Control Systems Specifications
A Practical Analysis

Overview

This document is created to help better comprehend the typical engineer's specification for temperature controls. Created from reviewing about a dozen different specifications from nearly as many different consulting engineers, the document analyzes the four major components of the controls section of a typical specification, and details the content and the normal arrangement of information. The document also attempts to "cut through" a lot of the usual filler contained in a specification, in order to provide a more streamlined view of what's important. The ultimate goal of this document is twofold: 1) to teach the ability to read and better understand an engineer's specification, knowing what to look for, where to look for it, and how to read between the lines to recognize the basic intents of the engineer, and 2) to teach the ability to write a "clear and concise" temperature controls specification for a particular project.

Specifications are documents that outline the requirements of a project. They are put together by the consulting engineer, in addition to the other contract documents (drawings, etc.). A common method of developing a specification for a particular project is to start with a "master spec", which is a generic framework of modules that typically compose a specification. The modules are each tailored to the project at hand, so that the proper details are included, and items irrelevant to the project are left out. This is academically the best method of developing a written specification.

Often an engineer will take specs that have already been written for particular projects, and piece them together to fit another project. While this "cut and paste" method is theoretically acceptable, it does sometimes lead to discrepancies. Care must be taken, as with any method of creating a specification, to avoid omission of pertinent items, inclusion of items that don't apply, contradictions with the drawings, and even contradictions within the specification itself.

The preparation of a written specification is a task that requires attention to detail. To do it right involves a substantial investment in time, and a devotion to accuracy. Not all engineers have the time to invest or the resources to expend in the preparation of written specs. Thus, not all specifications are given the attention that they deserve. Short of placing any blame on those of whom write specs, this document has been prepared with that in mind.

Section (Division) Number

The temperature controls portion of any project specification is generally found as part of Division 15 (Mechanical). The mechanical contractor's responsibilities start with Section 15000, and the control systems fall under the responsibility of the mechanical contractor, whether they sub the work out to a separate temperature controls contractor, or perform the work themselves (provided they have the capabilities for this). The temperature control work starts at either 15900 or 15975. With the advent of Direct Digital Controls and the ever-increasing realm of the Building Automation System contractors responsibilities, a networked DDC specification may even be given its own section, separate from the mechanical contractor's section. The engineer on a given BAS project may choose to deem the controls contractor's work as Section 17000, or Division 17.

Section Headings

The section headings vary with the engineer, and also with the type of system specified. For a simple stand-alone electric/electronic system, the heading may simply be Temperature Controls. For a fully networked, fully integrated DDC system, the heading may be more indicative of such a system. Below are some of the variations of temperature controls section headings. Bear in mind that the simple term "Temperature Controls" is a catchall for mechanical system controls, encompassing temperature, pressure, humidity, and other types of control typically associated with HVAC systems.

AUTOMATIC TEMPERATURE CONTROLS (SYSTEMS)
BUILDING AUTOMATION SYSTEM
DIRECT DIGITAL CONTROL SYSTEMS
HVAC INSTRUMENTATION AND CONTROLS
TEMPERATURE CONTROLS (SYSTEMS)

Major Parts

The temperature controls section is broken down into four standard parts, consistent among all engineers who write specifications. They are defined as follows:

PART 1 – GENERAL
PART 2 – PRODUCTS
PART 3 – EXECUTION
PART 4 – SEQUENCE OF OPERATION

Arrangement of Information

Information is arranged in outline form, and varies slightly among engineers. The typical setup is as shown below:

PART 1 – GENERAL

1.1 MAJOR TOPIC

A. Statement…

B. Statement…

1. Sub-statement
    a)
    b)

2. Sub-statement

Specification Description, Part by Part

Now we get into the "nitty-gritty" of the typical temperature controls specification. For each part, we will work through the major topics found in most specs, and work to understand what each "segment" means, what's important, and what's maybe not so important. This portion will give a very general outline of a typical controls specification, and will omit many details that typically are included, for the purpose of focusing on what's important to the reader.

Omission of certain clauses and phrases from this document does not necessarily mean that said clauses are unimportant. On the contrary, many of these clauses that I speak of must be included in a specification. A project specification is a legal contract document, and if/when problems and/or disputes arise, the specification is the first point of reference for settling the contention.

Other items omitted from this document are items that may be more so engineer's preferences or product attributes, items whose omissions will not necessarily detract from the intent of the project, nor lower the value and/or functionality of the finished product. Engineers all have their own preferences for certain items, and depending upon the project, the customer, the budget, and other variables, these items may or may not be required for a fully functional temperature control system, one that still meets the engineer's fundamental intents. For instance, a requirement for a dedicated controller for each major component of a boiler/chiller/pumping plant may be "specified overkill", if the entire plant can be handled by a single controller. The end user does not necessarily gain any additional value of multiple controllers serving his plant, for the added cost of multiple controllers versus one controller.

Oftentimes an engineer will use portions of (or even in its entirety!) a controls specification written by a controls manufacturer. This serves the purpose of more or less "locking in" said manufacturer for the given project. There may be certain attributes of the manufacturer's product of which cannot be readily or economically performed by the competition. Thus, the "specified" manufacturer stands a better chance of being awarded the project, solely on the basis of being able to offer these special attributes, whether or not they benefit the project or add any value to the control system. For instance, the specification of 3K ohm thermistor temperature sensors may favor one manufacturer over others on the spec list, yet may offer no real benefit to the end user, in terms of value and functionality.

PART 1 – GENERAL

DESCRIPTION OF WORK or SCOPE

This segment details, in point form (i.e. A, B, C, D, etc.), the overall scope of the project. It should be written to provide a general overview of the project and of its requirements, without going into too much detail. The list should summarize the scope of work as it pertains to the major mechanical systems and equipment.

Also in this section, it should be specified as to the level of technology required for the project. Stated as “This contractor shall provide…”, this can range from “a stand-alone electrical/electronic control system” to “a fully integrated Direct Digital Control (DDC) Building Automation System (BAS)”, and anything in between. In addition, other technology requirements should be included, for instance, open communications protocol, BACnet, LonWorks, etc. An engineer may wish for the control system to interface with a packaged piece of equipment’s microprocessor-based controller directly, via a common protocol or a gateway.

Finally in this section, it should be noted to “provide all required engineering, programming, supervision, parts and equipment, installation labor, technical support, and commissioning services for a fully functional temperature control system as described herein”.

RELATED DOCUMENTS (RELATED SECTIONS)

This segment (if included) lists other documents related to the project (engineer’s drawings), as well as other places within the overall project specification that may contain related information. This may read “all portions of Division 15 and Division 16”, in which Division 15 is the Mechanical section, and Division 16 is the Electrical section.

WORK INCLUDED (WORK BY OTHERS)

This segment begins to define the “demarcation of responsibilities” between the controls contractor and other related trades. Grey areas are hopefully picked up and accounted for here, such as whose responsible for line stat wiring of exhaust fans, interlock wiring, 120-volt power to T/C panels, VAV box control power, etc.

FURNISHED BUT NOT INSTALLED / FURNISHED BY OTHERS

This segment continues with the division of responsibilities, more specifically with whose responsible for what components. This has mainly to do with components that can justifiably fall under more than a single trade’s responsibility. For example, smoke detectors and starters can fall under either Division 15 or Division 16, depending upon the engineer’s preference, common practice, and other factors.

This segment also typically makes a distinction between the controls contractor and the mechanical contractor, and if they are not one in the same, this is quite pertinent. There will be items that will typically be furnished by the controls contractor, for installation by the mechanical contractor. These items include properly sized control valves, properly sized control dampers (sometimes), flow switches, sensor immersion wells, controllers for terminal units (VAV & fan powered boxes), etc. There should be a phrase reading like “Mechanical contractor shall provide all required pressure taps, and install all immersion wells, flow switches, airflow measuring stations…”.

This segment may also specify that certain control items are furnished (and installed) by the mechanical contractor, such as thermostatic control valves, and control dampers (actuators installed by the controls contractor).

Lastly, this segment may make reference to packaged equipment, with a line such as “Mechanical contractor to provide any controls associated with packaged equipment, for installation and wiring by the controls subcontractor.

COORDINATION WITH OTHER TRADES / RELATED WORK SPECIFIED ELSWHERE

This segment (if included) is closely related to the two previous segments, perhaps detailing more the installation of components relative to more than one trade. For example, the installation of starters and smoke detectors may be the responsibility of the electrical contractor, but the location of these devices may be best selected by the temperature controls contractor. Other items that require coordination: power for control panels (electrical contractor to provide circuits at the breaker panel…), VAV box air balancing (balancer shall balance boxes with portable service tool provided by the temperature controls contractor), etc.

DEFINITIONS AND ABBREVIATIONS

This segment (if included) simply lists out common terms and abbreviations, with a description of each.

QUALITY ASSURANCE

This segment, among other things, stipulates contractor requirements, such as, the minimum number of years the contractor has been in business, the minimum number of installations the contractor has performed, the contractor's experience level, service capabilities, locational requirements, etc.

Also included in this segment, is Applicable Codes and Standards, by which the contractor must conform to. Though the requirement for conduit for low voltage wiring may not be explicitly specified here, it will at least be implied (as to whether or not it's needed) by referring to the appropriate codes or standards. More likely, the EXECUTION part of the specification (PART 3) will detail the requirements for conduit, if they're to be found anywhere. This segment may simply carry the catchall clause "…in strict accordance with national and local electrical codes, and with the electrical section of these specifications…".

APPROVED CONTROL SYSTEM CONTRACTORS (AND MANUFACTURERS)

Often included under the previous heading (QUALITY ASSURANCE), this segment lists out pre-qualified, pre-approved companies. The segment may list installers (e.g. Johnson Controls Branch Office), or more commonly, will list manufacturers with the clause "Contractor qualified and certified to install…". The segment may allow for an "alternate bid for other…", or may include the phrase "or approved equal (in writing, via addendum by engineer)".

Sometimes this segment is included not here but in PART 2 – PRODUCTS. This being the case, the segment would simply list out manufacturers, and allude to the requirement for a qualified contractor to perform the installation.

SUBMITTALS (if not here, then in EXECUTION)

This segment includes guidelines regarding temperature controls submittals. Submittals must generally be turned in to the engineer, for approval, before any physical work can take place. This segment will specify how many copies must be turned in (4, 6, even 10 copies), and how quickly they must be received by the engineer after the contract has been awarded.

The submittal packages will be specified to include (but not limited to) one or more of the following, depending upon how demanding the engineer is: Riser diagrams (system network architecture), Description of Control, controller, sensor, and end device product information, wiring diagrams (preliminary), valve (and damper) schedules, and Points Lists.

WARRANTY

This segment simply states that the Work (both labor and materials) is to be warranted and free form defects for a period of 12 months after final completion. Also included are the contractor's responsibilities during the warranty period.

AS BUILTS (if not here, then in EXECUTION)

This segment includes guidelines regarding "closeout documentation", which includes (but is not limited to): final wiring and control diagrams, Sequence of Operation, program documentation and project diskette(s), and operation & maintenance (O&M) manuals.

TRAINING (if not here, then in EXECUTION)

This segment, whether included here or later on in the spec, lists the requirements for end user training. A typical networked DDC system will be specified to require twelve hours (minimum) of user training, provided by the control systems contractor. This is normally broken down as three four-hour sessions, with the last session required to take place in “the opposite season”. This segment will also typically detail what the training should cover.

SOFTWARE RIGHTS

“The owner and the party providing the software will enter into a software license agreement…”

PART 2 – PRODUCTS

This part seems to vary substantially among written specifications, so let us simply put forth our best efforts, by analyzing all of those specs, and try to come up with a decent, all-encompassing yet straightforward format and descriptions of each segment. This analysis will be based upon networked DDC.

Many specs seem to spend a lot of time on this part, listing details upon details, when in this day and age, most manufacturers’ products will either meet or exceed much of what is written. And if not, maybe then the spec is written too rigid, perhaps around a certain manufacturer’s product. Or maybe perhaps simply out of the engineer’s personal preference. The point is, when all is said and done, is the end user getting any value out of paying a premium for that 2% accuracy room humidity sensor, which is probably $100.00 more (per unit) than the 5% accuracy room sensor? Can anyone distinguish the difference in accuracy between the two, when the system is implemented and commissioned? Good question!

ACCEPTABLE MANUFACTURERS

This segment lists out the approved control systems. It is often included not here, but in the previous part (GENERAL).

NETWORK COMMUNICATIONS

This segment defines the network requirements, from cabling to protocol. Many specs talk in great detail about protocol, especially in this day and age, when BACnet and LonWorks are the buzzwords of the industry. The important thing is that the network spec fits the application. It is not particularly advantageous to specify BACnet for a two-story, stand-alone office building, when a simple proprietary or non-standard open protocol will fit the bill, for a fraction of the cost. The important thing is to understand what is meant by these terms (BACnet, Lon, open and proprietary protocol, interoperability, etc.), and how they fit into any given application.

Other network attributes that are often specified are baud rate, network levels, and possible number of controllers on the network.

Baud rate is the communication speed that the network is capable of operating at, and can be specified as anywhere from 4800 bps (bits per second), to 19.2K bps, to over 100K bps. On a project such as the one stated above (two-story office building), 100 thousand bits per second may offer very little benefit over 9600 bits per second.

“Network levels” most often relate to the controllers that reside on the network. Primary controllers, such as plant and equipment level configurable controllers, will reside on a “peer-to-peer” network, in which information can be passed directly between any controller on this network. This network level is also referred to as the primary tier network, the tier 1 network, the level 1 network, or the primary network. Secondary controllers, such as unitary or application specific controllers, will (often) reside on a “polling” network. Controllers on this network cannot directly share information. Information can be polled from controllers that sit on this network, by a primary controller that resides on the peer-to-peer network, and likewise information can be broadcast from the primary controller back to secondary controllers on the polling network. This network level is also referred to as the secondary tier network, the tier 2 network, the level 2 network, or the secondary network.

The possible number of controllers that can reside on any network may be specified. Most manufacturers have this pretty well covered, though. A particular manufacturer may require that, after so-and-so number of controllers, a repeater has to be installed on the network, in order to add any more controllers.

This segment may talk about an "enterprise level" or "network" controller. Depending upon the manufacturer, there may be such a device that supervises network communication. Some (lower end?) manufacturers do not have nor require such a device.

Lastly, there may be mention of integration or interface with third party equipment. If a piece of packaged equipment is furnished with microprocessor-based controls, the spec might call for the equipment controller to talk to the control network (and vice versa), via common protocol or via a gateway. This way the control system can exercise some supervisory control over the piece of equipment, and in turn can monitor some operating parameters without the need for additional sensing devices to be installed at the piece of equipment.

CONFIGURABLE CONTROLLERS

This segment lists the general requirements for "primary controllers". Specifications for these controllers typically state that they must be fully programmable, with the programs residing in non-volatile static memory, capable of stand-alone operation, with a real-time hardware clock and battery backup to keep the clock running in the event of loss of power to the controller. Other requirements may be for LED status for outputs, H-O-A switches for binary outputs, and RS232 ports for connecting devices such as portable laptops and modems. The spec may include point counts, i.e., minimum number of inputs and outputs (both binary and analog), and also may define the analog point types. The spec will define the environmental operating requirements (ambient operating temperature and humidity ranges). Finally, this segment may include the requirement for "spare capacity", which is the number of unused or spare input and output points per controller (for possible future use). Spare capacity can be specified as anywhere from 5 to 20 percent.

Most anything specified beyond this would tend to be manufacturer specific, and would not necessarily serve any additional benefit or insurance for a functionally acceptable system. Most reputable manufacturers keep up with the technologies and incorporate these technologies into their latest, present day product offering. Specifying these technologies would seem to only serve the purpose of preventing a contractor from pulling legacy controllers from stock and using them on the project. Much like trying to use a ten-year old computer to run present day software.

APPLICATION SPECIFIC CONTROLLERS

This segment lists the general requirements for "secondary controllers". Specifications for these controllers typically state that they must have non-volatile static memory, and be capable of stand-alone operation. They are not fully programmable, but customizable to fit a given unitary application (fan coil unit, VAV or fan powered box, packaged rooftop unit, etc). These are controllers that are manufactured as dedicated to control a specific piece of equipment, with the algorithms resident within the controller. Environmental operating requirements will be listed, as well as the requirement for a jack for controller access via a portable operator interface (laptop or handheld service tool). This segment may ask for controller interface to be able to be performed remotely at the (space) sensor wired to the controller, in addition to at the controller itself.

OPERATOR INTERFACE

This segment defines the requirements for the main (and secondary) interface(s) to the control system network. For a networked control system, this will typically be a personal computer running the appropriate software, and is often referred to as the operator workstation. The spec will list the hardware required for the particular project, and will include most or all of the following: PC, monitor, keyboard, mouse, printer, and modem. The workstation is "non-dedicated", meaning that it can be used for other basic applications, and does not have to be strictly dedicated to the networked control system. In addition, the control system is not dependent on the workstation for operation; the PC can be turned off or disconnected from the network, and the control system carries on with its functions.

Following is a typical *minimum* requirement for a standard, 2003 "front end" operator workstation:

- Pentium 266 MHz microprocessor

- 64 MB RAM, Windows NT/2000/XP
- 2 GB hard drive
- 16-bit color support
- 800x600 screen resolution
- CD-ROM
- Standard mouse and keyboard
- RS232 serial communication port
- 17" monitor

Other interfaces include portable laptop computers, local displays, and handheld service tools. A laptop can function identical to the main front end (workstation), but can be used to access controllers directly, or can be taken offsite and used to remotely access the network via dial-up connection.

Local displays can be specified as required. With a front end connected, is there a need for such devices? Maybe, maybe not. But they *can* add cost to the project. These are typically LCD displays with keypads, that are either integral to the (primary) controllers, or installed on the covers of the enclosures housing the controllers.

Handheld service tools are often specified, to be turned over to the building engineer upon completion of the project. With this, the engineer can access any controller on the network locally, typically for servicing and troubleshooting purposes. The spec will ask for either a manufacturer's proprietary device, or more commonly for a standard, commercially available PDA running the appropriate software. With a front end already in place, this device becomes a (pricey) redundancy, and its capabilities are limited as compared to the front end. Still, there may be a legitimate reason for specifying such a device.

OPERATING SYSTEM SOFTWARE FEATURES

This segment specifies some of the requirements for the front end software package, typically calling out for a navigation graphics package, with building floor plans and jump buttons to each zone, and to each major piece of equipment and system. The spec may also make reference of the type of programming method (line programming, menu driven, or graphical programming). The trend among major manufacturers is graphical programming and web-based front end graphics. Other requirements, such as password protection, alarm and trend logging, reports, and automatic dial-outs of alarms, are also commonly specified.

PROGRAM FEATURES

This segment (if included) lists out some standard HVAC-specific programs that the system is to be capable of implementing. Some of these are listed below:

- Scheduling
- Night setback
- Morning Warmup
- Timed override
- Reset
- Enthalpy changeover
- Demand limiting
- Optimal start/stop

Keep in mind that often these are listed without any regard to the particular project. A project may be such that there is no application for "reset control", yet it is listed in the specification for the project. Furthermore, most manufacturers offer these types of programs as standard, and if not, the programming methods today are powerful enough to implement any of these from scratch. If you are reading a specification for the purposes of acquiring a project, then you need not be too concerned with these items. If you are reading the specification for the purposes of designing a project, then these may apply. If a Sequence of Operation and/or a Points List is included in the spec, then refer to those items for application of any of these programs.

SENSORS AND TRANSMITTERS

This segment, and the remaining segments of this part, will take the form of a typical specification. Bear in mind that this is a very stripped down version of what may normally be found in this portion of the spec. Yet it may be enough! Be informed that details such as component accuracies are ignored here, assuming for now that all commercially available devices will meet or exceed the criteria for any given project. If there is a concern, then these details should be included and heeded. Also, if there are other sensing and control elements required for a given project that aren't included here (such as CO and CO2 transmitters), they will be included in this part of the specification for that particular project.

Sensors (general): All temperature sensors shall be of the two-wire thermistor type, with a resistance of [3K, 10K] ohms at 77 degrees F.

Space Sensors: Shall have a finished decorative cover, with setpoint adjustment (limited through software), and override button.

Outside Air Sensors: Shall be suitable for outdoor mounting, with a sun and weather shield, to be located on the North side of the building.

Duct Sensors: Shall be of the insertion type, with a length no shorter than 8 inches for duct widths up to 24 inches, no shorter than 12 inches for duct widths up to 36 inches, and no shorter than 18 inches for duct widths larger than 36 inches.

Averaging Sensors: For where mixing of airstreams may result in stratification, averaging sensors shall be used, the length of which shall be two times the maximum duct dimension.

Immersion Sensors: Shall be installed in a copper or stainless steel well, packed with conductive compound to facilitate heat transfer.

Transmitters: All variables not capable of being measured by passive devices are to be measured by transmitters. This includes pressure and relative humidity. Signals generated by transmitters shall be [1-5 VDC, 2-10 VDC, 4-20mA].

SWITCHES AND TWO-STATE CONTROLLERS

Freezestats: Shall be of the manual reset type. Controller to have at least a 20 foot sensing element, to be draped across the leaving side of the appropriate chilled water, hot water, or steam coil.

High Limit Static Pressure Switches: Shall be of the manual reset, diaphragm type.

Line Voltage Thermostats: Shall be of the snap-acting bimetal type, single pole double throw.

Current Sensing Switches: Shall be solid state with adjustable trip current setting.

Differential Pressure Switches: Shall be used where practical, for status indication, in lieu of current sensing switches.

Air Pressure Switches (for static or differential pressure applications): Shall be diaphragm type pressure switches.

Clogged Filter Switches: Shall be diaphragm type pressure switches.

Water Pressure Switches (for differential pressure applications): Shall be bellows type pressure switches.

Water Flow Switches: Shall be immersion paddle type flow switches.

END DEVICES

Control Dampers: Shall be duct size if two-position, and sized for the appropriate pressure drop if modulating. All control dampers shall be low leakage type. Dampers used in modulating applications shall be of the opposed blade type.

Damper Actuators (general): Shall be of the direct mount type, suitably sized for the dampers they serve. They shall require 24-volt AC power, and unless two-position control is explicitly specified, shall be able to accept a proportional control signal of 0-10 or 2-10 VDC. Unless otherwise specified, they shall be spring-return.

Control Valve Bodies: Shall be sized, using accepted industry standards, for the coils they serve. Valve bodies in the ½” to 2” range may either be globe or ball. A valve body shall not be selected that is less than half the line size. Valve bodies in the 2”-6” range shall be globe. Valve bodies larger than 6” shall be butterfly.

Valve Actuators (general): Shall be of the direct mount type, suitably sized for the valves they serve. They shall require 24-volt AC power, and unless two-position control is explicitly specified, shall be able to accept a proportional control signal of 0-10 or 2-10 VDC. Unless otherwise specified, they shall be spring-return.

Zone Damper and Zone Valve Actuators: Shall be of the direct mount type, shall require 24-volt AC power, and shall be able to accept either a proportional or floating type control signal. The application shall dictate whether or not they will be spring-return.

MISCELLANEOUS DEVICES

Control Enclosures: Shall be NEMA 1 (indoor, general use), or NEMA 3 (outdoor use) with perforated mounting panels and hinged doors.

Relays and Contactors: Shall be suitable for the loads that they handle.

Control Transformers and Power Supplies: Shall be UL listed, 24-volt, Class 2 current limiting type, or shall have fusing on both the primary and secondary sides.

Transducers: Shall be utilized where there is a need to convert one type of control signal to another. An example of this is an electronic-to-pneumatic transducer, which can take a 2-10 VDC or 4-20 mA electronic control signal, and convert it to a 3-15 psi pneumatic control signal, for modulation of a pneumatic actuator.

PART 3 – EXECUTION

GENERAL

This segment lists out some of the general requirements and expectations for the Work performed by this contractor. Following are a few examples of some of the general statements that might be contained in this segment:

“The BAS equipment and wiring shall be designed, installed, and commissioned in a fully operational manner…”

“All electrical installation shall be in compliance with the National Electrical Code, with any and all applicable local building codes, and with Division 16 of this specification…”

“Install equipment, conduits, and raceway parallel to building lines…”

“Verify integrity of all wiring…”

“Comply with acceptable industry specifications and standards…”

PROJECT MANAGEMENT

This segment is not commonly included, however if it is, then it will read something like this:

“Provide a designated Project Manager, whose responsibilities include but are not limited to:

A) Construct and maintain project schedule.
B) On-site coordination with other trades.
C) Attend project meetings as required.
D) Make necessary field decisions, relating to this scope of work.

E) Serve as the single point of contact."

COORDINATION

This is another segment that is more or less "optional", and if included, is usually in the form of a generic catchall statement, such as "Coordinate work with other trades…".

WIRING

This segment will contain the project requirements for wiring, and may include guidelines for wire sizes, color standards, cable types (plenum rated, twisted shielded pair, etc.). This section will also most likely be the place to find the requirements for conduit. Conduit requirements for low voltage control wiring can range from a complete lack of a requirement (highly unlikely), to a partial requirement (conduit in all exposed areas, plenum rated cabling above lay-in ceilings…), to a requirement for *all* low voltage control wiring to be in conduit, regardless (especially true in major metropolitan areas with strict building codes).

The segment may also lay out some guidelines for control panels. As such, the spec will ask that the wiring within the enclosures is neatly bundled and anchored, with all conductors tagged and color-coded. The spec may also make mention of control panel mounting requirements.

INSTALLATION REQUIREMENTS (DEVICES)

This segment will describe how certain devices should be installed, devices that are "at risk" of being installed incorrectly. The engineer can opt to list out all field devices within the scope of the project, and put forth guidelines on the installation of each and every one of them. However, it is more common to simply list out those items of which, as described above, are susceptible to incorrect installation. Such items will typically include duct averaging sensors, freezestats, duct and building static pressure transmitters, and outside air temperature sensors. Also included in this segment is the requirement for space thermostats to be a specific height above the floor, usually mandated to be 4'0" A.F.F. (Above Finished Floor).

STARTUP AND COMMISSIONING (VALIDATION)

Although sometimes longer and more detailed, this segment can realistically be handled with one or more simple generalities. Some specifications ramble on for paragraphs detailing the commissioning and validation process. This becomes more of an instructional segment, and is fine if the engineer warrants its inclusion. Yet the reputable contractor will normally be in the best position to formulate and implement the commissioning process for the specific project. Hence many engineers will simply write something to the tune of the following:

"The TCC (Temperature Controls Contractor) shall completely check out, calibrate, and test all connected hardware and software so as to ensure that the system performs in accordance with the specifications and the Sequence of Operation."

DEMONSTRATION AND ACCEPTANCE

This segment formally covers the turn-over of the completed project to the customer, and will typically take the form of a general statement, such as:

"Provide systems demonstration…"

or

"Demonstrate complete and operating system to the owner (owner walk-through)…"

PART 4-SEQUENCE OF OPERATION

Premise and Purpose

This part of the temperature controls specification is extremely important, and also all too often incomplete, inaccurate, or omitted altogether. Regardless, the Sequence of Operation and the Points List together are very powerful tools for specifying control systems. For DDC systems, the Points List (if done correctly) is of the utmost importance, and unbelievably enough, is sometimes not even included in the spec. Of the dozen or so specifications that were reviewed in preparation of this document, most all of them included a Sequence of Operation (for good or bad), yet only a few of them included a Points List!

This portion of the document will focus on how an engineer's specified Sequence of Operation is typically written, how it should be written, what it should include, what's important, etc. Fundamentally, the Sequence of Operation should outline the engineer's basic intentions on how the mechanical system(s) should operate, how they were designed to operate, and how they should be controlled to meet that end. The Sequence should be a direct reflection of the mechanical design. A Sequence of Operation failing to convey the engineer's basic design intentions will only serve to complicate the procurement process and the control systems design and submittal processes.

Sequence and Points List

A typical Sequence of Operation will take the form of one of two styles: point style or paragraph style. A Sequence written in point style would be as follows:

1) *Programmable thermostat signifies occupied mode.*
2) *Rooftop unit supply fan runs continuously.*
3) *Thermostat cycles heating and cooling as required to maintain occupied space temperature setpoints.*

The same Sequence written in paragraph style would be as follows:

When the programmable thermostat indicates the occupied mode the rooftop unit's supply fan runs continuously, and the thermostat cycles the heating and cooling as required to maintain occupied space temperature setpoints.

Specified Sequences will be in long or short form, as dictated by the particular engineer and his intentions. A short form Sequence of a thermostatically controlled exhaust fan may read as follows:

Generator room exhaust fan to be controlled by a space mounted thermostat.

The long version may read like this:

Space mounted thermostat controls the operation of the generator room exhaust fan. Upon a rise in temperature above the setpoint of the thermostat (80 degrees F. adj.), the exhaust fan is energized. Once the space temperature falls back below setpoint and through the differential of 2 degrees (adj.), then the exhaust fan de-energizes.

The long version provides more detail and more insight into the intended operation, and is acceptable for the T/C Sequence of Operation, especially if this is to be turned over to the customer and to the service company. The short version is typically more appropriate for specification purposes.

A Points List simply specifies the input and output points that are required for the project. Specifying points is a great method for getting what is needed on a DDC project. The idea is to account for all of the points up front and get them into the design. Then the Sequence can be created, revised, formulated over time, etc. Now, as long as all of the potentially required points are accounted for, any operational revisions down the road will take the form of software modifications, rather than (more costly) hardware modifications.

Common Faults with Engineer's Sequences

Writing good Sequences of Operation is an art, one that not all engineers are suited for. In addition to being an engineer and knowing the intentions of the mechanical design, this individual needs to be a good writer as well. Unfortunately this does not seem to be a common attribute among those of whom set out to describe the desired operation of mechanical systems. The result is that we end up with specified Sequences that are either inaccurate and incomplete, or are more or less "cut and paste" versions of previously written Sequences from past projects.

One common shortcoming in the typical engineer's Sequence is that, either all equipment is not accounted for, or equipment is described that is not part of the specified project. This stems from the use of generic specs or frameworks, in which the engineer starts with a basic skeleton, and then tailors it to the present project. This is an acceptable method of writing a Sequence, if implemented correctly. Unfortunately it's often not, and so you end up (for example) scouring the supporting design documents for the "terminal units" that are included in the Sequence as being part of the project, however even though the project is not a VAV system.

Sometimes an engineer's specified Sequence of Operation will ramble on for pages and pages, listing out details that are not entirely important for the bid and pre-design phases of the project. There are two problems with this. First of all, the more that is written, the less likely it is that it will be thoroughly read and heeded. Secondly, too often an engineer, although having good intentions, will contradict himself in a Sequence, by asking for one thing in one place, and asking for something else in another place, perhaps a contrasting scheme of control that may look okay on paper, but realistically will compromise the system operation as a whole.

As far as Points Lists go, a major fault of these when they are included in a specification is that they are "too" all-inclusive. This again stems from good intentions, as the engineer does not want to leave anything out that may be required for system operation. Yet this tends to lead to "specified overkill". An example of this would be if there are a dozen air handlers on a job, and the engineer has specified return air sensing for all of them. Is it needed for the control of the air handlers, as the engineer has described in the Sequence of Operation? Or is it there simply because the engineer wants it there, without any real regard as to what purpose it will serve, and to how important it is for the customer? If return air sensing has no control purposes, then it simply becomes a monitoring and trending point, and perhaps can be used for troubleshooting purposes. The point is, is it worth the cost (per point) to the customer? Remember that each point is made up of material cost, labor cost, controller "real estate", engineering and programming fees, and front end labor costs. Multiply that by a dozen, and you've just added some (unneeded?) costs to the project!

What a Specified Sequence *Should* Include

A specified Sequence of Operation should ideally be clear, concise, and complete. The main goal of the Sequence is to convey the engineer's basic intentions for the operation of the mechanical systems, in alignment with the design of the mechanical systems. To keep it from becoming too lengthy for anyone to want to read it, the Sequence should not spend a lot of time on details; it should get to the intents, first and foremost. An engineer should set out to write a Sequence with this in mind, and add details (if necessary) once he has developed the framework of the sequence, one that accurately and concisely reflects his mechanical systems design.

Safeties and limits should be included in the Sequence, in addition to the basic operating schemes. These will typically take the form of hardware devices, and will need to be accounted for.

The use of exact setpoints should be avoided. Generally the commissioning parties will have the best insight to this. It is impossible to predict exact setpoints, as many variables factor in to the end requirements for any given system. Baselines are acceptable (ex. 55 deg. F., adj.) and are typically included in the Sequence.

The Sequence should not detail the operational characteristics of packaged equipment. Specifying a piece of packaged equipment takes care of this already, and the Sequence does not need to spend time replicating the O&M manual of a packaged piece of equipment. Along the same lines as this, the Sequence should use industry accepted terms to specify certain descriptions of control (as possible), in lieu of completely describing a scheme of operation (ex. Morning Warmup).

The Sequence should include items such as: integral or remote thermostats, remote switches, remote sensors, interlocks, etc. A specified Sequence will sometimes include responsibilities, for example…exhaust fan controlled by a wall switch by Division 16 (Electrical)…

The engineer's specified Sequence of Operation should not belabor basic control fundamentals, as already accepted by the industry. For example, an engineer should not waste his time describing how a programmable thermostat should operate a packaged rooftop unit, or how a pressure-independent cooling-only VAV box should operate in the occupied mode. Alternatives to the above examples could be…programmable thermostat operates RTU in typical manner, and…cooling-only VAV box operates in typical pressure-independent fashion. The point is, the engineer's Sequence should "get to the point", in terms of what's important for the procurement and pre-design stages of the project.

What's Important, and Why, For the Reader

When reviewing an engineer's specified Sequence of Operation, the important thing is to be able to know *how* to read the Sequence. How to read between the lines. How to get into the engineer's head, to understand the mechanical systems thoroughly, to understand the equipment selection parameters, performance criteria, etc. so as to be able to align your interpretation of the Sequence with the engineer's basic design intents.

If you are reading a Sequence of Operation for the purpose of bidding on a project, remember that a well-written Sequence will define (expressly or implied) all of the required points for the project. For estimating purposes, it is more important to have knowledge of the required input and output points, than it is to know how the systems are to operate. If a separate Points List is provided, then this list will give upwards of 90 percent of what is required for the project, control-wise. Having a Points List does not exempt you from reading through the Sequence of Operation, however, for the Sequence may include miscellaneous additional items, such as safety and limit devices. Items that probably should be included in the Points List, but sometimes aren't.

If you are reading a Sequence of Operation for the purpose of designing the control systems for a project, then the actual control descriptions are extremely important. A consulting/specifying engineer may go the distance of writing a clear, accurate, and concise (yet detailed) Sequence of Operation, for the control systems engineer to design from. More likely, the specifying engineer will leave that up to the controls engineer to develop, so it's important for the controls engineer to fully understand what the specifying engineer has written, and perhaps even more importantly, what the engineer has drawn up (mechanical plans, details, and equipment schedules).

Sometimes an engineer will work from a manufacturer's specification, in order to build his control systems specification. Occasionally this will filter in to the Sequence. It is important for the control systems designer to differentiate what is relevant to system operation, from what is perhaps just an attribute of the specified vendor.

Other considerations

Maybe the most important thing in "developing" a specified Sequence of Operation is to account for all equipment specific to a project. This is where specifications tend to lose their credibility. A Sequence should be project specific. If the Sequence lists out equipment that is not a part of the particular project, then the purpose that it serves is diminished. Likewise if equipment is left out of the Sequence. This is typical of what can happen with the "cut and paste" method of putting together a Sequence. Suffice it to say that cutting and pasting is usually not the best way to go about writing a project-specific Sequence of Operation.

Once all equipment is accounted for, the specified Sequence should be clear and concise with the intended operation of each piece of equipment, without dragging on and listing every minute detail. There needs to be a certain balance struck, between listing out what's fundamentally important, and rambling on with operational details that will "come out in the wash", so to speak. Given this, there needs to be a certain amount of responsibility put onto the shoulders of the commissioning team, and a certain amount of faith put into them as well.

The funny thing about Sequences and Points Lists, at least on the surface, is that engineers, who take the time and put their efforts into creating these documents, subsequently turn around and ask for submittals from the T/C contractor, requiring that the submittals include Sequences and Points Lists! Why is this? With all that has been laid out thus far, it is probably not as difficult to understand this now, as it may have been prior to reading through the above.

The quasi-dimensional engineering firm may write a Sequence and Points List so accurate and so reflective of their mechanical design, that there is no need for the controls engineer to revise, regenerate, or elaborate on what the engineer has provided (barring any mechanical design changes). Typically this won't be the case, and the specifying engineer will "pass off" the task of generating a detailed Sequence of Operation to the controls engineer. This is the way it works, and is generally in the best interests of all parties. It may seem like the specifying engineer is "passing the buck", but this forces the control systems engineer to thoroughly understand the mechanical design intentions, and it allows the specifying engineer to evaluate the controls engineer's comprehension of the specifying engineer's intentions for the operation of the mechanical systems. On a lesser frequency, the competent, forthright specifying engineer may simply recognize that he is not in the best position to write the full-blown Sequence of Operation, for whatever reason.

The specified Sequence of Operation should not waste its time on commissioning details. A Points List and a concise Sequence shall suffice for the purpose of bidding a job and designing it. A "Description of Control" should be developed for each piece of equipment by the temperature controls contractor, with assistance and/or input from the specifying engineer, to be submitted to the engineer after the job has been awarded. When the project is completed (and not until then), a full-blown, detailed Sequence of Operation can and should be developed and provided, along with the "as-built" temperature control drawings. This is generally in everyone's best interests. It keeps the specification short and concise (as it should be), it allows the project to be awarded without "up-front" creation of a document that is subject to substantial change throughout the design process, it forces the controls contractor to understand the mechanical design concepts of the project, and it allows the consulting engineer to retain control over the final design of the HVAC control system. All of which is in the best interests of the customer (who?).

Perhaps the best that an engineer can do, in keeping everyone's best interests at heart, is to do his darndest in writing up concise descriptions for the control of each piece of equipment, and then provide some "disclaimer" that hands over the final development of the Sequences to the controls contractor. For instance:

"The following sequences are designed to describe the scope of control required…the contractor is responsible for expanding on these sequences to include operational details, setpoint parameters…final sequences are expected to be to the degree of detail suitable for commissioning and operating purposes."

or

"Prior to application programming, the controls Contractor shall meet with the Owner and Engineer to determine the final sequence, point name formats, required graphics…"

Conclusion

This document has laid out the "typical" formatting of a temperature controls specification. It is important to understand that there are deviations from this format. Therefore, it is imperative to read a specification for a project in its entirety. Sometimes engineers will "hide" clauses in places that you wouldn't expect to find them. They don't do this on purpose. It's more a result of the nature of the written specification not being completely standardized.

In addition to reading through the entire specification, it is also important to understand the jargon. The terminologies used in a specification sometimes cause vagueness and ambiguity (not to mention headache and nausea!). The interpretation of clauses and descriptions within a spec is perhaps a learned skill. Hopefully this document has helped teach that skill. To understand the jargon, and to recognize what's important to system design, operation, etc. To know what is pertinent to the project, and to know what to dismiss as generic filler or irrelevant fodder. To interpret the engineer's ink and align your thought processes with the engineer's basic intents.

For those of whom write specs, a word or two of advice from those of us that have to read them: Keep It Short! It is very difficult to read through a 100 page temperature controls spec and still focus on what's important. A well-written 20-page document tailored specifically for a project will likely benefit the project more than one with pages and pages of hardware specs and archaic clauses. If the individual preparing the specification is intimately familiar with the ins and outs of the project at hand, then it shouldn't be that difficult to write a custom spec for the project, leaving all of the usual filler and disclaimer material on the cutting room floor.

Project specifications are a part of any "plan and spec" project. They need to exist, for the good of the customer. However, there is a great deal of room for improvement for these documents. Specifications should be kept clear and concise. They should demonstrate accuracy and consistency, and should be developed on a per-job basis. More attention should be paid to the development of specs, as they can be a benefit or a detriment to a given project. The well-written spec can add value to a project, in terms of engineering, coordination, expectations, etc. The poorly written spec can hurt even the simplest project.

The engineer's written specification should be looked upon as a contract document that will assist all parties involved with a project, at the same time guaranteeing that the customer will get what is value to him. The specification should *not* be looked upon as, often as it is, a "necessary evil".