routes and site access shall be maintained. This includes mail, vending, delivery, construction traffic, and garbage pickup.
3. Emergency response routes shall be maintained where possible. If emergency response routes must be altered during construction, the Contractor shall notify the VT PM and the appropriate agencies of any changes.
4. Projects must maintain the flow of all traffic on and adjacent to the project site including road, trail, sidewalk, ADA routes, etc. Contractors shall follow the general notes requirements from DCSM section 2.7.5.12 and the general notes on the plans.

5. Construction activities (including screening) shall not block transportation sight distances. This is especially important at all transportation intersections. Follow VDOT standards for sight distances.

7.8.2 Project Signage

1. All exterior signage that is intended for traffic control shall meet VDOT Standards and follow the Virginia Tech Parking and Transportation Master Plan.
2. All signs related to transportation are to be approved by OUP.
3. All exterior signage shall follow the Appendix F: Campus Wayfinding Guidelines for materials standards and mounting methods, where applicable.
4. Signage shall be provided to guide pedestrians along general and Accessible routes necessary to navigate obstructions caused by project sites. Data and visual communication materials on boundaries of site fencing and other impacts shall also be provided, at a minimum, to the VT PM and OUP. The VT PM shall coordinate aggregation and submission of necessary communication materials.
5. All permanent parking signage shall be purchased by the project through the Virginia Tech Sign Shop.
6. ADA parking signs shall follow the standard in the VT Design Standard Detail Library.
7. Construction entrances shall have at least two 24″ × 24″ safety orange diagonal signs (one for each direction) stating “CONSTRUCTION ENTRANCE AHEAD” on the sign. The project name shall be placed below the construction entrance sign.

7.8.3 Road Closures and Traffic Disruptions

1. Temporary road or lane closures shall be in compliance with the current version of the Virginia Work Area Protection Manual to ensure clearly defined expectations for vehicle and bicycle operators.
2. For temporary lane or total road closures, the Contractor shall supply and set up at least two programmable message boards for a minimum of two weeks prior to the road closure or impact and shall maintain the message boards for the duration of the impact. Project-specific requirements and placement locations shall be coordinated with OUP through the VT PM.
3. Traffic disruptions request:
    a. Contractor shall follow the traffic disruption request requirements from DCSM section 2.7.5.12 and the general notes on the plans.
    b. If a map or sketch is needed, the A/E or Contractor shall provide it along with the Maintenance of Traffic (MOT) plans. The A/E or Contractor shall follow A

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

ppendix H: Maintenance of Traffic Plans when preparing plan-view illustrations of the traffic disruption.

c. When the traffic disruption request form is received, the information is distributed to the traffic disruption distribution email list for comments.
d. Traffic disruptions during VT events such as large home sporting events and commencements shall not be permitted. Exceptions shall be requested at least six months in advance, but are typically denied.

4. Further coordination of the traffic disruption or last-minute schedule changes should be done through VT Parking Services and/or VT Repair at 540-231-4300.

7.8.4 Traffic Gates

Installation or removal of traffic barricade gates shall be coordinated through the VT PM with OUP, NI&S, Engineering Services, and the Virginia Tech Office of Parking and Transportation.

7.8.5 Road Construction

7.8.5.1 Permits and Inspections

1. All road work shall require a VDOT permit unless waived by Virginia Tech.
2. Any work not inspected by VDOT requires coordination with the UBO.
3. VDOT has final review of VDOT permits and bonding. Upon VDOT and VT approval work can begin.
4. Inspections for all road work shall be coordinated through the VT PM but minimum inspections shall be at:
   a. Subgrade prior to placement of base stone
   b. Base stone prior to placement of pavement
   c. Pavement prior to pavement markings

7.8.5.2 Road Construction Process

1. The Contractor fills out the VDOT permits, prepares the MOT plan, and submits a plan sheet showing the work to be done.
2. The Contractor, the VT PM, and OUP discuss the project specifications, VDOT permits, VDOT bonding, and MOT plans. If the VT PM and OUP approve these, then the Contractor takes these to VDOT. OUP notifies VDOT of the upcoming work. OUP may waive VDOT permits and coordinate internally.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. The Contractor shall notify VDOT, the VT PM, and OUP at the stages of construction depicted in the specifications, but at a minimum, at the following times:
   a. When ditch (or subgrade) is ready for backfill
   b. During backfill and compaction
   c. Just before fine grading for asphalt
   d. During paving
   e. After pavement markings and signs are installed
4. The Contractor shall contact the VT PM, OUP, and VDOT for inspection between 36 to 48 hours before each of the construction stages.
5. When the project is complete to the satisfaction of OUP and VDOT, then VDOT can release the bonds.

7.8.5.3 Road Construction Specifications

1. The Contractor shall refer to the pavement repair detail in the VT Design Standard Detail Library.
2. Geotechnical testing shall confirm subgrade and pavement design per VDOT standards.
3. If existing pavement is used, pavement structure shall be confirmed during design.
4. All work (asphalt, landscaping, concrete, etc.) shall be graded to drain (i.e., positive drainage). No ponding shall be permitted.
5. Any drainage problems should be corrected before or during backfill with under-drains.

7.9 Temporary Parking and Staging Areas

7.9.1 Contractor Parking and Traffic

Follow the general notes requirements from DCSM section 2.7.5.12 and the general notes on the plans.

7.9.2 Staging Areas

1. Contractor or material staging areas must be approved by the University and clearly delineated in the construction documents.
2. For deliveries that cannot be accommodated within the staging area, follow the general notes requirements from DCSM section 2.7.5.12 and the general notes on the plans. See DCSM section 7.8.3 for requirements on road closures and traffic disruptions.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. The project plans should show designated travel routes between the staging area and the project site. These routes should minimize impacts to campus operations.

7.9.3 Project Laydown

1. The project team shall discuss the laydown area needed by the construction project during the schematic design phase. The size and location provided for the laydown area will vary from project to project. The project team should balance project costs and efficiency with impacts on the University and the neighboring locality.
2. Coordinate the permitting, management, and restoration requirements of the project laydown area with the VT PM.
3. Signage requirements shall be coordinated with the VT PM and OUP.

7.9.3.1 Laydown Area Locations

1. Laydown areas shall be fully enclosed by chain link fencing before any material is moved to the area.
2. Laydown areas will be suitable for use by the construction team and will avoid hills or hard slopes, established ADA paths, tree driplines, stormwater BMP areas, and other areas as designated by the VT PM.
3. Laydown locations provided are not guaranteed to be contiguous or entirely adjacent to the project.
4. Laydown locations shall be prioritized to:
    a. Minimize interference with the normal functions of the campus
    b. Minimize financial loss (i.e., loss of revenue-generating spaces)
    c. Minimize permanent damage to the campus landscape
5. Laydown locations should be selected, as available, in this order:
    a. Locations at or adjacent to the project site, if room is available
    b. Remote, open landscape locations
    c. On-campus, open landscape locations
    d. On-campus, revenue-generating spaces

7.9.3.2 Laydown Area Assignment

1. Minimum laydown areas are established by the project team. Additional laydown area shall be arranged through the VT PM and may be billed at a rate based on the type of location provided (e.g., open landscape or revenue-generating spaces).

2. Project additions that develop from change orders after the working design phase will not automatically increase the minimum laydown area allotted for the project.

7.10 Site Preparation

7.10.1 Utilities

1. Contact Virginia 811 no less than three business days in advance of any excavation, digging, etc. Do not disrupt the soil prior to the processing and approval of the dig ticket. It is the responsibility of the party doing the excavation to contact Virginia 811.
2. VTES or Utilities Distribution need to coordinate any utility shutdowns. Scheduled outages shall require a minimum advance notice of one week. Overtime charges may apply for outage related activities that take place outside of normal working hours.
3. VTES must escort contractor personnel in steam tunnels, substation areas, and in high voltage switch rooms in buildings. These activities shall be planned to take place during normal working hours. Contractors shall complete any required safety training in advance of the visit through their own sources and provide verification of training to Facilities Safety.

7.10.2 Tree and Plant Protection

Include the tree protection detail located in the VT Design Standard Detail Library in the drawing package as the required tree protection.

7.10.2.1 Tree Protection Fencing

1. Tree protection fencing is required for all trees within construction limit fencing or as noted on plans for projects where no construction limit fencing is specified.
2. Tree protection fencing shall be installed around existing trees noted to remain on plans within the fenced area. Fencing shall be installed and maintained at a distance from the trunk equal to 1.5 feet per inch of trunk diameter as measured at 4.5 feet above grade (DBH) or 10 feet, whichever is greater. For example, a tree with a 12-inch trunk diameter shall be fenced 18 feet from the trunk (36-foot diameter). See the tree protection detail located in the VT Design Standard Detail Library for specific requirements for tree protection zones (TPZ). Alternative shapes and sizes of TPZ may be considered on sites with size or location constraints and must be approved by the University Arborist office.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Fencing shall be installed before any equipment is placed on the site. Work may not begin until fencing is installed.
4. Fencing shall be galvanized chain link with a minimum height of 4 feet. The use of plastic fencing or snow fencing with wood stakes or T-posts is not acceptable.
5. Fencing shall be maintained for the duration of the project and shall not be removed without permission from the University Arborist.
6. No material storage, vehicles, or any other activity shall occur at any time within tree protection fencing. Coordinate with the VT PM if any landscape maintenance is required while the tree protection is installed.
7. Contractors shall pay for tree asset appraisal, replacement, and soil compaction remediation costs, as directed by the University Arborist office, if there is any incursion into tree protection zones.

7.10.2.2 Material Storage

1. Sites used for material laydown, equipment transport, and construction shall be planned to avoid conflicts with tree crowns. The University Arborist office may permit pruning of small branches and minimal reduction cuts to increase clearance when conflict is unavoidable.
2. Sites at the project that are designed for landscape use and tree planting should not be used for material laydown and equipment transport. In the event that these planting sites are impacted by any construction activities, compaction shall be remediated with the soil profile rebuilding technique or another process approved by OUP. See the soil profile rebuilding specifications on the Virginia Tech Urban Forestry website.

7.10.2.3 Critical Root Zones

1. All work occurring within the critical root zones of campus tree assets that involves excavating or soil disturbances, root cutting, and grade changes shall be planned during the preliminary design phase and supervised by the University Arborist who will develop a root pruning or tree preservation plan that must be completed before root damaging activities begin. Non-invasive techniques (e.g., horizontal boring, air spade excavation, and hydro-vac excavation) shall be considered before trenching, grading, and excavating or other soil disturbances are planned within the critical root zone of campus tree assets.
2. A layer of wood chip mulch, approximately 5 inches thick, shall be spread over the critical root zone. Special care shall be taken to avoid mulch

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

placement on trunk flare. Any areas outside of the critical root zone that may experience vehicle traffic and compaction shall be mulched in the same manner, to a depth of 8 to 12 inches thick.

7.10.3 Site Clearing and Building Removal

Project teams shall consult OUP and SID. The intent is to ensure proper protection and care of existing elements identified for salvage. Ensure protection of adjacent elements to remain after demolition. Sufficiently prepare for new construction elements on and around selective demolition. See DCSM section 1.7.5 for demolition of building requirements.

7.10.4 Dust, Mud, and Dirt Control

Contractor is required to maintain compliance with the VTAS&S.

7.10.5 Earthwork Specifications

Specifications shall be definite, not general.

1. Coordinate specifications with the drawings.
2. Include a geotechnical/soils report in the project manual and a disclaimer stating that the report is not part of the contract documents each time this report is referenced.
3. Specifications for materials and instructions shall state whether they are included in the base bid or will be an extra cost item.
4. Rock excavation shall be included in the base bid to the extent that locations are sufficiently identified in the geotechnical/soils report (see DCSM section 7.10.6).
5. Earthwork specifications shall include soil and aggregate material definitions for all materials used in the project. The soil materials shall be defined by a recognized soil classification system, such as the Unified Soil Classification System or the AASHTO Soil Classification System.

The definitions below are by the Unified system. The aggregates shall include gradations required for each material. All A/E standard specifications shall be edited to conform to the following requirements.

1. Structural Fill and Backfill: Generally restricted to GW, GP, GM, SM, SW, and SP unless other materials are specifically approved by the soils engineer or firm that conducted the on-site soils evaluations. SC, CL, and ML might be considered in some situations with the approval of the soils engineer.
2. General Fill and Backfill: Includes all classifications of materials noted above.

3. Unsuitable Materials: Includes OL, MH, CH, OH, and PT, saturated material which in the judgment of the soils engineer cannot be aerated to be made acceptable, uncompacted fill (for structural bearing conditions), fill with unacceptable quantities of non-soil products, or other materials judged unsuitable by the soils engineer.
4. Aggregates: They may include porous backfill, pipe bedding, underslab fill, any special blend or open-graded material required for a special bearing or drainage use.
5. Moisture Content of Soil Materials: Laboratory tests are generally conducted on samples to determine the maximum density of soils, usually achieved at optimum moisture content. Field conditions during construction prevent attaining and maintaining the optimum moisture content. This requires that a tolerance for departure from this optimum must be specified. This tolerance is generally specified in the range of plus or minus 3% to 5% from the optimum moisture content without significantly affecting the ability to achieve the specified density.
6. Quality Assurance and Testing: The specifications shall list the tests required to be performed on the work (e.g., ASTM, AASHTO, VDOT, or other test procedures) and stipulate the values to be achieved.

7.10.6 Rock Excavation

Where rock excavation is likely to be encountered, the site shall have an adequate number of borings taken. The A/E shall use this data to show on the plans enough assumed rock profiles over the entire area to be excavated to identify clearly the condition assumed for the base bid. The specifications shall state the method of volume calculation and pay lines to be used.

The A/E shall calculate and state in the Bid Form (see the example in the VT CPSM) an estimated quantity of rock to be excavated based on the assumed rock profiles. The bidder shall indicate a unit cost by which his bid for the rock excavation is calculated. This bid item shall be added to the other bid items to establish the Lump Sum Bid. The final net contract payment for rock excavation shall be adjusted (plus or minus) based on the actual quantity of rock excavated. This price shall include disposal of excess. General rock pay width shall be based on 18″ outside of a neat wall face; or vertical projection from the extremities of the base, whichever is greater. Trench rock quantity shall be based on the widths stated in the specifications.

Rock excavation shall be defined as hard bed rock, boulders or similar material requiring the use of rock drills and/or explosives for removal. The criteria for

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

classification of general excavation as rock shall be that material which cannot be removed by a track-mounted D-8 dozer with a heavy ripper or 3/4 CY track-mounted shovel with appropriate scoop. The criteria for trench rock shall be that material which cannot be removed by a 3/4 CY track-mounted backhoe with a proper width bucket. The trench unit price shall only apply to material below the general grading level.

When the overburden is removed and the rock surface is exposed, the A/E shall verify that the material is of a hardness which qualifies it for classification as rock excavation. Actual profiles shall then be taken. The net difference between the actual rock excavation and that estimated volume shown in the proposal shall be applied times the contract unit price for adjustment of the final payment.

All rock quantities shall be based on in-place volumes and shall be obtained by means of the method of average end areas or other method acceptable to the engineer. Truck counts will not be accepted as a method of determining earthwork quantities.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

CHAPTER 8 – INSPECTIONS AND OCCUPANCY

Inspections are performed by the UBO and CFR or designees as approved by the VT PM. Inspections performed by the office of the UBO include, but are not limited to, code inspections of the foundation, structural members, and all mechanical, electrical, and plumbing systems prior to concealment, substantial completion and final inspections, and special inspections (see DCSM sections 1.7.2.4.2 and 8.2).

CFR duties begin during the pre-construction phase and continue to the final inspections of work products. CFR responsibilities include the frequent or periodic monitoring of materials, workmanship, records, and tests during the construction process and final inspections of the completed work product. A list of services required from the CFR is listed in DCSM section 8.1.3.

8.1 Construction Field Representative Inspections

Except as provided in DCSM section 8.1.1, the VT PM shall designate a specific individual to serve as Construction Field Representative (CFR) on every project whenever work on the project is in progress. The name of the CFR shall be shown on the form HECO-8. Where completion of a HECO-8 is not required, the name of the CFR will be entered in the project file. CFR inspections do not nullify or otherwise replace inspections required by, and performed by, UBO staff as described in the DCSM. Communications from the CFR shall be primarily with the VT PM and the A/E.

The CFR shall be a duly authorized and qualified person who shall be available during the entire time work is in progress on the site. The A/E shall provide the CFR with a copy of all approved shop drawings, submittals, samples, schedules, change orders, clarifications, supplemental information, and other pertinent correspondence and material for the CFR's use at the jobsite.

8.1.1 Small Projects

For small or simple trade contract projects, a member of the university may serve as the CFR. The VT PM may designate a CFR for projects accomplished using in-house forces. For projects where the CFR is not full time, weekly reports are not required. The duties of the CFR will be consistent with the size and complexity of the job and similar to those listed in the following paragraphs.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

8.1.2 Minimum Qualifications of the CFR

The CFR shall meet the DCSM section 1.7.2.4.1 criteria and the Qualifications of Inspectors and Testing Technicians on the VT Facilities Forms web page. The CFR also shall have the following minimum qualifications:

1. Education, trade-related training, and experience in a design or construction related field;
2. Some knowledge of construction means, methods and procedures;
3. Be knowledgeable of and have reasonably convenient access to the codes and standards referenced in the contract documents which stipulate the requirements for installation and workmanship on the trades involved in the Work (ACI, SMACNA, NFPA, NEC, ICC, ASHRAE, etc.);
4. An understanding of the General Conditions of the Construction Contract;
5. The ability to read and understand the requirements of building plans and specifications;
6. The ability to read and understand a construction bar chart schedule; and
7. The ability to communicate effectively orally and in writing.

8.1.3 Duties of the CFR/Clerk of the Works

The following is a detailed listing of the duties, services, functions, and responsibilities of the CFR for capital outlay projects. This listing supplements and expands upon the duties, functions, and responsibilities generally described in section 16 of the General Conditions of the Construction Contract. The VT PM may assign the CFR other duties related to the project or to scheduled meetings. The CFR shall perform the following services unless modified by the contract for services.

The CFR is an employee of the university and is responsible to the university for performing the duties, observations, and services described. This does not relieve the A/E from providing and being responsible for his contractual obligations as described in the VT CPSM and the DCSM, the A/E contract, and the General Conditions of the Construction Contract, form CO-7. Administrative duties may be assigned to and performed by a Clerk of the Works in support of the CFR.

8.1.3.1 Communications and Reporting

1. Report directly to the VT PM.
2. Participate in progress meetings and monthly pay meetings with the VT PM, the A/E, the Contractor, and other designated representatives, to review the current status of work and any action needed to keep the project within budget and on schedule.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Submit a daily report in an approved format to the VT PM. Summarize the significant activities and occurrences at the project site. The daily report is the primary mechanism for the CFR to track a project and report progress to the project team.
4. Submit a weekly report in an approved format to the VT PM and the A/E. Summarize the significant activities and occurrences at the project site in the weekly report. Include copies of the daily reports with the weekly report.
5. Notify the Contractor of time-sensitive items that require notification to the VT PM and A/E.
6. Report, in writing, to the VT PM and A/E any notifications from the Contractor of dates and times that services will be disrupted.
7. Confirm to the VT PM that changes required by approved change orders are incorporated in the work at a time deemed appropriate by the Contractor, and are reflected in the Contractor's progress schedule. Spot check sub-contractors to ensure they have the updated changes.
8. Immediately report all discrepancies in the Contractor's work to the A/E and the VT PM. Also report any discrepancies noted in plans and specifications to the A/E for clarification or resolution.
9. Document and notify the VT PM of any safety violations, OSHA visits, accident reports, and corrective actions observed. Such reports do not relieve the Contractor of responsibility for safety under terms of the contract for construction.
10. Observe and report on all tests required by the contract documents and all tests performed by the Contractor. Record and report in the daily reports, to the A/E and VT PM, the Contractor's test procedures and, where applicable, results of the tests.
11. Report the presence of and activities performed by the university testing and inspection agents.

8.1.3.2 Reviewing, Verifying, and Recommending

1. Review the Contractor’s as-built drawings and on-site required documentation to ensure that the information is current.
2. Ensure that shop drawings and product submittals or samples have been approved prior to installation. Receive and log samples required to be furnished at the site. Notify the A/E when the samples are ready for examination. Record the A/E approval or other action and maintain custody of approved samples.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Review and provide a recommendation to the VT PM on the acceptability of all proposals submitted by the Contractor for changes initiated by the VT PM or A/E, and the acceptability of all claims for change orders initiated by the Contractor.
4. When the Contractor is directed to make changes based on unit costs, document the accuracy of quantities of material and labor (or other units of measure) attributable to change orders. Report to the VT PM that this type of change is being recommended. Verify that all change orders are complete.
5. Observe the Contractor's record drawings at intervals appropriate to the state of construction and notify the A/E and the VT PM of any apparent failure by the Contractor to maintain up-to-date records.
6. Throughout construction, review the Contractor's detailed schedule and advise the VT PM on the Contractor's progress and all other construction scheduling issues. Monitor the schedule, notify the VT PM and the A/E of any slippage in critical path time, make recommendations on accepting the Contractor's proposed schedule recovery plan, and maintain an annotated copy of the schedule that reflects actual progress of the work.
7. Review the HECO-6B with the VT PM to ensure coverage of all required inspections.
8. Verify invoices for on-site tests and site visits of independent testing entities, which are to be paid by the University. Verify hours reported by third party inspectors.
9. Review each certificate and application for payment. Advise the A/E and VT PM whether the documents accurately represent the progress of the work and the values of each line item in the schedule of values. Verify that stated quantities of stored materials are accurate. Based on the review and verification, recommend to the VT PM and A/E to approve or to revise the certificate and application for payment.

8.1.3.3 Monitoring and Inspecting

1. Monitor and inspect all construction materials, equipment, and supplies for compliance with the contract documents, shop drawings, and submittals. Take relevant pictures.
2. Inspect installation and workmanship for compliance with the contract documents, shop drawings and referenced standards (ACI, SMACNA, NFPA, NEC, BOCA, ASHRAE, etc.). Verify compliance prior to cover or close-in of work.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

3. Monitor quality and coordination of trade contractor work at all times. Recommend to the VT PM ways to alleviate identified problems. Identify all work not done in accordance with the contract documents and report it to the VT PM and the A/E. If trades are not coordinated, report to the VT PM and note it on the daily report.
4. Provide full-time inspection of the roof during its application. During roofing operations, maintain a daily written roofing report covering such items as: weather conditions, deck conditions, materials stored, and installation procedures including bitumen temperature at kettle and point of application, etc. Provide a copy of the daily report to the Contractor.
5. Ensure the Contractor has inspected work prior to contacting the UBO. When practical, the CFR shall attend UBO inspections. Create punch lists for the Contractor based on the UBO inspection.

8.1.3.4 Recordkeeping and Document Management

1. Maintain accurate and current records for the following throughout the project:
   a. Keep a daily log of construction activity roofing, tests, inspections, reports, photographs, and annotated drawings, in order to show the progress of and changes in the project during construction.
   b. Record actual start dates of activities on the project schedule. Record any updated project schedules.
   c. Record and maintain a running record of outstanding, unresolved issues. The record shall include the issue, date of occurrence, and date of resolution. Submit this running record with the weekly report. After an item has been corrected, delete it from the list in the weekly report.
   d. Record visits by the A/E and any A/E representatives.
   e. Keep a record of all proposal requests from the A/E, change order proposals from the Contractor, and executed change orders from the A/E. File copies with the VT PM monthly.
2. Ensure that the change log is being maintained by the project team.
3. Maintain current copies of the following at the jobsite:
   a. The current set of contract documents (addenda, contracts, drawings, specifications, change orders, proposed change orders, requests for clarification, construction change authorizations, A/E supplemental instructions, permit revision documents signed by the UBO, etc.);
   b. The project schedule with notations, highlighting, etc., that show work to date and any changes made in the critical path method (CPM) schedule.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

c. A complete set of meeting minutes as a running record of evolution of problems and solutions during the progress of the work.
d. All correspondence and reports of site conferences;
e. Shop drawings;
f. Samples and product data;
g. University's purchases, including material and equipment;
h. Supplementary drawings;
i. Color boards, schedules, and samples;
j. Names and addresses of Contractors, subcontractors, and principal material suppliers;
k. Contractor's applications for payment;
l. Running list of discrepancies/deficiencies and dates;
m. Running list of unresolved issues;
n. A/E punch lists with date of issue indicated on each;
o. Any other documents and revisions resulting from issues concerning the contract or work; and
p. Maintenance and operation manuals and instructions when received from Contractor.

8.1.4 Authority of the CFR

1. The CFR shall exercise authority for the following:
    a. Prohibit the Contractor from installing roofing materials without first having obtained from the A/E a copy of the manufacturer's certification confirming that roofing materials delivered for use on the project meet specified ASTM standards.
    b. Report to the A/E and the VT PM when in the CFR’s judgment the work being performed does not conform to the requirements of the contract documents or safety requirements are not being followed and, if appropriate, recommend suspension of the work.
    c. Make recommendations to the VT PM as appropriate concerning the Contractor's conformance to the schedule and/or recovery plans.
2. The CFR has no authority for and shall not do the following:
    a. Interpret or change approved plans and specifications;
    b. Authorize deviations from the contract documents;
    c. Enter into areas of responsibility of the Contractor's superintendent;
    d. Issue directions regarding construction means, methods, techniques, sequences or procedures, or safety precautions and programs in connection with the work;
    e. Authorize or suggest that the University occupy the project in whole or in part; or

f. Issue a certificate for payment.

8.2 UBO Special Inspections

8.2.1 General

The VCC Special Inspections and Tests section requires special inspections to be performed on a project and cites requirements for special inspections. These inspections have been, heretofore, provided on state projects by a combination of the University's Project Inspection, the A/E, and the University's independent testing lab. DCSM section 8.2.2 describes the procedures assuring that the structural, special, and other associated inspections are provided for the project.

The concept of the process is that:

1. The A/E will determine in the design the materials, strengths, configurations, quality and standards applicable to the work and describe that information to the Contractor in drawings and specifications;
2. The A/E will specify the submittals (e.g., shop drawings, manufacturer's data, and certificates of conformance), required from the Contractor and review the submittals;
3. The A/E and the VT PM shall review the list of special inspections for the applicable code edition, make appropriate notations on the list and forward the marked-up list with the completed Statement of Special Inspections (HECO-6A) to UBO for review and approval;
4. The Contractor shall review the submittals from its subcontractors, suppliers, fabricators and vendors to assure conformance with the contract documents and assure that materials, sizes, and configurations proposed are compatible with other trades and the space provided;
5. The fabricator, supplier, vendor or production plant shall secure and/or have ongoing the required testing and quality control/assurances program to meet the requirements specified and shall submit certificates of conformance to the applicable standards of practice and quality assurance;
6. The A/E will perform on-site observations of erections, placements, and installations to ascertain the intent of the contract documents and shop drawings are met;
7. The University's CFR/Clerk of the Works will observe day-to-day operations and report deviations/discrepancies in the materials and/or work versus contract documents and approved submittals;
8. The University's test lab will, for the indicated items, make on-site inspections, measurements, tests and sample collections, make applicable laboratory tests

and submit copies of the reports to the University, the Contractor, the A/E and the CFR; and the Contractor will have other tests made as specified and as necessary to assure conformance with the applicable regulations and standards of practice and workmanship;

9. The A/E structural engineer, the University's CFR and the VT PM or responsible person shall complete the HECO-13.1B and submit to UBO as soon as completed but prior to the substantial completion inspection report.

8.2.2 Structural and Special Inspection Forms

Structural and special inspection forms are available for download from the VT Facilities Forms web page.

Table 8-1. VT Facilities Structural and Special Inspection Forms

HECO-6	Schedule of Special Inspections
HECO-6A	Statement of Special Inspections
HECO-6C	Quality Assurance Plan
HECO-13.1B	Final Report of Special Inspections

8.3 University Roofing Inspection

The University shall have a full-time inspector on site while the roof is being applied. The inspector may be the CFR or someone qualified to inspect a roof installation. See qualifications for a roof inspector and roof consultant in DCSM sections 8.3.4 and 8.3.5.

8.3.1 Daily Report

The roofing inspector shall check all materials and application procedures and prepare a daily written report covering such items as: the weather conditions, the deck conditions, the materials stored, the materials installed, and the installation procedures used (including bitumen temperature at kettle and point of applications, etc.). A copy of the daily report shall be given to the contractor, A/E, and the VT PM in a timely manner. The inspector shall not permit installation of roofing materials without having first obtained from the design A/E a copy of the approved shop drawings showing the ASTM or other standards.

8.3.2 Pre-final Inspection Survey

Comply with the following survey provisions:

1. The A/E shall notify the VT PM, the Contractor, and the roofing contractor (in writing) that he has inspected the roof(s) and finds it (them) sufficiently

complete to permit a roofing survey. In no case shall the survey be made earlier than forty days before the substantial completion inspection.

2. The VT PM shall engage the services of an experienced, independent roof survey inspection service or laboratory to survey the roof(s). The service shall use infrared, nuclear moisture detection, or electronic leak detection methods. Roof probes or cuts shall not void the Contractor’s two-year guarantee and the manufacturer’s warranty/guarantee.
3. The roofing contractor shall cooperate and assist the inspection service by making and repairing any required cores, test cuts, or probes in such a way that the manufacturer's and the Contractor's warranty/guarantees are not voided.
4. A copy of the survey report shall be delivered to the UBO no later than ten days before the substantial completion inspection. Also, copies of all survey reports shall be delivered to the VT PM, A/E, Contractor, and roofing contractor.
5. The University shall pay for the service unless the survey shows roofing deficiencies caused by improper materials, poor workmanship, or Contractor negligence. In that case, the Contractor, at his expense, shall repair or replace the roof(s) and provide additional surveys until the roofing work complies with the contract documents. All corrective work shall be completed before the final inspection.
6. Acceptance of the roofing system shall be contingent on a roofing survey report that indicates the presence of no detrimental amount of moisture (moisture that would cause a significant lowering of the thermal resistance of the roof, separation of the roofing plies, blisters, etc.). Insulation or roofing materials determined in the roof survey to have detrimental amounts of moisture by the Consultant and any materials covering the insulation shall be replaced by the Contractor at no cost to the University.
7. In any case where the roofing survey reports insulation that has lost more than 20% of its dry thermal resistance (R-value), the insulation and any materials covering the insulation shall be replaced by the Contractor at no cost to the University.

8.3.3 Final Inspection

The following items must be given to the university representative at the Final Inspection:

1. A copy of the General Contractor’s and roofing contractor’s two-year guarantee.
2. A copy of the roofing manufacturer’s standard warranty/guarantee.

8.3.3.1 One Year Inspection

Representatives of the University (and the A/E), the Contractor, the roofing subcontractor, and the membrane manufacturer shall inspect the roof(s) between nine months and one year before the closing of the Contractor's one-year guarantee.

8.3.3.2 Two Year Inspection

The University shall also have the roof inspected at least three months before the two-year guarantee expires and notify the Contractor in writing of any defects noted. The University shall require that any defects be corrected at least 30 days prior to expiration of the guarantee.

8.3.4 The Roof Inspector

The minimum qualifications below serve as criteria for the University's selection of the roofing inspector.

1. The Inspector should have a thorough knowledge of roofing details, flashing, and systems employing single-ply, built-up, metal, shingle, slate, or other membranes as the main weatherproof barrier.
2. The Inspector shall have attended roofing related education in formal schools or seminars sponsored by agencies such as AIA, BURSI, RCI, Inc., CSI, NRCA, or roofing manufacturer's training courses, and shall obtain a minimum of twelve continuing education units annually in such courses, or shall have a current Registered Roof Observer Registration from RCI, Inc. Inspectors with other training must submit qualifications and be approved by the VT PM in advance.
3. The Inspector shall be thoroughly familiar with the latest edition of the NRCA Roofing Manual and specialized manuals prepared by NRCA.
4. The Inspector shall have a minimum of five years of full-time, practical roofing experience or approved equivalent experience.
5. The Inspector shall identify, in writing, at least three projects where he has been the full-time roofing inspector. He should provide names, addresses, and telephone numbers of roof owners and A/E for the roof projects.
6. The Inspector shall be trained and competent in the services he is providing
7. Roof Inspector's Scope of Work:
    a. The Inspector shall monitor the work for compliance with the contract documents.
    b. The Inspector shall continuously monitor and observe the work at the point of application during installation of the roof.

c. The Inspector shall immediately report any deficiencies or deviations to the A/E and the VT PM. A written report shall follow an oral report within two business days.
d. The Inspector may recommend suspension of work or rejection of non-complying work to the A/E and the VT PM.
e. The Inspector shall not:
    i. Authorize deviations from the contract documents.
    ii. Enter the area of responsibility of the Contractor's superintendent.
    iii. Issue orders on any aspect of construction means, methods, techniques, sequences, procedures, or safety in connection with the work.
f. The Inspector shall:
    i. Keep a daily log for each project.
    ii. Provide a copy of the log to the roofing contractor, the A/E, and the VT PM.
    iii. Record all pertinent information such as weather, daily progress, workmen on the job, material storage, deck condition, bitumen temperature, installation procedures, quality of workmanship, job-related visitors, and so forth.

8.3.5 The Roof Consultant/Inspection Services Provider

The Consultant shall have the following qualifications:

1. Roof consulting and testing services should be the Consultant's full-time occupation.
2. The Consultant shall have a minimum of five years of field experience in providing the service.
3. The Consultant shall have completed at least three service contracts in the recent past. Work for each of the completed contracts should be roughly equivalent in size and complexity to the proposed work.
4. The Consultant shall be required to submit three complete surveys of roofs that were repaired, recovered or replaced. The survey shall include names, addresses and telephone numbers of roof owners and A/Es responsible for preparing the drawings and specifications.
5. The Consultant shall have attended roofing related education in formal schools or seminars sponsored by agencies such as AIA, BURSI, RCI, Inc., CSI, NRCA, or roofing manufacturer's training courses and shall obtain a minimum of twelve continuing education units annually, or shall have a current Registered Roof

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

Consultant Registration from RCI, Inc. Consultants with other training must submit qualifications and be approved by the University in advance.

6. The Consultant should be trained, experienced, and competent in performing required services.
7. If testing is required, the Consultant shall be appropriately trained, certified, and licensed in the testing procedures (infrared, nuclear, electronic leak detection, core sampling, ASTM procedures, gravimetric analysis, etc.) required for the service.
8. The Consultant should submit documented experience of the firm and resumes of all participating employees.
9. The Consultant's resume should describe other related services and contributions, such as writing, lecturing, and serving as an expert witness. The Consultant should list professional qualifications or licenses.
10. The completed resume form must be submitted with the roof Consultant's response to the University's request for proposal. It will be used with other required items to evaluate the applicant.

8.3.6 Semiannual University Inspections

The University shall inspect the roof(s) semiannually, as a condition of the roofing guarantee. The University shall also inspect the roof(s) before the two-year guarantee expires.

8.4 Start-Up/Acceptance of Mechanical and Electrical Systems

1. It shall be the responsibility of the A/E to verify that the Contractor has all systems functioning properly per design intent and the following requirements are fulfilled.
   a. Equipment has been received per Shop Drawings previously approved by the A/E.
   b. All air handling equipment has been kept clean during construction.
      i. If air handling equipment is used during construction, filters shall be changed once a month or more often, if needed. Filter media shall be installed over return grilles. Inlets and outlets of fan coil units shall be covered when not in use.
      ii. The building must be turned over to the University upon project completion with clean air handling equipment and duct systems. A clean set of air filters shall be installed in the air handling equipment and a stock of spare filters for one additional change for building systems shall be provided.
   c. All system components have been adjusted and a record made of final settings.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

   d. Manual and automatic operating modes have been established for full load ranges prior to notifying the University that the system is ready for final start-up and acceptance testing.
2. The startup inspection team should conduct final inspections and acceptance testing as scheduled and complete the work without exceptional delay.
3. Major or time-consuming adjustments or modifications during final inspection shall be avoided. Final inspections requested when the systems are obviously not ready for such testing and inspections may result in a back-charge to the A/E or Contractor for the costs of inspection team visits and related costs. Applicable portions of the above requirements shall be included in the project specifications.

8.5 Substantial Completion Inspections

A Substantial Completion Inspection is required for all projects. When the Contractor determines that the work, or a designated phase or portion thereof, will be substantially complete and ready for testing and inspection, he shall complete and send form HECO-13.2A with a list of the work he knows to be unfinished or defective to the A/E at least 10 days prior to the date he has set for substantial completion. The A/E will forward the HECO-13.2A to the VT PM and the UBO and attach a written endorsement, based on his periodic inspections, as to whether or not he concurs that the project, or phase, should be substantially complete on the date set by the Contractor. The A/E will then coordinate and arrange a date on or shortly after the date set by the Contractor for the substantial completion inspection to be conducted.

Participants in the substantial completion inspection shall include representatives of the Contractor, including those of the mechanical, electrical, and major equipment subcontractors, the A/E, the VT PM, the UBO, the SFMO, and other university representatives as designated by the VT PM. The A/E shall conduct and document the inspection and compile a written list of the work or deficiencies noted (punch list) which need to be completed or corrected.

If the A/E, the SFMO, and the university representatives agree that this project, or this portion of the project being inspected, is substantially complete in accordance with the contract documents, the A/E shall execute the appropriate HECO-13.1A, and submit them to the University. Attach copies of the punch list, the Contractor's HECO-13.2A, the HECO-13.3A, and other documents as appropriate.

If one or more re-inspections of the work that the Contractor declared to be Substantially Complete are required because the work was not substantially complete as stated, the Contractor shall reimburse the University for the costs of the re-inspections. The UBO will not accept the project as Substantially Complete unless the facility (part or whole) is ready for occupancy.

8.6 Final Completion Inspection

When the Contractor determines that the items listed in the “punch list” have been completed and that the work is complete and ready for final testing and inspection, he shall complete form HECO-13.2 and send it to the A/E at least five days prior to the date the Contractor has set for the work to be ready for Final Inspection. The A/E will forward the HECO-13.2 to the VT PM and attach a written endorsement, based on his periodic inspections, as to whether or not he concurs with the date set by the Contractor.

The A/E shall receive the HECO-13.2, the CO-13, written guarantees, equipment and operating manuals and related documents assembled by the Contractor, review same and turn them over to the VT PM at the final inspection. The A/E shall record any items noted for completion or correction. He shall promptly follow up on the items and notify the VT PM, in writing, when they are completed.

The A/E shall conduct the final inspection. A representative of the SFMO either will be present at the inspection or otherwise inspect the completed work and advise the VT PM and the UBO whether the work meets the fire safety requirements of the applicable building code.

The University may have other persons participate in the inspection. If one or more re-inspections are required because the work purported to be complete is not complete, the Contractor shall reimburse the University for all re-inspection costs.

If the A/E and the SFMO representative agree that the building is complete in accordance with the contract documents, and safe to occupy, the A/E shall execute the HECO-13.1 and deliver it, along with the record drawings and all other required material, to the VT PM for final acceptance of the project.

8.7 Guarantee Period Inspection

Prior to the expiration date of the Contractor’s one-year guarantee period, but not before nine months of this period has elapsed, the University shall make an inspection of the building, equipment, and/or any other work included in the original Contract to determine whether any defects in materials or workmanship have developed. The University and A/E representative will provide the Contractor with written notice of such defects and shall notify the A/E for advice in the correction of the defects.

8.8 Building Occupancy

The UBO may approve a building or facility being occupied when it is substantially complete. A new building, addition to a building, or a renovated building with a new Use Group classification shall not be occupied until the UBO issues a form HECO-13.3A. The VT PM shall apply to the UBO for a Certificate of Occupancy by submitting a form HECO-13.3A and a HECO-13.3B, Checklist for Beneficial Occupancy with the required reports and Certificates of Substantial or Final Completion attached. Requests for Partial or Temporary Occupancy shall also include a small-scale floor plan with the subject areas for occupancy noted.

The application shall include the following documents:

1. Form HECO-13.1 or HECO-13.1A
2. Form HECO-13.1B
3. Form HECO-13.2 or HECO-13.2A
4. A copy of the Contractor and A/E punch lists
5. A letter or report from the regional SFMO stating there are no objections to the building being occupied or stating conditions for occupancy of the building
6. Form HECO-13.3B

If the A/E construction visits/inspections were limited, also include a HECO-13.1C (Certificate of Partial or Substantial Completion by Construction Inspector, Project Manager, or Construction Administrator). Projects which have elevators, food service/kitchen facilities, and/or water or wastewater treatment facilities are required to be inspected separately and have a certificate of compliance issued by the inspecting entity. Include copies of certificates with the Application for Certificate of Use and Occupancy. The UBO may issue a Certificate of Use and Occupancy when the building is substantially complete and all life and fire safety elements of the project design are functioning properly.

8.8.1 Non-capital Procedures Prior to Occupancy

The UBO shall assure that all inspections and tests are performed and that the work performed conforms to the requirements of the applicable codes and standards and that the building is safe and ready for occupancy.

1. The Contractor shall complete form HECO-13.2 or 13.2A.
2. The A/E (or VT PM/CFR) shall complete a form HECO-13.1 or 13.1A, and a form HECO-13.3B, and submit them to the UBO.
3. The VT PM shall procure other documentation as applicable, such as the potable water report, lightning protection certificate, elevator inspection certificate,

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

testing and balance report, and medical gas certification, and submit them to the UBO.

4. If the project is a new building, or an addition to or renovation of an existing building, the SFMO shall inspect and provide a report recommending acceptance for occupancy.
5. On new buildings, on building additions, or on renovations that involve a change in Use Group classification, the VT PM shall submit the above documents to the UBO along with form HECO-13.3A.

8.8.2 Issuance of Certificate of Use and Occupancy

The non-capital construction project work shall be inspected by the UBO for conformance with the VUSBC as shown on the approved plans and specifications. The VT PM shall submit the forms HECO-13.1A, HECO-13.1B, HECO-13.2A, HECO-13.3B, and other applicable certificates or reports to the UBO, along with the HECO-13.3A when requesting that a Certificate of Use and Occupancy be issued. The UBO may waive some of these requirements based on project size and scope.

Renovation-only projects (not involving an addition to an existing building) or which do not involve a change in use or occupancy for the existing building will not be issued a Certificate of Use and Occupancy. Upon completion, the VT PM shall submit to the UBO forms HECO-13.1, HECO-13.2, HECO-13.3B, and HECO-13.1B in order to close the permit when the construction is completed. The project is not complete as long as any deficiencies identified by the UBO or the A/E have not been completed, corrected or otherwise resolved.

8.8.3 Temporary Change of Use and Occupancy

Temporary change of use and occupancy requires a Temporary Certificate of Occupancy or issuance of a Special Use Permit by the UBO. The application for Temporary Certificate of Occupancy must be complete, and include an Operational Policy that provides safety measures to address the life safety, health, and welfare of the occupants.

A Temporary Certificate of Occupancy is not required for temporary structures (see DCSM section 1.3.8.3).

8.9 Beneficial Occupancy – New Buildings, Additions and Renovations

Once the VT PM, the A/E, the Contractor, and the SFMO have confirmed in writing that the facility, or a usable portion thereof, is substantially complete and ready for occupancy, the VT PM will submit the HECO-13.3A along with a HECO-13.3B, copies of the HECO-13.1A, HECO-13.1B (if applicable), HECO-13.2A, the SFMO final acceptance report and other required operations permits to the UBO.

During project closeout, insurance coverage must be transferred to the University. The VT PM shall prepare and submit the New Building Information form linked in the VT Design Standard Forms Library.

The UBO, when satisfied that the project and/or portion of the project is in fact substantially complete in accordance with the contract documents, may issue written authorization (HECO-13.3A) to the VT PM to occupy the project, or applicable portion thereof, subject to any conditions or stipulations stated thereon.

The University shall not occupy the facility until the certification from the SFMO that the project complies with the fire safety requirements and applicable codes and the HECO-13.3A is issued by the UBO. Occupancy of the facility without approval is unlawful and is a misdemeanor (*Code of Virginia* § 36-106, as amended).

The following material is required for consideration of a request for a Temporary or Partial Certificate of Use and Occupancy:

1. Floor plans (small scale) showing areas requested for occupancy and exits/egress routes
2. Type of Occupancy requested: move furniture in for staff, set up/prepare for students, etc.
3. HECO-13.1A with punch list from A/E
4. HECO-13.2A with any attachment from Contractor
5. HECO-13.3B
6. SFMO report and recommendation
7. Document stating that the asbestos abatement, if any, is complete
8. HECO-13.3A with data on entire project and separate sheet showing data on area requested to be occupied.

The University may take Beneficial Occupancy of a portion or unit of the project before completion of the entire project only with the prior written approval of the UBO.

8.10 Beneficial Occupancy – Renovations with No Change of Use

For renovations or alterations to existing buildings or portions of buildings which do not constitute a change of use or occupancy classification for the whole building or any part of the building, the VT PM shall prepare and submit form HECO-13.3A. Issuance by the UBO of an approved form HECO-13.3A closes the permit and authorizes re-occupancy of renovated spaces for projects that required the renovation areas to b

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

e vacated during construction. If the work has been determined to be substantially complete, but still has work remaining which must be completed under the open permit, the VT PM shall request re-occupancy of the building or specific spaces. The UBO may waive some of these requirements based on project size and scope.

Sterrett Facilities Complex
230 Sterrett Drive
Blacksburg, Virginia 24061

APPENDICES

Appendix A	Campus Design Principles
Appendix B	The Virginia Tech Student Experience: VT's Next 20 Years
Appendix C	University Space Management
Appendix D	Site Furnishing Guide
Appendix E	Interior Signage Standards Manual
Appendix F	Campus Wayfinding Guidelines
Appendix G	Hokie Stone Masonry Guide Specifications
Appendix H	Maintenance of Traffic Plans
Appendix I	Approved Plant and Tree Lists
Appendix J	BAS Standards: Sequence of Operations