SECTION 25 00 00
INTEGRATED AUTOMATION

Note: All building controls projects will be Tridium Niagara DDC based.

Note: This section provides an overview of the entire Division 25. It includes background information for reference on Stanford building control systems. It includes important controls specific details related to submittals, execution, and project deliverables. These details can be retained in this section for standalone controls projects, or they can be moved and integrated within the Division 1 section for large projects.

Background note: Stanford has now standardized on a commercial DDC based software system (based upon the Tridium Niagara platform) capable of performing front end control system requirements. These requirements include: common user interface for all buildings, single point user authentication, user access security consistent with University IT protocols, central alarm management, central occupancy scheduling, automated program and data backup.

GENERAL

1.1 SUMMARY

A. Section includes the general requirements for the Integrated Automation systems. This includes all building control and monitoring systems related to HVAC and utility interface.

B. Related Sections:
1. 25 00 00 Integrated Automation
2. 25 05 13 Conductors and Cables
3. 25 05 28 Pathways
4. 25 05 53 Identification
5. 25 06 11 Integrated Automation Definitions
6. 25 11 19 Building Control Systems Server
7. 25 12 19 Integration Protocols
8. 25 12 23 Client-Server Information/Database Integration
9. 25 13 00 Control and Monitoring Network
10. 25 13 13 Building Level Controller
11. 25 14 00 Local Control Units
12. 25 14 23 Field Equipment Panels
13. 25 15 00 Building Control Systems Server Software
14. 25 15 16 Software for Programming Local Control Unit
15. 25 15 23 Graphics
16. 25 33 13 Thermal Utility Metering Interface
17. 25 35 13 Actuators and Operators
18. 25 35 15 Switches and Relays
19. 25 35 16 Sensors and Transmitters
20. 25 35 17 Air and Gas Pressure and Flow Measurement
21. 25 35 18 Liquid Pressure and Flow Measurement
22. 25 35 19 Control Valves
23. 25 35 26 Compressed Air Supply
24. 25 35 28 Guideline for Control Sequences
25. 25 56 00 Monitoring and Control of Electrical Equipment
C. Where architectural features govern location of work, refer to architectural drawings and coordinate with other trades.

1.2 REFERENCES

A. Object Naming and Tags Spreadsheet. Latest version furnished to Contractor by Stanford FAC.

B. Stanford University Niagara 4 Standards. Latest version furnished to Contractor by Stanford FAC.

C. This section includes any rules and regulations of Federal, State, local authorities, and utility companies in force at the time of execution of contract.

D. Agencies or publications referenced herein refer to the following:
   2. ANSI/CEA Standard 709.C LonTalk protocol
   3. ASHRAE American Society for Heating, Refrigeration, Air-Conditioning Engineers
   4. ASHRAE Fundamentals Heating and Cooling Load Calculation Methods
   5. ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy
   6. ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality
   8. California Energy Commission (C.E.C.) Title 24
   9. DIN-IEC 751 Standard for platinum sensors
   10. FCC Federal Communications Commission
   12. NEC 725 ......Class 1, Class 2, and Class 3 Remote Control, Signaling And Power-Limited Circuits
   13. NEC 800 Communications Circuits
   14. NEMA National Electrical Manufacturers Association
   15. NEMA WD7 Occupancy Motion Sensors.
   16. UL Underwriters Laboratories, Inc.
   17. UL 773A Non-Industrial Photoelectric Switches for Lighting Controls.
   18. Sheet Metal and Air Conditioning Contractor's National Association (SMACNA)
   20. Stanford Guidelines for Sustainable Buildings

Note: Edit the above list for each project. Make sure each item is appropriate and are coordinated.

1.3 DEFINITIONS

A. Refer to 25 06 11 Integrated Automation Definitions

1.4 SYSTEM DESCRIPTION

Stanford utilizes multiple control system platforms based upon the application level (see below) and the functional requirements of the associated processes.

A. Utilities:
   1. Stanford utilizes Tridium Niagara to integrate Building thermal utility metering and interface data consolidated in the Utility Interface Panel. This includes chilled water, hot water, and process steam.
B. Building Level:
   1. Stanford utilizes Tridium Niagara to integrate DDC based systems for campus wide monitoring and control. All occupancy scheduling is controlled from Tridium Niagara.

C. Air Handling Unit Level:
   1. Tridium Niagara integrated DDC controllers shall be used to control and monitor air handling units.

D. Zone Level:
   1. Use DDC controllers to control and monitor zone level (variable air volume, fan coils, etc) units.

Note: Scope of Work, Alternates, and Unit Prices must be defined for each project. The following language is a template from a typical DDC retrofit project.

1.5 SCOPE OF WORK

A. The contractor shall furnish and install a fully integrated temperature control system, UL listed, incorporating a Lon-based direct digital control (DDC) for energy management, equipment monitoring and control, including color graphics.
   a. Each copy of Tridium Niagara software shall include a 5 year Niagara Software Maintenance Agreement.

B. Furnish and install Distech EC-Bos Building Level Controllers connected by TCP/IP network and one LonMark Certified DDC Controller per VAV box and fan coil unit. Location and minimum quantity of Network Controllers is specified in the System Architecture Schematic.

C. Furnish and install all network cabling, routers and hubs required to provide a fully functional network.

D. Furnish and install a Tridium Vykon Supervisor Station on an Owner-furnished Building Control System Server (Virtual Machine) connected to the Distech EC-Bos Building Level Controllers via TCP/IP network.

E. Contractor is responsible to ensure that Building Level Controllers are connected to Owner’s TCP/IP network, and that remote monitoring and alarming is fully functional before any piece of equipment connected to Building Level Controllers may be left to run unattended in automatic mode of operation.
   1. Owner is responsible for functionality of Owner’s TCP/IP network.

F. Furnish and install a Modbus 485 RTU connection from the Distech EC-Bos Building Level Controller to the Delta V system if specified in the System Architecture Schematic.

G. Furnish and install all instrumentation specified in the sequence of operations and/or control schematics required for a complete and operating system.

H. Furnish and install transformers and all associated wiring, conduit, panels, and tubing for all DDC controls.

I. Contractor shall develop and publish simple one-page thermostat instructions for each type of thermostat. Submit thermostat instructions for FAC review.

J. The contractor shall be responsible for work associated with the temperature control system.

K. The contractor shall be responsible for system integration and commissioning.

L. The contractor shall be responsible for Lighting Controls System integration and demonstrating Lighting Plug Fest. Refer to Section 25 56 00, Monitoring and Control of Electrical Equipment.
M. The contractor shall include up to 10% additional trends, beyond specified trends, if requested by Owner.

N. The contractor is responsible for the accuracy and completeness of latest Stanford N4 Standards including applying all Relations, all Mandatory Device Level Tags, and all Type-Dependent Tags, which are Mandatory If Applicable.

O. The Contractor shall be responsible to demonstrate all (typical) Local Control Unit programming to the satisfaction of the Owner’s representative.

P. Contractor is responsible for all required submittals. Failure to submit any required submittal does not alleviate Contractor’s responsibility to implement Owner’s corrections, at no additional cost to Owner and with no slippage of installation schedule.

Q. The contractor shall be responsible for installation of field devices necessary for measurement, verification and control of the various HVAC components that make up the DDC System. A list of VAV boxes and fan coil units is listed in the attached Updated Mechanical Schedule. Locations of thermostats and Updated Mechanical Drawings.

1. VAV boxes with integrated flow sensor – Reuse existing where operational.
2. VAV box controller – Remove and replace with DDC controller and differential pressure transducer.
3. Pneumatic Damper actuator – Remove and replace with electric actuator. Actuator may be integrated into DDC controller.
4. Thermostats – Remove and replace with DDC thermostat.

R. The Contractor shall be responsible to provide power from the control power distribution to all control devices per latest NEC code and FDG requirements. Contractor to conduct field survey and provide construction documents, including power floor plans and panel schedules, for electrical work.

S. Non-operational VAV boxes, reheat valves and fan coil hot water valves shall be replaced as additional work.

1.6 ALTERNATES AND UNIT PRICES

A. Alternates

1. VAV Box Replacement
   a. Replace existing VAV box with reheat coil with larger VAV box with reheat and new control valve and VAV box controls.

2. Reheat Valve & actuator replacement
   a. Replace existing reheat valve & pneumatic actuator with DDC control valve with actuator.

3. Re-piping for valves that do not fit
   a. Re-pipe the existing reheat valve where a retrofit actuator will not fit.

B. Unit Prices

1. Unit Pricing No. 1 - Replace existing reheat coils at VAV terminals and modify existing ductwork as required. Heat hot water coils shall be designed as follows:
   a. Select coil to match existing coil capacity as listed on original record drawing
   b. Select coil with 50°F delta-T, 155°F inlet water temperature, and 105°F leaving water temperature.
   c. Use 2-row coils.
   d. See Stanford FDG for coil specification.
2. Unit Pricing No. 2 - Completely replace existing VAV terminals with new VAV terminals with factory reheat coils and piping. Modify existing ductwork as required.

3. Unit Pricing No. 3 - Replace existing reheat control valves with new ball type control valves. Modifying existing piping as required. Replace existing 2-way and 3-way reheat coil control valve as follows:
   a. Belimo CCV Spring return or electronic fail-safe normally closed chrome plated brass ball or approved equal.

1.7 SPARE PARTS

   A. Furnish the following quantities of Spare Parts calculated as percent of quantity of devices furnished to meet project scope of work.
      1. Refer to Section 25 14 00 Local Control Units for definition of Primary Equipment Controller and Secondary Equipment Controller.
      2. For all controller calculations, include separate percentage calculation based on quantity of controller expansion modules.
      3. All percentage calculations round up to zero decimal place.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Percent of Spare Parts Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated as percent of quantity of devices furnished to meet project scope of work rounded up to zero decimals.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>JACE (No License Required)</td>
<td>20%</td>
</tr>
<tr>
<td>Primary Equipment Controller</td>
<td>25%</td>
</tr>
<tr>
<td>Secondary Equipment Controller</td>
<td>20%</td>
</tr>
<tr>
<td>Sensors - Primary Equipment Applications</td>
<td>20%</td>
</tr>
<tr>
<td>Sensors - Secondary Equipment Applications</td>
<td>10%</td>
</tr>
<tr>
<td>Actuators - Primary Equipment Applications</td>
<td>25%</td>
</tr>
<tr>
<td>Actuators - Secondary Equipment Applications</td>
<td>20%</td>
</tr>
<tr>
<td>Thermostats</td>
<td>20%</td>
</tr>
<tr>
<td>Transformers and Power Supplys</td>
<td>10%</td>
</tr>
<tr>
<td>Relays</td>
<td>25%</td>
</tr>
</tbody>
</table>

1.8 SUBMITTALS

   Note: These are unique building controls related submittal requirements. These can be combined with the project Division 1 document, or retained in this document.

   A. No work may begin on any segment of this Project until the related submittals have been reviewed for conformity with the Project Specifications and the Contractor has responded to all comments to the satisfaction of the Owner's Representative.

   B. Contractor assumes all responsibility for required submissions. Failure to submit any required submittal does not alleviate Contractor's responsibility to implement Owner's corrections, at no additional cost to Owner and with no slippage of installation schedule.

   C. All programming and configuration, including graphics, directory structure, Tagging, Hierarchies, Relations, References, Templates, Modules (jar files) and point naming in Building Control System Server, Building Level Controllers, Local Control Units and any additional devices included in the project scope of work, must be submitted for approval of Stanford FAC before
Contractor may proceed with work. Contractor assumes all responsibility for required submissions. Failure to submit any required submittal does not alleviate Contractor’s responsibility to implement Owner’s corrections, at no additional cost to Owner and with no slippage of installation schedule.

D. All modifications to Owner-furnished Stations, programming code and Stanford Standard graphics must be described in writing and submitted for approval of FAC before Contractor may proceed with work. Failure to submit any required submittal does not alleviate Contractor’s responsibility to implement Owner’s corrections, at no additional cost to Owner and with no slippage of installation schedule.

E. All Contractor modifications to Owner-furnished Stations, programming code and Stanford Standard graphics that are not described in writing and submitted for approval of FAC shall be corrected by the Contractor to the satisfaction of Owner, at no additional cost to Owner and with no slippage of installation schedule.

F. Identify proposed enhancements or deviations from project documents. Include specific drawings or specifications impacted

G. Submit a Project Schedule
   1. For details of Project Schedule requirements, refer to 3.3 Scheduling
   2. All Submittal Packages shall be included as tasks in the Project Schedule.

H. Schedule of Submittal Packages:
   1. Allow minimum 10 working days for approval.
   2. Submittal Package 1 (Hardware, Shop Drawings and Equipment Naming).
   4. Submittal Package 3 (JACE Station(s), Controller Programming and Points List) shall be submitted no less than 15 working days before software is to be installed in field devices.
   6. Submittal Package 5 (Final Supervisor Station with Graphics) must be submitted and approved before Training may be scheduled
   7. Submittal Package 6 (Commissioning and Acceptance Reports)
   8. Submittal Package 7 (Training Materials) must be submitted and approved before Training may be scheduled
   9. Submittal Package 8 (O&M Manuals)

I. Submission and Resubmission Procedure
   1. Each submittal shall have a unique Submittal Package Number and Name: SUBMITTAL 2 (JACE Station, Controller Programming and Points List).
   2. Each resubmittal shall have an original unique Submittal Package Number and Name plus unique revision number such as SUBMITTAL 2 (JACE Station, Controller Programming and Points List) REVISION 1.
   3. Submit one copy of submittal in electronic format specified under each submittal package below. Submissions made in the wrong format will be returned without action.
   4. Owner’s Representative will return a memo or mark-up of submittal with comments and corrections noted where required.
5. Make corrections
   a. Revise initial submittal to resolve review comments and corrections.
   b. Indicate any changes that have been made other than those requested.
   c. Clearly identify resubmittal by original submittal number and revision number.

6. Resubmit revised submittals until no exceptions are taken.
7. Once submittals are accepted with no exceptions taken, record PDF files for coordination with other trades. PDF files will serve as submittal for record and coordination.

J. Submittal Package 1 (Hardware, Shop Drawings and Equipment Naming)

1. Hardware
   a. Organize by specification section.
   b. Do not submit products that are not used even if included in specifications.
   c. Include a summary Table Of Contents listing for every submitted device:
      1). Tab of submittal file/binder where submittal is located
      2). Specification section number (down to the lowest applicable heading number)
      3). Whether device is per specifications and a listed product or a substitution
      4). Manufacturer
      5). Model number
      6). Device accuracy (where applicable)
      7). Accuracy as installed including wiring and A/D conversion effects (where applicable)
   d. A paragraph-by-paragraph specification compliance report indicating compliance for each numbered paragraph. The following format shall be used in completing the compliance report:
      1). Qualify—meet the functional intent. For each paragraph, the contractor shall identify all differences in specific functions stated in the given paragraph and provide a description of what is excluded or how the qualifying system will meet the function specified.
      2). Comply—without exception
      3). Does not comply—cannot meet specified function.
      4). Does not apply – not used or not required
   e. Submittal shall include manufacturer’s description and technical data, such as performance data and accuracy, product specification sheets, and installation instructions for all control devices and software.
   f. When manufacturer’s cut-sheets apply to a product series rather than a specific product, the data specifically applicable to the Project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawings shall clearly reference the specification or drawing that the submittal is to cover. General catalogs shall not be accepted as cut sheets to fulfill submittal requirements.
   g. When manufacturer’s cut-sheets apply to multiple products, all products that are not applicable to this project shall be crossed out, or otherwise clearly denoted as “Not Applicable.”
   i. Table of Contents with Tabs to easily locate corresponding specific cut sheet.

2. Shop Drawings
   1). System architecture one-line diagram indicating schematic location of all control units, and physical location of all control system servers, JACEs, gateways, etc. Indicate address and type for each control unit. Indicate media, protocol, and type of each LAN.
2) Schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment and control devices. The schematics provided on Drawings shall be the basis of the schematics with respect to layout and location of control points.

3) The drawings will indicate the exact location of all control devices with a clear code so that the device can be traced to a controller and sequence of operation.

4) All physical points on the schematic flow diagram shall be indicated with names as listed in the points list.

5) Label each input and output with the appropriate range.

6) Device table (Bill of Materials). With each schematic, provide a table of all materials and equipment including.
   a) Device tag as indicated in the schematic and actual field labeling (use tag as indicated in these specifications where applicable and practical)
   b) Device tag as indicated in these specifications where applicable and if it differs from schematic device tag
   c) Description
   d) Proposed manufacturer and model number
   e) Range
   f) Quantity

7) With each schematic or on separate valve sheet, provide valve and actuator information including size, Cv, design flow, target pressure drop, actual design pressure drop, manufacturer, model number, close off rating, etc. Indicate normal positions of spring return valves and dampers.

8) Indicate all required electrical wiring. Electrical wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.

9) Provide 24V AC transformer load table.

10) Details of control panels, including controls, instruments, and labeling shown in plan or elevation indicating the installed locations.

11) Scale plan view drawings shall show the specific location of all control devices such as sensors, panels, etc.

12) Format
   a) Sheets shall be consecutively numbered.
   b) Each sheet shall have a title indicating the type of information included and the mechanical/electrical system controlled.
   c) Table of Contents listing sheet titles and sheet numbers.
   d) Legend and list of abbreviations.
   e) Schematics
   f) Include AutoCAD or Visio source files

3. Equipment Naming
   a) Submit Niagara Database Equipment Naming for all equipment defined in the project scope of work.
   b) Submit typical naming schema for terminal equipment.
   c) Submit in Excel spreadsheet format (.xlsx)
   d) Match Mechanical Equipment Schedule name by using a naming scheme that converts equipment name as listed in Mechanical Equipment Schedule, to a name that does not violate JAVA object naming rules.
1). The only acceptable character separator is an underscore character, (_).
2). Minimize use of underscore characters.
3). Blank spaces are not acceptable.
4). The first character in the name must be a letter (not a numeral).
5). Example: Equipment Schedule: VAV 1-221; Niagara Equipment Name: VAV1_221

K. Submittal Package 2 (Acceptance Forms – I/O Calibration, Functional Performance Testing, Start Up Reports, etc.)

1. I/O Calibration Forms
   a. Submit all forms used for recording calibration procedures for all system Inputs and Outputs (I/O), consisting of validating field I/O calibration, loop checks, actuator stroking, and integrated system operation validation.

2. Functional Performance Testing (FPT) Forms
   a. Submit all forms used for Functional Performance Testing (FPT) and Sequence of Operation Verification Procedures

3. Start Up Report / Checkout Forms
   a. A checkout form shall be submitted for each system/sequence. Checkout form is to include areas to check and record each facet of the sequence of operations including, but not limited to the following:
      1). Start/Stop
      2). Interlocks
      3). Safeties
      4). Valve and damper stroke
      5). PID Loops
      6). Modes of Operation
      7). Power failure/Recovery

L. Submittal Package 3 (JACE Station(s), Controller Programming and Points List)

1. Subdivide Submittal Package 3
   a. Due to the modular nature of DDC programming, it is acceptable to subdivide this submittal by Building, Floor or Wing, to accommodate Preliminary FPT. i.e Submittal Package 3A – Floor 3 and 4, Submittal Package 3B – Rooftop Air Handlers
   b. Contractor’s proposed subdivision of Submittal Package 3 shall be discussed at the Project Kick-off meeting and is subject to approval of Owner’s Representative.
   c. Each submittal package must be a complete submittal Including JACE Station, Controller Programming and Point Naming for each JACE.
   d. Parsing multiple submittal packages of controller code for controllers attached to the same JACE, is not acceptable.
   e. Graphics developed for Preliminary FPT, do not require approval prior to FPT.

2. JACE Station
   a. All JACE stations must be submitted for review and approval before connecting to any Stanford network or any live data.
b. It is acceptable to submit one typical JACE Station for multiple Stations only if programming and types of controlled equipment are the same; only quantities of controlled equipment differ.

c. Submit JACE Station(s) in .dist format.

d. Submit screen capture of all Niagara point folders and wiresheet programming, in .PDF format, for review by consultants that do not have access to Workbench.

e. During Submittal Review period, the Contractor shall demonstrate all (typical) Niagara programming to the satisfaction of the Owner’s representative.

3. Controller Programming

a. Controller source code for at least one of every unique controller model number and at least one of every permutation of controller programming logic for every controller shall be submitted for every controller attached to JACE in the same submittal.

b. Parsing multiple submittal packages of controller code for controllers attached to the same JACE, is not acceptable.

c. Submit screen capture of all wiresheet programming, in .PDF format, for review by consultants that do not have access to Workbench.

d. During Submittal Review period, the Contractor shall demonstrate all (typical) Local Control Unit programming to the satisfaction of the Owner’s representative.

e. Include specified English-language Sequences of Operation (SOO) of each control sequence updated to reflect any suggested changes made by the Contractor to clarify or improve the sequences. Changes shall be clearly marked. SOO shall be fully consistent with the graphical programming.

4. Points List

a. Submit Points List in a Microsoft Excel spreadsheet, (.xlsx) format. Group points by equipment type. Include separate tab for each equipment type.

b. Include the following Column Headers:

1. Local Control Unit (GFX) Point Name
2. Controller (Equipment) Name (must match submitted Equipment Names)
3. Niagara Point Name;
   a). Any Local Control Unit Point Name not proxied into Niagara indicate; N/A.
4. Final Prepended Name (History). Niagara Point Name prepended with Controller (Equipment) Name. Cannot exceed 44 characters total.

c. Points List shall include sufficient description of point functionality to determine how Point Name is applied in programming.

d. Approval of Submitted Points List Names, is not approval of programming that uses the submitted point name.

e. Any multi-iteration submittal of point names must clearly indicate all point names that have been previous submitted, with identifying date of previous point name submission.

M. Submittal Package 4 (Partial Supervisor Station without Graphics).

a. The purpose of Submittal Package 4 is to attempt to identify Niagara Supervisor deficiencies as early as possible.

b. Supervisor station must be submitted for review and approval before connecting to any Stanford network or any live data from JACEs.

c. Partial Supervisor Station because it is acceptable to submit:
1. Typical Niagara Point Naming
2. Typical Niagara wiresheet programming.
3. Typical Tagging and Relations.
4. Typical Alarms
5. Typical Trend Histories
6. Typical Occupancy Scheduling
7. Partial Graphics developed for FPT.
d. Submit Supervisor Station(s) in .dist format.
e. Submit screen capture of all Niagara wiresheet programming, in .PDF format, for review by consultants that do not have access to Workbench.

N. Submittal Package 5 (Final Supervisor Station with Graphics)
1. A complete and final Supervisor station must be submitted for detailed review and approval before project acceptance and before Training may be scheduled
   a. Submit Supervisor Station(s) in .dist format.
   b. Submit screen capture of all Niagara wiresheet programming, in .PDF format, for review by consultants that do not have access to Workbench.
   c. Submit screen capture of all graphic pages, in .PDF format.

O. Submittal Package 6 (Commissioning and Acceptance Reports)
1. I/O Calibration Forms
   a. Submit all executed Reports recording calibration procedures for all system Inputs and Outputs (I/O), consisting of validating field I/O calibration, loop checks, actuator stroking, and integrated system operation validation.

2. Functional Performance Testing (FPT) Reports
   a. Submit all executed Reports from Functional Performance Testing (FPT) and Sequence of Operation Verification Procedures

3. Start Up Report / Checkout Forms
   1). Submit all executed Start up and System Checkout Reports

P. Submittal Package 7 (Training Materials)
1. Proposed Training Agenda
   a. Submit Training Agenda in word-searchable format.
   b. Organize training materials per user group and into different training sessions. Owner to provide user groups.
   c. Separate agenda for each training session including but be not limited to.
       1). Detailed review of as-built documentation and conditions with general equipment layout
       2). In depth discussion of theory of sequence of operations
       3). Review organization and usability of O&M documentation
       4). Maintenance (preventative, sensor calibration, etc.) procedures and schedules
       5). Pertinent safety requirements
       6). Operator control functions including graphic operation and navigation
       7). Explanation of adjustment, calibration and replacement procedures
2. Training Manual
   a. Submit Training Manual in word-searchable format.
   b. Separate Training Manual required for each training Session, to include but not limited to:
      1). Explanation of procedures to restore any building level controller or building control system server database. Training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task.
      2). Explanation of procedures to restore any local control unit database. Scenarios to explain include: restoring a database that is corrupted in an existing unit; restoring a database in a new unit that replaces an identical existing unit; and restoring a database in a new unit that is a different controller than the failed unit being replaced. Training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task, for each type of DDC controller installed.
      3). Detailed review of all DDC logic, programming and programming documentation. Control logic shall be graphical and annotated to describe how it accomplishes the sequence of operation. Annotations shall be sufficient to allow Owner’s Representative to relate each program component block to corresponding portions of the specified Sequence of Operation. Training manual shall include screen captures, including instructional annotation, of all DDC logic, programming and programming documentation, for each type of DDC controller installed.
      4). Additional specific topics will be requested by Owner in advance of Training session. Each custom topic/session will require the Contractor to prepare and submit training manual with the same level of detail (screen captures, annotation, written instructions) as described above.

Q. Submittal Package 8 (O&M Manuals)

1. Operation Manuals (Electronic copy only):
   a. Include a table of contents
   b. Tab manual based on specification chapters or sections
   c. Network architecture and communications diagrams
   d. Uploading and downloading software to the field hardware
   e. Detailed descriptions of all software programs
   f. Complete set of software engineering manuals
   g. Complete system design and engineering manual same as used by manufactures’ personnel
   h. Application Programming
   i. DVD of any configuration tools used in project
   j. Operator training or User Manual
   k. Calibration and/or verification sheets

2. Maintenance Manuals:
   a. Include a table of contents
   b. 1 copy on DVD
   c. Include field condition updates
   d. Document material, make and model numbers where appropriate
   e. Update details, schedules, risers, etc.
   f. I/O point as-builts
   g. Sequence details, modifications, or updates
   h. Control loops including final set-points and parameters (other than default)
i. Mark and detail on coordination drawings, exact locations of equipment installed and wiring drawings of both power and communication.

j. Panel details for each unique panel

k. Organize by manual by specification section number

l. Index sheet listing contents in alphabetical order

m. Include the following:
   1). Installation instructions
   2). Manufacturer's operating and maintenance instructions (not product submittals)
   3). Factory and field-test records, including calibration and factory setup
   4). Snapshot printout of each system installed
   5). Signed checklist of each system
   6). Factory training schedule and course description catalog
   7). Archived backup of software, drawings, and record documents
   8). Installation contractor and service representative information
   9). Licensing and warranty information

Note: Edit the above submittal requirements for each project. Make sure each item is appropriate. If the above submittals are not required in the project, delete them. Coordinate with Div. 1 requirements

1.9 QUALITY ASSURANCE

Note: These are unique building controls related QA requirements. These can be combined with the project Division 1 document, or retained in this document.

A. The Contractor shall be regularly engaged in the installation and maintenance of DDC systems and shall have a minimum of five (5) years of demonstrated technical expertise and experience in the installation and maintenance of BAS and HVAC systems similar in size and complexity to the project and have a maintained service organization. Provide evidence of such work in higher education environment.

B. The Contractor shall have at least 2 full-time employees who are Tridium Niagara 4 Certified at the time of bid and contract award with at least one Tridium Niagara 4 Certified employee assigned to the project.

C. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic control systems and shall be manufacturer’s latest standard design that complies with the specification requirements.

D. Owner shall reserve the right to have Employees or Agents of Contractor removed from the project. Owner shall make final determination of qualifications of Contractor’s employee. Owner shall make a request in writing to Contractor citing the circumstances, i.e. Contractor’s employee applying programming practices that are in clear violation of Tridium’s published standards. Contractor shall replace unqualified employee within three business days of Owner’s request with no impact to project schedule.

E. All controls shall be accomplished using LonMark based devices (where the application has a LonMark profile defined) or BACnet Testing Laboratory (BTL) listed devices. All controllers shall be freely programmable to their application and shall at all times maintain their LonMark and BTL certifications.

F. All systems, equipment, components, accessories, software and installation hardware must be new, free from defects, and currently in production.
G. Provide the same manufacturer components of a given type product throughout project.

H. Digital equipment furnished under this contract shall have been tested and made to comply with limits of Class A computing device pursuant to Subpart J of Part 15 of FCC Rules.

I. Maintain NEC workspace clearances and comply with all aspects of NEC requirements.

J. Install and operationally check systems utilizing factory-trained competent technicians skilled in the setting and adjustment of equipment used in this project.

K. Test, adjust, and calibrate all end to end instruments.

L. The practice of adding point extensions to Niagara Network Proxy Points (read-only copies of Niagara Proxy Points) is not acceptable under any circumstances.

M. Follow project communication protocol for all correspondence. Any changes, decisions, etc. must be properly documented. The Engineer will not issue verbal directions. Verbal interpretations, clarifications, conversations, etc., are non-binding without proper documentation.

N. Request for Information (RFI) shall include:
   1. Referenced drawing and/or Specification Section number
   2. Single request per RFI
   3. Single proposed solution per RFI
   4. Attached sketch of solution (if applicable)
   5. Attached specification verbiage (if applicable)
   6. Contact person
   7. Incomplete RFI’s will be returned without response
   8. RFI answers are for clarification only and do not authorize additional work or change orders.

   Note: If the above RFI requirements are already in the Div 1, delete them. Coordinate with Div. 1 requirements

O. Install devices in appropriate enclosure and in an accessible location.

P. Install systems and devices in a neat, workmanlike manner and in accordance with manufacturer's recommendations.

Q. Continually monitor the field installation for code compliance and quality workmanship.

R. Remove and re-install any systems or devices where installation is deemed of poor quality by Owner or Engineer.

S. Comply with all health and safety regulations.

T. Include automatic restart logic for loss of power, safeties, fire alarm shutdown, etc.

1.10 DELIVERY, STORAGE, AND HANDLING

A. Store products according to manufacturer's recommendations.

B. Store products in original manufacturers packaging.

C. Do not store products more than 3 months prior to schedule installation.

D. Coordinate deliveries of material with construction schedule and appropriate trades.

1.11 WARRANTY

A. Submit warranty documentation upon completion of project or phase and acceptance by Engineer and Owner.
B. Warranty start date shall be the date of project written acceptance by Engineer and Owner.
   1. Warranty period shall be minimum 1 year parts and labor. Any manufacturer’s warranty that
      exceeds one year shall be extended to Owner.

C. Repair or replace systems or parts found defective at no cost to Owner including: but not limited
   to:
   1. Building Controls System Server software, project-specific software, graphic software,
      database software, and firmware updates that resolve known software deficiencies, as
      identified by the Contractor or Owner, shall be provided and installed at no charge during
      the warranty period.
   2. Contractor to apply all software updates and security patches immediately (within 72 hours)
      as they become available, from the start of the project until the end of the warranty period.
   3. All corrective software modifications made during the warranty period shall be updated on
      all user documentation and on user and manufacturer archived software disks.
   4. Include parts, labor, and necessary travel during warranty.
   5. All parts should be replaced with the exact products. If exact parts are not available then the
      equivalency determination rests with the Owner.
   6. Troubleshooting service, preventative maintenance, and scheduled re-calibration of the
      system is the responsibility of the Owner. Such routine tasks shall not impact Contractor
      warranty obligations.

D. Owner will initiate service calls when the system is not functioning properly. Qualified personnel
   shall be available to provide service to the complete system. Furnish Owner with a telephone
   number where service representative can be reached at all times. Service personnel shall be
   at the site within 24 hours after receiving a request for service.

E. Provide vendor specific warranty information.

F. At the end of the warranty period, Contractor shall ensure every instance of Tridium Niagara
   software has the latest Tridium software maintenance release installed.

G. Expiration of the warranty period does not relieve Contractor of the responsibility for correcting
   all deficiencies identified during the warranty period. Expiration of the warranty period does not
   relieve Contractor of the responsibility for fulfilling all specified obligations during warranty
   period.

Note: Coordinate specific Warranty requirements with Owner. Coordinate with Div. 1 requirements

1.12 OWNER’S TRAINING

A. In no case shall training be scheduled until Final Supervisor Station and all graphics are
   approved and accepted by FAC.

B. Training shall not be scheduled until FAC has reviewed and approved the Training Submittal.

C. Provide a minimum of 32 hours of training, organized into eight separate sessions of 4 hours
   each session. Training will be conducted over a maximum period of 4 days (consisting of two 4-
   hour sessions per day); the four training days are not required to be contiguous days.

D. Provide a factory-trained instructor or representative to give full instructions to designated
   personnel in the operation, maintenance, and programming of each piece of equipment or
   system. Instructors shall be thoroughly familiar with all aspects of the subject matter. The
   Contractor shall provide all equipment and material required for classroom training.

E. Qualifications of proposed training instructor is subject to Owner approval.

F. The training shall be specifically oriented to the system and interfacing equipment installed.
G. Organize training per user group and into different training sessions. Owner to provide user groups.

H. Include classroom instruction and field demonstration.

I. Classroom instruction should include at a minimum:
   1. Detailed review of as-built documentation and conditions with general equipment layout
   2. In depth discussion of theory of sequence of operations
   3. Review organization and usability of O&M documentation
   4. Maintenance (preventative, sensor calibration, etc.) procedures and schedules
   5. Pertinent safety requirements
   6. Operator control functions including graphic operation and navigation
   7. Explanation of adjustment, calibration and replacement procedures
   8. Explanation of procedures to restore any building level controller or building control system server database. Training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task.
   9. Explanation of procedures to restore any local control unit database. Scenarios to explain include: restoring a database that is corrupted in an existing unit; restoring a database in a new unit that replaces an identical existing unit; and restoring a database in a new unit that is a different controller than the failed unit being replaced. Training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task, for each type of DDC controller installed.
   10. Detailed review of all DDC logic, programming and programming documentation. Control logic shall be graphical and annotated to describe how it accomplishes the sequence of operation. Annotations shall be sufficient to allow Owner’s Representative to relate each program component block to corresponding portions of the specified Sequence of Operation. Training manual shall include screen captures, including instructional annotation, of all DDC logic, programming and programming documentation, for each type of DDC controller installed.
   11. Additional specific topics will be requested by Owner in advance of Training session. Each custom topic/session will require the Contractor to prepare and submit training manual with the same level of detail (screen captures, annotation, written instructions) as described above.

J. Field instruction, if determined by Owner to be required for this project, should include at a minimum
   1. Normal maintenance procedures
   2. Demonstration of operation
   3. Demonstration of safeties and interlocks
   4. Walk-through of the job to locate control components

Note: Edit the above training requirements for each project. Make sure each item is appropriate and coordinate with Owner. Coordinate with Div. 1 requirement

1.13 CALIBRATION AND COMMISSIONING

A. Contractor shall participate in the commissioning process, as directed by Owner’s Representative.

B. Refer to Acceptance Testing section below for unique commissioning requirements for Division 25 work.

Note: Coordinate specific commissioning requirements with Commissioning Authority and Stanford for unique project requirements, specifically the scope relative to the DDC and Delta V systems
1.14 ACCEPTANCE TESTING

A. Submit a detailed acceptance test procedure designed to demonstrate compliance with contract requirements at least 4 weeks before the start of testing. This procedure to be approved prior to the start of the testing.

B. During acceptance testing provide services of a fully qualified building automation technician who is knowledgeable of the project.

C. Using the commissioning test data Owner and/or its representative shall select, at random, functions to be demonstrated. These functions shall be demonstrated by the Contractor in accordance with the acceptance test procedure. At least 10% of the terminal unit control systems (VAV box, CAV box, FCU, etc.) shall be demonstrated. All 100% of the primary equipment controllers, (AHU, building hot water system, building chilled water system, etc.) shall be demonstrated. All 100% of the functions demonstrated must perform as specified and documented on commissioning data sheets or the system must be re-tested.

D. Calibration of analog inputs:
   1. Use calibration tool with twice the accuracy of instrument being tested. Record calibration offset on spreadsheet.
   2. Provide documentation to show that calibration tool has been calibrated in the last year.

E. Instrument Air Piping Pressure Test:
   1. Test all high pressure (80 psig) piping at 100 psig sustained for 24 hours. Pressure loss shall not exceed 10 psig at the end of the 24 hour test period.
   2. Test all low pressure (25 psig) piping at 30 psig sustained for 24 hours. Pressure loss shall not exceed 3 psig at the end of the 24 hour test period.
   3. Notify FAC and HVAC Shops of the testing schedule, with 1 week advance notice, so that operating personnel may observe testing.

F. Submit the results of functional and diagnostic tests, loop tuning parameters and calibrations in a three ring binder (including table of contents and tabs) for final system acceptance. System will not be considered complete until all tests are successfully completed and documented. Provide documentation of all On-Site Testing to Owner as part of the O&M package.

1.15 SYSTEM TESTING

A. General: Upon completion of all system start-up and checkout procedures, and while the mechanical systems are monitoring and controlling in a "normal operating" condition, the Contractor and Owner shall jointly demonstrate the performance of the complete system to maintain flows, temperatures, levels, relative humidity, and pressures. The test shall cover a continuous time period of at least three consecutive days. The test must meet the particular building's design requirements to be considered passed and acceptable. Any failures shall require the test to be restarted.

PRODUCTS

2.1 NOT USED

Note: Products are defined in the various sections of Division 25

EXECUTION

3.1 EXAMINATION

A. Prior to start of any work, check, verify, and coordinate work with drawings and specifications prepared for other trades. Include modifications, relocations, or adjustments necessary to complete work or to avoid interference with other trades.
B. Promptly request clarification and instruction or report any conflicts, inadequate conditions or missing information in the Project Documents. Report unacceptable conditions immediately.

C. Inspect site to verify that equipment can be installed as shown.

D. Examine drawings and specifications for work of others.

E. Perform necessary changes in specified work caused by failure or neglect to report discrepancies.

Note: The following sections on Project Management and Scheduling contain additional details required for retrofit applications. These can be edited out for New Construction projects.

3.2 PROJECT MANAGEMENT

A. No later than the project kick-off meeting, Contractor shall identify in writing:
   1. One employee of the Contractor who has the primary responsibility for managing the project. For purposes of scheduling and project management, this person shall be known as the Contractor’s Project Manager.
   2. One employee of the Contractor who has the primary responsibility for supervising the control system physical installation. For purposes of scheduling and project management, this person shall be known as the Contractor’s Installation Supervisor.
   3. One employee of the Contractor who has the primary responsibility for programming controllers, programming control system database and developing graphics. For purposes of scheduling and project management, this person shall be known as the Contractor’s Chief Programmer.
   4. Depending on size of project, the three above-listed roles may be performed by the same Contractor’s employee.

B. For purposes of scheduling and project management, the project shall generally be divided into 3 phases.
   1. Installation Phase shall be the period from project start until physical installation of all controllers, appurtenant devices and computers is complete.
   2. Database/Graphics Finalizing Phase shall be the period from the completion of Installation Phase until Contractor has completed all system programming and graphics development.
   3. Project Close Out Phase shall be the period from the completion of the Database/Graphics Finalizing Phase until Owner has accepted the project.

C. The Contractor shall attend all project meetings and provide meeting minutes and action items to all attendees within 3 working days of each meeting.
   1. During the Installation Phase, project meetings shall occur weekly at a regularly scheduled meeting time. Contractor’s Project Manager and Contractor’s Installation Supervisor shall attend all meetings during the Installation Phase. If requested by Owner, Contractor’s Chief Programmer shall attend any meeting during the Installation Phase. Contractor shall furnish updated project schedule, with all applicable milestones, at least 1 day prior to the meeting.
   2. During the Database/Graphics Finalizing Phase, project meetings shall occur as determined by Owner. Owner will give 1 week advance notice of any project meetings during this phase. Contractor’s Project Manager and Contractor’s Chief Programmer shall attend all meetings during the Database/Graphics Finalizing Phase. If requested by Owner, Contractor’s Installation Supervisor shall attend any meeting during the Database/Graphics Finalizing Phase. Contractor shall furnish updated project schedule, with all applicable milestones, at least 1 day prior to the meeting.
   3. During the Project Close Out Phase, project meetings shall occur as determined by Owner. Owner will give 1 week advance notice of any project meetings during this phase. Contractor’s Project Manager and Contractor’s Chief Programmer shall attend all meetings during the Project Close Out Phase. If requested by Owner, Contractor’s Installation Supervisor shall attend any meeting during the Project Close Out Phase.
Supervisor shall attend any meeting during the Project Close Out Phase. Contractor shall furnish updated project schedule, with all applicable milestones, at least 1 day prior to the meeting.

D. Meeting minutes shall represent a true and accurate record of the meeting. Corrections or clarifications to the meeting minutes shall be by a written request for correction within 7 days of the date of issuance of meeting minutes.

E. Contractor accepts that during the Project Close Out Phase, Owner may rely on third party consultants, i.e. Commissioning Authority, to complete independent test and review of project deliverables from Contractor.

F. During the Database/Graphics Finalizing Phase and Project Close Out Phase, all Niagara database modifications shall be performed on the Live stations only. Contractor understands that during the Database/Graphics Finalizing Phase and Project Close Out Phase, other parties, i.e. Stanford FAC Engineers, University IT personnel, Monitoring-Based Commissioning Authority, Master System Integrator, etc., may need to make minor changes to the Supervisor and/or JACE stations. During the Database/Graphics Finalizing Phase, Owner’s Representative will give at least 24-hour advance notice of any modifications performed on the “Live” Stations. Contractor shall be responsible to ensure that changes by Owner’s Representatives shall not be overwritten or otherwise lost by Contractor.

G. The Contractor shall maintain a “red-lined” copy of the as-built drawings on-site at all times.

H. The contractor shall have Functional Performance Test and start up sheets available on-site at all times.

3.3 SCHEDULING

A. The contractor is required to provide a schedule of activities and continually update the schedule as the project progresses. Clearly distinguish between commissioning activities performed solely by the temperature control contractor and commissioning activities involving the Commissioning Authority.

B. During Installation Phase, the Contractor shall update schedule weekly, at least 1 day prior to the project meeting, to provide a 3-week look-ahead schedule with a list of construction impacts for occupants.

C. Project Schedule shall include, at a minimum, with at least 3 weeks advance notice, the following project milestones:
   1. Submittal Package 1 (Hardware, Shop Drawings and Equipment Naming).
   2. Submittal Package 2 (Acceptance Forms – I/O Calibration, Start Up Report, Functional Performance Testing, etc.)
   3. Submittal Package 3 (JACE Station(s), Controller Programming and Points List) shall be submitted no less than 15 working days before software is to be installed in field devices.
   5. Submittal Package 5 (Final Supervisor Station with Graphics) must be submitted and approved before Training may be scheduled
   6. Submittal Package 6 (Commissioning and Acceptance Reports)
   7. Submittal Package 7 (Training Materials) must be submitted and approved before Training may be scheduled
   8. Submittal Package 8 (O&M Manuals)
   9. Contractor start physical installation.
   10. Validating Field I/O Calibration.
   11. Functional Performance Testing (FPT) Schedule
   12. Any Utility Shut Down required by project.
13. Contractor ready to connect Building Level Controller to Stanford Campus Controls Network.
14. Contractor complete physical installation.
15. Contractor complete and ready for Commissioning (Cx) Modbus Points (If applicable).
16. Contractor ready for preliminary controller FPT and programming review (1 of each type of controller or controller application.
17. Contractor ready for final zone terminal unit controller FPT and programming review (Verifies AHU reset strategies and occupancy scheduling are functioning correctly).
18. Contractor ready for building heating/cooling, central plant or whole building FPT (as applicable).
19. Training sessions.

D. Included in this project are connections to equipment provided by others. Coordinate deliveries, final locations, factory mounting, and various connections required.

E. Coordinate activities with contract project schedule.
   1. Ensure integration activities are incorporated into project schedule.
   2. Communicate requirements to prevent potential damage from paint, dust, water, weather, etc. Monitor and take measures to assure protection for all equipment.

F. Coordinate all IT requirements with owner and contract project schedule.

3.4 INSTALLATION

A. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.

B. Provide sufficient slack, flexible connections and isolation to allow for equipment vibration.

C. Verify elevations and measurements prior to installation of materials.

D. Beginning installation means contractor accepts existing conditions.

E. Conceal wiring in conduit in mechanical spaces, above hard ceilings, and other spaces where exposed wiring could be damaged.

F. Provide temporary service, routing of service, or other temporary requirements to minimize downtime of service.

G. Equipment and wiring shall be selected and installed for conditions in which it will be required to perform. (i.e., general purpose, weatherproof, rain-tight, explosion proof, dust tight, or any other special type as required.)

H. Arrange for necessary openings in building to allow for admittance of all apparatus.

I. Install equipment with ample space allowed for removal, repair or changes to equipment. Provide ready accessibility to equipment and wiring without requiring movement of other equipment, which is to be installed or which is already in place.

J. Coordinate all systems in order to minimize access door requirements.

K. Coordinate final locations, sizes and rough-in dimensions for access doors.

L. Verify door swings for proper clearance before installing.

M. Perform the work in a safe and competent manner and use industry accepted installation procedures required for the work.
3.5 CONTROL SYSTEM SWITCH-OVER (CONTROLS RETROFIT PROJECTS)

A. Switch-over from the existing control system to the new system shall be fully coordinated with the Owner. A representative of the Owner may be on site during switch-over.

B. The control system downtime during switch-over shall be limited to 48 hours for each zone. Temperatures shall be maintained between 64 degrees and 78 degrees throughout the switch-over. Sufficient installation mechanics shall be on site so that the entire switch-over can be accomplished in this time frame unless unforeseen mechanical equipment deficiencies are discovered. Sufficient testing of mechanical equipment shall be completed before switch-over to ensure readiness, including point to point checkouts and functional testing if necessary.

C. The control system downtime during switch-over shall be limited to 8 hours for 100% of zones. Temperatures shall be maintained between 64 degrees and 78 degrees throughout the switch-over. Sufficient installation mechanics shall be on site so that the entire switch-over can be accomplished in this time frame unless unforeseen mechanical equipment deficiencies are discovered. Sufficient testing of mechanical equipment shall be completed before switch-over to ensure readiness, including point to point checkouts and functional testing if necessary.

D. Functional Performance Testing shall be performed on the first terminal unit of each type after switch-over prior to uploading the programs on the remaining terminal unit controllers. Testing shall be conducted with an Owner’s Representative. The Contractor shall provide notice of two weeks for testing. Contractor shall review Controls Logic Documentation with Owner’s Representatives. Contractor must have written acceptance from Owner’s Representative approving the programming and the completeness of the programming documentation prior to uploading the programs on the remaining terminal unit controllers.

E. Demolition of the existing control system shall occur after the new temperature control system is in place and fully functional.

3.6 CLEANING

A. Upon completion of each phase (system, panel, etc.) clean all system panels, enclosures and field device enclosures.

B. Clean debris from equipment, control panels, security panels, fire panel enclosures, junction boxes, and pull boxes and arrange wire neatly with surplus length cut off prior to installation of covers.

C. Thoroughly clean equipment of stains, paint spots, dirt and dust. Remove temporary labels not used for instruction or operation.

3.7 DEMONSTRATION

A. Demonstrate operation of systems with Owner or Engineer.

B. Coordinate with commissioning activities.

3.8 COMMISSIONING, TESTING, AND ACCEPTANCE

A. The calibration and commissioning procedure shall consist of validating field I/O calibration, loop checks, actuator stroking, and integrated system operation validation. Document all commissioning information on commissioning data sheets, which shall be submitted to Owner for approval prior to testing. Notify Owner of the testing schedule so that operating personnel may observe calibration and commissioning.

B. Field I/O Calibration and Commissioning: Prior to system program commissioning, bring on-line each control device by:

1. Performing a single point measurement validation of all analog devices.
2. It is not acceptable to use an infrared non-contact thermometer to calibrate temperature sensors.

3. Verifying instrument ranges.

4. Verifying and documenting binary switch settings.

5. Verifying and documenting actuator operating ranges.

6. Verifying and documenting fail-safe position on loss of control signal.

7. Submit calibration data sheets. Data sheets shall include the device designation, the date of calibration and the name of person who performed calibration.

C. Loop checks: Perform test of every control device with Owner personnel.

D. System Program Commissioning: After control devices have been calibrated and loop control verified, each program shall be put on-line and commissioned. Owner shall confirm that the program logic follows the approved software flow chart and sequence of operation. Each control loop shall be adjusted to provide stable control within the specified accuracies.

E. Point to Point Installation Verification Procedure to consist of the following (as a minimum):

1. Documentation - An Excel spreadsheet listing all I/O in the system including point name, address, Controller ID#, analog range or digital normal state, engineering units. Provide one signature block per page for contractor’s representative and Owner’s Representative to accept the test results.

2. Digital Inputs: Jumper or open the wires at the device and verify change of state at controller and/or GUI. Record results on spreadsheet.

3. Analog Inputs: Lift wire at device to see change of state and record default value on spreadsheet.

4. Digital/Analog Outputs: Command the field device from the controller and verify corresponding change of state at the field device. Record results on spreadsheet.

F. Functional Performance Testing (FPT) and Sequence of Operation Verification Procedures to consist of the following (as a minimum):

1. Control Loop Tuning:
   a. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop as part of the O&M package. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows for general space conditioning applications. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained:
      1). Duct air temperature: ± 1°F.
      2). Space Temperature: ± 2°F.
      3). Chilled Water: ± 1°F.
      4). Hot water temperature: ± 3°F.
      5). Duct pressure: ± 0.25” w.g.
      6). Water pressure: ± 1 psid.
      7). Duct or space Humidity: ± 5%.
      8). Air flow control: ± 5% of setpoint velocity.
   b. Where the same mechanical system is installed in multiple locations, one system must be tuned and the same tuning parameters may be used in other controllers.
   c. Tuning constants shall be set so that continuous oscillation of actuators does not occur. A steady state shall be achievable.
   d. When floating (3-point, incremental) control is used for VAV control, continual pulsing of actuator against end stops (end stop dithering) shall not occur when box is full open or closed.
e. Trend logging or other graphical proof of loop tuning stability shall be submitted.

f. Actuator movement shall not occur before the effects of previous movement have had sufficient time (minimum one time constant) to have affected the sensor.

g. A detailed sequence of operation is provided for each system, including instructions for testing the sequence.

h. A checkout form is provided for each system/sequence. Checkout form is to include areas to check and record each facet of the sequence of operations including, but not limited to the following:
   1). Start/Stop
   2). Interlocks
   3). Safeties
   4). Valve and damper stroke
   5). PID Loops
   6). Modes of Operation
   7). Power failure/Recovery

i. Checkout form is intended to be a functions (yes/no/comment) test form.

G. 72 Hour test Procedures to consist of the following (as a minimum):
   1. Place Entire System in Automatic Operation.
   2. Generate Trends and Trend Logs of all I/O as directed by Owner’s Representative.
   3. Review Trend Logs with Owner’s Representative to ensure system is controlling properly and that control loops do not exhibit excessive oscillation.
   4. Owner’s Representative shall have the right to change set points and verify that system responds properly.
   5. Repair any deficiencies found during 72 Hour test.
   6. Re-Execute 72 Hour Test until no deficiencies are found.

3.9 PROTECTION

A. Protect installation against and be liable for damage to work and to material caused by Contractor's work or employees.

B. Maintain protection for work and equipment until inspected, tested, and accepted.

C. Protect material not immediately installed.

D. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

E. Material sensitive to temperature, dust, humidity, or other elements found unprotected shall be replaced.

F. Material showing signs of exposure shall be replaced.

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