SECTION 15900

CONTROLS AND INSTRUMENTATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. The General Provisions of the Contract, including General, Supplementary, and Special Conditions, and Division 1 - General Requirements, apply to work specified in this section. Subcontractor must familiarize himself with the terms of the above documents.

1.2 QUALIFICATIONS OF BIDDER

A. All bidders must be energy automation contractors in the business of installing direct digital control Energy Management Systems for a minimum of 7 years in California.

B. The basis of design is TAC Andover Continuum Controls by a TAC Andover Controls Corporation.

C. All bidders must have a trained staff of application engineers, who have been certified by the manufacturer in the configuration, programming and service of the automation system.

D. Acceptable Control Systems:

1. TAC Andover Continuum Controls by EMCOR Services (760) 839.8342

2. Alerton Controls by Climatec (949) 474.0955

3. Staefa Controls.by ControlWorks (909) 627.7155

1.3 SCOPE OF WORK

A. Except as otherwise noted, the control system shall consist of all Ethernet Network Controllers, Standalone Digital Control Units, software, sensors, transducers, relays, valves, dampers, damper operators, control panels, along with a complete system of electrical interlocking wiring to satisfy the intent of the specification and provide for a complete and operable system. Coordination may be required with other site Contractors.

B. The EMS contractor shall review and study all HVAC drawings and the entire specification to familiarize them with the equipment and system operation and to verify the quantities and types of dampers, operators, alarms, etc. to be provided prior to fabrication and installation.

C. All interlocking, wiring and installation of control devices associated with the equipment listed below shall be provided under this Contract. When the EMS system is fully installed and operational, the EMS Contractor and owner representatives will review and check out the system. At that time, the EMS contractor shall demonstrate the operation of the system and prove that it complies with the intent of the drawings and specifications.

D. The Contractor shall furnish and install a complete Energy Management System including all necessary hardware and all operating and applications software necessary to perform the control sequences of operation as called for in this specification. At a minimum, provide controls for the following:

1. A/C Systems

2. Exhaust fans

3. Split Packaged Air Conditioning Units

E. All work performed under this section of the specifications will comply with all codes, laws and governing bodies. If the drawings and/or specifications are in conflict with governing codes, the Contractor shall furnish any additional materials and labor to meet code restrictions at no additional cost to the owner. If this specification and associated drawings exceed governing code requirements, the specification and associated drawings will govern. The Contractor shall obtain and pay for all necessary construction permits and licenses.

1.4 SYSTEM DESCRIPTION

A. The Energy Management System (EMS) shall incorporate a PC-EMS workstations and microcomputer controllers of modular design providing distributed processing capability, and allowing future expansion of both input/output points and processing/control functions.

B. For this project the system shall consist of the following components:

1. Standalone Digital Control Units (SDCUs).
   a. Provide the necessary quantity and types of SDCUs to meet the requirements of the project for mechanical equipment control including rooftop A/C units, and terminal unit control. Each SDCU will operate completely standalone, containing all of the I/O and programs to control its associated equipment.

1.5 RELATED WORK SPECIFIED ELSEWHERE

A. The EMS Contractor shall coordinate with other contractors prior to performing the work on this project and cooperate as necessary to achieve a complete and neat installation. To that end, each contractor shall consult the drawings and specifications for all trades to determine the nature and extent of others' work prior to fabrication and installation. The owner and engineer shall be immediately notified if an area of conflict occurs between trades prior to fabrication and installation.

B. The Electrical Contractor shall provide:

1. All power wiring to motors, heat trace, junction boxes for power to EMS panels. The controls contractor shall be responsible for all additional electrical distribution from these connection points to the control panels and other controls devices.

2. Furnish smoke detectors and wire to the building fire alarm system. Electrical Contractor to mount devices and run wiring necessary to the DDC control panel. EMS contractor to hardwire to fan shut down. Please refer to mechanical plans for air handling unit's smoke detectors trade responsibilities.

1.6 CODE COMPLIANCE

A. Provide EMS components and ancillary equipment, which are UL-916 listed and labeled.

B. All equipment or piping used in conditioned air streams, spaces or return air plenums shall comply with NFPA 90A Flame/Smoke/Fuel contribution rating of 25/50/0 and all applicable building codes or requirements.

C. All wiring shall conform to the National Electrical Code.

D. All smoke dampers shall be rated in accordance with UL 555S.

E. Comply with FCC rules, Part 15 regarding Class A radiation for computing devices and low power communication equipment operating in commercial environments.

F. Comply with FCC, Part 68 rules for telephone modems and data sets.

1.7 SUBMITTALS

A. All shop drawings shall be prepared in AutoCAD software. In addition to the drawings, the Contractor shall furnish a diskette containing the identical information. Drawings shall be 11" x 17" size or larger.

B. Shop drawings shall include a riser diagram depicting locations of all controllers and workstations, with associated network wiring. Also included shall be individual schematics of each mechanical system showing all connected points with reference to their associated controller. Typical drawings will be allowed where appropriate.

C. Submittal data shall contain manufacturer's data on all hardware and software products required by the specification.

D. Software submittals shall contain narrative descriptions of sequences of operation, program listings, point lists, and a complete description of the graphics, reports, and alarms. Information shall be bound or in a three ring binder with an index and tabs.

E. Submit five (5) copies of submittal data and shop drawings to the Engineer for review prior to ordering or fabrication of the equipment. The Contractor prior to submitting shall check all documents for accuracy.

F. The Engineer will make corrections, if required, and return to the Contractor. The Contractor will then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the Engineer and the submittals are fully approved.

1.8 SYSTEM STARTUP & COMMISSIONING

A. Each point in the system shall be tested for both hardware and software functionality. In addition, each mechanical and electrical system under control of the EMS will be tested against the appropriate sequence of operation specified herein. Successful completion of the system test shall constitute the beginning of the warranty period. A written report will be submitted to the owner indicating that the installed system functions in accordance with the plans and specifications.

B. The EMS contractor shall commission and set in operating condition all major equipment and systems, such as the air handling systems, in the presence of the equipment manufacturer's representatives, as applicable, and the owner and Architect's representatives.

1.9 TRAINING

A. The EMS Contractor shall provide on-site training to the owner's representative and maintenance personnel per the following description:

1. Additional On-site training shall consist of a minimum of (2) hours of hands-on instruction geared at the operation and maintenance of the systems. The curriculum shall include
   a. System Overview
   b. System Software and Operation
   c. System access
   d. Software features overview
   e. Changing set points and other attributes
   f. Scheduling
   g. Editing programmed variables
   h. Displaying color graphics
   i. Running reports
   j. Workstation maintenance
   k. Application programming
   l. Operational sequences including start-up, shutdown, adjusting and balancing.
   m. Equipment maintenance

1.10 OPERATING AND MAINTENANCE MANUALS

A. The operation and maintenance manuals shall contain all information necessary for the operation, maintenance, replacement, installation, and parts procurement for the entire EMS. This documentation shall include specific part numbers and software versions and dates. A complete list of recommended spare parts shall be included with the lead-time and expected frequency of use of each part clearly identified.

B. Following project completion and testing, the EMS contractor will submit as-built drawings reflecting the exact installation of the system. The as-built documentation shall also include a copy of all application software both in written form and on CD.

1.11 WARRANTY

A. The EMS contractor shall warrant the system for 12 months after system acceptance and beneficial use by the owner. During the warranty period, the EMS contractor shall be responsible for all necessary revisions to the software as required to provide a complete and workable system consistent with the letter and intent of the Sequence of Operation section of the specification.

B. Updates to the manufacturer's software shall be provided at no charge during the warranty period.

PART 2 - PRODUCTS

2.1 SYSTEM ARCHITECTURE

A. The Energy Management System shall consist of Network Control Units (NCUs), a family of Standalone Digital Control Units (SDCUs), and Input/Output Unit Modules (IOU Modules). The EMS shall provide control, alarm detection, scheduling, reporting and information management for the entire facility, and Wide Area Network (WAN) from a single ODBC-compliant dataBASe.

B. Level 1 Network Description

1. Level 1, the main backbone of the system, shall be an Ethernet LAN/WAN. Network Control Units, Operator Workstations, and the Central File Server shall connect directly to this network without the need for Gateway devices. (Not required).

C. Level 2 Network Description

1. Level 2 of the system shall consist of one or more field buses managed by the Network Control Units. The Level 2 field buses may consist of one or both of the following types:

2. An RS485, token passing bus that supports up to 127 Standalone Digital Control Units (SDCUs) for operation of HVAC equipment, lighting, access controls or an RS485 field bus that supports up to 32 devices from a family of plug-in, IOU modules. These IOU modules may be mounted within the NCU enclosure or remotely mounted via a single, twisted, shielded pair of wires.

D. EMS

1. The EMS shall be capable of being segmented, through software, into multiple local area networks (LANs) distributed over a wide area network (WAN), sharing a single file server. This enables workstations to manage a single LAN (or building), and/or the entire system with all devices being assured of being updated by and sharing the most current dataBASe. In the case of a single workstation system, the workstation shall contain the entire dataBASe – with no need for a separate file server.

E. Remote Communications

1. An RS485, token passing bus that supports up to 127 Standalone Digital Control Units (SDCUs) for operation of HVAC equipment, lighting, access controls or an RS485 field bus that supports up to 32 devices from a family of plug-in, IOU modules.

F. System Expansion

1. The EMS system shall be scalable and expandable at all levels of the system using the same software interface, and the same Level 1 and Level 2 controllers. Systems that require replacement of either the workstation software or field controllers in order to expand the system shall not be acceptable.

2. The EMS shall be expandable to include Security and Access Control functions at any time in the future with no additional workstations, front-end software or Level 1 controllers required. Standalone Digital Control Units or IOU modules shall be able to be added to the existing Level 1 controller's field bus(es), to perform security and card access applications. In this way, a Owner's existing investment in wiring infrastructure may be leveraged and the cost and inconvenience of adding new field bus wiring will be minimized.

3. Additionally, an integrated video badging option must be able to be included with no additional workstations required. This photo ID option must share the same dataBASe as the EMS in order to eliminate the need for updating multiple dataBASE.

4. The system shall use the same application programming language for all levels: Operator Workstation, Network Control Unit, Remote Site Control Unit and Standalone Digital Control Unit. Furthermore, this single programming language shall be used for all applications: environmental control, card access control, intrusion detection and security, lighting control, leak detection / underground storage tank monitoring, and digital data communication interfaces to third party microprocessor-EMS devices.

G. Support for Open Systems Protocols

1. The EMS design must include solutions for the integration of the following "open systems" protocols: BACnet and digital data communication to third party

microprocessors such as chiller controllers, fire panels and variable frequency drives (VFDs).

2. The system shall also provide the ability to program custom ASCII communication drivers that will reside in the NCU, for communication to third party systems and devices. These drivers will provide real time monitoring and control of the third party systems.

H. Network Control Units (NCUs)

1. General
   a. Network Control Units shall be microprocessor EMS, multi-tasking, multi-user, and employ a real time operating system. Each NCU control panel shall consist of modular hardware including power supply, CPU board, and input/output modules. A sufficient number of NCUs shall be supplied to fully meet the requirements of this specification.

I. Hardware Specifications

1. Memory:
   a. A minimum of 4MB of RAM shall be provided for NCUs with expansion up to 8MB. The 8MB versions shall include a floating-point math co-processor.

2. Communication Ports:
   a. Each NCU shall provide communication to both the Workstation(s) (if applicable) and the field buses. In addition, each NCU must have at least 3 other communications ports that support a telephone modem, portable service tool, serial printer and connection to third party controllers such as a chiller control panel. On a LAN/WAN system the NCU shall be provided with a 10/100 Mbps plug-in Ethernet TCP/IP network interface card (NIC).

3. Input/Output (I/O):
   a. Each NCU shall support the addition of the following types of inputs and outputs:
      1) Digital Inputs for status/alarm contacts
      2) Counter Inputs for summing pulses from meters.
      3) Thermistor inputs for measuring temperatures in space, ducts and thermowells.
      4) Analog inputs for pressure, humidity, flow and position measurements.
      5) Digital Outputs for on/off equipment control.
      6) Analog Outputs for valve and damper position control, and capacity control of primary equipment.

J. Modular Expandability:

1. The system shall employ a modular I/O design to allow easy expansion. Input and output capacity is to be provided through plug-in modules of various types or DIN-mountable IOU modules. It shall be possible to combine I/O modules as desired to meet the I/O requirements for individual control applications.

K. Hardware Override Switches:

1. All digital output units shall include three position manual override switches to allow selection of the ON, OFF, or AUTO output state. These switches shall be built into the unit and shall provide feedback to the controller so that the position of the override switch can be obtained through software. In addition each analog output shall be equipped with an override potentiometer to allow manual adjustment of the analog output signal over its full range, when the 3 position manual override switch is placed in the ON position.

L. Local Status Indicator Lamps:

1. Provide as a minimum LED indication of CPU status, Ethernet LAN status, and field bus status. For each output, provide LED indication of the value of the output (On/Off). For each output module provide an LED which gives a visual indication of whether any outputs on the module are manually overridden.

M. Real Time Clock (RTC):

1. Each NCU shall include a battery-backed, real time clock, accurate to 10 seconds per day. The RTC shall provide the following: time of day, day, month, year, and day of week. In normal operation the system clock will be EMS on the frequency of the AC power. The system shall automatically correct for daylight savings time and leap years and be Year 2000 compliant.

N. Power Supply:

1. The power supply for the NCUs shall be auto sensing, 120-220VAC, 60/50 Hz power, with a tolerance of +/- 20%. Line voltage below the operating range of the system shall be considered outages. The controller shall contain over voltage surge protection, and require no additional AC power signal conditioning. Optionally, if indicated on the drawings, the power supply shall accept an input voltage of (–48 VDC).

O. Automatic Restart After Power Failure:

1. Upon restoration of power after an outage, the ECU shall automatically and without human intervention: update all monitored functions; resume operation EMS on current, synchronized time and status, and implement special start-up strategies as required.

P. Battery backup:

1. Each NCU with the standard 120-220VAC power supply shall include a programmable DC power backup system rated for a minimum of 72 hours of battery backup to maintain all volatile memory or, a minimum of 2 hours of full UPS including modem power. This power backup system shall be configurable such that at the end of a settable timeframe (such as 1 hour) of running on full UPS, the unit will shut off full UPS and switch to memory retention-only mode for the remainder of the battery power. The system shall allow the simple addition of more batteries to extend the above minimum battery backup times.

Q. Software Specifications

1. General
   a. The NCU shall contain flash ROM as the resident operating system. Application software will be RAM resident. Application software will only be limited by the amount of RAM memory. There will be no restrictions placed on the type of application programs in the system. Each NCU shall be capable of parallel processing, executing all control programs simultaneously. Any program may affect the operation of any other program. Each program shall have the full access of all I/O facilities of the processor. This execution of control function shall not be interrupted due to normal user communications including interrogation, program entry, printout of the program for storage, etc.

2. User Programming Language:
   a. The application software shall be user programmable. This includes all strategies, sequences of operation, control algorithms, parameters, and set points. The source program shall be English language-EMS and programmable by the user. The language shall be structured to allow for the easy configuration of control programs, schedules, alarms, reports, telecommunications, local displays, mathematical calculations, passwords, and histories. The language shall be self-documenting. Users shall be able to place comments anywhere in the body of a program. Program listings shall be configurable by the user in logical groupings.

3. Control Software:
   a. The NCU shall have the ability to perform the following pre-tested control algorithms:
      1) Proportional, Integral plus Derivative Control (PID)
      2) Self Tuning PID
      3) Two Position Control
      4) Digital Filter
      5) Ratio Calculator
      6) Equipment Cycling Protection
      7) Mathematical Functions:
         a) Each controller shall be capable of performing BASic mathematical functions (+, -, *, /), squares, square roots, exponential, logarithms, Boolean logic statements, or combinations of both. The controllers shall be capable of performing complex logical statements including operators such as >, <, =, and, or, exclusive or, etc. These must be able to be used in the same equations with the mathematical operators and nested up to five parentheses deep.
      8) Energy Management Applications:
         a) NCUs shall have the ability to perform any or all of the following energy management routines:
            i) Time of Day Scheduling
            ii) Calendar BASed Scheduling
            iii) Holiday Scheduling
            iv) Temporary Schedule Overrides
            v) Optimal Start
            vi) Optimal Stop
            vii) Night Setback Control
            viii) Dry-bulb Switchover (Economizer)
            ix) Peak Demand Limiting
            x) Temperature Compensated Duty Cycling
            xi) CFM Tracking
            xii) Heating/Cooling Interlock
            xiii) Hot/Cold Deck Reset
            xiv) Free Cooling
            xv) History Logging
      9) Each controller shall be capable of logging any system variable over user defined time intervals ranging from 1 second to 1440 minutes. Any system variables (inputs, outputs, math calculations, flags, etc.) can be logged in history. A maximum of 32767 values can be stored in each log. Each log can record either the instantaneous, average, minimum or maximum value of the point. Logs can be automatic or manual. Logged data shall be downloadable to the Operator Workstation for long term archiving BASed upon user-defined time intervals, or manual command.
      10) Alarm Management:
         a) For each system point, alarms can be created BASed on high/low limits or conditional expressions. All alarms will be tested each scan

of the NCU and can result in the display of one or more alarm messages or reports.

b) Up to 8 alarms can be configured for each point in the controller.

c) Messages and reports can be sent to a local or remote, to the front-end workstation(s), or individual email boxes, or pager systems.

d) Alarms will be generated BASed on their priority. A minimum of 255 priority levels shall be provided.

e) If communication with the Operator Workstation is temporarily interrupted, the alarm will be buffered in the NCU. When communications return, the alarm will be transmitted to the Operator Workstation if the point is still in the alarm condition.

11) Reporting:

a) The NCU shall be able to generate user-definable reports to a locally connected printer or terminal. The reports shall contain any combination of text and system variables. Report templates shall be able to be created by user's in a word processing environment. Reports can be displayed BASed on any logical condition or through a user command.

2.2 STANDALONE DIGITAL CONTROL UNITS (SDCUS)

A. General:

1. Standalone Digital Control Units shall provide control of HVAC and lighting (if required). Each controller shall have its own control programs and will continue to operate in the event of a failure or communication loss to its associated NCU.

B. Memory:

1. Control programs shall be stored in battery backed-up RAM and EPROM. Each controller shall have a minimum of 32K bytes of user RAM memory and 128K bytes of EPROM.

C. Communication Ports:

1. SDCUs shall provide a communication port to the field bus. In addition, a port shall be provided for connection of a portable service tool to support local commissioning and parameter changes with or without the NCU online. It shall be possible from a service port on any SDCU to view, enable/disable, and modify values of any point or program on any controller on the local field bus, any NCU or any SDCU on a different field bus.

D. Input/Output:

1. Each SDCU shall support the addition of the following types of inputs and outputs:
   a. Digital Inputs for status/alarm contacts
   b. Counter Inputs for summing pulses from meters.
   c. Thermistor Inputs for measuring temperatures in space, ducts and thermowells.
   d. Analog inputs for pressure, humidity, flow and position measurements.
   e. Digital Outputs for on/off equipment control.
   f. Analog Outputs for valve and damper position control, and capacity control of primary equipment.

E. Expandability:

1. Input and output capacity shall be expandable through the use of plug-in modules. A minimum of two modules shall be added to the BASe SDCU before additional power is required.

F. Networking:

1. Each SDCU will be able to exchange information on a peer to peer BASis with other Standalone Digital Control Units during each field bus scan. Each SDCU shall be capable of storing and referencing global variables (on the LAN) with or without any workstations online. Each SDCU shall be able to have its program viewed and/or enabled/disabled either locally through a portable service tool or through a workstation connected to an NCU.

G. Indicator Lamps:

1. SDCUs will have as a minimum, LED indication of CPU status, and field bus status.

H. Real Time Clock (RTC):

1. An SDCU shall have a real time clock in either hardware or software. The accuracy shall be within 10 seconds per day. The RTC shall provide the following information: time of day, day, month, year, and day of week. Each SDCU shall receive a signal, every hour, over the network from the NCU which synchronizes all SDCU real time clocks.

I. Automatic Restart After Power Failure:

1. Upon restoration of power, the SDCU shall automatically and without human intervention, update all monitored functions, resume operation BASed on current, synchronized time and status, and implement special start-up strategies as required.

J. Battery Back Up:

1. Each SDCU shall have at least 3 years of battery back up to maintain all volatile memory.

K. Alarm Management:

1. For each system point, alarms can be created BASed on high/low limits or conditional expressions. All alarms will be tested each scan of the SDCU and can result in the display of one or more alarm messages or reports.

2. Up to 8 alarms can be configured for each point in the controller enabling the escalation of the alarm priority (urgency) BASed upon which alarm(s) is/are triggered.

3. Alarm messages can be sent to a local terminal or modem connected to an NCU or to the Operator's Workstation(s).

4. Alarms will be generated BASed on their priority. A minimum of 255 priority levels shall be provided.

5. If communication with the NCU is temporarily interrupted, the alarm will be buffered in the SDCU. When communications return, the alarm will be transmitted to the NCU if the point is still in the alarm condition.

L. Unitary Controllers

1. Unitary Controllers shall support, but not be limited to, the control of the following systems as described in the Execution portion of this specification, and for future expansion:
   a. Unit Ventilators

b. Heat Pumps (Air to Air, Water to Water)
c. Packaged Rooftops
d. Fan Coils (2 or 4 Pipe)
e. The I/O of each Unitary Controller shall contain the sufficient quantity and types as required to meet the sequence of operation found in the Execution portion of this specification. In addition, each controller shall have the capability for time of day scheduling, occupancy mode control, after hour operation, lighting control, alarming, and trending.

M. Display Controllers

1. Display controllers are standalone, touch screen BASed operator interfaces. The controller shall be designed for flush mounting in a finished space, with a minimum display size of 9 x 9 inches.

2. Software shall be user programmable allowing for custom graphical images that simulate floor plans, menus, equipment schematics along with associated real time point values coming from any NCU on the network.

3. The touch screen display shall contain a minimum of 64 possible touch cells that permit user interaction for changing screens, modifying set points or operating equipment.

4. Systems that do not offer a display controller as specified must provide a panel mounted computer with touch screen capability as an alternative.

2.3 DDC SENSORS AND POINT HARDWARE

A. Temperature Sensors

1. All temperature devices shall use precision thermistors accurate to +/- 1 degree F over a range of –30 to 230 degrees F. Space temperature sensors shall be accurate to +/- .5 degrees F over a range of 40 to 100 degrees F.

2. Standard space sensors shall be available in an off white enclosure for mounting on a standard electrical box.

3. Where manual overrides are required, the sensor housing shall feature both an optional sliding mechanism for adjusting the space temperature set point, as well as a push button for selecting after hours operation.

4. Where a local display is specified, the sensor shall incorporate either an LED or LCD display for viewing the space temperature, set point and other operator selectable parameters. Using built in buttons, operators shall be able to adjust set points directly from the sensor.

5. Duct temperature sensors shall incorporate a thermistor bead embedded at the tip of a stainless steel tube. Probe style duct sensors are useable in air handling applications where the coil or duct area is less than 14 square feet.

B. Averaging sensors shall be employed in ducts which are larger than 14 square feet. The averaging sensor tube must contain at least one thermistor for every 3 feet, with a minimum tube length of 12 feet.

C. Immersion sensors shall be employed for measurement of temperature in all chilled and hot water applications as well as refrigerant applications. Thermal wells shall be brass or stainless

steel for non-corrosive fluids below 250 degrees F and 300 series stainless steel for all other applications.

D. A pneumatic signal shall not be allowed for sensing temperature.

PART 3 - EXECUTION

3.1 CONTRACTOR RESPONSIBILITIES

A. General

1. Installation of the Energy Management System shall be performed by the Contractor or a subcontractor. However, all installation shall be under the personal supervision of the Contractor. The Contractor shall certify all work as proper and complete. Under no circumstances shall the design, scheduling, coordination, programming, training, and warranty requirements for the project be delegated to a subcontractor.

B. Code Compliance

1. All wiring shall be installed in accordance with all applicable electrical codes and will comply with equipment manufacturer's recommendations. Should any discrepancy be found between wiring specifications in Division 16 and this specification, wiring requirements of this section will prevail.

C. Cleanup

1. At the completion of the work, all equipment pertinent to this contract shall be checked and thoroughly cleaned, and all other areas shall be cleaned around equipment provided under this contract. Clean the exposed surfaces of tubing, hangers, and other exposed metal of grease, plaster, or other foreign materials.

3.2 WIRING, CONDUIT, TUBING AND CABLE

A. All wire will be copper and meet the minimum wire size and insulation class listed below:

Wire Class	Wire Size	Isolation Class
Power	12 Gauge	600 Volt
Class One	14 Gauge Std.	600 Volt
Class Two	18 Gauge Std.	300 Volt
Class Three	18 Gauge Std.	300 volt
Communications	Per Mfr.	Per Mfr.

B. Power and Class One wiring may be run in the same conduit. Class Two and Three wiring and communications wiring may be run in the same conduit.

C. Where different wiring classes terminate within the same enclosure, maintain clearances and install barriers per the National Electric Code.

D. Where wiring is required to be installed in conduit, EMT shall be used. Conduit shall be minimum 1/2 inch galvanized EMT. Set screw fittings are acceptable for dry interior locations.

Watertight compression fittings shall be used for exterior locations and interior locations subject to moisture. Provide conduit seal off fitting where exterior conduits enter the building or between areas of high temperature/moisture differential.

E. Flexible metallic conduit (max. 3 feet) shall be used for connections to motors, actuators, controllers, and sensors mounted on vibration producing equipment. Liquid-tight flexible conduit shall be use in exterior locations and interior locations subject to moisture.

F. Junction boxes shall be provided at all cable splices, equipment termination, and transitions from EMT to flexible conduit. Interior dry location J-boxes shall be galvanized pressed steel, nominal four-inch square with blank cover. Exterior and damp location JH-boxes shall be cast alloy FS boxes with threaded hubs and gasketed covers.

G. Where the space above the ceiling is a supply or return air plenum, the wiring shall be plenum rated. Teflon wiring can be run without conduit above suspended ceilings. EXCEPTION: Any wire run in suspended ceilings that is used to control outside air dampers or to connect the system to the fire management system shall be in conduit.

3.3 HARDWARE INSTALLATION

A. Installation Practices for Wiring and Tubing

B. All controllers are to be mounted vertically and per the manufacturer's installation documentation.

C. The 120VAC power wiring to each Ethernet or Remote Site controller shall be a dedicated run, with a separate breaker. Each run will include a separate hot, neutral and ground wire. The ground wire will terminate at the breaker panel ground. This circuit will not feed any other circuit or device.

D. A true earth ground must be available in the building. Do not use a corroded or galvanized pipe, or structural steel.

E. Wires are to be attached to the building proper at regular intervals such that wiring does not droop. Wires are not to be affixed to or supported by pipes, conduit, etc.

F. Conduit's are required in areas where wiring is susceptible to damage.

G. Conduit required, in non-finished areas where possible, will be concealed in ceiling cavity spaces, plenums, furred spaces, and wall construction.

H. Wires are to be kept a minimum of three (3) inches from hot water, steam, or condensate piping.

I. Where sensor wires leave the conduit system, they are to be protected by a plastic insert.

J. Wire or pneumatic tubing will not be allowed to run across telephone equipment areas.

K. Installation Practices for Field Devices

1. Well-mounted sensors will include thermal conducting compound within the well to insure good heat transfer to the sensor.

2. Actuators will be firmly mounted to give positive movement and linkage will be adjusted to give smooth continuous movement throughout 100 percent of the stroke.

3. Relay outputs will include transient suppression across all coils. Suppression devices shall limit transients to 150% of the rated coil voltage.

4. Water line mounted sensors shall be removable without shutting down the system in which they are installed.

5. For duct static pressure sensors, the high pressure port shall be connected to a metal static pressure probe inserted into the duct pointing upstream. The low pressure port shall be left open to the plenum area at the point that the high pressure port is tapped into the ductwork.

6. For building static pressure sensors, the high pressure port shall be inserted into the space via a metal tube. Pipe the low pressure port to the outside of the building.

L. Enclosures

1. For all I/O requiring field interface devices, these devices where practical will be mounted in a field interface panel (FIP). The Contractor shall provide an enclosure which protects the device(s) from dust, moisture, conceals integral wiring and moving parts.

2. FIPs shall contain power supplies for sensors, interface relays and contactors, safety circuits, and I/P transducers.
   a. The FIP enclosure shall be of steel construction with baked enamel finish, NEMA 1 rated with a hinged door and keyed lock. The enclosure will be sized for twenty percent spare mounting space. All locks will be keyed identically.
   b. All wiring to and from the FIP will be to screw type terminals. Analog or communications wiring may use the FIP as a raceway without terminating. The use of wire nuts within the FIP is prohibited.
   c. All outside mounted enclosures shall meet the NEMA-4 rating.
   d. The tubing and wiring within all enclosures shall be run in plastic track. Wiring within controllers shall be wrapped and secured.
   e. Identification
      1) Identify all control wires with labeling tape or sleeves using either words, letters, or numbers that can be exactly cross-referenced with as-built drawings.
      2) Identify all pneumatic tubing with labeling tape or sleeves using either words, letters, or numbers that can be exactly cross referenced with as-built drawings.
      3) All field enclosures, other than controllers, shall be identified with a bakelite nameplate. The lettering shall be in white against a black or blue background.
      4) Junction box covers will be marked to indicate that they are a part of the EMS system.
      5) All I/O field devices (except space sensors) that are not mounted within FIP's shall be identified with name plates.
      6) All I/O field devices inside FIP's shall be labeled.

3. Location
   a. The location of sensors is per mechanical and architectural drawings.
   b. Space humidity or temperature sensors will be mounted away from machinery generating heat, direct light and diffuser air streams.
   c. Outdoor air sensors will be mounted on the north building face directly in the outside air. Install these sensors such that the effects of heat radiated from the building or sunlight is minimized.

d. Field enclosures shall be located immediately adjacent to the controller panel(s) to which it is being interfaced.

3.4 SOFTWARE INSTALLATION

A. General

1. The Contractor shall provide all labor necessary to install, initialize, start-up and debug all system software as described in this section. This includes any operating system software necessary for successful operation of the system.

B. DataBASe Configuration

1. The Contractor will provide all labor to configure those portions of the dataBASe that are required by the points list and sequence of operation.

C. Documentation

1. As built software documentation will include the following:
   a. Descriptive point lists
   b. Application program listing
   c. Application programs with comments.
   d. Printouts of all reports.

2. Alarm list.
   a. Printouts of all graphics

3. Commissioning and System Startup

D. Point to Point Checkout:

1. Each I/O device (both field mounted as well as those located in FIPs) shall be inspected and verified for proper installation and functionality. A checkout sheet itemizing each device shall be filled out, dated and approved by the Project Manager for submission to the Owner or Owner's representative.

E. Controller and Graphical Checkout:

1. A field checkout of all controllers and front end equipment (computers, printers, modems, etc.) shall be conducted to verify proper operation of both hardware and software. A checkout sheet itemizing each device and a description of the associated tests shall be prepared and submitted to the Owner or Owner's representative by the completion of the project.

F. System Acceptance Testing:

1. All application software will be verified and compared against the sequences of operation. Control loops will be exercised by inducing a set point shift of at least 10% and observing whether the system successfully returns the process variable to set point. Record all test results and attach to the Test Results Sheet.

2. Test each alarm in the system and validate that the system generates the appropriate alarm message, that the message appears at all prescribed destinations (workstations or printers), and that any other related actions occur as defined (i.e. graphic panels are invoked, reports are generated, etc.). Submit a Test Results Sheet to the Owner.

3. Perform an operational test of each unique graphic display and report to verify that the item exists, that the appearance and content are correct, and that any special features work as intended. Submit all Test Results Sheet to the Owner.

END OF SECTION 15900

SECTION 15960
VARIABLE FREQUENCY DRIVES (VFD)

PART 1 - GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, Division 1 - General Requirements, and Section 15050 - Basic Materials and Methods, and other Sections in Division 15 specified herein.

1.2 SCOPE

A. Furnish complete and operational VFD systems as shown on the plans. All work to be furnished and installed under this Section shall comply with all the requirements of Division 1, and shall include, but not necessarily be limited to, the following:

1. Variable frequency drives (VFDs).

2. Controls and control connections.

3. Electrical power connections.

1.3 RELATED WORK IN OTHER SECTIONS

A. Section 15050: Basic Materials and Methods

B. Section 15734: Make-Up Air Units

C. Section 15900: Controls and Instrumentation

D. Section 15990: Testing, Adjusting and Balancing

E. Electrical: Coordination of interface items between the Mechanical equipment and controls and the Electrical Work specified in Division 16.

1.4 QUALITY ASSURANCE

A. Supplier of VFD shall be solely responsible for assuring that the VFD shall work properly with the motor(s) being controlled. VFD supplier shall provide all materials and labor required to replace motors, bearing, shafts, etc. that may be incompatible with VFD or become damaged by VFD at no additional cost to the owner. VFD supplier shall reimburse Architect and Engineer at their standard hourly rates for their involvement in resolving failures due to their VFDs.

B. Manufacturer shall have a minimum of 15 years experience building similar equipment for controlling the speed for induction motors and at least one hundred successful installations with a variety of VFD sizes and applications.

C. To insure quality and minimize failures the VFD(s) and connected motor(s) shall be by one manufacturer. To reduce the known problem of bearing failures by "fluting" the VFD switching rates shall be 6-8 Khz wherever possible. Manufactured VFDs at switching rates of 12-15 Khz shall be accompanied by an additional extended warranty to cover bearings and motors to a period of ten (10) years. Should it be impossible to provide matched motor and VFD's provide a shaft grounding system for the driven motor. Acceptable manufacturer is Shaft Grounding Systems in Albany, Oregon (Representative: DP&A Sales 541-997-4068) or Aegis Shaft Grounding Ring (www.est-aegis.com/cse)

D. To insure quality and minimize infantile failures at the job site, the VFD shall be burned in at the factory at an ambient of 104°F minimum for at least 8 hours. The VFD shall be operating a dynamometer and the load speed shall be cycled during the test. All optional and special features shall be functionally tested at the factory for proper operation.

E. Codes and Standards: Provide VFDs conforming to the requirements of the latest addition of the following:

1. ANSI/EIA 508Electrical Performance Standards for Television Broadcast Transmitters.

2. UL508. all VFD equipment provided under this section must be labeled as UL508 approved.

3. ANSI/IEEE 518Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources.

4. ANSI/IEEE 519-1992: IEEE Recommended Practices and Requirements for Harmonic Control in Electrical power systems.

1.5 SUBMITTALS

A. Prior to construction submit for approval the following materials:

1. VFD supplier shall provide reference list showing at least ten years of prior manufacturing experience in production of VFDs and a list of at least twenty successful installations with a variety of VFD sizes and applications.

2. Manufacturer's data, installation instructions, and maintenance and operational instructions for variable frequency drives. Indicate electrical service and special requirements. Include manufacturer's descriptive literature, repair data, and parts listing.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver units to the site in containers with manufacturer's stamp or label affixed.

B. Protect units against dirt, water, chemical, and mechanical damage. Do not install damaged units. Remove damaged equipment from site.

1.7 WARRANTY

A. Provide two-year (24 months) warranty under provisions of Division 1. Provide extended ten (10) year warranty on motors and bearings as described above, if applicable. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. ABB, Reliance, or approved equal by Mitsubishi Electric, Square D, Safetronics, Toshiba, Yaskawa, Danfoss-Graham, or Allen-Bradley. Connected motors should be by the same manufacturer whenever possible.

2.2 GENERAL

A. Furnish a complete VFD as scheduled on the plans. Each fan or pump motor shall have a dedicated VFD unit. All standard and optional features shall be included within the VFD enclosure unless otherwise specified. The VFD enclosure shall be provided to match the environment requirements where the VFD will be mounted and operated. Provide NEMA rated enclosure as required.

B. The adjustable frequency controller shall convert three-phase, 60 Hz utility power to adjustable voltage and frequency, three-phase, AC power for stepless motor speed control from 10% to 100% of the motor's 60 Hz speed.

C. The VFD shall include a converter and an inverter section. The converter section shall convert fixed frequency and voltage AC utility power to a DC voltage. Drive shall utilize a single surface mount micro-processor.

D. The VFD shall be of the pulse width modulation (PWM) type. VFDs shall be provided with an advanced flux vector frequency control to limit noise at drive and motor.

E. Drive manufacturer or sales representative shall evaluate electrical system of the project. Any additional protective equipment such as line filters, reactors or input isolation transformers required to prevent interference from drive with other electrical equipment in the building shall be included as part of the bid. No additional expense shall be incurred by Owner for provision or installation of these devices if required for electrical system operation after drive has been purchased. Units shall include factory mounted input line reactors.

F. The VFD maximum output current rating shall be 110% of the motor nameplate full load current. VFD shall be able to start into a rotating load in either direction without trip.

G. The VFD and options shall be tested to ASNI/EIA Standard 508 and listed by a nationally recognized testing agency such as UL or ETL.

H. The VFD and options shall comply with the applicable requirements of the latest standards of ANSI, IEEE, and the National Electrical Code.

I. Power line noise shall be limited to a voltage distortion factor and line notch depth as defined in ANSI/IEEE Standard 519.

J. The drive efficiency shall be 97% (minimum) and have a fundamental power factor of 0.98 at all speeds.

2.3 BASIC FEATURES

A. The VFD shall be housed in a NEMA enclosure appropriate to the mounting location.

1. NEMA 12 enclosure shall be used for dusty locations, plenum mechanical rooms, penthouses, or air stream mounting.

2. NEMA 3R is required for all locations exposed to falling rain, snow or ice or to indoor locations subject to falling water.

3. If NEMA 1 enclosure is suitable it shall be louvered, vented through cabinet using a removable louver/filter, and equipped with an integral cooling fan with thermostat control, and arranged so that units can be mounted back to back on a frame and/or side to side on a wall. Venting fans shall be supplied in enclosure if required. If a different NEMA enclosure is indicated the enclosure shall provide means of maintaining the drive at temperature acceptable to the drive manufacturer in exterior ambient temperatures. Enclosure shall be complete with no requirements for low voltage wiring. Factory mounted main circuit breaker disconnect shall be included.

B. The following operator controls shall be located on the front of the enclosure:

1. Door mounted operator digital controls consisting of auto/manual switch, start/stop switch with reset and manual speed control. In the auto position, the drive will start/stop from a remote contact closure and motor speed is determined by the follower signal. In the manual position, motor speed is determined by manual speed selection. Manual potentiometers are not acceptable.

2. Power on pilot light to indicate that the VFD is being supplied by the power line.

3. Fault digital display to indicate that the VFD has tripped on a fault condition. The drive shall retain in memory the last three (3) fault conditions that caused the drive to trip. Indication should include but not be limited to the following: Under voltage, over voltage, overcurrent, over temperature, phase loss, phase imbalance and external trip.

4. Digital display to indicate voltage, current, frequency or RPM. Selectable by the operator while the VFD is running.

C. VFD shall be provided with two (2) each form C dry contacts for indication of run and fault starters. In addition each drive shall have an analog output signal 0 to 10_{VDC} (or $4\text{-}20_{MA}$)to indicate drive speed (percent of full load).

D. While in the remote mode, the VFD will attempt at least five (5) restarts after a power outage, drive fault or external fault before requiring manual reset. After ten minutes of runtime, the restart attempts return to zero. The VFD shall display a countdown timer when auto restart is being attempted, or incorporate programming to select number of restarts, number of faults per time period, and time between restarts.

2.4 PROTECTIVE FEATURES

A. Protection against input transient voltage spikes.

B. Overload protection for the motor. If power input or output is interrupted while the control is in operation, no damage shall result. The unit shall be able to operate without any equipment connected to the inverter output. The drive must protect itself against all phase-to-phase short circuits and ground faults.

C. Protection against input power undervoltage, overvoltage and phase loss.

D. Protection against output current overload and overcurrent.

E. Protection against over-temperature within the VFD enclosure.

F. Protection against overvoltage on the DC bus.

G. Drive shall have an auxiliary contact to permit a remote trip.

H. DC bus discharge circuit and warning light for protection of service personnel or meet UL requirements for DC bus discharge.

I. Drive shall be capable of operating and insensitive to imbalance or out-of-rotation incoming power phase.

J. Lockable main fused input disconnect shall be factory mounted as specified on the drawings or as required by the application.

2.5 ADJUSTMENTS

A. Maximum speed, adjustable to 100% base speed.

B. Minimum speed, adjustable to 10% base speed.

C. Acceleration time, adjustable 1 to 360 seconds (minimum) factory set at 20 seconds.

D. Deceleration time, adjustable 1 to 360 seconds (minimum) factory set at 20 seconds.

E. Current limit, adjustable 50 to 110%.

F. Adjustable speed lock-outs for three (3) operating ranges.

G. Capable of following $0\text{-}5_{MA}$, $4\text{-}20_{MA}$, $10\text{-}50_{MA}$, $0\text{-}4_{VDC}$, $0\text{-}8_{VDC}$, $0\text{-}10_{VDC}$ grounded or ungrounded signal as required to interface with the building control system.

2.6 SERVICE CONDITIONS

A. The VFD shall be designed to operate within the following service conditions:

1. Ambient temperature, 29°F-104°F.

2. Relative humidity, 5-95%, non-condensing.

3. Elevation to 3,300 feet without derating.

4. AC line voltage variation, -10% to +10% of nominal.

2.7 SPECIAL FEATURES

A. All control wiring, and accessories shall be factory installed in the drive casing so that only the connection of the remote auxiliary start/stop and override contacts is required to provide override control as described above.

B. All drives shall be equipped with fail safety speed control (adjustable 20-100%), factory installed and wired, that operates as follows: If the drive is on (in either normal or override mode) and no signal is detected from the building control system, the drive shall operate at a preset adjustable speed. On resumption of the building control system signal, the drive shall operate as normal. Fail safe speed shall be adjusted through digital keyboard mounted on the outside drive cabinet.

C. Drives shall be protected with input line reactors factory mounted.

D. Provide drive with a communications board enabling it to communicate with the building management system (BMS) over a serial RS-485 interface or with a BACNET, LonWorks, Modbus, Profibus or BMS proprietary interface.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Verify that mounting surface is ready to receive work. Mount the VFD(s) on the wall or at supports. Provide a layout drawing of VFD locations to electrical installer.

B. If the disconnect for the equipment powered by the VFD is in a location where it is probable that it will be placed in an off position prior to shutting down the VFD, the contractor is to provide electrical protection for the VFD. This may be in the form of a conduit and wire interlock between disconnect

and drive or internal protection integral to the VFD.

C. Coordinate wiring and control with Control Contractor. Control installers shall install all wiring associated with control signals into the VFD and for interlock control wiring between disconnects and VFDs.

D. Electrical installer shall install all line voltage power wiring and conduit from electrical switchgear and from the VFD to the disconnect at the controlled motor. The only exception to this is when the motor and drive are factory installed on a packaged piece of equipment. In that case the wiring from drive to motor is to be installed in the factory to meet the requirements herein. Coordinate with Division 16 work.

E. Line length between VFD and driven motor shall be as short as possible. Line length shall not exceed twenty (20) feet without prior approval from Engineer.

F. Input and output power wiring shall be installed in separate grounded conduit. In addition, control wiring shall be installed in its own separate grounded conduit.

G. Use symmetric motor cable between the VFD and motor, with low inductance shield or conduit, and with all joints joined with bonding straps. MC metal clad 3 phase type cable per NEC 334-1, UL approved, 3 phase conductors and 3 ground conductors. Sheath to be continuous corrugated aluminum. Manufacturer and type to be BICC 2 kV rated Drives Cable, Anixter series 7V, or approved equal.

H. Use cable connectors with 360 degree connections to the armor conduit at both ends of motor cable. Verify electrical path from inverter cabinet entry plate to armor / conduit to motor terminal box.

I. Install an auxiliary high frequency bonding connection for potential equalization between VFD frame and building steel.

J. Unless absolutely necessary do not install disconnect between VFD and connected motor. VFD is to be furnished with a lockable disconnect.

K. Installation in "Fan Wall " Air Handlers: When a single VFD supplies multiple fans, assemble and prewire units at the factory, installing conduit and conductors between the fan motor, VFD, and terminal strips. Wiring from the VFD output terminals to the fan motor shall be Belden VFD Cable installed in conduit (295XX Series).

3.2 MANUFACTURER'S START-UP SERVICES

A. The manufacturer shall provide start-up service in the form of a factory trained service technician. The service technician shall verify correct installation, verify control wiring, verify power wiring, start-up the drive, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Harmonic test with scope shall be also performed at the job site and results submitted to the Owner's Representative. Fully staffed parts and service personnel shall be within four hours travel from the jobsite.

B. Carrier Frequency Set up:

1. Set initial carrier frequency at 2 kHz.

2. Manually raise VFD speed output from 10 Hz to 60 Hz by 10 Hz increments, allowing at least 15 seconds between each adjustment. If excessive motor noise is heard at any speed, raise carrier frequency by 2 kHz increments until motor noise is no longer excessive. Do not set carrier frequency higher than 10 kHz.

3. If excessive motor noise continues to be heard at or below 10 kHz, inform owner. If the motor is provided by the VFD manufacturer, either repair, replace, or provide 5 year extended warranty on the effected motor.

C. Lockout of resonant frequencies:

1. With carrier frequency set per the above specification, manually and slowly raise VFD speed output from 10 Hz to 60 Hz by 1 Hz increments. If excessive motor, frame, or driven load noise is heard at any speed, lock out that frequency.

2. Each frequency skip shall be programmed with as narrow a bandwidth as possible, while still avoiding the most objectionable range of resonant frequencies. Each frequency skip bandwidth shall not exceed 5 Hz without approval by Engineer.

D. Training:

1. Provide 1 hour training session to the owner's representative.

2. Training to include
   a. Demonstration of operation of bypass switch and door-mounted disconnect switches. Explain emergency operation.
   b. Demonstrate operation of operator keypads for viewing data and setting parameters.
   c. Demonstrate operation in manual mode, including setting of specific speeds.
   d. Explain the drive parameters that might require operator adjustment.
   e. Describe troubleshooting techniques and warranty procedure.

END OF SECTION 15960

SECTION 15990
TESTING, ADJUSTING AND BALANCING

PART 1 GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, Division 1 - General Requirements, Section 15050 - Basic Materials and Methods, and other Sections in Division 15 specified herein.

1.2 WORK RELATED IN OTHER SECTIONS

A. Section 15050: Basic Materials and Methods

B. Section 15880: Air Distribution

C. Section 15900: Controls and Instrumentation

D. Division 16: Electrical.

1.3 SUMMARY

A. Scope: Extent of testing, adjusting and balancing work required by this Section is indicated on the drawings, in schedules, and by the requirements of this Section, and Section 15050 -Basic Mechanical Requirements.

B. Systems: Testing, adjusting and balancing specified in this Section shall include, but not be limited to, the following systems:

1. Air handling systems including supply, return and exhaust.

2. Air distribution ductwork including supply, return and exhaust.

3. Automatic temperature control system.

4. General exhaust systems.

5. Domestic hot water supply and return.

6. Instruction of Owner's personnel for future balancing of systems.

1.4 REFERENCE STANDARDS

A. ASHRAE-Standard 111--1988 Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air Conditioning, and Refrigeration Systems.

B. ASHRAE —2003 HVAC Applications Handbook: Chapter 37--Testing, Adjusting and Balancing.

C. AABC--National Standards for Total System Balance.

D. SMACNA--HVAC Systems--Testing, Adjusting and Balancing.

E. Sheet Metal Industry--Testing, Adjusting, Balancing Bureau (TABB) Certified Technician Standards, Procedures and Specifications.

F. American National Standards Institute (ANSI): Comply with the following:

1. S1.4Specification For Sound Level Meters.

2. S1.11Specification For Octave-Band and Fractional-Octave-Band Analog and Digital Filters.

1.5 QUALITY ASSURANCE

A. Contractors Qualifications: A specialist certified by the Associated Air Balance Council (AABC) with at least 5 years of experience in those testing, adjusting and balancing requirements similar to those required for this project, who is not the installer of the system to be tested and is otherwise independent of the project.

B. Testing, adjusting, and balancing shall be performed by a certified AABC technician under direct field supervision of a Certified AABC Supervisor.

C. Penalty: The Contractor shall submit the name of the organization he proposes to employ for approval within 30 days after contract award. If the Contractor fails to submit the name of an acceptable agency within the specified time, a firm may be selected to accomplish the work, and this selection shall be binding upon the Contractor at no additional cost.

D. Retainages: In addition to any other sums retained or withheld pursuant to the provisions of this Contract, the amount of dollars will be withheld from payments to the contractor until such time as the work has been completed and accepted. In no event will this amount be paid to the Contractor prior to 60 days following acceptance of the project; during such time, the Contractor shall investigate and correct any reported deficiencies unless such deficiencies are a result of unauthorized tampering by building occupants.

E. Calibration of Testing Instruments: All measurement instruments used for testing, adjusting, balancing, and commissioning shall be calibrated. The time between the most recent calibration data and the final test report date shall not be over 6 months

F. Testing and balancing agency, as part of its contract, shall act as authorized inspection agency responsible to Consulting Engineer and Owner, and shall list all items that are installed incorrectly, require correction, or have not been installed in accordance with contract Drawings and Specifications, pertaining to air distribution, cooling and heating systems. The testing and balancing agency is required to provide written reports of all deficiencies and proposed recommendations to the Owner' Representative, Contractor, Architect and Engineer.

G. The testing and balancing agency shall provide with his bid a performance guarantee covering all phases of the work as herein specified.

H. The General and mechanical contractors shall cooperate with the selected testing and balancing agency in the following manner:

1. Provide sufficient time before final completion dates so that tests and balancing can be accomplished.

2. The various system installers, suppliers and contractors shall provide all required materials, labor and tools to make corrections when required without undue delay. Install balancing dampers as required by testing and balancing agency.

3. The contractor shall put all heating, ventilating and air conditioning systems and equipment into full operation and shall continue the operation of the same during each working day of testing and balancing.

4. Testing and balancing agency shall be kept informed of any major changes made to the system during construction, and shall be provided with a complete set of Record Drawings.

5. The General Contractor shall make space and other facilities available to the testing and balancing agency to enable their work to progress. The General Contractor shall schedule the work of other trades to avoid conflicts with this work.

1.6 SUBMITTALS

A. Conform to the Submittals requirements of Division 1.

B. Forms: The Contractor shall deliver a complete copy of AABC standard forms for testing and balancing work associated with the project. These forms shall serve as specific guidelines for producing final test report. Hybrid or non-standards forms are not acceptable. Data shall include, but not be limited to, a title page with building information, instrument lists, air flows, water flows, temperatures, sound levels, capacities, nameplate data.

C. Test Reports: Provide six (6) certified test reports, signed by the test and balance supervisor who performed the work. The final reports shall include identification and types of instruments used, and their most recent calibration date, and key plans identifying all inlets and outlets. Final test reports shall be typed. Hand written reports are not acceptable.

D. Maintenance Data: Include, in maintenance manuals, copies of certified test reports and identification of instruments.

E. Qualifications: The Contractor shall submit the certified individual qualifications of all persons responsible for supervising and performing the actual work and the name of the certifying engineer. Provide a reference list of five (5) similar size projects with contact person and telephone number.

1.7 AGENDA

A. Agenda: A preliminary report and agenda shall be submitted and approved prior to the start of testing and balancing work.

1. Review plans and specifications prior to installation of any of the affected systems, and submit a report indicating any deficiencies in the systems that would preclude the proper adjusting, balancing, and testing of the systems.

2. The agenda shall include a general description of each air and water system with its associated equipment and operation cycles for heating and cooling.

3. The agenda shall include a list of all air and water flows to be performed at all mechanical equipment.

4. The agenda shall incorporate the proposed selection points for sound measurements, including typical spaces as well as sound sensitive areas such as conference rooms.

5. The agenda shall also include specific test procedures and parameters for determining specified quantities (e.g. flow, drafts, sound levels) from the actual field measurements to establish compliance with contract requirements. Samples of forms showing application of procedures and calculations to typical systems shall be submitted.

6. Specific test procedures for measuring air quantities at terminals shall specify type of instrument to be used, method of instrument application (by sketch) and factors for:
   a. Air terminal configuration.

b. Flow direction (supply or exhaust).
c. Velocity corrections.
d. Effective area applicable to each size and type of air terminal.
e. Density corrections.

7. The agenda shall include identification and types of measurement instruments to be used, and their most recent calibration date.

1.8 JOB CONDITIONS

A. General: Do not proceed with testing, adjusting and balancing work until the following conditions have been met.

1. Work has been completed and is operable. Ensure that there is no latent residual work yet to be completed on the tested equipment.

2. Work scheduled for testing, adjusting and balancing is clean and free from debris, dirt and discarded building materials.

3. All architectural openings (doors, windows, and other openings) which may affect the operation of the system to be tested, adjusted, and balanced shall be at their normal states.

4. All related mechanical systems which may affect the operation of the system to be tested, adjusted, and balanced shall be at their normal operating conditions.

PART 2 PRODUCTS

2.1 TEST HOLES

A. Test holes shall be provided in ducts, housings and pipes as necessary for the proper air and water measurements and to balance systems. At each location where ducts or plenums are insulated, test holes shall be provided with an approved extension with plug fitting.

2.2 PATCHING MATERIALS

A. Material: Seal, patch and repair ductwork, piping and equipment drilled or cut for testing purposes.

1. Plastic plugs with retainers may be used to patch drilled holes in ductwork and housings.

2. Piping shall be capped with materials the same as the piping system.

3. Insulation shall be neatly hemmed with metal or plastic edging, leaving test points visible for future testing.

2.3 TEST INSTRUMENTS

A. Standards: Utilize instruments and equipment of type, precision, and capacity as recommended in the AABC manual MN-1.

B. Test Instruments: All instruments used for measurements shall be accurate and calibration histories for each instrument shall be available for examination. Each test instrument shall be calibrated by an approved laboratory or by the manufacturer. A representative has the right to request instrument recalibration, or the use of other instruments and test methodology, where accuracy of readings is questionable.

C. Additional Instruments: Permanently installed measuring instruments, such as temperature and pressure gauges, shall be checked against transfer standard instruments. Any instrument which does not meet specification requirement shall be replaced or recalibrated.

D. Cone Instruments: The Contractor shall employ manufactured enclosure type cones, capable of air volume direct readings, for all diffuser/grille/register air flow measurements. The readout meters shall meet calibration requirements.

PART 3 EXECUTION

3.1 PROCEDURES AND INSTRUMENTS, GENERAL

A. Requirements: All systems and components thereof shall be adjusted to perform as required by drawings and specifications.

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

C. Instrumentation: Method of application of instrumentation shall be in accordance with the approved agenda.

1. All instruments shall be applied in accordance with the manufacturer's certified instructions.

2. All labor, instruments, and appliances required shall be furnished by the Contractor. Permanently installed instruments used for the tests (e.g., flow meters and Btu meters) shall not be installed until the entire system has been cleaned and ready for operation.

3.2 DUCT SMOKE DETECTORS

A. The testing and balancing agency shall direct the placement of all duct mounted smoke detectors.

1. Obtain information from the Contractor who is to furnish the smoke detectors on the proper device placement and installation limitations and on the proper differential pressure across the sampling tubes of the duct detectors.

2. Based on the submitted manufacturer's installation guidelines indicate the proper mounting location to the installing Contractor.

B. After the installation of all smoke detectors test them again in the final installation position and report differential pressures.

3.3 AIR SYSTEM PROCEDURES

A. Adjustments: Adjust all air handling systems to provide approximate design air quantity to or through, each component, and to maintain stable and comfortable interior temperatures, free of drafts or stagnant conditions. Adjusting and balancing of all systems shall be conducted during periods of the year approximating maximum seasonal operation.

B. Equalizers: Equalizing devices shall be adjusted to provide uniform velocity across the inlets (duct side for supply) of terminals prior to measuring flow rates.

C. Balance: Flow adjusting (volume control) devices shall be used to balance air quantities (i.e., proportion flow between various terminals comprising system) to the extent that their adjustments do not create objectionable air motion or sound (i.e., in excess of specified limits).

1. Balancing between runs (submains, branch mains, and branches) generally shall be accomplished by flow regulating devices at, or in, the divided-flow fitting.

2. Restriction imposed by flow regulating devices in or at terminals shall be minimal.

3. Final measurements of air quality shall be made after the air terminal has been adjusted to provide the optimum air patterns of diffusion.

D. Fan Adjustment: Total air system quantities, generally, shall be varied by adjustment of fan speeds or axial-flow fan wheel blade pitch. Damper restriction of a system's total flow may be used only for systems with direct-connected fans (without adjustable pitch blades), provided system pressure is less than 1/2-inch W.G. and sound level criteria is met.

E. Air Measurement: Where air quantity measuring devices are specified in other sections such systems shall be used as a cross-check of portable measuring equipment.

1. Except as specifically indicated herein, pitot tube traverses shall be made of each duct to measure air flow therein. Pitot tubes, associated instruments, traverses, and techniques shall conform to the ASHRAE "Handbook Fundamentals Inch Pound Edition."

2. For ducts serving modular office areas with movable partitions, which are subject to change, pitot tube traverses may be omitted provided the duct serves only a single room or space and its design volume is less than 2000 cfm. In lieu of pitot tube traverses, airflow in the duct shall be determined by totaling volume of individual terminals served, measured as described herein.

3. Where duct's design velocity and air quantity are both less than 1000 (fpm/cfm), air quantity may be determined by measurements at terminals served.

F. Test Holes: Test holes shall 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.

G. Air Terminal Balancing: Generally, measurement of flow rates by means of velocity meters applied to individual terminals, with or without cones or other adapters, shall be used only for balancing. Measurement of air quantities at each type of air terminal (inlet and outlet) shall be determined by the method approved for the balancing agenda. Laboratory tests shall be conducted to prove of methodology when so directed. Such tests shall be conducted in conformance with applicable ASHRAE or American Society of Mechanical Engineers (ASME) codes and shall be made at no cost.

H. Air Motion: Air motion and distribution shall be as specified and indicated on drawings. The Contractor at no additional cost shall, in addition to air motion measurements, make smoke tests wherever requested to demonstrate the air distribution from air terminals.

I. Air System Test and Balance Procedure: Perform the following tests, and balance each system in accordance with the following requirements:

1. Test and adjust blower RPM to design requirements.

2. Test and record motor full load amperes.

3. Make pitot tube traverse of main supply ducts and obtain design CFM at fans.

4. Test and record system pressures, suction and discharge.

5. Test and adjust system for design recirculated air, CFM.

6. Test and adjust system for design CFM outside air.

7. Test and record entering air temperatures.

8. Test and record leaving air temperatures.

9. Adjust all supply, return and exhaust air ducts to proper design CFM.

10. Adjust all zones to proper design CFM, supply and return.

11. Test and adjust duct systems and each diffuser, grille, and/or register to within 10% of design requirements.

12. Each grille, diffuser and register shall be identified as to location and area.

13. Size, type and manufacturer of VAV boxes, diffusers, grilles, registers and all tested equipment shall be identified and listed. Manufacturer's ratings on all equipment shall be used to make required calculations.

14. Readings and tests of diffusers, grilles and registers shall include required FPM velocity and test resultant velocity, required CFM and test resultant CFM after adjustment.

15. In cooperation with the control manufacturer's representative, setting adjustments of automatically operated dampers to operate as specified, indicated, and/or noted. Testing agency shall check all controls requiring adjustment by control installers. Room thermostats shall be checked for cooling and heating response.

16. All diffusers, grilles and registers shall be adjusted to minimize drafts in all areas.

17. Adjust overall system balances to allow all self-closing exterior doors to close from any open position. Maximum interior air pressure in a 100% outside air intake mode shall not exceed 0.05" static pressure relative to the outside air pressure.

18. As part of the work of this contract, the HVAC contractor shall make any changes in the pulleys, belts and dampers or the addition of dampers required for correct balance as recommended by air balance agency, at no additional cost to Owner.

19. After air balancing is completed and RPM determined, HVAC Contractor shall provide fixed pitch pulleys.

20. All mixing boxes, VAV air valves, control dampers, smoke dampers and similar devices which operate at 100% shut off shall be tested for leakage.

3.4 AIR SYSTEM DATA

A. Report: The certified report shall include for each air handling system the data listed below.

1. Equipment (Fan or Factory Fabricated Station Unit):
   a. Installation data
      1) Manufacturer and model
      2) Size
      3) Arrangement, discharge and class
      4) Motor hp, voltage, phase, cycles, and full load amps
      5) Location and local identification data

b. Design data
   1) Data listed in schedules on drawings and specifications.
c. Fan recorded (test) data
   1) cfm
   2) static pressure
   3) rpm
   4) motor operating amps
   5) motor operating bhp

2. Duct Systems:
   a. Duct air quantities (maximum and minimum) - main, submains, branches, outdoor (outside) air, total air, and exhaust:
      1) duct size(s)
      2) number of pitot tube (pressure measurements)
      3) sum of velocity measurements (Note: Do not add pressure measurements)
      4) average velocity
      5) recorded (test) cfm
      6) design cfm
   b. Individual air terminals
      1) terminal identification supply or exhaust, location and number designation
      2) type size, manufacturer and catalog identification applicable factor for application, velocity, area, etc., and designated area
      3) design and recorded velocities - fpm (state "core," "inlet," etc., as applicable)
      4) design and recorded quantities - cfm (deflector vane or diffusion cone settings)

3.5 SOUND TEST PROCEDURES

A. Scope: Tests of sound levels shall be made at each selection point included in the agenda.

B. Timing: Sound level measurements shall be taken at times when the building is unoccupied, or when activity in surrounding areas and background noise level in areas tested are at a minimum and relatively free from sudden changes in noise levels.

   1. Measurements shall be taken with all equipment turned off, except that being tested.

   2. The required sound levels shall be measured at any point within a room not less than 6 feet from an air terminal or room unit, and not closer than 3 feet from any floor, wall, or ceiling surface.

C. Meters: Sound levels shall be measured with a sound meter complying with ANSI S1.4. The "A" scale shall be used to measure over all sound levels. To determine the specified octave band levels, the above sound level meter, set on "C" scale, shall be supplemented by an octave band analyzer complying with ANSI S1.11.

D. Equipment Components: The "Equipment Component" of room sound equals LPt-C. The "Equipment Component" of room sound (noise) levels shall be determined for each of eight octave bands as follows:

   1. Measure room sound pressure level "LPb" with equipment to be tested shut off.

   2. Measure room sound pressure level "LPt" with equipment to be tested turned on.

   3. Calculate LPt-LPb; if this value is less than 1, applicable test must be rerun with lower background level (LPb) unless LPt is within sound pressure level specified for equipment.

   4. Determine "c" from the table below.

LPt-LPb (db)	c (db)
1	7
2	4
3	3
4 to 4- ½	2
5 to 5- ½	1 – ½
6 to 7- ½	1
8 to 12	½
over 12	0

3.6 SOUND LEVEL DATA

A. Report: certified report shall record data on sound levels, taken at each selected location, as follows:

1. Source of sound and location.

2. Diagram or description of relationship of sound source to measuring instrument.

3. "A" scale readings equipment being tested turned off (ambient) equipment being tested turned on (operating conditions).

4. Readings at each specified octave band frequency equipment being tested turned off (ambient) equipment being tested turned on (operating conditions).

5. "Equipment Components" of sound (noise) levels with applicable calculations per "Sound Test Procedures".

6. Graph showing relationship between pressure levels specified and recorded readings

B. Retest: Subsequent to any correctional construction work, such as acoustic corrections, measurement shall be made to verify that associated air and water quantities, as previously measured, have not been disrupted.

1. Certified report shall record all sound data, and their locations, after final adjustments of air and water systems involves.

3.7 CERTIFIED REPORTS

A. Submittals: Six (6) copies of the reports described herein, covering air and water system performance, air motion (fpm), and sound pressure levels, shall be submitted prior to final tests and inspection.

B. Instrument Records: Types, serial numbers, and dates of calibration of all instruments shall be included.

C. Reports: Reports shall conspicuously identify items not conforming to contract requirements, or obvious malfunction and design deficiencies.

D. Certification: Certification shall include checking of adherence to agenda, of calculations, of procedures, and evaluation of final summaries.

3.8 FINAL COMMISSIONING TESTS, INSPECTIONS AND ACCEPTANCE

A. Scope: Test shall be made to demonstrate that capacities and performance of air and water systems comply with contract requirements.

1. At the time of final inspection, the Contractor shall recheck, random selection of data (water and air quantities, air motion, and sound levels) recorded in the certified report. In addition, all courtrooms, auditoriums, and conference rooms shall be rechecked.

2. Points and areas for recheck shall be selected by the commissioning team.

3. Measurement and test procedures shall be the same as approved for work forming basis of certified report.

4. Selections for recheck (specific plus random), in general, 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.

B. 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, as 10 percent or more of the rechecked selections, the report shall be automatically rejected. In the event the report is rejected, all systems shall be readjusted and tested, new data recorded, new certified reports submitted, and new inspection tests made, all at no additional cost. Retainage time shall be based on the date of the final acceptance of the certified report.

C. Marking of Settings: Following final acceptance of certified reports, the settings of all valves, splitters, dampers, and other adjustment devices shall be permanently marked by the Contractor so that adjustment can be restored if disturbed at any time. Devices shall not be marked until after final acceptance.

END OF SECTION 15990