Capital Projects Standards Manual

Capital Projects Group
General Services Department
County of Santa Barbara

Revision – 8/28/13

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Revision Record

Revision Date	By	Comments
July 2013	AT	Original draft.
7/19/12	AT	Draft work
7/23/13	AT	Draft issuance for breakout meetings.
8/1/13	AT	Revised from breakout meetings.
8/28/13	AT	Revised irrigation and human factors. Draft for posting.

Copyright Notice

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Objectives

Our Mission is to provide a full range of services, guidance and expertise that enable County government to deliver public services effectively. (County of Santa Barbara) We can continue to support our mission statement with this set of Capital Projects Standards by:

- Establishing best practice standards to serve the public responsibly as a duties of the County;
- Creating a central location for requirements with no redundant ambiguity;
- Maintaining a controlled and updated Capital Projects web presence;
- Posting all standards publicly available;
- Establishing the standards herein as ordinance for County construction;
- Empowering the General Services Director to enforce the standards herein;
- Provide clear contractor and consultant pre-qualification strategies for certain types of projects;
- Maintaining a controlled and updated base General Conditions.

Owners Project Requirements and Basis of Design

This document is not intended to provide project-specific building performance requirements. The intent of this document is to sit alongside the project-specific Owner's Project Requirements (OPR) to form a complete set of performance criteria. The County is responsible for authoring the project specific OPR.

This document is not intended to provide specific direction on specific system types or equipment. A detailed Basis of Design document is expected from the design team for review in response to this Owner's Project Requirements. The consultant is responsible for developing the project specific BOD.

Environmental and Sustainability Goals

Energy Efficiency Goals

The following are overall energy efficiency goals for the project including all systems:

1. Overall energy efficiency goal of Title 24 compliance plus 15%.
2. Lighting system efficiency goal of Title 24 compliance plus 20%.
3. Conformance with goals listed within individual system sections.

Refer to County of Santa Barbara Transition to Renewables resolution (forthcoming).
The net-zero energy goal for County projects is by 2030.

(Tranovich, 2013) (Hapeman, 2013)

Title 24

All county construction projects, whether new construction or retrofit, shall be Title 24 building code compliant.

All projects shall require Title 24 2013 Part 6 commissioning and acceptance testing as required for the size and complexity of project attempted. (Tranovich, 2013)

Early Consultant / Utilities Coordination

The project consultants will coordinate early with PG&E and related utilities companies to maximize the possibility of incentives, reimbursements, and grants, such as Savings by Design. (Hapeman, 2013)

CALGreen

The facility shall meet the applicable mandatory requirements of the Title 24 Part 11 Green Building Standards ("CALGreen") as applicable to this facility type and size. Design team to confirm with the County which mandatory measures which may (such as light pollution prevention) or may not apply (such as bicycle parking, occupant thermal controls).

Project should attempt to meet CALGreen Tier 1 Voluntary Measures if possible to facilitate meeting energy efficiency goals stated above (T24+15%, etc) (aggressive water use reduction, energy conservation, reflective roof, etc); if not possible design team to reference specifically why. (California, California Code of Regulations - Title 24 Part 11 California Green Building Standards (CALGreen), 2010) (Tranovich, 2013)

LEED Equivalence

LEED equivalence will be determined on a per-project basis at the discretion of the project manager.

Commissioning

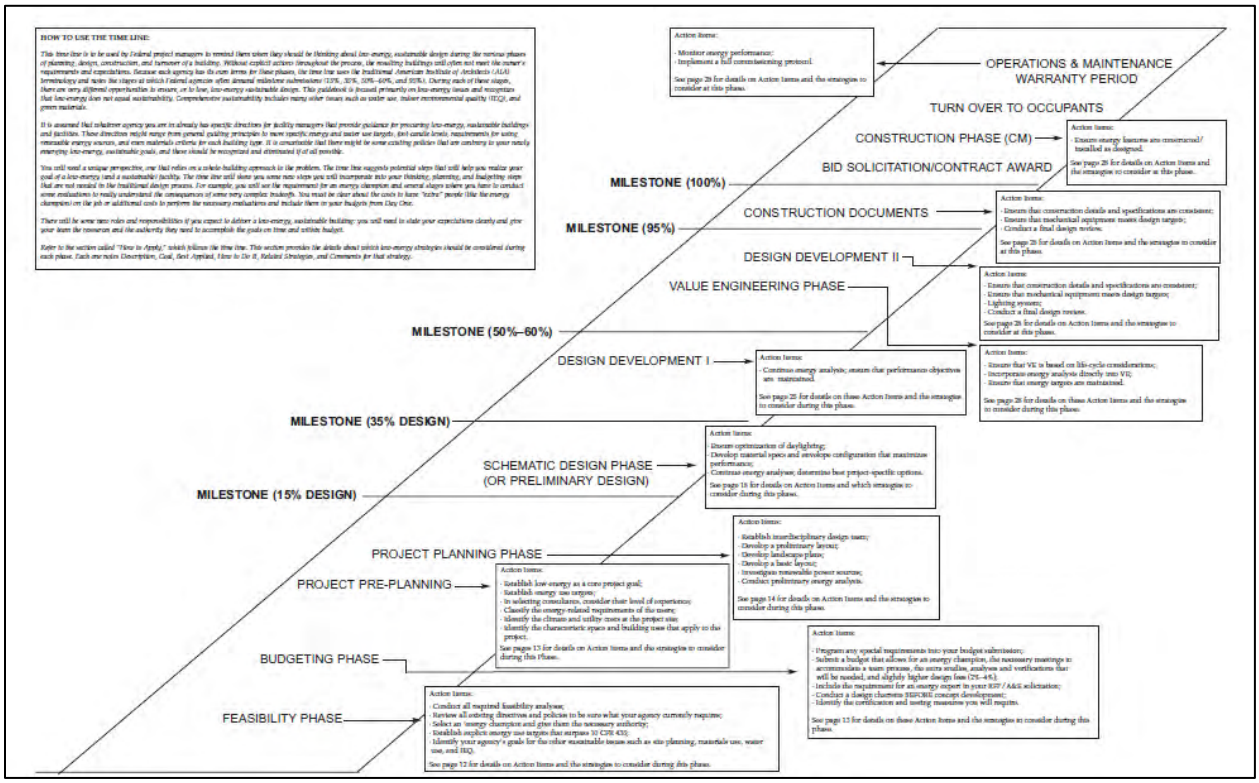
Project commissioning shall also be governed by the County of Santa Barbara Facilities Commissioning Policy (available by request). Projects shall be re-commissioned per the policy requirements and all documentation saved in soft-copy for ease of retrieval. (Hapeman, 2013) (Tranovich, 2013)

Commissioning will ensure the project meets the unique needs of its owner and occupants, and is designed, constructed, and then operating to meet the Owners Project Requirements, the Basis of Design, and the design documents. The commissioning process is a team effort, led by a commissioning authority who verifies that the building meets the owner's expectations at each stage of the design and construction process. Since each building project is unique, the project manager will adapt the process to meet the project's specific goals. (Collaborative, 2006)

Scope of commissioning requirements will include *at minimum* 1. Owner's or owner representative's project requirements; 2. Basis of design; 3. Design phase design review; 4. Commissioning measures shown in the construction documents; 5. Commissioning plan; 6. Functional performance testing; 7. Documentation and training; and 8. Commissioning report. (California, Title 24, Part 6, 2013) A warranty-phase review & trend analysis report will also be requested. (Tranovich, 2013)

Federal Sustainability Guidance

Certain sustainability guidance is available for federal facilities. The County can utilize these standards at the County level for adoption for selected capital projects. The Low Energy Building Design Guidelines: Energy-efficient design for new Federal facilities is a valuable resource for the County project manager and relevant consultants regarding overall sustainability approach methodology and guidance for various activities such as design reviews. Reference pages 22 and 23 of the source document for the valuable design and implementation timeline guidance previewed below.



(Energy) (Tranovich, 2013)

Benchmarking and Metering

The project will be designed and constructed in a way to facilitate practical and accurate benchmarking and metering. See individual sections for further details if applicable. Reference the County of Santa Barbara Benchmarking policy approved in April of 2013.

Dark Sky Compliance

See electrical and lighting section.

Photovoltaic Generation and Solar Ready

Projects will be at minimum solar-photovoltaic-ready. The requirements for net zero building energy usage is approaching in 2030 and projects must be set up for compliance. See electrical section for further details.

Solar Thermal Preheat

Projects will utilize solar thermal preheat where practical. See plumbing and mechanical sections for further details.

Good Neighbor Facility

Projects are intended to be good neighbor facilities with adjacent existing and future developments in the surrounding area. Low light penetration to adjacent lots and low noise to adjacent lots are priorities. (Tranovich, 2013)

Composting and Recycling

Projects must include comprehensive recycling collection bins.
Composting of food scraps will be pursued if practical for the project.

Visual Displays of Green Features

Projects will include visual displays in high visibility areas to share with the public the sustainable features of the project.

Electric Vehicle Provisions

Projects will provide stub-outs for one electrical vehicle charging station per every 30 parking spaces. Provide at minimum both electrical and data conduit runs and stub-ups for this. Both electrical and data conduit are required for each charging station. Do not place stub ups for charging stations next to each other, instead place every few spaces so the charging cables can reach multiple spaces per charging station. Review placement with County project manager. Procurement and installation of actual charging stations is at the discretion of the project manager. (Hapeman, 2013)

Sustainable Janitorial Products

Janitorial products for the facility, including all paper products and soaps, shall be reviewed in detail. Paper and janitorial supply dispensers should be compatible with existing. (Hosking, 2013)

If greywater systems are utilized, soaps and cleaning products shall be biodegradable and in compliance with the final greywater treatment and distribution. Specified equipment must also be compatible with these types of chemicals and soaps. (Tranovich, 2013) (Ooley, 2013)

Overall System Considerations

This section describes overall system considerations applicable to systems of all types, including mechanical, electrical, and plumbing systems.

Adaptability

Projects will be adaptable to future expansion and reconfiguration. This will be accomplished by, at minimum:

- Logical placement of infrastructure, equipment, and empty space for future in mechanical and electrical rooms and yards;
- Logical and generous placement of empty conduit where identified for both data and electrical uses as needed;
- Configuration of all systems in a manner conducive for future unknowns such as orientation and placement.

(Tranovich, 2013)

Human Factors Requirements and Elimination of Barriers

Thoughtful design is a priority of the County. Improve County human factor interaction with systems and enable elimination of barriers to the public and county staff by reference the following:

- Americans with Disabilities Act – Current Version
- Human Factors Design Handbook – Current Version; Woodson, Tillman, Tillman

(Ooley, 2013)

System Locations

Access to system equipment of any type shall be away from the public where possible. If access to equipment must be located near the public, locate in a space where the public do not spend the majority of their time, such as a hallway, and provide lockable access panels. Access panels pose a safety risk. All access panels in public areas need to be lockable grade and all keyed the same (confirm with facilities). (Hosking, 2013) (Tranovich, 2013)

System Locations – Noise

Systems near noise sensitive areas such as attorney or conference rooms shall have sound attenuating devices attached to the equipment (such as vibration isolation) and to the distribution (such as supply and return ducting). System penetrations into and out of system rooms (such as mechanical rooms) shall be sealed for sound and fire protection. (ASHRAE, Handbook - HVAC Applications, 2011) (Tranovich, 2013)

System Locations – Maintenance

Systems will be located for ease of maintenance by staff and located in a fashion which minimizes entry into the secure or public areas. Unified plumbing chases and mechanical chases should be used for single point of entry repair access. (Tranovich, 2013)

Fire suppression devices located in chases or plenums for return air to be avoided; device accessibility in chases & plenums for maintenance. (Hosking, 2013)

System Locations – Future and Emergency Considerations

Locate IT rooms and electrical rooms near external facility walls for possible future system expansion or augmentation. Electrical rooms should be located near exterior walls, which should be next to open space for expansion (such as trailer for battery bank or trailer mounted generator) out of view of main entrance and public approach to the facility. (Hapeman, 2013)

System Type Considerations for Maintenance

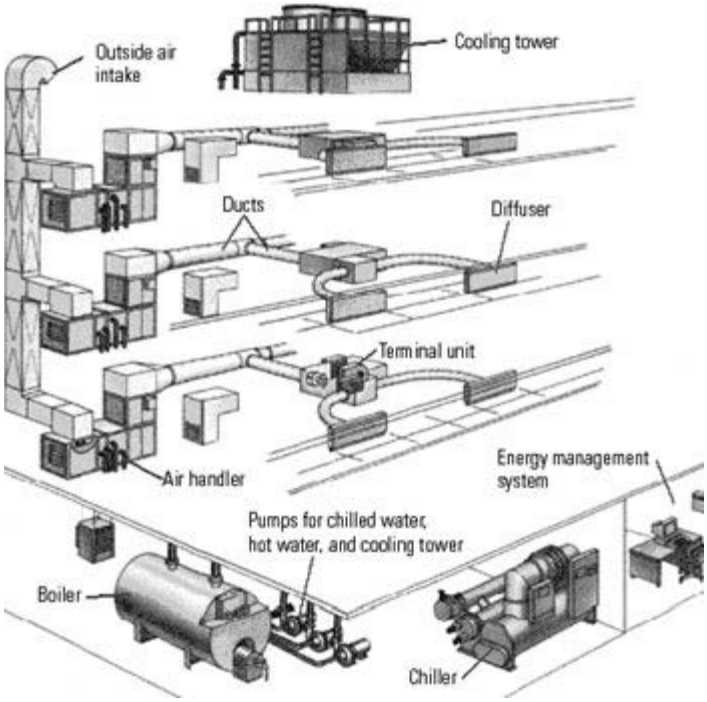
System types for selection should be discussed with the County with regards to the facilities team's ability to maintain what is specified. Discuss with the County if maintenance will be completed in-house or through a third party for certain equipment. Reference the matrix provided in the appendix.

Future Cogeneration Plant

Where possible consider cogeneration plant as part of project. If cost prohibitive, make provisions for possible future cogen plant installation. These provisions could possibly include placement of equipment and placement of infrastructure conducive to retrofit. (Tranovich, 2013)

Labeling and Identification

All equipment shall be labeled and numbered in clear and similar manner. Labeling shall be at minimum white on black Bakelite type labels with 1 inch minimum lettering height. Identification strategy shall be similar across disciplines (mechanical to plumbing, etc). All equipment shall be serialized numbering for identification, commissioning, and maintenance tracking. (Hosking, 2013) (Tranovich, 2013)



Mechanical

Review facility occupancy assumption with County project managers. Occupied conditioned spaces are to be stable year round and hot and cold drafts minimized. HVAC generated noise must not interfere with office or meeting room functions for operations. The number of comfort complaints from operations staff should be less than 1 per month. The HVAC control system must function properly, providing easily understood graphical information that allows staff to ascertain the status of comfort and systems in the facility. An HVAC caused failure to provide cooling must not occur. Office lights are to be off when rooms or building are unoccupied, however design should take into consideration lighting and its particular time schedules for heat loading, which will differ from conventional office usage. (Tranovich, 2013)

All major equipment air filters shall have at minimum magnahelic gauges for pressure drop across filters. Consider building automation system connected differential pressure sensors where appropriate. (Hosking, 2013) (Tranovich, 2013)

Negative space pressure rooms shall have visual magnahelic gauges or equivalent in line of sight to monitor. Where applicable these gauges will be a monitored point on the building automation system. (Hosking, 2013) (Tranovich, 2013)

Energy Efficiency – ASHRAE Standards

Mechanical work executed in County facilities shall comply with the latest editions of relevant ASHRAE standards. Some common relevant ASHRAE standards applicable are:

- Standard 100 - Energy Conservation in Existing Buildings
    - A readily available list of energy efficiency measures for consideration is listed in this standard and available on the internet.
- Standard 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings
- Standard 189.1 – Standard for the Design of High-Performance Green Buildings
- Guideline 0 – The Commissioning Process

(Tranovich, 2013)

Energy Efficiency – ASHRAE Measure Matrix

The available spreadsheet matrix from ASHRAE as a supplement for Procedures for Commercial Building Energy Audits, Second Edition is available on the internet and on the County local area network. This resource will clearly list energy efficiency measures considered and assist the County project manager and relevant consultants quantify the savings anticipated. Example calculation:

***Procedures for Commercial Building Energy Audits*, Second Edition**
Sample EEM Summary Table

Measure Number	Measure Description	Annual Energy and Cost Savings				Payback with Incentive						
		Peak Demand Savings (kW)	Electricity Savings (kWh)	Gas/Fuel Savings (therms)	Total Cost Savings	Measure Cost	Potential Utility Incentive	Measure Life (years)	Net Measure Cost	IRR (over Life of Measure)	NPV*	Simple Payback (yr)
EEM-1	Replace Incandescent Lamps with CFLs	7.6	15,245	-	$ 1,906	$ 1,875	$ 545	3	$ 1,330	132%	$ 3,958	0.7
EEM-2	Reduce Pressure Setting on Pneumatic Compressor	-	2,312	-	$ 206	$ -	$ -	3	$ -	N/A	$ 571	-
EEM-3	Install VFD on Tenant Condenser Loop Pump to Reduce Flow	19.0	163,872	-	$ 25,188	$ 17,386	$ 13,110	10	$ 4,276	589%	$ 200,021	0.2
EEM-4	Install VFD and Implement Demand-Controlled Ventilation for AHU-1	-	12,448	423	$ 2,290	$ 11,136	$ 1,418	10	$ 9,718	20%	$ 8,855	4.2
EEM-5	Install CO Sensors and VFD to Control Garage Exhaust Fan	18.8	48,948	-	$ 8,811	$ 25,616	$ 3,916	10	$ 21,700	39%	$ 49,762	2.5
EEM-6	Add Hot-Water Resets Control and Install Condensing Boiler	-	44,838	17,203	$ 25,274	$ 102,511	$ 20,790	20	$ 81,721	31%	$ 261,758	3.2
EEM-7	Replace Garage HPS Fixtures with LED Fixtures with Integrated Motion Sensor	6.8	29,854	-	$ 4,114	$ 29,598	$ 2,174	15	$ 27,423	12%	$ 18,316	6.7
EEM-8	Repair Economizers on All Air Handlers	5.0	22,342	-	$ 2,904	$ 12,864	$ 2,511	5	$ 10,354	12%	$ 2,577	3.6
EEM-9									$ -	N/A	$ -	N/A
EEM-10									$ -	N/A	$ -	N/A
EEM-11									$ -	N/A	$ -	N/A
EEM-12									$ -	N/A	$ -	N/A
TOTALS (Recommended Measures)		**57.3**	**339,860**	**17,625**	**$ 70,692**	**$ 200,985**	**$ 44,464**		**$ 156,521**	**44%**	**$ 545,819**	**2.2**

* NPV assumes a discount rate of 4%

(ASHRAE, 2011) (Tranovich, 2013)

Energy Efficiency – Equipment

To help minimize energy usage we request the following equipment requirements are used:

1. Variable frequency drives on motors over 5 horsepower (with associated controls, no fixed speed VFDs allowed);
2. Premium efficiency electric motors, both stand-alone and within specified equipment;
3. Required outside air economizers on forced air equipment in occupied spaces;
4. High efficiency boilers, chillers, etc.;
5. High quality and complete insulation requirements for all conditioned pipes and ductwork;

(Tranovich, 2013)

Energy Efficiency – Strategies

Consider amount of outside air delivery and exhaust. To help minimize energy usage we request the following strategies are explored:

1. Outside air economizers with associated dry-bulb controls (Enthalpy control of these should be avoided due to the inaccuracy of humidity measurement);
    a. **NOTE: Economizers shall be used on all air handling equipment. If an economizer cannot be used, provide County project manager explanation <u>in writing as to why not</u>.**
2. Provide natural ventilation where possible;
3. Enthalpy wheels for heat recovery on ventilation systems;
4. Ground loop heat pumps (bore field investigation would be required);
5. Thermal storage methods such as using the well water and greywater storage tanks as heat sinks for off peak chiller usage, then used as a first stage during the day;
6. Combined heat and power system (cogeneration);

7. Variable air volume systems with associated controls in variable occupancy zones;
8. Heat capture from boiler stacks, laundry exhaust, kitchen exhaust, etc;
9. Using cooling towers alone on a heat exchanger instead of chillers when outside air conditions allow;
10. Up-sizing cooling tower fans;
11. Variable speed cooling tower fans;
12. Modular and logical system design which permits certain zones to be deactivated when unoccupied which leaving other zones active;
13. Direct evaporative air tempering as a first stage of cooling due to the dry environment;
14. Intelligent kitchen hood control and interlocks;

(Tranovich, 2013)

Space Heaters

120V space heaters shall not be used in any County Facility without manager approval. Manager is ultimately responsible for the increase in energy usage.

Equipment Standards

Air-Side

Forced air DX units: Carrier, Trane, Mitsubishi, include economizer and high SEER.
Premium efficiency motors.

VFD's on motors greater than 5hp, include bearing induced current protection. Consider brushless and magnetic bearings.

Water-Side

VFD's on motors greater than 5hp, include bearing induced current protection. Consider brushless and magnetic bearings.

Cooling Towers

Avoid the use of cooling towers where possible due to wind and dust loading from adjacent agricultural land. Consider instead an adjacent ground loop bore field or other similar possible system. The number one objective of this is to avoid water waste due to treatment and water loss. (Hapeman, 2013)

Redundancy

Essential equipment should be backed up with standby units for use during maintenance or failure of the lead units. Essential equipment shall be defined by the County project manager.

Smoke Management

Discuss with the County the costs and complexity of smoke management in the proposed facility. (Tranovich, 2013)

Equipment Placement – Solar Ready Roof

The mechanical equipment shall be placed in a logical manner to permit as much contiguous roof surface area as possible for future photovoltaic panels. Other equipment placement on south facing roofs shall be avoided in preparation for this. (Hapeman, 2013)

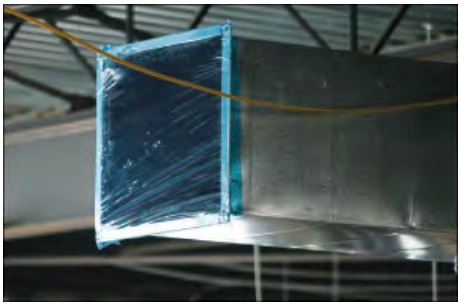
Solar Thermal Preheat

Solar thermal preheat equipment shall be located adjacent to the connected system to avoid heat loss through piping. Locate near relevant equipment such as domestic water heater. County standard technology: Drain-back using distilled water with flat plat collectors. (Hapeman, 2013)

Indoor Environmental Quality during Construction

Any air moving equipment operated during construction shall have temporary MERV 8 filters taped to the return ducts feeding back to the unit (not just in the unit itself). See example photo:

All ductwork, fittings, outlets, and equipment shall be sealed with plastic before transit to site, during transit to site, awaiting installation on site, during installation on site, and after installation awaiting startup. Only at startup, and only after the general contractor has cleaned the spaces to "mop clean" will the plastic be removed. See example photos:



(Tranovich, 2013)

Indoor Environmental Quality after Construction

Final filtration in air moving equipment in occupied spaces will be MERV 13 rated. The use of outdoor air for cooling and ventilation should be maximized. Unoccupied spaces shall be MERV 8 or better. Internally generated pollutants including odors from the kitchen, break rooms and restrooms, should be

exhausted to the outside and not returned via the HVAC outdoor air inlets. Outside air delivery shall be per ASHRAE 62.1 at minimum. Air born pollutant zones such as restrooms and janitorial closets shall have negative space pressure to adjacent spaces. Medical use spaces shall have negative pressure to adjacent spaces. (Tranovich, 2013)

Additional Specific Criteria

Classroom Considerations

Noise levels between 25 and 30 RC. Airflow in accordance with 62.1.

Interview Room Considerations

Noise levels between 25 and 30 RC. Minimum airflow of 6 air changes per hour. Minimum 0.06CFM/ft^2 outside air. Low noise diffusers and grilles.

IT Rooms

Consider a condenser loop for the IT rooms and other 24 hour spaces so that lower energy heat pumps may be used instead of conventional split systems. Economizer consideration is mandatory.

Laundry Considerations

100% outside air with full exhaust when in use. Negative pressure to adjacent spaces. Maximum noise level 45-50 RC. Consider direct evaporative outside air tempering. Consider uses for waste heat, both water and air.

Kitchen Considerations

Review ASHRAE Standard 154 for guidance.
(Tranovich, 2013)

Control System – Summary

Building control systems shall be BACnet native, with only BACnet Testing Labs (BTL) listed devices. All software control points shall be available for integration. Define early if a dedicated computer will be required located on site. This system shall be integrated back to the main front-end in Santa Barbara. Graphical displays with consideration of color blind individuals shall be created. Major equipment shall have software hand off auto switches available. All equipment shall be capable of group and individual scheduling. All equipment shall have trending capability and trends will be set up before commissioning, during commissioning, and during occupancy per a trending plan the commissioning authority will develop and provide. (Tranovich, 2013)

Control System – Energy Metering

1. *Future specific input required from County Energy Manager in design development phase. A review meeting with the County Energy Manager is mandatory.*
2. Provide real time energy monitoring of facility energy usage by building - other metering as defined by the County Energy Manager. High quality rated energy measurement system however revenue-grade is not required.

3. Provide real time water usage monitoring of utility domestic water feeding the site, grey water feeding the site, and other utilities or water flows as defined by the County Energy Manager.

(Tranovich, 2013)

Control System – Strategies

The following control strategies should be used on the project:

- In high density occupancy spaces with forced air ventilation, CO2 demand control ventilation should be used to improve energy efficiency.
- Temperature set point reset featuring trim and respond logic (always trimming, 3 or more zones calling causes setpoint response).
- Duct static pressure set point reset featuring trim and respond logic (always trimming, 3 or more zones calling causes setpoint response).
- Avoid rogue zone conducive programming (always more than 2 zones require calls for major equipment to enable).
- Dual maximum logic where fan coil reheat type equipment is used such as VAV boxes (must be compatible with current version of Title 24 and ASHRAE 90.1) Reference: http://www.oeashrae.org/Presentations/2012_13/Dual_Maximum_VAV_Control_Logic.pdf
- Differential pressure control of hydronic systems with 2-way valves and variable speed motor drives
- Ability to adjust how many "calls for heating or cooling" a control zone has. For example, setting this number to 0 would effectively remove that zone from calculations (useful if there is a trouble zone), and setting it to 2 would weigh priority on it over zones with a call count of 1.
- Others strategies possible in future revisions.

(Tranovich, 2013)

Plumbing

Plumbing Fixture Standards

Flow rates on all plumbing fixtures shall be reviewed in accordance with the Environmental and Sustainability Goals section of this document. Any special fixture requirements for grey water systems shall be addressed per Recycled Water Systems section.

Additional fixture requirements:

- Water aerators mandatory in faucets;
- Waterless urinals for bathrooms – "waterless" brand;
- 1 gallon per flush toilets for bathrooms - American Standard brand;
- Low flow <1.7 GPM shower heads;

(Hapeman, 2013) (Tranovich, 2013) (Hosking, 2013)

Plumbing Equipment Standards

Plumbing equipment shall be energy efficient and modern with point of use on demand water heaters utilized where tank style water heater sustained flow rates are not required. Plumbing equipment shall be reviewed in accordance with the Environmental and Sustainability Goals section of this document.

- Water Heater – Natural gas tank-less condensing if possible, consider in conjunction with solar thermal preheat (described in other section).
- Tank type water heaters only where required (such as showers).
- **Do not include recirculation loops; if recirculation loops are required, justification in writing must be provided to and approved by County Energy Manager.**

(Tranovich, 2013)

Plumbing in Raised Floor Applications

In raised floor areas, such as a data room, locate floor drains at low point to direct water to drain. Separating water from networking infrastructure and electrical supply is a primary concern. (Leaver, 2013)

Rainwater Collection

The facility will be designed for current or future rainwater collection and use as greywater on site. The roof gutters will capture run-off to collection tanks and percolate back to the site, roof runoff from 2nd story roofs prioritized. If project cannot afford this type of system, project must be ready for future install. See also the Storm Water Management section. (Garnand, 2013)
Review system layout with County Energy Manager at Design Development phase.

Wastewater Plumbing Systems

Wastewater Utility

Freshwater Utility

Provide vault and straight pipe with unions for future sub metering. Provide PVC conduit to vault for data line from future sub-meter. Review system layout with County Energy Manager at Design Development phase. (Hapeman, 2013)

Recycled Water Systems

Consider a grey water recycling system which collects and stores sink, shower, and rainwater (gutters) runoff into holding tanks, then treats the water to a grey water standard and pumps from holding tanks to toilets for flushing and for drip irrigation of landscaping on the exterior of the building (avoid spray nozzles). (Tranovich, 2013)

Solar Thermal Preheat

Solar thermal preheat equipment shall be located adjacent to the connected system to avoid heat loss through piping. Locate near relevant equipment such as domestic water heater. County standard technology: Drain-back using distilled water with flat plat collectors. (Hapeman, 2013)

Electrical

Electrical Distribution

Standard Equipment:

- Panel boards – Square D
- Integrate metering to head-end server
- Sizing and features is project specific.

Redundancy and Adaptability Measures

Electrical infrastructure can be most cost effectively installed during the initial construction of a facility (as opposed to future retrofit). Provide in design and construction generous conduit sizing and additional empty conduits for future/redundancy use from all electrical rooms and in all trenches. All outdoor trenches will have multiple additional conduits of various sizes for adaptability purposes. (Hapeman, 2013) (Tranovich, 2013)

On-Site Generator

On-site generator may be provided for critical loads. Generators will be zoned per certain logical areas and emergency circuits to be defined, likely per building. Project will have 25kw or less goal per generator (does not require permitting). Determine only specific emergency lighting and = needs to be zoned with generators. (Hosking, 2013) Use propane generators versus diesel, colored receptacles designate emergency. (Leaver, 2013)

For data closets and data rooms, include all equipment, plug loads, HVAC, and lighting in generator loading calculation unless otherwise directed. (Leaver, 2013)

Design team shall consider the use of a solar/battery array as an “emergency generator” prior to consideration of a fossil fuel generator. (Hapeman, 2013)

Uninterruptible Power Supply

For data closets and data rooms, include all networking equipment unless otherwise directed. Size for battery backup duration goal of 20 minutes minimum. Identify all electrical outlets on UPS power with labeling and orange colored outlet (confirm with County Project Manager). (Leaver, 2013)

Interior Lighting

Lighting must be energy efficient, consistent from space to space and standardized to limit inventory but versatile enough to enhance space functionality, which is impacted by varying space use and day and nighttime conditions. Local lighting controls must be easy to operate and occupancy sensors provided where applicable to minimize unnecessary lighting use in sporadic usage areas. Maximize the use of natural day lighting. Minimize light pollution per applicable environmental and sustainability requirements. Provide A/B/C circuiting (or similar strategy) so if one circuit goes down due to an unforeseen or maintenance issue, half of the lights remain on. Provide dimming as required for compliance with Title 24 2014.

(Tranovich, 2013)

Lamp Color/Size/Style/Brand

- T8 Lamps: Sylvania or GE F28T8/XL/SP41/ECO, 24 watt rapid start ballast standard 4' or 2' fixtures;
- T5 Lamps: Sylvania or GE 3500K color temp
- Spot lighting - compact LED;
- High bay lights to be LED;
- Parking lot lights LED, Black Sky compliant;
- Exterior Building lights LED, Black Sky Compliant ;
  See appendix for the evaluated County standard for exterior LED lighting.

(Hosking, 2013)

Exterior Lighting and Dark Sky Compliance

The exterior lighting must also be dark sky compliant, meaning that no light is visible above the horizon. Lighting will not intrude onto neighboring properties. These goals can be most easily accomplished with directional LED floodlighting.

See appendix for the evaluated County standard for exterior LED lighting.
Two different Light Fixtures for outside use attached for wall pack and area lights duty. All outside lights must be controlled by a central lighting controller to be specified later, not on-board photocell. Any special needs lighting must be in the same family of lighting and approved by the County Energy Manager.

- Color Temp is 4100k - 41
- Outside Finish is Bronze- BZ
- All fixture shall have Stainless Steel Screws
- All fixture shall be mounted to be dark sky compliant only.

(Hapeman, 2013) (Tranovich, 2013)

Photovoltaic Generation and Distribution – Solar Ready

The project will be at minimum solar photovoltaic generation-ready. Electrical distribution switchgear will be designed and specified to permit practical and efficient future integration of photovoltaic generation into the facility. The following are a selection of provisions that are low/no cost during design phase which will permit this:

- Conduit of generous size stubbed up to all large roofs down to electrical rooms for future wiring;
- Parking lot solar ready with conduit runs installed and capped for future system installation;
- Facility single line diagram laid out in a fashion which permits practical integration of solar generation at the best location in the system – showing future solar point of connections;
- Electrical panel board and switchgear panel schedules showing future solar circuits explicitly labeled and held as vacant;

- Space reserved explicitly in electrical rooms and on roof for future photovoltaic system equipment, such as inverters;

County Photovoltaic standards are as follows:

- Generation shall use single large inverters as opposed to multiple smaller inverters
- Panel: Solar World Mono 265 (or greater)
- Invertor: Solectria Invertors

(Hapeman, 2013) (Tranovich, 2013)

Security and Access Control

Level 1 Areas (Non-Secure)

- Non-detention locks will be WinDSX card system integrated into existing WinDSX server.
- Single device access, either keypad or card reader, never both in same location.
- Refer to General Services WinDSX operations and policies document, available by request.

Level 2 Areas (Secure)

See project specific Owner's Project Requirements.

Networking and ICT Infrastructure

General Requirements

- Locate only end user devices in public areas.
- Rack Capacity - Confirm loading assumptions with IT department through the County project manager.

Responsibilities

- **General/Sub Contractors** – Install walls, conduits with pull-strings, backbone raceways and cable management, junction boxes, sleeves, monuments, floor boxes, plywood backing boards, grounding buses,
- **County Telephone Contractor** – Install horizontal cabling, racks, cabinets, room-level raceways and cable management, telephones, data-jacks, telephone jacks, coax cable, security camera cabling
- **County Networking Technicians** – Install network cabling, network equipment, computers, wireless access points, closet stand-alone UPS systems,
- **County Communications Technician** – Security cameras, DVR equipment
- **County Facilities/County Sub Contractor** – WinDSX device installation

Cable Routing

- Position lights fixtures minimum three feet from IT cables throughout entire building. Open raceways for cable are acceptable.
- Use CAT 6 or current standard and include any other requirements associated with that standard. Utilize color specific cables for certain uses. Bundle cable colors separately in raceways.
- Sleeves in Walls Between Rooms (Installed by project contractors)
    - Minimum 4" sleeve, quantity 2 (applies above drop ceilings, and in raised floor)
- Conduit Sizing (Installed by project contractors)
    - Minimum ¾" conduits for single line
    - Minimum 1" conduits for double line
    - Minimum 1 ½" conduit for more than double line pulls
    - Minimum 4" conduit for floor-to-floor vertical travel
    - Minimum 6" conduit, minimum quantity 2, to any microwave location

(Leaver, 2013) (Thornton, 2013)

Data Closets

- Data closet is defined as a networking infrastructure location with no servers. Minimum size for data closet is 6'x9' floor space. Minimum 8 foot ceiling height.
- ¾ inch plywood on all walls as backing board (Thornton, 2013)
- Ground bus in room, above raised floor, copper, bolted to wall (Thornton, 2013)
- 110V Power (Thornton, 2013)
- Specific type of rack, min distance between racks per code, earthquake strapping for top & bottom of racks to be confirmed with IT department. (Leaver, 2013) Owner will furnish racks and equipment.
- Confirm heat loading requirements to mechanical engineer for cooling calculations. (Tranovich, 2013)
- If providing sprinkler fire suppression, provide dry pipe system.
- Stand-alone UPS unit supplied by County.

Data Rooms

- Data closet is defined as a networking infrastructure location containing servers.
- ¾ inch plywood on all walls as backing board. (Thornton, 2013)
- Standard power feed is 208 volt service. (Leaver, 2013)
- 2 feeds per rack, coming from both separate panels and separate phases. (Leaver, 2013)
- Fire suppression in data room should be FM200, dry stand pipe sprinkler. (Slayman, 2013)
- Raised floor preferred for power & data in data rooms (>6"). (Slayman, 2013)
- Floor boxes under cabinets recessed & angled location not to take space from bottom slot on racks. (Leaver, 2013)
- Specific type of rack, floor box & floor tile orientation to racks, min distance between racks per code, earthquake strapping for top & bottom of racks to be confirmed with IT department. (Leaver, 2013) (Holman, 2013) Owner will furnish racks and equipment.

- Confirm heat loading requirements to mechanical engineer for cooling calculations. (Tranovich, 2013)

Bandwidth and Utility Capability

Bandwidth capability is of primary concern. Review requirements with IT department. (Slayman, 2013)

Anticipated Loading

- See project specific OPR.

Anticipated Utilities

Cable data service, nearest connection, fees, and capabilities need to be reviewed. Verizon data capabilities need to be reviewed. Data requirements of facility will drive what source and services are needed.

Architectural

General Orientation and Aesthetics

- Project will have a civic approach, with a sense of civic importance and commanding respect.
- Separate the receiving & business vehicles zone away from the front of the building. Size, scale, bulk: keep as far away as possible from public road. (Ooley, 2013)
- Use architectural features as wind breaks for prevailing wind. Minimize wind tunnel effect between buildings. Orient facility for high adaptability with minimal civil re-work. (Ooley, 2013)
- Use buildings placement to create outdoor spaces (such as courtyards) per the Facilities Policy Framework. Provide an attractive publicly available courtyard for visitors. (Ooley, 2013)
- Define and use a unified motif and logo for single tenant buildings. In multi-tenant buildings, each suite shall have continuity.
- Integrate art seamlessly, use appropriate artwork. (Ooley, 2013)

Building Orientation and Solar Ready Roof

This project will be solar photovoltaic generation-ready. Southwest facing roof surfaces will be maximized. (Hapeman, 2013)

Building Orientation and Day Lighting

Create natural day lighting opportunities (and therefore possible energy savings) when determining building orientations. Consider the use of light shelves to reflect daylight into the occupied spaces. (Tranovich, 2013)

High Reflectance Roof

Use any combination of strategies to meet the following criterion: (Area of Nonroof Measures / 0.5) + (Area of High-reflectance Roof / 0.75) + (Area of Vegetated Roof / 0.5) ≥ Total Site Hardscape Area + Total Roof Area.

Provide roof surfaces with a solar reflectance index (SRI) greater than:

- Low-sloped roof, ≤ 2:12 slope, SRI minimum 78
- Steep-sloped roof, > 2:12 slope, SRI minimum 29

(Council, 2013) (Tranovich, 2013)

High Reflectance Hardscape

Use hardscape materials with a solar reflectance index of at least 29. (Council, 2013)

Roof Materials

30 year or greater roof with a 10 year or greater maintenance program. Approved Vendors are Tremco or Garland Manufacturing. (Hosking, 2013)

Building Materials

Provide a 100 year life cycle building. Provide logical assemblies and details for ease of future replacement of materials and assemblies which will wear out. (Ooley, 2013)

Elevators

Project will have non-proprietary elevator control systems. Elevator will come with one year maintenance contract, after which it will be added to the County standing maintenance contract. (Hosking, 2013)

Way Finding

Door signage – adopt the University of Cincinnati number system. Implement easy public way finding strategies. Confirm with County project manager and project architect. (Hosking, 2013)

County Space Standards

Review and comply with County space standards. Confirm with County project manager and County Architect.

Lockers, Showers, and Active Lifestyle

Locate lockers near all new shower installations for promotion of a healthy and active lifestyle. (Tranovich, 2013) Locker and shower facilities shall be available for all County staff to use regardless of department assignment. Take this into account when locating shower and changing facilities and their respective lock hardware/WinDSX permissions. Locate near common areas for general employee access.

Bathroom Dispensers

- Pump Soap dispensers provided by Facilities;
- Toilet Paper is standard roll;
- Paper towels is standard roll towel, no try fold type;
- Sanitary toilet cover set holders stainless steel;
- No sanitary napkin dispensers or holders (provided by the department);
- Confirm submittals with County Facilities;

(Hosking, 2013)

Paint Standards

- South County
    - ICI Egret Eggshell
- North County
    - ICI Swiss Coffee
    - ICI Rice II

(Hosking, 2013) (Ooley, 2013)

Carpet

- Carpet Tile determined on per-project basis. (Hosking, 2013)

Door Hardware

Primary access shall be via WinDSX card system. Keyed access shall only be issued for senior staff and maintenance.

- All lock hardware: Schlage products with a Primus Key way,
- All hardware needs to be compatible to the WinDSX system.
- Door hardware: Von Duprin closers, panic bars, and the rest of the products that open and close the doors.

(Hosking, 2013)

Windows

Current Title 24 revision compliant or greater. Window appearance should match typical nearby existing windows. New building window systems may depend on geographic location (North County vs. South County…).
(Ooley, 2013)

Kitchen and Dining Facilities

See project specific OPR.

Landscaping Strategies

Layout – Building Shading, Solar Ready Roof and Parking Lot

Provide logical landscape design which can provide both immediate and future shading of non-south facing building surfaces from sunlight, thereby decreasing the overall energy usage of a thermostatically control HVAC system. However- Landscaping (such as trees - keep under 20') not to cast shadows on South facing roofs for future photovoltaic installation. Design parking lot landscaping as photovoltaic ready (keep clear of tall trees). (Hapeman, 2013)

Layout – Flora Selections and Placement

Select only native plants requiring minimal to zero water. Place plants in logical locations where root systems can provide structure to required areas in the soils and prevent erosion, such as the walls of bioswale drainage ditches and ponds. (Tranovich, 2013)

Storm Water Management

The responsible collection and reuse of rain water as greywater is a priority, followed by responsible percolation back to the water table on site using bio retention. Direction of rain water off site will be avoided at all costs except for a defined flood type scenario. The storm water management shall be engineered and multi-stage. (Tranovich, 2013)

Irrigation Systems

Rain bird is the standard. At a minimum that any new irrigation system requires a sub meter, programmable zones, rain sensor, and Rotor Heads, and adjustable metal heads. System shall be designed to use or be converted to recycled water in the future.

Fire Alarm

All County facilities shall utilize hard-wired alarm-strobe combination smoke detectors and shall comply with code. (Hapeman, 2013)

All County facilities shall utilize carbon monoxide detectors.

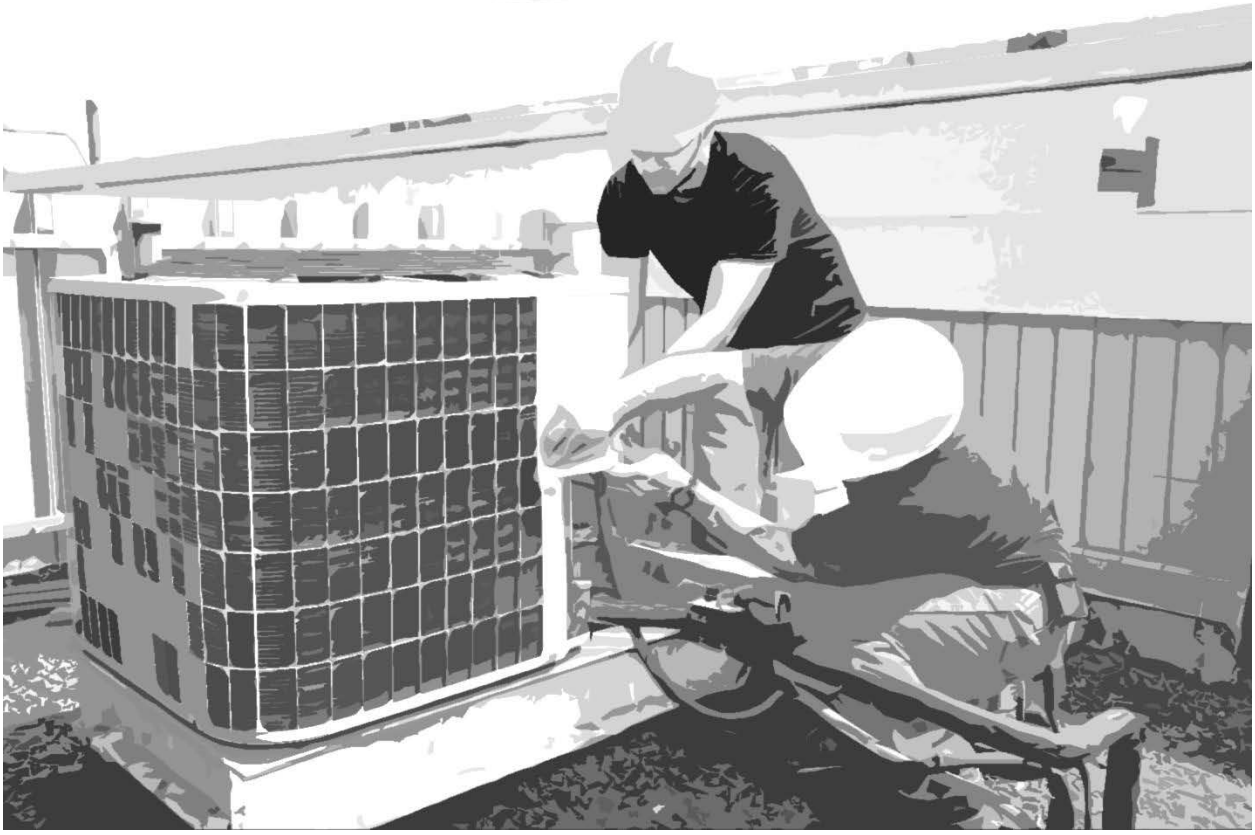
Building Occupant and Operations and Maintenance Expectations

Responsibilities Matrix

The following shows the intended responsibilities of operating and maintaining systems at the project.

NOTE: Future updates expected.

System	Operated by	Maintained by	Major Repairs by
HVAC - Pumps	*County Facilities*	*County Facilities*	*Outside Contractor*
HVAC - Chillers/Boilers	*County Facilities*	*County Facilities*	*Outside Contractor*
HVAC - Air Handlers	*County Facilities*	*County Facilities*	*Outside Contractor*
HVAC - Controls	*County Facilities*	*County Facilities with support if needed*	*Outside Contractor*
HVAC – IT Rooms	*County IT Dept*	*Outside Contractor*	*Outside Contractor*
Lighting – Fixtures/Systems	*County Facilities*	*County Facilities*	*Outside Contractor*
Plumbing - Fixtures	*County Facilities*	*County Facilities*	*County Facilities*
Plumbing – Equipment/WH	*County Facilities*	*County Facilities*	*County Facilities*
Access Control System	*County Facilities*	*County Facilities*	*Outside Contractor*
Security Cameras	*County Facilities*	*Communications Dept.*	*Communications Dept.*
IT Systems	*County IT Dept*	*County IT Dept*	*County IT Dept*
AV Conferencing	*County IT Dept*	*County IT Dept*	*County IT Dept*
Photovoltaic	*County Facilities*	*Outside Contractor*	*Outside Contractor*
Landscape Irrigation	*County Facilities*	*Outside Contractor*	*Outside Contractor*



Appendices

County Approved LED Fixture and Lamp Cut Sheets

Two different Light Fixtures for outside use attached for wall pack and area lights duty. All outside lights must be controlled by a central lighting controller to be specified later, not on-board photocell. Any special needs lighting must be in the same family of lighting and approved by the County Energy Manager.

- Color Temp is 4100k - 41
- Outside Finish is Bronze- BZ
- All fixture shall have Stainless Steel Screws
- All fixture shall be mounted to be dark sky compliant only.

Minimum Specifications Content

- **Div 01 – General Commissioning Requirements**
- **Div 22 – Commissioning of Plumbing Systems**
- **Div 23 – Test and Balance Minimum Specification**
- **Div 23 – Controls Minimum Specification**
- **Div 23 – Controls Integration Minimum Specification**
- **Div 23 –Commissioning of Mechanical Systems**
- **Div 26 – Commissioning of Electrical Systems**

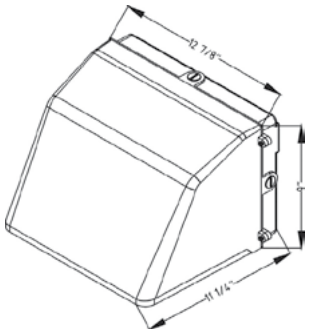
LED lighting

D444-LED

Medium Trapezoidal Cutoff Wallpack

Job Information
Type:
Catalog #:
Project:
Comments:
Prepared by:

Dimensions



Description

The D444-LED medium trapezoidal cutoff wall pack offers a sleek design and cutoff performance with a wide range of uses. It delivers the lighting needed for the exteriors of retail buildings, businesses, walkways, underpasses or door entrances.

Features

- Heavy duty two piece, die-cast aluminum housing aluminum reflector
- Silicone gasketing provides protection against moisture
- Mounts directly to 3.5" octagon, or 4" square outlet box
- .5" NPS tapped holes provided in three locations for surface conduit entry for optional photocell control
- Dark bronze powder coated finish for impact, corrosion and UV resistance
- Integral cast-in aluminum hinges
- Clear tempered glass lens is thermal and shock resistant
- UL 1598 listed for wet locations
- Can be used as an uplight for wall washing applications
- Dark Sky friendly
- Standard color is bronze; also available in black and white. Contact factory for custom finishes.

DECO digital lighting systems | DLC APPROVED | lighting facts

ORDERING INFORMATION:

Example: (D444-LED-20-50-UNV-BZ-PC)

D444-LED – [ ] – [ ] – [ ] – [ ] – [ ]

Series
Medium Trapezoidal Cutoff Wall Pack

Wattage/Lumens
20 - 20W/2540[3]
30 - 30W/3810[3]
40 - 40W/5080[3]

Color Temp.
41 - 4100K
50 - 5000K[4]

Voltage
UNV - 122-277V
347 - 347V
480 - 480V
(Step-Down Transformer used for 480V Divider)

Finish
BZ - Bronze[1]
BL - Black
WH - White
CU - Custom[2]

Options
WDF - Wired Double Fuse
WSF - Wired Single Fuse
PC - Photocell

[1] Standard color for this fixture
[2] Contact factory for custom finishes
[3] Initial lumens delivered
[4] Standard Color temperature

LED Lighting DECO™ LIGHTING

LED lighting

DECO digital™
lighting systems

D816-LED

16” Area Light

Transforming tomorrow’s lighting....today!

Job Information
Type:
Catalog #:
Project:
Comments:
Prepared by:

INDUSTRY BEST 10 YEAR WARRANTY INCLUDES LABOR ALLOWANCE

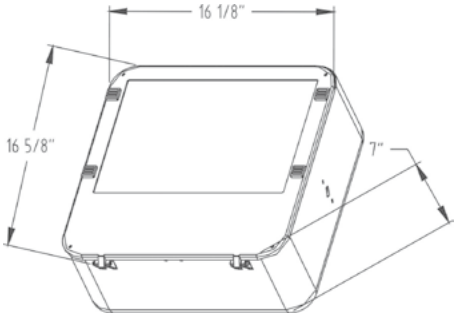
LED lighting facts A Program of the U.S. DOE

ControlScope CONNECTED

Buy American Act COMPLIANT

c UL us LISTED

Dimensions



Description

The D816-LED utilizes a soft-cornered aerodynamic design to provide excellent light distribution and an aesthetically appealing appearance. Ideal for storage areas, rail yards, loading docks, and building perimeters. One piece die cast aluminum door has two captive stainless steel fasteners and can be removed from the die cast aluminum housing for easy maintenance Attractive dark bronze, polyester powder coated finish for excellent impact, corrosion and UV resistance.

Features

- Extruded silicone rubber gasket for long life
- UL 1598 listed for wet locations
- Dark Sky friendly when used with Type III, IV or V reflectors (at 90° full cutoff position)
- Standard color is bronze; also available in black and white. Contact factory for custom finishes.
- EPA 0.96
- Energy Star Rated

LED Lighting DECO™ LIGHTING

DECO digital™ lighting systems

LED lighting

D816-LED

16" Area Light

Transforming tomorrow's lighting....today!

Job Information
Type:
Catalog #:
Project:
Comments:
Prepared by:

ORDERING INFORMATION:

Example: (D816-LED-60-50-UNV-YM-BZ-WDF)

D816-LED – [ ] – [ ] – [ ] – [ ] – [ ] – [ ] – [ ]

Series
16" Area Light

Wattage/Lumens
20 - 20W/2540[4]
30 - 30W/3810[4]
40 - 40W/5080[4]
60 - 60W/7620[4]
80 - 80W/10160[4]
120 - 120W/15240[4]

Color Temp.
41 - 4100K
50 - 5000K[5]

Voltage
UNV - 122-277V
347 - 347V
480 - 480V
(Step-Down Transformer used for 480V Divider)

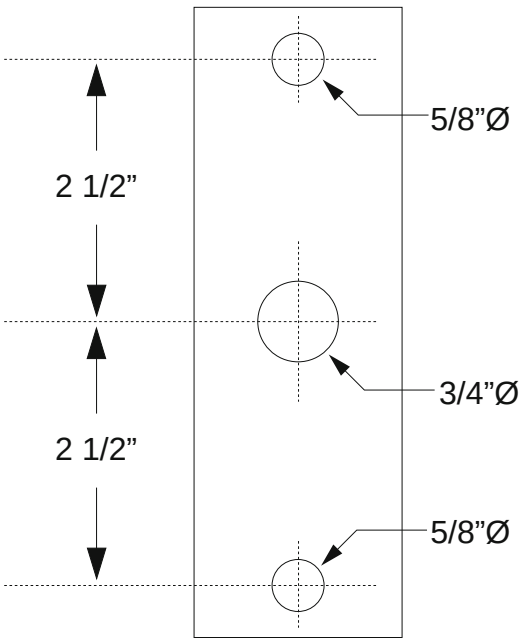
Mounting
YM - Yoke Mount
LYM - Large Yoke Mount
ESF - External Slip Fitter
SF - Slip Fitter
PM - Pole Mount[3]

Finish
BZ - Bronze[1]
BL - Black
WH - White
CU - Custom[2]

Options
PC - Photocell
PT3 - 3' Pre-wired Cord
PT6 - 6' Pre-wired Cord
WSF - Wired Single Fuse
WDF - Wired Double Fuse
PG - Polycarbonate Lens Guard
PM - Pole Mount Arms (6-10-12-18")
HK - Heavy Duty Adjustable
VS - Visor
BF - Baffle
GS - Glare Shield
WG - Wire Guard
SS - Stainless Steel Screws

[1] Standard color for this fixture
[2] Contact factory for custom finishes
[3] Bolt pattern 2" on center
5/16" bolts
AAA hardened steel screws
[4] Initial lumens delivered
[5] Standard Color temperature

Drilling Pattern



LED Lighting DECO™ LIGHTING

LED lighting

DECO digital™
lighting systems

D816-LED

16” Area Light

Transforming tomorrow’s lighting....today!

Job Information
Type:
Catalog #:
Project:
Comments:
Prepared by:

LED Lighting

DECO™ LIGHTING

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 01 91 13

GENERAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

B. OPR and BOD documentation are included by reference for information only.

C. Division 01, Section 017700, Closeout Procedures

D. Division 21, Section 210800, Commissioning of Fire Suppression Systems.

E. Division 22, Section 220800, Commissioning of Plumbing Systems.

F. Division 23, Section 230800, Commissioning of HVAC Systems.

G. Division 26, Section 260800, Commissioning of Electrical Systems.

H. Division 28, Section 280800, Commissioning of Fire Alarm Systems.

1.02 REFERENCES

A. Standards:

1. Comply with ASHRAE Guideline 0.

2. Title 24, Part 6, Section 120.8 Building Commissioning, Revision 2013

3. Comply with requirements of applicable green building code for this project such as LEED, CHPS, or CalGreen. (Verify with Owner.)

1.03 DEFINITIONS

A. Basis of Design (BOD): The BOD is developed by the design consultants for the systems used in the facility. It defines the assumptions made for the designed systems. This document is written to agree with the Owners Project Requirements (OPR).

B. Building Automation System (BAS): The building digital control system.

C. Commissioning Authority (CxA): An agent hired directly by the Owner which assists the Contractor with coordinating commissioning activities and witnesses and reviews the activities on behalf of the Owner.

D. Commissioning Issue: An issue which must be resolved to complete the commissioning process.

E. Commissioning Issues List: A log maintained by the CxA listing all Cx Issues documented during the commissioning.

F. Commissioning Plan: A document that outlines the organization, coordination, and requirements of the commissioning in detail.

G. General Contractor: The contractor directly contracted to the Owner with overall responsibility for the project and all commissioning activities.

H. Commissioning Coordinator (CxC): General Contractor employee who plans, schedules, and coordinates the Sub-Contractor's commissioning activities, and serves as the CxA's single point of contact for all administrative, documentation and coordination needs.

I. Deferred Testing: Testing performed at a later time for a certain reason.

J. Functional Performance Test (FPT): A test of the operation and control sequences of equipment and systems to verify system performance. Systems are tested under various operating modes,

such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, alarm, power failure, etc.

K. Installation Verification (IV): Field verification and documentation of proper installation of system equipment.

L. Monitoring: The recording of parameters of equipment operation using data-loggers or the Trending capabilities of BAS or control systems.

M. Owner's Project Requirements (OPR): A document written by the Owner describing the operational and functional requirements of a project, the expectations of how the facility will be used and operated, and the equipment and system expectations and requirements.

N. Sampling: Witnessing the startup or testing of a selected fraction of the total number of identical or near-identical pieces of equipment such as VAV boxes.

O. Pre-Functional Checks: These are various checks and tests performed on a piece of equipment or system just before, during or after the initial Startup. Examples include pipe system pressure tests, duct leakage tests, mechanical system test and balance and electrical equipment NETA testing. They must be completed prior to functional testing.

P. Startup: Initial starting or activating of equipment performed by the Sub-Contractor or the Manufacturer's representative.

Q. System Readiness Checklist (SRC): A checklist, covering the commissioning tasks and required documentation to verify that a system is ready for functional testing. The SRCs must be completed and signed by the General Contractor prior to conducting the functional testing.

R. Test and Balance (TAB): Testing, Adjusting, and Balancing work on the air and water systems to ensure design flow conditions are met.

S. Sub-Contractor: Typically a subcontractor to the General Contractor who provides and installs specific building components and systems and/or provides certain services.

T. Trending: Monitoring using the Building Automation System to aid in functional testing and to verify system operation and performance under operating conditions.

1.04 DESCRIPTION OF WORK

A. The following systems comprise the scope of commissioning:

1. All equipment and controls of the HVAC systems (does not include any process refrigeration equipment).
2. Building Automation System / HVAC System Controls
3. Lighting system controls
4. Domestic hot water heating systems
5. Electrical systems including emergency generators, ATS, UPS and power distribution system
6. Life safety systems (fire alarm, egress pressurization, fire protection)
7. Domestic & rain water harvesting systems
8. Sanitary Sewage pumping system
9. Plumbing systems

B. Coordinate with trades as needed to provide services.

C. The work includes the completion and documentation of formal commissioning procedures by the General Contractor and Sub-Contractors.

1.05 SUMMARY DESCRIPTION OF COMMISSIONING

A. Commissioning is a quality assurance process for verifying and documenting that building systems are installed and performing per the OPR, BOD, and the requirements of the contract documents.

B. Construction Phase commissioning shall achieve the following specific objectives:

1. Commissioning review of the Trade Sub-Contractor submittals for systems to be commissioned, concurrent with the Design Professional's review.
2. Finalize the commissioning specific details within the Commissioning Plan.
3. Verify that applicable equipment and systems are installed according to the manufacturer's requirements and they receive the required operational checkout and testing by the Sub-Contractors.
4. Verify and document proper performance of equipment and systems.
5. Verify that operation and maintenance documentation is provided by the Sub-Contractors
6. Develop a systems manual as applicable that provides future operating staff the information necessary to operate the commissioned systems.
7. Verify that the Owner's facilities and operations personnel are trained per the contract document requirements.

C. The commissioning process does not take away from or reduce the responsibility of the General Contractor to provide a finished and fully functioning building. The General Contractor has overall responsibility to assure that all systems are properly tested and commissioned, and that all required commissioning documents are completed and provided to the Owner.

D. The Project will meet the Commissioning Requirements of the project's applicable green building guidelines such as LEED, CHPS, or Title 24 2013 as required. The General Contractor, Sub-Contractors, and suppliers are responsible to ensure all requirements for commissioning are met in their respective work.

1.06 GENERAL COMMISSIONING PROCESS

A. Unless otherwise noted in the trade specific commissioning specification sections, the general commissioning process is as follows. See the trade specific commissioning specification sections for additional details on the commissioning process.

B. Submittal Reviews by the CxA (concurrent with the Design Team reviews) - The General Contractor shall include the CxA on the distribution of the Sub-Contractor issued submittals to the Design Professionals, for the systems to be commissioned. The CxA will provide review comments to the Design Professionals prior to the submittal return deadline.

C. Cx Plan and Form Development - The Commissioning Authority (CxA) shall prepare a Cx Plan that provides guidance in the execution of the commissioning process during construction. The CxA shall develop the SRC and FPT forms and provide them to the General Contractor and Sub-Contractors for review and comment prior to use.

D. System Readiness - The Trade Sub-Contractors shall perform Installation Verification, Startup and Pre- Functional activities. The Sub-Contractors and the CxC shall document completion of these activities on the SRC forms and attach the completed Installation Verification, Startup, and Pre-Functional forms to the SRC. The CxA will perform various observation inspections during the installation phase and back-checks of the completed activities. The CxA will also witness a percent sampling of the Startups and Pre-Functional activities, including TAB procedures.

E. Functional Testing - Once the SRC forms are completed, the FPTs are executed by the Sub-Contractors and a sample are witnessed by the CxA, as agreed and defined in the Cx Plan. The FPTs may be achieved by a combination of manual testing, monitoring or trending. Any deferred testing will be defined in the Cx Plan.

F. Commissioning Issues - The Commissioning Issues shall be recorded by the CxA on the Commissioning Issues List and distributed to the team on a regular basis. The General Contractor and Sub-Contractors shall correct Commissioning Issues and retest the system(s) without delay at no additional cost to the Owner. The CxA will verify the completion of the issues and make all amendments to the issues list.

G. O&M Manuals, and Final Documentation - The CxA will verify that the final O&M documentation is provided to the Owner per contract requirements. The CxA will develop, as applicable, the Systems Manual with assistance from the General Contractor and Sub-Contractors. The systems to be included shall be defined in the Cx Plan. The CxA will complete the Final Construction Phase Commissioning Report and documentation for the Owner with assistance from the General Contractor and Sub-Contractors.

H. Training Verification - The General Contractor shall submit to the CxA and Owner a training schedule and specific training agendas (for each training class), for review prior to conducting any training. The CxA shall verify completion of the training by receiving a copy of the training class sign-in sheets and any training materials / handouts, provided by the General Contractor.

I. Post-Occupancy Warranty Phase Commissioning - No later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility O&M staff, walk the facility and review systems operation and trend data where applicable. Key representatives from the General Contractor and Trade Sub-Contractors shall attend a site walk-through and meeting, as determined by the CxA. Any performance issues, warranty items or problems identified will be reported by the CxA to the CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Trade Sub-Contractors prior to the end of the warranty period.

1.07 QUALITY ASSURANCE

A. Commissioning Provider Qualifications:

1. The commissioning provider shall have an individual assigned to this project with one of the following credentials: Building Commissioning Association CCP, Association of Energy Engineers CBCP, ASHRAE CPMP, or AABC CxA.

2. All Work by this agency shall be done under direct supervision of the credentialed individual.

3. All instruments used by this agency shall be accurately calibrated and maintained in good working order. Calibration may be confirmed on site by owner's representative. Instruments without current calibration and documentation may have their results up to that point nullified and re-work with calibrated instruments would be required.

4. Conduct tests in the presence of the Owner's Representative.

1.08 COMMISSIONING TEAM

A. The Commissioning Team is responsible for performing the commissioning process as directed by the CxA and achieving successful commissioning results. The Commissioning Team is comprised of the following:

1. Owner and Owner's Representatives

2. Design Professionals (DP) and Architects/Engineers (A/E)

3. Commissioning Authority (CxA).

4. General Contractor

5. General Contractor's Commissioning Coordinator (CxC)

6. Sub-Contractors including:

a. Mechanical Contractor

b. Electrical Contractor (including generator representative, UPS representative)

c. HVAC Controls Contractor

d. Testing and Balance (TAB) Contractor

e. Plumbing Contractor (including fire suppression representative, irrigation representative, rainwater harvesting representative)

f. Fire Alarm Contractor

1.09 RESPONSIBILITIES

A. General.

1. The Commissioning Team shall follow the Commissioning Plan, attend the commissioning kickoff meeting, and attend additional commissioning meetings as necessary.

B. Commissioning Authority (CxA) shall:

1. Oversee and lead the commissioning team and assist the General Contractor and Sub-Contractors in executing the commissioning process.
2. Prepare the Cx Plan and develop the SRC and FPT forms.
3. Work with the General Contractor to coordinate the schedule of commissioning activities.
4. Lead commissioning team meetings, prepare meeting agendas and distribute meeting minutes.
5. Observe equipment installation, start-up, checkout, and testing for compliance with the OPR, BOD, and Contract Documents; and review completion of commissioning documentation.
6. Witness the execution of the FPTs by the Trade Sub- Contractors. The CxA shall witness at minimum one (1) re-test of any commissioned equipment or system free of charge.
7. Review commissioning test results and other commissioning program elements completion. Prepares, maintains and distributes the Cx Issues List.
8. Review and comment on training agendas and O&M Manuals, and verify that training is completed and O&M manuals are delivered.
9. Compile the Systems Manual as applicable per contract and project relevant Green Building Code.
10. Assemble the commissioning documents and prepare the Commissioning Report.
11. The CxA is not responsible for:
    a. Design concept or design criteria
    b. Review for code compliance
    c. Inspector of record services
    d. Design and construction scheduling
    e. Cost estimating
    f. Construction management
    g. Providing tools and test equipment used for commissioning.
    h. Scheduling startup and testing
    i. Performing startup and testing

C. General Contractor shall:

1. Be responsible for tasks assigned to Sub-Contractors and ensures that all Sub-Contractors execute their commissioning responsibilities according to the Contract Documents, Cx Plan, and schedule.

2. Include the cost for commissioning in the project cost.
3. Assign a CxC for the duration of the project with responsibilities outlined herein.
    a. The CxC shall have at least five years' experience within the disciplines of construction.
    b. The General Contractor shall submit the name of the person(s) assigned as the CxC to the CxA within one month of contract award.
4. Schedule and coordinate the commissioning meetings with the CxA.
5. Plan, schedule, coordinate and facilitate the commissioning work performed by the Sub-Contractors.
6. Provide sufficient lead-time of at least 10 days to notify the CxA in advance of commissioning activities.
7. Update the master construction schedule periodically with commissioning progress and activities.
8. Review, comment, and accept the Cx Plan prepared by the CxA.
9. Furnish continual updates of any construction related documents such as change orders, submittals, shop drawings, ASIs and RFIs to the CxA. Electronic files are preferred.
    a. The CxC shall ensure that the requested submittals for review by the CxA are also issued to the CxA when issued to the Design Team.
10. Obtain and review the Sub-Contractor installation and prefunctional forms prior to use.
11. Use the IV, Startup, pre-functional, SRC, and FPT forms, to document and certify that all work is complete and systems are installed, operational and functionally tested.
12. Organize all Sub-Contractor completed Cx forms to be submitted to the CxA for review.
13. Evaluate deficiencies identified on the Cx Issues List. Issues will be tracked according to the responsible entity. Collaborate with Sub-Contractors and recommend corrective action.
14. Assure all Cx Issues are resolved.
15. Prepare a training schedule along with the Sub-Contractor training agendas and submit to CxA and Owner for review. Execute training of Owner's personnel per approved training schedule and agendas.
16. Prepare O&M Manuals in accordance with the Contract Documents.
17. Assist the CxA in developing the Systems Manual as applicable.

D. Sub-Contractors:
    1. See trade-specific specification sections.

1.10 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. CxA shall submit electronic copies of all Cx deliverables described herein to the Owner upon request.

C. Instruments Used by CxA
    1. A complete list of instruments proposed to be used, organized in appropriate categories, with data sheets for each. Show:
        a. Manufacturer, model and serial number.

b. Description and use when needed to further identify the instrument.

c. Size or capacity range.

d. Latest calibration date and certificates of calibration.

1.10 SUBSTITUTIONS

A. Not applicable.

1.11 WARRANTY

A. Warranties shall be in accordance with Section 01 78 36 – Warranties.

B. The CxA shall warrant the conclusions drawn from functional testing and trend analysis for accuracy.

1. It is the CxA's responsibility to coordinate with the test and balance and controls contractors for accurate test result readings and trend data received.

2. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, CxA shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order to provide accurate system conclusions and recommendations.

3. The CxA shall provide revised system functionality conclusions, FPT documentation, and trend analysis as needed to replace the flawed and void previous documentation.

C. The general and subcontractors shall warrant the data drawn from functional testing and trend analysis to be accurate and correct. (most importantly: test and balance and controls contractors)

1. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, the responsible contractors shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order for the CxA to provide accurate system conclusions and recommendations.

PART 2 - PRODUCTS

2.01 None.

PART 3 - EXECUTION

3.01 SCHEDULING AND COORDINATION

A. The CxA will provide an initial list of commissioning milestones and deliverables to the CxC for scheduling purposes at the commissioning kick off meeting.

B. The General Contractor shall integrate all commissioning activities, milestones and deliverables into the master construction schedule with assistance from the CxA.

C. The CxC shall provide sufficient notice to the CxA and Owner for scheduling and coordinating commissioning activities. A minimum 10 day's notice shall be provided to the CxA for witnessing equipment Start-ups, Pre-Functionals, and Functional Performance Testing.

D. The Commissioning Team shall address scheduling problems and make necessary modifications in a timely manner in order to expedite the commissioning process.

3.02 MEETINGS

A. When commissioning team member attendance is required, as determined by the CxA and CxC, be punctual and attentive during the meeting.

1. The CxA shall conduct a commissioning kick-off meeting, usually within 60 days of the commencement of construction. All team members involved in the commissioning process shall attend the kick-off meeting.

2. The CxA shall conduct a commissioning “pre-startup” meeting, to confirm the final plan for startup and witnessing of equipment. All team members involved in the commissioning process shall attend.
3. The CxA will plan other commissioning meetings as deemed necessary as construction progresses. These meetings will cover planning and coordination, and Commissioning Issues resolution.
4. The frequency of meetings will vary through construction, but generally increase during start-up and commissioning activities.

B. The CxA shall write and distribute meeting minutes documenting the meeting discussion, conclusions, and actions for each team member.

3.03 COMMISSIONING ISSUES, BACK-CHECKS, AND RE-TESTING

A. All Deficiencies and Commissioning Issues shall be corrected promptly. The responsible party shall correct the issue and inform the CxC and CxA of the resolution and completion date. The CxA will record completion on the Commissioning Issues List once the issue is successfully back-checked or verified.
1. For all Commissioning Issues identified during the pre-functional system readiness activities, the CxA will back-check and verify the completion of the issues where appropriate.
2. For all Commissioning Issues identified during FPT, retesting is required to verify the resolution of the issue and to complete the FPT.
3. The CxA shall witness one (1) re-test for each equipment and will perform one (1) back-check verification of any completed system readiness issue.
4. The Owner may back-charge the General Contractor for any additional fees from the CxA, resulting from any re-testing or repeated system readiness issues list back-checks beyond the first re-test or back-check.

3.04 COMMISSIONING ACCEPTANCE, CLOSEOUT AND REPORTING

A. Regarding substantial completion, reference Division 01, Section 017700, Closeout Procedures.

B. After completion of the commissioning activities and following review of the completed commissioning documents that includes the draft Cx Report executive summary, all test results and the latest Cx Issues List with all remaining commissioning issues and deficiencies, the Owner will provide a formal written acceptance of the project construction phase commissioning. At that point, any remaining construction phase commissioning issues or seasonal/deferred testing will be transferred to the warranty phase and tracked by the CxA as part of the Post-Occupancy Warranty Phase Commissioning.

C. Upon completion of all commissioning activities, the CxA will prepare and submit to the Owner a Final Commissioning Report detailing all completed commissioning activities and documentation.

D. The CxC shall support this effort by providing all General Contractor and Trade Sub-Contractor commissioning documentation.

E. The Owner’s written acceptance of construction phase commissioning will be included in the Final Commissioning Report.

END OF SECTION

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the technical specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 22 08 00

COMMISSIONING OF PLUMBING SYSTEMS

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Division 22, ….

B. …

1.02 REFERENCES

A. Reference Standards:

1. Comply with ASHRAE Guideline 0.
2. Title 24, Part 6, Section 120.8 Building Commissioning, Revision 2013
3. Comply with requirements of applicable green building code for this project such as LEED, CHPS, or CalGreen. (Verify with Owner.)

1.03 DEFINITIONS

A. Basis of Design (BOD): The BOD is developed by the design consultants for the systems used in the facility. It defines the assumptions made for the designed systems. This document is written to agree with the Owners Project Requirements (OPR).

B. Building Automation System (BAS): The building digital control system.

C. Commissioning Authority (CxA): An agent hired directly by the Owner which assists the Contractor with coordinating commissioning activities and witnesses and reviews the activities on behalf of the Owner.

D. Commissioning Issue: An issue which must be resolved to complete the commissioning process.

E. Commissioning Issues List: A log maintained by the CxA listing all Cx Issues documented during the commissioning.

F. Commissioning Plan: A document that outlines the organization, coordination, and requirements of the commissioning in detail.

G. General Contractor: The contractor directly contracted to the Owner with overall responsibility for the project and all commissioning activities.

H. Commissioning Coordinator (CxC): General Contractor employee who plans, schedules, and coordinates the Sub-Contractor's commissioning activities, and serves as the CxA's single point of contact for all administrative, documentation and coordination needs.

I. Deferred Testing: Testing performed at a later time for a certain reason.

J. Functional Performance Test (FPT): A test of the operation and control sequences of equipment and systems to verify system performance. Systems are tested under various operating modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, alarm, power failure, etc.

K. Installation Verification (IV): Field verification and documentation of proper installation of system equipment.

L. Monitoring: The recording of parameters of equipment operation using data-loggers or the Trending capabilities of BAS or control systems.

M. Owner's Project Requirements (OPR): A document written by the Owner describing the operational and functional requirements of a project, the expectations of how the facility will be used and operated, and the equipment and system expectations and requirements.

N. Sampling: Witnessing the startup or testing of a selected fraction of the total number of identical or near-identical pieces of equipment such as VAV boxes.

O. Pre-Functional Checks: These are various checks and tests performed on a piece of equipment or system just before, during or after the initial Startup. Examples include pipe system pressure tests, duct leakage tests, mechanical system test and balance and electrical equipment NETA testing. They must be completed prior to functional testing.

P. Startup: Initial starting or activating of equipment performed by the Sub-Contractor or the Manufacturer's representative.

Q. System Readiness Checklist (SRC): A checklist, covering the commissioning tasks and required documentation to verify that a system is ready for functional testing. The SRCs must be completed and signed by the General Contractor prior to conducting the functional testing.

R. Test and Balance (TAB): Testing, Adjusting, and Balancing work on the air and water systems to ensure design flow conditions are met.

S. Sub-Contractor: Typically a subcontractor to the General Contractor who provides and installs specific building components and systems and/or provides certain services.

T. Trending: Monitoring using the Building Automation System to aid in functional testing and to verify system operation and performance under operating conditions.

1.04 DESCRIPTION OF WORK

A. The following systems comprise the scope of commissioning:

1. Domestic Hot Water Systems
2. Sewage Booster Pumps
3. Lift Station
4. …

B. Coordinate with trades as needed to provide services.

C. The work includes the completion and documentation of formal commissioning procedures by the General Contractor and Sub-Contractors.

1. Commissioning is the process of verifying the installation and performance of building systems to meet the design intent, contract documents, Owner's requirements, and operational needs.
2. The Design Professionals, General Contractor and Sub-Contractors provide the quality control for the design, installation, startup and checkout of the systems. The commissioning process provides review and qualitative functional testing in order to formally observe and document that the quality control efforts are successfully completed.
3. The Sub-Contractors and the factory service representatives shall be responsible for participation in the commissioning process as outlined in this specification and Section 01 91 13 General Commissioning Requirements, and as directed by the General Contractor's CxC as overseen by the CxA.
4. Refer to Section 01 91 13, General Commissioning Requirements for summary description of the general commissioning process and requirements.

1.05 QUALITY ASSURANCE

A. Commissioning Provider Qualifications:

1. The commissioning provider shall have an individual assigned to this project with one of the following credentials: Building Commissioning Association CCP, Association of Energy Engineers CBCP, ASHRAE CPMP, or AABC CxA.

2. All Work by this agency shall be done under direct supervision of the credentialed individual.
3. All instruments used by this agency shall be accurately calibrated and maintained in good working order. Calibration may be confirmed on site by owner's representative. Instruments without current calibration and documentation may have their results up to that point nullified and re-work with calibrated instruments would be required.
4. Conduct tests in the presence of the Owner's Representative.

1.06 CONSTRUCTION PHASE COMMISSIONING PROCESS

A. Submittal Review by the CxA

1. The CxA shall review the Trade Sub-Contractor's submittals for the scope systems concurrently with the Design Team and provide review comments to the Owner and Design Team before submittal approval.
2. The General Contractor shall provide a submittal log to the CxA for referencing requested submittals to be reviewed by the CxA.
3. Information from the submittals will also be used by the CxA to develop commissioning forms and test procedures.

B. Cx Plan and Form Development

1. The CxA shall write a Preliminary Commissioning Plan and provide to Owner for review.
2. The CxA shall facilitate a commissioning kickoff meeting where the commissioning process and systems are reviewed.
3. The CxA shall develop the SRC checklists which track the completion of the Installation, Startup, and Pre-Functional Checks required for each system. The SRC forms shall be provided for peer review at the kickoff meeting.
4. The CxC shall submit to the CxA, for review and approval, representative blank forms for completing Installation Verification, Startup, and Pre-Functional Checks on request.
    a. Installation Verification forms are used to provide field verification and documentation of proper installation of equipment and system prior to formal Startup.
    b. Startup and Pre-Functional Check forms are usually Manufacturer and/or Trade Sub-Contractor startup and checkout sheets and shall be used where required and appropriate.
    c. Where appropriate, IV forms and startup forms may be combined, such as on small fan installations.
    d. Where appropriate, these forms can be checklists taken from the Manufacturer's installation manual.
    e. The Pre-Functional Test forms shall also include forms for recording results from system specific tests such as pipe system pressure tests, duct leakage tests, mechanical system TAB, electrical equipment NETA testing, etc.
5. The CxA will develop Functional Performance Testing (FPT) procedures and forms. These test procedures shall be provided to the Owner, General Contractor, and Trade Sub-Contractors for review and comment.

C. System Readiness Activities

1. Meetings shall be conducted throughout construction with Commissioning Team members, as required, to plan, coordinate, and schedule commissioning activities, review documentation, and resolve Cx Issues.
2. The Sub-Contractors shall perform Installation, Startup and Pre-Functional Check & Test activities to verify that the system is ready for operation or functional testing.

3. The Trade Sub-Contractors and the CxC shall document completion of these activities on the SRC forms and attach the completed Installation Verification, Startup, and Pre-Functional Check & Test forms to the SRC.
    a. In general, Installation Verification should be completed prior to Startup, but where appropriate, they can be completed into one activity.
4. The CxA shall perform multiple inspections during these phases.
5. The CxA shall witness a percent sampling of the Startups and Pre-Functional Checks & Tests, including TAB procedures. Sampling approach to be approved by Owner.

D. Functional Testing

1. Functional Performance Tests (FPTs) are tests of the control function and performance of the systems. These tests are used to verify that the sequences of operation are correctly implemented and that the design intent and performance criteria of the systems have been met.
2. The CxA shall develop FPT forms that contain:
    a. Specific procedures to execute the tests in a clear and repeatable format
    b. Any control system point value or setpoint overrides required to simulate a test condition or sequence mode.
    c. The expected system response and acceptance criteria of proper performance with a Yes/No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
    d. A section for recording actual system response, notes and comments.
3. The CxA shall provide a trending plan which contains:
    a. A list of control system trend data to be collected and provided to the CxA in electronic format for analysis and review.
    b. The list shall contain at minimum: point name and description, units, time series or change of value data type, time series trending intervals.
    c. The list shall have two columns of trend interval values, one with shorter trending intervals for high resolution data collection during functional testing and an additional column for lower resolution data collection for ongoing trend analysis of the system beyond the functional testing.
4. Once the SRC checklists are completed the FPTs shall be executed by the Sub-Contractors with all or a sample witnessed by the CxA, as defined in the Cx Plan and agreed with the owner.
5. Any deferred testing will be defined in the Cx Plan.

E. Commissioning Issues and Resolution

1. Issues shall be recorded by the CxA on the Commissioning Issues List and distributed to the commissioning team.
2. The General Contractor and Sub-contractors shall correct Commissioning Issues and retest the system(s), where applicable, without delay at no additional cost to the Owner.
3. The CxA will verify the completion of the issues and make all amendments to the issues list.

F. O&M Manuals, Training Verification and Final Documentation

1. The General Contractor shall compile and complete the Operations & Maintenance (O&M) Manuals provided by the Trade Sub-Contractors, per the contract documents requirements.

2. The CxA shall verify that the correct O&M content has been delivered to the Owner per the contract requirements and may request electronic copies of the O&M Manuals to aid in the completion of the Systems Manual if applicable.
3. The General Contractor shall submit a training schedule and specific training agendas provided by the Trade Sub-Contractors for each training to occur to the CxA and Owner for review prior to conducting any training.
4. The CxA shall review and provide comment to the Owner and General Contractor on the specified training agendas.
5. The CxA shall verify completion of the training by verifying a copy of the training sign-in sheets, provided by the General Contractor.
6. The CxA shall develop the Systems Manual (if applicable) with assistance from the General Contractor and Sub- Contractors. The systems to be included shall be confirmed with Owner.
7. The CxA shall complete the Construction Phase Commissioning Report and documentation for the Owner.

G. Post-Occupancy/Warranty Phase Commissioning

1. If contracted, no later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility O&M staff, walk the facility and review systems operation.
2. Key representatives from the General Contractor and Trade Sub-Contractors shall also attend, as determined by the CxA.
3. Any performance issues, warranty items or problems identified will be reported by the CxA to the Owner and CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Sub-Contractors prior to the end of the warranty period.

1.07 COMMISSIONING TEAM

A. The Commissioning Team is responsible for performing the commissioning process as directed by the CxA and achieving successful commissioning results. The Commissioning Team is comprised of the following:

1. Owner and Owner's Representatives
2. Design Professionals (DP) and Architects/Engineers (A/E)
3. Commissioning Authority (CxA).
4. General Contractor
5. General Contractor's Commissioning Coordinator (CxC)
6. Plumbing Contractor

1.08 RESPONSIBILITIES

A. General.

1. The Commissioning Team shall follow the Commissioning Plan, attend the commissioning kickoff meeting, and attend additional commissioning meetings as necessary.

B. Commissioning Authority (CxA)

1. See Section 01 91 13, General Commissioning Requirements.

C. General Contractor:

1. See Section 01 91 13, General Commissioning Requirements.

D. Sub-Contractors:

1. Provide submittal data, including manufacturer's installation checks and startup procedures, commissioning forms, and any other requested contract documentation for systems to be commissioned. Electronic files are preferred.
2. Attend commissioning meetings as directed by the CxA and General Contractor's CxC to facilitate the commissioning process.
3. Assign personnel with expertise and authority to act on behalf of the General Contractor and schedule them to participate in and perform assigned commissioning tasks.
4. Demonstrate and properly document proper system installation, startup and performance per contract requirements and manufacturer's forms.
5. Complete all Installation, Startup and Pre-Functional Check & Test documentation clearly and legibly. Provide a copy of all forms to the CxC and CxA as part of completing the SRC forms.
6. Provide access for the CxA to witness any equipment Startup and Pre-Functional Checks & Tests.
7. Notify the CxC and CxA at least 5 working days in advance of Startup and Pre-Functional Checks & Tests.
8. Ensure that any required manufacturer factory tests are performed and provide the factory test data.
9. Ensure that any required manufacturer's representative field tests and on-site installation verification, startup and checkout of selected equipment are performed per the contract documents.
10. Provide completed manufacturer documentation and commissioning forms for these activities to the CxC.
11. Address applicable Cx Issues promptly. All Installation Verification, Startup and Pre-Functional issues must be resolved before the FPT can proceed.
12. Assist CxA in preparing the FPT procedures, clarifying the operation and control of commissioned equipment where the specifications, control drawings or equipment documentation are not sufficient for writing detailed testing procedures.
13. Review the FPT procedures to ensure feasibility, warranty protection, safety and equipment protection, and provide necessary written alarm limits and overrides to be used during the tests.
14. As part of the FPTs, the Trade Sub-Contractor shall setup any additional software points, overrides of any sensor values or relays, and overrides of any setpoints or schedules, to simulate certain conditions and operating modes, in order to conduct the FPTs.
15. Perform the FPTs as written. Execution of FPTs shall be witnessed by the CxC and CxA and fully documented.
16. Assist the CxA in collecting all requested Trend data associated with FPTs.
17. Prepare a training agenda and sign-in sheet for each training class (to be reviewed by the CxA) and work with the General Contractor and Owner to schedule training. Execute training of Owner's personnel per approved training agenda and schedule.
18. Prepare O&M Manuals according to the Contract Documents.
19. Assist the CxA in developing the Systems Manual if applicable.

1.09 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. CxA shall submit electronic copies of all Cx deliverables described herein to the Owner upon request.

C. The Sub-Contractors shall submit to the CxA blank forms for Installation Verification, Startup and Pre-Functional Checks for review and comment.

D. The CxA will review these submitted commissioning forms for completeness including any project specific requirements.

E. The CxA may request additional data, changes and/or additions to these forms to make sure they are complete prior to their use. If the submitted forms are not available or are not sufficient, then the CxA will provide forms based on the construction documents and specifications, manufacturer installation manuals and procedures, and/or industry standards or guidelines.

F. The Trade Sub-Contractors shall submit to the CxA any equipment and construction submittals and shop drawings, including detailed sequences of operation, as requested by the CxA.

G. Instruments Used by CxA

1. A complete list of instruments proposed to be used, organized in appropriate categories, with data sheets for each. Show:

   a. Manufacturer, model and serial number.

   b. Description and use when needed to further identify the instrument.

   c. Size or capacity range.

   d. Latest calibration date and certificates of calibration.

1.10 SUBSTITUTIONS

A. Not applicable.

1.11 JOB CONDITIONS

A. For existing conditions, obtain building as-built drawings from the Owner for pre-construction requirements.

B. Prior to start of functional testing:

1. Outside conditions to be within 15 percent relative to design conditions.

2. Building lights shall be turned "on" when testing cooling system, "off" when testing heating system.

3. Special equipment such as computers, laboratory equipment, electronic equipment or engine generator to be in full operation.

4. Close all windows and doors.

C. Notification: Promptly report any deficiencies noted during performance of services. Rectify these deficiencies, and any tests interrupted shall be re-done.

1.12 WARRANTY

A. Warranties shall be in accordance with Section 01 78 36 – Warranties.

B. The CxA shall warrant the conclusions drawn from functional testing and trend analysis for accuracy.

1. It is the CxA's responsibility to coordinate with the test and balance and controls contractors for accurate test result readings and trend data received.

2. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, CxA shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order to provide accurate system conclusions and recommendations.

3. The CxA shall provide revised system functionality conclusions, FPT documentation, and trend analysis as needed to replace the flawed and void previous documentation.

C. The general and subcontractors shall warrant the data drawn from functional testing and trend analysis to be accurate and correct. (most importantly: test and balance and controls contractors)

1. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, the responsible contractors shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order for the CxA to provide accurate system conclusions and recommendations.

PART 2 - PRODUCTS

2.01 DOCUMENTATION

A. The Sub-Contractors have specific responsibilities for assisting in the development of the commissioning forms used, and in performing and documenting commissioning tests, as directed by the CxC and as overseen by the CxA.

B. The Sub-Contractors shall provide, system checks and testing, test reports, factory test data and reports, checklists, operational verifications and demonstration, etc. , per contract documents whether specified or not in the commissioning sections.

2.02 TEST EQUIPMENT

A. The Sub-Contractors shall provide all test equipment to execute Pre-Functional and Functional Performance Tests.

B. The test equipment shall be provided in sufficient quantities to execute testing in an expedient fashion.

C. The test equipment shall be of industrial quality and suitable for testing and calibration with accuracy within the tolerance necessary to demonstrate system performance per the Contract Documents. If not otherwise specified, the following minimum requirements apply:

1. Temperature sensors and digital thermometers shall have a certified calibration within the past 12 months to an accuracy of 0.5 degree F and a resolution to + or – 0.1 degree F.

2. Pressure sensors shall have an accuracy of + or – 2.0 percent of the value range being measured (not full range of meter) and have been calibrated within the past 12 months.

D. The test equipment shall have calibration certification per equipment manufacturer’s interval level or within one year if not otherwise specified. The calibration tags shall be affixed or certificates readily available for all test equipment.

PART 3 - EXECUTION

3.01 STARTUP AND SYSTEM READINESS

A. All tests and start-up procedures shall be conducted without compromise to human or equipment safety.

B. The General Contractor and Sub- Contractors shall be responsible for the liability and safety of conducting all tests and startup.

C. The General Contractor shall clearly identify and list any Deficiencies resulting from the Installation Verification, Start-up and Pre-Functional Checks on the associated forms and immediately notify the CxA. Once Deficiencies are corrected and verified or tested, update and resubmit the associated forms.

D. The CxC and Trade Sub-Contractors shall a minimum 10 day’s notice to the CxA for witnessing equipment Start-ups and Pre-Functional Checks & Tests.

3.02 FUNCTIONAL PERFORMANCE TESTS

A. Functional testing shall be performed and documented for 100% of all equipment in the scope of commissioning.

B. At the discretion of the CxA and per the approved Cx Plan, the CxA may witness a percentage (sample) of the functional tests for selected, multiple identical pieces of non-life-safety or non-critical equipment (example: VAV boxes).

C. The General Contractor and Sub-Contractors shall be responsible for the liability and safety of conducting all tests.

D. Ensure the following are completed prior to the start of the FPTs:

1. CxA and CxC certify through the System Readiness Checklist (SRC) forms that the HVAC systems, controls and instrumentation, equipment and assemblies have been installed, calibrated, started and are operating per the Contract Documents. Approval of the completed SRC forms by the CxA is required prior to conducting the FPTs.

2. As part of the system readiness, the TAB Trade Contractor shall conduct and complete all testing, reporting, field inspection and verification work, and discrepancies and corrective work, per specifications, prior to HVAC system FPT.

3. As part of the system readiness, all pipe system cleaning, flushing, and pressure testing, duct leakage testing and duct cleaning per the Contract Documents is completed and applicable plans and reports are provided to the CxA.

4. As part of the system readiness, the Controls Contractor shall complete the BAS pre-functional checks and tests, including sensor calibration, actuator testing, and point-to-point checks, prior to FPTs of the HVAC systems.

5. And the BAS graphics and programming for the sequence of operations and associated setpoints, schedules, and alarms shall be configured and the system operation checked and confirmed, including the control loop tuning, prior to starting functional testing.

    a. Prior to conducting the FPTs, place the systems and controls into the operating modes to be tested (e.g., normal occupied mode, normal startup and shutdown modes, unoccupied modes including after-hours override and night setback operation, emergency power, etc.).

    b. Check all control system safety cutouts, alarms, and interlocks with smoke control and fire-life safety during each mode of operation prior to functional testing.

6. The controls contractor shall execute a pre-test of the functional test on the approved FPT forms prior to the final witnessed test. This will give the controls contractor the confidence the witnessed test will pass.

E. Sub-Contractors shall execute all FPTs per the approved test procedures on the FPT forms. All testing results shall be documented on the final FPT forms; the forms shall be signed and dated by the representative performing the tests.

F. The CxC and Sub-Contractors shall coordinate all FPT with the CxA, and provide a minimum of 10 day's notice prior to conducting each system test.

G. FPT for each system must be successfully completed and signed by the CxA prior to formal approval of system commissioning.

H. FPT may be conducted using these approved test methods:

1. Manually manipulating the equipment settings to observe performance.

2. Overwriting control system sensor values to simulate a condition, such as overwriting the outside air temperature to be something other than it actually is.

3. Altering setpoints to force equipment into a mode of operation to verify a sequence.

4. Using indirect indicators, such as readings from a control system screen reporting a damper is 100 percent open, for testing responses will be allowed only after the actual conditions represented by the indirect indicators have been directly verified, calibrated and documented on the SRC forms (as a pre-functional check/test).
5. Monitoring performance by analyzing the control system Trend data. The CxA will then analyze the control system Trend data and provide conclusions to the Owner.

I. Setup

1. The Sub-Contractor executing the test shall document the pre-test normal condition on the test form.
2. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible.
3. The Trade Sub-Contractor executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. to execute the test according to the test procedures.
4. At completion of the test, the Trade Sub-Contractor shall return all affected building equipment and systems to their pre-test normal condition.

3.03 FUNCTIONAL PERFORMANCE TESTS AND TREND ANALYSIS

A. The CxA will prepare a Trend Analysis Plan with a points list and trend interval, as part of the FPTs to verify integrated system operation and performance. The Trend analysis will be conducted after the FPTs for the HVAC control sequences and operating modes are completed and any issues and deficiencies are corrected.

B. The BAS Trade Contractor shall set up the trend log definitions. Trend data shall be provided by the BAS Trade Contractor to the CxA in an electronic format, either a text file, CSV file or Excel file, with related system parameters grouped together.

C. If performance issues are found through the Trend analysis, the issues shall be corrected by the BAS Trade Contractor and the trending shall be restarted and analysis repeated by the CxA.

3.04 COMMISSIONING ISSUES AND RETESTING

A. All Deficiencies and Issues shall be documented on the appropriate forms in use, and will additionally be documented by the CxA on a Cx Issues List.

B. The CxA will maintain and update the Commissioning Issues List, and document the issues resolution process. Copies will be distributed to the General Contractor, Owner, and Sub-Contractors as appropriate.

C. All Commissioning Issues shall be corrected promptly. The responsible party shall correct the issue and inform the CxC and CxA of the resolution and completion date. The CxA will record completion on the Commissioning Issues List once the issue is successfully back-checked or verified and the CxC shall reschedule testing with the CxA and Sub-Contractor. Testing shall be repeated until passing performance is achieved or the Owner accepts the noted issue.

D. Immediate correction of minor issues identified during testing may be allowed at the discretion of the CxA. The issue and identified resolution must still be documented on the commissioning form in use.

E. When Cx Issues are identified during FPT, the CxA will discuss with the executing Sub-Contractor and/or CxC and determine whether testing can proceed or be suspended.

F. The Commissioning Issue and any identified resolution will be documented on the test form in use in addition to the Commissioning Issues List.

G. When there is a dispute regarding a Cx Issue, whether it is valid or who is responsible, additional parties may be brought into the discussion as appropriate.

H. The CxA will have the final interpretive authority on Cx Issues and Deficiencies and the Owner will have the final approval authority.

I. The CxA may recommend solutions to Deficiencies and Commissioning Issues. However, the burden of responsibility to solve, correct and perform required retests is with the General Contractor, Trade Sub-Contractors, and the Design Professional(s).

J. Additional Back-check Verifications and Re-testing:

1. For all Issues identified during the pre-functional system readiness activities, the CxA will back-check and verify the completion of the issues where appropriate.

2. For all Commissioning Issues identified during FPT, retesting is required to verify the resolution of the issue and to complete the FPT.

3. The CxA will witness one (1) re-test for each equipment and will perform one (1) back-check verification of any completed system readiness issue.

4. The Owner may back-charge the General Contractor for any additional fees from the CxA, resulting from any re-testing or repeated system readiness issues list back-checks beyond the first re-test or back-check.

5. A minimum 48 hour's notice is required for scheduling any re-testing, though the CxA will attempt to accommodate a shorter timeframe if feasible.

6. Any required retesting shall not be considered a justified reason for a claim of delay or for a time extension.

K. For any re-testing required, the CxA will determine if the entire test must be re-tested or if it is acceptable to re-test specific portions of the test that had failed.

3.05 DEFERRED TESTING

A. Before or during the end of the first year Warranty Period, any Seasonal or Deferred Testing as defined in the Cx Plan, shall be completed as part of this contract. Tests shall be conducted by the Trade Sub-Contractor responsible for the equipment and systems, completed in the same manner as all other commissioning tests, and shall be witnessed by the CxA.

B. The General Contractor shall coordinate with CxA and Owner and schedule all Deferred and Seasonal Testing.

C. The General Contractor shall make final adjustments to the as-built documentation or drawings for any modifications made during Deferred or Seasonal Testing.

3.06 O&M MANUALS AND TRAINING VERIFICATION

A. The General Contractor and the CxC shall coordinate and schedule the training for Owner Personnel. The CxC shall ensure that training is completed per the requirements of the construction documents and specifications.

B. Trade Sub-Contractors responsible for specific equipment and system training shall submit to the CxC, a written training agenda for each training class for the equipment and systems to be commissioned, no less than 14 days prior to start of training.

C. The General Contractor shall submit the training agendas and sign-in sheets (blank) to CxA and Owner for review and approval.

D. The training agendas shall cover the following elements:

1. Equipment and/or systems included in training

2. Intended audience

3. Location of training

4. Subjects covered (including a brief description and duration, presentation methods, etc.)

5. Instructor's name and qualifications
6. Copy of any handout materials or presentations.
7. Sing-In Sheet

E. The CxA will review the training plans to verify compliance with the specifications.

F. The General Contractor shall submit to CxA the signed and completed attendance sheets for each training session and a copy of the final training presentations and materials.

G. The CxA will verify with the Owner that the final O&M manuals have been delivered per the Contract Documents.

3.07 ACCEPTANCE AND CLOSE OUT

A. Regarding substantial completion, reference Division 01, Section 01 77 00, Closeout Procedures.

B. After completion of the commissioning activities and review of the completed commissioning documents the Owner will provide a formal written acceptance of the project construction phase commissioning. At that point, any remaining construction phase commissioning issues or seasonal/deferred testing will be tracked by the CxA as part of the Post- Occupancy Warranty Phase Commissioning if applicable.

C. Upon completion of all commissioning activities, the CxA will prepare and submit to the Owner a Final Commissioning Report detailing all completed commissioning activities and documentation. The CxC shall support this effort by providing all General Contractor and Trade Sub-Contractor commissioning documentation.

D. The Owner's written acceptance of construction phase commissioning will be included in the Final Commissioning Report.

E. The CxA will complete a Systems Manual for the systems and equipment commissioned (if applicable), with assistance provided by the CxC and Trade Sub-Contractors. The Systems Manual will provide the operating staff the information needed to understand and optimally operate the commissioned systems. The Systems Manual will contain at minimum the following sections:

1. Final version of the BOD.
2. Systems single line diagrams and schematics.
3. Final as-built sequence of operations, control drawings (P&IDs), points lists and as-left set points.
4. Supplemental operating instructions for integrated building systems such as water-side and air-side HVAC systems and controls, lighting controls, etc.
5. Recommended schedule of maintenance requirements and frequency
    a. A summary of the preventative maintenance and service procedures is recommended in the Systems Manual, for the major MEP equipment, including a schedule matrix checklist (checked as weekly, monthly, quarterly, annually, etc.).
    b. Recommended schedule for retesting of commissioned systems with blank test forms from the Final Commissioning Plan.
    c. Recommended schedule for calibrating sensors and actuators.

3.08 POST-OCCUPANCY WARRANTY PHASE COMMISSIONING

A. If applicable, no later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility staff, walk the facility and review systems operation to identify any issues. Key representatives from the General Contractor and Trade Sub- Contractors original project team shall attend, as determined by the CxA.

B. The CxA shall review BAS trend data during the Warranty Phase. The Controls Contractor will be responsible for providing post-occupancy trend data to the CxA.

C. Any performance issues, warranty items or problems identified will be reported by the CxA to the CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Trade Sub-Contractors prior to the end of the warranty period. The CxC shall work with the Trade Sub-Contractors and O&M staff to make corrections and modifications as required.

D. After correcting noted Warranty Phase Cx Issues, the General Contractor shall notify the CxA in writing, and the CxA will back-check and verify that the Warranty Phase Cx Issue was resolved.

E. Issues identified during the warranty period will remain Warranty Phase Cx Issues until satisfactory completion by General Contractor and back-check verification by CxA, even if the warranty period expires during the correction and back-check period.

END OF SECTION

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the technical specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 23 05 93

TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Division 23, ….

B. …

1.02 REFERENCES

A. Reference Standards:

1. Comply with applicable procedures and standards of "National Standards for Field Measurements and Instrumentation, Total System Balance" by the Associated Air Balance Council (AABC).
2. Comply with applicable procedures and standards of NEBB - National Environmental Balancing Bureau
3. SMACNA - Sheet Metal and Air Conditioning Contractors National Association
4. ASHRAE - Handbook of Fundamentals

1.03 DESCRIPTION OF WORK

A. Provide services for testing mechanical and plumbing equipment described in this section and Section 23 08 00, Commissioning of HVAC.

B. Provide services required for a completely balanced, tested and certified air and water system. This includes reinstated sections of existing systems if applicable. Coordinate with trades as needed to provide services.

1. Independent agency certified by the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB).
2. Provide services of a test and balance agency whose business is dedicated to the balancing, adjusting and testing of heating, ventilating, and air conditioning systems, to balance, adjust, and test air and water moving equipment and distribution systems, and control systems as specified.
3. Complete and test all systems early enough to enable completion of balancing prior to owner move-in.
4. During warranty period, calibrate and adjust controls and re-balance areas as required to maintain satisfactory space requirements.

1.04 QUALITY ASSURANCE

A. Test and Balance Agency:

1. Qualifications: The balance and testing agency to provide proof of having successfully completed at least five projects of similar size and scope and to comply with all standards as set forth by the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB).
2. All Work by this agency shall be done under direct supervision of a qualified heating and ventilating engineer employed by them.
3. All instruments used by this agency shall be accurately calibrated and maintained in good working order per AABC or NEBB guidelines. Calibration may be confirmed on site by owner's representative. Instruments without current calibration and documentation may have

their results up to that point nullified and balancing with calibrated instruments would be required.

4. Conduct tests in the presence of the Owner's Representative.

1.05 INCLUDED SYSTEMS AND EQUIPMENT

A. The following is a list of the equipment and system test requirements included in this section:

1. Air Handling Systems
2. Exhaust/Supply Fans
3. AC Split Systems
4. Confirm extent of existing systems balance prior to bid.

B. The testing requirements for the following system are identified in other Division (15 or 23) specifications. There are no additional requirements in this Specification Section.

1. Building Automation System; covered by Section 23 09 23, EMS/DDC Commissioning.

1.06 GENERAL REQUIREMENTS

A. Overlapping test requirements identified in this Section and Specification Section 23 09 00, BAS/DDC Commissioning or 23 09 23, Building Automation System need not be repeated. The GC and CxA will collaborate to make certain that all test requirements are performed only once.

1.07 PREREQUISITES

A. Test and balance agency to coordinate with contractors for the completion of these items as needed.

1. Test, adjust and balance (TAB) draft report provided and approved by CxA and owner's representative for support of functional testing.
2. Vibration control report approved (if required).
3. Piping system flushing complete and required report approved.
4. Water treatment system complete and operational.
5. All A/E punchlist items that could affect functional testing corrected. CxA or Owner's Representative to determine exceptions.
6. Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
7. Pre-Commissioning Report complete per Specification Section 23 09 23.
8. EMS/DDC Commissioning complete per Specification Section 23 09 23.

1.08 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. Submit the name of selected Test and Balance agency for approval within thirty days after award of contract. If the Contractor fails to submit an acceptable agency within 30 days, owner may select firm to accomplish the work. Selection is binding upon the Contractor at no increase in contract sum.

C. First Submittal:

1. Submit two hard copy and one digital copy (Adobe PDF or Microsoft Word) of documentation to confirm compliance with quality assurance provisions:

a. Transmittal and table of contents confirming contents of submittal.

b. Organization, supervisor and personnel training, and qualifications, including registration of certified Test and Balance engineer.

c. Specimen copy of each of the report forms proposed for use for this specific job and scope. Forms shall be equal to those shown in Chapter 27 of the "National Standards for the Total System Balance" of the Air Balance Council, 1989 Edition.

d. Narrative plan of testing procedures and sequences.

e. Description of each air and water system with its associated equipment as interpreted by the test and balance agency.

f. List experience of similar type projects and references including Owner, Architect, Consulting Mechanical Engineer and Mechanical Contractor.

D. Second Submittal: With the initial mechanical Shop Drawing and at least 60 days prior to starting field work, submit two hard copy and one digital copy (Adobe PDF or Microsoft Word) of:

1. Transmittal and table of contents confirming contents of submittal.

2. The “test and balance plan” consisting of the following items:

3. All report forms for use on this job filled out with all design flow values and equipment pressure drops, including required CFM for air terminals. These forms should be in a ready-to-use state of completion. Owner’s Representative or CxA to review.

4. A complete list of instruments proposed to be used, organized in appropriate categories, with data sheets for each. Show:

a. Manufacturer, model and serial number.

b. Description and use when needed to further identify the instrument.

c. Size or capacity range.

d. Latest calibration date and certificates of calibration.

5. A detailed description of the balancing and testing procedures. These procedures shall conform to AABC or NEBB requirements and recommendations.

6. Owner's Representative will review submittals for compliance with Contract Documents, and will return one set marked to indicate:

a. Discrepancies noted between data shown and Contract Documents. Review is not intended to document all discrepancies.

b. Additional or more accurate instruments required.

c. Requests for re-calibration of specified instruments.

d. Further clarification of test procedures and sequences.

1.10 SUBSTITUTIONS

A. Submit in accordance with Section 01 25 13 - Product Substitution Procedures

1.11 JOB CONDITIONS

A. For existing conditions, obtain building as-built drawings from the Owner for pre-construction requirements.

B. Prior to start of testing, adjusting and balancing:

1. Systems installation to be complete, started up, and in full operation.

2. Outside conditions to be within 15 percent relative to design conditions.

3. Building lights shall be turned "on" when balancing cooling system, "off" when balancing heating system.

4. Special equipment such as computers, laboratory equipment, electronic equipment or engine generator to be in full operation.

5. Close all windows and doors.

C. Notification: Promptly report any deficiencies noted during performance of services. Rectify these deficiencies, and any tests interrupted shall be re-done.

1.12 WARRANTY

A. The Contractor shall provide a written warranty covering the performance, workmanship and installation of equipment and systems furnished under this Section for period of two (2) years after acceptance of substantial completion. The Contractor shall assume responsibility for all costs incurred in achieving satisfactory performance during the warranty period. Warranties shall be in accordance with Section 01 78 36 – Warranties.

PART 2 - PRODUCTS

2.01 Products and materials as described in Part 3 of this Section and related sections.

PART 3 - EXECUTION

3.01 PRE-BALANCING REQUIREMENTS

A. Advise Owner's Representative in writing when systems have been completed and tested and are ready for balancing.

B. Submit report on measured CFM, GPM, RPM, AMPS, inlet and outlet pressures of all equipment before balancing by Balancing Contractor.

C. Complete, perform and coordinate with other contractors the following Work prior to commencement of the balancing procedure.

1. Complete pre-testing of systems; confirm ready for detailed balancing.

2. Mechanical Contractor to install dampers and other balancing devices shown, specified, and required. Check to be sure they are properly installed, indexed, and in good working order.

3. Schedule the Work of other trades to eliminate system shutdown for any reason once balancing is started.

4. Prior to the start of balancing, complete punch list items that will affect balancing of the system. Coordinate with Contractor to have all devices installed at no increase in contract sum.

5. Schedule the Work of other trades to assure uninterrupted access to mechanical equipment rooms as well as conditioned spaces.

6. Provide labor and material necessary to perform any system revisions required to allow completion of balancing.

7. Air systems pre-balancing requirements supplemental to AABC or NEBB requirements:

a. Align drives.

b. Set sheaves to provide indicated capacities at specified static pressures.

c. Set manual dampers to 100 percent open position.

d. Check all damper operations to ensure smooth, free activation by the proper controls.

e. Remove adjustable pitch pulleys from motor shaft; clean and lightly oil shaft and pulley threads; and remount, align and properly adjust pulley.

f. Drill 3/8-inch diameter holes in low velocity ductwork with burrs removed, for temperature, pressure and velocity readings; and provide holes in drive guards that will permit

tachometer readings without removing guards. Locate as specified hereinafter and as directed. Install replaceable rubber plug in each hole.

g. Clean interior of plenums, casing, coils and ducts; and install temporary and final filters before starting any systems.

h. Drill test holes in the following locations: Each side of each filter, fan, coil and multi-blade damper; 12 inches on center for traverse readings in main ducts and as directed in the field. Turn at least ten extra plugs over to the Owner for use during balancing period.

8. Water systems pre-balancing requirements supplemental to AABC or NEBB requirements:

a. Set balancing cocks to 100 percent open position.

b. Remove, clean and replace strainer screens, vent air from piping, verify proper operation of automatic air vents.

c. Verify correct pump rotation.

d. Position normally open valves full open.

e. Examine water in system to determine if water has been treated and cleaned.

9. Existing systems pre-balancing requirements supplemental to AABC or NEBB requirements:

a. When connecting to existing systems, verify existing air and water balance meets NEW quantities required in remodeled systems prior to construction. Notify Architect in writing of any discrepancies.

b. Test, balance and record existing air and water systems prior to commencing any work. Include the following:

1) Confirm extent of existing systems balance prior to bid.

2) Record air and water flows at each existing supply, return and exhaust air outlet, duct, terminal device and coil serving areas directly in this scope of work, and at each air outlet, duct, terminal device and coil that is outside the immediate scope of work but is connected to distribution systems of air handlers, fans, pumps, etc. that serve the remodeled areas.

3) Record air and water flows, inlet and outlet temperatures and pressures at existing air handlers, fans, pumps and other equipment that serve the affected areas.

4) Submit survey in typed form with final balance report.

3.02 INSPECTION

A. Review plans and specifications prior to installation of any of the affected systems. Prepare a schedule to inspect air and water systems and equipment. Submit written report with suggestions for work to be performed or devices added to allow for proper balancing. Added devices are at no increase in contract sum.

B. The Test and Balance Agency shall visit the jobsite a minimum of three times during the early stages of fabrication to inspect duct, pipe and equipment installation. Submit report to the Owner's Representative listing any deficiencies found that would preclude proper adjusting, balancing and testing.

C. Make field inspection prior to closing in portions of systems to be balanced. Verify that the Work, fittings, dampers, balancing devices, etc., are properly fabricated and installed as specified or shown and that proper balancing can be done.

3.03 INSTALLATION

A. Test Balance Service:

1. Perform analysis, test and balance services upon completion of air and water systems, after completion of general operating tests, Pre-balancing Requirements and after the Work specified above.

B. Performances and Capacity Checks:

1. Take readings as shown, specified and as required to demonstrate that all equipment, coils, terminal devices, controls, etc. are operating in accordance with scheduled or manufacturer's published ratings.

2. Recommend adjustments and/or corrections to equipment, air and water systems necessary for proper capacity and balancing. Submit report to Owner's Representative.

3. Provide each automatic control valve with a permanent brass tag stamped with the following information: valve model number, size and Cv.

4. Perform capacity checks of heating systems during the balancing period and again during a design day the following winter.

5. Perform capacity checks for cooling systems during the balancing period and again during a design day the following summer.

6. Operating tests of heating and cooling coils, fans, pumps and other equipment to be of not less than four hours duration, after stabilized operating conditions have been established. Capacities to be based on temperatures, air and water quantities measured during such tests.

C. Existing Systems:

1. Balance new air and water flows in remodeled areas.

2. Re-balance entire existing air and water systems outside the remodeled areas to match pre-construction quantities recorded in the initial survey or as directed. This includes all air outlets, ducts, terminal devices and coils that are connected to equipment that serves the remodeled areas.

3. Re-balance existing air handlers, fans, pumps and other equipment to obtain new and restored air and water flows.

4. Replace filters at air handling units if, in the opinion of the Owner's facilities department or as indicated by filter gages, they are nearing the end of their useful life.

5. Pull and clean existing strainers.

3.04 AIR BALANCING

A. Adjust all air handling systems to provide the required design air quantity to, or through, each component. Keep doors and windows closed and all other ancillary systems in simultaneous operation. Balance under normal traffic conditions.

1. Balancing between runs (sub-mains, branch mains and branches): Use flow regulating devices at, or in, the divided-flow fitting to the extent that adjustments do not create objectionable air motion or sound. Minimize restriction imposed by flow regulating devices, in, or at, terminals.

2. Final Measurements of Air Quantity: Make final measurements of air quantity, after the air terminal has been adjusted to provide the optimum air patterns of diffusion.

B. Air Measurements and Balancing:

1. Use Pitot tube traverses to measure air flow except as specifically indicated herein. Pitot tubes, associated instruments, traverses and techniques to conform to the ASHRAE Handbook of Fundamentals.

2. Pitot-tube traverse may be omitted if the duct serves only a single room or space and its design volume is less than 500 cfm. In lieu of Pitot-tube traverse, determine air flow in the duct by totaling volume of individual terminals served, measured as described herein.
3. Where duct's design velocity and air quantity are less than 800 (fpm/cfm), air quantity may be determined by measurements at terminals served.
4. Test holes, ventlock type, to be in a straight duct, as far as possible downstream from elbows, bends, take-offs and other turbulence generating devices, to optimize reliability of flow measurements.
5. Use measurement of flow rates by means of velocity meters applied to individual terminals, with or without cones or other adapters, only for balancing. Determine measurement of air quantities at each type of air terminal (inlet and outlet) by the method approved.

C. Adjust air quantities to following tolerance:
1. Each outlet of 200 cfm or less: Minus 0 to plus 10 percent of design.
2. All other outlets: Minus 5 to plus 5 percent.
3. Each room with multiple outlets: Minus 0 to plus 5 percent.
4. Each floor or major zone: Minus 0 to plus 10 percent of design.
5. Fans: Minus 0 to plus 10 percent of design.
6. Temperature readings: Within 1/2-degree F.
7. Pressure readings: Within 0.02-inch W.G.
8. Under no circumstances can room pressure relationships change from that shown on drawings or required by code, even if within specified tolerances (i.e. equal room cannot become negative or positive, etc.)

D. Coordinate with controls contractor to adjust control sequence, setting, and operation of automatically controlled dampers for normal operating conditions.

E. Plainly mark final position of manual dampers after balancing is complete. Perform air-terminal readings in accordance with the recommendations of the air device manufacturer.

F. First utilize main dampers, then branch dampers. Use dampers behind grilles only as a final adjustment.

G. Make allowance for air filter resistance at time of tests. Main air supplies shall be at design air quantities and at air resistance across the filter bank midway between the design specifications for clean and dirty filters.

H. Air balance shall be completed with final MERV rating of filters to be installed for occupancy. For example: if MERV 8 filters are used during construction, with MERV 13 filters planned for occupancy, MERV 13 filters shall be in place during air balance.

I. As part of balancing procedures, set fresh air and return air dampers to put the entire system into operating balance as shown and required.

J. Take duct and outlet readings with Anemotherms or Alnor velometers. Take readings on large air intakes, coil banks and filter banks with anemometer. Take static pressure readings with Dwyer U-tube manometer No. 400 or equal. Electrical current readings to be made with clamp-on type ammeter.

K. Provide positive identification points of measurements such as a marked print.

L. Tabulated fan capacity may exceed summation of register and diffuser readings. Leakage allowance as specified in Section 23 31 00 – HVAC Ducts and Casings.

M. Mechanical Contractor provide additional dampers and pressure plates where required to facilitate balancing and to prevent damper, grille and diffuser noise. Provide at no increase in Contract Sum.

N. Check and adjust fan rpm to design requirements and record fan motor amperes.

O. Test, adjust and record system static pressures, suction and discharge ducts.

P. Test and adjust system for design, supply, recirculated, outside and exhaust air, cfm.

Q. Use manufacturer's ratings on all equipment to make required calculations.

R. Adjust all diffusers and registers to eliminate drafts in all areas and result in uniform distribution.

S. Verify leakage tests of all ductwork in accordance with paragraph titled, "Leakage Test" in Section 23 31 00 – HVAC Ducts and Casings.

T. Make any adjustments to or change-out of the pulleys, belts, axial fan blade pitch and dampers, or the addition of dampers required for correct balance, as recommended by the Testing Agency, at no additional cost. RPM shown on drawings are for guidance only.

3.05 WATER BALANCING

A. Adjust all hydronic systems to provide required quantity to, or through, each component.

B. Initial Testing and Balance Procedure for Water Systems:

1. Balance hot water coils after balancing multiple coil sections for even water distribution through tubes.

C. Final Testing and Balance Procedure for Water Systems:

1. The testing agency shall perform the following test and adjustments upon completion of preparation and initial test:

a. After adjustments to coils and valves are made, recheck settings at the pumps and converters and readjust if required.

b. Read pressure drop through coils at set flow rate on call for full cooling or heating.

c. Adjust water quantities to the following tolerance:

1) Water flow: Minus 5 to plus 5 percent of design.

2) Temperature: within 1/2 percent F.

3) Pressure: within 1/2 percent psi.

d. Measure water quantities and pressures with calibrated meters, if applicable:

1) Water measurements and balancing: Use venturi tubes, orifices or other metering fittings and pressure gages. Adjust systems to provide the approved pressure drops through the heat transfer equipment (coils, cooling towers, etc.), prior to the capacity testing.

2) Where flow metering fittings are not installed, determine flow balance by measuring temperature differential across the heat transfer equipment. Perform measurement of temperature differential with the air system, adjusted as described herein, in operation.

e. Position automatic control valves for full flow through heat transfer equipment of the system during tests.

f. Adjust flow through by-pass circuits at three-way valves to balance that through the supply circuit.

g. Adjust distribution by means of balancing devices (cocks, valves and fittings) and automatic flow control valves. Do not use service valves for adjustment. Where

automatic flow control valves are utilized in lieu of venturi tubes, record only pressure drop across the valves if said pressure drop is within the pressure drop rating.

h. Special procedures: Where available pump capacity is less than total flow requirements of individual heat transfer units of system served, full flow may be simulated by the temporary restriction of flow to portions of the systems.

i. Assure that all modulation control valves provide full throttling from wide open (design) flows to 100 percent shut-off. Verify control sequences, settings and operation to all automatic control valves.

j. Mechanical Contractor trim pump impellers to extent permitted to deliver the gpm equal to the lowest actual total systems head pressure.

k. Lock set points and plainly mark final position of all balance valves after balancing is complete. Read and record data.

l. Utilize thermometer wells, time-quantity devices and other line flow-measuring devices specified. In closed systems, where no line devices are installed, use a surface pyrometer probe.

m. Where pyrometers are used, tabulate surface temperature differentials between inlet and outlet of heat exchange devices. Pyrometers shall be Alnor Type 4200, scale 0-degrees to 500 degrees F, with 2 degree F graduations and appropriate pipe probe.

3.06 BUILDING BAKEOUT

A. After installation of furniture, equipment, etc., operate air handling systems at 100 percent outside air with all thermostats at full heating continuously for 48 hours. At end of period, operate all air handling units and reset all thermostats under normal working conditions.

B. Submit data from temperature recorder documenting indoor temperatures over entire bakeout period.

3.07 PERFORMANCE PERIOD

A. After completion of balancing, operate all systems and equipment under normal working conditions for three consecutive 7-hour days. Submit written confirmation of performance period.

3.08 VIBRATION TESTING

A. Assure vibration isolation system is operating properly.

B. Operate equipment and make audible and visual inspection to determine obvious rough operation. Mechanical Contractor shall correct these conditions before proceeding further.

C. Submit report to Architect.

3.09 TESTING PROCEDURE FOR SOUND LEVELS

A. Using recently calibrated instruments, conduct sound level tests in every room of the building. Measure sound level readings in decibels on the "A" and "C" scales of the General Radio Company sound level meter, or sound level meter that meets the current American Standard (Z34-3). Take sound level readings of the selected rooms or areas with the system in operation, as compared to total background sound level with the system not in operation.

B. Identify each outlet by room name, room number and air outlet number.

C. Measure sound levels in decibels at each diffuser, grille or register in areas designated and where directed. Measure sound levels approximately five feet above the floor on a line directly below the center of the diffuser, on the "A" and "C" scales of a General Radio Company sound level meter.

3.10 CERTIFIED REPORTS

A. DRAFT REPORT

1. Submit a draft report in entirety to Owner, CxA, and Owner's Engineer or Representative for review within one working week of balancing activity conclusion for review.
2. Hand written values preferred so no time is lost for typing the draft if not originally typed on site.
3. Include any relevant drawings or sketches.
4. Include a list of all assumptions and issues.
5. Requirements in this section "Certified Reports" apply to the draft report.

B. FINAL REPORT

1. Requirements in this section "Certified Reports" apply to the final report.

C. Reference AABC or NEBB standards for certified reports. The requirements listed below are for reference. Where there are additional requirements listed in this specification beyond AABC or NEBB, consider them added required scope.

D. Air System Data: Include for each air-handling system the data listed below:

1. Equipment (fan or factory fabricated station unit):
    a. Installation Data
        1) Identification number.
        2) Manufacturer and model.
        3) Size.
        4) Service.
        5) Arrangement, discharge and class.
        6) Motor hp, rated voltage, phase, cycles, and rated full load amps.
        7) Full load amperes.
        8) Location and local identification data.
    b. Design data: Data listed in schedules on Drawings and Specifications or submittals.
    c. Fan recorded (test) data:
        1) CFM
        2) Static pressure: Suction, discharge, total.
        3) Fan rpm.
        4) Motor rpm.
        5) Motor sheave diameter: adjustable or solid.
        6) Fan sheave diameter.
        7) Outlet velocity.
        8) Motor operating amperes.
        9) Motor operating BHP.
        10) Actual voltage.
2. Duct system:
    a. Duct air quantities-Main, submains, branches, outside air, total supply air, return and exhaust:
        1) Duct size(s).

2) Number of pitot tube (pressure) measurements.
3) Sum of velocity measurement, excluding pressure measurements.
4) Average velocity.
5) Recorded (test) CFM and FPM.
6) Design CFM and FPM.

b. Individual air terminals:
1) Terminal identification (supply, return or exhaust, location and number designation).
2) Type, size, manufacturer and catalog identification.
3) Design and recorded quantities-CFM.
4) Deflector vane or diffusion cone settings.
5) Applicable factor for application, velocity, area, etc.
6) Design and recorded velocities-FPM (state "core", "inlet", etc., as applicable).

3. Filter and coil data as specified; scheduled on drawings or as required.

E. Room temperatures.
1. Temperatures during heating testing.
2. Temperatures during cooling testing.

F. Water System Data:
1. Pumps:
a. Installation Data
1) Identification number.
2) Manufacturer and model.
3) Size.
4) Type drive.
5) Motor hp, voltage, phase and rated full load amperes.
6) Impeller size.

b. Design data:
1) GPM.
2) Total dynamic head.
3) RPM.
4) BHP and amperes.

c. Recorded data:
1) Discharge pressures (full-flow and no-flow).
2) Suction pressures (full-flow and no-flow)
3) Operating total dynamic head.
4) Operating GPM (from pump curves if metering is not provided).
5) Complete pump curve with balanced operating point clearly shown compared to designed operating point.

6) No-load amperes (where possible).

7) Full-flow amperes.

8) No-flow amperes.

9) Elevation of each gauge above floor.

2. Flow devices including control valves:

a. Service

b. Locations

c. Size

d. Required GPM

e. Measured pressure difference

f. Resultant actual GPM from venturi curves

3. Air heating and cooling equipment including coils, chillers, cooling towers, boilers and converters:

a. Design data:

1) Load in BTUH and MBH

2) GPM

3) Entering and leaving water temperature

4) Entering and leaving air conditions (DB and WB)

5) CFM

6) Water pressure drop

b. Recorded data:

1) Type of equipment and identification (location or number designation)

2) Entering and leaving air conditions (DB and WB)

3) Entering and leaving water temperatures

4) GPM (if metered)

5) Temperature rise or drop

6) Water and air pressure drop

3.11 FINAL TESTS, INSPECTION AND ACCEPTANCE

A. General: Make tests to demonstrate that capacities and general performance of air and water systems comply with contract requirements. Provide written record of system balanced capacity, include the list of assumptions and description of the testing environment during test.

B. After the Test and Balance contractor has submitted records of final readings and measurements for all systems:

1. Final inspection: At the time of final inspection, spot-check, in the presence of the Owner's Representative, random selections of data, water and air quantities, air motion and sound levels recorded in the Certified Report.

2. Points and areas for spot-check: As selected by the Owner's Representative.

3. Measurement and test procedures: As approved for work forming basis of Certified Report.

4. Selections for spot-check (specific plus random): In general, selections for check will not exceed 25 percent of the total number tabulated in the report, except that special air systems may require a complete recheck for safety reasons.

C. Retests: If random tests elicit a measured flow deviation of 10 percent or more from, or a sound level of 2 dB or more greater than that recorded in the Certified Report listings, at 10 percent or more of the spot-checked selections, the report will be automatically rejected. In the event the report is rejected, readjust all systems concerned in the presence of the Owner's Representative. Test and record new data, submit new Certified Reports and make new inspection tests.

D. Marking of Settings: Following final acceptance of Certified Reports by the Architect, permanently mark the settings of all valves, splitters, dampers and other adjustment devices that are exposed to misuse, so that adjustment can be restored if disturbed at any time. Do not mark devices until after final acceptance.

END OF SECTION

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the technical specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 23 08 00

COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Division 23, ….

B. …

1.02 REFERENCES

A. Reference Standards:

1. Comply with ASHRAE Guideline 0.
2. Title 24, Part 6, Section 120.8 Building Commissioning, Revision 2013
3. Comply with requirements of applicable green building code for this project such as LEED, CHPS, or CalGreen. (Verify with Owner.)

1.03 DEFINITIONS

A. Basis of Design (BOD): The BOD is developed by the design consultants for the systems used in the facility. It defines the assumptions made for the designed systems. This document is written to agree with the Owners Project Requirements (OPR).

B. Building Automation System (BAS): The building digital control system.

C. Commissioning Authority (CxA): An agent hired directly by the Owner which assists the Contractor with coordinating commissioning activities and witnesses and reviews the activities on behalf of the Owner.

D. Commissioning Issue: An issue which must be resolved to complete the commissioning process.

E. Commissioning Issues List: A log maintained by the CxA listing all Cx Issues documented during the commissioning.

F. Commissioning Plan: A document that outlines the organization, coordination, and requirements of the commissioning in detail.

G. General Contractor: The contractor directly contracted to the Owner with overall responsibility for the project and all commissioning activities.

H. Commissioning Coordinator (CxC): General Contractor employee who plans, schedules, and coordinates the Sub-Contractor's commissioning activities, and serves as the CxA's single point of contact for all administrative, documentation and coordination needs.

I. Deferred Testing: Testing performed at a later time for a certain reason.

J. Functional Performance Test (FPT): A test of the operation and control sequences of equipment and systems to verify system performance. Systems are tested under various operating modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, alarm, power failure, etc.

K. Installation Verification (IV): Field verification and documentation of proper installation of system equipment.

L. Monitoring: The recording of parameters of equipment operation using data-loggers or the Trending capabilities of BAS or control systems.

M. Owner's Project Requirements (OPR): A document written by the Owner describing the operational and functional requirements of a project, the expectations of how the facility will be used and operated, and the equipment and system expectations and requirements.

N. Sampling: Witnessing the startup or testing of a selected fraction of the total number of identical or near-identical pieces of equipment such as VAV boxes.

O. Pre-Functional Checks: These are various checks and tests performed on a piece of equipment or system just before, during or after the initial Startup. Examples include pipe system pressure tests, duct leakage tests, mechanical system test and balance and electrical equipment NETA testing. They must be completed prior to functional testing.

P. Startup: Initial starting or activating of equipment performed by the Sub-Contractor or the Manufacturer's representative.

Q. System Readiness Checklist (SRC): A checklist, covering the commissioning tasks and required documentation to verify that a system is ready for functional testing. The SRCs must be completed and signed by the General Contractor prior to conducting the functional testing.

R. Test and Balance (TAB): Testing, Adjusting, and Balancing work on the air and water systems to ensure design flow conditions are met.

S. Sub-Contractor: Typically a subcontractor to the General Contractor who provides and installs specific building components and systems and/or provides certain services.

T. Trending: Monitoring using the Building Automation System to aid in functional testing and to verify system operation and performance under operating conditions.

1.04 DESCRIPTION OF WORK

A. The following systems comprise the scope of commissioning:

1. HVAC Systems
2. Building Automation Systems
3. …

B. Coordinate with trades as needed to provide services.

C. The work includes the completion and documentation of formal commissioning procedures by the General Contractor and Sub-Contractors.

1. Commissioning is the process of verifying the installation and performance of building systems to meet the design intent, contract documents, Owner's requirements, and operational needs.
2. The Design Professionals, General Contractor and Sub-Contractors provide the quality control for the design, installation, startup and checkout of the systems. The commissioning process provides review and qualitative functional testing in order to formally observe and document that the quality control efforts are successfully completed.
3. The Trade Sub-Contractors and the factory service representatives shall be responsible for participation in the commissioning process as outlined in this specification and Section 01 91 13 General Commissioning Requirements, and as directed by the General Contractor's CxC as overseen by the CxA.
4. Refer to Section 01 91 13, General Commissioning Requirements for summary description of the general commissioning process and requirements.

1.05 QUALITY ASSURANCE

A. Commissioning Provider Qualifications:

1. The commissioning provider shall have an individual assigned to this project with one of the following credentials: Building Commissioning Association CCP, Association of Energy Engineers CBCP, ASHRAE CPMP, or AABC CxA.
2. All Work by this agency shall be done under direct supervision of the credentialed individual.

3. All instruments used by this agency shall be accurately calibrated and maintained in good working order. Calibration may be confirmed on site by owner's representative. Instruments without current calibration and documentation may have their results up to that point nullified and re-work with calibrated instruments would be required.
4. Conduct tests in the presence of the Owner's Representative.

1.06 CONSTRUCTION PHASE COMMISSIONING PROCESS

A. Submittal Review by the CxA

1. The CxA shall review the Trade Sub-Contractor's submittals for the scope systems concurrently with the Design Team and provide review comments to the Owner and Design Team before submittal approval.
2. The General Contractor shall provide a submittal log to the CxA for referencing requested submittals to be reviewed by the CxA.
3. Information from the submittals will also be used by the CxA to develop commissioning forms and test procedures.

B. Cx Plan and Form Development

1. The CxA shall write a Preliminary Commissioning Plan and provide to Owner for review.
2. The CxA shall facilitate a commissioning kickoff meeting where the commissioning process and systems are reviewed.
3. The CxA shall develop the SRC checklists which track the completion of the Installation, Startup, and Pre-Functional Checks required for each system. The SRC forms shall be provided for peer review at the kickoff meeting.
4. The CxC shall submit to the CxA, for review and approval, representative blank forms for completing Installation Verification, Startup, and Pre-Functional Checks on request.
    a. Installation Verification forms are used to provide field verification and documentation of proper installation of equipment and system prior to formal Startup.
    b. Startup and Pre-Functional Check forms are usually Manufacturer and/or Trade Sub-Contractor startup and checkout sheets and shall be used where required and appropriate.
    c. Where appropriate, IV forms and startup forms may be combined, such as on small fan installations.
    d. Where appropriate, these forms can be checklists taken from the Manufacturer's installation manual.
    e. The Pre-Functional Test forms shall also include forms for recording results from system specific tests such as pipe system pressure tests, duct leakage tests, mechanical system TAB, electrical equipment NETA testing, etc.
5. The CxA will develop Functional Performance Testing (FPT) procedures and forms. These test procedures shall be provided to the Owner, General Contractor, and Trade Sub-Contractors for review and comment.

C. System Readiness Activities

1. Meetings shall be conducted throughout construction with Commissioning Team members, as required, to plan, coordinate, and schedule commissioning activities, review documentation, and resolve Cx Issues.
2. The Sub-Contractors shall perform Installation, Startup and Pre-Functional Check & Test activities to verify that the system is ready for operation or functional testing.

3. The Trade Sub-Contractors and the CxC shall document completion of these activities on the SRC forms and attach the completed Installation Verification, Startup, and Pre-Functional Check & Test forms to the SRC.
    a. In general, Installation Verification should be completed prior to Startup, but where appropriate, they can be completed into one activity.
4. The CxA shall perform multiple inspections during these phases.
5. The CxA shall witness a percent sampling of the Startups and Pre-Functional Checks & Tests, including TAB procedures. Sampling approach to be approved by Owner.

D. Functional Testing

1. Functional Performance Tests (FPTs) are tests of the control function and performance of the systems. These tests are used to verify that the sequences of operation are correctly implemented and that the design intent and performance criteria of the systems have been met.
2. The CxA shall develop FPT forms that contain:
    a. Specific procedures to execute the tests in a clear and repeatable format
    b. Any control system point value or setpoint overrides required to simulate a test condition or sequence mode.
    c. The expected system response and acceptance criteria of proper performance with a Yes/No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
    d. A section for recording actual system response, notes and comments.
3. The CxA shall provide a trending plan which contains:
    a. A list of control system trend data to be collected and provided to the CxA in electronic format for analysis and review.
    b. The list shall contain at minimum: point name and description, units, time series or change of value data type, time series trending intervals.
    c. The list shall have two columns of trend interval values, one with shorter trending intervals for high resolution data collection during functional testing and an additional column for lower resolution data collection for ongoing trend analysis of the system beyond the functional testing.
4. Once the SRC checklists are completed the FPTs shall be executed by the Sub-Contractors with all or a sample witnessed by the CxA, as defined in the Cx Plan and agreed with the owner.
5. Any deferred testing will be defined in the Cx Plan.

E. Commissioning Issues and Resolution

1. Issues shall be recorded by the CxA on the Commissioning Issues List and distributed to the commissioning team.
2. The General Contractor and Sub-contractors shall correct Commissioning Issues and retest the system(s), where applicable, without delay at no additional cost to the Owner.
3. The CxA will verify the completion of the issues and make all amendments to the issues list.

F. O&M Manuals, Training Verification and Final Documentation

1. The General Contractor shall compile and complete the Operations & Maintenance (O&M) Manuals provided by the Trade Sub-Contractors, per the contract documents requirements.

2. The CxA shall verify that the correct O&M content has been delivered to the Owner per the contract requirements and may request electronic copies of the O&M Manuals to aid in the completion of the Systems Manual if applicable.
3. The General Contractor shall submit a training schedule and specific training agendas provided by the Trade Sub-Contractors for each training to occur to the CxA and Owner for review prior to conducting any training.
4. The CxA shall review and provide comment to the Owner and General Contractor on the specified training agendas.
5. The CxA shall verify completion of the training by verifying a copy of the training sign-in sheets, provided by the General Contractor.
6. The CxA shall develop the Systems Manual (if applicable) with assistance from the General Contractor and Sub- Contractors. The systems to be included shall be confirmed with Owner.
7. The CxA shall complete the Construction Phase Commissioning Report and documentation for the Owner.

G. Post-Occupancy/Warranty Phase Commissioning

1. If contracted, no later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility O&M staff, walk the facility and review systems operation.
2. Key representatives from the General Contractor and Trade Sub-Contractors shall also attend, as determined by the CxA.
3. Any performance issues, warranty items or problems identified will be reported by the CxA to the Owner and CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Sub-Contractors prior to the end of the warranty period.

1.07 COMMISSIONING TEAM

A. The Commissioning Team is responsible for performing the commissioning process as directed by the CxA and achieving successful commissioning results. The Commissioning Team is comprised of the following:

1. Owner and Owner's Representatives
2. Design Professionals (DP) and Architects/Engineers (A/E)
3. Commissioning Authority (CxA).
4. General Contractor
5. General Contractor's Commissioning Coordinator (CxC)
6. Mechanical Contractor
7. BAS / HVAC Controls Contractor
8. TAB Contractor

1.08 RESPONSIBILITIES

A. General.

1. The Commissioning Team shall follow the Commissioning Plan, attend the commissioning kickoff meeting, and attend additional commissioning meetings as necessary.

B. Commissioning Authority (CxA)

1. See Section 01 91 13, General Commissioning Requirements.

C. General Contractor:

1. See Section 01 91 13, General Commissioning Requirements.

D. Sub-Contractors:

1. Provide submittal data, including manufacturer's installation checks and startup procedures, commissioning forms, and any other requested contract documentation for systems to be commissioned. Electronic files are preferred.
2. Attend commissioning meetings as directed by the CxA and General Contractor's CxC to facilitate the commissioning process.
3. Assign personnel with expertise and authority to act on behalf of the General Contractor and schedule them to participate in and perform assigned commissioning tasks.
4. Demonstrate and properly document proper system installation, startup and performance per contract requirements and manufacturer's forms.
5. Complete all Installation, Startup and Pre-Functional Check & Test documentation clearly and legibly. Provide a copy of all forms to the CxC and CxA as part of completing the SRC forms.
6. Provide access for the CxA to witness any equipment Startup and Pre-Functional Checks & Tests.
7. Notify the CxC and CxA at least 5 working days in advance of Startup and Pre-Functional Checks & Tests.
8. Ensure that any required manufacturer factory tests are performed and provide the factory test data.
9. Ensure that any required manufacturer's representative field tests and on-site installation verification, startup and checkout of selected equipment are performed per the contract documents.
10. Provide completed manufacturer documentation and commissioning forms for these activities to the CxC.
11. Address applicable Cx Issues promptly. All Installation Verification, Startup and Pre-Functional issues must be resolved before the FPT can proceed.
12. Assist CxA in preparing the FPT procedures, clarifying the operation and control of commissioned equipment where the specifications, control drawings or equipment documentation are not sufficient for writing detailed testing procedures.
13. Review the FPT procedures to ensure feasibility, warranty protection, safety and equipment protection, and provide necessary written alarm limits and overrides to be used during the tests.
14. As part of the FPTs, the Trade Sub-Contractor shall setup any additional software points, overrides of any sensor values or relays, and overrides of any setpoints or schedules, to simulate certain conditions and operating modes, in order to conduct the FPTs.
15. Perform the FPTs as written. Execution of FPTs shall be witnessed by the CxC and CxA and fully documented.
16. Assist the CxA in collecting all requested Trend data associated with FPTs.
17. Prepare a training agenda and sign-in sheet for each training class (to be reviewed by the CxA) and work with the General Contractor and Owner to schedule training. Execute training of Owner's personnel per approved training agenda and schedule.
18. Prepare O&M Manuals according to the Contract Documents.
19. Assist the CxA in developing the Systems Manual if applicable.

E. Controls Contractor Specific Requirements

1. In addition to the general Sub-Contractor responsibilities outlined above, the Controls Contractor responsibilities during commissioning shall include, but are not limited to:

    a. Prior to any controls construction activity, provide approved submittals, including shop drawings, control drawings, points list and detailed sequences of operation for each piece of equipment and system to be controlled.

    b. The system sequence of operation shall fully describe their equipment components and functionality, including setpoints and alarm functions. The detailed sequence of operation shall be provided regardless of the completeness and clarity of the sequences in the controls specification and/or drawings. Electronic files are preferred.

    c. Provide a complete control points list in MS Excel or other pre-approved format. Points list shall include point name, point description, display units (i.e. degrees F, percent, psi), panel identification, point type (AI, AO, BI, BO, virtual/software), field device controlled (through network, dry contact, actuator limit switch or other specific equipment), BAS application or energy management function associated with point, and associated alarm points and parameters, etc.

    d. The BAS Trade Sub-Contractor shall make all points available for continuous trending.

    e. Provide control system diagrams showing all control points, sensor locations, actuators, and controllers.

    f. Provide a list of test metering and sensors to be used for calibration purposes. The list shall include test meter and sensor accuracy for comparison to the BAS sensor accuracy requirements specified in contract documents. All test meter and sensors shall have been calibrated within a year and have calibration documentation.

    g. The control system installation verification and pre-functional checks (and associated documentation) shall include checking sensor installation; program setup check (point type, range/scale, etc.); point-to-point checks; sensor calibration or checks; and actuator checks. At a minimum, the actuators shall be physically checked at full open (100% open), half-open (50% open) and full close positions (0% open). For the sensor checks, each analog input sensor reading on the BAS shall be checked against a hand-held sensor of equal accuracy for verification purposes.

    h. The Controls Contractor shall set up the appropriate Trends per the final FPT forms provided by the CxA and shall provide trend data into a usable electronic format, such as a text, CSV or Excel format to the CxA. The CxA will analyze and review the trend data as part of the FPT.

        1) The trend points list may include both hardware (inputs, outputs) and virtual / software points. The appropriate trend intervals and minimum duration will be provided on the FPT forms.

        2) As an Owner approved alternative, the BAS Trade Sub-Contractor may provide the CxA remote access to the control system, with Owner permission, that will allow the CxA to directly download the Trend data.

    i. The Controls Contractor shall also provide trend data to the CxA during the post-occupancy warranty phase for review by the CxA, where required.

2. Balancing Contractor Specific Requirements:

    a. As part of developing the submittal requirements for commissioning, and prior to conducting any test and balancing (TAB) work, provide a TAB Plan that outlines the TAB procedures and approach for each system type along with the associated forms and drawings to be used in the TAB work on this specific project with the design values pre-populated from the most current mechanical plans and bulletins.

    b. The TAB plan provided should include all documentation required to begin the actual taking of measurements.

c. Additionally the TAB Plan shall include any TAB qualification certificates and TAB device calibration certificates.

d. The TAB Plan and certificates shall be submitted to the Design Professional and CxA for review, in addition to any other submittal requirements. Electronic files are preferred.

e. Provide access for the CxA to witness TAB work. Notify the CxC and CxA at least 5 working days in advance of TAB work.

1) Immediately report any deficiencies discovered which may affect or delay the commissioning process.

f. Submit a Draft Field TAB Report with the completed field forms and data to the Owner, Design Professionals, and CxA for review, within 72 hours following completion of the TAB activities, and prior to any TAB field inspections and verification work conducted with the DP, Owner, or the CxA.

g. The TAB Trade Contractor shall support commissioning by participating in the commissioning TAB Field Review, in which the TAB Trade Contractor demonstrates specified results to the CxA, after completion of the Draft Field TAB Report.

1) The TAB Field Review shall include field demonstrations of any final fan and pump pressure setpoints and back-check measurements of the air-side and water-side systems, performed by the TAB Trade Contractor and witnessed by the CxA and/or the DP, for a random 10% sampling.

2) The TAB Field Review back-check measurements shall be recorded on the Final TAB Report for documentation purposes.

3) If major discrepancies are noted in the field review, the sampling percentage for demonstration may be increased, and re-balancing may be required.

h. Submit the Final TAB Report to the Owner, DP, and CxA for review after completion of the Draft Field TAB Report review.

1.09 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. CxA shall submit electronic copies of all Cx deliverables described herein to the Owner upon request.

C. The Sub-Contractors shall submit to the CxA blank forms for Installation Verification, Startup and Pre-Functional Checks for review and comment.

D. The CxA will review these submitted commissioning forms for completeness including any project specific requirements.

E. The CxA may request additional data, changes and/or additions to these forms to make sure they are complete prior to their use. If the submitted forms are not available or are not sufficient, then the CxA will provide forms based on the construction documents and specifications, manufacturer installation manuals and procedures, and/or industry standards or guidelines.

F. The Trade Sub-Contractors shall submit to the CxA any equipment and construction submittals and shop drawings, including detailed sequences of operation, as requested by the CxA.

G. Instruments Used by CxA

1. A complete list of instruments proposed to be used, organized in appropriate categories, with data sheets for each. Show:

a. Manufacturer, model and serial number.

b. Description and use when needed to further identify the instrument.

c. Size or capacity range.

d. Latest calibration date and certificates of calibration.

1.10 SUBSTITUTIONS

A. Not applicable.

1.11 JOB CONDITIONS

A. For existing conditions, obtain building as-built drawings from the Owner for pre-construction requirements.

B. Prior to start of functional testing:

1. Outside conditions to be within 15 percent relative to design conditions.

2. Building lights shall be turned "on" when testing cooling system, "off" when testing heating system.

3. Special equipment such as computers, laboratory equipment, electronic equipment or engine generator to be in full operation.

4. Close all windows and doors.

C. Notification: Promptly report any deficiencies noted during performance of services. Rectify these deficiencies, and any tests interrupted shall be re-done.

1.12 WARRANTY

A. Warranties shall be in accordance with Section 01 78 36 – Warranties.

B. The CxA shall warrant the conclusions drawn from functional testing and trend analysis for accuracy.

1. It is the CxA's responsibility to coordinate with the test and balance and controls contractors for accurate test result readings and trend data received.

2. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, CxA shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order to provide accurate system conclusions and recommendations.

3. The CxA shall provide revised system functionality conclusions, FPT documentation, and trend analysis as needed to replace the flawed and void previous documentation.

C. The general and subcontractors shall warrant the data drawn from functional testing and trend analysis to be accurate and correct. (most importantly: test and balance and controls contractors)

1. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, the responsible contractors shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order for the CxA to provide accurate system conclusions and recommendations.

PART 2 - PRODUCTS

2.01 DOCUMENTATION

A. The Sub-Contractors have specific responsibilities for assisting in the development of the commissioning forms used, and in performing and documenting commissioning tests, as directed by the CxC and as overseen by the CxA.

B. The Sub-Contractors shall provide, system checks and testing, test reports, factory test data and reports, checklists, operational verifications and demonstration, etc. , per contract documents whether specified or not in the commissioning sections.

2.02 TEST EQUIPMENT

A. The Sub-Contractors shall provide all test equipment to execute Pre-Functional and Functional Performance Tests.

B. The test equipment shall be provided in sufficient quantities to execute testing in an expedient fashion.

C. The test equipment shall be of industrial quality and suitable for testing and calibration with accuracy within the tolerance necessary to demonstrate system performance per the Contract Documents. If not otherwise specified, the following minimum requirements apply:

1. Temperature sensors and digital thermometers shall have a certified calibration within the past 12 months to an accuracy of 0.5 degree F and a resolution to + or – 0.1 degree F.

2. Pressure sensors shall have an accuracy of + or – 2.0 percent of the value range being measured (not full range of meter) and have been calibrated within the past 12 months.

D. The test equipment shall have calibration certification per equipment manufacturer's interval level or within one year if not otherwise specified. The calibration tags shall be affixed or certificates readily available for all test equipment.

PART 3 - EXECUTION

3.01 STARTUP AND SYSTEM READINESS

A. All tests and start-up procedures shall be conducted without compromise to human or equipment safety.

B. The General Contractor and Sub- Contractors shall be responsible for the liability and safety of conducting all tests and startup.

C. The General Contractor shall clearly identify and list any Deficiencies resulting from the Installation Verification, Start-up and Pre-Functional Checks on the associated forms and immediately notify the CxA. Once Deficiencies are corrected and verified or tested, update and resubmit the associated forms.

D. The CxC and Trade Sub-Contractors shall a minimum 10 day's notice to the CxA for witnessing equipment Start-ups and Pre-Functional Checks & Tests.

3.02 FUNCTIONAL PERFORMANCE TESTS

A. Functional testing shall be performed and documented for 100% of all equipment in the scope of commissioning.

B. At the discretion of the CxA and per the approved Cx Plan, the CxA may witness a percentage (sample) of the functional tests for selected, multiple identical pieces of non-life-safety or non-critical equipment (example: VAV boxes).

C. The General Contractor and Sub-Contractors shall be responsible for the liability and safety of conducting all tests.

D. Ensure the following are completed prior to the start of the FPTs:

1. CxA and CxC certify through the System Readiness Checklist (SRC) forms that the HVAC systems, controls and instrumentation, equipment and assemblies have been installed, calibrated, started and are operating per the Contract Documents. Approval of the completed SRC forms by the CxA is required prior to conducting the FPTs.

2. As part of the system readiness, the TAB Trade Contractor shall conduct and complete all testing, reporting, field inspection and verification work, and discrepancies and corrective work, per specifications, prior to HVAC system FPT.

3. As part of the system readiness, all pipe system cleaning, flushing, and pressure testing, duct leakage testing and duct cleaning per the Contract Documents is completed and applicable plans and reports are provided to the CxA.
4. As part of the system readiness, the Controls Contractor shall complete the BAS pre-functional checks and tests, including sensor calibration, actuator testing, and point-to-point checks, prior to FPTs of the HVAC systems.
5. And the BAS graphics and programming for the sequence of operations and associated setpoints, schedules, and alarms shall be configured and the system operation checked and confirmed, including the control loop tuning, prior to starting functional testing.
    a. Prior to conducting the FPTs, place the systems and controls into the operating modes to be tested (e.g., normal occupied mode, normal startup and shutdown modes, unoccupied modes including after-hours override and night setback operation, emergency power, etc.).
    b. Check all control system safety cutouts, alarms, and interlocks with smoke control and fire-life safety during each mode of operation prior to functional testing.
6. The controls contractor shall execute a pre-test of the functional test on the approved FPT forms prior to the final witnessed test. This will give the controls contractor the confidence the witnessed test will pass.

E. Sub-Contractors shall execute all FPTs per the approved test procedures on the FPT forms. All testing results shall be documented on the final FPT forms; the forms shall be signed and dated by the representative performing the tests.

F. The CxC and Sub-Contractors shall coordinate all FPT with the CxA, and provide a minimum of 10 day's notice prior to conducting each system test.

G. FPT for each system must be successfully completed and signed by the CxA prior to formal approval of system commissioning.

H. FPT may be conducted using these approved test methods:
1. Manually manipulating the equipment settings to observe performance.
2. Overwriting control system sensor values to simulate a condition, such as overwriting the outside air temperature to be something other than it actually is.
3. Altering setpoints to force equipment into a mode of operation to verify a sequence. For example, to see the AC compressor lockout work at an outside air temperature below 55F, when the outside air temperature is above 55F, a FPT would temporarily change the lockout setpoint to be 2F below the current outside air temperature.
4. Using indirect indicators, such as readings from a control system screen reporting a damper is 100 percent open, for testing responses will be allowed only after the actual conditions represented by the indirect indicators have been directly verified, calibrated and documented on the SRC forms (as a pre-functional check/test).
5. Monitoring performance by analyzing the control system Trend data. The CxA will then analyze the control system Trend data and provide conclusions to the Owner.

I. Setup
1. The Trade Sub-Contractor executing the test shall document the pre-test normal condition on the test form.
2. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible.

3. The Trade Sub-Contractor executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. to execute the test according to the test procedures.

4. At completion of the test, the Trade Sub-Contractor shall return all affected building equipment and systems to their pre-test normal condition.

3.03 FUNCTIONAL PERFORMANCE TESTS AND TREND ANALYSIS

A. The CxA will prepare a Trend Analysis Plan with a points list and trend interval, as part of the FPTs to verify integrated system operation and performance. The Trend analysis will be conducted after the FPTs for the HVAC control sequences and operating modes are completed and any issues and deficiencies are corrected.

B. The BAS Trade Contractor shall set up the trend log definitions. Trend data shall be provided by the BAS Trade Contractor to the CxA in an electronic format, either a text file, CSV file or Excel file, with related system parameters grouped together.

C. If performance issues are found through the Trend analysis, the issues shall be corrected by the BAS Trade Contractor and the trending shall be restarted and analysis repeated by the CxA.

3.04 COMMISSIONING ISSUES AND RETESTING

A. All Deficiencies and Issues shall be documented on the appropriate forms in use, and will additionally be documented by the CxA on a Cx Issues List.

B. The CxA will maintain and update the Commissioning Issues List, and document the issues resolution process. Copies will be distributed to the General Contractor, Owner, and Sub-Contractors as appropriate.

C. All Commissioning Issues shall be corrected promptly. The responsible party shall correct the issue and inform the CxC and CxA of the resolution and completion date. The CxA will record completion on the Commissioning Issues List once the issue is successfully back-checked or verified and the CxC shall reschedule testing with the CxA and Sub-Contractor. Testing shall be repeated until passing performance is achieved or the Owner accepts the noted issue.

D. Immediate correction of minor issues identified during testing may be allowed at the discretion of the CxA. The issue and identified resolution must still be documented on the commissioning form in use.

E. When Cx Issues are identified during FPT, the CxA will discuss with the executing Sub-Contractor and/or CxC and determine whether testing can proceed or be suspended.

F. The Commissioning Issue and any identified resolution will be documented on the test form in use in addition to the Commissioning Issues List.

G. When there is a dispute regarding a Cx Issue, whether it is valid or who is responsible, additional parties may be brought into the discussion as appropriate.

H. The CxA will have the final interpretive authority on Cx Issues and Deficiencies and the Owner will have the final approval authority.

I. The CxA may recommend solutions to Deficiencies and Commissioning Issues. However, the burden of responsibility to solve, correct and perform required retests is with the General Contractor, Trade Sub-Contractors, and the Design Professional(s).

J. Additional Back-check Verifications and Re-testing:

1. For all Issues identified during the pre-functional system readiness activities, the CxA will back-check and verify the completion of the issues where appropriate.

2. For all Commissioning Issues identified during FPT, retesting is required to verify the resolution of the issue and to complete the FPT.

3. The CxA will witness one (1) re-test for each equipment and will perform one (1) back-check verification of any completed system readiness issue.
4. The Owner may back-charge the General Contractor for any additional fees from the CxA, resulting from any re-testing or repeated system readiness issues list back-checks beyond the first re-test or back-check.
5. A minimum 48 hour's notice is required for scheduling any re-testing, though the CxA will attempt to accommodate a shorter timeframe if feasible.
6. Any required retesting shall not be considered a justified reason for a claim of delay or for a time extension.

K. For any re-testing required, the CxA will determine if the entire test must be re-tested or if it is acceptable to re-test specific portions of the test that had failed.

3.05 DEFERRED TESTING

A. Before or during the end of the first year Warranty Period, any Seasonal or Deferred Testing as defined in the Cx Plan, shall be completed as part of this contract. Tests shall be conducted by the Trade Sub-Contractor responsible for the equipment and systems, completed in the same manner as all other commissioning tests, and shall be witnessed by the CxA.

B. The General Contractor shall coordinate with CxA and Owner and schedule all Deferred and Seasonal Testing.

C. The General Contractor shall make final adjustments to the as-built documentation or drawings for any modifications made during Deferred or Seasonal Testing.

3.06 O&M MANUALS AND TRAINING VERIFICATION

A. The General Contractor and the CxC shall coordinate and schedule the training for Owner Personnel. The CxC shall ensure that training is completed per the requirements of the construction documents and specifications.

B. Trade Sub-Contractors responsible for specific equipment and system training shall submit to the CxC, a written training agenda for each training class for the equipment and systems to be commissioned, no less than 14 days prior to start of training.

C. The General Contractor shall submit the training agendas and sign-in sheets (blank) to CxA and Owner for review and approval.

D. The training agendas shall cover the following elements:

1. Equipment and/or systems included in training
2. Intended audience
3. Location of training
4. Subjects covered (including a brief description and duration, presentation methods, etc.)
5. Instructor's name and qualifications
6. Copy of any handout materials or presentations.
7. Sing-In Sheet

E. The CxA will review the training plans to verify compliance with the specifications.

F. The General Contractor shall submit to CxA the signed and completed attendance sheets for each training session and a copy of the final training presentations and materials.

G. The CxA will verify with the Owner that the final O&M manuals have been delivered per the Contract Documents.

3.07 ACCEPTANCE AND CLOSE OUT

A. Regarding substantial completion, reference Division 01, Section 01 77 00, Closeout Procedures.

B. After completion of the commissioning activities and review of the completed commissioning documents the Owner will provide a formal written acceptance of the project construction phase commissioning. At that point, any remaining construction phase commissioning issues or seasonal/deferred testing will be tracked by the CxA as part of the Post- Occupancy Warranty Phase Commissioning if applicable.

C. Upon completion of all commissioning activities, the CxA will prepare and submit to the Owner a Final Commissioning Report detailing all completed commissioning activities and documentation. The CxC shall support this effort by providing all General Contractor and Trade Sub-Contractor commissioning documentation.

D. The Owner's written acceptance of construction phase commissioning will be included in the Final Commissioning Report.

E. The CxA will complete a Systems Manual for the systems and equipment commissioned (if applicable), with assistance provided by the CxC and Trade Sub-Contractors. The Systems Manual will provide the operating staff the information needed to understand and optimally operate the commissioned systems. The Systems Manual will contain at minimum the following sections:

1. Final version of the BOD.
2. Systems single line diagrams and schematics.
3. Final as-built sequence of operations, control drawings (P&IDs), points lists and as-left set points.
4. Supplemental operating instructions for integrated building systems such as water-side and air-side HVAC systems and controls, lighting controls, etc.
5. Recommended schedule of maintenance requirements and frequency
    a. A summary of the preventative maintenance and service procedures is recommended in the Systems Manual, for the major MEP equipment, including a schedule matrix checklist (checked as weekly, monthly, quarterly, annually, etc.).
    b. Recommended schedule for retesting of commissioned systems with blank test forms from the Final Commissioning Plan.
    c. Recommended schedule for calibrating sensors and actuators.

3.08 POST-OCCUPANCY WARRANTY PHASE COMMISSIONING

A. If applicable, no later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility staff, walk the facility and review systems operation to identify any issues. Key representatives from the General Contractor and Trade Sub- Contractors original project team shall attend, as determined by the CxA.

B. The CxA shall review BAS trend data during the Warranty Phase. The Controls Contractor will be responsible for providing post-occupancy trend data to the CxA.

C. Any performance issues, warranty items or problems identified will be reported by the CxA to the CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Trade Sub-Contractors prior to the end of the warranty period. The CxC shall work with the Trade Sub-Contractors and O&M staff to make corrections and modifications as required.

D. After correcting noted Warranty Phase Cx Issues, the General Contractor shall notify the CxA in writing, and the CxA will back-check and verify that the Warranty Phase Cx Issue was resolved.

E. Issues identified during the warranty period will remain Warranty Phase Cx Issues until satisfactory completion by General Contractor and back-check verification by CxA, even if the warranty period expires during the correction and back-check period.

END OF SECTION

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 23 09 23

HVAC Control Systems

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

B. OPR and BOD documentation for information.

C. Section 23 05 00 – Common Work Results for HVAC

D. Section 25 55 00 – Integrated Automation Control of HVAC

E. Division 26 - Electrical Work.

1.02 REFERENCES

A. County of Santa Barbara Energy Action Plan, revision in place when contract is awarded.

B. Comply with requirements of applicable green building code for this project such as LEED, CHPS, or CalGreen. (Verify with Owner.)

C. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:

1. National Electric Code (NEC)
2. City and County of Santa Barbara Building Codes
3. ASHRAE/ANSI 135-2010: Data Communication Protocol for Building Automation and Control Systems (BACNET)

D. UL 916 Energy Management Systems.

E. FCC-Part 15 Subparagraph J. Class A. Emissions Requirements.

F. ASHRAE 85- Automatic Control Terminology for Heating, Ventilating, and Air Conditioning.

G. NEMA EMCI - Energy Management Systems Definitions.

H. CEC - California Energy Commission Mandatory Requirements.

I. California Energy Code

1.03 SECTION SUMMARY

A. The Contractor shall design, furnish and install a complete temperature control system in accordance with the requirements of the contract documents, which shall include but not be limited to completion of the following items stated below.

B. System shall be stand-alone functional per project requirements.

C. System shall be native BACnet and all workstations and controllers, including unitary controllers, shall be native BACnet devices. No substitutions.

D. Provide all necessary BACnet-compliant hardware and software to meet the system’s functional requirements.

E. Provide Protocol Implementation Conformance Statement (PICS) for every controller in system, including routers, gateways, & etc. No substitutions.

F. All BACnet communicating devices shall be BTL listed. No substitutions.

G. Prepare individual hardware layouts, interconnection drawings, and software configuration from project design data. Typical hardware layouts are only acceptable for exact repeated equipment.

H. Implement the detailed design for all analog and binary objects, system databases, and logic control based on control descriptions, logic drawings, configuration data, and bid documents.

I. Design, provide, and install all equipment cabinets, panels, data communication network cables needed, and all associated hardware.

J. Provide and install all interconnecting cables between supplied cabinets, application controllers, and input/output devices.

K. Provide complete manufacturer's specifications for all items that are supplied. Include vendor name of every item supplied.

L. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.

M. The Commission Authority (CxA) shall be called in on progressive stages (typically every month) for the entire duration of the project.

N. Provide a comprehensive operator and technician training program as described herein.

O. Provide as-built documentation, operator's terminal software, diagrams, and all other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.

P. Provide new sensors, dampers, valves, and install only new electronic actuators. No used components shall be used as any part or piece of installed system.

Q. The contractor shall be responsible to provide all concealed conduit for HVAC control. The contractor shall submit shop drawing of any concealed conduit run within 30 days after issue of Notice to Proceed.

R. Drawings are diagrammatic and may not show all components required for a complete system. Failure to mention any specific item or device does not relieve the contractor of the responsibility for installing such device or item in order to comply with the intended control functions of this specification, sequence of operation, and to provide a complete and functioning temperature control system.

1.04 GENERAL DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of digital controllers.

B. The system shall directly control HVAC equipment as specified on contract drawings.

C. Each zone controller shall provide occupied and unoccupied modes of operation by individual zone.

D. If applicable, furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified on contract drawings.

E. Provide for future system expansion to include monitoring of occupant card access, fire alarm, and lighting control systems.

F. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. Schedules, set points, trends, and alarms specified on contract drawings shall be BACnet objects.

1.05 READINESS FOR INTEGRATION

A. The work described herein shall be integrated at a later date into the County front end computer by others. In preparation for this future integration, the controls contractor for this project shall:

1. Make all available BACnet points visible and writeable for all devices capable of BACnet communication;
2. Make all logical points visible and writeable, such as on-controller schedules, demand limiting function variables, and others;
3. Provide enabled ethernet communication port on high level controllers as part of this project;
4. Provide at minimum one extra 120V convenience outlet in each large controller enclosure/cabinet for future use;
5. Provide all logic programming per provided engineered sequence of operations with temporary values for logical writeable variables, such as outside air lockout or DX cooling lockout;
6. Provide temporary construction schedules, verified with owner, for the time elapsing between controls final functional testing and future integration by others;
7. If provided different settings for control logic by balancer, engineer, Owner, or CxA, set the new values to permit system testing and setup within 3 days or request.

B. All controllers, devices, and control logic specified for this project shall function stand-alone per sequence of operation requirements regardless of future integration status.

C. The relevant integration specification section is 25 55 00 – Integrated Automation Control of HVAC.

1.06 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Section 23 21 13 - Heating and cooling piping:
1. Control valves
2. Flow switches
3. Press and temp sensor wells & sockets
4. Temp sensor wells and sockets

B. Section 23 00 00 - Duct accessories:
1. Automated dampers
2. Terminal unit controls

C. Division 26 - Equipment Wiring Systems: Installation and connection of all power wiring. Power wiring shall be defined as follows:
1. Wiring of power feeds through all disconnect starters to electric motors.
2. 120 VAC Emergency power feeds to all critical BAS and/or temperature control panels.
3. 120 VAC wiring to DDC terminal units and temperature control panel as shown on Electrical plans.
4. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by this section.

1.07 PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

A. None

1.08 DEFINITIONS

A. PICS: Protocol Implementation Conformance Statement

B. Native BACnet: Controllers and microprocessor equipped devices shall communicate using the BACnet communication protocol without the need for any additional gateway modules or hardware.

C. BTL Listed: Listed by BACnet Testing Labs as BACnet compliant

D. Basis of Design (BOD): The BOD is developed by the design consultants for the systems used in the facility. It defines the assumptions made for the designed systems. This document is written to agree with the Owners Project Requirements (OPR).

E. Building Automation System (BAS): The building digital control system.

F. Commissioning Authority (CxA): An agent hired directly by the Owner which assists the Contractor with coordinating commissioning activities and witnesses and reviews the activities on behalf of the Owner.

G. Commissioning Issue: An issue which must be resolved to complete the commissioning process.

H. Commissioning Issues List: A log maintained by the CxA listing all Cx Issues documented during the commissioning.

I. Commissioning Plan: A document that outlines the organization, coordination, and requirements of the commissioning in detail.

J. Commissioning Coordinator (CxC): General Contractor employee who plans, schedules, and coordinates the Sub-Contractor's commissioning activities, and serves as the CxA's single point of contact for all administrative, documentation and coordination needs.

K. Deferred Testing: Testing performed at a later time for a certain reason.

L. Functional Performance Test (FPT): A test of the operation and control sequences of equipment and systems to verify system performance. Systems are tested under various operating modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, alarm, power failure, etc.

M. Installation Verification (IV): Field verification and documentation of proper installation of system equipment.

N. Monitoring: The recording of parameters of equipment operation using data-loggers or the Trending capabilities of BAS or control systems.

O. Owner's Project Requirements (OPR): A document written by the Owner describing the operational and functional requirements of a project, the expectations of how the facility will be used and operated, and the equipment and system expectations and requirements.

P. Sampling: Witnessing the startup or testing of a selected fraction of the total number of identical or near-identical pieces of equipment such as VAV boxes.

Q. Pre-Functional Checks: These are various checks and tests performed on a piece of equipment or system just before, during or after the initial Startup. Examples include pipe system pressure tests, duct leakage tests, mechanical system test and balance and electrical equipment NETA testing. They must be completed prior to functional testing.

R. Startup: Initial starting or activating of equipment performed by the Sub-Contractor or the Manufacturer's representative.

S. System Readiness Checklist (SRC): A checklist, covering the commissioning tasks and required documentation to verify that a system is ready for functional testing. The SRCs must be completed and signed by the General Contractor prior to conducting the functional testing.

T. Test and Balance (TAB): Testing, Adjusting, and Balancing work on the air and water systems to ensure design flow conditions are met.

U. Sub-Contractor: Typically a subcontractor to the General Contractor who provides and installs specific building components and systems and/or provides certain services.

V. Trending: Monitoring using the Building Automation System to aid in functional testing and to verify system operation and performance under operating conditions.

1.09 QUALITY ASSURANCE

A. All materials and equipment used shall be standard components, of regular manufacture for this application.

B. All systems and components shall have been thoroughly tested and proven in actual use for a minimum period of two (2) years.

C. Like items of equipment specified herein shall be the end product of one manufacturer in order to achieve standardization of appearance, operation, maintenance, spare parts and manufacturer's services.

D. All HVAC controls and end devices equipment shall have factory mounted and tested.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

F. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilation Systems."

G. Comply with ASHRAE 135 for DDC system control components.

H. Vendor shall be in the business of vending controls systems for the previous 10 years.

1.10 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. Direct Digital Control System Hardware

1. Complete bill of materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.

2. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:

a. Controllers

b. Transducers and transmitters

c. Sensors (include accuracy data)

d. Actuators

e. A schedule of control valves including the valve size, model number (including the pattern and connections), flow Cv, pressure rating, and location.

f. Relays and switches

g. Drawings and details of temperature control panels.

h. Drawings and details of free standing mounting supports of control panels.

i. Power supplies

j. Batteries

k. Operator interface equipment

l. Wiring

m. A schedule of all control dampers including damper size, pressure drop, manufacturer and model number.

n. Submit details of proposed nameplates, labels, tags and markers including a sample of each showing sample symbols, lettering style and size, color coding and banding.

3. Points list showing all system points and objects, data ranges, accuracy required (matching this specification) and the proposed English language object names.
4. Wiring diagrams and layouts for each control panel. Show termination numbers.
5. Floor plan schematic diagrams indicating field sensor and controller locations including thermostat/sensors, indoor static pressure sensors and static pressure regulator locations.
6. Riser diagrams showing control network layout, communication protocol, and wire types.

C. Sequence of operations for each system under control. This sequence shall be specific for the use of the Control System being provided for this project. Sequence shall be functionally equivalent with engineered sequence of operation specified for this project.

D. Control system CAD generated drawings including schematic, point-to-point wiring diagram, ladder diagram, and all pertinent data to provide a functional operating system.

E. Data sheets for all hardware and software control components.

F. A description of the installation materials including conduit, wire, flex, etc.

G. Central System Control and Network Hardware and Software

1. Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.
2. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
    a. Building level controller
    b. Power supplies
    c. Battery backups
    d. Interface equipment between other control panels
3. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
4. Network riser diagrams of wiring between central control unit and control panels.

H. Controlled Systems

1. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.
2. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
3. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
4. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified on contract drawings. Indicate alarmed and trended points.

I. Description of process, report formats, and checklists to be used for testing and pre functional activities.

J. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

K. Schedules

1. Within one month of contract award, provide schedule of work indicating:

a. Intended sequence of work items

b. Start date of each work item

c. Duration of each work item

d. Planned delivery dates for ordered material and equipment and expected lead times

e. Milestones indicating possible restraints on work by other trades or situations

2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

1.11 SUBSTITUTIONS

A. Control system must communicate native BACnet – no substitutions.

B. Other items, submit in accordance with Section 01 25 13 - Product Substitution Procedures

1.12 MINIMUM SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

1. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.

2. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.

3. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work station will be current, within the prior 60 seconds.

4. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.

5. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.

6. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.

7. Multiple Alarm Annunciations. Each device or workstation on the network shall receive alarms within 5 sec of other workstations.

8. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.

9. Control Stability and Accuracy. Control loops shall maintain measured variable at set point within tolerances listed in Table 2.

Table 1 – Required Reporting Accuracy

Measured Variable	**Reported Accuracy**
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±1ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Dioxide (CO_2)	±50 ppm

Note 1: 10% - 100% of scale

Note 2: For both absolute and differential pressure

Note 3: Not including utility-supplied meters

Table 2 – Required Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.13 MANUFACTURER'S & INSTALLER'S QUALIFICATIONS

A. Manufacturer: The company shall be specialized in the manufacturing of products specified in this section, with a minimum of ten (10) years of experience in the design, manufacturing, and installation of building automation and energy management systems similar in scope and performance to that specified herein, and shall submit evidence of this experience as a condition of acceptance and approval prior to bidding.

B. Installer:

1. The Building Automation and Energy Management system shall be installed by the manufacturer or competent installer regularly employed by the manufacturer of the BAS and automatic temperature control equipment.

2. The Building Automation and Energy Management system installer and manufacturer shall have a local office within a 50 mile radius of the job site, staffed with factory trained engineers fully capable of providing instruction, routine maintenance and 24 Hour emergency maintenance service on all system components.

3. The Contractor shall have a minimum five years of experience record in the design and installation of computerized building systems similar in scope and performance to that specified herein, and shall be prepared to provide evidence of this history as condition of acceptance and approval prior to bidding.

1.14 PROJECT RECORD DOCUMENTS

A. Submit under provisions of Section 01 78 39.

B. General: Complete documentation of the system installed shall be provided to the Owner upon Completion of the Project. This documentation shall be provided with an index sheet listing the contents in Alphabetical order and shall include, but not be limited to the following:

C. Project Record Drawings.

1. As-built versions of submittal shop drawings provided as AutoCAD 2007 (or newer) compatible files omad lash drive (file format: .DWG, .DXF, .VSD, or comparable) and 3 prints of each drawing on 11" x 17" paper.

2. AutoCAD files of contract drawings will be supplied to contractor for their use in creating project record drawings.

D. Testing and Commissioning Reports and Checklists.

1. Completed versions of reports, checklists, and trend logs used to meet requirements of this specification section and the commissioning requirements for the project.

E. Operating and Maintenance (O&M) Manual - These shall be as-built versions of the submittal product data. In addition to that required for the submittals, the O&M manual shall include:

1. As-built versions of submittal product data.

2. Names, address and 24-hour telephone numbers of Contractors installing equipment, and the control systems and service representative of each.

3. Operators Manual with procedures of operating the control systems including logging on/off, alarm handling, producing point reports, trending data, overriding computer control, and changing set points and other variables.

4. Programming Manual with a description of the programming language including syntax, statement descriptions including algorithms and calculations used, point database creation and modification, program creation and modification, and use of the editor.

5. Engineering, Installation and Maintenance Manual(s) that explains how to design and install new points, panels, and other hardware; preventative maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware.

6. Documentation of programs created using custom programming language including set points, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, set points, tuning parameters, and objects can be viewed using furnished programming tools. Include as-built final sequence of operation.

7. A listing and documentation of all custom software created using the programming language including the point database. One digital set of media containing files of the software and database shall also be provided.

8. A list of recommended spare parts with part numbers and supplies.

9. Complete original issue documentation, installation and maintenance information of all third party hardware provided including equipment and sensors.

10. Complete original issue diskettes for all software provided including operating systems, programming language, operator workstation software or web server software, and graphics software.

11. Licenses, Guarantee, and Warrantee documents for all equipment and systems.

12. Recommended preventive maintenance procedures for all system components including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions.

F. Training Materials:

1. Provide course outline and materials for each class at least three weeks before first class. Training shall be furnished via instructor-led sessions on site. Engineer may modify course outlines and materials if necessary to meet the Owner's needs. Engineer will review and approve course outlines and materials at least two weeks before first class.

1.15 EXTRA MATERIALS

A. The Contractor shall provide the following spare parts:

1. One outside air sensor.
2. Two sets of typical temperature sensors for offices.
3. Two sets of typical carbon dioxide sensors (if applicable)
4. One Zone Controller
5. One Unitary Controller

1.16 OWNERSHIP OF PROPRIETARY MATERIALS

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:

1. Record drawings
2. Database
3. Application programming code
4. Documentation

1.17 WARRANTY

A. Warranties shall be in accordance with Section 01 78 36 – Warranties.

B. The Contractor shall warrant all work as follows:

1. Labor and materials for the control system specified shall be warranted free from defects for a period of two (2) years after acceptance of substantial completion. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner. The contractor shall respond to the owner’s request for warranty service within 24 hours during normal business hours.
2. All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up. If the work specified is split into multiple contracts or a multi-phase contract, then each contract or phase shall have a separate warranty start date and period.
3. At the end of the final start-up, testing, and commissioning phase, if equipment and systems are operating satisfactorily to the engineer, the engineer shall sign certificates certifying that the control system’s operation has been tested and accepted in accordance with the terms of this specification. The date of acceptance shall be the start of warranty.
4. Operator workstation software, project-specific software, graphic software, database software, and firmware updates that resolve known software deficiencies as identified by the contractor shall be provided at no charge during the warranty period.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Alerton,

B. Trane,

C. Delta Controls,

D. T.A.C,

E. Automated Logic Corporation (ALC)

F. Novar

G. Or approved equal.

2.02 GENERAL

A. The BAS/ATC as specified and shown herein shall be fully programmed and installed as a complete package by a single Contractor. The Contractor shall furnish all materials, including all hardware and software, operator input/output peripherals, field hardware panels, sensors and field control devices, installed wiring and piping.

B. The Contractor shall be responsible for engineering, supervision of installation, labor services, system calibration, initial software programming, and system checkout as necessary to provide a complete and fully operational MCS as specified herein. The entire energy management and building controls system must be native BACnet at all levels including management level, integration level, field controller level and sensor/actuator level.

C. Manufacturer shall supply the latest available hardware and software at the time of submittal for Engineer's approval. Software upgrade release within 2 years shall be provided without additional cost to the Owner.

D. Equipment and labor not specifically referred to herein or on the plans required to meet the functional intent, shall be provided without additional cost to the Owner.

E. The Building Automation System shall include but not be limited to the following components.

1. System Application Controllers shall manage the Energy and Building Management capabilities of the automation system as well as facilitate remote communications and central monitoring, including trend logs.

2. Application Specific Controllers shall provide distributed, pre-engineered control, specific to the mechanical equipment specified.

3. Custom Application Controllers with distributed custom programming capability shall provide control for nonstandard control sequences.

4. The Data Communications capability shall allow data to be shared between the various controllers in the architecture.

5. The system software shall include system software for global application functions, application software for distributed controllers, and operator interface software.

6. All controllers and control devices associated with the smoke control, smoke purge and fire alarm systems shall be UL listed.

7. End devices such as sensors, actuators, dampers, valves, and relays.

8. The energy management and building automation control system shall consist of a network of DDC controllers providing full stand-alone operation of the building. The DDC controllers shall contain the necessary programming to accomplish the sequence of operation for building control as shown on plans and as specified herein after.

9. The system shall allow unlimited number of iterations to allow application specific controllers to be custom programmed.

F. The failure of any single component shall not interrupt the control strategies of other operational devices. System expansion shall be through the addition of end devices, controllers, and other devices described in this specification.

G. Controllers shall normally execute the control strategy to use peer-to-peer communication capabilities. Upon loss of communication, the stand-alone control unit shall be able to execute its own stand-alone programming.

H. Operator workstation connectivity shall not be necessary to sustain building operation.

2.03 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to most current ASHRAE BACnet Standard.

B. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

C. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.

2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified on contractdrawings. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

D. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.

E. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.04 CONTROLLER SOFTWARE

A. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. System Security. See Paragraph (Security) and Paragraph (Operator Activity).

C. Scheduling. See Paragraph (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:

1. Weekly. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).

2. Exception. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.

3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

D. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

E. Binary and Analog Alarms. See Paragraph (Alarm Processing).

F. Alarm Reporting. See Paragraph (Alarm Reactions).

G. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.

H. Demand Limiting.

1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.

2. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified on contract drawings. When demand drops below adjustable levels, system shall restore loads as specified.

I. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified on contract drawings.

J. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified on contract drawings.

K. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.

L. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.

M. Energy Calculations.

1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.

2. System shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.

3. System shall calculate a fixed-window average. Window interval start shall be defined by utility meter digital input signal to synchronize system's and utility's fixed-window averages.

N. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

O. On and Off Control with Differential. System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.

P. Runtime Totalization. System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified on contract drawings.

Q. All features shall be available for reading and writing externally over BACnet.

2.05 CONTROLLERS

A. General. Provide Building Controllers (BC)/Global Control Module (GCM), Advanced Application Controllers (AAC)/Unitary Control Module (UCM), Application Specific Controllers (ASC)/Zone Control Module (ACM), and Smart Actuators (SA) as required to achieve performance specified in Section 23 09 23, Article 1.10 (System Performance).

B. BACnet.

1. Building Controllers (BCs)/Global Control Module (GCM). Each BC shall substantially conform to BACnet Building Controller (B-BC) device profile as specified in ASHRAE/ANSI 135-2010, BACnet Annex L.
2. Advanced Application Controllers (AACs)/Unitary Control Module (UCM).
    a. Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ASHRAE/ANSI 135-2010, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
3. Application Specific Controllers (ASCs)/Zone Control Module (ACM).
    a. Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ASHRAE/ANSI 135-2010, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
4. Smart Actuators (SAs).
    a. Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ASHRAE/ANSI 135-2010, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
5. BACnet Communication.
    a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
    b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
    c. Each AAC and ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    d. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

C. Communication.
1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
4. Stand-Alone Operation. Each piece of equipment specified on contract drawings shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.

D. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at 0°F to 140°F.
2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 32°F to 120°F.

E. Keypad. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized

use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.

F. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

G. Serviceability.

1. Controllers shall have diagnostic LEDs for power, communication, and processor.
2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
3. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

H. Memory.

1. Controller memory shall support operating system, database, and programming requirements.
2. Each controller shall retain BIOS and application programming for at least 72 hours in the event of power loss.
3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

I. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft)..

J. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.06 INPUT/OUTPUT INTERFACE

A. System architecture shall allow for point expansion in one of the following ways:

1. The addition of input/output cards to an existing System Application Controller.
2. A slave controller may be used to expand point capacity.
3. Space Point Capacity: 15% expansion capacities for all point types in all DDC panels.
4. The distribution of these surplus points shall be equal among four types of points.

B. General. Hard-wire, in a permanent and high workmanship quality manner, input and output points to BCs, AACs, ASCs, or SAs.

C. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

D. Digital (Binary) inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of 12 mas at 12 VDC to be compatible with commonly available control devices.

E. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

F. Analog inputs shall allow the monitoring of low voltage, current, or resistance signals and shall have a minimum resolution of 0.1% of the sensing range. Analog inputs shall be compatible with, and field configurable to commonly available sensing devices.

G. Digital (Binary) outputs shall provide a continuous low voltage signal for on/off control of remote devices. Where specified in the sequence of operations or indicated on the points list, binary outputs shall have 3-position (on/off/auto) override switches, status lights, and shall be able to be selected for either normally open or normally closed position.

H. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10 VDC or a 4 to 20-ma signal as required to provide proper control of the output device.

I. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tristate outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as duct-mounted heating coils.

J. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

K. If applicable, provide an Auto-answer, auto-dial modem system for purposes of remote diagnostics and notification of desired exceptions. The modem shall provide the following functions:

1. Access to the entire facility control system to provide service and diagnostic support.

2. Access to the entire facility control system from off-site for similar purposes, and for remote operation, monitoring, and adjustment of facility functions.

L. Hardwired inputs and outputs may tie into the system through System Application, Custom Application, or Application Specific Controllers. Slave devices are also acceptable. Any critical points requiring immediate reaction shall be tied directly into the controller hosting thecontrol software algorithm for the critical function.

2.07 BUILDING CONTROLLERS / GLOBAL CONTROL MODULES

A. BCS/GCM controller shall be capable of standalone direct digital operation utilizing its own 32 bit processor, non-volatile flash memory, input/output, 12-bit A to D conversion, (8-bit A/D is acceptable for Rooftop applications), hardware clock/calendar, voltage transient protection devices. All non-volatile flash memory shall have a battery backup of at least five years.

B. Controller for Multi-Equipment applications shall accommodate multiple I/O Expander Modules via a designated expansion I/O bus port.

C. Data shall be shared between networked Controllers.

D. Controller shall maintain all BIOS and programming information in the event of power loss for at least 72 hours

E. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120Hz and from keyed radio up to 5 W at 3 ft.

F. Each controller shall contain both software and firmware to perform full DDC PID control loops and programs. Firmware revisions shall be made from the Operator Workstation. Controllers that require component changes to implement Firmware revisions are NOT acceptable.

G. Controller for Multi-Equipment applications shall accommodate multiple I/O Expander Modules via a designated expansion I/O bus port. Expander modules shall expand the total point capacity of each controller up to 192 points

H. All point data, algorithms and application software within a controller shall be custom programmable from the Operator Workstation.

I. Application programs, calculations, and control commands shall be executed via a 32-bit microcomputer resident in the controller. All operating parameters for application programs shall

be stored in read/writable non-volatile flash memory within the controller and shall be uploaded/downloaded to/from the Operator Workstation.

J. Controller shall contain a serial port for the interface of maintenance personnel's' portable computer. Other controllers shall be accessible from this port.

K. Input-Output Processing:

1. Digital outputs shall be relays, 24VAC or VDC maximum, 3 amp maximum current. Each output shall have a manual Hand-Off-Auto switch to allow for override and an LED to indicate the operating mode of the output.

2. Universal inputs shall be Thermistor (BAPI Curve II) 10K Ohm at 77 [illegible] 10K Ohm maximum source impedance, 0-20mA - 24 VDC loop power, 250 Ohm input impedance, dry contact - 0.5mA maximum current.

3. Analog output shall be electronic, voltage mode 0-10VDC or current model 4-20mA.

4. Analog pneumatic outputs shall be 0-20psi. Each pneumatic output shall have a feedback transducer that measures the actual psi output value and not a calculated value. Each pneumatic output shall have a manual override switch, configured as: open, closed, or automatic operation. An LED shall indicate the state of each output

L. Communications. Each Building Controller shall reside on a BACnet inter-network using the ISO 8802-3 (Ethernet) or ARCNET (ASTM 878.1) Physical/Data Link layer protocol. Each Building Controller shall also perform routing to a network of Custom Application and Application Specific Controllers.

M. A local keypad and display shall be provided where specified in the sequence of operations or points list. An optional system security password shall be available to prevent unauthorized use of the keypad/display.

2.08 UNITARY CONTROLLERS

A. Controller shall be capable of standalone direct digital operation utilizing its own 32 bit processor, non-volatile flash memory, input/output, A to D conversion, hardware clock/calendar, voltage transient protection devices. A separate co-processor shall be used for communications to the controller network. All nonvolatile flash memory shall have a battery backup of at least five years.

B. Controller for Multi-Equipment applications shall accommodate multiple I/O Expander Modules via a designated expansion I/O bus port.

C. Unitary Controller shall maintain all BIOS and programming information in the event of power loss for at least 72 hours

D. All point data, algorithms and application software within a controller shall be custom programmable from the Operator Workstation

E. Application programs, calculations, and control commands shall be executed via a 32-bit microcomputer resident in the controller. All operating parameters for application programs uploaded/downloaded to/from the Operator Workstation

F. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120Hz and from keyed radio up to 5 W at 3 ft.

G. Each controller shall contain both software and firmware to perform full DDC PID control loops and programs. Firmware revisions shall be made remotely via Flash memory

H. Controller shall contain a USB or Ethernet port for the interface of maintenance personnel's' portable computer. Other controllers shall be accessible from this port

I. A local keypad and display shall be provided where specified in the sequence of operations or points list. Keypad shall be provided for interrogating and editing data. An optional system security password shall be available to prevent unauthorized use of the keypad/display.

2.09 APPLICATION SPECIFIC CONTROLLERS / ZONE CONTROLLERS

A. Controller shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. The Controller shall be utilizing its own processor, non-volatile flash memory and shall be easily upgraded. All non-volatile flash memory shall have a battery backup of at least five years.

B. Sensor Support: Controller shall be able to support various types of zone temperature sensors, such as; temperature sensor only, temperature sensor with built-in local override switch and temperature sensor with built-in setpoint adjustment switch.

C. Airflow Transducer: Controllers for pressure independent VAV applications shall have a built-in airflow transducer for air flow measurement.

D. Visual Status: Each Unitary Controller and Unitary Controller Interface shall have LED indication for visual status of communication, power, and all outputs.

E. Standalone Algorithm: In the event of a loss of communication, each Unitary Controller shall control from a standalone algorithm, which maintains the assigned space temperature until communication with the connectivity is restored.

F. Output points must be available with manual software and hardware overrides with feedback indication that an output is presently overridden.

G. Each controller shall have a real time clock, which shall remain active during power failure for up to seven (7) days under normal operating conditions. When the controller is used with a higher-level system, the time clock shall be automatically synchronized with the system controller.

H. The local controller shall provide backup of all memory for a period of seven (7) days under normal operating conditions if commercial power to the controller is interrupted.

I. The local controller shall include an RS232, USB, or Ethernet port for connection to a personal computer for upload, download and editing of data.

J. Input/Output Processing:

1. Digital outputs shall be relays, 24 Volts AC or DC maximum, having a 1 Amp maximum current. Each relay shall be configured as normally open or normally closed, and provide a dry contact.

2. Universal inputs shall be Thermistor Precon Type II, dry contacts or 0-5VDC with 0-10K Ohm input impedance

3. Enhanced Zone Sensor Input. The input shall provide one thermistor input, one local setpoint adjustment, one timed local override switch, and an occupancy LED indicator

4. Analog output electronic, voltage mode 0-10VDC

2.10 ENERGY MONITORING (ELECTRICAL)

A. Contractor shall furnish and install a power monitoring interface with local display and/or remote connection to a building automation system as specified here-in before. Contractor shall be responsible to provide all the required interfacing communication module, end devices, control wiring, control transformer, current transformers, voltage disconnect switch block, etc.

B. The power monitoring unit shall be housed in a NEMA 12 enclosure.

C. The power monitoring interface unit shall be provided with the following features:

1. Auto-corrects for wiring errors.

2. Three-phase (Wye or Delta) or single-phase systems.

3. Voltage selector switch (120-600V).
4. Accepts 5 amp, 1 amp or .333 Volt CT's.
5. Low voltage alarm contact.
6. Two 4-20 mA outputs.
7. Pulse output for kWH with selectable pulse rate.
8. LCD display.
9. Communication module to interface with building automation and energy management systems.

D. Contractor shall provide voltage disconnect switch block for voltage disconnect and CT short/disconnect to protect power monitoring equipment.

E. All associated components used with the power monitoring system shall be UL listed.

F. Manufacturer: Kele ModelPT- 9500-D, Veris or approved equal.

2.11 ENERGY MONITORING (BTU AND FLOW METERS)

A. The entire Energy Measurement System shall be built and calibrated by a single manufacturer, ONICON Incorporated (or approved equal), and shall consist of a flow meter, two temperature sensors, a Btu meter, temperature thermowells, and all required mechanical installation hardware. A certificate of NIST* traceable calibration shall be provided with each system. All equipment shall be covered by the manufacturer's two year warranty.

B. BTU Meter: Provide an ONICON BTU Meter. The Btu meter shall provide the following points both at the integral LCD and as outputs to the building control system: Energy Total, Energy Rate, Flow Rate, Supply Temperature and Return Temperature. Output signals shall be either serial network (protocol conforming to BACnet® MS/TP, BACnet/IP) or via individual analog and pulse outputs. Each Btu meter shall be factory programmed for its specific application, and shall be re-programmable using the front panel keypad (no special interface device or computer required).

C. Temperature sensors: Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched (NIST* traceable) for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within +0.15°F (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).

D. Flow Meter: Refer to meter schedule for specific flow meter type. The flow meter shall be installed either in the supply or return pipe of the system to be measured following the manufacturer's instructions with particular attention to upstream and downstream straight pipe runs. Insertion type flow meters shall be provided with all installation hardware necessary to enable insertion and removal of the meter without system shutdown and shall be hand insertable up to 400 psi.

E. Inline (full bore) Electromagnetic Type:

1. Provide an ONICON Electromagnetic Flow Meter complete with integral or remote electronics module. The electronics module shall include a graphic display. Connections to the piping shall be ANSI class 150 flanges. The installing contractor is responsible for providing suitable mating flanges. The flow tube shall be epoxy coated steel; the sensing electrodes shall be 316 SS; the liner shall be polypropylene or ebonite for low temperature service, PFTE for hot water service. Each flow meter shall be individually wet-calibrated and accurate to within ±0.2% of reading from 3 to33 feet per second velocity. A certificate of calibration shall be provided with each flow meter. Output signals shall be 4-20 mA and programmable pulse. The flow meter shall be capable of measuring bi-directional flow. For installations in non-metallic pipe, install grounding rings between flanges. Each flow meter shall be factory programmed for its specific application, and shall be re-programmable using the integral keypad on the converter (no special interface device or computer required).

2.12 AUXILIARY CONTROL DEVICES

A. Dampers

1. The Contractor shall provide all automatic control dampers not specified to be supplied integral to the HVAC equipment.
2. All proportional dampers shall be Low Leakage opposed blade type. Two position dampers may be opposed or parallel blade type.
3. Motorized dampers, unless otherwise specified elsewhere, shall be as follows:
    a. Damper frames shall be 13 gauge galvanized steel channel or 1/8” extruded aluminum with reinforced corner bracing.
    b. Damper blades shall not exceed 8” in width or 48” in length. Blades shall be suitable for medium velocity performance (2,000 fpm). Blades shall be not less than 16 gauges.
    c. Damper shaft bearings shall be as recommended by manufacturer for application, Oilite or better.
    d. All blade edges and top and bottom of the frame shall be provided with replaceable butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel. The blade seals shall provide for a maximum leakage rate of 10 CFM per square foot at 4” W.C. differential pressure. Pressure drop shall not exceed (0.04” airfoil blades) (0.10” regular blades) W.C. at a wide-open face velocity of 1,500 fpm.
    e. Individual damper sections shall not be larger than 48”x60”. Provide minimum of one damper actuator per section.
    f. Modulating dampers shall provide a linear flow characteristic where possible.
    g. Dampers shall have exposed linkages.
4. Control dampers shall be parallel or opposed blade type and as specified hereinafter.
    a. Outdoor and/or return air mixing dampers and face and bypass dampers shall be combination parallel/opposed blade, approximately 57% opposed blade, arranged to direct air streams towards each other.
    b. Other modulating dampers shall be opposed blade type.
    c. Two-position shut-off dampers may be parallel or opposed type with blade and side seals.

B. Damper Actuators

1. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator.
2. When shown, for power-failure/safety applications, an internal mechanical spring return mechanism shall be built into the actuator housing.
3. All rotary spring return actuators shall be capable of both clockwise or counter clockwise spring return operation. Linear actuators shall spring return to the retracted position.
4. Proportional actuators shall accept a 0-10 VDC or 0-20 mA control signal and provide a 2-10 VDC or 4-20 mA operating range.
5. All 24 VAC/DC actuators shall operate on Class 2 wiring and shall not require more than 10 VA or AC or more than 8 W for DC applications. Actuators operating on 120 VAC or 230 VAC shall not required more than 11 VA.
6. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.

7. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.
8. Actuators shall be provided with a conduit fitting and a minimum 1m electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
9. Actuators shall be Underwriters Laboratories Standard 873 listed.
10. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque.

C. Control Valves

1. Control valves shall be two-way or three-way type for two-position or modulating service as shown.
2. Close-off (Differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
    a. Water Valves:
        i. Two-way: 150% of total system (pump) head.
        ii. Three-way: 300% pressure differential between ports A and B at design flow or 100% of total system (pump head.
    b. Ports. Valves providing modulating service shall have equal percentage ports.
    c. Sizing.
        i. Two-position service: line size.
        ii. Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 35 kPa (5 psi).
        iii. Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 35 kPa (5 psi).
    d. Fail Position. Water valves shall fail normally open or closed as follows unless otherwise specified.
        i. Water zone valves: normally open.
        ii. Heating coils in air handlers: normally open.
        iii. Chilled water control valves: normally closed.
    e. Other applications: as scheduled or as required by sequences of operation.

D. Pressure Independent Characterized Control Valves

1. Control Valves: Factory fabricated of type, body material and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.
2. Pressure Independent Characterized Control Valves (PICCV): Forged brass body rated at no less than 600 psi, chrome plated brass ball and stem, female, NPT union ends.
3. The modulating control valves shall be pressure independent.
4. The control valve shall accurately control the flow from 0 to 100% full rated flow with an equal percentage flow characteristic. The flow shall not vary more than +/- 5% due to system pressure fluctuations across the valve with a minimum of 5 psid across the valve.
5. Combination of actuator and valve shall provide a minimum close-off pressure rating of 200 psi.

6. The control valve shall require no maintenance and shall not include replaceable cartridges.
7. The actuator shall be directly coupled to the valve at the factory.
8. The manufacturer shall warrant all components for a period of 5 years from the date of production, with the first two years unconditional.
9. Calibrated Balancing Valves and Automatic Flow-Control Valves shall not be required on devices where self-contained pressure independent characterized control valves are installed.
10. Manufacturer: Belimo Model PICCV, or approved equal.

E. Temperature Sensors

1. Temperature sensors shall be Resistance Temperature Detector (RTD) or Thermistor type and as directed by the requirements of this specification.
2. Duct sensors shall be rigid or averaging as specified in the sequence of operations. Averaging sensors shall be a minimum of 5 feet in length.
3. Immersion sensors shall be provided with a separable stainless steel well.
4. Space sensors shall be equipped with set point adjustment and/or override switch as specified on the plans or in the sequence of operations.
5. Accuracy shall be +/- 1F for standard specifications. Where high accuracy is required, accuracy shall be +/- .20F.
6. Supply room sensors with tamper and vandal proof locking cover (BEKO Model BTGRK, BTG-RO or approved equal)
7. Provide outside air sensors with watertight inlet fitting, shielded from direct rays of sun.
8. Room thermostats shall be capable of being replaced without the need for controller recalibration.
9. Each room thermostat shall have a backlit liquid crystal display (LCD) with the capability of include a momentary pushbutton for override of unoccupied operation, displays the setpoint, room and outside air temperatures, and fan status.
10. The unit shall be capable of changing setpoints within established limits.
11. Room thermostats and temperature sensors for the controllers as indicated, shall have heating and cooling set points constructed to prevent overlap of set points.
12. All room thermostat shall be installed 4’ above finished floor.
13. Room temperature sensors shall be provided with single or dual set points as indicated on the drawings. Dual set point devices shall be provided with an internal software interlock, which provides a programmable heat/cool dead band.
14. Manufacturer: T.A.C VT7200 series, or approved equal.

F. Carbon Dioxide Sensors

1. The wall type carbon dioxide sensor shall be UL listed.
2. Provide carbon dioxide as indicated on the drawings, and the carbon dioxide sensor shall have the following minimum features:
    a. Provide a non-dispersive infrared Carbon Dioxide (CO2) BACnet compatible analog transmitter. The transmitter shall be in an attractive, high plastic enclosure. The system shall operate from 20-30 VAC or 18-30VDC power.
    b. The transmitter shall have an operating measurement range of 0 -2,000 ppm CO2 with an accuracy factor of +/- 5% reading Maximum cell drift per year shall be no more than

+/- 75ppm. The transmitter shall have an operating temperature of 0 degrees C to + 50 degrees C.

c. The transmitter shall produce a linear analog signal of 4-20mA or 0 – 10 VDC (user selectable) suitable for direct input to building management system. A relay output shall be provided. The building management system shall provide control to the building fresh air intake based on the information signal received from the CO2 transmitter. When the CO2 level in the return air reach 800 ppm, fresh air shall be introduced by the building management system.

d. The contractor shall provide the analog transmitter, and include all wiring, conduit and control panel interconnection required for a successful installation.

e. The unit shall have a 4-digit LCD digital Display. All Carbon Dioxide sensors shall be installed between 3' to 6' above finished floor.

f. Provide heavy duty type Vandal-Proof lockable enclosure (BEKO Model BTG-RK for offices, Model BTG-54VLf, or approved equal)

g. The carbon dioxide sensor shall require recalibration no less than 5 years. Manufacturers: Critical Environment Technologies Model AST-IC2 – Wall Mounted, or approved equal.

3. Duct mounted carbon dioxide sensor and carbon dioxide gas sensor module shall be UL listed. Provide duct mounted carbon dioxide and carbon dioxide gas sensor module as indicated on the drawings. The carbon dioxide sensor and carbon dioxide sensor module shall have the following minimum features:

a. Provide a non-dispersive infrared Carbon Dioxide (CO2) BACnet compatible analog transmitter. A duct sampling kit shall be included, consisting of a probe assembly to be installed on the return air duct and tubing to the sensor. The transmitter shall be in a high impact plastic enclosure. A LCD display shall be provided. The system shall operate from 20-30 VAC or 18-30VDC power.

b. The transmitter shall have an operating measurement range of 0 -2,000 ppm CO2 with an accuracy factor of +/- 5% reading Maximum cell drift per year shall be no more than +/- 75ppm. The transmitter shall have an operating temperature of 0 degrees C to + 50 degrees C.

c. The transmitter shall produce a linear analog signal of 4-20mA or 0 – 10 VDC (user selectable) suitable for direct input to building management system. A relay output shall be provided. The building management system shall provide control to the building fresh air intake based on the information signal received from the CO2 transmitter.

d. The contractor shall provide the analog transmitter, and include all wiring, conduit and control panel interconnection required for a successful installation.

e. The carbon dioxide sensor shall be protected with a vandal proof cage with a display for reading CO2 level.

f. The carbon dioxide sensor shall require recalibration at no less than 5 year increments.

G. Differential Pressure Switches

1. Flow-proving switches shall be differential pressure type as shown on the drawings and as specified hereinafter.

2. Differential pressure type switches (air or water service) shall be UL listed, SPDT snapacting, pilot duty rated (125 VA minimum), NEMA Type 1 enclosure, with scale range and differential suitable for intended application, or as specified.

3. Current sensing relays may be used for flow sensing or terminal devices.

4. Provide single pole double throw switch with fully adjustable differential pressure settings.

H. High Limit Thermostats

1. High limit thermostats shall be manual reset type set at 120F or at engineered setting.

I. Low Limit Thermostats

1. Safety low limit thermostats shall be vapor pressure type with an element 2 ft. minimum length. Element shall respond to the lowest temperature sensed by any one foot section.
2. Low limit shall be manual reset only.

J. Temperature Control Panel (TCP)

1. Furnish and install pre-wired, lock equipped, control panels of code gauge steel for mounting all appropriate control devices, meeting all applicable requirements of Title 24, California Administrative Code.
2. Control panel shall be freestanding or wall mounted and shall be located where shown on plans.
3. Control panel shall be factory wired with a terminal strip ready for field installation.
4. Provide engraved bakelite nameplates for all devices mounted on the face of the temperature control panel.
5. Control panel shall conform to UL 50 and all components mounted in the control panel shall be UL listed.
6. Panels where heat built-up may be an issue, they shall be fitted with side mounted extract fans and relief holes for proper air volume.
7. Control panel shall be rated NEMA Type 12 for indoor, NEMA 3R for outdoor, NEMA Type 12 for mechanical room, and NEMA 4X for corrosive environment.
8. All switches, gages and light indicators shall be flush mounted.
9. All Direct Digital Controllers, H-O-A switches, interface hardware, electric control relays, control transformers, smoke detector's test/reset button and miscellaneous control devices, shall be installed inside the temperature control panel. No control devices shall be located at other locations except for sensors and actuators.
10. Control Panels housing Direct Digital Controllers shall be provided with the following minimum features:
    a. 120/240 V selectable transformer.
    b. Access for wire and conduit to enter the cabinet.
    c. All control wiring and system communication shall be electrically terminated inside the TCP.
    d. Duplex receptacle inside the enclosure.
11. Control panel shall include the following elements:
    a. Orange light indicator for each fan. Light "on" indicates that fan's motor is operating.
    b. Green "flow" light indicator for each supply/exhaust fan. Flow indicator shall be interlocked with flow switches located at each fan. Flow indicator light shall come on only when the minimum required flow is detected. If a fan is on line but required flow is not detected, the indicating yellow light for "fan failure" shall be on.
    c. Each duct smoke detector shall be provided with red indicator light for "alarm," green indicator light for "pilot"; and a key test/reset button.
    d. A HAND-OFF-AUTO switch shall be provided for each fan and shall be panel flush mounted.

12. Drawings and details for the control panels and free standing mounting supports shall be submitted to the Engineer for approval.

13. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.

K. Relays

1. Control relays shall be UL listed plug-in type with dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage suitable for application.

2. Time delay relays shall be UL listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable plus or minus 200% (minimum) from set point shown on plans. Contact rating, configuration, and coil voltage suitable for application. Provide NEMA Type 1 enclosure when not installed in local control panel.

L. Transformers and Power Supplies

1. Power Supplies

a. Control transformers shall be UL listed, Class 2 current-limiting type, or shall be furnished with over-current protection in both primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

b. Unit output shall match the required output current and voltage requirements. Current output shall allow for a 50% safety factor. Output ripple shall be 3.0 mV maximum Peak-to-Peak. Regulation shall be 0.10% line and load combined, with 50 microsecond response time for 50% load changes. Unit shall have builtin over-voltage protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

c. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

d. Line voltage units shall be UL recognized and CSA listed.

2. Power Line Filtering.

a. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

b. Dielectric strength of 1000 V minimum

c. Response time of 10 nanoseconds or less

d. Transverse mode noise attenuation of 65 dB or greater

e. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

M. Current Switches

1. Current-operated switches shall be self-powered, solid state with adjustable trip current. The switches shall be selected to match the current of the application and requirements of the control system

N. Outside Air Sensor (Platinum Type)

1. Sensing element (Temperature): Platinum RTD.

2. Sensor types: 2.252K, 3K, 10K, 20K, 100K

3. Accuracy: +/- 0.50F

4. Temperature response: Negative temperature coefficient

5. Long Term Stability: 0.240F over five years
6. Temperature Range: -100F to +200F.
7. The temperature-sensitive element shall be shielded in a stainless steel tube.
8. Sensor enclosure shall be moisture proof and rated NEMA 3R.
9. Sensor shall be installed in accordance with the manufacturer recommendations.
10. Manufacturers: Kele Model ST series or equal.

O. Outside Air Sensor (Thermister Type)
1. Sensing element (Temperature): Thermister (thermal resistor).
2. Sensor types: 2.252K, 3K, 10K, 20K, 100K
3. Accuracy: +/- 0.50F
4. Temperature response: Negative temperature coefficient
5. Stability: 0.240F over five years
6. Temperature Range: -100F to 300F.
7. The temperature-sensitive element shall be shielded in a stainless steel tube.
8. Sensor enclosure shall be moisture proof and rated NEMA 3R.
9. Sensor shall be installed in accordance with the manufacturer recommendations.
10. Manufacturers: Kele Model US series or equal.

P. Binary Temperature Devices.
1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetaloperated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetalactuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

Q. Humidity Sensors.
1. Not used.

R. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).
1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

S. Override Timers.

1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0-6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

T. Current Transducers.

1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

U. Current Transducers.

1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

V. Voltage Transmitters.

1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL recognized at 600 Vac rating.

W. Voltage Transformers.

1. AC voltage transformers shall be UL recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4°C-55°C (40°F-130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

X. Pressure Transducers.

1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.) Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

Y. Pressure-Electric (PE) Switches. PE switches shall be UL listed, pilot duty rated (125 VA minimum) or motor control rated, metal or neoprene diaphragm actuated, operating pressure rated for 0-175 kPa (0-25 psig), with calibrated scale minimum setpoint range of 14-125 kPa (2-18 psig).

1. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application.
2. Switches shall be open type (panel-mounted). Exception: Switches shall be enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
3. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

Z. AIRFLOW MEASURING STATION

1. Provide airflow measurement devices at all outside air intake plenum, supply duct or as indicated on the plans. Fan inlet measurement devices shall not be substituted for duct or plenum measurement devices.
2. Each measurement device shall consist of one or more sensor probe assemblies and a single microprocessor-based transmitter. Each sensor probe assembly will contain one or more independently wired sensor housings. Multiple sensor housings shall be equally weighted and averaged by the transmitter prior to output.
3. All Sensor Probe Assemblies
    a. Each sensor housing shall be manufactured of a U.L. listed engineered housing.
    b. Each sensor housing shall utilize two hermetically sealed thermistor probes to determine airflow rate and ambient temperature. Devices that use “chip” type thermistors are unacceptable. Devices that do not have 2 thermistors in each sensor housing are not acceptable.
    c. Each sensor housing shall be calibrated at a minimum of 16 airflow rates and have an accuracy of +/-2% of reading over the entire operating airflow range.
    d. Each sensor assembly shall be calibrated to standards that are traceable to the National Institute of Standards and Technology (NIST).
    e. Devices whose accuracy is the combined accuracy of the transmitter and sensor probes must demonstrate that the total accuracy meets the performance requirements of this specification throughout the measurement range.
    f. The operating temperature range for the sensor probe assembly shall be -20° F to 160° F. The operating humidity range for the sensor probe assembly shall be 0-99% RH (non-condensing).
    g. Each temperature sensor shall be calibrated at a minimum of 3 temperatures and have an accuracy of +/-0.15° F over the entire operating temperature range. Each temperature sensor shall be calibrated to standards that are traceable to the National Institute of Standards and Technology (NIST).
    h. Each sensor probe assembly shall have an integral, U.L. listed, plenum rated cable and terminal plug for connection to a remotely mounted transmitter. All terminal plug interconnecting pins shall be gold plated.
    i. Each sensor assembly shall not require matching to the transmitter in the field.
    j. A single manufacturer shall provide both the airflow/temperature measuring probe(s) and transmitter at a given measurement location.
4. Duct and Plenum Sensor Probe Assemblies
    a. Sensor housings shall be mounted in a 316 stainless steel tube probe assembly.
    b. The number of sensor housings provided for each location shall be as follows:

i. <= 1 sqtf, 2 sensors
ii. >1 to <4 sqtf, 4 sensors
iii. 4 to <8 sqtf, 6 sensors
iv. 8 to <12 sqtf, 8 sensors
v. 12 to <16 sqtf,12 sensors
vi. >=12 sqtf, 16 sensors

c. Probe assembly mounting brackets shall be constructed of 316 stainless steel. Probe assemblies shall be mounted using one of the following options:
i. Insertion mounted through the side or top of the duct
ii. Internally mounted inside the duct or plenum
iii. Standoff mounted inside the plenum

d. The operating airflow range shall be 0 to 5,000 FPM unless otherwise indicated on the plans.

5. Transmitters
a. The transmitter shall have an LCD display capable of displaying airflow and temperature. Airflow shall be field configurable to be displayed as a velocity or a volumetric rate.
b. The transmitter shall be capable of displaying the individual airflow and temperature readings of each sensor on the LCD display.
c. The transmitter shall operate on 24 VAC. The transmitter shall not require an isolated power source.
d. The operating temperature range for the transmitter shall be -20° F to 120° F. The transmitter shall be protected from weather and water.
e. The transmitter shall be capable of communicating with the host controls using one of the following interface options as required by BMS :
i. RS-485: Field selectable BACnet-MS/TP
ii. 10 Base-T Ethernet: Field selectable BACnet Ethernet, BACnet-IP, ModBus-TCP and TCP/IP

6. The measuring device shall be UL listed as an entire assembly.
7. Contractor installing the air measurement devices to provide adequate NEMA enclosure to protect the transmitters.
8. The manufacturer's authorized representative shall review and approve placement and operating airflow rates for each measurement location indicated on the plans. A written report shall be submitted to the consulting mechanical engineer if any measurement locations do not meet the manufacturer's placement requirements.
9. Manufacturer: EBTRON, Inc. Model GTx116-P (No Known Equal), or approved equal.

AA. AQUASTAT (Domestic Hot Water)

1. Remote bulb type, line voltage, externally adjustable from 100 to 2400 F, SPDT switching for low-limit circulator control, with 1/2" remote sensing well, NEMA 1 enclosure, and UL listed. The unit shall be wired to the domestic hot water circulating pump for controls.
2. Manufacturer: Honeywell or equal.

BB. ULTRASONIC CONTROLLER

1. The controller shall capable of liquid level and volume in up to ten vessels and provide averaging measurements for any selected vessels.
2. The output signal shall be proportional to material level respectively or average both levels from 0% to 100% for any optimum accuracy of =+/- 0.25% of range or 0.24", whichever is greater. Up to ten discrete 4-20mA output can be programmed utilizing the AO-10 analog output module.
3. Programming shall be accomplished via removable, infrared programmer without the need to open the enclosure for programming thus maintaining the NEMA 4 integrity of the enclosure. There shall be no internal potentiometers or switches used in programming controller.
4. The indicator display shall be graphic 2" x 5" LCD for measurement readings and operational status. Features include two four digit numeric displays with floating decimal point, level bar graph, alarm status, point being scanned, data communication indication, filing/emptying indication, temperature and rate of change.
5. The transceiver shall have an EEPROM for storage of entered parameters and operational data.
6. The transmitter shall process al echo from stored memory which is continually updated after echo enhancement. The echo shall be processed comparing returns for largest area echo, tallest echo spike and first echo returned. The patented sonic Intelligence shall compared the various returns and select the echo the greatest confidence factor.
7. Power requirements: 115 VAC, 50/60HZ, 15VA
8. Manufacturer: Siemens, model LU10 or approved equal.

CC. ULTRASONIC TRANSDUCER

1. The ultrasonic transducer shall be permanently mounted at the measuring point and shall be installed according to the manufacturer's recommendations.
2. The measuring range of the ultrasonic transducer is 1 to 33 feet. Temperature range is -40 to 164 F and compatible with ultrasonic controller as specified.
3. Cable: RG62U cable
4. Manufacturer: Siemens, model ST-H or approved equal.

2.13 WIRING AND RACEWAYS

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

2.14 FIBER OPTIC CABLE SYSTEM

A. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

B. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

2.15 DUCT SMOKE DETECTOR

A. General: Duct smoke detector shall be photoelectric air duct smoke type. Duct smoke detector shall be of the size and type as shown on plans and as specified hereinafter.

B. Duct smoke detector shall be photoelectric type which are capable of sensing smoke in air velocities from 100 to 4,000 feet per minute.

C. Duct smoke detector shall be capable of local testing via magnetic switch or remote testing from the RTS451 or RTS451KEY Remote Test Station.

D. Smoke sensor shall have communication address.

E. The duct smoke detector shall be UL listed per UL 268A, Standard for Smoke Detectors for Duct Applications, specifically for use in air handling systems. The duct smoke detector housing shall incorporate an airtight smoke chamber in compliance with UL 268A.

F. The housing shall be capable of mounting to either rectangular or round ducts without adapter brackets. An integral filter system shall be included to reduce dust and residue effects, thereby reducing maintenance and servicing. Sampling tubes shall be installed after the housing is mounted to the duct by passing through the duct housing.

G. These intelligent sensors communicate and are continuously monitored through the communication line. Detector sensitivity changes caused by dirt, temperature, or humidity are reported to the panel, allowing compensation algorithms to maintain the sensor's set sensitivity. An advance indication at the panel specifies the sensor address, allowing for selected maintenance to be performed as needed.

H. The duct smoke detector shall be fire marshal approved.

I. The duct smoke detector must be compatible with the fire alarm control panel.

J. The duct smoke detector shall be analog addressable, and incorporate with a tamper indication that will signal a trouble condition to the fire alarm control panel after 20 minutes if the cover is removed or improperly installed.

K. Manufacturers: FCI, Siemens, or approved equal.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.

B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer for resolution before starting rough-in work.

C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate Section 23 09 23 work with work of others.

D. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.02 PROTECTION

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

B. Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.03 INSTALLATION REQUIREMENTS

A. All electrical work performed in the installation of the system as described in this specification shall be per the National Electrical Code (NEC) and per applicable state and local codes. Where exposed, conduit shall be run parallel to building lines properly supported and sized at a maximum of 40% fill. In no cases shall field installed conduit smaller than 1/2" trade size be allowed.

3.04 INSTALLATION INSTRUCTIONS

A. General Workmanship

1. Install in accordance with manufacturer's instructions.
2. Location of sensors is diagrammatic. The Contractor shall locate them properly to ensure accuracy and performance.
3. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100 Part A of the NEC code.
4. All interlocking wiring and temperature control wiring required to operate any field control devices shall be furnished and installed under this section.
5. All electrical power wiring from the temperature control panel to sub-systems and control devices shall be furnished and installed under this section.
6. All other relays, switches, interface hardware, static pressure controllers and miscellaneous control devices shall be enclosed in the temperature control panel. No control devices shall be located at other locations except for sensors and actuators. The controllers shall be furnished for front of panel mounting and installed in the temperature control panel.
7. All equipment installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

B. Examination

1. The project plans shall be thoroughly examined for control devices and equipment locations. Any discrepancies, conflicts or omissions shall be reported to the Engineer for resolution before rough-in work is started.

C. Site and Test and Balance Coordination

1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.
3. Provide the Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
4. Train the Test and Balance Contractor to use control system interface tools.
5. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.
6. The Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

D. Life Safety

1. Interlock smoke detectors to air handlers for shutdown as shown on drawing.
2. Smoke dampers and actuators required for duct smoke isolation are provided under mechanical specification division. Interlock smoke dampers to air handlers per contract drawings.

E. Coordination with Other Controls.

1. Integrate with and coordinate controls and control devices furnished or installed by others as follows:

2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described on drawing regardless of where within the contract documents those products are described.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

F. Wiring:

1. All control and interlock wiring shall comply with national and local electrical codes and Division 26 of this specification. Where the requirements of this section differ from those in Division 26, the requirements of this section shall take precedence.
2. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway according to NEC and Division 26 requirements.
3. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub fused when required to meet Class 2 current limit.)
4. All wiring in mechanical, electrical, or service rooms or where subject to mechanical damage shall be installed in raceway at levels below 3 m (10 ft).
5. Class 2 wiring shall not be installed in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
6. Wiring shall not be installed in raceway containing tubing.
7. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.
8. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.
9. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
10. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
11. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
12. Not used.
13. Size of raceway and size and type of wire shall be the responsibility of the contractor, in keeping with the manufacturer’s recommendations and NEC requirements, except as noted elsewhere.
14. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
15. Use coded conductors throughout with conductors of different colors.
16. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
17. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g., steam pipes or flues).

18. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
19. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.
20. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
21. The Contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
22. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
23. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.
24. Control signal wiring shall be routed clear of all lighting ballasts or other electromagnetic devices, which may damage the integrity of the control signal.
25. All temperature and interlock wiring shall be installed in conduit. Power or interlocking wire shall be run in separate conduit from sensor wiring

G. Communication Wiring:

1. The Contractor shall adhere to the items listed in Sub-Section 3.2.D, "Wiring" of this specification.
2. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.
3. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.
4. Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
5. Contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
6. All runs of communication wiring shall be unspliced length when that length is commercially available.
7. All communication wiring shall be labeled to indicate origination and destination data.
8. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

H. Control Air Tubing

1. Main air tubing shall be sized by the contractor. Main air runs on a floor shall be looped, as opposed to a series of straight air runs.
2. Sensor tubing shall be sized by the contractor. Locate sensors to minimize tubing runs at the expense of increased wiring distances.
3. Mechanically attach tubing to supporting surfaces. Sleeve through concrete surfaces in minimum 1 in. sleeves, extended 15 cm (6 in.) above floors and 3 cm (1 in.) below bottom surface of slabs.

4. Purge tubing with dry, oil-free compressed air before connecting control instruments.
5. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.
6. Piping above suspended ceilings shall be supported from or anchored to structural members or other piping and/or duct supports. Tubing shall not be supported by or anchored to electrical raceways or ceiling support systems.
7. For air pressures greater than 200 kPa (30 psig), compression or solder type connection shall be used.
8. Perform a pressure test on the entire pneumatic system as follows:
    a. Test high-pressure air piping at 1000 kPa (150 psig) air pressure. Maintain this pressure for two hours without loss of pressure. If loss of pressure is indicated, correct and retest until the system shows no loss of pressure for two hours.
    b. Test low-pressure air tubing at 200 kPa (30 psig) air pressure. Maintain this pressure for 2 hours without pumping, during which time the pressure shall not drop more than 7 kPa (1 psi). Should pressure loss occur, determine the leak, repair with new equipment or piping, and retest until the system show no more than 7 kPa (1 psi) pressure drop in two hours.
    c. Leaks at pipe and tube joints shall be corrected by remaking of the joints.

I. Installation of Sensors

1. Install sensors in accordance with the manufacturer's recommendations.
2. Thermostat Mounting: Each room thermostat shall be installed approximately five (5) feet above the floor to the center of thermostat on a neat cast iron or steel back, flush plaster and provided with logs to secure cover an thermostat frame screws.
3. Duct smoke detectors shall be furnished and installed where shown on plans under Div. 23.
4. Mount sensors rigidly and adequately for the environment within which the sensor operates.
5. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.
6. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.
7. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
8. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m of sensing element for each 1 m^2 (1 ft of sensing element for each 1 ft^2) of coil area.
9. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
10. Install outdoor air temperature sensors on northern wall, complete with sun shield at designated location.
11. Differential air static pressure
    a. Supply Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap butting of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.

b. Return Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.

c. Building Static Pressure: Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a highvolume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.

d. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.

e. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.

f. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shutoff valves installed before the tee.

J. Installation of Flow Switches

1. Use correct paddle for pipe diameter per manufacturer's instructions.

2. Adjust flow switch in accordance with manufacturer's instructions.

K. Installation of Actuators

1. Mount and link control damper actuators according to manufacturer's instructions.

2. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5 degrees open position, manually close the damper, and then tighten the linkage.

3. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

4. Provide all mounting hardware and linkages for actuator installation.

5. Electric/Electronic Dampers: Actuators shall be direct-mounted on damper shaft or jackshaft unless shown as a linkage installation. For l0-leakage dampers with seals, the actuator shall be mounted with a minimum 5
mounted following manufacturer's recommendations.

☐ available for ti

6. Electric/Electronic Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

L. Interfacing With Fire Alarm System

1. Interface shall be UL Listed for smoke control

2. Interface shall be UL Listed under UL 864 categories UOJZ, UOXX, UUKL, UDTZ and QVAX, UL 1076 category APOU, and UL 916 category PAZX.

3. All hardware used for interfacing the building automation system to the fire alarm system shall be UL Listed for smoke control under UL 864 category UUKL.

4. All hardware used for interfacing the building automation system to the fire alarm system shall be UL Listed under the following categories: UL 864 categories UOJZ, UOXX, UUKL, UDTZ, QVAX, UL 1076 category APOU, UL 916 category PAZX

M. Fiber Optic Cable

1. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

2. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.05 COUNTY REQUIRED SETPOINTS

A. Effective December 2012, HVAC settings shall be 69°F for heat and 73°F for cooling for all County of Santa Barbara facilities.

B. Effective December 2013 the HVAC settings shall be 69°F for heat and 74°F for cooling for all County of Santa Barbara facilities

C. These limits shall not apply in areas where other temperature settings are required by law or by specialized needs of equipment, server rooms or scientific experimentation.

D. For the County office spaces with limited or no heating and cooling:

1. If a building does not have a cooling system or a proper cooling system, then the 73°F cooling setting shall not apply or shall be set higher.

2. If a building does not have a heating system or proper heating system, then the 69°F heating setting shall not apply or should be set lower.

E. Per the County of Santa Barbara Energy Action Plan, the following are the required domestic hot water set points:

1. Domestic hot water temperatures should not be set above 115°F.

2. These limits shall not apply in areas where other temperature settings are required by law or by specialized needs of equipment or scientific experimentation.

3.06 SEQUENCE OF OPERATION

A. The sequence of operation for the control system is listed on the contract drawings.

1. Contractor shall develop a controls version of the sequence to show how the controls programming implements the sequence provided in the mechanical design. Include controls sequence of operation in submittals.

2. The sequence of operation shall comply with the County required set points listed in this section.

3.07 FIELD QUALITY CONTROL

A. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances.

B. Continually monitor field installation for code compliance and workmanship quality.

C. Contractor shall arrange for work inspection by local or state authorities having jurisdiction over the work.

3.08 EXISTING EQUIPMENT

A. Not Used.

3.09 IDENTIFICATION

A. All devices mounted on the master control panel shall be provided with permanently engraved bakelite nameplates per specifications labeling requirements, indicating system space title and required tag number.

B. All field sensing devices except room thermostat shall be appropriately labeled in accordance with schedule tag number.

C. All cables, wiring from and terminal blocks including that within factory-fabricated panels shall be identified by labels, tags or other permanent means. Marking shall clearly indicate the function and source of all cable, wiring and terminals.

D. All valves installed under this contract shall be provided with numbered tags chained to the valve operator. Tags shall be 1/4" diameter, 18 gauge minimum brass and stamped with the appropriate markings.

E. All panels shall be provided with permanently attached labels with identifying names and functions in accordance with project nomenclature.

F. Identify room sensors relating to terminal box or valves with nameplates.

G. All plug-in components shall be labeled such that removal of the component does not remove the label.

H. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

I. Warning Labels

1. Permanent warning labels shall be affixed to all equipment that can be automatically started by the DDC system

2. All labels shall be white lettering (12-point type or larger) on a red background.

3. Warning labels shall be as follows: "CAUTION This equipment is operating under automatic control and may start or stop anytime without warning. Switch disconnect to "Off" position before servicing."

4. Permanent warning labels shall be affixed to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects as follows: "CAUTION: This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing."

3.10 TRAINING

A. Provide 8 hours of training on-site.

B. A manufacturer's technical representative for the equipment specified herein shall be presented at the job site and or in a classroom designated by the County for the services listed below, travel time excluded.

C. Training Manuals: The Contractor shall provide an agenda and training documentation for all training classes at least two weeks prior to the first class. The Engineer reserves the right to modify any or all of the training course outline and training materials. Provide one copy of training material per student (assume 3 copies unless instructed otherwise).

D. The instructor(s) shall be factory-trained instructors experienced in presenting this material.

E. Contractor shall specifically address the following subjects including and not limited to the following:

1. System sequence of operation, in detail.

2. Walk-through of the job to locate control components.

3. Explanation of drawings, sequence of operations and maintenance manuals.

4. Understand control system architecture and configuration.

5. Understand system operation, including DDC system control and optimizing routines

6. Adjust and change system set points, time schedules, and holiday schedules.

7. Recognize malfunctions of the system

8. Emergency service support

9. System restart after power failure

10. Stand-alone system backup and restoration procedures

11. Replacement procedures of each system component.
12. Adjustment, calibration and initialization procedures.
13. Operation of maintenance service programs.
14. Using portable operator station to perform system maintenance and operation functions.
15. To generate and maintain the control programming logic
16. Create, delete, and modify alarms, including annunciation and routing of these.
17. Add, remove, and modify system's physical points.
18. Create, modify, and delete programming.
19. Perform DDC system field checkout procedures.
20. Perform DDC controller unit operation and maintenance procedures
21. Perform DDC system diagnostic procedures.
22. Configure hardware including PC boards, switches, communication, and I/O points.
23. Maintain, calibrate, trouble shoot, diagnose, and repair hardware.
24. Adjust, calibrate, and replace system components
25. Making changes to the control system, expanding the control system by adding logic and hardware devices, and reprogramming.

F. Provide one set of the special tools, reference materials (manuals), test instruments, and software manufactured or modified by the manufacturer for use in the installation, troubleshooting, and repair of installed devices. Include portable test terminal, test boxes, circuit card extenders, calibration modules, etc.

3.11 START-UP AND TESTING

A. The Contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this contract.

B. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.

C. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.

D. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.

E. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The Contractor shall check all control valves and automatic dampers to ensure proper action and closure. The Contractor shall make the required adjustment to valve stem and damper blade travel.

F. Verify that the system operation adheres to the sequence of operation. Simulate and observes all modes of operation by over overriding and varying inputs and schedules. Tune all DDC loops and optimum start/stop routines.

G. Alarm and Interlocks:

1. Check each alarm separately by including an appropriate signal at a value that will trip the alarm
2. Interlock shall be tripped using field contacts to check the logic as well as to ensure that the fail-safe condition for all actuators is in the proper directions.

3. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.
4. Test fan and pump failure.

H. Logic Tests
1. Override Test: Verify manual override capability for start/stop and modulated point types.
2. Exercise all control logic before witnessed testing by Owner or CxA
3. Check time response to a step-change in set point.

I. Test Failure Modes:
1. Verify all stand-alone operation in DDC mode by disconnecting communication lines between standalone control units and verifying continued operation.
2. Disconnect and reapply 120 VAC power to confirm proper recovery from power failure.
3. Disconnect and reconnect controller power to confirm proper recovery from power failure

J. The contractor shall supply all instruments for testing and turn over it to the County after acceptance testing.
1. All test instruments shall be submitted for approval and shall be calibrated for the following accuracy:
a. Temperature: 1/4F or 1/2% full scale, whichever is less.
b. High Pressure (psi): ½ psi or 1/2% full scale, whichever is less.
c. Low Pressure (in w.c.): 1/2% of full scale
d. Humidity: 2% RH
e. Electrical: 1/4% full scale

3.12 DEMONSTRATION AND ACCEPTANCE

A. Point-to-Point Checkout
1. Maintain and submit to Owner a log showing:
a. Point name
b. Point type
c. Reading (if applicable)
d. Date checked
e. Technician's initials
f. Any corrective action taken or needed.
2. Verify all actuators and control valves at minimum three points of stroke, including full closed, half open, full open, and record in log.
3. Provide log to owner and CxA for review.

B. Demonstration and Commissioning
1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in this specification.

The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.

3. The demonstration process shall follow that approved in Part 1, “Submittals.” The approved checklists and forms shall be completed for all systems as part of the demonstration.
4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
5. Demonstrate compliance with section “System Performance.”
6. Coordinate with CxA (if applicable) for test script content and witnessing.
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

C. Acceptance

1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and the County prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.
2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in section “Submittals.”

3.13 CLEANING

A. The Contractor shall clean up all debris resulting from the installation work. Waste shall be collected and placed in a designated location.

B. At the end of each workday, the Contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc. All occupied areas shall be kept in a “show ready” condition.

C. Upon completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.14 SCHEDULING AND COORDINATION

A. Controls contractor shall support the commissioning process in good faith.

B. The CxA will provide an initial list of commissioning milestones and deliverables to the CxC for scheduling purposes at the commissioning kick off meeting.

C. The General Contractor shall integrate all commissioning activities, milestones and deliverables into the master construction schedule with assistance from the CxA.

D. The CxC shall provide sufficient notice to the CxA and Owner for scheduling and coordinating commissioning activities. A minimum 10 day’s notice shall be provided to the CxA for witnessing equipment Start-ups, Pre-Functionals, and Functional Performance Testing.

E. The Commissioning Team shall address scheduling problems and make necessary modifications in a timely manner in order to expedite the commissioning process.

3.15 MEETINGS

A. When commissioning team member attendance is required, as determined by the CxA and CxC, be punctual and attentive during the meeting.

1. The CxA shall conduct a commissioning kick-off meeting, usually within 60 days of the commencement of construction. All team members involved in the commissioning process shall attend the kick-off meeting.

2. The CxA shall conduct a commissioning “pre-startup” meeting, to confirm the final plan for startup and witnessing of equipment. All team members involved in the commissioning process shall attend.

3. The CxA will plan other commissioning meetings as deemed necessary as construction progresses. These meetings will cover planning and coordination, and Commissioning Issues resolution.

4. The frequency of meetings will vary through construction, but generally increase during start-up and commissioning activities.

B. The CxA shall write and distribute meeting minutes documenting the meeting discussion, conclusions, and actions for each team member.

3.16 COMMISSIONING AND DEMONSTRATION ISSUES, BACK-CHECKS, AND RE-TESTING

A. All Deficiencies and Commissioning Issues shall be corrected promptly. The responsible party shall correct the issue and inform the CxC and CxA of the resolution and completion date. The CxA will record completion on the Commissioning Issues List once the issue is successfully back-checked or verified.

1. For all Commissioning Issues identified during the pre-functional system readiness activities, the CxA will back-check and verify the completion of the issues where appropriate.

2. For all Commissioning Issues identified during FPT, retesting is required to verify the resolution of the issue and to complete the FPT.

3. The CxA shall witness one (1) re-test for each equipment and will perform one (1) back-check verification of any completed system readiness issue.

4. The Owner may back-charge the General Contractor for any additional fees from the CxA, resulting from any re-testing or repeated system readiness issues list back-checks beyond the first re-test or back-check.

END OF SECTION

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 25 55 00

INTEGRATED AUTOMATION CONTROL OF HVAC

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

B. OPR and BOD documentation for information.

C. Section 23 05 00 – Common Work Results for HVAC

D. Section 25 09 23 – HVAC Control Systems

E. Division 26 - Electrical Work.

1.02 REFERENCES

A. County of Santa Barbara Energy Action Plan, revision in place when contract is awarded.

B. Comply with requirements of applicable green building code for this project such as LEED, CHPS, or CalGreen. (Verify with Owner.)

C. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:

1. National Electric Code (NEC)
2. City and County of Santa Barbara Building Codes
3. ASHRAE/ANSI 135-2010: Data Communication Protocol for Building Automation and Control Systems (BACNET)

D. UL 916 Energy Management Systems.

E. FCC-Part 15 Subparagraph J. Class A. Emissions Requirements.

F. ASHRAE 85- Automatic Control Terminology for Heating, Ventilating, and Air Conditioning.

G. NEMA EMCI - Energy Management Systems Definitions.

H. CEC - California Energy Commission Mandatory Requirements.

I. California Energy Code

1.03 SECTION SUMMARY

A. The Contractor shall integrate a complete temperature control system in accordance with the requirements of the contract documents into the existing County front-end which shall include but not be limited to completion of the following items stated below.

B. System shall be stand-alone functional per project requirements.

C. System shall be native BACnet and all workstations and controllers, including unitary controllers, shall be native BACnet devices. No substitutions.

D. Provide all necessary BACnet-compliant hardware and software to meet the system's functional requirements.

E. Provide Protocol Implementation Conformance Statement (PICS) for every controller in system, including routers, gateways, & etc. No substitutions.

F. All BACnet communicating devices shall be BTL listed. No substitutions.

G. Provide and install all interconnecting cables between supplied cabinets, application controllers, and input/output devices.

H. Provide complete manufacturer's specifications for all items that are supplied. Include vendor name of every item supplied.

I. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.

J. Provide a comprehensive operator and technician training program as described herein.

K. Provide as-built documentation, operator's terminal software, diagrams, and all other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.

L. The contractor shall be responsible to provide all concealed conduit for integration needs. The contractor shall submit shop drawing of any concealed conduit run within 30 days after issue of Notice to Proceed.

M. Drawings are diagrammatic and may not show all components required for a complete system. Failure to mention any specific item or device does not relieve the contractor of the responsibility for installing such device or item in order to comply with the intended control functions of this specification, sequence of operation, and to provide a complete and functioning integration.

1.04 GENERAL DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of digital controllers.

B. The system shall control HVAC equipment as specified on original project contract drawings.

C. Each zone shall provide occupied and unoccupied modes of operation by individual zone.

D. If applicable, furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified on contract drawings.

E. Provide for future system expansion to include monitoring of occupant card access, fire alarm, and lighting control systems.

F. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. Schedules, set points, trends, and alarms specified on contract drawings shall be BACnet objects.

1.05 READINESS FOR INTEGRATION (FOR REFERENCE ONLY)

A. In preparation for this integration, the original project controls contractor was required to:

1. Make all available BACnet points visible and writeable for all devices capable of BACnet communication;

2. Make all logical points visible and writeable, such as on-controller schedules, demand limiting function variables, and others;

3. Provide enabled ethernet communication port on high level controllers as part of this project;

4. Provide at minimum one extra 120V convenience outlet in each large controller enclosure/cabinet for future use;

5. Provide all logic programming per provided engineered sequence of operations with temporary values for logical writeable variables, such as outside air lockout or DX cooling lockout;

6. Provide temporary construction schedules, verified with owner, for the time elapsing between controls final functional testing and future integration by others;

7. If provided different settings for control logic by balancer, engineer, Owner, or CxA, set the new values to permit system testing and setup within 3 days or request.

B. All controllers, devices, and control logic specified for this project shall function stand-alone per sequence of operation requirements regardless of future integration status.

1.06 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Section 23 21 13 - Heating and cooling piping:

1. Control valves
2. Flow switches
3. Press and temp sensor wells & sockets
4. Temp sensor wells and sockets

B. Section 23 00 00 - Duct accessories:

1. Automated dampers
2. Terminal unit controls

C. Division 26 - Equipment Wiring Systems: Installation and connection of all power wiring. Power wiring shall be defined as follows:

1. Wiring of power feeds through all disconnect starters to electric motors.
2. 120 VAC Emergency power feeds to all critical BAS and/or temperature control panels.
3. 120 VAC wiring to DDC terminal units and temperature control panel as shown on Electrical plans.
4. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by this section.

1.07 PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

A. None

1.08 DEFINITIONS

A. PICS: Protocol Implementation Conformance Statement

B. Native BACnet: Controllers and microprocessor equipped devices shall communicate using the BACnet communication protocol without the need for any additional gateway modules or hardware.

C. BTL Listed: Listed by BACnet Testing Labs as BACnet compliant

D. Basis of Design (BOD): The BOD is developed by the design consultants for the systems used in the facility. It defines the assumptions made for the designed systems. This document is written to agree with the Owners Project Requirements (OPR).

E. Building Automation System (BAS): The building digital control system.

F. Commissioning Authority (CxA): An agent hired directly by the Owner which assists the Contractor with coordinating commissioning activities and witnesses and reviews the activities on behalf of the Owner.

G. Commissioning Issue: An issue which must be resolved to complete the commissioning process.

H. Commissioning Issues List: A log maintained by the CxA listing all Cx Issues documented during the commissioning.

I. Commissioning Plan: A document that outlines the organization, coordination, and requirements of the commissioning in detail.

J. Commissioning Coordinator (CxC): General Contractor employee who plans, schedules, and coordinates the Sub-Contractor's commissioning activities, and serves as the CxA's single point of contact for all administrative, documentation and coordination needs.

K. Deferred Testing: Testing performed at a later time for a certain reason.

L. Functional Performance Test (FPT): A test of the operation and control sequences of equipment and systems to verify system performance. Systems are tested under various operating modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, alarm, power failure, etc.

M. Installation Verification (IV): Field verification and documentation of proper installation of system equipment.

N. Monitoring: The recording of parameters of equipment operation using data-loggers or the Trending capabilities of BAS or control systems.

O. Owner's Project Requirements (OPR): A document written by the Owner describing the operational and functional requirements of a project, the expectations of how the facility will be used and operated, and the equipment and system expectations and requirements.

P. Sampling: Witnessing the startup or testing of a selected fraction of the total number of identical or near-identical pieces of equipment such as VAV boxes.

Q. Pre-Functional Checks: These are various checks and tests performed on a piece of equipment or system just before, during or after the initial Startup. Examples include pipe system pressure tests, duct leakage tests, mechanical system test and balance and electrical equipment NETA testing. They must be completed prior to functional testing.

R. Startup: Initial starting or activating of equipment performed by the Sub-Contractor or the Manufacturer's representative.

S. System Readiness Checklist (SRC): A checklist, covering the commissioning tasks and required documentation to verify that a system is ready for functional testing. The SRCs must be completed and signed by the General Contractor prior to conducting the functional testing.

T. Test and Balance (TAB): Testing, Adjusting, and Balancing work on the air and water systems to ensure design flow conditions are met.

U. Sub-Contractor: Typically a subcontractor to the General Contractor who provides and installs specific building components and systems and/or provides certain services.

V. Trending: Monitoring using the Building Automation System to aid in functional testing and to verify system operation and performance under operating conditions.

1.09 QUALITY ASSURANCE

A. All materials and equipment used shall be standard components, of regular manufacture for this application.

B. All systems and components shall have been thoroughly tested and proven in actual use for a minimum period of two (2) years.

C. Like items of equipment specified herein shall be the end product of one manufacturer in order to achieve standardization of appearance, operation, maintenance, spare parts and manufacturer's services.

D. Comply with ASHRAE 135 for DDC system control components.

E. Vendor shall be in the business of vending controls systems for the previous 10 years.

1.10 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. Sequence of operations for each system under control. This sequence shall be specific to the integration, graphics, energy limiting, optimum starting, and trending portion of the work. (High level logic)

C. Control system CAD generated drawings including schematic, point-to-point wiring diagram, ladder diagram, and all pertinent data to provide a functional operating system.

D. Data sheets for all hardware and software control components.

E. A description of the installation materials including conduit, wire, flex, etc.

F. Central System Control and Network Hardware and Software

1. Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.

2. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:

a. Building level controller

b. Power supplies

c. Battery backups

d. Interface equipment between other control panels

3. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.

4. Network riser diagrams of wiring between central control unit and control panels.

G. Controlled Systems

1. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.

2. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.

3. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.

4. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified on contract drawings. Indicate alarmed and trended points.

H. Description of process, report formats, and checklists to be used for testing and pre functional activities.

I. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

J. Schedules

1. Within one month of contract award, provide schedule of work indicating:

a. Intended sequence of work items

b. Start date of each work item

c. Duration of each work item

d. Planned delivery dates for ordered material and equipment and expected lead times

e. Milestones indicating possible restraints on work by other trades or situations

2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

1.11 SUBSTITUTIONS

A. Control system must communicate native BACnet – no substitutions.

B. Other items, submit in accordance with Section 01 25 13 - Product Substitution Procedures

1.12 MINIMUM SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

1. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
2. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
3. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work station will be current, within the prior 60 seconds.
4. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.
5. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
6. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
7. Multiple Alarm Annunciations. Each device or workstation on the network shall receive alarms within 5 sec of other workstations.
8. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
9. Control Stability and Accuracy. Control loops shall maintain measured variable at set point within tolerances listed in Table 2.

Table 1 – Required Reporting Accuracy

Measured Variable	**Reported Accuracy**
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±1ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Dioxide (CO_2)	±50 ppm

Note 1: 10% - 100% of scale

Note 2: For both absolute and differential pressure

Note 3: Not including utility-supplied meters

Table 2 – Required Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.13 MANUFACTURER'S & INSTALLER'S QUALIFICATIONS

A. Manufacturer: The company shall be specialized in the manufacturing of products specified in this section, with a minimum of ten (10) years of experience in the design, manufacturing, and installation of building automation and energy management systems similar in scope and performance to that specified herein, and shall submit evidence of this experience as a condition of acceptance and approval prior to bidding.

B. Installer:

1. The Building Automation and Energy Management system shall be installed by the manufacturer or competent installer regularly employed by the manufacturer of the BAS and automatic temperature control equipment.

2. The Building Automation and Energy Management system installer and manufacturer shall have a local office within a 50 mile radius of the job site, staffed with factory trained engineers fully capable of providing instruction, routine maintenance and 24 Hour emergency maintenance service on all system components.

3. The Contractor shall have a minimum five years of experience record in the design and installation of computerized building systems similar in scope and performance to that specified herein, and shall be prepared to provide evidence of this history as condition of acceptance and approval prior to bidding.

1.14 PROJECT RECORD DOCUMENTS

A. Submit under provisions of Section 01 78 39.

B. General: Complete documentation of the system installed shall be provided to the Owner upon Completion of the Project. This documentation shall be provided with an index sheet listing the contents in Alphabetical order and shall include, but not be limited to the following:

C. Project Record Drawings (if applicable)

1. As-built versions of submittal shop drawings provided as AutoCAD 2007 (or newer) compatible files omad lash drive (file format: .DWG, .DXF, .VSD, or comparable) and 3 prints of each drawing on 11" x 17" paper.

2. AutoCAD files of contract drawings will be supplied to contractor for their use in creating project record drawings.

D. Testing and Commissioning Reports and Checklists.

1. Completed versions of reports, checklists, and trend logs used to meet requirements of this specification section and the commissioning requirements for the project.

E. Operating and Maintenance (O&M) Manual (if applicable) - These shall be as-built versions of the submittal product data. In addition to that required for the submittals, the O&M manual shall include:

1. As-built versions of submittal product data.

2. Names, address and 24-hour telephone numbers of Contractors installing equipment, and the control systems and service representative of each.

3. Operators Manual with procedures of operating the control systems including logging on/off, alarm handling, producing point reports, trending data, overriding computer control, and changing set points and other variables.

4. Programming Manual with a description of the programming language including syntax, statement descriptions including algorithms and calculations used, point database creation and modification, program creation and modification, and use of the editor.

5. Engineering, Installation and Maintenance Manual(s) that explains how to design and install new points, panels, and other hardware; preventative maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware.

6. Documentation of programs created using custom programming language including set points, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, set points, tuning parameters, and objects can be viewed using furnished programming tools. Include as-built final sequence of operation.

7. A listing and documentation of all custom software created using the programming language including the point database. One digital set of media containing files of the software and database shall also be provided.

8. A list of recommended spare parts with part numbers and supplies.

9. Complete original issue documentation, installation and maintenance information of all third party hardware provided including equipment and sensors.

10. Complete original issue diskettes for all software provided including operating systems, programming language, operator workstation software or web server software, and graphics software.

11. Licenses, Guarantee, and Warrantee documents for all equipment and systems.

12. Recommended preventive maintenance procedures for all system components including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions.

F. Training Materials:

1. Provide course outline and materials for each class at least three weeks before first class. Training shall be furnished via instructor-led sessions on site. Engineer may modify course outlines and materials if necessary to meet the Owner's needs. Engineer will review and approve course outlines and materials at least two weeks before first class.

1.15 EXTRA MATERIALS

A. The Contractor shall provide the following spare parts:

1. None

1.16 OWNERSHIP OF PROPRIETARY MATERIALS

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:

1. Record drawings
2. Database
3. Application programming code
4. Documentation

1.17 WARRANTY

A. Warranties shall be in accordance with Section 01 78 36 – Warranties.

B. The Contractor shall warrant all work as follows:

1. Labor and materials for the control system specified shall be warranted free from defects for a period of two (2) years after acceptance of substantial completion. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner. The contractor shall respond to the owner’s request for warranty service within 24 hours during normal business hours.
2. All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up. If the work specified is split into multiple contracts or a multi-phase contract, then each contract or phase shall have a separate warranty start date and period.
3. At the end of the final start-up, testing, and commissioning phase, if equipment and systems are operating satisfactorily to the engineer, the engineer shall sign certificates certifying that the control system’s operation has been tested and accepted in accordance with the terms of this specification. The date of acceptance shall be the start of warranty.
4. Operator workstation software, project-specific software, graphic software, database software, and firmware updates that resolve known software deficiencies as identified by the contractor shall be provided at no charge during the warranty period.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Integrate with existing system.

2.02 GENERAL

A. The Contractor shall furnish all materials, including all hardware and software, operator input/output peripherals, field hardware panels, sensors and field control devices, installed wiring and piping necessary for the integration scope.

B. The Contractor shall be responsible for engineering, supervision of installation, labor services, system calibration, initial software programming, and system checkout as necessary to provide a complete and fully operational integration as specified herein. The entire energy management

and building controls system must be native BACnet at all levels including management level, integration level, field controller level and sensor/actuator level.

C. Manufacturer shall supply the latest available hardware and software at the time of submittal for Engineer's approval. Software upgrade release within 2 years shall be provided without additional cost to the Owner.

D. Equipment and labor not specifically referred to herein or on the plans required to meet the functional intent, shall be provided without additional cost to the Owner.

E. The failure of any single component shall not interrupt the control strategies of other operational devices. System expansion shall be through the addition of end devices, controllers, and other devices described in this specification.

F. Controllers shall normally execute the control strategy to use peer-to-peer communication capabilities. Upon loss of communication, the stand-alone control unit shall be able to execute its own stand-alone programming.

G. Operator workstation connectivity shall not be necessary to sustain building operation.

2.03 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to most current ASHRAE BACnet Standard.

B. Connection shall support memory downloads and other commissioning and troubleshooting operations.

C. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

D. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.

2.04 CONTROLLER SOFTWARE

A. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. System Security. See Paragraph (Security) and Paragraph (Operator Activity). Provide varying levels of access account types including view-only, operator, and administrator.

C. Scheduling. See Paragraph (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:

1. Weekly. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).

2. Exception. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.

3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

D. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

E. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.

F. Demand Limiting.

1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.

2. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified on contract drawings. When demand drops below adjustable levels, system shall restore loads as specified.

G. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified on contract drawings.

H. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified on contract drawings.

I. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.

J. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.

K. Energy Calculations.

1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.

2. System shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.

3. System shall calculate a fixed-window average. Window interval start shall be defined by utility meter digital input signal to synchronize system's and utility's fixed-window averages.

L. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

M. On and Off Control with Differential. System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.

N. Runtime Totalization. System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified on contract drawings.

O. All features shall be available for reading and writing externally over BACnet.

2.05 OPERATOR FUNCTIONS

A. Operator interface shall allow each authorized operator to execute the following functions as a minimum:

B. Log In and Log Out. System shall require user name and password to log in to operator interface.

C. Point-and-click Navigation. Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.

D. View and Adjust Equipment Properties. Operators shall be able to view controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration.

E. View and Adjust Operating Schedules. Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.

F. View and Respond to Alarms. Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.

G. View and Configure Trends. Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.

H. View and Configure Reports. Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.

I. Manage Control System Hardware. Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.

J. Manage Operator Access. Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

2.06 SYSTEM SOFTWARE

A. Operating System shall be Microsoft Windows.

B. System Graphics. Operator interface shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

C. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.

D. Animation. Graphics shall be able to animate by displaying different image files for changed object status.

E. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.

F. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

G. System Tools. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

H. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.

I. Controller Memory Download. Operators shall be able to download memory from the system database to each controller.

J. System Configuration. Operators shall be able to configure the system.

K. Online Help. Context-sensitive online help for each tool shall assist operators in operating and editing the system.

L. Security. System shall require a user name and password to view, edit, add, or delete data.

M. Operator Access. Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object. Authorized operators shall be able to vary and deny each operator's accessible functions based on equipment or geographic location.

N. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.

O. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

P. System Diagnostics. System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).

Q. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified on contract drawings.

R. Alarms shall be BACnet alarm objects and shall use BACnet alarm services.

S. Alarm Messages. Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.

T. Alarm Reactions. Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.

U. Alarm Maintenance. Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.

V. Trend Configuration. Operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified. Trends shall be BACnet trend objects.

W. Object and Property Status and Control. Operator shall be able to view, and to edit if applicable, the status of each system object and property by menu, on graphics, or through custom programs.

X. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.

Y. Standard Reports. Furnish the following standard system reports:

Z. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.

AA. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.

BB. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period: Alarm History and Trend Data. Operator shall be able to select trends to be logged.

CC. Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.

DD. Graphics Generation. Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.

EE. Graphics Library. Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.

FF. Custom Application Programming. Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

GG. Language. Language shall be graphically based or English language oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks. If English language oriented, language shall be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and shall allow for free-form programming that is not column-oriented or "fill-in-the-blanks."

HH. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.

II. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.

JJ. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax

KK. and for execution errors.

LL. Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.

MM. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.

NN. Variables: Operator shall be able to use variable values in program conditional statements and mathematical functions.

OO. Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control

logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.

PP. System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

QQ. BACnet. Web server or workstation shall have demonstrated interoperability during at least one BMA Interoperability Workshop and shall substantially conform to BACnet Operator Workstation (B-OWS) device profile as specified in ASHRAE/ANSI 135-2010, BACnet Annex

2.07 INPUT/OUTPUT INTERFACE

A. General. Hard-wire, in a permanent and high workmanship quality manner, input and output points to BCs, AACs, ASCs, or SAs.

B. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

C. Digital (Binary) inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of 12 mas at 12 VDC to be compatible with commonly available control devices.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

E. Analog inputs shall allow the monitoring of low voltage, current, or resistance signals and shall have a minimum resolution of 0.1% of the sensing range. Analog inputs shall be compatible with, and field configurable to commonly available sensing devices.

F. Digital (Binary) outputs shall provide a continuous low voltage signal for on/off control of remote devices. Where specified in the sequence of operations or indicated on the points list, binary outputs shall have 3-position (on/off/auto) override switches, status lights, and shall be able to be selected for either normally open or normally closed position.

G. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10 VDC or a 4 to 20-ma signal as required to provide proper control of the output device.

H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tristate outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as duct-mounted heating coils.

I. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

J. If applicable, provide an Auto-answer, auto-dial modem system for purposes of remote diagnostics and notification of desired exceptions. The modem shall provide the following functions:

1. Access to the entire facility control system to provide service and diagnostic support.

2. Access to the entire facility control system from off-site for similar purposes, and for remote operation, monitoring, and adjustment of facility functions.

K. Hardwired inputs and outputs may tie into the system through System Application, Custom Application, or Application Specific Controllers. Slave devices are also acceptable. Any critical points requiring immediate reaction shall be tied directly into the controller hosting thecontrol software algorithm for the critical function.

2.08 WIRING AND RACEWAYS

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

2.09 FIBER OPTIC CABLE SYSTEM

A. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

B. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.

B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer for resolution before starting rough-in work.

C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate Section 23 09 23 work with work of others.

D. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.02 PROTECTION

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

B. Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.03 INSTALLATION REQUIREMENTS

A. All electrical work performed in the installation of the system as described in this specification shall be per the National Electrical Code (NEC) and per applicable state and local codes. Where exposed, conduit shall be run parallel to building lines properly supported and sized at a maximum of 40% fill. In no cases shall field installed conduit smaller than 1/2" trade size be allowed.

3.04 INSTALLATION INSTRUCTIONS

A. General Workmanship

1. Install in accordance with manufacturer's instructions.

2. Location of sensors is diagrammatic. The Contractor shall locate them properly to ensure accuracy and performance.

3. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100 Part A of the NEC code.

4. All interlocking wiring and temperature control wiring required to operate any field control devices shall be furnished and installed under this section.

5. All electrical power wiring from the temperature control panel necessary for successful front-end integration shall be furnished and installed under this section.
6. All equipment installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

B. Examination

1. The project plans shall be thoroughly examined for control devices and equipment locations. Any discrepancies, conflicts or omissions shall be reported to the Engineer for resolution before work is started.

C. Site and Test and Balance Coordination

1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

D. Coordination with Other Controls.

1. Integrate with and coordinate controls and control devices furnished or installed by others as follows:
2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described on drawing regardless of where within the contract documents those products are described.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

E. Wiring:

1. All control and interlock wiring shall comply with national and local electrical codes and Division 26 of this specification. Where the requirements of this section differ from those in Division 26, the requirements of this section shall take precedence.
2. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway according to NEC and Division 26 requirements.
3. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub fused when required to meet Class 2 current limit.)
4. All wiring in mechanical, electrical, or service rooms or where subject to mechanical damage shall be installed in raceway at levels below 3 m (10 ft).
5. Class 2 wiring shall not be installed in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
6. Wiring shall not be installed in raceway containing tubing.
7. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.
8. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

9. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
10. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
11. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
12. Size of raceway and size and type of wire shall be the responsibility of the contractor, in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.
13. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
14. Use coded conductors throughout with conductors of different colors.
15. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
16. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g., steam pipes or flues).
17. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
18. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.
19. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
20. The Contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
21. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
22. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.
23. Control signal wiring shall be routed clear of all lighting ballasts or other electromagnetic devices, which may damage the integrity of the control signal.
24. All temperature and interlock wiring shall be installed in conduit. Power or interlocking wire shall be run in separate conduit from sensor wiring

F. Communication Wiring:

1. The Contractor shall adhere to the items listed in Sub-Section 3.2.D, "Wiring" of this specification.
2. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.
3. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.

4. Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
5. Contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
6. All runs of communication wiring shall be unspliced length when that length is commercially available.
7. All communication wiring shall be labeled to indicate origination and destination data.
8. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

G. Control Air Tubing

1. Main air tubing shall be sized by the contractor. Main air runs on a floor shall be looped, as opposed to a series of straight air runs.
2. Sensor tubing shall be sized by the contractor. Locate sensors to minimize tubing runs at the expense of increased wiring distances.
3. Mechanically attach tubing to supporting surfaces. Sleeve through concrete surfaces in minimum 1 in. sleeves, extended 15 cm (6 in.) above floors and 3 cm (1 in.) below bottom surface of slabs.
4. Purge tubing with dry, oil-free compressed air before connecting control instruments.
5. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.
6. Piping above suspended ceilings shall be supported from or anchored to structural members or other piping and/or duct supports. Tubing shall not be supported by or anchored to electrical raceways or ceiling support systems.
7. For air pressures greater than 200 kPa (30 psig), compression or solder type connection shall be used.
8. Perform a pressure test on the entire pneumatic system as follows:
    a. Test high-pressure air piping at 1000 kPa (150 psig) air pressure. Maintain this pressure for two hours without loss of pressure. If loss of pressure is indicated, correct and retest until the system shows no loss of pressure for two hours.
    b. Test low-pressure air tubing at 200 kPa (30 psig) air pressure. Maintain this pressure for 2 hours without pumping, during which time the pressure shall not drop more than 7 kPa (1 psi). Should pressure loss occur, determine the leak, repair with new equipment or piping, and retest until the system show no more than 7 kPa (1 psi) pressure drop in two hours.
    c. Leaks at pipe and tube joints shall be corrected by remaking of the joints.

H. Interfacing With Fire Alarm System

1. Interface shall be UL Listed for smoke control
2. Interface shall be UL Listed under UL 864 categories UOJZ, UOXX, UUKL, UDTZ and QVAX, UL 1076 category APOU, and UL 916 category PAZX.
3. All hardware used for interfacing the building automation system to the fire alarm system shall be UL Listed for smoke control under UL 864 category UUKL.
4. All hardware used for interfacing the building automation system to the fire alarm system shall be UL Listed under the following categories: UL 864 categories UOJZ, UOXX, UUKL, UDTZ, QVAX, UL 1076 category APOU, UL 916 category PAZX

I. Fiber Optic Cable

1. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

2. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.05 COUNTY REQUIRED SETPOINTS

A. Effective December 2012, HVAC settings shall be 69°F for heat and 73°F for cooling for all County of Santa Barbara facilities.

B. Effective December 2013 the HVAC settings shall be 69°F for heat and 74°F for cooling for all County of Santa Barbara facilities

C. These limits shall not apply in areas where other temperature settings are required by law or by specialized needs of equipment, server rooms or scientific experimentation.

D. For the County office spaces with limited or no heating and cooling:

1. If a building does not have a cooling system or a proper cooling system, then the 73°F cooling setting shall not apply or shall be set higher.

2. If a building does not have a heating system or proper heating system, then the 69°F heating setting shall not apply or should be set lower.

E. Per the County of Santa Barbara Energy Action Plan, the following are the required domestic hot water set points:

1. Domestic hot water temperatures should not be set above 115°F.

2. These limits shall not apply in areas where other temperature settings are required by law or by specialized needs of equipment or scientific experimentation.

3.06 SEQUENCE OF OPERATION

A. The sequence of operation for the control system is listed on the contract drawings.

1. Contractor shall review the sequence programmed sequence from the base project and shall integrate without, unless specifically requested in writing, additional modification.

2. The sequence of operation shall comply with the County required set points listed in this section.

3.07 FIELD QUALITY CONTROL

A. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances.

B. Continually monitor field installation for code compliance and workmanship quality.

C. Contractor shall arrange for work inspection by local or state authorities having jurisdiction over the work.

3.08 EXISTING EQUIPMENT

A. Existing control system shall be integrated into County front-end.

3.09 IDENTIFICATION

A. All devices mounted on the master control panel shall be provided with permanently engraved bakelite nameplates per specifications labeling requirements, indicating system space title and required tag number.

B. All field sensing devices except room thermostat shall be appropriately labeled in accordance with schedule tag number.

C. All cables, wiring from and terminal blocks including that within factory-fabricated panels shall be identified by labels, tags or other permanent means. Marking shall clearly indicate the function and source of all cable, wiring and terminals.

D. All valves installed under this contract shall be provided with numbered tags chained to the valve operator. Tags shall be 1/4" diameter, 18 gauge minimum brass and stamped with the appropriate markings.

E. All panels shall be provided with permanently attached labels with identifying names and functions in accordance with project nomenclature.

F. Identify room sensors relating to terminal box or valves with nameplates.

G. All plug-in components shall be labeled such that removal of the component does not remove the label.

H. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

I. Warning Labels

1. Permanent warning labels shall be affixed to all equipment that can be automatically started by the DDC system

2. All labels shall be white lettering (12-point type or larger) on a red background.

3. Warning labels shall be as follows: "CAUTION This equipment is operating under automatic control and may start or stop anytime without warning. Switch disconnect to "Off" position before servicing."

4. Permanent warning labels shall be affixed to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects as follows: "CAUTION: This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing."

3.10 TRAINING

A. Provide 6 hours of training on-site.

B. A manufacturer's technical representative for the equipment specified herein shall be presented at the job site and or in a classroom designated by the County for the services listed below, travel time excluded.

C. Training Manuals: The Contractor shall provide an agenda and training documentation for all training classes at least two weeks prior to the first class. The Engineer reserves the right to modify any or all of the training course outline and training materials. Provide one copy of training material per student (assume 3 copies unless instructed otherwise).

D. The instructor(s) shall be factory-trained instructors experienced in presenting this material.

E. Contractor shall specifically address the following subjects including and not limited to the following:

1. System sequence of operation, in detail.

2. Understand control system architecture and configuration.

3. Understand system operation, including DDC system control and optimizing routines

4. Adjust and change system set points, time schedules, and holiday schedules.

5. Recognize malfunctions of the system

6. Emergency service support

7. System restart after power failure

8. Stand-alone system backup and restoration procedures
9. Replacement procedures of each system component.
10. Adjustment, calibration and initialization procedures.
11. Operation of maintenance service programs.
12. Using portable operator station to perform system maintenance and operation functions.
13. To generate and maintain the control programming logic
14. Create, delete, and modify alarms, including annunciation and routing of these.

F. Provide one set of the special tools, reference materials (manuals), test instruments, and software manufactured or modified by the manufacturer for use in the installation, troubleshooting, and repair of installed devices. Include portable test terminal, test boxes, circuit card extenders, calibration modules, etc.

3.11 START-UP AND TESTING

A. Verify that the system operation adheres to the sequence of operation. Simulate and observes all modes of operation by varying inputs and schedules.

B. Alarm and Interlocks:

1. Check each alarm separately by including an appropriate signal at a value that will trip the alarm
2. Interlock shall be tripped using field contacts to check the logic as well as to ensure that the fail-safe condition for all actuators is in the proper directions.
3. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.
4. Test fan and pump failure.

C. Logic Tests

1. Override Test: Verify manual override capability for start/stop and modulated point types.
2. Exercise all control logic before witnessed testing by Owner or CxA
3. Check time response to a step-change in set point.

D. Test Failure Modes:

1. Verify all stand-alone operation in DDC mode by disconnecting communication lines between standalone control units and verifying continued operation.
2. Disconnect and reapply 120 VAC power to confirm proper recovery from power failure.
3. Disconnect and reconnect controller power to confirm proper recovery from power failure

E. The contractor shall supply all instruments for testing and turn over it to the County after acceptance testing.

1. All test instruments shall be submitted for approval and shall be calibrated for the following accuracy:
   a. Temperature: 1/4F or 1/2% full scale, whichever is less.
   b. High Pressure (psi): ½ psi or 1/2% full scale, whichever is less.
   c. Low Pressure (in w.c.): 1/2% of full scale
   d. Humidity: 2% RH
   e. Electrical: 1/4% full scale

3.12 DEMONSTRATION AND ACCEPTANCE

A. Point-to-Point Checkout

1. Verify point-to-point connections down to controller level from front-end. If there are additional issues below controller level, notify owner.

2. Maintain and submit to Owner a log showing:

a. Point name

b. Point type

c. Reading (if applicable)

d. Date checked

e. Technician's initials

f. Any corrective action taken or needed.

3. Provide log to owner and CxA for review.

B. Demonstration and Commissioning

1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.

2. Coordinate with CxA (if applicable) for test script content and witnessing.

3. Demonstrate compliance with sequences of operation through all modes of operation.

4. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

C. Acceptance

1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and the County prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.

2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in section "Submittals."

3.13 CLEANING

A. The Contractor shall clean up all debris resulting from the installation work. Waste shall be collected and placed in a designated location.

B. At the end of each workday, the Contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc. All occupied areas shall be kept in a "show ready" condition.

C. Upon completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.14 SCHEDULING AND COORDINATION

A. Controls contractor shall support the commissioning process in good faith.

B. The CxA will provide an initial list of commissioning milestones and deliverables to the CxC for scheduling purposes at the commissioning kick off meeting.

C. The General Contractor shall integrate all commissioning activities, milestones and deliverables into the master construction schedule with assistance from the CxA.

D. The CxC shall provide sufficient notice to the CxA and Owner for scheduling and coordinating commissioning activities. A minimum 10 day's notice shall be provided to the CxA for witnessing equipment Start-ups, Pre-Functionals, and Functional Performance Testing.

E. The Commissioning Team shall address scheduling problems and make necessary modifications in a timely manner in order to expedite the commissioning process.

3.15 MEETINGS

A. When commissioning team member attendance is required, as determined by the CxA and CxC, be punctual and attentive during the meeting.

1. The CxA shall conduct a commissioning kick-off meeting, usually within 60 days of the commencement of construction. All team members involved in the commissioning process shall attend the kick-off meeting.

2. The CxA shall conduct a commissioning "pre-startup" meeting, to confirm the final plan for startup and witnessing of equipment. All team members involved in the commissioning process shall attend.

3. The CxA will plan other commissioning meetings as deemed necessary as construction progresses. These meetings will cover planning and coordination, and Commissioning Issues resolution.

4. The frequency of meetings will vary through construction, but generally increase during start-up and commissioning activities.

B. The CxA shall write and distribute meeting minutes documenting the meeting discussion, conclusions, and actions for each team member.

3.16 COMMISSIONING AND DEMONSTRATION ISSUES, BACK-CHECKS, AND RE-TESTING

A. All Deficiencies and Commissioning Issues shall be corrected promptly. The responsible party shall correct the issue and inform the CxC and CxA of the resolution and completion date. The CxA will record completion on the Commissioning Issues List once the issue is successfully back-checked or verified.

1. For all Commissioning Issues identified during the pre-functional system readiness activities, the CxA will back-check and verify the completion of the issues where appropriate.

2. For all Commissioning Issues identified during FPT, retesting is required to verify the resolution of the issue and to complete the FPT.

3. The CxA shall witness one (1) re-test for each equipment and will perform one (1) back-check verification of any completed system readiness issue.

4. The Owner may back-charge the General Contractor for any additional fees from the CxA, resulting from any re-testing or repeated system readiness issues list back-checks beyond the first re-test or back-check.

END OF SECTION

Note: The content in this section represents a minimum quality and standard of care for this scope. It is the responsibility of the consulting design engineers to integrate these specifications elegantly into the technical specs package. Parts expected to require revision during integration are highlighted in yellow; confirm/revise, then un-highlight. Please delete this text box.

SECTION 26 08 00

COMMISSIONING OF ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE

A. Division 26, ….

B. …

1.02 REFERENCES

A. Reference Standards:

1. Comply with ASHRAE Guideline 0.
2. Title 24, Part 6, Section 120.8 Building Commissioning, Revision 2013
3. Comply with requirements of applicable green building code for this project such as LEED, CHPS, or CalGreen. (Verify with Owner.)

1.03 DEFINITIONS

A. Basis of Design (BOD): The BOD is developed by the design consultants for the systems used in the facility. It defines the assumptions made for the designed systems. This document is written to agree with the Owners Project Requirements (OPR).

B. Building Automation System (BAS): The building digital control system.

C. Commissioning Authority (CxA): An agent hired directly by the Owner which assists the Contractor with coordinating commissioning activities and witnesses and reviews the activities on behalf of the Owner.

D. Commissioning Issue: An issue which must be resolved to complete the commissioning process.

E. Commissioning Issues List: A log maintained by the CxA listing all Cx Issues documented during the commissioning.

F. Commissioning Plan: A document that outlines the organization, coordination, and requirements of the commissioning in detail.

G. General Contractor: The contractor directly contracted to the Owner with overall responsibility for the project and all commissioning activities.

H. Commissioning Coordinator (CxC): General Contractor employee who plans, schedules, and coordinates the Sub-Contractor's commissioning activities, and serves as the CxA's single point of contact for all administrative, documentation and coordination needs.

I. Deferred Testing: Testing performed at a later time for a certain reason.

J. Functional Performance Test (FPT): A test of the operation and control sequences of equipment and systems to verify system performance. Systems are tested under various operating modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, alarm, power failure, etc.

K. Installation Verification (IV): Field verification and documentation of proper installation of system equipment.

L. Monitoring: The recording of parameters of equipment operation using data-loggers or the Trending capabilities of BAS or control systems.

M. Owner's Project Requirements (OPR): A document written by the Owner describing the operational and functional requirements of a project, the expectations of how the facility will be used and operated, and the equipment and system expectations and requirements.

N. Sampling: Witnessing the startup or testing of a selected fraction of the total number of identical or near-identical pieces of equipment such as VAV boxes.

O. Pre-Functional Checks: These are various checks and tests performed on a piece of equipment or system just before, during or after the initial Startup. Examples include pipe system pressure tests, duct leakage tests, mechanical system test and balance and electrical equipment NETA testing. They must be completed prior to functional testing.

P. Startup: Initial starting or activating of equipment performed by the Sub-Contractor or the Manufacturer's representative.

Q. System Readiness Checklist (SRC): A checklist, covering the commissioning tasks and required documentation to verify that a system is ready for functional testing. The SRCs must be completed and signed by the General Contractor prior to conducting the functional testing.

R. Test and Balance (TAB): Testing, Adjusting, and Balancing work on the air and water systems to ensure design flow conditions are met.

S. Sub-Contractor: Typically a subcontractor to the General Contractor who provides and installs specific building components and systems and/or provides certain services.

T. Trending: Monitoring using the Building Automation System to aid in functional testing and to verify system operation and performance under operating conditions.

1.04 DESCRIPTION OF WORK

A. The following systems comprise the scope of commissioning:

1. Lighting Control Systems
2. Generator and ATS
3. UPS System
4. …

B. Coordinate with trades as needed to provide services.

C. The work includes the completion and documentation of formal commissioning procedures by the General Contractor and Sub-Contractors.

1. Commissioning is the process of verifying the installation and performance of building systems to meet the design intent, contract documents, Owner's requirements, and operational needs.
2. The Design Professionals, General Contractor and Sub-Contractors provide the quality control for the design, installation, startup and checkout of the systems. The commissioning process provides review and qualitative functional testing in order to formally observe and document that the quality control efforts are successfully completed.
3. The Sub-Contractors and the factory service representatives shall be responsible for participation in the commissioning process as outlined in this specification and Section 01 91 13 General Commissioning Requirements, and as directed by the General Contractor's CxC as overseen by the CxA.
4. Refer to Section 01 91 13, General Commissioning Requirements for summary description of the general commissioning process and requirements.

1.05 QUALITY ASSURANCE

A. Commissioning Provider Qualifications:

1. The commissioning provider shall have an individual assigned to this project with one of the following credentials: Building Commissioning Association CCP, Association of Energy Engineers CBCP, ASHRAE CPMP, or AABC CxA.

2. All Work by this agency shall be done under direct supervision of the credentialed individual.
3. All instruments used by this agency shall be accurately calibrated and maintained in good working order. Calibration may be confirmed on site by owner's representative. Instruments without current calibration and documentation may have their results up to that point nullified and re-work with calibrated instruments would be required.
4. Conduct tests in the presence of the Owner's Representative.

1.06 CONSTRUCTION PHASE COMMISSIONING PROCESS

A. Submittal Review by the CxA

1. The CxA shall review the Trade Sub-Contractor's submittals for the scope systems concurrently with the Design Team and provide review comments to the Owner and Design Team before submittal approval.
2. The General Contractor shall provide a submittal log to the CxA for referencing requested submittals to be reviewed by the CxA.
3. Information from the submittals will also be used by the CxA to develop commissioning forms and test procedures.

B. Cx Plan and Form Development

1. The CxA shall write a Preliminary Commissioning Plan and provide to Owner for review.
2. The CxA shall facilitate a commissioning kickoff meeting where the commissioning process and systems are reviewed.
3. The CxA shall develop the SRC checklists which track the completion of the Installation, Startup, and Pre-Functional Checks required for each system. The SRC forms shall be provided for peer review at the kickoff meeting.
4. The CxC shall submit to the CxA, for review and approval, representative blank forms for completing Installation Verification, Startup, and Pre-Functional Checks on request.
    a. Installation Verification forms are used to provide field verification and documentation of proper installation of equipment and system prior to formal Startup.
    b. Startup and Pre-Functional Check forms are usually Manufacturer and/or Trade Sub-Contractor startup and checkout sheets and shall be used where required and appropriate.
    c. Where appropriate, IV forms and startup forms may be combined, such as on small fan installations.
    d. Where appropriate, these forms can be checklists taken from the Manufacturer's installation manual.
    e. The Pre-Functional Test forms shall also include forms for recording results from system specific tests such as pipe system pressure tests, duct leakage tests, mechanical system TAB, electrical equipment NETA testing, etc.
5. The CxA will develop Functional Performance Testing (FPT) procedures and forms. These test procedures shall be provided to the Owner, General Contractor, and Trade Sub-Contractors for review and comment.

C. System Readiness Activities

1. Meetings shall be conducted throughout construction with Commissioning Team members, as required, to plan, coordinate, and schedule commissioning activities, review documentation, and resolve Cx Issues.
2. The Sub-Contractors shall perform Installation, Startup and Pre-Functional Check & Test activities to verify that the system is ready for operation or functional testing.

3. The Trade Sub-Contractors and the CxC shall document completion of these activities on the SRC forms and attach the completed Installation Verification, Startup, and Pre-Functional Check & Test forms to the SRC.
    a. In general, Installation Verification should be completed prior to Startup, but where appropriate, they can be completed into one activity.
4. The CxA shall perform multiple inspections during these phases.
5. The CxA shall witness a percent sampling of the Startups and Pre-Functional Checks & Tests. Sampling approach to be approved by Owner.

D. Functional Testing

1. Functional Performance Tests (FPTs) are tests of the control function and performance of the systems. These tests are used to verify that the sequences of operation are correctly implemented and that the design intent and performance criteria of the systems have been met.
2. The CxA shall develop FPT forms that contain:
    a. Specific procedures to execute the tests in a clear and repeatable format
    b. Any control system point value or setpoint overrides required to simulate a test condition or sequence mode.
    c. The expected system response and acceptance criteria of proper performance with a Yes/No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
    d. A section for recording actual system response, notes and comments.
3. The CxA shall provide a trending plan which contains:
    a. A list of control system trend data to be collected and provided to the CxA in electronic format for analysis and review.
    b. The list shall contain at minimum: point name and description, units, time series or change of value data type, time series trending intervals.
    c. The list shall have two columns of trend interval values, one with shorter trending intervals for high resolution data collection during functional testing and an additional column for lower resolution data collection for ongoing trend analysis of the system beyond the functional testing.
4. Once the SRC checklists are completed the FPTs shall be executed by the Sub-Contractors with all or a sample witnessed by the CxA, as defined in the Cx Plan and agreed with the owner.
5. Any deferred testing will be defined in the Cx Plan.

E. Commissioning Issues and Resolution

1. Issues shall be recorded by the CxA on the Commissioning Issues List and distributed to the commissioning team.
2. The General Contractor and Sub-contractors shall correct Commissioning Issues and retest the system(s), where applicable, without delay at no additional cost to the Owner.
3. The CxA will verify the completion of the issues and make all amendments to the issues list.

F. O&M Manuals, Training Verification and Final Documentation

1. The General Contractor shall compile and complete the Operations & Maintenance (O&M) Manuals provided by the Trade Sub-Contractors, per the contract documents requirements.

2. The CxA shall verify that the correct O&M content has been delivered to the Owner per the contract requirements and may request electronic copies of the O&M Manuals to aid in the completion of the Systems Manual if applicable.
3. The General Contractor shall submit a training schedule and specific training agendas provided by the Trade Sub-Contractors for each training to occur to the CxA and Owner for review prior to conducting any training.
4. The CxA shall review and provide comment to the Owner and General Contractor on the specified training agendas.
5. The CxA shall verify completion of the training by verifying a copy of the training sign-in sheets, provided by the General Contractor.
6. The CxA shall develop the Systems Manual (if applicable) with assistance from the General Contractor and Sub- Contractors. The systems to be included shall be confirmed with Owner.
7. The CxA shall complete the Construction Phase Commissioning Report and documentation for the Owner.

G. Post-Occupancy/Warranty Phase Commissioning

1. If contracted, no later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility O&M staff, walk the facility and review systems operation.
2. Key representatives from the General Contractor and Trade Sub-Contractors shall also attend, as determined by the CxA.
3. Any performance issues, warranty items or problems identified will be reported by the CxA to the Owner and CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Sub-Contractors prior to the end of the warranty period.

1.07 COMMISSIONING TEAM

A. The Commissioning Team is responsible for performing the commissioning process as directed by the CxA and achieving successful commissioning results. The Commissioning Team is comprised of the following:

1. Owner and Owner's Representatives
2. Design Professionals (DP) and Architects/Engineers (A/E)
3. Commissioning Authority (CxA).
4. General Contractor
5. General Contractor's Commissioning Coordinator (CxC)
6. Electrical Contractor
7. Lighting Controls Contractor
8. Generator/ATS Contractor (if applicable)
9. UPS Contractor (if applicable)

1.08 RESPONSIBILITIES

A. General.

1. The Commissioning Team shall follow the Commissioning Plan, attend the commissioning kickoff meeting, and attend additional commissioning meetings as necessary.

B. Commissioning Authority (CxA)

1. See Section 01 91 13, General Commissioning Requirements.

C. General Contractor:

1. See Section 01 91 13, General Commissioning Requirements.

D. Sub-Contractors:

1. Provide submittal data, including manufacturer's installation checks and startup procedures, commissioning forms, and any other requested contract documentation for systems to be commissioned. Electronic files are preferred.
2. Attend commissioning meetings as directed by the CxA and General Contractor's CxC to facilitate the commissioning process.
3. Assign personnel with expertise and authority to act on behalf of the General Contractor and schedule them to participate in and perform assigned commissioning tasks.
4. Demonstrate and properly document proper system installation, startup and performance per contract requirements and manufacturer's forms.
5. Complete all Installation, Startup and Pre-Functional Check & Test documentation clearly and legibly. Provide a copy of all forms to the CxC and CxA as part of completing the SRC forms.
6. Provide access for the CxA to witness any equipment Startup and Pre-Functional Checks & Tests.
7. Notify the CxC and CxA at least 5 working days in advance of Startup and Pre-Functional Checks & Tests.
8. Ensure that any required manufacturer factory tests are performed and provide the factory test data.
9. Ensure that any required manufacturer's representative field tests and on-site installation verification, startup and checkout of selected equipment are performed per the contract documents.
10. Provide completed manufacturer documentation and commissioning forms for these activities to the CxC.
11. Address applicable Cx Issues promptly. All Installation Verification, Startup and Pre-Functional issues must be resolved before the FPT can proceed.
12. Assist CxA in preparing the FPT procedures, clarifying the operation and control of commissioned equipment where the specifications, control drawings or equipment documentation are not sufficient for writing detailed testing procedures.
13. Review the FPT procedures to ensure feasibility, warranty protection, safety and equipment protection, and provide necessary written alarm limits and overrides to be used during the tests.
14. As part of the FPTs, the Trade Sub-Contractor shall setup any additional software points, overrides of any sensor values or relays, and overrides of any setpoints or schedules, to simulate certain conditions and operating modes, in order to conduct the FPTs.
15. Perform the FPTs as written. Execution of FPTs shall be witnessed by the CxC and CxA and fully documented.
16. Assist the CxA in collecting all requested Trend data associated with FPTs.
17. Prepare a training agenda and sign-in sheet for each training class (to be reviewed by the CxA) and work with the General Contractor and Owner to schedule training. Execute training of Owner's personnel per approved training agenda and schedule.
18. Prepare O&M Manuals according to the Contract Documents.
19. Assist the CxA in developing the Systems Manual if applicable.

1.09 SUBMITTALS

A. Submittals shall be made in accordance with Section 01 33 00 – Submittal Procedures and Section 23 05 00 – Common Work Results for HVAC.

B. CxA shall submit electronic copies of all Cx deliverables described herein to the Owner upon request.

C. The Sub-Contractors shall submit to the CxA blank forms for Installation Verification, Startup and Pre-Functional Checks for review and comment.

D. The CxA will review these submitted commissioning forms for completeness including any project specific requirements.

E. The CxA may request additional data, changes and/or additions to these forms to make sure they are complete prior to their use. If the submitted forms are not available or are not sufficient, then the CxA will provide forms based on the construction documents and specifications, manufacturer installation manuals and procedures, and/or industry standards or guidelines.

F. The Trade Sub-Contractors shall submit to the CxA any equipment and construction submittals and shop drawings, including detailed sequences of operation, as requested by the CxA.

G. Instruments Used by CxA

1. A complete list of instruments proposed to be used, organized in appropriate categories, with data sheets for each. Show:

   a. Manufacturer, model and serial number.

   b. Description and use when needed to further identify the instrument.

   c. Size or capacity range.

   d. Latest calibration date and certificates of calibration.

1.10 SUBSTITUTIONS

A. Not applicable.

1.11 JOB CONDITIONS

A. For existing conditions, obtain building as-built drawings from the Owner for pre-construction requirements.

B. Prior to start of functional testing:

1. Outside conditions to be within 15 percent relative to design conditions.

2. Building lights shall be turned "on" when testing cooling system, "off" when testing heating system.

3. Special equipment such as computers, laboratory equipment, electronic equipment or engine generator to be in full operation.

4. Close all windows and doors.

C. Notification: Promptly report any deficiencies noted during performance of services. Rectify these deficiencies, and any tests interrupted shall be re-done.

1.12 WARRANTY

A. Warranties shall be in accordance with Section 01 78 36 – Warranties.

B. The CxA shall warrant the conclusions drawn from functional testing and trend analysis for accuracy.

1. It is the CxA's responsibility to coordinate with the test and balance and controls contractors for accurate test result readings and trend data received.

2. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, CxA shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order to provide accurate system conclusions and recommendations.

3. The CxA shall provide revised system functionality conclusions, FPT documentation, and trend analysis as needed to replace the flawed and void previous documentation.

C. The general and subcontractors shall warrant the data drawn from functional testing and trend analysis to be accurate and correct. (most importantly: test and balance and controls contractors)

1. If data used for functionality or performance conclusions is found to be inaccurate or fundamentally flawed within one year from substantial completion, the responsible contractors shall provide their time and manpower to retest the affected systems per their FPT script free of charge in order for the CxA to provide accurate system conclusions and recommendations.

PART 2 - PRODUCTS

2.01 DOCUMENTATION

A. The Sub-Contractors have specific responsibilities for assisting in the development of the commissioning forms used, and in performing and documenting commissioning tests, as directed by the CxC and as overseen by the CxA.

B. The Sub-Contractors shall provide, system checks and testing, test reports, factory test data and reports, checklists, operational verifications and demonstration, etc. , per contract documents whether specified or not in the commissioning sections.

2.02 TEST EQUIPMENT

A. The Sub-Contractors shall provide all test equipment to execute Pre-Functional and Functional Performance Tests.

B. The test equipment shall be provided in sufficient quantities to execute testing in an expedient fashion.

C. The test equipment shall be of industrial quality and suitable for testing and calibration with accuracy within the tolerance necessary to demonstrate system performance per the Contract Documents. If not otherwise specified, the following minimum requirements apply:

1. Temperature sensors and digital thermometers shall have a certified calibration within the past 12 months to an accuracy of 0.5 degree F and a resolution to + or – 0.1 degree F.

2. Pressure sensors shall have an accuracy of + or – 2.0 percent of the value range being measured (not full range of meter) and have been calibrated within the past 12 months.

D. The test equipment shall have calibration certification per equipment manufacturer’s interval level or within one year if not otherwise specified. The calibration tags shall be affixed or certificates readily available for all test equipment.

PART 3 - EXECUTION

3.01 STARTUP AND SYSTEM READINESS

A. All tests and start-up procedures shall be conducted without compromise to human or equipment safety.

B. The General Contractor and Sub- Contractors shall be responsible for the liability and safety of conducting all tests and startup.

C. The General Contractor shall clearly identify and list any Deficiencies resulting from the Installation Verification, Start-up and Pre-Functional Checks on the associated forms and immediately notify the CxA. Once Deficiencies are corrected and verified or tested, update and resubmit the associated forms.

D. The CxC and Trade Sub-Contractors shall a minimum 10 day's notice to the CxA for witnessing equipment Start-ups and Pre-Functional Checks & Tests.

3.02 FUNCTIONAL PERFORMANCE TESTS

A. Functional testing shall be performed and documented for 100% of all equipment in the scope of commissioning.

B. At the discretion of the CxA and per the approved Cx Plan, the CxA may witness a percentage (sample) of the functional tests for selected, multiple identical pieces of non-life-safety or non-critical equipment (example: VAV boxes).

C. The General Contractor and Sub-Contractors shall be responsible for the liability and safety of conducting all tests.

D. Ensure the following are completed prior to the start of the FPTs:

1. CxA and CxC certify through the System Readiness Checklist (SRC) forms that the HVAC systems, controls and instrumentation, equipment and assemblies have been installed, calibrated, started and are operating per the Contract Documents. Approval of the completed SRC forms by the CxA is required prior to conducting the FPTs.

2. As part of the system readiness, the TAB Trade Contractor shall conduct and complete all testing, reporting, field inspection and verification work, and discrepancies and corrective work, per specifications, prior to HVAC system FPT.

3. As part of the system readiness, all pipe system cleaning, flushing, and pressure testing, duct leakage testing and duct cleaning per the Contract Documents is completed and applicable plans and reports are provided to the CxA.

4. As part of the system readiness, the Controls Contractor shall complete the BAS pre-functional checks and tests, including sensor calibration, actuator testing, and point-to-point checks, prior to FPTs of the HVAC systems.

5. And the BAS graphics and programming for the sequence of operations and associated setpoints, schedules, and alarms shall be configured and the system operation checked and confirmed, including the control loop tuning, prior to starting functional testing.

   a. Prior to conducting the FPTs, place the systems and controls into the operating modes to be tested (e.g., normal occupied mode, normal startup and shutdown modes, unoccupied modes including after-hours override and night setback operation, emergency power, etc.).

   b. Check all control system safety cutouts, alarms, and interlocks with smoke control and fire-life safety during each mode of operation prior to functional testing.

6. The controls contractor shall execute a pre-test of the functional test on the approved FPT forms prior to the final witnessed test. This will give the controls contractor the confidence the witnessed test will pass.

E. Sub-Contractors shall execute all FPTs per the approved test procedures on the FPT forms. All testing results shall be documented on the final FPT forms; the forms shall be signed and dated by the representative performing the tests.

F. The CxC and Sub-Contractors shall coordinate all FPT with the CxA, and provide a minimum of 10 day's notice prior to conducting each system test.

G. FPT for each system must be successfully completed and signed by the CxA prior to formal approval of system commissioning.

H. FPT may be conducted using these approved test methods:

1. Manually manipulating the equipment settings to observe performance.

2. Overwriting control system sensor values to simulate a condition, such as overwriting the outside air temperature to be something other than it actually is.
3. Altering setpoints to force equipment into a mode of operation to verify a sequence.
4. Using indirect indicators, such as readings from a control system screen reporting a damper is 100 percent open, for testing responses will be allowed only after the actual conditions represented by the indirect indicators have been directly verified, calibrated and documented on the SRC forms (as a pre-functional check/test).
5. Monitoring performance by analyzing the control system Trend data. The CxA will then analyze the control system Trend data and provide conclusions to the Owner.

I. Setup

1. The Sub-Contractor executing the test shall document the pre-test normal condition on the test form.
2. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible.
3. The Trade Sub-Contractor executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. to execute the test according to the test procedures.
4. At completion of the test, the Trade Sub-Contractor shall return all affected building equipment and systems to their pre-test normal condition.

3.03 FUNCTIONAL PERFORMANCE TESTS AND TREND ANALYSIS

A. The CxA will prepare a Trend Analysis Plan with a points list and trend interval, as part of the FPTs to verify integrated system operation and performance. The Trend analysis will be conducted after the FPTs for the HVAC control sequences and operating modes are completed and any issues and deficiencies are corrected.

B. The BAS Trade Contractor shall set up the trend log definitions. Trend data shall be provided by the BAS Trade Contractor to the CxA in an electronic format, either a text file, CSV file or Excel file, with related system parameters grouped together.

C. If performance issues are found through the Trend analysis, the issues shall be corrected by the BAS Trade Contractor and the trending shall be restarted and analysis repeated by the CxA.

3.04 COMMISSIONING ISSUES AND RETESTING

A. All Deficiencies and Issues shall be documented on the appropriate forms in use, and will additionally be documented by the CxA on a Cx Issues List.

B. The CxA will maintain and update the Commissioning Issues List, and document the issues resolution process. Copies will be distributed to the General Contractor, Owner, and Sub-Contractors as appropriate.

C. All Commissioning Issues shall be corrected promptly. The responsible party shall correct the issue and inform the CxC and CxA of the resolution and completion date. The CxA will record completion on the Commissioning Issues List once the issue is successfully back-checked or verified and the CxC shall reschedule testing with the CxA and Sub-Contractor. Testing shall be repeated until passing performance is achieved or the Owner accepts the noted issue.

D. Immediate correction of minor issues identified during testing may be allowed at the discretion of the CxA. The issue and identified resolution must still be documented on the commissioning form in use.

E. When Cx Issues are identified during FPT, the CxA will discuss with the executing Sub-Contractor and/or CxC and determine whether testing can proceed or be suspended.

F. The Commissioning Issue and any identified resolution will be documented on the test form in use in addition to the Commissioning Issues List.

G. When there is a dispute regarding a Cx Issue, whether it is valid or who is responsible, additional parties may be brought into the discussion as appropriate.

H. The CxA will have the final interpretive authority on Cx Issues and Deficiencies and the Owner will have the final approval authority.

I. The CxA may recommend solutions to Deficiencies and Commissioning Issues. However, the burden of responsibility to solve, correct and perform required retests is with the General Contractor, Trade Sub-Contractors, and the Design Professional(s).

J. Additional Back-check Verifications and Re-testing:

1. For all Issues identified during the pre-functional system readiness activities, the CxA will back-check and verify the completion of the issues where appropriate.

2. For all Commissioning Issues identified during FPT, retesting is required to verify the resolution of the issue and to complete the FPT.

3. The CxA will witness one (1) re-test for each equipment and will perform one (1) back-check verification of any completed system readiness issue.

4. The Owner may back-charge the General Contractor for any additional fees from the CxA, resulting from any re-testing or repeated system readiness issues list back-checks beyond the first re-test or back-check.

5. A minimum 48 hour's notice is required for scheduling any re-testing, though the CxA will attempt to accommodate a shorter timeframe if feasible.

6. Any required retesting shall not be considered a justified reason for a claim of delay or for a time extension.

K. For any re-testing required, the CxA will determine if the entire test must be re-tested or if it is acceptable to re-test specific portions of the test that had failed.

3.05 INTEGRATED SYSTEMS TESTING

A. Provide and demonstrate a full-power loss simulation test in the presence of Owner, CxA, and Owner's Representative.

B. Demonstrate power restoration returning all systems to normal operation automatically.

C. Demonstrate all settings in systems were persistently saved, such as lighting control schedules.

D. If applicable, demonstrate how automatic transfer switches transfer loads to generator or UPS bank.

E. …

3.06 DEFERRED TESTING

A. Before or during the end of the first year Warranty Period, any Seasonal or Deferred Testing as defined in the Cx Plan, shall be completed as part of this contract. Tests shall be conducted by the Trade Sub-Contractor responsible for the equipment and systems, completed in the same manner as all other commissioning tests, and shall be witnessed by the CxA.

B. The General Contractor shall coordinate with CxA and Owner and schedule all Deferred and Seasonal Testing.

C. The General Contractor shall make final adjustments to the as-built documentation or drawings for any modifications made during Deferred or Seasonal Testing.

3.07 O&M MANUALS AND TRAINING VERIFICATION

A. The General Contractor and the CxC shall coordinate and schedule the training for Owner Personnel. The CxC shall ensure that training is completed per the requirements of the construction documents and specifications.

B. Trade Sub-Contractors responsible for specific equipment and system training shall submit to the CxC, a written training agenda for each training class for the equipment and systems to be commissioned, no less than 14 days prior to start of training.

C. The General Contractor shall submit the training agendas and sign-in sheets (blank) to CxA and Owner for review and approval.

D. The training agendas shall cover the following elements:

1. Equipment and/or systems included in training
2. Intended audience
3. Location of training
4. Subjects covered (including a brief description and duration, presentation methods, etc.)
5. Instructor's name and qualifications
6. Copy of any handout materials or presentations.
7. Sing-In Sheet

E. The CxA will review the training plans to verify compliance with the specifications.

F. The General Contractor shall submit to CxA the signed and completed attendance sheets for each training session and a copy of the final training presentations and materials.

G. The CxA will verify with the Owner that the final O&M manuals have been delivered per the Contract Documents.

3.08 ACCEPTANCE AND CLOSE OUT

A. Regarding substantial completion, reference Division 01, Section 01 77 00, Closeout Procedures.

B. After completion of the commissioning activities and review of the completed commissioning documents the Owner will provide a formal written acceptance of the project construction phase commissioning. At that point, any remaining construction phase commissioning issues or seasonal/deferred testing will be tracked by the CxA as part of the Post- Occupancy Warranty Phase Commissioning if applicable.

C. Upon completion of all commissioning activities, the CxA will prepare and submit to the Owner a Final Commissioning Report detailing all completed commissioning activities and documentation. The CxC shall support this effort by providing all General Contractor and Trade Sub-Contractor commissioning documentation.

D. The Owner's written acceptance of construction phase commissioning will be included in the Final Commissioning Report.

E. The CxA will complete a Systems Manual for the systems and equipment commissioned (if applicable), with assistance provided by the CxC and Trade Sub-Contractors. The Systems Manual will provide the operating staff the information needed to understand and optimally operate the commissioned systems. The Systems Manual will contain at minimum the following sections:

1. Final version of the BOD.
2. Systems single line diagrams and schematics.
3. Final as-built sequence of operations, control drawings (P&IDs), points lists and as-left set points.

4. Supplemental operating instructions for integrated building systems such as water-side and air-side HVAC systems and controls, lighting controls, etc.
5. Recommended schedule of maintenance requirements and frequency
    a. A summary of the preventative maintenance and service procedures is recommended in the Systems Manual, for the major MEP equipment, including a schedule matrix checklist (checked as weekly, monthly, quarterly, annually, etc.).
    b. Recommended schedule for retesting of commissioned systems with blank test forms from the Final Commissioning Plan.
    c. Recommended schedule for calibrating sensors and actuators.

3.09 POST-OCCUPANCY WARRANTY PHASE COMMISSIONING

A. If applicable, no later than 90 days prior to the expiration of the first 12 month warranty period of building occupancy, the CxA will return to the facility to interview facility staff, walk the facility and review systems operation to identify any issues. Key representatives from the General Contractor and Trade Sub- Contractors original project team shall attend, as determined by the CxA.

B. The CxA shall review BAS trend data during the Warranty Phase. The Controls Contractor will be responsible for providing post-occupancy trend data to the CxA.

C. Any performance issues, warranty items or problems identified will be reported by the CxA to the CxC via a Warranty Phase Commissioning Issues List for correction by the General Contractor and Trade Sub-Contractors prior to the end of the warranty period. The CxC shall work with the Trade Sub-Contractors and O&M staff to make corrections and modifications as required.

D. After correcting noted Warranty Phase Cx Issues, the General Contractor shall notify the CxA in writing, and the CxA will back-check and verify that the Warranty Phase Cx Issue was resolved.

E. Issues identified during the warranty period will remain Warranty Phase Cx Issues until satisfactory completion by General Contractor and back-check verification by CxA, even if the warranty period expires during the correction and back-check period.

END OF SECTION