This document includes **guidelines** only.
The intent is to promote discussion and coordination between consultants, contractors and MSU personnel.
# Table of Contents

I. Overview................................................................................................................................................ 7  
   A. Intent of Guidelines............................................................................................................................ 7  
   B. Campus System Philosophies ........................................................................................................... 7  
   C. Codes & Standards............................................................................................................................ 7  
   D. MSU Energy Efficiency Guidelines .................................................................................................... 8  
   E. Existing System Information.............................................................................................................. 8  
   F. Other MSU Guidelines....................................................................................................................... 9  

II. Top Mechanical Design Issues............................................................................................................ 10  

III. General Mechanical Requirements...................................................................................................... 11  
   A. Access, Maintenance and Replacement Considerations ................................................................. 11  
   B. Temporary Utilities (Electrical, Natural Gas, Steam, Domestic Water, Sewer) ............................. 11  
   C. Temporary Space Conditioning ....................................................................................................... 12  
   D. System Demolition and Removal ..................................................................................................... 12  
   E. System Installation and Performance .............................................................................................. 12  
   F. Vibration and Seismic Control.......................................................................................................... 12  

IV. Campus Utility Systems................................................................................................................... 13  
   A. Utility Locates .................................................................................................................................. 13  
   B. Utility Tunnel System ....................................................................................................................... 13  
   C. Primary Electrical System ................................................................................................................ 14  
   D. Natural Gas System .......................................................................................................................... 14  
   E. Campus Steam / Condensate System ............................................................................................. 14  
   F. Future Campus Condenser (Source) Water System ....................................................................... 14  
   G. Domestic Water System .................................................................................................................. 15  
   H. Fire Protection System ..................................................................................................................... 15  
   I. Sanitary Sewer and Storm Drainage System................................................................................... 16  
   J. Irrigation Water System .................................................................................................................... 16  
   K. Compressed Air for Controls .......................................................................................................... 16  

V. HVAC System Environmental Guidelines............................................................................................ 17  
   A. General............................................................................................................................................ 17  
   B. Design Temperature Conditions ..................................................................................................... 17  

VI. HVAC Hydronic Systems.................................................................................................................... 18
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>General Piping and Piping Applications</td>
<td>18</td>
</tr>
<tr>
<td>B.</td>
<td>Steam / Condensate Systems</td>
<td>20</td>
</tr>
<tr>
<td>C.</td>
<td>Heating Water Systems</td>
<td>21</td>
</tr>
<tr>
<td>D.</td>
<td>Chilled Water Systems</td>
<td>21</td>
</tr>
<tr>
<td>E.</td>
<td>Cooling Tower Systems</td>
<td>22</td>
</tr>
<tr>
<td>F.</td>
<td>Pumping Systems</td>
<td>22</td>
</tr>
<tr>
<td>VII.</td>
<td>HVAC Air Distribution Systems</td>
<td>24</td>
</tr>
<tr>
<td>A.</td>
<td>General</td>
<td>24</td>
</tr>
<tr>
<td>B.</td>
<td>Air Handling Systems and Specialties:</td>
<td>24</td>
</tr>
<tr>
<td>C.</td>
<td>Fume Hoods and Laboratory Systems</td>
<td>26</td>
</tr>
<tr>
<td>VIII.</td>
<td>HVAC Refrigeration Cooling Systems</td>
<td>27</td>
</tr>
<tr>
<td>A.</td>
<td>General</td>
<td>27</td>
</tr>
<tr>
<td>B.</td>
<td>Variable Refrigerant Flow Systems</td>
<td>27</td>
</tr>
<tr>
<td>C.</td>
<td>Refrigeration Systems</td>
<td>27</td>
</tr>
<tr>
<td>IX.</td>
<td>HVAC System General Electrical Requirements</td>
<td>28</td>
</tr>
<tr>
<td>A.</td>
<td>HVAC Motors</td>
<td>28</td>
</tr>
<tr>
<td>B.</td>
<td>Variable Frequency Drives</td>
<td>28</td>
</tr>
<tr>
<td>X.</td>
<td>HVAC System Control</td>
<td>29</td>
</tr>
<tr>
<td>A.</td>
<td>General</td>
<td>29</td>
</tr>
<tr>
<td>B.</td>
<td>Building Pressure Control</td>
<td>29</td>
</tr>
<tr>
<td>C.</td>
<td>Air Handling Systems</td>
<td>29</td>
</tr>
<tr>
<td>D.</td>
<td>VAV Terminal Units</td>
<td>30</td>
</tr>
<tr>
<td>E.</td>
<td>Steam and Heating Water Systems</td>
<td>30</td>
</tr>
<tr>
<td>F.</td>
<td>Fans and Pumps</td>
<td>30</td>
</tr>
<tr>
<td>G.</td>
<td>MSU HVAC Virtual Private Network (VPN) Numbering and Device Addressing</td>
<td>30</td>
</tr>
<tr>
<td>XI.</td>
<td>Plumbing Systems</td>
<td>35</td>
</tr>
<tr>
<td>A.</td>
<td>General</td>
<td>35</td>
</tr>
<tr>
<td>B.</td>
<td>Fixtures</td>
<td>35</td>
</tr>
<tr>
<td>C.</td>
<td>Emergency Fixtures</td>
<td>35</td>
</tr>
<tr>
<td>D.</td>
<td>Water Efficiency</td>
<td>35</td>
</tr>
<tr>
<td>E.</td>
<td>Domestic Water Systems</td>
<td>36</td>
</tr>
<tr>
<td>F.</td>
<td>Domestic Hot Water Systems</td>
<td>36</td>
</tr>
</tbody>
</table>
G. Waste and Vent Systems ................................................................. 36
H. Fire Protection Systems ................................................................. 37

XII. Metering .................................................................................. 38
     A. In Progress ........................................................................... 38

XIII. Top Lighting Design Issues ..................................................... 39

XIV. General Lighting Requirements .............................................. 41
     A. Access, Maintenance and Replacement Considerations ........ 41
     B. System Demolition and Removal .......................................... 41
     C. Spare Parts ......................................................................... 41
     D. Lighting Rebates: ................................................................. 42

XV. Interior Lighting ......................................................................... 43
     A. General .............................................................................. 43
     B. Interior LED Performance Requirements ............................. 43
     C. Luminaire Selection: ......................................................... 44

XVI. Exterior Lighting ....................................................................... 45
     A. General .............................................................................. 45
     B. Exterior LED Performance Requirements ........................... 45
     C. Luminaire Selection ............................................................ 45
     D. Lamp and Ballasts .............................................................. 45
     E. Luminaire Mounting and Poles ............................................ 45
     F. Light Pollution and Trespass ............................................... 46

XVII. Emergency Egress and Exit Lighting ....................................... 47
     A. General .............................................................................. 47
     B. Emergency Egress and Exit Lighting .................................... 47

XVIII. Central Lighting Control Systems ......................................... 48
        A. General ........................................................................... 48
        B. Interior Lighting Controls ............................................... 48
        C. Exterior Lighting Controls ............................................... 49

XIX. System Commissioning, TAB & Training Requirements ......... 50
        A. HVAC Testing, Adjusting and Balancing ........................... 50
        B. HVAC Commissioning ..................................................... 50
        C. Lighting Commissioning .................................................. 50
D. Demonstration (Functional Testing) without Third-Party Commissioning Agent .............................. 51
E. Training............................................................................................................................................ 52
F. Operating and Maintenance Manuals .............................................................................................. 53
I. Overview

The Montana State University-Bozeman Engineering & Utilities department recognizes the importance of clearly communicating general campus information, design concepts and building requirements to key participants involved in the design and construction of engineered systems. This guideline is a living document that will be updated as needed.

A. Intent of Guidelines

This document is intended to help improve the efficiency and quality of future planning and construction efforts. It is intended to accomplish the following:

- Standardize systems
- Focus design efforts on preferred arrangements
- Decrease design time requirements
- Reduce project review time
- Reduce inventory of spare parts

B. Campus System Philosophies

The philosophies used to guide overall design and installation of engineered systems on the MSU campus are presented below. These five key areas should be carefully considered by consultants, contractors and vendors.

1. **Priority on Public Safety.** Public safety is a primary focus when designing systems and specifying equipment for engineered systems.

2. **Expected Building and System Life Span.** MSU expects most campus core buildings to have a life span of at least 50 years. Major systems should be designed and selected for a life of at least 25 years between major remodels.

3. **Operating and Maintenance Efficiency.** Operating and maintenance costs are a major factor in the life cycle cost of a building. Systems should be selected that provide the lowest life cycle cost. University Services employees maintain the majority of the systems constructed on campus. Select and design systems that reduce maintenance costs and provide a safe working environment.

4. **Energy Conservation.** MSU is committed to sustainable building design and other energy management initiatives that reduce operation costs and exemplify good stewardship of state funds and natural resources.

5. **Creative Design Solutions.** MSU encourages creative design solutions and progressive building systems that balance the reduced maintenance of equipment while increasing energy savings.

C. Codes & Standards

Consultants, contractors and vendors are required to make themselves aware of all applicable codes and ordinances and assure compliance. This includes, but is not limited to:

2. IESNA Handbook, 10th Edition

3. Relevant IESNA Recommended Practice handbooks

4. City of Bozeman Uniform Development Code (UDC)

5. LEED Requirements, if applicable.


7. Montana S.B. 49, which requires state funded buildings exceed IECC 2012 by 20%

D. MSU Energy Efficiency Guidelines

1. Provide energy efficient systems meeting current International Energy Code requirements (or current ASHRAE Standard 90.1).


3. For buildings or remodel projects larger than 10,000 sq ft, perform energy studies for alternative systems as requested by MSU University Services personnel to determine arrangement with lowest Life Cycle Cost.


5. Provide system suitable for recovering heat from water-cooled cooling systems in laboratory buildings, and others as requested.

6. Contact MSU University Services personnel for current utility costs and expected inflation rates. Average rates for 2018 are:
   - Electricity: blended rate $0.10/kWh
   - Steam from Heating Plant: $10.00/1000 lbs
   - Natural Gas: $8.00/dkth
   - Water: $28.00/MCF
   - Sewer: $38.00/MCF

E. Existing System Information

The following information is available and can be requested from MSU University Services personnel:

- Building (wall) plans
- Original building plans, specs, O&M manuals
- Remodel plans, specs, O&M manuals
- Utility system plans
- Site plans (ground elevations, surfaces, surface features, etc)
F. Other MSU Guidelines

The following guidelines are also available and can be requested from MSU Facilities Services personnel:

- MSU Primary Electrical Guidelines
- MSU Irrigation Specifications
- MSU Classroom Guideline
- MSU Campus Ambient Noise Guideline
- MSU Division 23 Mechanical Master Guideline Specification
- MSU Facilities CAD Standards Manual
II. **Top Mechanical Design Issues**

The following design issues are regularly identified by MSU University Services personnel through the design review process. These design issues should be carefully considered by consultants, contractors and vendors. All questions should be directed to the MSU University Engineer.

1. **Local Climate.** MSU is in a very harsh environment, with a very low outside design temperature and likely snow accumulations for much of the year. Systems should be properly designed and equipment locations selected based on these conditions.

2. **Maintenance Accessibility.** For all equipment, provide adequate access and clearance for maintenance. Provide local storage for materials typically used for periodic maintenance (filters, etc.). Provide elevators or stairs for access to large mechanical areas. Avoid ladders where possible. Install hoists and other devices where materials must be lifted at stairs or ladders. Clearly show maintenance access on Construction Documents.

3. **System Redundancy.** Provide redundancy for major systems or components where failure of those systems or components would prevent reasonable functionality of areas served.

4. **HVAC Control Systems.** For new buildings, provide digital control systems from list of pre-approved MSU vendors. For existing buildings, extend existing control systems using current vendor. Connect to and/or extend campus-level systems where present for a vendor.

5. **HVAC Control Points.** Provide available input and output points on each controller for future use. Do not fill controllers completely. Provide BAS alarming functions for all critical equipment.

6. **Metering.** Meter all utilities (electricity, water, gas, and steam condensate, unless requested otherwise) for each building. Provide sub-metering within buildings where requested. Connect to existing Schneider ION campus level metering system. Temporary metering may be required when using campus utilities during construction.

7. **Mechanical (Grooved) Pipe Joints.** Provide rigid couplings for all systems, except at specific locations where required for expansion or vibration compensation. Avoid grooved joints in piping for any system in a non-accessible location. Grooved joining systems are not allowed on Heating Water Systems or Steam Systems. Design systems with defined expansion compensating systems and show on Construction Drawings.

8. **Resilient Materials.** No butterfly valves or other valve types with elastomeric materials to be used for Heating Water Systems or Steam Systems.

9. **Temporary Heating, Cooling, Ventilation and Humidification.** For renovation areas that will be occupied during construction, provide temporary heating, cooling, and/or ventilation systems as required to maintain functionality of areas served.
III. General Mechanical Requirements

A. Access, Maintenance and Replacement Considerations

1. Provide adequate and safe access to all mechanical equipment for maintenance, repair and replacement based on manufacture guidelines and discussion with MSU University Engineer. Include suitable access doors and clearances.
2. Provide local storage for materials typically used for periodic maintenance (filters, spare parts, etc.).
3. Consider adequately sized doors, openings and egress paths for equipment transport through and in/out of buildings.
4. Provide elevators or stairs for access to large mechanical areas. Provide hoists, trap doors or other devices where access to mechanical areas is limited to stairs or ladders.
5. Equipment requiring routine maintenance should preferably be mounted at or near floor level. For heavy equipment mounted above the floor, consider if rigging is required and provide access for rigging equipment.
6. Equipment in ceilings should be accessible with an 8-ft ladder. Where possible, install equipment above hallway ceilings rather than above office or classroom space. If located in rooms, ensure access with ladder without moving furniture.
7. Consider lay-in ceilings to provide maintenance access and flexibility for future renovations. For hard ceilings, review access door locations with MSU University Architect and MSU University Engineer.
8. Provide fall protection where roof-mounted equipment must be located within 10 ft of roof edge.
9. Provide building mounted access ladders for roof access where a roof hatch is not available.

B. Temporary Utilities (Electrical, Natural Gas, Steam, Domestic Water, Sewer)

1. General: Use of temporary campus utilities must be coordinated with MSU University Engineer. Temporary utilities may be provided to the Contractor via connection to the MSU campus infrastructure or directly to the Contractor by the individual Utility Company.
2. New Building Construction and Major Additions: Coordinate temporary metering requirements with MSU Engineering & Utilities Manager when using MSU campus utilities during construction. Project budget to include cost of utilities during construction.
C. Temporary Space Conditioning

1. **Existing Buildings:** Renovations affecting existing HVAC systems must provide temporary heating, cooling and humidification as needed to maintain specific environmental conditions for critical systems and spaces. Address method of temporary heating / cooling with MSU University Engineer.

2. **New Building Construction and Major Additions:** Use of equipment to provide heating, cooling or ventilation during construction must be reviewed with MSU University Engineer. Consider minimizing energy use impact.

D. System Demolition and Removal

1. MSU buildings typically go through numerous remodels and additions throughout their lifetime. Remove abandoned systems wherever practical.

2. All active and/or inactive utility piping or distribution within the construction footprint shall be removed and relocated as appropriate. Confirm relocation with MSU University Services.

E. System Installation and Performance

1. **Equipment Location:** MSU is in a very harsh environment, with a very low outside design temperature and likely snow accumulations for much of the year. Locate equipment inside buildings whenever practical.

2. **Visual Impacts:** Review visual impact of mechanical systems with MSU Planning and Architectural staff, and University Facilities Planning Board (UFPB).

3. **Noise Impacts:** Adhere to MSU Classroom Guidelines for noise transmission inside buildings. Adhere to MSU Campus Ambient Noise Guidelines for noise transmission outside of buildings.

F. Vibration and Seismic Control

1. Provide vibration isolation where required to prevent noise transmission.
IV. Campus Utility Systems

MSU owns piping and distribution systems for most/all utility systems serving the campus core including high-voltage electrical, steam/condensate, natural gas, domestic water, fire protection water, irrigation water, sewer, storm drain and compressed air for controls.

A. Utility Locates

1. All utilities should be locatable by MSU.
2. For non-conducting piping, use industry standard methods such as tracer wire to allow utilities to be located. Ensure that tracer wire is terminated above ground in an easily identified location.
3. Ensure proper ground depth when using omni-ball type locating devices. Confirm that utilities can be located after installation.
4. Verify that utility locate methods work properly with third party utility locator or MSU personnel if available.
5. As-built drawings should include general locate information such as method used (tracer wire, omni-ball or other) and location of termination.
6. MSU prefers that all utilities be GPS recorded prior to backfill and referenced to MSU GPS base station. Horizontal and vertical accuracies should be included. At a minimum, include real world coordinates on as-built drawings with at least three control points.
7. For work on existing utilities, ensure that locate methods remain in place and functional for future use. Replace as needed if locate devices are damaged such as severing of tracer wire.

B. Utility Tunnel System

MSU utility tunnels typically contain steam, electricity, domestic water, irrigation and control system compressed air. Projects that require extension of utility services shall be coordinated with MSU University Engineer. Accessible tunnels are the preferred method for extending utility services to new buildings wherever practical.

1. Precast concrete tunnel sections are the preferred method of constructing new tunnels, but may not be suitable for all applications. Consult MSU University Engineer.
2. Consider tunnel dimensions to allow for maintenance access and tunnel travel.
3. Determine proper exterior tunnel waterproofing system to ensure adequate drainage and moisture control. Include details on Design Documents.
4. Minimize tunnel penetrations and where required ensure water tight construction.
5. Provide anchors and guide racks for systems located in tunnels. Include details on Design Documents and provide adequate clearance for access and maintenance.
6. Provide electrical outlets at regular intervals.
7. Provide valves at all connections to tunnel piping that will allow service from either
direction in loop and to allow isolation of all systems for maintenance without building
shutdown.
8. Extend campus radio communication system whenever new tunnel sections are
constructed. Radiax cable, dividers, antennas and hangers shall be properly detailed
on Design Documents. Determine if new campus radio repeaters and antennas are
required. Properly detail on Design Documents. Confirm location for new radio
repeaters and antenna locations with MSU University Engineer.

C. Primary Electrical System
1. Primary electrical is located in tunnels, underground and overhead. Systems operate
at 12.5 KV.
2. Consult MSU Primary Electrical Guidelines before modifying or extending these
systems.

D. Natural Gas System
1. Natural gas is distributed at 5 - 12 psig.
2. Use plastic piping underground.
3. Reduce pressure before entering buildings, to a maximum of 2 psig (preferred) and 5
psig (absolute).
4. Do not penetrate tunnels or buildings below grade.

E. Campus Steam / Condensate System
1. Steam and condensate piping and distribution systems are located in tunnels and
some are direct-buried.
2. Campus steam is distributed through a network of medium pressure mains at 45 psig
to most buildings on campus.
3. Condensate is collected and returned to the Heating Plant by condensate pumps in
each building.
4. Design of steam piping within tunnels shall include expansion joints, guides and
anchors. In-line manufactured expansion joints shall be avoided where possible. Use
offset loops, guides and anchors to absorb expansion where possible. When
unavoidable, review with MSU University Engineer and provide service valves and
drain connection.
5. Provide manufactured pre-insulated piping systems for direct-buried piping.
6. Where feasible, convert campus steam to hot water for comfort heating.
7. Electric resistance heating is to be avoided whenever possible.

F. Future Campus Condenser (Source) Water System
1. In the future, MSU is interested in utilizing a district source water loop approach to
transfer excess energy between buildings. It is expected that this loop will operate
between about 60°F-90°F and will not contain glycol.
2. Building water source loops should be designed with this future application in mind. Arrange heating, cooling, and heat recovery systems to enable connections to a future district source water loop.

3. Current expectations are that building and campus source water loops will be separated by a heat exchanger. The campus loop will be a direct-return arrangement with campus level pumping provided outside of building projects. Provide building level pumps to handle typical pumping requirements. Where campus source loop is not present, provide piping stubs and valves in convenient location for future installation of heat exchanger and connection to campus loop.

G. Domestic Water System

1. Domestic water at City of Bozeman pressure is located in tunnels and underground piping.

2. Cross contamination control in all facilities is a critical concern. Where appropriate and feasible, consider separate water distribution systems within each facility, i.e., potable, non-potable, fire and irrigation. The non-potable system shall serve laboratory and similar end-user requirements.

3. A single pipe can be brought into building for domestic water and fire protection from MSU-owned systems. Connections to City systems may have other requirements.

4. Backflow Devices
   a) Install redundant backflow devices at domestic water service to each building, so that the water service can be maintained while one device is being tested or repaired. Allow for generous space in such areas for proper testing and maintenance.
   b) All building distribution systems must be isolated from each other by backflow prevention devices. Allow for generous space in such areas for proper testing and maintenance.
   c) A separate backflow device shall be inserted on any branch line leading to mechanical equipment or other devices that present a contamination hazard.

H. Fire Protection System

1. Domestic water may be used for fire protection systems. Consult records maintained by the Safety and Risk Management department and the MSU Fire Marshall for MSU fire hydrant flow and residual pressure tests.

2. All new buildings shall be provided with wet-pipe sprinkler fire protection systems throughout, except where disallowed by code or where dry-pipe or other type is required for freeze protection or other reasons.

3. Match existing fire alarm system vendor in existing buildings unless directed otherwise by MSU University Engineer.

4. In new buildings, provide fire alarm systems by Edwards System Technology.

5. Consult MSU Fire Alarm Guidelines (in progress) before modifying or extending these systems.
I. Sanitary Sewer and Storm Drainage System
   1. Sanitary sewer and storm drainage systems are separated. All inactive sanitary or storm piping within the construction footprint shall be removed.
   2. Corrosive waste may require a dilution/neutralizing tank and/or monitoring system. Coordinate with MSU University Engineer and City of Bozeman. Radioactive wastes are disposed of by a collection service.

J. Irrigation Water System
   1. Irrigation water from an MSU pond is distributed in tunnels and underground.
   2. Consult MSU University Services and MSU Irrigation Specifications before extending these systems.

K. Compressed Air for Controls
   1. Compressed air for control systems is distributed at 100 psig in tunnels. Air is filtered and dried and suitable for direct supply to control systems. Extend system for controls where required.
   2. Air is not for laboratory or general building use. These applications must be reviewed and approved by MSU University Engineer.
V. HVAC System Environmental Guidelines

A. General

1. **Indoor Air Quality**: HVAC design shall comply with the International Mechanical Code. Systems shall be designed to make use of outside air for free-cooling “air side economizer” where feasible.

2. **Mechanical Cooling**: MSU is in a heating dominated climate. Many of the existing buildings and HVAC systems were designed without mechanical cooling. The addition of mechanical cooling during building or system renovations shall be discussed with MSU University Engineer. Mechanical cooling for new construction and major additions shall be discussed with MSU University Engineer early in the design process. For dormitories, the use of mechanical cooling shall be limited to common spaces only.

3. **Continuous Air Conditioning**: Those areas requiring continuous air conditioning shall be provided with a stand-alone / independent air conditioning system. HVAC systems that must operate large fans/ motors to serve these areas and other portions of the building during unoccupied hours is unacceptable. This includes data closets, communication closets and other areas with continuous high-density cooling requirements:

4. **Occupied / Unoccupied Temperatures**: HVAC systems shall be sized appropriately to bring buildings from unoccupied setpoint temperatures during winter design conditions within a reasonable time frame by incorporating morning warm-up strategies and appropriate system sizing.

5. **Humidification**: Humidification shall not be used unless program requires. If humidification is required, see Section VII: HVAC Air Distribution Systems for equipment requirements.

B. Design Temperature Conditions

1. **Indoor Design Conditions**: Basic temperature standards are 68°F for heating and 75°F for cooling (where mechanical cooling is available). Specific uses and applications may require different comfort guidelines. Proposed design comfort levels must be approved by MSU University Engineer early in the design process.

2. **Outdoor Design Conditions**: MSU is in a very harsh environment, with a very low outside design temperatures. Systems should be properly designed based on these conditions.
VI. HVAC Hydronic Systems

A. General Piping and Piping Applications

1. **Drawings**: Provide one-line diagram on construction drawings showing general arrangement of major system elements and control sequences.

2. **Mechanical (Grooved) Pipe Joints**: Provide rigid couplings for all systems, except at specific locations where required for expansion or vibration compensation. Avoid grooved joints in piping for any system in a non-accessible location. Grooved joining systems are not allowed on Heating Water Systems or Steam Systems. Design systems with defined expansion compensating systems and show on Construction Drawings.

3. **Dielectric Unions**: Avoid use of threaded dielectric unions. Provide transition between piping systems of different materials with flanged dielectric unions in accessible location. Provide isolating valve on system side of flanged union to isolate branch piping and unions from mains.

4. **Expansion Joints**: In-line manufactured expansion joints shall be avoided where possible. Use offset loops, guides and anchors to absorb expansion where possible. When unavoidable, review with MSU University Engineer and provide service valves and drain connection.

5. **Piping Insulation**:
   a) Insulation shall comply with current IECC requirements or ASHRAE Standard 90.1 latest edition.
   b) Ensure sufficient access around piping in field to install and seal joints on insulation system.
   c) Provide complete and continuous insulation wherever possible. Provide continuous unbroken vapor barriers for piping systems carry material at temperatures that will likely be below ambient dewpoint at any time.
   d) Provide removable insulation covers for large items requiring access for maintenance. Covers to be form-fitting, finished on inside and outside with a durable cover suitable for system temperatures and held in place by Velcro, wire and hooks or other approved method.

6. **Valves**:
   a) Install all valves in accessible locations.
   b) Install valves to permit equipment service without drain down.
   c) Provide valves on all terminal heating and cooling units.
   d) Provide isolation valves and riser drains at the base of each main distribution riser. Valves shall also isolate floors and where practical isolate areas of main and sub-main piping on large floor plans for service and future tie-ins.
7. **Pressure Gauges:**
   a) Pressure gauges shall have a minimum of 4” dial and be selected to read near center of range during normal conditions. Gauges shall be visible from the floor.
   b) Provide pressure gauges for all pumps, at expansion tanks, pressure reducing stations and building service entrances.

8. **Temperature Gauges:** Provide temperature gauges at hydronic supply and return piping serving major equipment including heat exchangers, AHU coils, etc.

9. **Pressure / Temperature Test Plugs:**
   a) Test plugs shall be installed at all terminal heating and cooling devices on both supply and return pipes. This includes all chilled water and heating water coils.
   b) Test plugs shall be installed at any pressure/differential pressure measuring devices.

10. **Air Venting:**
    a) Provide automatic air vents at all system high points and major equipment, with vent outlets piped to drain or glycol tank.
    b) Provide manual air vents at all small coils. Manual air vent to be 1/4" ball valve with 24” long piece of 1/4” OD piping on outlet.

11. **Water Feed Systems:**
    a) Provide a non-potable water source with pressure regulator and water meter near all hydronic systems. Provide direct connection to systems without glycol and provide hose connection for systems with glycol.
    b) Provide glycol feeder for glycol systems. Route drains, relief valve discharge, and air vent outlet piping to glycol feeder tank. Route feeder overflow to floor drain.

12. **Water Treatment:**
    a) Provide all chemical feed system equipment in contract. Equipment shall be suitable for chemicals from current MSU supplier.
    b) Provide chemicals from current MSU supplier. Contact MSU University Engineer for current supplier information.
    c) Provide raw glycol that is hard water compatible.
    d) Provide inhibitor matching MSU campus standard.
    e) Flush new piping until water runs clean, remove and clean strainers. Steam piping does not need to be flushed. When first energized, each strainer must be blown down. New condensate piping shall be cleaned by flushing condensate through the receiver tank to drain for a minimum of 12 hours.
    f) Flushing through any heat exchanger is not allowed. Provide bypass to equipment prior to flushing.
13. **System Pressure Control**:
   a) Note design pressures at significant points in the system on the drawings, including expansion tank air pre-charge, fill pressure, maximum tank pressure, relief valve pressure setting, etc.
   b) Note approximate system volume.
   c) Note glycol %.
   d) Size expansion tanks for minimum 40% propylene glycol, which requires larger tanks.
   e) Install tank isolation valve, and a drain valve between isolation valve and tank, for draining tank and checking pre-charge.

B. **Steam / Condensate Systems**

1. **Building Steam Entrance**:
   a) Building entrances require a main steam shut-off gate valve and pressure gauge for the entire building.
   b) Provide a pressure reducing station, 1/3 – 2/3 system type, where steam enters the building to reduce pressure to (5-15 psig) unless approved by MSU University Engineer. No bypass required.
   c) Provide Fischer 92B pressure regulators for uniformity.
   d) Provide flash steam heat recovery where medium pressure steam is used for major equipment and where a simultaneous use for the recovered heat is available.

2. **Steam to Heating Water Converters (Heat Exchangers)**:
   a) For systems with glycol, provide normally-closed spring return steam valves for steam-water heat exchangers. Power to valves shall be hard-wired through auto-reset high temperature limit controller and independent of any control logic. Controller shall remove valve energy source when heating water temperature exceeds design temperature by approximately 20°F. After three high-limit events (monitored through relay) within a reasonable period of time, lockout valve operation and alarm through DDC system. Provide reset through DDC interface.
   b) Steam control valves shall be 1/3 – 2/3 type.

3. **Steam Traps**:
   a) Provide minimum 6-12" drop from equipment condensate outlet to steam trap. Size trap based on head pressure generated by drop (1/4 psid for 6" and ½ psid for 12", etc)
   b) Provide equalizing line with check valve between modulating steam valve at coil/device and outlet of trap or vacuum breaker. Equalizing line is preferred.
   c) Provide redundant traps or multiple partial-capacity traps for all important equipment.
d) Provide a schedule on design documents for steam traps, indicating type, operating pressure and differential pressure at desired capacity.

e) Provide Spirax/Sarco, Hoffman or Armstrong for uniformity.

f) Steam traps and equipment they serve must both be in the same room. This should be clear on drawings.

4. **Steam Coils:**
   a) Air unit steam coils in contact with mixed or outside air shall be non-freeze type.
   b) Coils shall be mounted high enough to allow for proper condensate drainage by gravity through the trap.

5. **Condensate Pumps:**
   a) Pumps shall be duplex, low NPSH type with TEFC motors.
   b) Provide cast-iron receivers when available.
   c) Provide pump suction isolation valves.
   d) Provide lead-lag pump operation.
   e) Provide alarm to DDC on lag pump operation.
   f) See additional pump requirements in **Section F: Pumping Systems**.

C. **Heating Water Systems**

1. **System Temperature:** Provide low temperature heating water systems wherever possible, with maximum temperature of approximately 140°F.

2. **Resilient Materials:**
   a) No butterfly valves or other valve types with elastomeric materials.
   b) Provide rigid couplings for all systems. Grooved joining systems are not allowed on Heating Water or Steam systems unless approved by MSU University Engineer.
   c) Provide Graphonics flange gaskets for all flanged piping systems.

3. **Heating Water Pumps:**
   a) Provide redundant heating water pumps with lead-lag controls.
   b) See additional pump requirements in **Section F: Pumping Systems**.

D. **Chilled Water Systems**

1. **Chiller Type and Configuration:**
   a) Specify chillers to allow competition between manufacturers.
   b) Provide water-cooled chillers wherever practical.
   c) Provide primary-secondary pumping for larger systems, with constant chiller flow and variable coil flow where practical. Variable primary flow systems must be approved by MSU University Engineer.
   d) Provide minimum 5-10 gallons system water volume per ton of installed chiller capacity, or as recommended by chiller manufacturer.
2. **Flat Plate Heat Exchangers:**
   a) Provide min ¾” access ports for flushing on both Hot and Cold sides of heat exchanger.
   b) Provide isolation valves on all heat exchanger piping.
   c) Provide manufacturer recommended strainers on the entering side of the heat exchanger. Provide accessibility to fully remove strainer for cleaning.

3. **Glycol:**
   a) Provide glycol for chilled water systems wherever possible. Glycol must be provided for all systems that cannot otherwise be protected from freezing without drain-down.
   b) Provide glycol feeder.

4. **Chilled Water Pumps:**
   a) Provide redundant chilled water pumps with lead-lag controls.
   b) See additional pump requirements in Section F: Pumping Systems.

E. **Cooling Tower Systems**
1. Provide permanent structures for access to all tower components.
2. Remote sumps located inside buildings are not preferred. Prevent spring/fall freezing through control strategies that allow for draining. Discuss approach with MSU University Engineer.
3. Provide three-way tower bypass valves or other capacity modulating strategy as approved by MSU University Engineer.
4. **Chemical Feed Systems:**
   a) Provide all chemical feed system equipment in contract. Equipment shall be suitable for chemicals from current MSU supplier.
   b) Provide chemicals from current MSU supplier. Contact MSU University Engineer for current supplier information.
   c) Provide raw glycol that is hard water compatible.
   d) Provide inhibitor matching MSU campus standard.
   e) Biocides: Manual dry feed with ability to vary amount of biocide.
   f) Feed chemical based on make-up water volume.
   g) Bleed system water on total dissolved solids.

F. **Pumping Systems**
1. Provide redundant pumps where serving important functions with lead-lag controls.
2. Provide vibration isolation where required to prevent noise transmission.
3. **Pump Valves:**
   a) Provide separate isolation valves, check valve and manual balance valve for each pump.
b) Provide manual balance valve at each pump or other method for directly reading flow. Avoid triple-duty valves where practical. Venturi type are preferred.

4. **Pump Pressure Gauges:**
   a) Provide pressure gauges for suction, discharge and suction diffuser pressures on all pumps.
   b) Pressure gauges shall be selected to read near center of range during normal conditions.
   c) Gauges shall be visible from the floor.

5. **Controls:**
   a) Provide lead-lag controls.
   b) Provide separate electrical circuit to feed each pump.
VII. HVAC Air Distribution Systems

A. General

1. **Drawings**: Provide one-line diagram on construction drawings showing general arrangement of major system elements and control sequences.

2. **Access for Maintenance**: Provide access doors for all louvers, automatic dampers, filters, motors, controls, upstream of reheat coils, upstream and downstream of AHU coils, and other components requiring inspection or maintenance.

3. **Humidification**: If humidification is required, campus steam is not allowed to be used for direct humidification due to chemical treatment. Lined ductwork is not allowed downstream of humidifiers.

B. Air Handling Systems and Specialties:

1. **Air Handling Units**:
   a) Provide air-side economizers wherever practical.
   b) Provide backdraft (preferred) or automatic dampers (if back-draft are not possible) at each fan in parallel fan systems (i.e. redundant fans and/or Fan Wall systems).
   c) Reduce the generation and transmission of noise in air handling systems by use of sound-reducing construction and spring isolation systems.
   d) Provide filter racks if not provided by equipment manufacturer.

2. **VAV Terminal Units**:
   a) Show control box location and access requirements on plans for coordination with other trades.
   b) Select boxes for largest box that will control properly at minimum airflow to reduce noise.
   c) Provide VAV boxes with integral sound attenuators or line outlet ducts to reduce noise.

3. **Heat Recovery Units**:
   a) General:
      (1) Stationary flat-plate type preferred. Discuss other arrangements with MSU University Engineer prior to use.
      (2) Discharge condensate drain to area not subject to freezing.
      (3) Provide automatic dampers in outside air and exhaust air ducts to close when unit is off.
   b) Defrost Control:
      (1) Provide defrost control suitable for -30°F operation.
      (2) Exhaust and supply fans to operate during defrost cycles for areas requiring continuous outside air.
c) Duct Insulation:
   (1) Insulate outside air, exhaust air, and supply air ducts.

4. Fans:
   a) Inline fans are not preferred due to maintenance access. Discuss applications with MSU University Engineer prior to use.

5. Duct Systems:
   a) Ensure sufficient access around ductwork in field to install and seal joints on insulation system.
   b) Provide access doors upstream of all reheat coils, fan powered boxes, and VAV boxes to permit inspection and cleaning of coils. Provide access door near motorized dampers, fire dampers and smoke dampers.
   c) Provide sheet-metal duct systems with sealed joints. Non-metal duct board is not acceptable. Fabric duct maybe used when approved by MSU University Engineer for specific applications.
   d) Provide adequate duct-length, flex duct and/or other measures to reduce noise transmission from manual dampers and VAV boxes to diffusers and grilles.
   e) Do not install 90 degree miter vanes in elbows that do not have equal inlet and outlet dimensions. Use radius elbows or adjustable vanes.
   f) Provide ducted return air wherever practical.
   g) Provide plenums with drains for intake louveres.
   h) Avoid underground duct systems.
   i) Provide 1/2” mesh screens at un-ducted return openings in ceiling spaces.

6. Dampers & Louvers:
   a) Back-draft Dampers: Install back-draft dampers in main return air openings into ceiling plenums. Dampers to prevent outside air from leaky OSA dampers from entering ceiling spaces.
   b) Manual Dampers:
      (1) Provide balancing dampers with locking quadrant actuators and full length axles. “Jiffy” damper sets are not acceptable.
      (2) Provide manual balancing dampers at least 4 ft from grilles. Avoid opposed blade dampers at grilles.
   c) Automatic Dampers
      (1) Provide diagonal bracing at low leakage dampers to provide long-term stability of damper geometry. Low leak dampers have very tight tolerances, and often require that diagonal dimensions be within (+/- 1/8") for proper operation. Measure and confirm that dampers are installed within mfr tolerances, and that braces are installed to maintain that geometry.
(2) Provide 1” jackshafts with separate connection to each damper section for multi-section dampers.

d) Fire-Smoke Dampers
   (1) Provide suitable access for smoke detectors, damper actuators, fire links, controls and damper blades.
   (2) Provide resettable links.
   (3) Provide test stations located so that they can be reached from the floor without a ladder.

7. Diffusers and Grilles:
   a) Provide adjustable-throw ceiling supply diffusers in offices wherever possible, to allow easy adjustment from horizontal to vertical throw to reduce drafts.
   b) Provide double-deflection wall supply grilles where used.

8. Monitoring and Gauges:
   a) Provide temperature gauges at important locations in air handling systems including outside air, mixed air, supply air, terminal unit discharge and other locations important for assessing system function and control.
   b) Provide averaging bulb sensing elements where airstreams are not well mixed or can otherwise be expected to have varying temperatures across duct.

9. Variable Frequency Drives (VFD):
   a) See requirements in Section IX: HVAC System General Electrical Requirements.

C. Fume Hoods and Laboratory Systems

1. Fume Hoods:
   a) New fume hood systems shall be face velocity controlled using variable air volume controls where connected system is compatible.
   b) Consider occupancy sensor setback and / or automatic sash repositioning.
VIII. HVAC Refrigeration Cooling Systems

A. General

1. Piping shall be brazed copper unless coordinated otherwise with MSU University Engineer.
2. Install oil traps on suction lines when necessary for proper oil return. Refer to manufacturer requirements.
3. Provide low ambient control, filter dryer, sight glass / moisture indicator, liquid line solenoid valve and refrigerant service valves.
4. Condensers that utilize domestic water as source of heat rejection are allowed in some applications. Discuss with MSU University Engineer prior to use.
5. Provide phase monitors for all three phase condensers/compressors.

B. Variable Refrigerant Flow Systems

1. Identify relevant characteristics of VRF systems in specifications and/or on drawings, including
   a) whether system provides heat recovery,
   b) when system can provide heat recovery,
   c) heating capacities and design ambient temperature
   d) cooling capacities and design ambient temperature
2. Coordinate location of “master” thermostats that determine branch selector box heating-cooling mode.
3. Install all refrigerant piping joints in accessible locations.
4. Coordinate VRF systems with any other heating or cooling systems serving the same area.
5. Provide separate occupied and unoccupied temperature setpoints.
6. Provide occupancy scheduling functions, preferably through building DDC system if available.
7. Interface VRF systems with building DDC systems if possible and identify monitoring points and other coordinating requirements on construction documents.

C. Refrigeration Systems

1. Water source when applicable and used for heat recovery.
2. Provide a pump down system on all walk-in coolers and freezers.
3. Provide service access for all evaporator coils to disable power and allow the compressors to pump refrigerant down into a receiver.
4. Locate time clocks for defrost control in mechanical room with compressor.
5. Provide liquid filter dryers on all refrigerant loops.
6. Provide a suction accumulator on the refrigerant loop for all freezers.
IX. HVAC System General Electrical Requirements

A. HVAC Motors

1. For redundant / multiple pump and fan configurations, provide separate electrical circuit to feed each motor where practical.
2. Motors for use in VSD applications shall be inverter ready type motors.
3. Motors for use in VSD applications shall be provided with shaft grounding rings to reduce VFD-induced bearing failure. Preferably factory installed.

B. Variable Frequency Drives

1. General:
   a) Provide integral disconnect, overload protection and short-circuit protection.
   b) Provide brown-out and phase-loss protection.
   c) VFD input power voltage and phase to be same as motor nominal voltage and phase
   d) Provide line reactors or other devices on large motors or where required to avoid problems caused by harmonic distortion.

2. VFD Bypasses and Redundancy:
   a) Provide VFD with integral bypass for all non-redundant systems, where equipment can operate at 60 HZ without compromising system operation.
   b) Provide redundant VFDs where equipment cannot operate at 60 HZ without compromising system operation, i.e. direct-drive fans that need to operate at non-synchronous (1800, 3600, etc.) speed.
   c) Provide redundant VFDs for systems where multiple fans in parallel are intended to operate at the same time (i.e. Fan Wall).

3. VFD Setup:
   a) Provide hard copy of all non-default set-up parameters to Owner.
   b) For series and parallel fans, set up VFD to properly brake when systems are rotating forward or reverse upon startup.
   c) When VFDs with bypasses serve belt-drive equipment, provide belt drive suitable for proper operation at 60 HZ.
X. HVAC System Control

A. General

1. Match existing control system vendor in existing buildings where possible or include replacement as alternate.
2. In new buildings, provide control systems by one of the following manufacturers/vendors:
   a) Johnson Controls Incorporated
   b) Electro Controls (Delta/Siemens Building Technologies)
   c) Facility Improvement Corporation (Andover)
   d) Mechanical Technology Incorporated (Invensys)
3. For digital systems, make operating and maintenance (O&M) information available at user interface locations. O&M information to include data sheets for products, system as-built diagrams, and sequences of operation.
4. Provide as-built and sequence of operation as separate links on graphics main page.
5. Provide uninterruptable power supply and surge protector for all digital control systems to prevent power surges and short-term power outages (less than 5 min) from affecting stability of control systems.
6. Controls and building level controllers for any systems on emergency power should also be on emergency power.
7. Provide available input and output points on each controller for future use. Do not fill controllers completely.
8. Provide BAS alarming functions for all critical equipment.

B. Building Pressure Control

1. Building Pressurization: Provide control sequences that will maintain positive building pressure during all likely circumstances.

C. Air Handling Systems

1. **Unoccupied Override Requirements:**
   a) General: Provide occupant-accessible unoccupied period override capability for all systems. Override for minimum 2 hours.
   b) Single Zone Systems Serving One Room: One override control accessible to occupants in room.
   c) Single Zone Systems Serving Multiple Rooms: Provide one override control in location accessible to all occupants.
   d) Multiple Zone Systems: Provide separate override control for each zone. Main AHU to operate when override activated. Activated zones are to maintain occupied temperatures. Other zones to maintain unoccupied temperatures.
2. **Control Dampers:**
   a) Provide one actuator per damper shaft. Avoid piggy-back actuators.
b) Provide multiple damper shafts and multiple actuators when one actuator cannot provide adequate torque for entire assembly.

c) Do not use pilot positioning devices on pneumatic actuators for outside air, relief air, or exhaust air dampers, because those devices apply full pressure (to open NC dampers) when pilot spring fails.

d) Cross-brace duct sections with dampers to maintain dimensional stability of dampers and ensure long term operation. Low leakage dampers require diagonal tolerances of about 1/8” to maintain proper operation and torque ratings.

D. VAV Terminal Units

1. Controls shall typically include dual maximum control logic for efficiency. Volume control settings shall adjust CFM such that minimum flow is determined based upon ASHRAE 62 standards and not necessarily CFM required for heating.

2. Boxes shall have unoccupied mode settings and the ability to be individually scheduled.

E. Steam and Heating Water Systems

1. For systems with glycol, provide normally-closed spring return steam valves for steam-water heat exchangers. Power to valves shall be hard-wired through auto-reset high temperature limit controller and independent of any control logic. Controller shall remove valve energy source when heating water temperature exceeds design temperature by approximately 20°F. After three high-limit events (monitored through relay) within a reasonable period of time, lockout valve operation and alarm through DDC system. Provide reset through DDC interface.

F. Fans and Pumps

1. **Status:** Use current sensors or paddle-type flow switches for system status. Do not use pressure differential sensors.

G. MSU HVAC Virtual Private Network (VPN) Numbering and Device Addressing

1. **General:**
   a) All HVAC devices utilizing the MSU campus network must be connected to the HVAC VPN, unless specifically allowed to do otherwise.

   b) All HVAC devices on the HVAC VPN using BACnet communication protocols must adhere to the following addressing standards for proper operation.

2. **BACnet Network Number:** (Range 0 – 65535):
   a) The BACnet Standard requires that all devices on the same network segment, follow the SAME network numbering structure to avoid conflicts. In the case of the HVAC VPN subnet at MSU, even though it serves multiple buildings across campus, it is currently configured as one network segment.
b) There are three types of physical networks (IP, Ethernet, MS/TP) in the BACnet architecture. Given the current configuration of the MSU HVAC subnet, the only networks capable of utilizing unique network numbers would be MS/TP trunks, because their physical network segment falls beneath their parent Ethernet or IP device, thereby isolating them.

3. **BACnet IP Network Number (all devices):** 10001.

4. **BACnet Ethernet Network Number (all devices):** 20001.

5. **BACnet MS/TP Network Numbers:** Five Digit Network Number, with digits as follows:
   
   a) Digit 1: 3 or higher for MS/TP network type.
   
   b) Digits 2, 3, and 4: Three-digit building number. MSU will provide this number for each building.
   
   c) Digit 5: Instance/trunk number. First MS/TP trunk could be 0, tenth trunk could be 9. Note that if you exceed 10 MS/TP trunks, then you can start the 11th by increasing the digit 1 (mentioned above) from 3 to 4 in order to allow more MS/TP trunks.

6. **BACnet Device Addressing:** (Range 0 – 4194303):
   
   a) Digit 1: Range 0 to 3, starting with 1 for Bozeman campus.
   
   b) Digits 2, 3, and 4: Three-digit building number. Always use three digits, even if building number is less than 100. (Range 0 - 999)
   
   c) Digit 5: Building network instance number (Range 1 to 9). If there are more than 9 subnets, then you can increase the value of digit 1 by 1 and start over.
   
   d) Digits 6 and 7: Device ID. This is actually an extension of Digit 5, so that the device ID is actually a three digit number 100-199, 200-299, etc.

7. **Operator Workstations, Laptops or Servers:**
   
   a) Provide desktop user workstation inside of buildings with new DDC systems.
   
   b) Provide current antivirus/malware software that is compatible with vendor software and Owner's facilities.
   
   c) Must be compatible with Owner's current virtual private network (VPN) and local area network (LAN).
   
   d) Systems must be coordinated with Facilities Network Administrators. Provide minimum one week notice of intent to install and/or connect systems to MSU VPN or LAN.

8. **Building Level Network:**
   
   a) Protocols: BACnet and/or proprietary.
   
   b) Functionality
      
      1) Control and coordination of all building control systems.
      
      2) Monitoring and changing any system parameters.
      
      3) Programming changes.
(4) All systems to be arranged to operate effectively in stand-alone mode when network communications are lost.
   (a) Provide local outside air temperature sensor or other controls if required to provide appropriate control in stand-alone mode.
   (b) Provide description of system operation in stand-alone mode. Typically, stand-alone mode should provide “occupied mode” control, and suitable operation under all conditions.

c) Operator Interface at Building
   (1) Web browser access through campus network as indicated for external network operator interface.
   (2) Graphics/text presentation similar to that for external network operator interface.
   (3) Direct connection to building level controller (and/or other locations):
      (a) Access via proprietary “tool”, and/or laptop computer.
      (b) Provide all hardware and software required for fully functional operator interface at building level and major system controllers.
      (c) Graphical/text access to entire system functionality.

9. **External Network Interface**:
   a) Campus Network: Connect to existing campus HVAC virtual private network (VPN). Coordinate location of network connections and IP addresses with Owner.
   b) Structure systems to provide one network address (IP) that serves as a single access point for all HVAC systems in the building.
   c) Integrate new building systems with existing vendor hardware and software serving campus whenever possible. Provide new systems or upgrade existing systems where required for new systems to be integrated into existing systems.
   d) Functionality:
      (1) Monitoring any system parameter.
      (2) Changing parameters where required for trouble-shooting, maintenance or operating functions.
      (3) Suitable for minimum of 10 simultaneous users with view, invoke and command/adjust capabilities.
      (4) Trending set-up, access, and printing.
10. **External Operator Interface:**
   a) **General:**
      (1) Standard Web browser interface.
      (2) Text/tabular format option for system parameters.
      (3) Graphics option with presentation similar to that for internal network operator interface.
   b) **Security:**
      (1) Password hierarchy for various user access capabilities.
      (2) Owner-definable limits on IP addresses which are allowed access.
      (3) Embedded operating system that is not susceptible to security problems or 10 years of software upgrades and patches to address discovered security problems.
   c) **Mechanical System Diagrams:**
      (1) Summary page showing major system parameters and alarms.
      (2) Provide diagrams for all major systems (air handling, heating, cooling, etc.)
      (3) Graphical representation of system and components, with hyperlinks to specific information for individual components.
      (4) Information for all system parameters including current value, status, set-points, and current alarms.
      (5) Interactive capability for appropriate parameters (set-points, schedules, etc).
   d) **Building Systems and Plans:**
      (1) Summary page showing zone temperatures and alarms.
      (2) Floor plan representation of building with room numbers from construction documents.
      (3) Line drawings, text, and/or colors showing general locations of equipment, and areas served by systems, zones, etc.
      (4) Location of control elements outside of mechanical areas (duct pressure sensors, room sensors, etc.)
      (5) Space control points (temperature, humidity, or other as provided), with current value, set-points, and current alarms.
      (6) Interactive capability for appropriate parameters (set-points, schedules, etc).
      (7) Hyperlinks on plans to access related system diagrams; i.e. hyperlink to proper VAV box and AHU serving a room.

11. **Trending:**
   a) Capability to trend all significant system parameters.
   b) Trends to be set up by contractor for all significant system parameters. Coordinate with Owner.
c) Contractor to set up trends so that data are kept at all times for main system parameters. Trends should be at least 3 days, and preferably 7 days, at a minimum of 15 minute intervals or change of state.

d) For vendors with campus level servers, provide long term trending for all parameters. Oldest trends to be deleted first as storage capacity is reached.

e) Contractor to provide a simple way to graph and print selected parameters. Graphs to be capable of having multiple parameters on one graph.

f) Review trending capabilities and trend set-up during start-up phase and coordinate requirements with Owner.
XI. **Plumbing Systems**

A. **General**

1. Cross contamination control in all facilities is a critical concern. Where appropriate and feasible, consider separate water distribution systems within each facility, i.e., potable, non-potable, fire and irrigation. The non-potable system shall serve laboratory and similar end-user requirements.

2. Provide minimum 24" width clear in plumbing chases where access to valves, carriers, and piping is required for maintenance.

3. Provide isolating valves at all branch mains to each floor, groups of fixtures, and elsewhere to ensure that a minimum number of fixtures are affected by maintenance activities.

4. Provide floor drains in all toilet rooms and in other areas where water is likely to end up on the floor through maintenance activities or failure of equipment.

B. **Fixtures**

1. Coordinate desired type of plumbing fixtures and trim for basis of design with MSU Facilities Services plumbing foreman.

2. Specify relevant qualities of desired fixtures and trim to allow bidding for multiple manufacturers. Specify three manufacturers of acceptable products where possible.

3. Provide ceramic-disk, quarter-turn valves/levers for dual-handle faucets.

4. Provide automatic flush for urinals.

5. Avoid automatic flush for water closets.

6. Provide battery powered automatic operator for public lavatories.

7. Do not use waterless fixtures.

C. **Emergency Fixtures**

1. Provide tempered water for laboratory emergency fixtures (ie eyewash stations / showers) to meet current OSHA guidelines.

D. **Water Efficiency**

1. Provide water efficient fixtures that are at or below the following maximum flow rates:
   a) Showers: Maximum 1.5 gpm
   b) Lavatory Faucets: Maximum 0.5 gpm lavatory faucets. For metering faucets maximum rate of 0.25 gallons per cycle.
   c) Kitchen Faucets: Maximum 1.5 gpm
   d) Water Closets: Maximum 1.28 gpf
   e) Urinals: Maximum 0.5 gpf
E. Domestic Water Systems

1. Backflow Devices:
   a) Install redundant backflow devices at domestic water service to each building, so that the water service can be maintained while one device is being tested or repaired. Allow for generous space in such areas for proper testing and maintenance.
   b) All building distribution systems must be isolated from each other by backflow prevention devices. Allow for generous space in such areas for proper testing and maintenance.
   c) A separate backflow device shall be inserted on any branch line leading to mechanical equipment.

F. Domestic Hot Water Systems

1. General:
   a) Store hot water above 140°F to reduce potential for legionella growth.
   b) Provide water tempering valve to maintain hot water to fixtures at desired temperature.

2. Water Heaters:
   a) Steam instantaneous water heaters are preferred where storage is not required. Patterson Kelly PK or approved equal. Aerco units not allowed.
   b) Provide alternate fuel water heater where required. Condensing gas water heaters are preferred.
   c) Provide means to schedule water heater off during unoccupied periods. Provide expansion tank to address expansion.
   d) Condensing gas water heaters to have stainless steel heat exchangers. Lochinvar or similar.

3. Hot Water Recirculation:
   a) Provide recirculation pumps with manual balance valves, check valve, pressure and temperature gauges, and time-clock and/or temperature controlled operation.
   b) Provide balancing valve (manual or automatic), PT plug or temp gauge, check valve, and isolation valves at each parallel branch.
   c) Provide testing and balancing for HWR systems to ensure adequate flow and temperature in each circuit.

G. Waste and Vent Systems

1. General: Install cleanouts in accessible areas. Provide wall cleanouts instead of floor when possible.

2. Materials:
   a) Provide cast-iron waste and vent systems, unless otherwise coordinated with MSU University Engineer.
b) Provide fire-rated poly-propylene piping for acid waste and vent, with fused joints in inaccessible locations and mechanical joints in exposed locations.

c) Discuss specialized materials required for unusual systems or applications.

3. **Sump Pumps**:

   a) Provide duplex pumps for all sump pump systems.

   b) Waste system pumps to be grinder type.

   c) Pumps and floats to be maintainable without entering sump pit.

   d) Sump pit high water alarm to DDC system.

   e) Elevator sump pumps to discharge to hose bibb outside of pit. Provide high water alarm and manual switch operation outside of pit with signs. Send high water alarm to DDC where available.

H. **Fire Protection Systems**

   1. Provide Storz Model 6000 adapters at new fire hydrants on the large diameter outlet fittings.
XII. Metering
   A. In Progress
XIII. Top Lighting Design Issues

MSU University Services personnel regularly identify the following design issues through the design review process. Consultants, contractors and vendors should carefully consider these design issues. All questions should be directed to the MSU University Engineer.

1. **Maintenance Accessibility.** Do make all equipment accessible and provide adequate clearance for maintenance. Indirect lighting, at a more accessible height, may be more appropriate than luminaires in a high ceiling. Avoid mounting locations that require scaffolding or lifts for maintenance. Remote mount drivers for high ceiling applications, when feasible.

2. **Spare Parts.** Limit the quantity of luminaire styles, when possible, to make common replacement components more easily sourced or stocked for replacement.

3. **Control System Complexity.** It is not possible for MSU to maintain a myriad of control systems. To limit the reliance on local vendors and off-site manufacturers, controls shall be simplified to the extent possible.

4. **Durability.** Lensed luminaires are prone to damage and collect insects. Lens styles for specialized troffers change frequently and can be difficult to match or replace. Consideration shall be given to flat panel LEDs for general recessed linear lighting, as well as other high performance and durable products.

5. **Glare.** Source glare from high efficacy LEDs shall be considered, along with the viewer/task/luminaire orientation and luminaire optics. Dimming controls assist in mitigating complaints from occupants more sensitive to glare from LED sources.

6. **Color Temperature.** Color temperature shall be carefully selected for the space type & application. Classrooms shall vary from breakout spaces & common areas to promote fast-paced tasks vs spaces meant for relaxation or breaks. Acceptable color temperature ranges can be found within this document.

7. **Color Quality.** Art instruction spaces, medical instruction areas, and other specialized applications shall have special CRI considerations. These shall be coordinated with the user group during design. Minimum CRIs for various applications can be found within this document.

8. **Battery Replacement.** Centralize battery systems for emergency lighting to simplify maintenance and testing.

9. **Driver Locations.** Drivers fail much sooner than the luminaire and require more frequent replacement. Consideration shall be given to remote drivers for hard to reach or high ceiling applications. Locations of remote drivers shall be coordinated with university personnel and labeled appropriately within the building.
10. **Light Loss Factor (LLF) and Criteria.** The designer shall make their design criteria clear to the university personnel and demonstrate compliance with those criteria prior to issuing construction drawings. Careful thought shall be given to the light loss factors used for LED luminaires, based on LM79/LM80 data and other, more conventional factors. **It is critical for the designer to establish proper illuminance levels for the function of the space without creating excess illumination.**
XIV. General Lighting Requirements

A. Access, Maintenance and Replacement Considerations

1. Design shall allow for adequate and safe access to all lighting & lighting control equipment.

2. Coordinate work with Architect and/or MSU University Services to provide maintenance access including adequate access doors and clearances.
   a) Where appropriate in construction documents, indicate areas to be kept free of obstructions for service access, including replacement of equipment.
   b) Building Information Modeling (BIM) shall also be utilized, when possible, to coordinate maintenance access.
   c) A meeting shall be scheduled on each project between the designer and MSU University Services to review maintenance access.

3. Where possible consider the use of lay-in ceilings (in lieu of gypsum or hard ceilings), which permit improved maintenance access and more flexibility for future renovations.

4. Equipment in ceilings should be accessible with an 8-ft ladder whenever possible. Where the opportunity arises, install equipment above hallway ceilings rather than above office or classroom space. If equipment is located in rooms, ensure access with ladder without moving furniture such as above the door swing.

5. Luminaires requiring a lift for maintenance (atria, etc.) shall have remote mounted drivers and consideration shall be given to utilizing a daylight dimming control to extend the lifetime of the luminaires.
   a) Gymnasiums are an exception: Due to higher output requirements, remote mounted drivers are not economically feasible.

B. System Demolition and Removal

1. MSU buildings typically go through numerous remodels and additions throughout their lifetime. Remove abandoned systems wherever practical. This includes all wiring & raceway back to the source.

2. All active and/or inactive power or control wiring/raceway for lighting, within the construction footprint, shall be removed and relocated as appropriate. Confirm relocation with MSU University Services.

3. Fluorescent lamps being removed or replaced with LED type shall be recycled in accordance with EPA recommendations.
   a) Proper disposal of fluorescent lamps is the responsibility of the contractor and documentation shall be provided to MSU University Services.

C. Spare Parts

1. Drivers: 2%, minimum one (1) of each type

2. LED Boards: 2%, minimum one (1) of each type
D. Lighting Rebates:

1. Prior to starting the lighting design on each project, the electrical engineer shall review
   the lighting rebates available from Northwestern Energy for new and remodel projects.
   Evaluate the cost and payback associated with the necessary lighting upgrades to
   acquire the various rebates and discuss with MSU. The lighting system shall be
   designed to acquire the lighting rebates that are cost effective.

2. Coordinate all rebates with MSU Resource Conservation Specialist.
XV. Interior Lighting

A. General

1. All new and retrofit interior lighting shall be LED type, no exceptions.
2. The designer shall make a conscious effort to limit the quantity of driver and LED board types, to facilitate ease of maintenance of the lighting system.
3. Provide appropriate lighting levels for the tasks performed in each space. Do not over illuminate. Produce and review design criteria with MSU University Services, prior to completion of construction documents.
4. Design illuminance (lux or fc) levels shall be based on the recommended values given in the IESNA Handbook, 10th Edition, allowances prescribed by the energy codes, and as indicated below:

B. Interior LED Performance Requirements

1. **Warranty:** 5 years minimum (10 years preferred and may be requested)
2. Tested in accordance with IESNA TM-21
3. **Minimum L70:** 50,000 hours
4. **Minimum Efficacy:**
   a) Troffers or flat panels: 100 lm/W
   b) Downlights: 70 lm/W
   c) Linear: 85 lm/W
5. **Correlated Color Temperature:**
   a) Typical spaces will be 3500K. Consideration shall be given to the space use type, within a range of 2700K-3500K.
   b) Special applications shall be discussed with MSU during design development or earlier.
   c) Dynamic white designs and automatic controls are to be considered for special applications and the above constraints do not apply to those projects.
6. **Color Rendering Index (CRI):**
   a) Minimum 82
   b) Special applications shall require 90+ CRI
      (1) Art/architecture studios or instruction areas
      (2) Specialized laboratories or instruction areas, which deal with bodily fluids
      (3) Gallery or exhibit spaces which display student work
      (4) Coordinate other specialized application types with Architect and/or MSU University Services
C. Luminaire Selection:

1. Select luminaires according to the function of the space, for low maintenance requirement, high-energy efficiency, and long life.

2. The LED flat panel products listed below meet MSU lighting guideline minimum performance requirements. Equal products are also acceptable. Products not meeting minimum guidelines will be rejected.
   a) Axlen LED flat panel luminaire
   b) Lithonia HE LED flat panel luminaire

3. Incandescent lighting is not allowed. LED sources are required in new construction. TLED lamps may be considered for remodels of existing spaces that currently utilize fluorescent luminaires.

4. Specify glass, metal, and other long-life materials for luminaire construction that are not degraded quickly by age, environment, and exposure to UV radiation.

5. Locate luminaires to facilitate maintenance and driver replacement. Avoid locating luminaire drivers in non-accessible ceiling spaces, unless access panels are carefully coordinated in the project design. If remote drivers are specified for maintenance accessibility:
   a) Locate drivers in a central closet or custodial location if distance allows.
   b) Locate drivers in groups for ease of maintenance.

6. Downlights, which allow access to their own driver, must be minimum 4” aperture for access. Locate overhead luminaires so that they are accessible by ladder, power lift, or other readily available means. Luminaires placed over stairs are not allowed.

7. Luminaires that utilize high-pressure sodium or mercury vapor HID lamps are not allowed. Consult MSU University Engineer or Resource Conservation Specialist for LED lamp replacement specifications for HID retrofit projects & applications.
XVI. Exterior Lighting

A. General

1. All new and retrofit exterior lighting shall be LED type, no exceptions.
2. The designer shall make a conscious effort to limit the quantity of driver and LED board types, to facilitate ease of maintenance of the lighting system.
3. Refer to ‘Montana State University – Exterior Lighting Master Plan’ for additional information and requirements for exterior illumination.
4. Existing pole mounted luminaires for walkways, parking lots, and roadways throughout the campus are a mix of Kim Archetype and Philips Pureform luminaires. The Kim Archetype luminaires originally utilized a high-pressure sodium lamp (70 watt HPS for the walkways, 150 watt HPS for the roadways and 250 watt HPS for the parking lots). Many of these luminaires have been retrofitted with an LED replacement lamp.
5. The University Centennial Mall utilizes 3000K Philips Pureform edge lit technology, as of spring 2019.

B. Exterior LED Performance Requirements

1. Design illumination (lux or fc) levels shall be based on the recommended values given in the IESNA Handbook, 10th Edition.

C. Luminaire Selection

1. All new pole mounted luminaires shall be a Philips Pureform with LED light engine or approved equal by MSU. LED color temperature shall be 3000K, in accordance with City of Bozeman requirements.
2. For new site lighting projects near the Centennial Mall, consideration shall be given to Philips Pureform 3000K low glare edge lit technology.
3. Existing pole mounted 4000K Pureform heads can be updated with a replacement 3000K LED board.
4. Building mounted area luminaires shall utilize an LED light source. Size and shape of luminaire shall be coordinated with the architecture of the building. All building mounted luminaires shall have a color temperature of 3000K.
5. All new installations (pole and fixtures) shall have an in-line fuse installed in the pole base. Fuse shall be sized a 125% of the fixture amps.

D. Lamp and Ballasts

1. Exterior lighting shall utilize LED light sources and be full cut off. Approval of all exterior luminaires is required by MSU during design process.

E. Luminaire Mounting and Poles

1. Building mounted luminaires shall be mounted on flush mounted junction boxes or recessed in canopies or horizontal surfaces (preferred).
2. Conduit for building mounted luminaires shall not be exposed on building surface.
3. All exterior lighting circuits shall have a separate insulated ground wire.

4. Each pole-mounted luminaire shall be mounted to a Ameron concrete pole to match the existing poles. In order to minimize the variety of poles on campus, non-standard poles will be rejected unless there is substantial cause from a design standpoint.

5. Pole specifications for various applications are as follows:
   a) Walkway luminaires shall use 16 ft-5in Ameron pole (catalog number MEO-5). Exceptions will be considered with prior approval. Consideration shall be given to new design projects that utilize increased pole height to achieve proper illuminance and reduced pole quantity.
   b) Roadway lighting shall have a mounting height of 25ft and shall use 29ft-11in Ameron pole (catalog number MEO-9).
   c) Parking lot luminaires shall use 27ft-11in Ameron pole (catalog number MBO-8.5). Parking lot poles and poles located in areas that may be subject to damage are to be mounted on a concrete base with base height between 30 and 36 inches above grade.

F. Light Pollution and Trespass

1. Area or roadway luminaires located adjacent to residential neighborhoods and other developed areas, or where light trespass is regulated by local codes, shall have internal shielding to avoid light trespass into adjacent property.


3. Special consideration shall be given to site illumination adjacent to on-campus residential facilities and light trespass into dwelling unit fenestration. Mounting heights and optics shall be adjusted accordingly.

4. Calculations shall be provided to comply with City of Bozeman UDC, for illumination adjacent to properties not owned by Montana State University, or city streets.
   a) Calculations must be submitted within the construction documents, as part of the City of Bozeman permitting process.
XVII. Emergency Egress and Exit Lighting

A. General

1. Emergency illumination is to be integrated into the lighting layout of the space in which it is required and controlled with the space during normal operation. “Bug eye” luminaires shall be avoided in new construction projects.

2. If a generator is available, and a life safety system is fed from the generator, the engineer shall place emergency lighting on the generator, via a UL 924 transfer device (Bodine GTD or equal).

3. When feasible or possible, centralized inverter or ‘space by space’ battery backup shall be specified, in lieu of individual battery drivers.

4. In corridors and stairwells, an inverter that dims the entire zone to a uniform output shall be considered, in lieu of providing backup power to a fraction of the luminaires in the space. The Bodine ELI-S-250 and ELI-S-100 inverter units provide this function for higher connected loads. Consult manufacturer for additional requirements.

B. Emergency Egress and Exit Lighting

1. Central/large scale emergency inverters, where utilized, shall have a typical efficiency (AC out/AC in) of 98%. SNMP communication interface, extended warranty with factory startup, external bypass switch, and upgraded battery charger.

2. Distributed emergency inverters (Bodine ELI series or equal) shall be used where possible.

3. Locate emergency egress lighting to provide illumination levels prescribed by the local codes in effect.

4. Egress illumination shall be provided in accordance with IBC 2012, section 1006.

5. Emergency egress illumination shall be provided for all multi-occupant restroom spaces.

6. Provide a minimum of one (1) emergency luminaire in each electrical and mechanical room. This luminaire may be switched by occupancy control.

7. Illuminated EXIT signs shall be LED with RED lettering. Exit signs must be of high quality construction. In areas of higher architectural importance (to be coordinated with architect), edge lit, recessed exit signs shall be utilized. For back of house areas, a die-cast aluminum exit signs are preferred. Plastic housings are not allowed.
XVIII. Central Lighting Control Systems

A. General

1. Match existing control system vendor in existing buildings.
2. In new buildings, provide control systems by one of the following manufacturers/vendors:
   a) nLight (Acuity)
   b) Lutron
   c) Wattstopper
   d) Crestron
3. For digital systems, make operating and maintenance (O&M) information available at user interface locations. O&M information to include data sheets for products, system as-built diagrams, and sequences of operation.
4. Provide uninterruptable power supply and surge protector for all digital control systems to prevent power surges and short-term power outages (less than 5 min) from affecting stability of control systems.

B. Interior Lighting Controls

1. Lighting controls shall meet the minimum requirements of IECC 2012 & SB 49.
2. Since most LED based luminaires have native 0-10v dimming ballasts as standard, higher consideration shall be given to dimming controls in common space types. Multi-level switching with dimmable LED luminaires is not allowed.
3. Use of “Daylight Harvesting” by dimming luminaires where applicable with photo controls shall be evaluated on all projects. If dimming is not provided, the luminaires within the daylight zone shall be switched separate from the rest of the room.
4. Provide multi-level control as required by the energy code.
5. In areas where automatic lighting shutoff is required by the energy code, provide occupancy sensors for control of the lighting. Light controls that are based on a time clock are not desired.
6. Occupancy sensors in rooms or in locations with modular furniture or other obstructions shall utilize dual technology. Designer or engineer shall verify spacing with control system manufacturer during design. Occupancy sensors in modular furniture areas shall have adjustable PIR and ultrasonic settings, with the initial field setting set to the maximum level.
7. In areas with audio-visual presentation requirements, provide scene setting controls or a dimming zone to reduce work plane illuminance to 10 fc (100 lux) average and mitigate glare on the presentation medium.
8. In classrooms with podiums, provide podium control or the ability to interface with classroom audio-visual technology.
C. Exterior Lighting Controls

1. Consider vacancy-based response exterior dimming of building mounted and pole mounted luminaires for dimming during unoccupied hours with instant return to full power upon motion detection. Coordinate with MSU.
2. Control exterior lighting with photocell input.
XIX. System Commissioning, TAB & Training Requirements

A. HVAC Testing, Adjusting and Balancing

1. TAB contractor shall be NEBB certified firm and TAB activities shall be reviewed by a certified TAB Supervisor or Professional.
2. Testing and balancing of air systems shall be performed in complete accordance with the latest version of NEBB Procedural Standards for TAB Environmental Systems.
3. Testing, adjusting and balancing shall be provided by an independent consultant who directly subcontracts to the General Contractor. The test and balance contractor shall not subcontract to the Mechanical Contractor.
4. Before TAB work begins, TAB contractor shall meet with the Owner and Design Engineer to develop and approve TAB strategies, procedures and reporting format.
5. TAB reports shall be reviewed and approved by the Design Engineer of Record to verify that design intent has been met. TAB reports shall include single line schematic diagrams showing HVAC system components, balancing devices, and measurement locations. Include make, model and settings for drive components. Balancing devices shall be marked by the Balancer to indicate final settings.

B. HVAC Commissioning

1. Third-party commissioning agent (CxA) contracted directly to Owner to be provided for all new buildings and large or complex remodel projects. Fees for CxA to be included in project budget
2. Projects without CxA to have functional testing by MSU staff and consultants in accordance with Demonstration specifications below.
3. Coordinate commissioning scope of work with Owner for each project.

C. Lighting Commissioning

1. Discuss and coordinate commissioning approach and scope of work with MSU for each project.
2. For projects of smaller scale and lesser complexity, provide at a minimum factory setup and field adjustment by a local, certified, manufacturer's representative.
3. For all new buildings and large or complex remodel projects, provide:
   a) Third-party commissioning agent (CxA) contracted directly to MSU. Fees for CxA to be included in project budget.
   b) Commissioning of the lighting controls shall be both in accordance with the requirements of IECC 2012, and in accordance with the best practices as defined by the controls manufacturer.
   c) Produce specifications (260800 – LIGHTING CONTROLS COMMISSIONING) to outline responsibilities for the CxA and electrical contractor.
d) At least 50% of the building controls shall be tested and verified, including, but not limited to:
   (1) Wall devices
   (2) Occupancy sensors
   (3) Daylight sensors

e) A final commissioning report shall be produced by the CxA and approved by the Engineer.

D. Demonstration (Functional Testing) without Third-Party Commissioning Agent

1. General: Demonstration (functional testing) is distinctly separate from Training. Provide training per Section D: Training below.

2. Demonstration Program:

   a) Engineer to develop a demonstration program to verify the proper operation of all required systems. Submit program to Owner and Contractor at least two weeks prior to Demonstration.

   b) Engineer to work with Contractor to generate methods to be used to verify sequences and modes of operation that cannot be verified directly.

   c) For complex sequences, or where setting up tests are not practical, provide trends and graphs of related system parameters showing proper sequences and stability of control loops.

   d) Engineer to provide at least one copy of all submittals, contract drawings, specifications, and changes related to systems to be demonstrated. Documents to be made available during Demonstration.

   e) Contractor to provide at least one copy of draft Operating and Maintenance Manuals to be used during demonstration, including specified sequences of operation for field-constructed systems, and operating sequences for all manufactured equipment.

3. Demonstration Session:

   a) Verify that all systems are functional and ready to operate in all modes prior to demonstration.

   b) Assemble all program materials required for demonstration.

   c) Contractor to provide all equipment necessary for access to, and operation of, systems including tools, ladder, lighting, and diagnostic equipment.

   d) Verify operation of individual components within systems.

   e) Verify controls of related components are coordinated.

   f) Verify all operating sequences, operating modes, and safety controls.

   g) Record all pressures, temperatures, and other relevant data available from installed devices.
h) Where digital control systems are available, set-up trend reports of relevant parameters which will confirm proper operation of systems installed, modified, or affected by changes made during this project. Provide copies of reports to Engineer and Owner for review. Review, analyze, and discuss results, and provide follow-up reports as required to confirm proper operation.

E. Training

1. **General**:
   a) General: Training is distinctly separate from Demonstration (functional testing). Provide Demonstration per **Section C: Demonstration** above.
   b) The system training is intended to familiarize the Owner’s operating and maintenance staff with all systems requiring maintenance. Training is to be provided after the systems are in place and operational, after issues noted during the Demonstration have been resolved, and before final acceptance.
   c) Provide second set of training sessions for automatic control systems about 6-9 months after the first sessions.

2. **Systems Requiring Training**:
   a) All mechanical, electrical, safety, standby, and automatic control systems in the project, and other systems specified elsewhere to have training.

3. **Attendance**:
   a) Training is to be provided by contractor’s representatives that are familiar with the system’s operation and maintenance requirements. Individual training sessions (modules) are to be provided for each type or group of systems, separated roughly by trade group that will be performing maintenance on the system. MSU trades groups and systems typically requiring training are:
      1. Electricians (Power, lighting, fire alarm and detection, standby power systems)
      2. Grounds Maintenance (Grounds surfaces, lawn sprinkler systems)
      3. Heating Plant (Hydronic and steam heating systems, fan systems, controls)
      4. Plumbers (Plumbing, gas-fired heating, lawn sprinkler systems, fire sprinklers, miscellaneous process piping systems)
      5. Refrigeration (Refrigeration, chilled water, packaged cooling systems, controls)

4. **Documentation**:
   a) Contractor to submit draft copy of agenda and training documents to Owner for review at least two weeks prior to training date.
   b) Provide a copy of the following items for each person that will be attending the training sessions. Coordinate required number with the Owner.
(1) Training agenda.
(2) Summary of new systems and existing systems affected by this project.
(3) Summary of work performed under this project.
(4) Control system drawings and sequences of operation.
(5) List of important maintenance and trouble-shooting operations for all systems.

c) Provide minimum of 2 copies of following items:
   (1) Contract documents including all drawings, specifications, addendums, and change orders.

5. **Training Sessions**:
   a) Assemble at location to be determined by the Owner.
   b) Distribute training documentation as indicated above.
   c) Provide classroom style training if required for orientation, discussion of new systems and existing systems affected by this project, and other issues appropriate for a classroom format.
   d) Visit site and review locations, and perform detailed review of operation and maintenance requirements for current systems.

6. **Scheduling**:
   a) Duplicate training sessions are to be provided for each training module, so that Owner's operating personnel can be split into two groups during training.
   b) Provide duplicate training sessions in different weeks to allow those on vacation or otherwise not available to get training.
   c) Schedule ample time for training. Length of training sessions will be determined by scope of training indicated below, and as coordinated with Owner after draft copy of training documents have been reviewed.
   d) Schedule all training for a trades group consecutively on the same day, for example:
      (1) Monday: Refrigeration
      (2) Tuesday: Electricians
      (3) Wednesday: Plumbers
      (4) Thursday: Heat techs
      (5) Friday: Controls (heat and refrigeration techs)
   e) Schedule training between 9am – 12pm and 1-4 pm. Allow time for one break in middle of each session.

F. **Operating and Maintenance Manuals**
   1. Provide electronic (PDF) copy of draft manuals for Owner and Engineer to review.
   2. Provide PDF and three paper copies of approved O&M manuals to Owner.