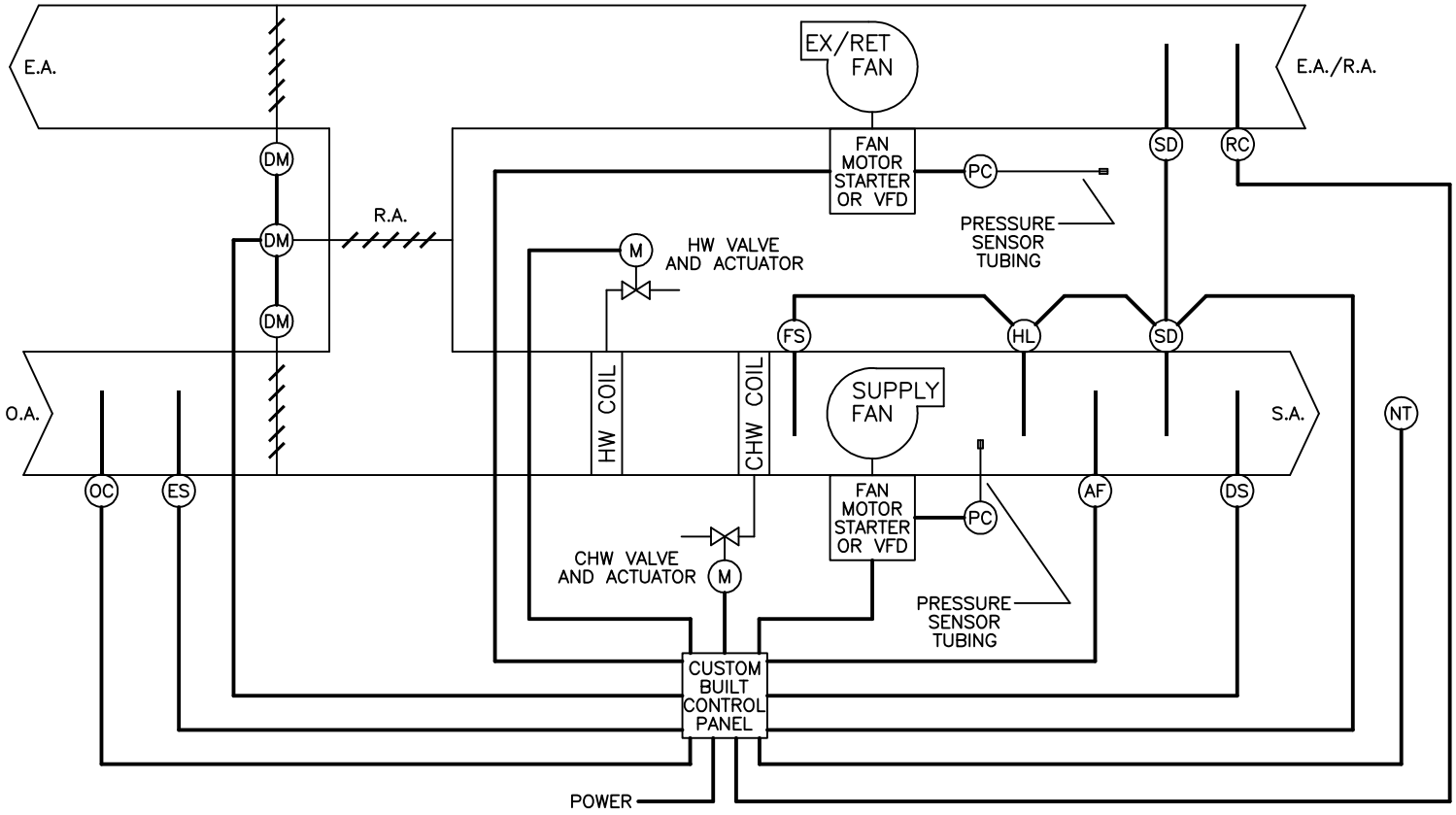
ENGINEERING SOLUTIONS



CONTROLS ESTIMATING AND DESIGN GUIDELINE

Welcome to the ***PCS* Engineering Solutions *Controls Estimating and Design Guideline***. This purpose of this guideline is twofold: as the name suggests, it is to be used as a guideline for both designing and quickly estimating various control systems.

When a mechanical system is conceived, oftentimes the last thing on the designer's mind is the control system. When a project is bid on and sold, many of the controls that must be included for the system to operate properly are often overlooked. Items as simple and as frequently required as freezestats and duct smoke detectors are many times not thought about up front, and are therefore not included in the estimate. Other issues, such as whether to go with two position or modulating control valves on reheat systems, are not thought out well enough up front. Invariably, the result is a budget that will not cover the cost of the required controls (both labor and material) for the given project.

This guideline hopefully can help. With this information in the hands of the project estimator, a controls "awareness" can be instilled right from the very beginning. Knowing what type of mechanical system is being considered, the user can "cross-reference" the appropriate controls system within this guideline. The user can effectively "design" the control system using this guideline. Then, with the system designed and the appropriate controls selected (and omitted, as the case may be), an estimate for both labor and materials can be arrived at.

In order to use this guideline effectively and accurately, certain rules must be established and adhered to. These rules must be read and thoroughly understood by the user:

1) Any three phase power wiring is not included, as it falls under the category of "power wiring".
2) Mounting of starters, disconnects, and variable frequency drives is not included, as it falls under the category of "power wiring".
3) Power to any powered device is included in the labor factor of the device, assuming that there is an available power source within 25 feet of the device.
4) The issue of whether the control wiring is run in conduit or not is addressed on the following page.
5) Certain controls are furnished as part of a system. VAV box zone sensors, for instance, are furnished with the VAV boxes. These controls are not priced within this guideline. Refer to the system supplier's quote.
6) Certain pages within this guideline refer to other pages. To effectively arrive at a suitable design and budget number, items must not be overlooked.
7) The mechanical equipment selected must fit the application. A rooftop unit must not be used in a 100 percent make up air application.
8) Certain mechanical equipment, such as rooftop units and make up air units, must be ordered with the proper controls to fit the application. A rooftop unit with VAV controls must not be ordered for a single zone constant volume application, and vice versa.
9) All guidelines are based upon "ideal conditions". For example, ideal conditions for a built up air handling unit would mean a nice clean equipment room with an empty wall to mount the control panel on, a condensing unit in close proximity to the equipment room, etc. If conditions are somewhat less than "ideal", then labor factors must be increased accordingly.
10) The line item for Startup and Commissioning refers to the amount of time needed to calibrate and check out the control system, and is separate from the "startup" time spent on equipment. It is "above and beyond" the time spent on charging refrigerant systems, checking motor rotations, taking amp readings, etc. It is a conservative estimate, though it doesn't take into account unforeseen problems that a startup technician may encounter, such as miswiring, component failure, damper linkage problems, and other problems that can arise during startup.
11) The line item for Engineering Time refers to the amount of time needed to design the system, create the sequence of operation and the wiring diagram(s), and order the components. It is a conservative estimate, though it doesn't take into account unforeseen problems that can arise, such as changes in scope and design, startup problems, etc.
12) Labor factors generally come down when repeating a task many times. This should be kept in mind when estimating the labor for a project with a dozen rooftop units as opposed to one, or with several dozen VAV boxes as opposed to just a few. This same rule applies to startup and engineering times as well.
13) All content included in this manual represents "stand-alone" control systems, whether or not DDC-based. The extension of any controls estimate (generated with the use of this manual) to reflect accurate pricing for a fully networked Building Automation System (BAS) is beyond the functionality of this estimating tool.
14) This is only a guideline. It should be used only as a tool in the estimating process, and should be considered as such. There are many variables in designing and estimating controls. This tool can help pin down some of those variables. However, this estimating and design guideline does not replace a solid knowledge of control systems and an understanding of what is needed to make mechanical systems work properly. Hopefully, this tool can help teach that knowledge and convey that understanding.

THE CONDUIT ISSUE AND HOW THIS GUIDELINE HANDLES IT

The use of conduit is required in most of the applications that are encountered in this manual, even though much of the control wiring may be low voltage. All wiring run in mechanical/equipment rooms and run outdoors must be in conduit, line voltage or not. Furthermore, much of the thermostat wiring that is installed is normally run in conduit, at least from the thermostat/outlet box, up the wall and through the ceiling into the plenum space. Finally, depending upon the town and the codes that they follow, the use of conduit may be required for all wiring (except perhaps for inherently low voltage wiring such as telecommunication and signal wiring).

Following is an outline of how this guideline addresses the conduit issue:

- **For general thermostat wiring:** the labor factors are based on the assumption that the wiring has to be piped at least from the stat up to the plenum. From that point on to where it terminates, the difference in labor between running the wire in conduit or not is assumed to be negligible. If the wire is not run in conduit in the plenum space, it still needs to be neatly run and tied down, which takes time**.**
- **For rooftop units:** component wiring, for items such as smoke detectors and freezestats, is assumed to be run in conduit, and the labor factors reflect this.
- **For VVT systems:** interconnecting wiring between VVT dampers is assumed to be run "free air". If conduit is required, increase the zone sensor labor by a factor of 1.25 or 1.5.
- **For make up air units:** as often as not the control wiring between the control panel and the unit is line voltage (120 volts). Therefore, all wiring for make up air units is assumed to be in conduit, and the labor factors reflect this.
- **For fan coil units:** all wiring local to the fan coil unit is assumed to be run in conduit, and the labor factors reflect this.
- **For built up air handling units:** which are normally located in equipment rooms or outdoors, all wiring local to the unit, and from the unit components to the control panel, is assumed to be run in conduit. The labor factors reflect this.
- **For VAV and fan powered boxes:** power loop wiring, interlock wiring, and DDC communication link wiring is assumed to be run "free air". If conduit is required, increase the VAV box labor by a factor of 1.5 or 2.
- **For pumps, boilers, chillers, heat exchangers, and any other equipment that is normally located in a mechanical/equipment room:** the wiring is assumed to be run in conduit, and the labor factors reflect this.
- **For any equipment in an open warehouse, such as unit heaters and make up air units:** the wiring is assumed to be in conduit, and the labor factors reflect this.
- **Certain guidelines address the conduit issue individually,** giving a labor factor for conduit based on lineal feet.
- **A final note, for thermostat and/or zone sensor wiring of rooftop units and VAV boxes:** if the project only has a few zones, the labor factors shown on the guidelines will work just fine. However, if there are dozens and dozens of zones, then the project must be looked at a bit closer. If conduit is required, then these labor factors may be a bit light. Likewise, if conduit is not required, then these labor factors may be a bit heavy.

Conduit Material Costs

Normally, the conduit used in wiring HVAC controls is ½" to ¾" thinwall. Seldom is there a need for anything larger or more "heavy duty" than this, except in the case of lengthy conduit runs that include many wires. With this presumption, the cost of conduit (pipe, fittings, junction boxes, and miscellaneous materials) equates to less than 10 percent of the **total material cost** of the project. Hence, if the project is foreseen to be "conduit heavy", then multiply the total material cost by this percentage (or less), and add this figure to the total cost of the project.

HVAC SYSTEMS LIST
Rev. 11/17/05

Rooftop Units

- **Constant Volume Single Zone** *[1.1]*
- **Constant Volume With Electric Reheat** *[1.2]*
- **Constant Volume With Hot Water Reheat** *[1.3]*
- **Constant Volume With VVT System** *[1.4]*
- **Variable Air Volume (VAV)** *[1.5]*

Make Up Air Units

- **Packaged Make Up Air Unit – 100 Percent Outside Air** *[2.1]*
- **Packaged Make Up Air Unit – Return Air Capabilities** *[2.2]*
- **Built Up Make Up Air Unit With Electric Heating** *[2.3]*
- **Built Up Make Up Air Unit With Steam Heating** *[2.4]*
- **Built Up Make Up Air Unit – Addition Of DX Cooling** *[2.5]*

Fan Coil Units

- **DX Cooling & Two-Position Hot Water Heating** *[3.1]*
- **DX Cooling & Modulating Hot Water Heating** *[3.2]*
- **DX Cooling & Staged Electric Heating** *[3.3]*
- **DX Cooling & Staged Gas Fired Heating** *[3.4]*
- **Two-Position Chilled Water Cooling & Hot Water Heating** *[3.5]*
- **Two-Position Chilled Water Cooling & Staged Electric Heating** *[3.6]*
- **Two-Position Chilled Water Cooling & Staged Gas Fired Heating** *[3.7]*
- **Two-Position "Dual-Temp" System** *[3.8]*
- **Modulating "Dual-Temp" System** *[3.9]*
- **Modulating Chilled Water Cooling & Staged Electric Heating** *[3.10]*
- **Modulating Chilled Water Cooling & Staged Gas Fired Heating** *[3.11]*
- **Modulating Chilled Water Cooling & Hot Water Heating** *[3.12]*

Built Up Air Handling Units – Single Zone Temperature Control

- **DX Cooling & Modulating Hot Water Heating** *[4.1]*
- **DX Cooling & Staged Electric Heating** *[4.2]*
- **Modulating Chilled Water Cooling & Hot Water Heating** *[4.3]*

Built Up Air Handling Units – Discharge Air Temperature Control

- **DX Cooling & Two-Position Hot Water Heating (For AM Warmup & Night Setback)** *[5.1]*
- **DX Cooling & Electric Heating (For AM Warmup & Night Setback)** *[5.2]*
- **Modulating Chilled Water Cooling & Two-Position Hot Water Heating (For AM Warmup & Night Setback)** *[5.3]*

Built Up Air Handling Units – Multizone Systems

- **DX Cooling & Modulating Hot Water Heating** *[6.1]*
- **DX Cooling & Staged Electric Heating** *[6.2]*
- **Modulating Chilled Water Cooling & Hot Water Heating** *[6.3]*

VAV Boxes

- **Cooling Only** *[7.1]*
- **Cooling With Electric Reheat** *[7.2]*
- **Cooling With Two-Position Hot Water Reheat** *[7.3]*
- **Cooling With Modulating Hot Water Reheat** *[7.4]*

Fan Powered Boxes

- **Cooling With Electric Reheat** *[8.1]*
- **Cooling With Two-Position Hot Water Reheat** *[8.2]*
- **Cooling With Modulating Hot Water Reheat** *[8.3]*

Reheat Coils

- **Electric Reheat Coil** *[9.1]*
- **Hot Water Reheat Coil – Two Position Control** *[9.2]*
- **Hot Water Reheat Coil – Modulating Control** *[9.3]*
- **Steam Reheat Coil – Two Position Control** *[9.4]*
- **Steam Reheat Coil – Modulating Control** *[9.5]*

Fans

- **Exhaust Fans (& Supply Fans)** *[10.1]*

Pumping Systems

- **Single Pump** *[11.1]*
- **Two Pumps With Manual Controls** *[11.2]*
- **Two Pumps With Automatic Controls** *[11.3]*
- **Three Pumps With Manual Controls** *[11.4]*
- **Three Pumps With Automatic Controls** *[11.5]*

Boilers

- **Hot Water Boiler – Single Boiler** *[12.1]*
- **Hot Water Boiler – Multiple Boilers** *[12.2]*
- **Steam Boiler – Single Boiler** *[12.3]*
- **Steam Boiler – Multiple (Two) Boilers** *[12.4]*

Chillers

- **Air Cooled Chiller** *[13.1]*
- **Air Cooled Chiller With Remote (Indoor) Evaporator** *[13.2]*
- **Condenserless Chiller With Remote Air Cooled Condenser** *[13.3]*
- **Water Cooled Chiller** *[13.4]*
- **Multiple Air Cooled Chillers** *[13.5]*
- **Multiple Water Cooled Chillers** *[13.6]*
- **Refrigerant Monitoring / Ventilation System** *[13.7]*

Steam to Hot Water Heat Exchangers

- **Single Valve Control** *[14.1]*
- **Dual Valve Control** *[14.2]*

Duct Mounted Humidifiers

- **Steam Utilizing** *[15.1]*
- **Steam Generating** *[15.2]*

Unitary Heating Equipment

- **Unit Heater – Steam or Hot Water** *[16.1]*
- **Unit Heater – Gas Fired or Electric** *[16.2]*
- **Cabinet Unit Heater – Steam or Hot Water** *[16.3]*
- **Cabinet Unit Heater – Electric** *[16.4]*
- **Baseboard Heater – Steam or Hot Water** *[16.5]*
- **Baseboard Heater – Electric** *[16.6]*

Computer Room A/C Systems

- **Air Cooled System** *[17.1]*
- **Tower Water System** *[17.2]*
- **Glycol Cooled System** *[17.3]*

Variable Frequency Drive Systems

- **Pressure Control of Fan Speed** *[18.1]*
- **Temperature Control of Fan Speed** *[18.2]*
- **Pressure Control of Pump Speed** *[18.3]*
- **Temperature Control of Pump Speed** *[18.4]*

Damper Control Schemes

- **Two-Position** *[19.1]*
- **Modulating** *[19.2]*

Valve Control Schemes

- **Two-Position** *[20.1]*
- **Modulating** *[20.2]*

Variable Frequency Drives

- **230 Volt Pricing** *[21.1]*
- **460 Volt Pricing** *[21.2]*

Damper Motors

- **Two-Position or Modulating Control** *[22.1]*

Hot & Chilled Water Control Valves

- **Two-Way Bodies, Two-Position Control** *[23.1]*
- **Three-Way Bodies, Two-Position Control** *[23.2]*
- **Two-Way Bodies, Modulating Control** *[23.3]*
- **Three-Way Bodies, Modulating Control** *[23.4]*

Steam Control Valves

- **Two-Way Bodies, Two-Position Control** *[24.1]*
- **Two-Way Bodies, Modulating Control** *[24.2]*

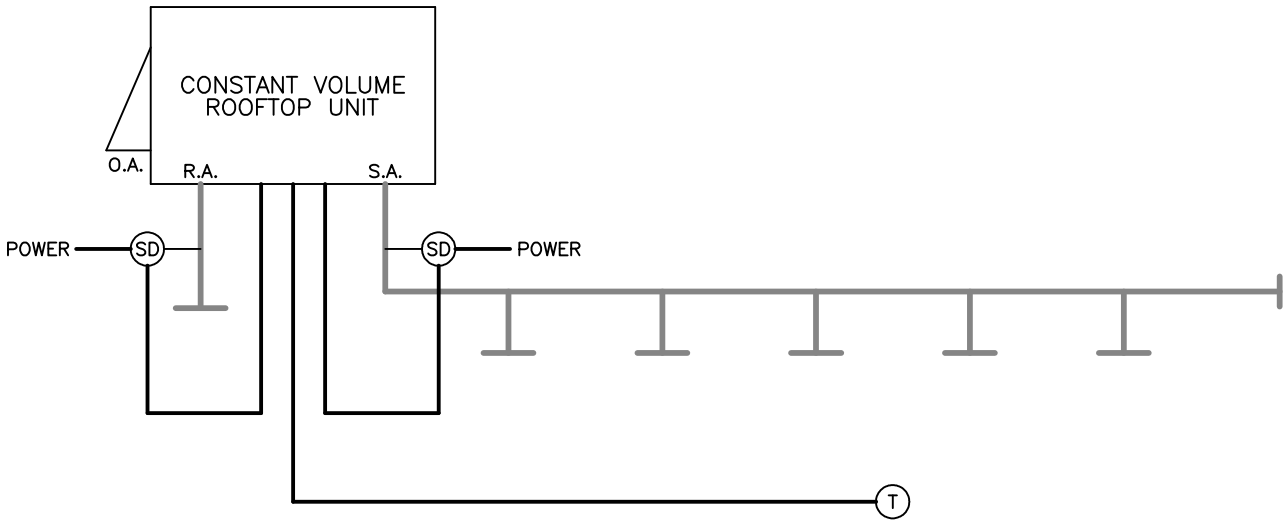
Motor Starters & Control Panels

- **Three Phase Motor Starters** *[25.1]*
- **Custom Built Control Panels** *[25.2]*

A/C Unit Alternating Systems

- **Primary / Backup Systems (each unit sized for the full load)**
  - **Units With Microprocessor Based Controls** *[26.1]*
  - **Staged Units – Single Point Control** *[26.2]*
  - **Staged Units – Two Point Control (Separate Operating & Failure Thermostats)** *[26.3]*
- **Lead / Lag Systems (each unit sized for half the load)**
  - **Units With Microprocessor Based Controls** *[26.4]*
  - **Single Stage Units** *[26.5]*
  - **Two Stage Units** *[26.6]*

ROOFTOP UNIT – CONSTANT VOLUME SINGLE ZONE



DESCRIPTION

Commercial packaged rooftop unit with distribution ductwork serving a single zone with a thermostat in the zone.

COMPONENTS

		NOTES	LABOR (hours)	MATERIAL (cost)
(T)	THERMOSTAT, PROGRAMMABLE (or)	[1]	4.0	200.00
(T)	THERMOSTAT, NON–PROGRAMMABLE		4.0	90.00
(SD)	DUCT MOUNTED SMOKE DETECTOR(S)	[2] [3]	4.0 (6.0)	150.00 ea.
	STARTUP AND COMMISSIONING: 2 hours	TOTALS:		
	ENGINEERING TIME: –––––			

NOTES

[1] Most programmable thermostats have remote sensing capabilities. Two conductor from the thermostat to the remote sensor. Add cost of sensor ($50.00) and labor required to mount and wire sensor (2 hours).

[2] No smoke detector required if the rooftop unit CFM is less than 2000. Two smoke detectors required if the rooftop unit CFM is greater than 15000. Otherwise, one detector required in the supply air duct.

[3] Labor includes power wiring to the detector and interlocking the detector to the rooftop unit. Labor does not include interlock to any fire alarm system.