

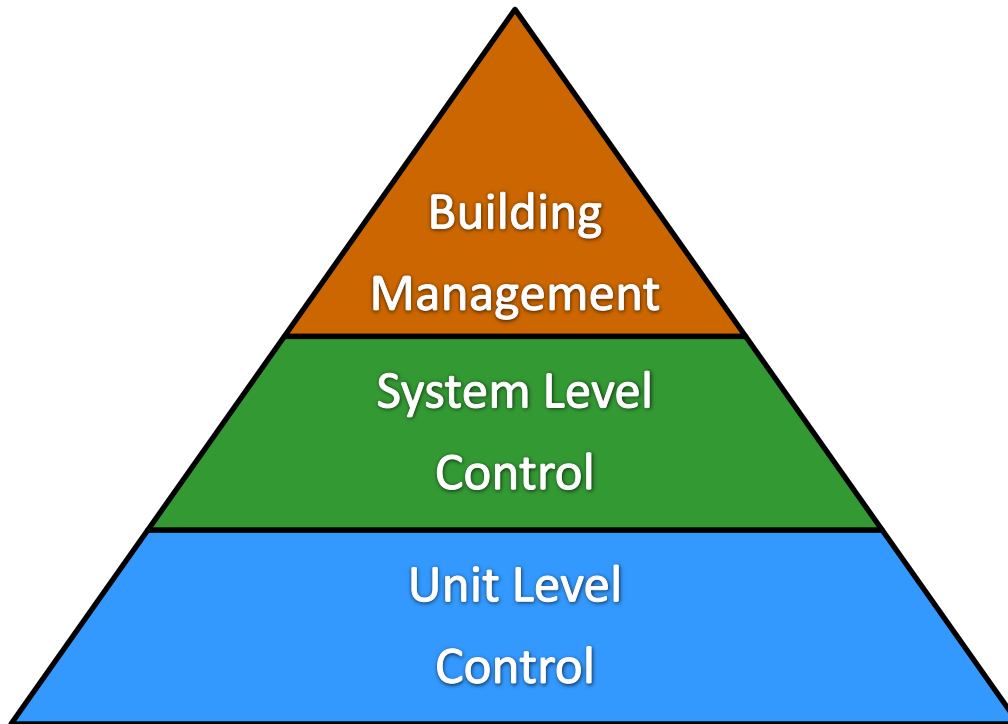


Fundamentals of HVAC

Controls



Levels of Controls



Controls theory – Unit Level

Unit level also referred to as distributed

Value

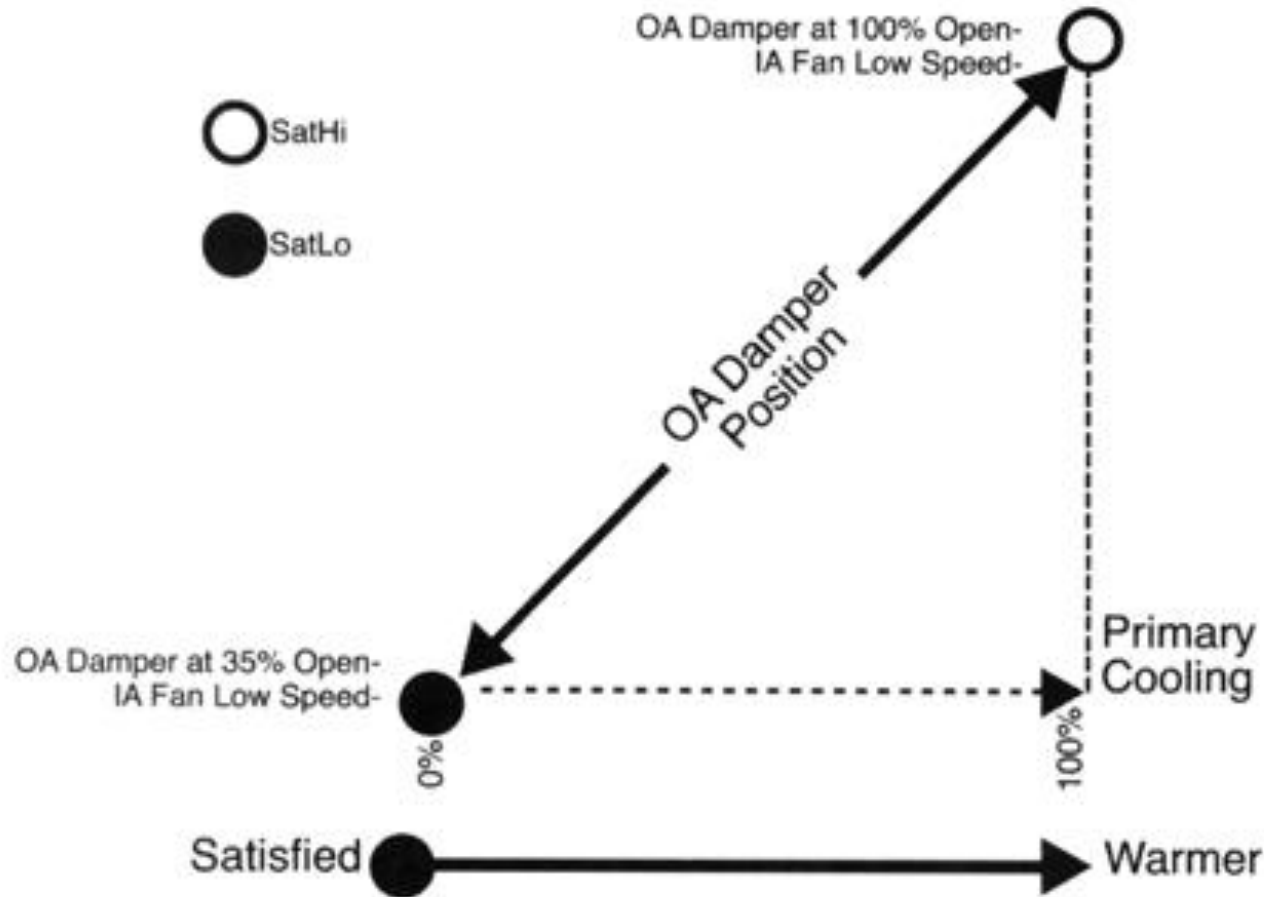
- **Stand-alone control**
- **Safeties, alarms, and diagnostics**
- **Installed, tested, and commissioned in factory**



Terminology

- **Controlled Variable**
 - Measured and controlled parameter
- **Sensor**
 - Measures controlled variable
- **Controlled agent**
 - Medium that is manipulated by the controlled device (energy source)
- **Controlled device**
 - Reacts to signal (output) from the controller to takes action to vary the controlled agent
- **Controller**
 - Reads sensor (input) then transmits corrective action (output) to controlled device

Close Loop Control



Control Points

- Binary input point (BI)
 - Examples: fan status (on/off), dirty filter
- Binary output point (BO)
 - Examples: start/stop fan or pump, open/close damper
- Analog input point (AI)
 - Examples: temperature, pressure, airflow
- Analog output point (AO)
 - Examples: control valve or damper position
temperature setpoint

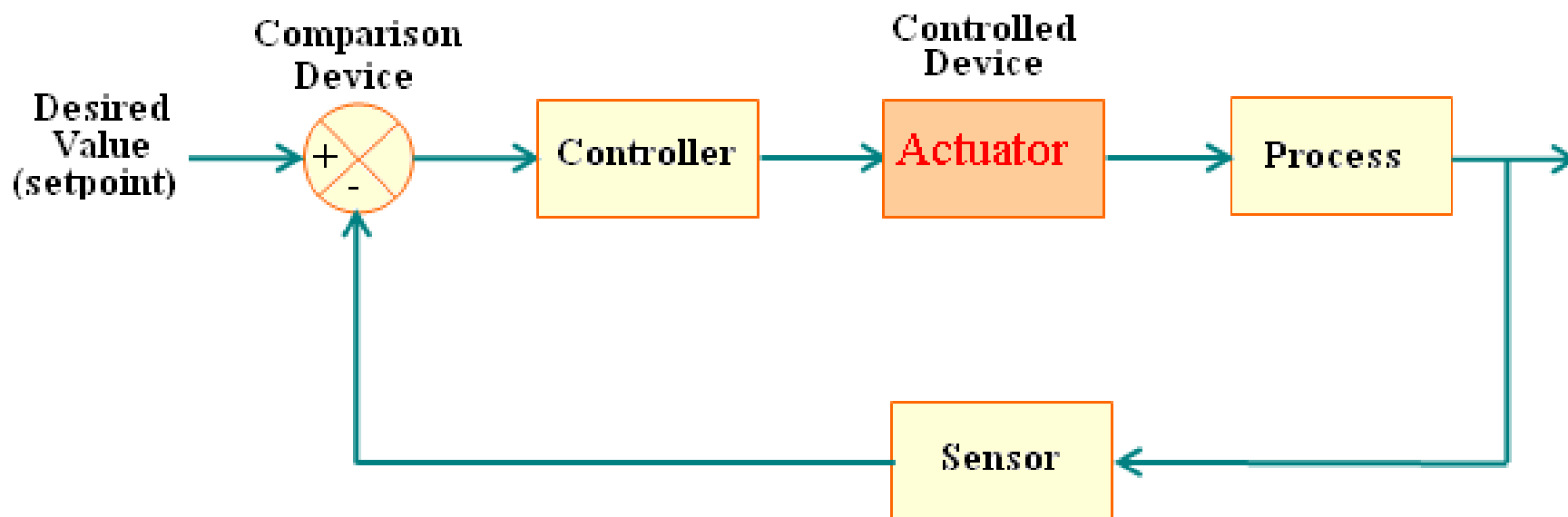
Control Methods

- Two Position (BI/BO)
 - Input Switches
 - On/Off Outputs
 - Absolute Threshold
- Modulation (AI/AO)
 - Discrete Value

Types of Modulating Control

- Floating Point
 - Analog to binary
- Proportional
- Proportional with Integral
- Proportional with Integral and Derivative

Modulating Closed Loop Control



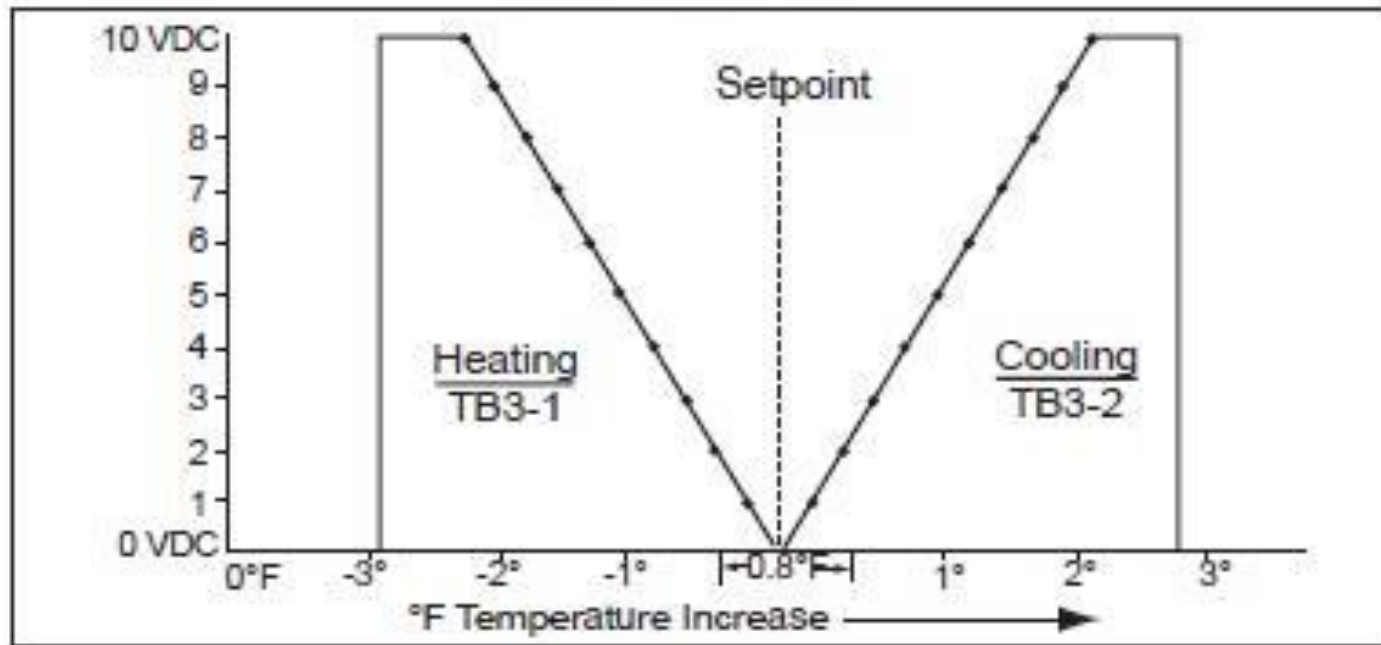
Control Loop Diagram

Floating Point

- Two binary outputs
 - Analog from binary
 - Pulsed control

Proportional Control

- Output in direct proportion to the difference from the setpoint



Adding Integral Control

- Adjusts the control signal based on how far the sensor reading is from setpoint and for how long its been that far from setpoint

Adding Derivative Control

- Adjusts control signal based on how quickly the sensor reading is approaching the target setpoint reading

Controllers

- Pneumatic Control
 - Pneumatic HVAC systems in operation in some buildings, such as schools and offices, which can be a century old
- Electric Control
 - Electromechanical relays in ladder logic
 - Relays became electronic switches as transistors eventually could handle greater current loads
- Digital Control
 - Programmed microprocessor

Pneumatic Controls

- Uses a network of compressed air to achieve control
- Orifices are either opened or closed by mechanical control devices
- Based on the presence or absence of pressure in a branch a control function is carried out

Pneumatic Controls

- Compressor
 - Provides the overall pressure to the system
- Regulator
 - Limits the total pressure to an appropriate level for a specific branch
- Device
 - Manipulates or is manipulated by the pressure on it's branch to achieve control

Electric Controls

- Uses electric signals to achieve control
 - Line or Low voltage applications
 - Voltage signals manipulated by various electronic devices

DDC

- Use a microprocessor based controller
- Programmable
- Advanced/adjustable sequence of operations
- Communications

Control Devices

- Sensors
 - Range
 - Accuracy
 - Repeatability
 - Response Time

Control Devices

- Sensors
 - Temperature
 - Room
 - Duct
 - Outdoor
 - Pipe
 - Types
 - Bimetal
 - Rod and Tube
 - Sealed Bellows
 - Remote Bulb
 - Thermistor
 - RTD

Temperature Sensor Examples

- Probe Temperature Sensor
 - Thermo well
 - Outdoor air

Pipe Sensor Examples

- Pipe Sensors

Control Devices

- Sensors
 - Humidity
 - Mechanical
 - Electronic
 - Chilled Mirror
 - Dispersive Infrared (DIR)

Control Devices

- Sensors
 - Pressure
 - Differential
 - Bellows
 - Diaphragm
 - Bourdon Tube
 - Electronic

Control Devices

- Sensors
 - Flow
 - Orifice Plate
 - Pitot Tube
 - Venturi
 - Turbine
 - Vortex shedding
 - Doppler Effect

Control Devices

- Sensors
 - Gas
 - CO₂
 - CO
 - Refrigerant

Sensors vs. Switches

- All of the above exist in sensor and switch varieties
 - Similar form, fit, and function
 - Switches will not provide analog feedback to the device they are serving

Switches

- Normally open vs. Normally closed
 - Indicates the state of the position of the switch when in it's natural or not-powered state
 - Should be selected based on the following
 - What the controlling device is expecting
 - What position the switch should go to in a loss of power

Control Devices

- Relays and Contactors
 - Essentially binary outputs
 - Coil rating
 - Contact rating
 - Poles and throws

Actuators

Device on valves and dampers causing mechanical motion

- Types

- Pneumatic
 - Compressed gas produces a force (Typical: 3-15 PSI)
 - Cost of compressors, installation and maintenance of air line - HIGH
- Electromechanical Solenoid Valves (Refrigerant)
- Direct Digital Control (DDC)
 - Typical valve and damper for new HVAC

Control Devices - Valves

Important component of fluid distribution systems

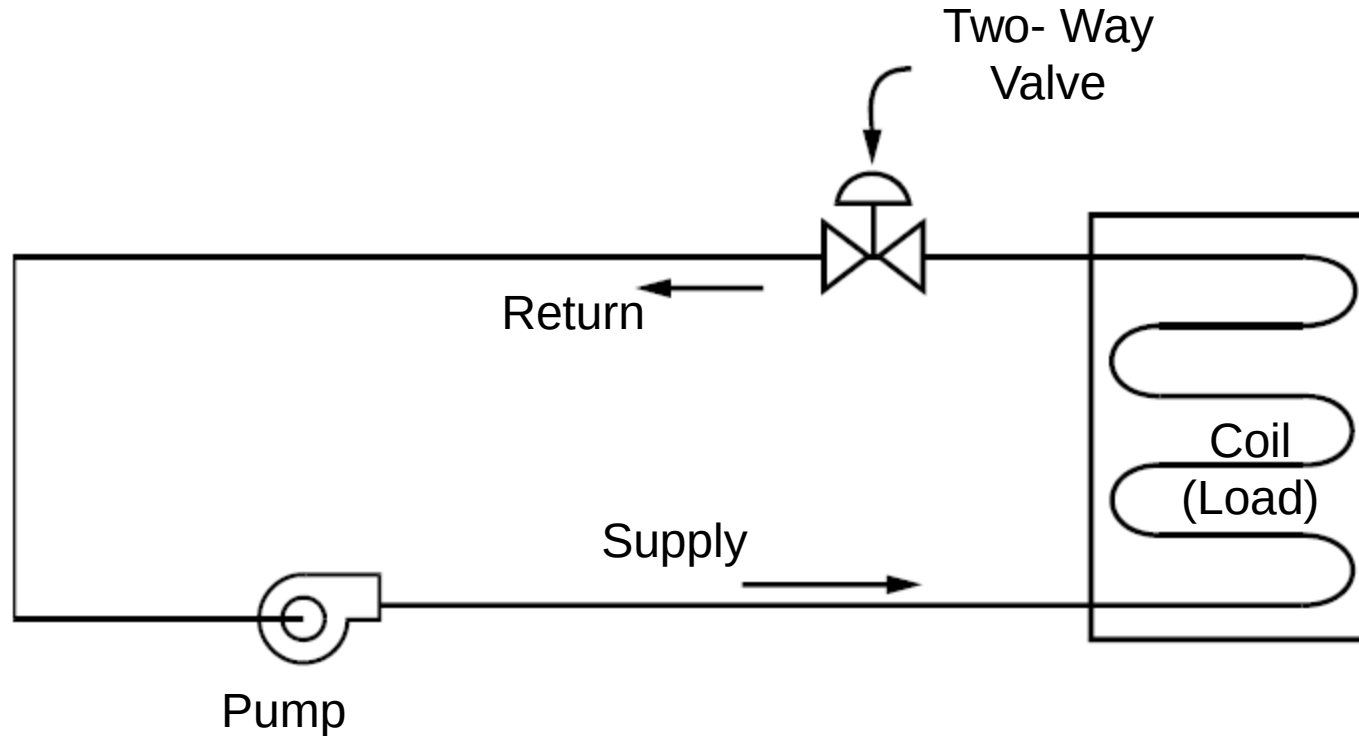
- Common types:
 - Globe valves (Commonly used for 2 position & modulating)
 - Ball valves (Commonly used for shut off and balancing)
 - Butterfly valves (Commonly used for 2 position)
- Valve material
 - Bronze, cast iron, steel

Control Devices - Valves

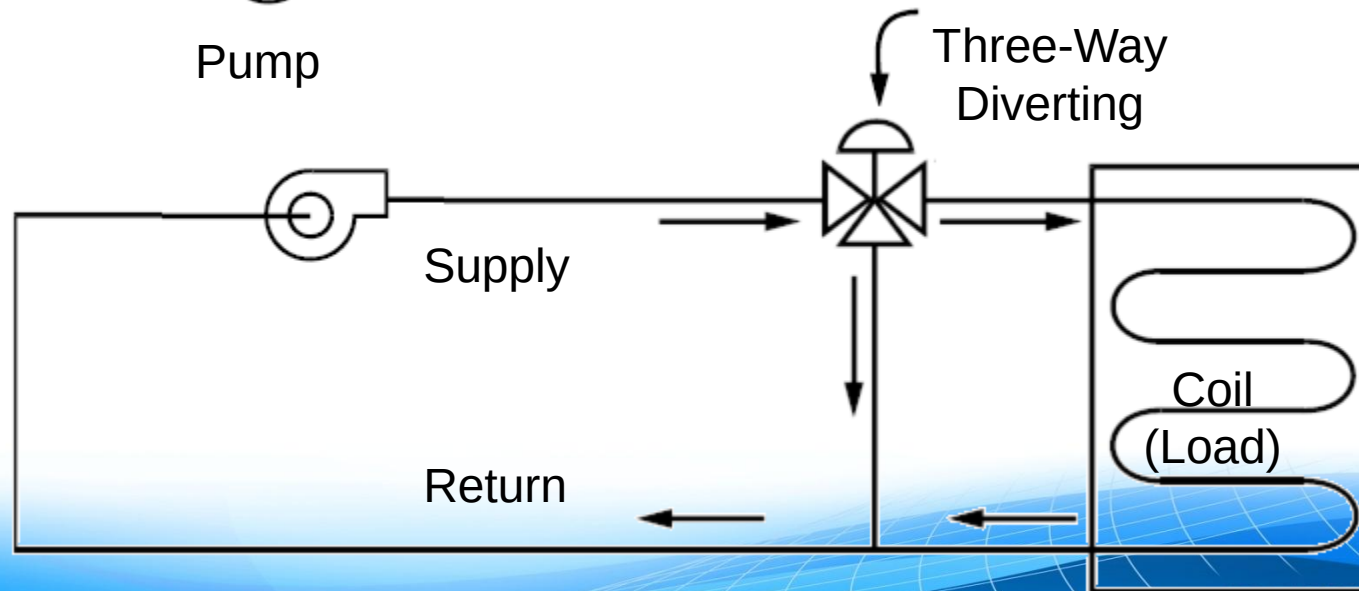
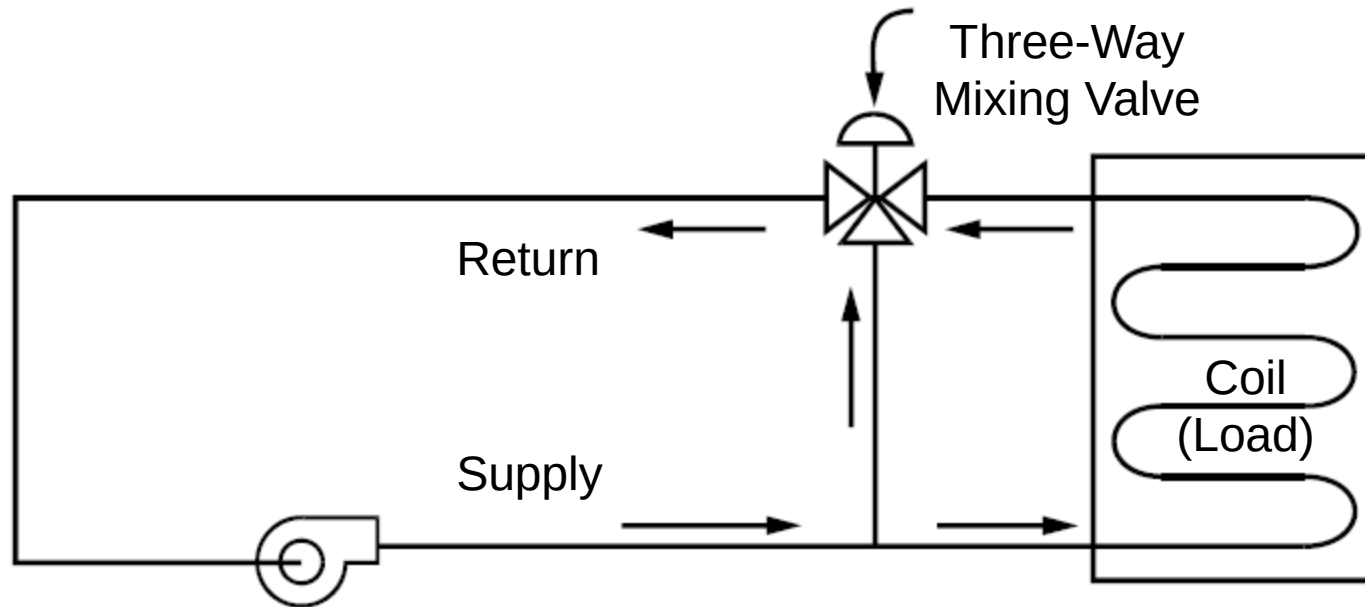
- **2-way Valves for variable flow**
 - More sensitive to high differential pressure
 - Harder to close off against line pressure
- **3-way: for constant flow**
 - Actuator does not need to be as powerful

Control Devices – Valve Circuits

Two-Way



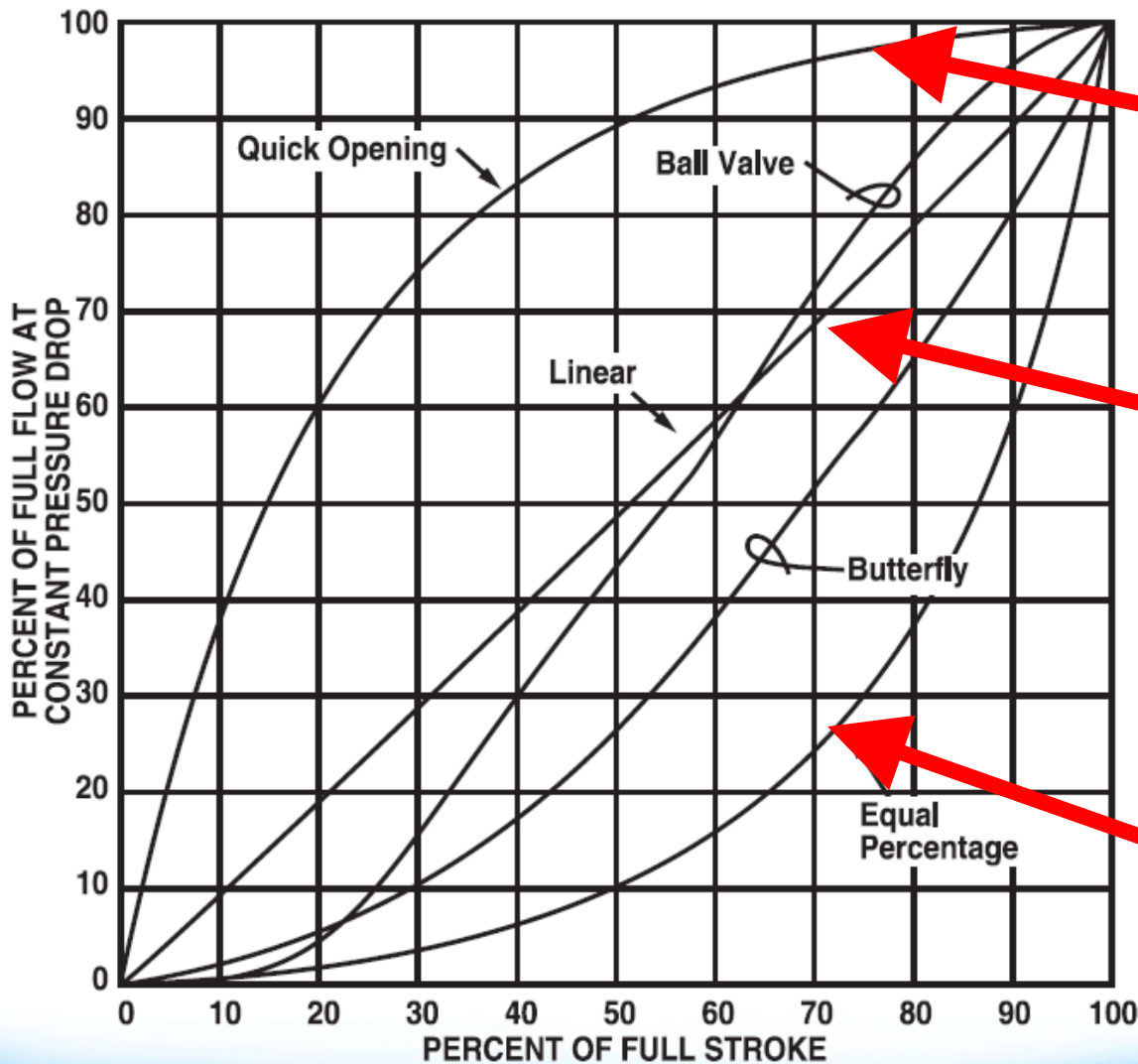
Control Devices – Valve Applications



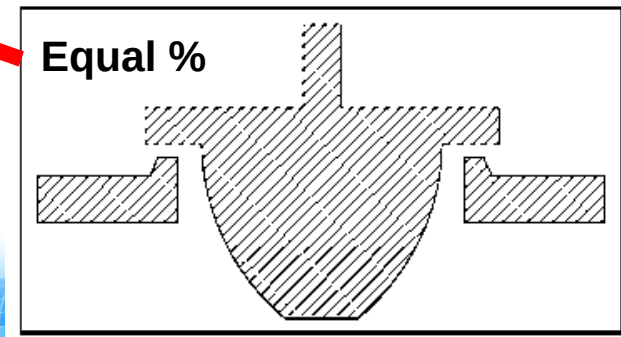
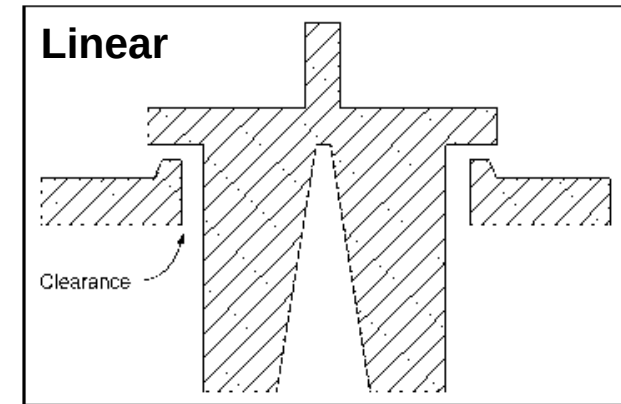
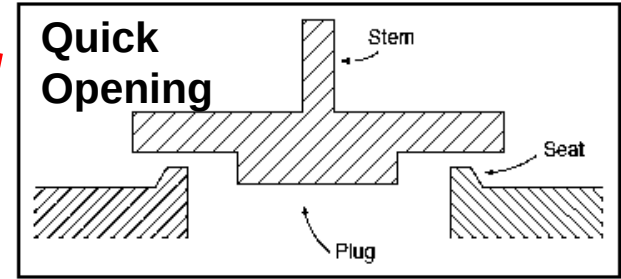
Valves Flow Characteristics

- Valve flow characteristics
 - Relationship between the stem travel of a valve, expressed in percent of travel, and the fluid flow through the valve, expressed in percent of full flow
- Typical flow characteristics
 - Linear
 - Equal percentage
 - Quick opening

Valves Flow Characteristics



Globe Valves



[Source: ASHRAE, 2008.]

Fundamentals of HVAC Control Systems

Valve Selection

Things you need to know when sizing a valve:

1. What is the piping arrangement and pipe size?
2. Does the application require two-position or proportional control?
3. Does the application require a normally open or normally closed valve?
4. Should the actuator be direct acting or reverse acting?
5. Is tight shut-off necessary?
6. What differential pressure does the valve have to close against?
7. How much actuator close-off force is required?
8. What type of medium is being controlled?
9. What are the temperature and pressure ranges of the medium?
10. What is the pressure drop across the valve? Is it high enough?

Valve Selection

- Effects of undersized or oversized control valve
- Undersized
 - Pump energy usage increase to overcome valve pressure drop
 - Could effect pump size (larger)
 - Venturi effect casing pitting or whistling
 - Higher controllability (**small** valve travel causes **small** delta flow rate)
- Oversized
 - Lower controllability (**small** valve travel causes **large** **delta** flow rate)
 - Erratic control with poor stability and accuracy
 - Pump energy usage decrease - less valve pressure drop to overcome
 - Could effect pump size (smaller)

Dampers

Types of Control Dampers

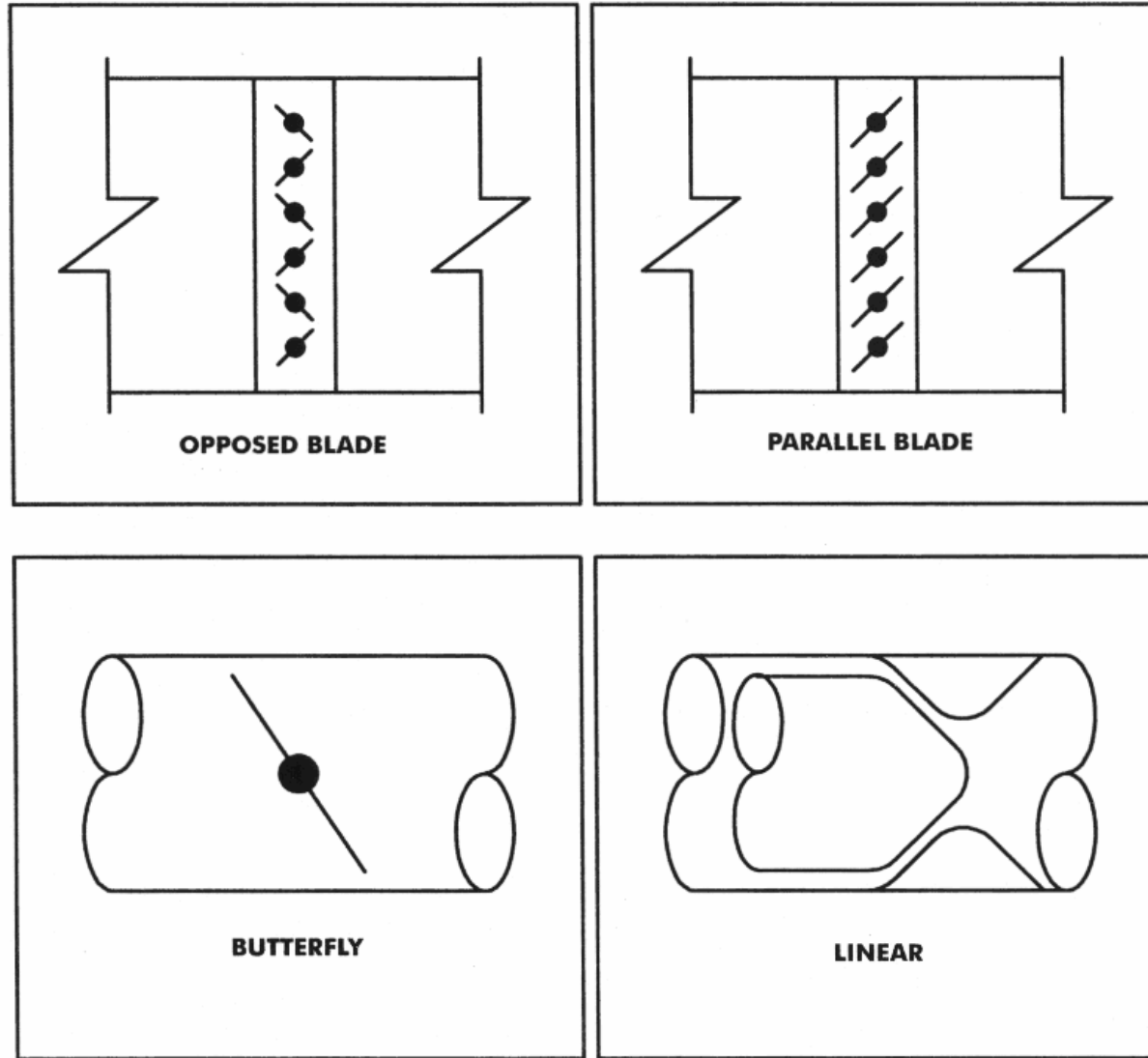
- **Fire damper:**
 - A thermally actuated to restrict the passage of fire and/or heat where an opening violates the integrity of a fire partition or floor
- **Smoke damper**
 - A damper arranged to control passage of smoke through an opening or a duct
- **Volume control damper**
 - A device used to regulate the flow of air in an HVAC system

Volume Control Dampers

- Types

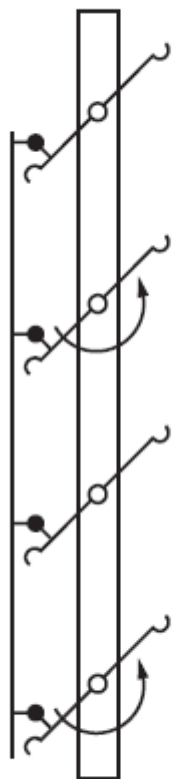
- Multiple Blade Dampers (Selected for best air mixing)
 - Parallel Blade
 - Opposed Blade
- Single Blade
 - Butterfly Damper (Typical in Zone Applications - VAV Boxes)
- Linear (Air Valve) (Typical in labs and hospitals)

Dampers

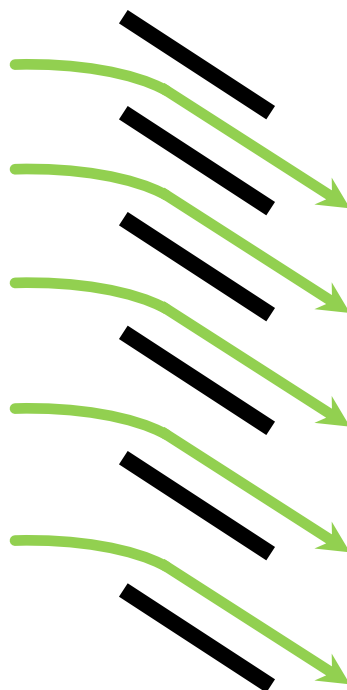


[Source: Shadpour, F., 2001. The Fundamentals of HVAC Direct Digital Control]

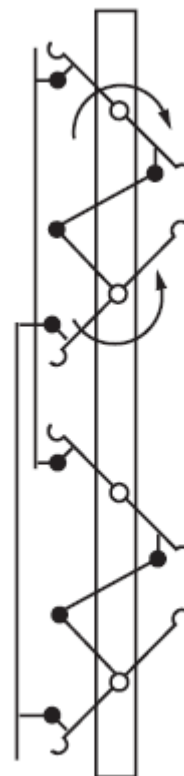
Multiple Damper Operation



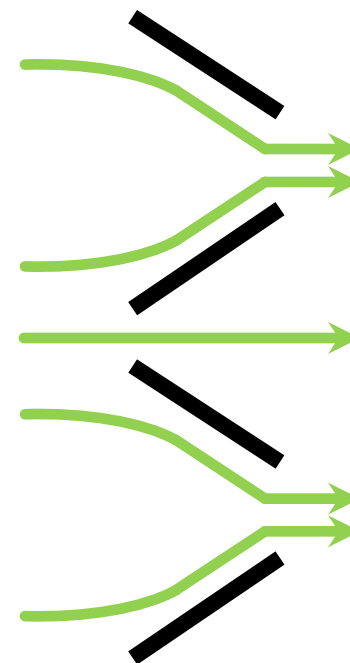
PARALLEL
OPERATION



Airflow through
parallel blade
1/3 open



OPPOSED
OPERATION



Airflow through
opposed blade
1/3 open

Damper Performance

Leakage ratings

- For typical dampers, leakage increases more significantly with the number of blades than with the length of the blades

Torque requirements

- **Closing torque:** the torque required to force the blades together sufficiently to achieve minimum possible leakage
- **Dynamic torque:** required to overcome the effect of high velocity airflow over the blades

Schematics

- Piping and Wiring
- Key Components
 - Terminal Blocks
 - 'By others'/Field Wiring
 - Wire numbers
 - Common symbols

Terminal Blocks and By Others

- Terminal block numbers will match what's in the control box
- If wiring is to be done in the field it will be indicated

Wire Numbers

- Wire numbers will correspond to wires in the control box

End of Lesson

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