MECH3023: Building Energy Management & Control Systems

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# Hardware Components (I)


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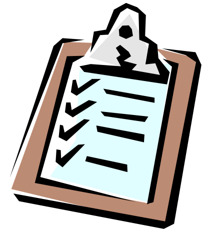
# Contents



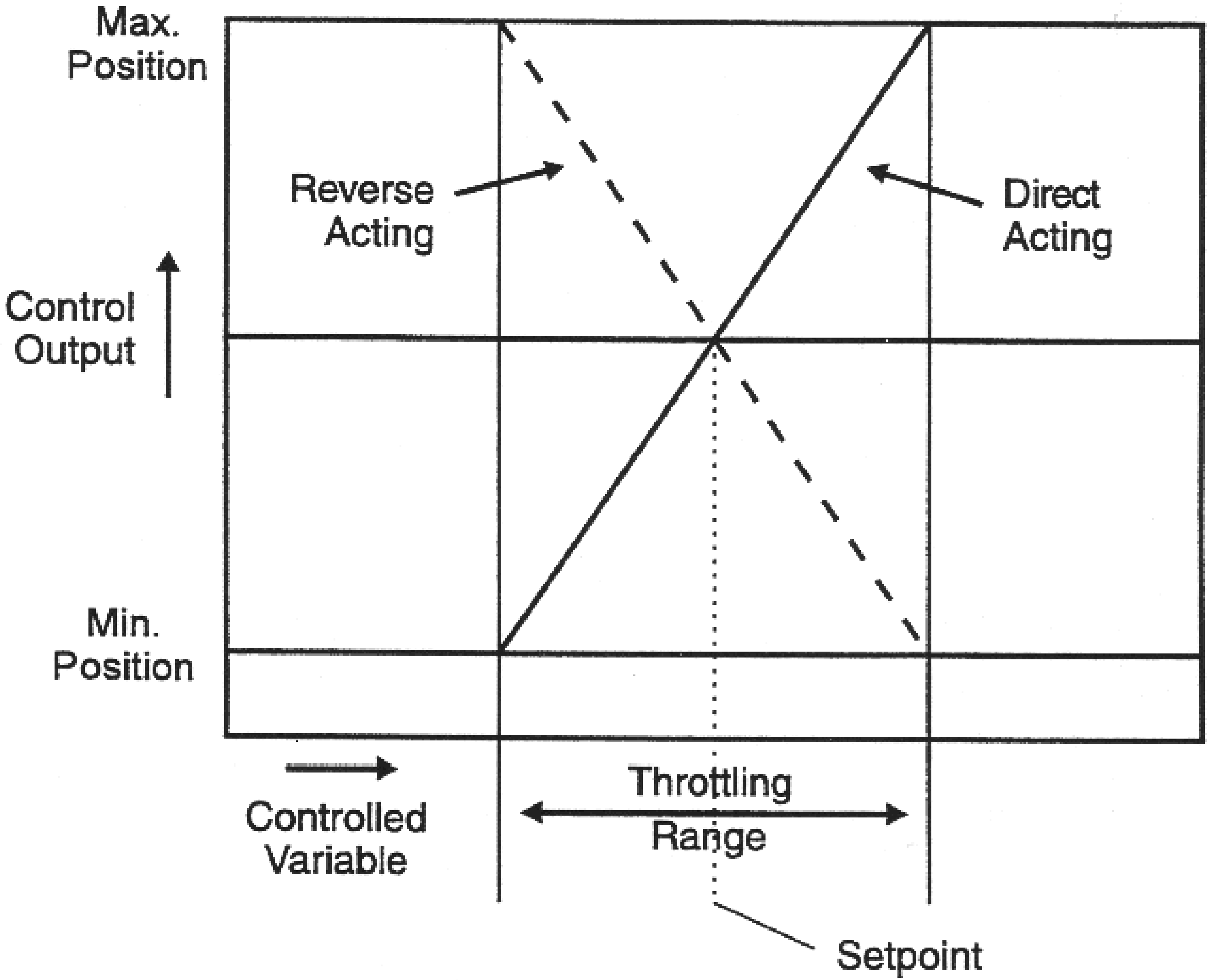
- Control Fundamentals
  - Definitions and terminology
  - Control system components
  - Control methods
- The Basics
  - Six steps of HVAC DDC system design
  - DDC controllers
  - Basics of HVAC controls

# Control Fundamentals

- Definitions and terminology, such as
  - Analogue:
    - Continuously variable (e.g. a valve controlling water from off to full flow)
  - Digital:
    - A series of on and off pulses arranged to convey information
  - Controller:
    - A device that senses changes in the controlled variable (or receives input from a remote sensor) and derives the proper correction output

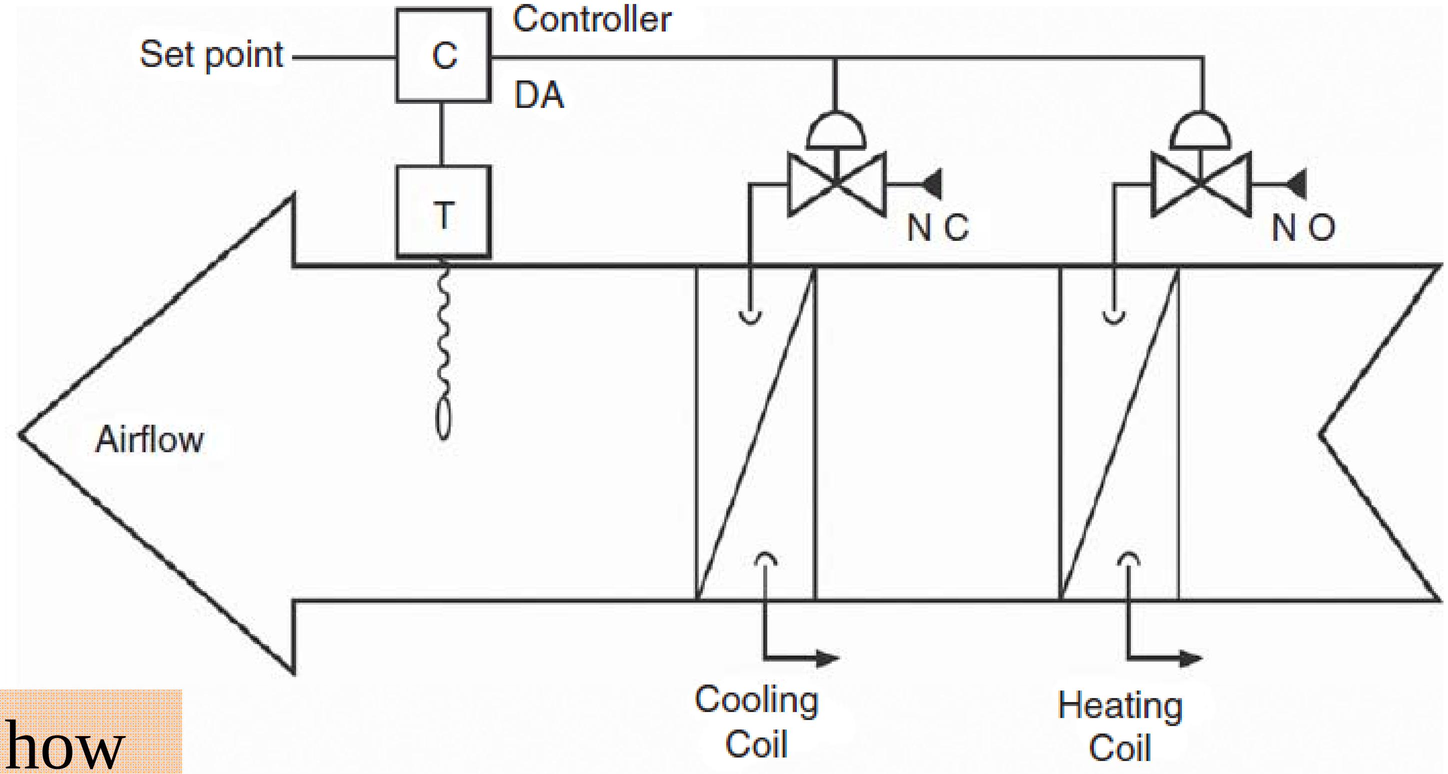
# Control Fundamentals

- Definitions and terminology (cont'd)
  - Controlled variable:
    - The quantity or condition that is measured & controlled, e.g. temperature, pressure, relative humidity, and flow
  - Setpoint:
    - The value (desired control point) set at the controller
  - Throttling range: (in a proportional controller)
    - The control point range through which the controlled variable must pass to move the final control element through its full operating range
  - Deadband:
    - Range of controlled variable in which no corrective action is taken

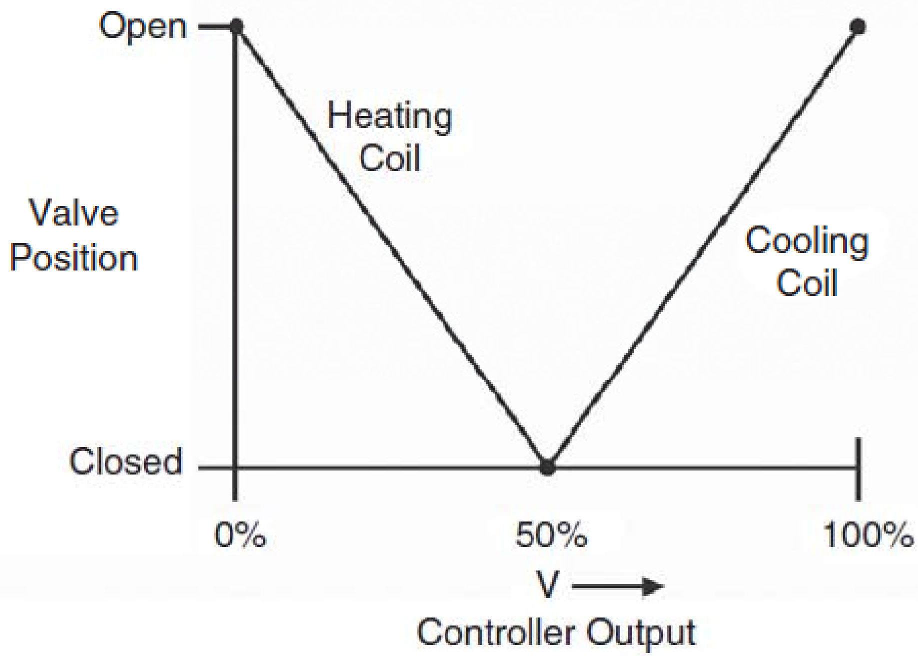



**Proportional Control**

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]




Do you know how to control them over a year?




[Source: Montgomery, R. and McDowall, R., 2008. *Fundamentals of HVAC Control Systems*]

# Control Fundamentals

- Control system components
  - 1. Sensing elements
    - Temperature
    - Humidity/moisture
    - Pressure
    - Flow
    - Proof of operation (e.g. for safety interlock)
  - Design factors: accuracy, reliability, repeatability, precision

# Control Fundamentals

- Temperature sensing elements can be
  - Bimetal strip
  - A rod-and-tube element
  - A sealed bellows
  - A sealed bellows attached to a capillary or bulb
  - A resistive wire
  - A thermistor or resistance temp. device (RTD)
    - Rapid response to temperature

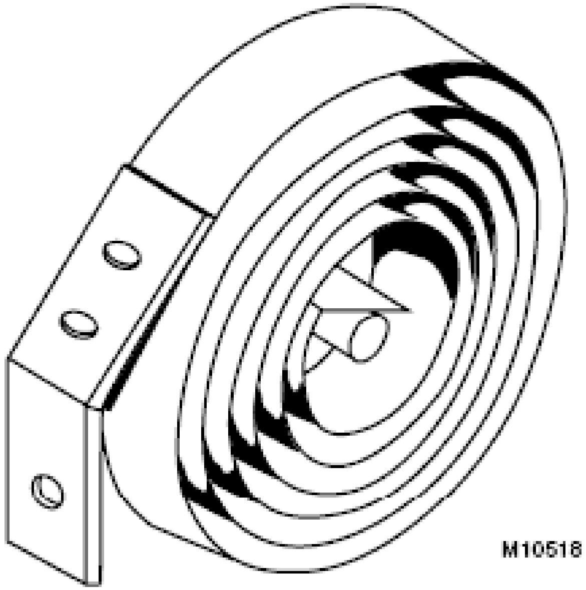



**Fig. 49. Coiled Bimetal Element.**

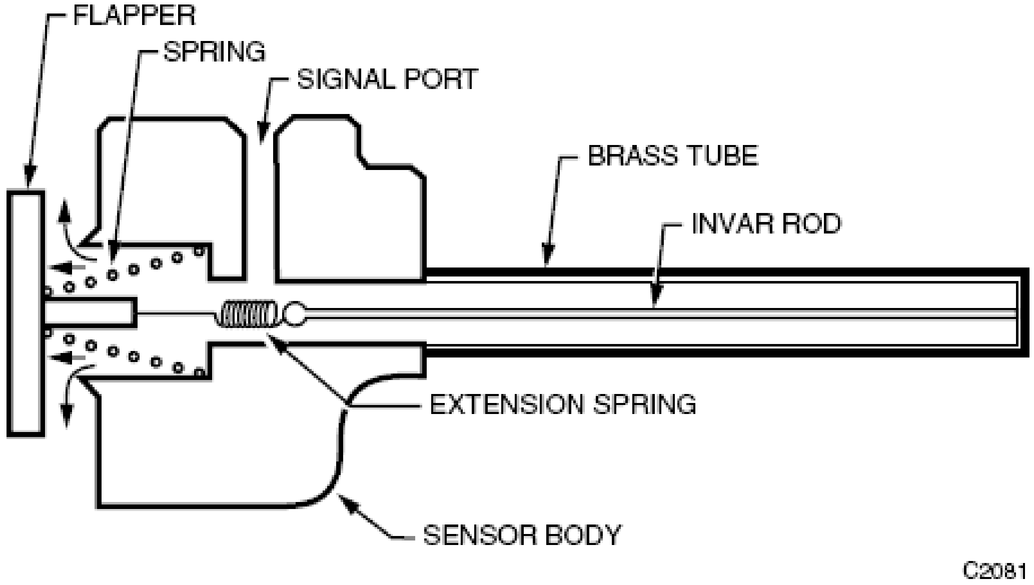



**Fig. 50. Rod-and-Tube Element.**

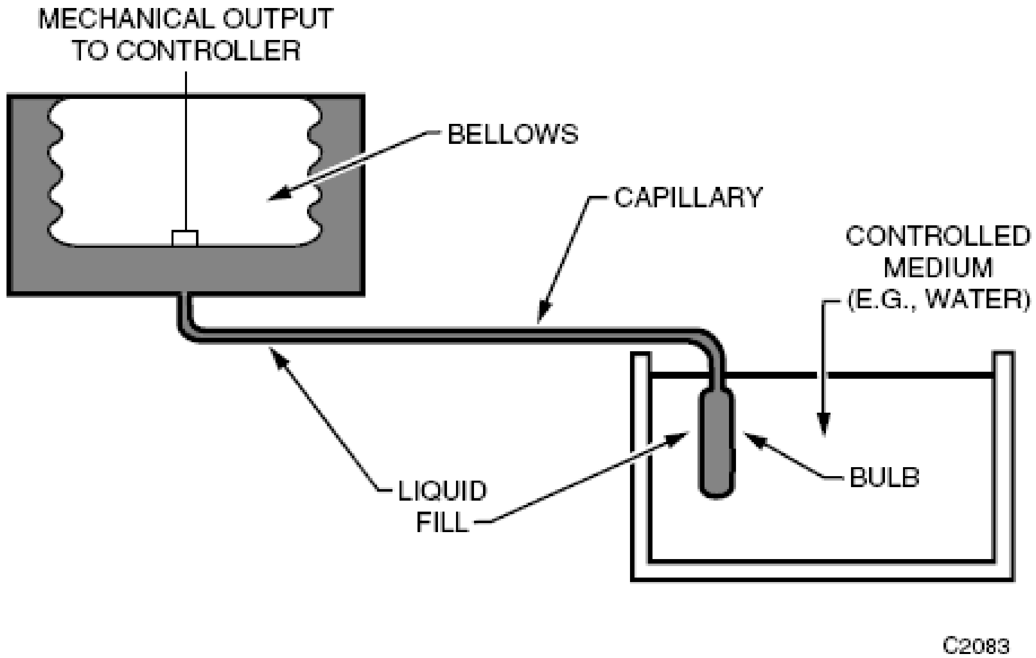



**Fig. 51. Typical Remote-Bulb Element.**

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

# Control Fundamentals

- Moisture sensing elements
  - Mechanical – expand and contract as the moisture level change (“hygroscopic”), e.g. nylon
  - Electronic – change in either the resistance or capacitance of the element
    - Can be affected by temperature changes
    - Temperature compensation may be needed
  - A dew point sensor senses dew point directly or detects condensation on a cooled surface

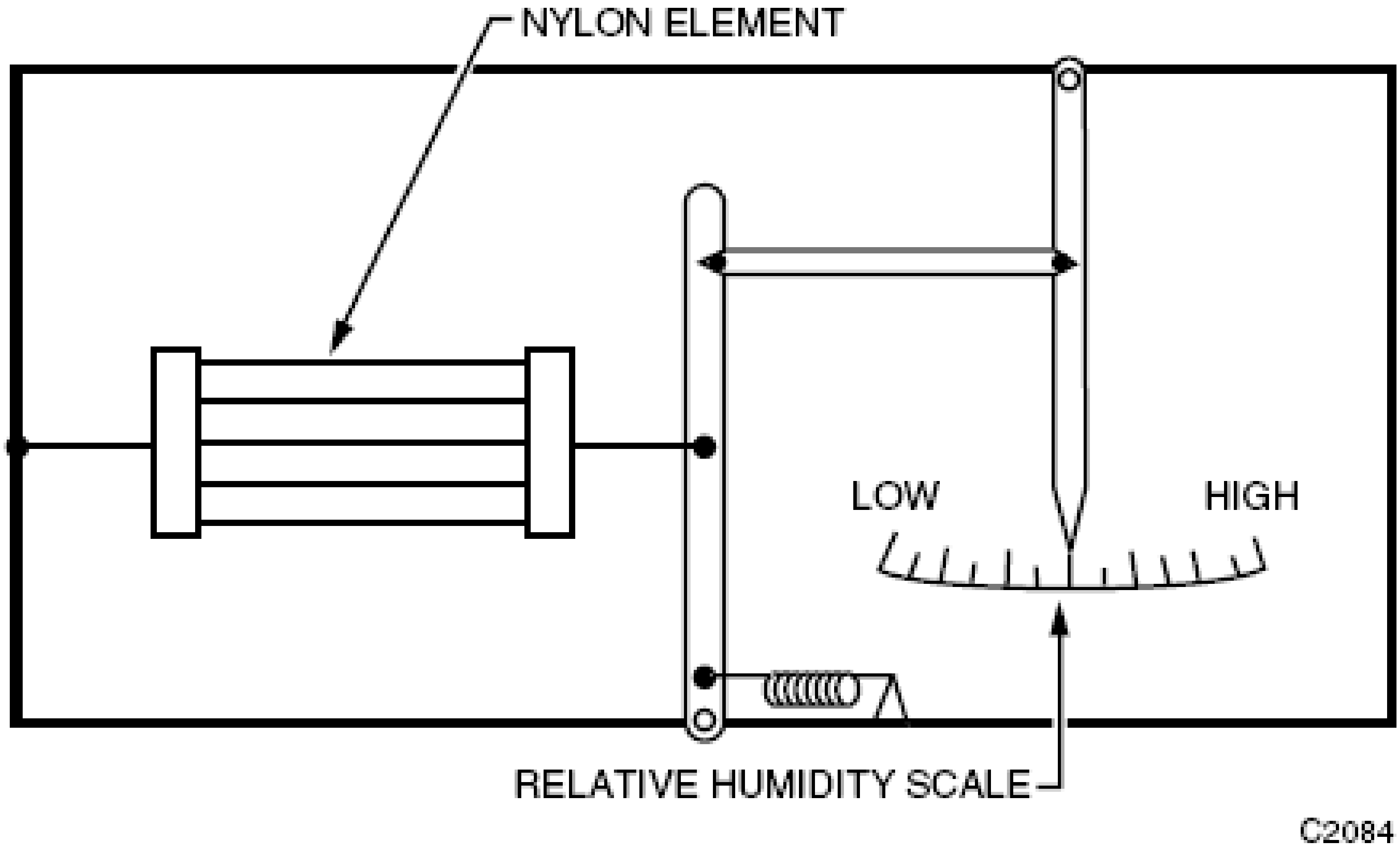
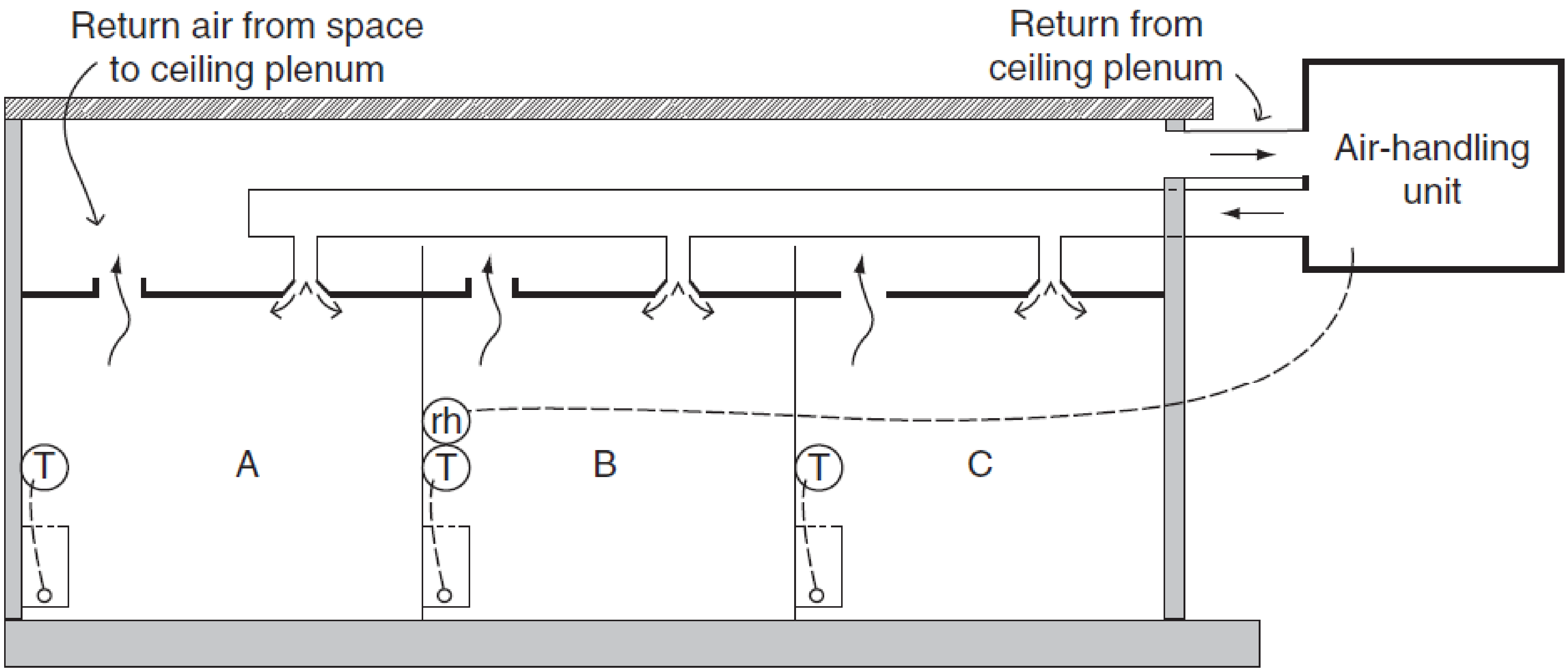



**Fig. 52. Typical Nylon Humidity Sensing Element.**

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

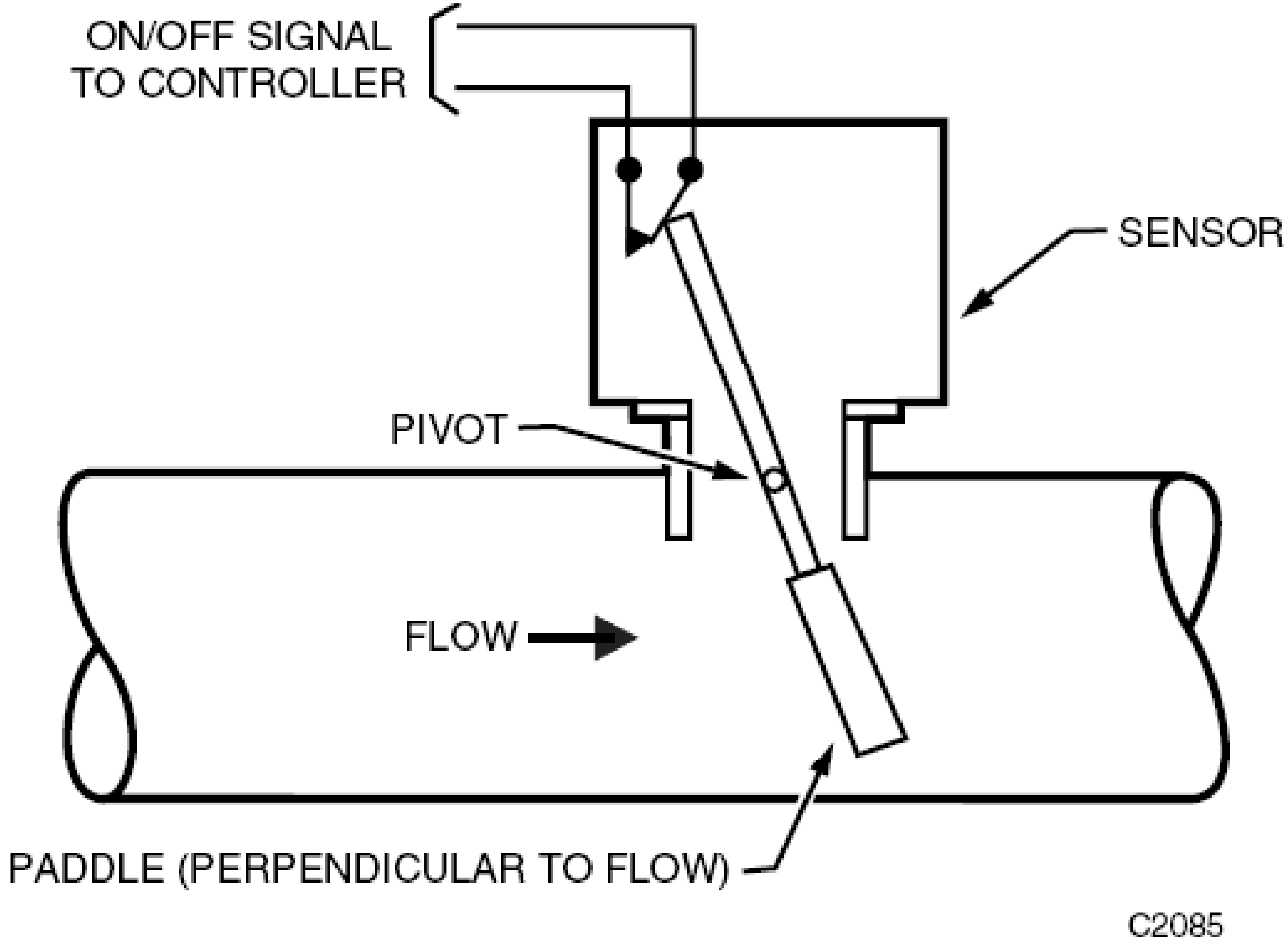
# Will the position of temp/RH sensors affect the control?




[Source: Montgomery, R. and McDowall, R., 2008. *Fundamentals of HVAC Control Systems*]

# Control Fundamentals

- Flow sensors
  - Sense the rate of liquid and gas flow
    - Flow is difficult to sense accurately under all conditions
  - Selecting the best flow-sensing technique for an application requires considering many aspects
    - Level of accuracy required
    - The medium being measured
    - The degree of variation in the measured flow




# Fig. 53. Paddle Flow Sensor.

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

# Control Fundamentals

- Selecting flow measuring devices
  - Ref.: see the article from *HPAC Engineering*
    - What flow meters measure (volume/mass)
    - Chilled water flow meters
      - Differential pressure
      - Magnetic
      - Turbine
      - Ultrasonic
      - Vortex shedding & fluidic
    - Selection criteria & considerations

# Control Fundamentals

- Control system components (cont'd)
  - 2. Transducers
    - Convert (change) sensor inputs and controller outputs from one analogue form to another, more usable, analogue form, e.g. pressure-to-voltage
  - 3. Controllers
    - Receive inputs from sensors
    - Compares the input signal with the setpoint
    - Generates an output signal to operate a controlled device

# Control Fundamentals

- Control system components (cont'd)
  - 4. Actuators
    - A device that converts electric or pneumatic energy into a rotary or linear action, e.g. for valves and dampers (can be pneumatic or electrical controlled)
  - 5. Auxiliary element
    - Transducers to convert signals from one type to another (e.g. from pneumatic to electric)
    - Relays and switches to manipulate signals, electric power and compressed air supplies to power the control system
    - Indicating devices to facilitate monitoring of control system activity

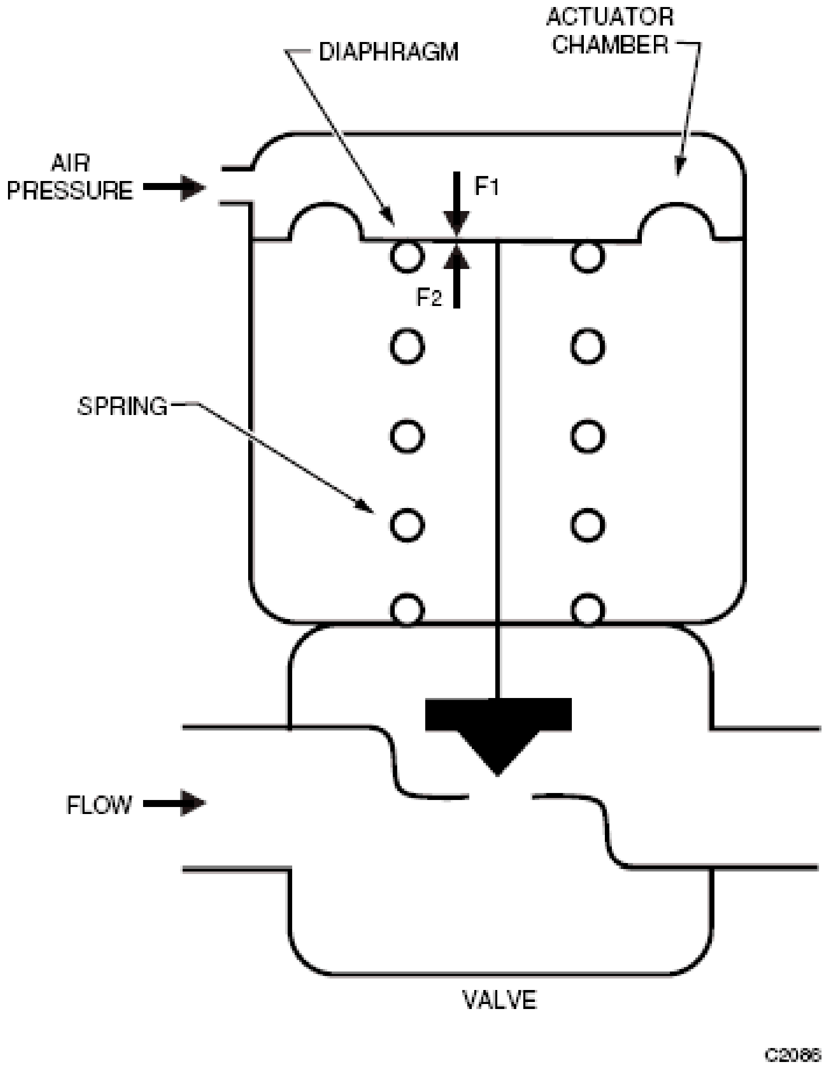
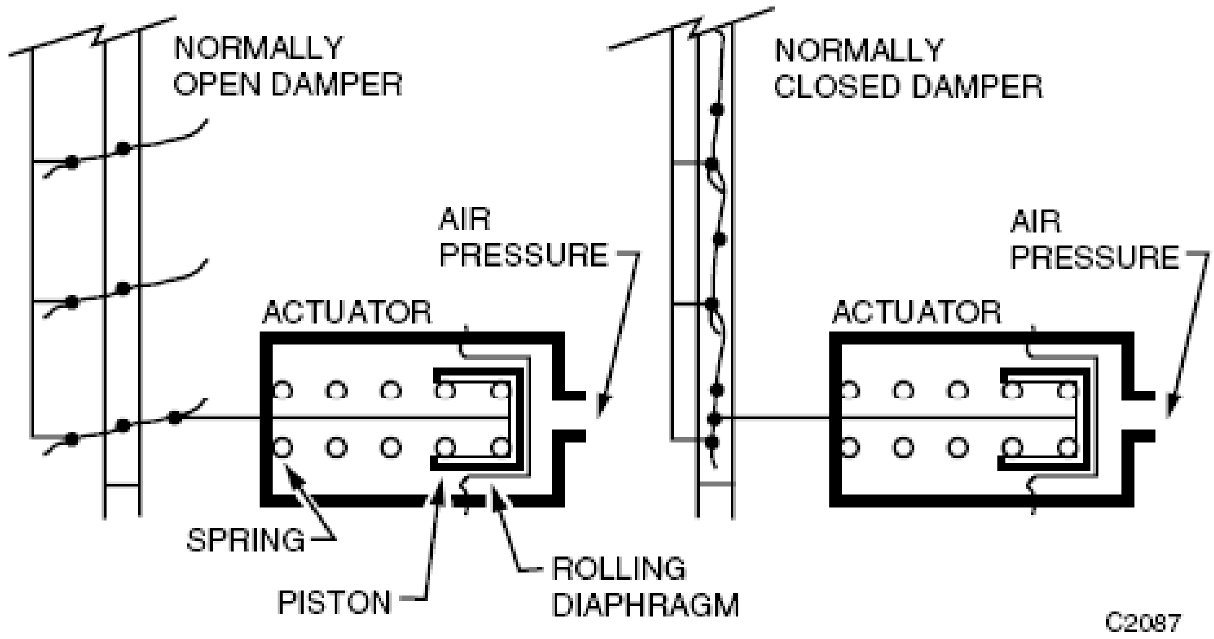



**Fig. 54. Typical Pneumatic Valve Actuator.**




[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

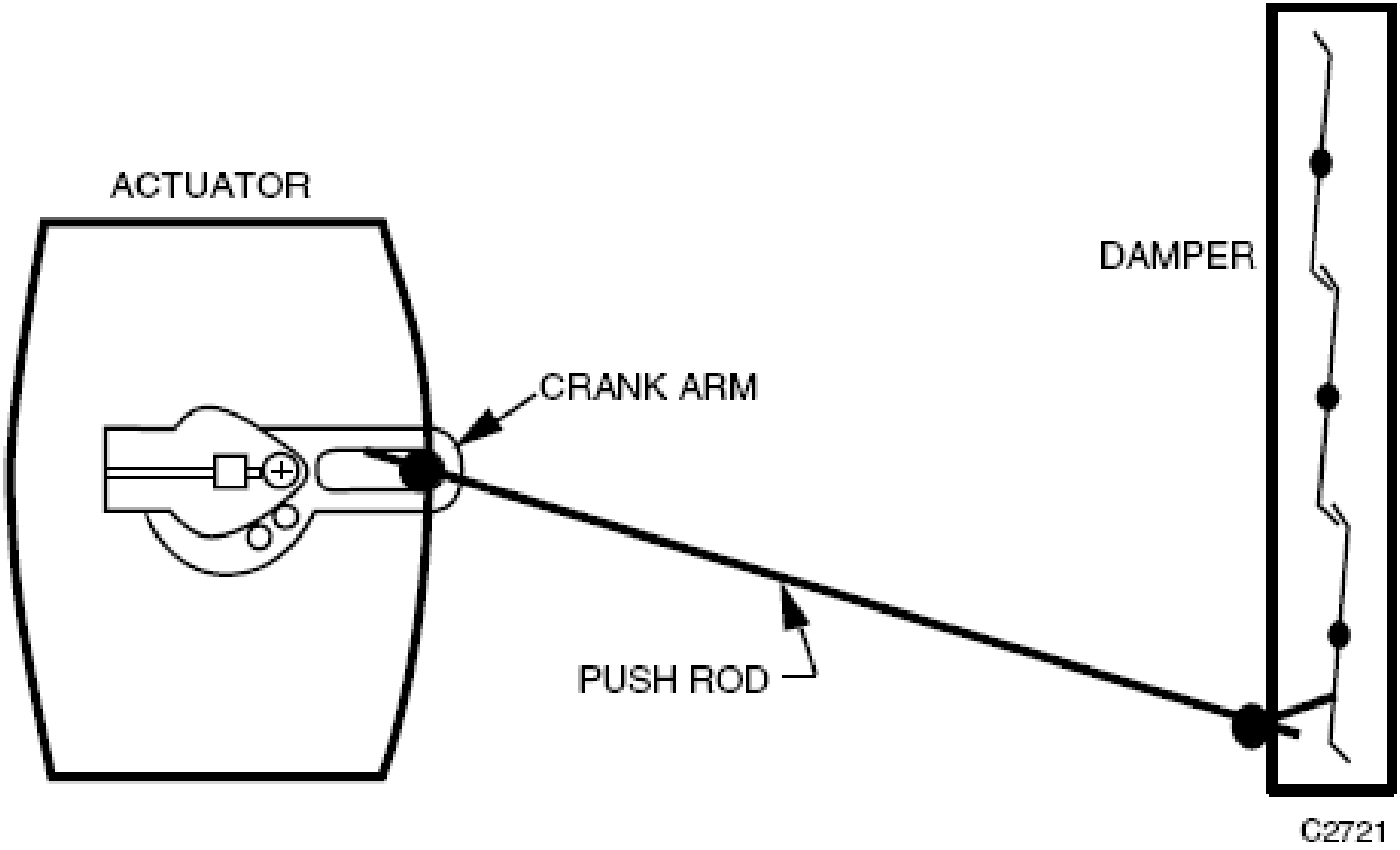
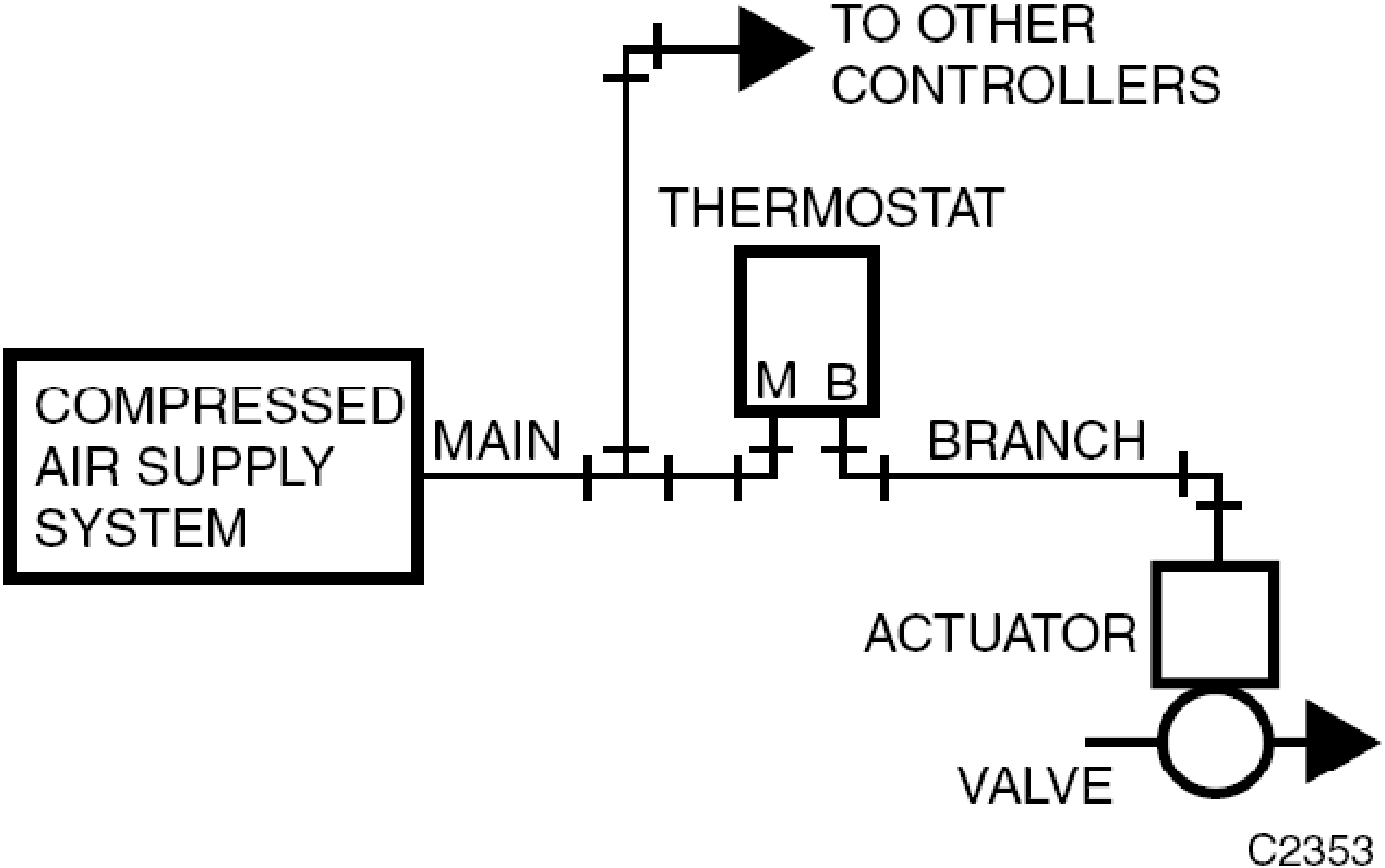



**Fig. 56. Typical Electric Damper Actuator.**

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

# Control Fundamentals

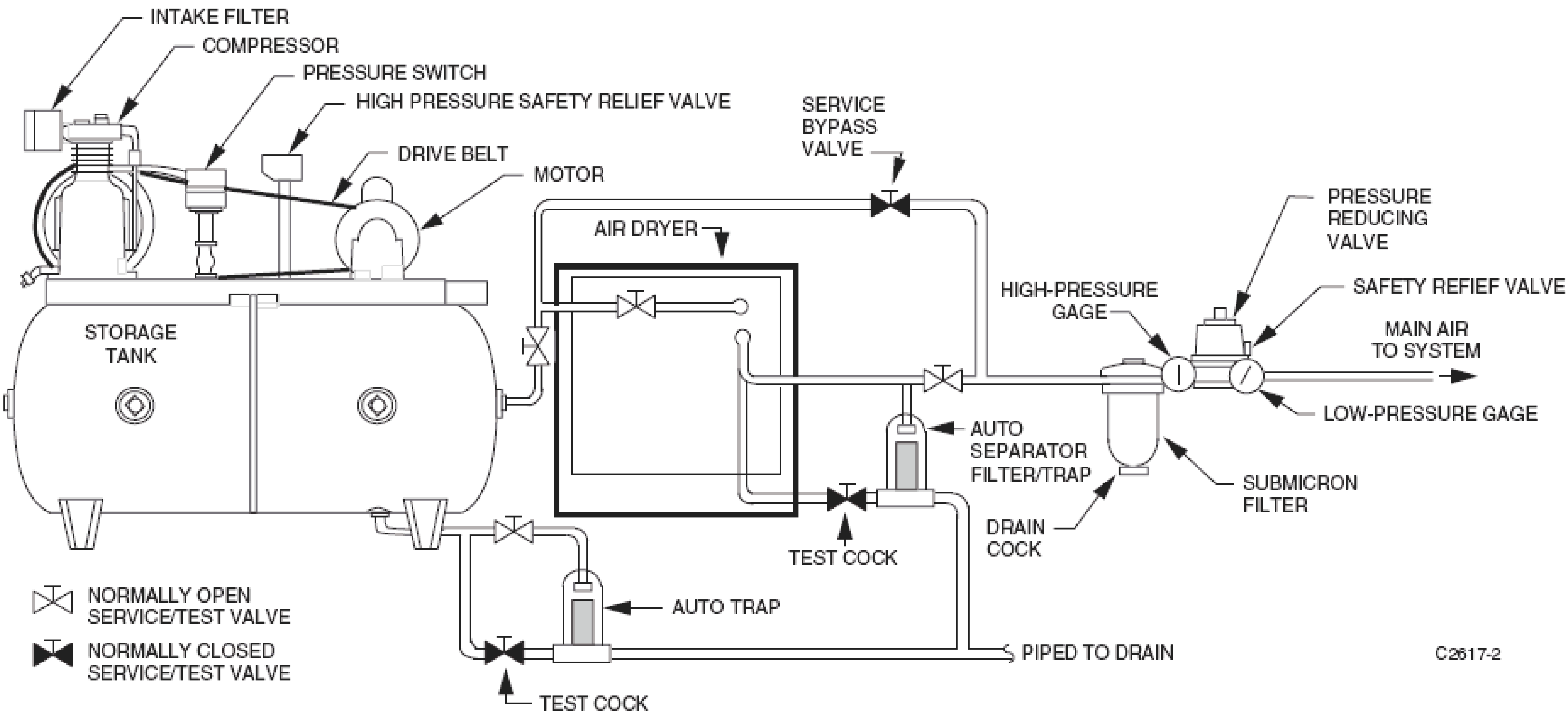
- Common control methods
  - 1) Pneumatic
  - 2) Electric
  - 3) Electronic
  - 4) Microprocessor-based/DDC




Basic pneumatic control system

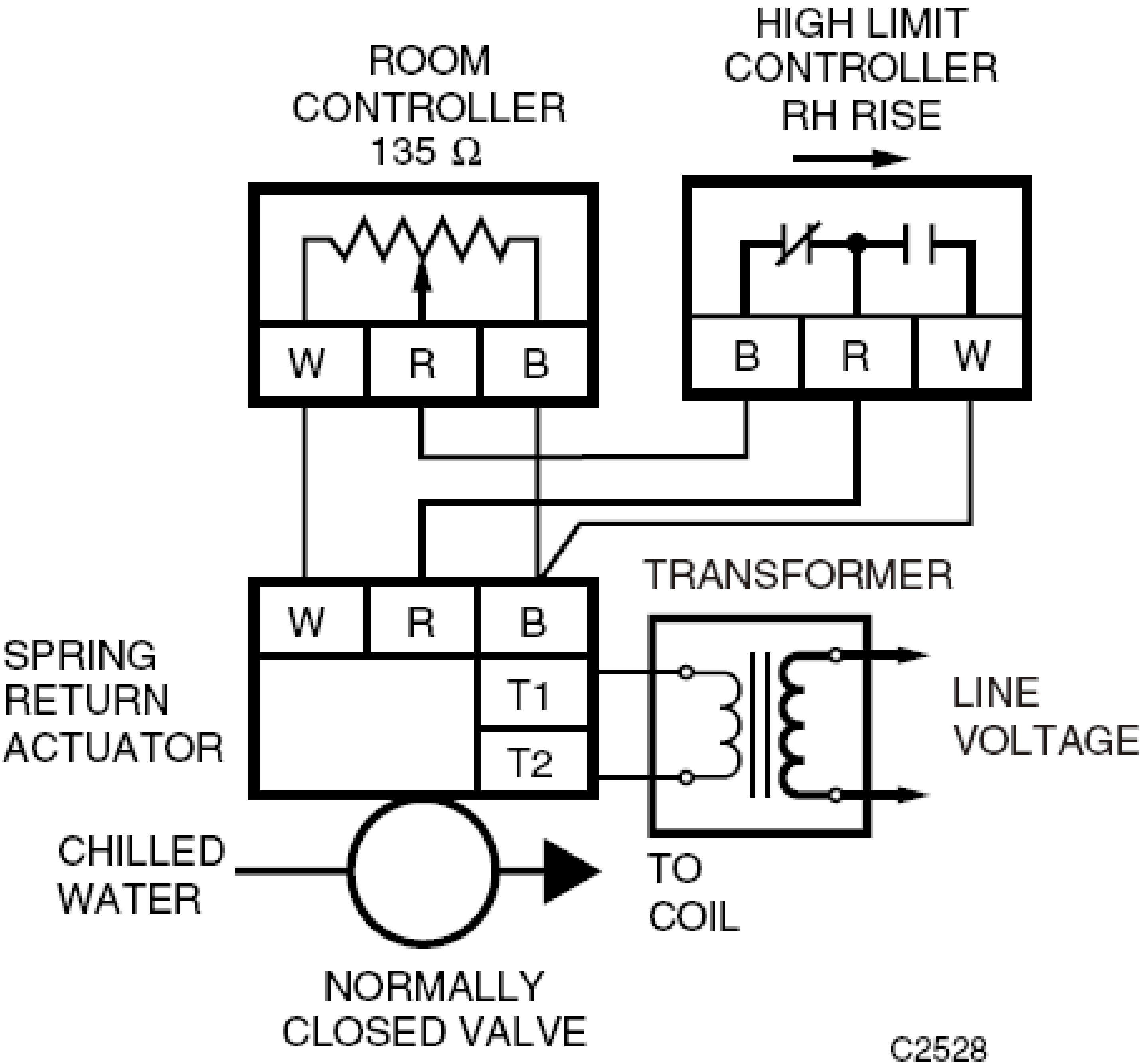
[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

# You can hear the sound when the system is operating.



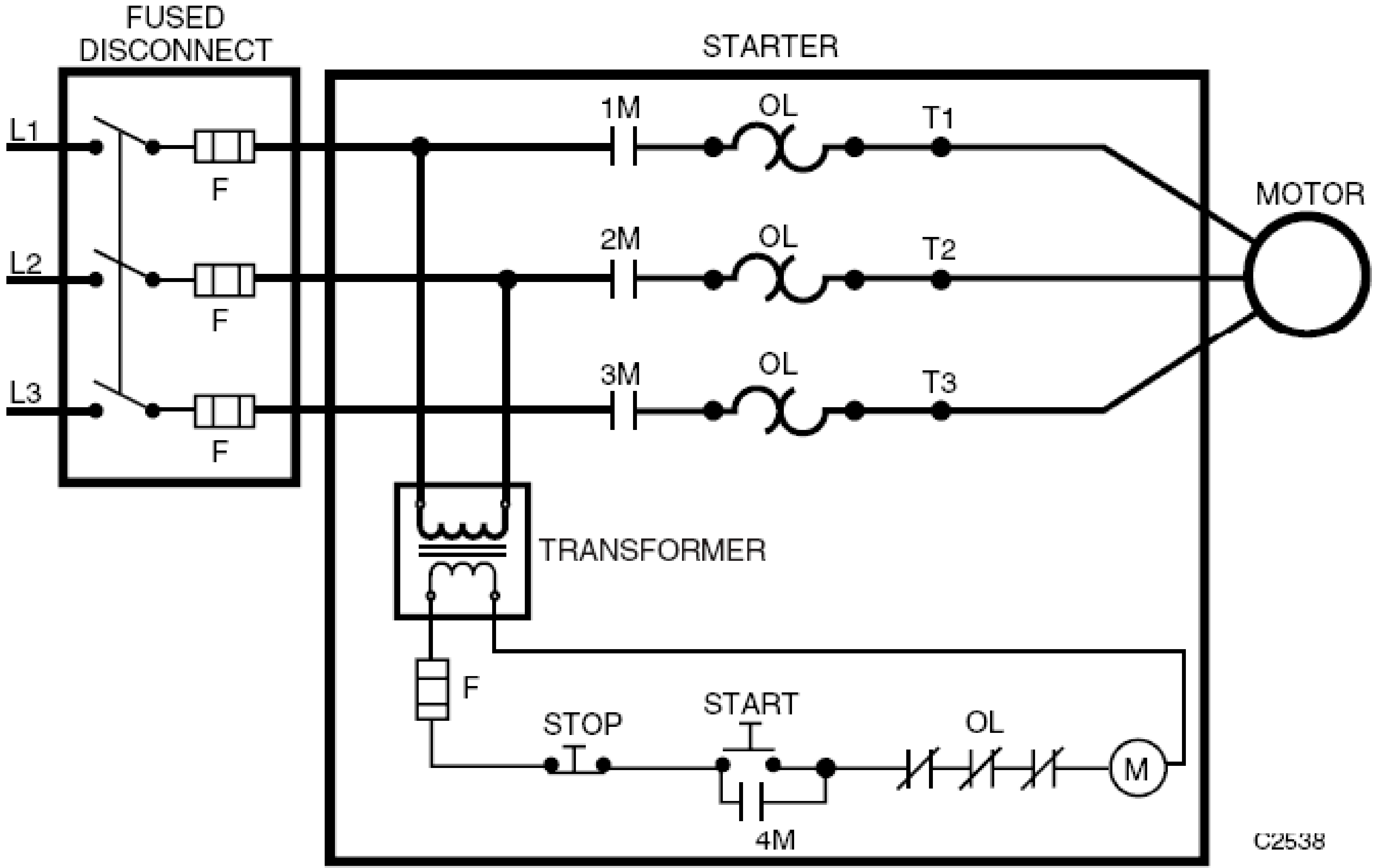

Typical compressed air supply system

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]



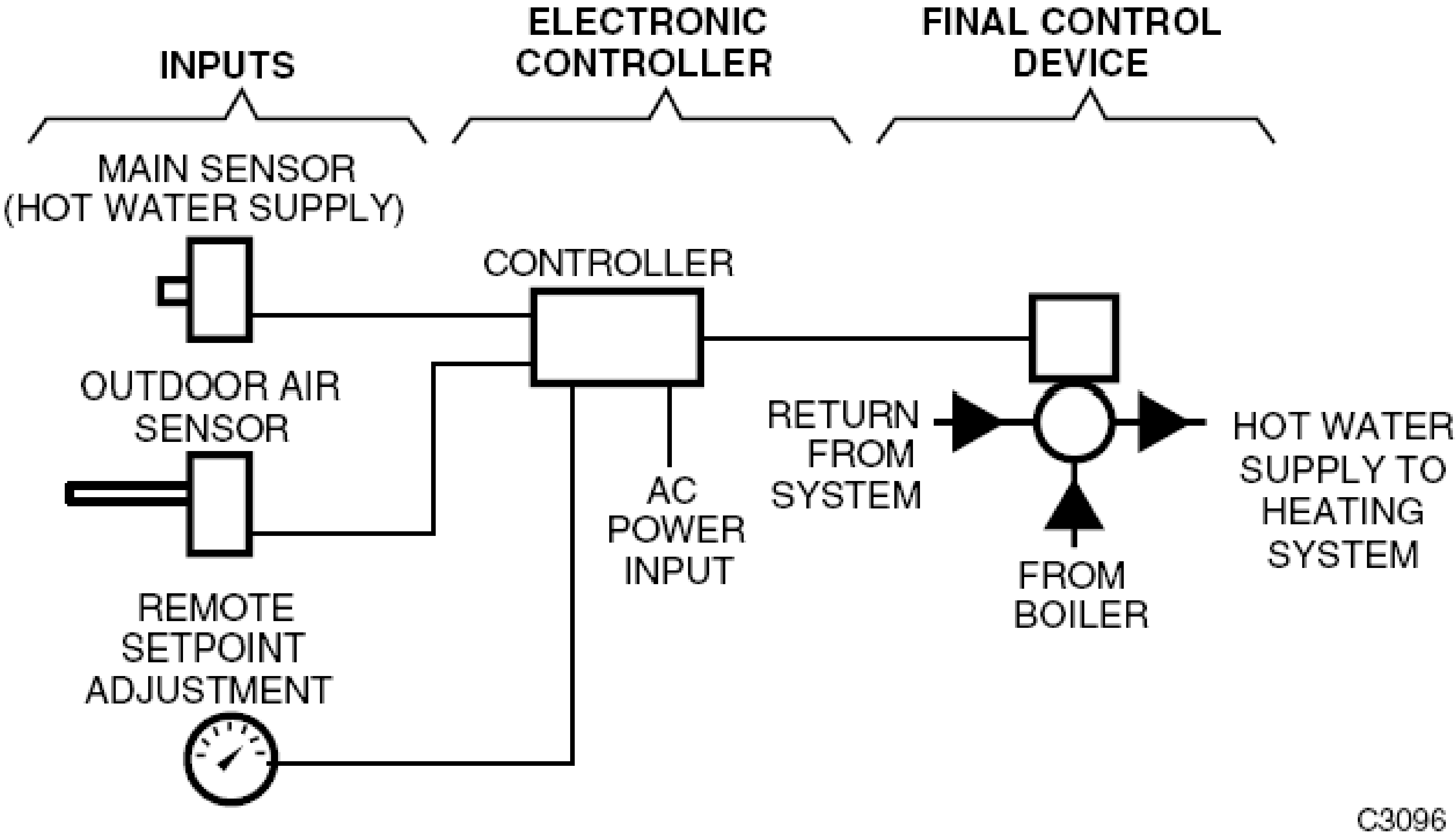

Typical electric control circuit

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]




# Fig. 35. Momentary Push-button Start-Stop Circuit.

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]




Simple electronic control system

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

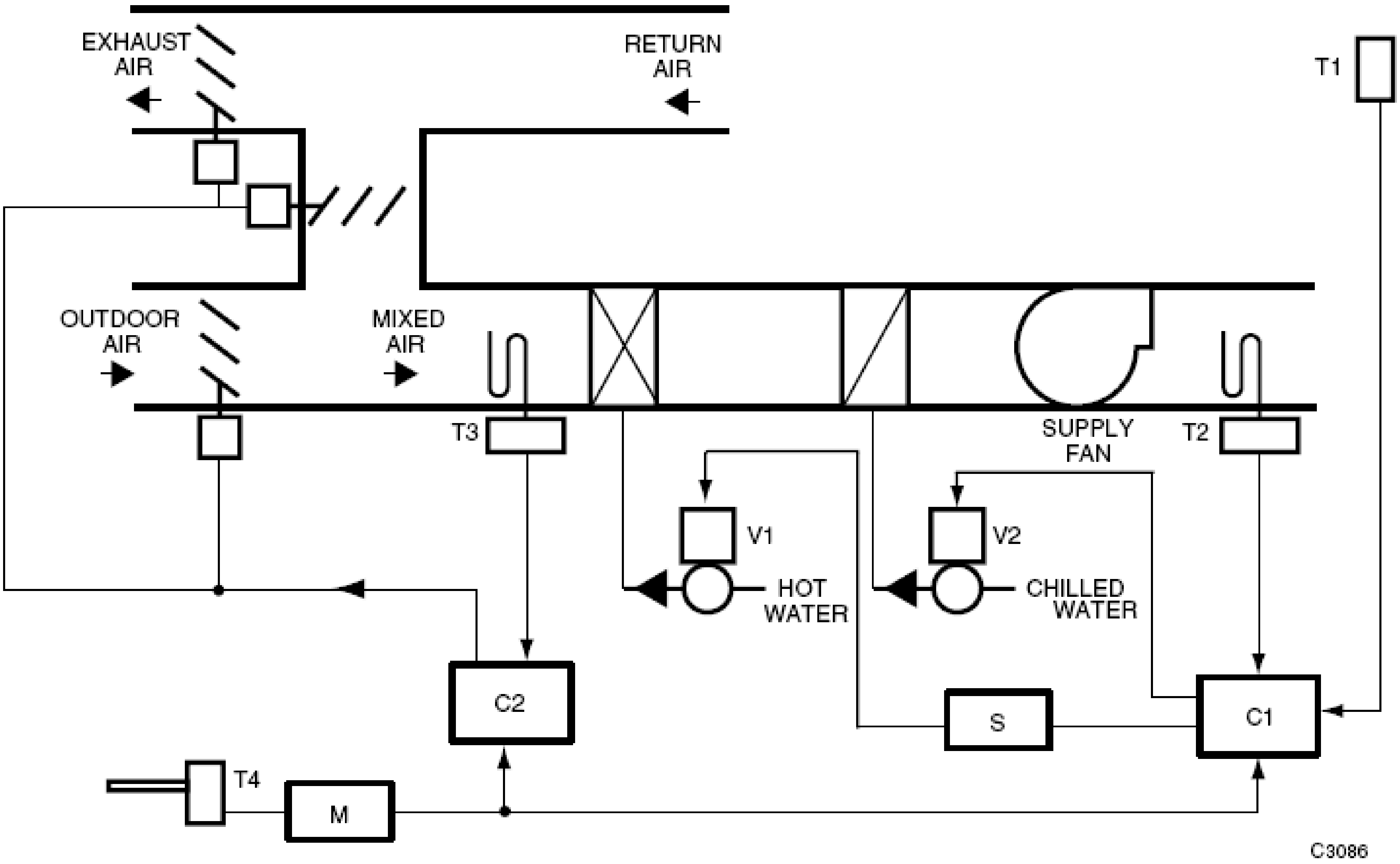



**Fig. 22. Typical Application with Electronic Controllers.**

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

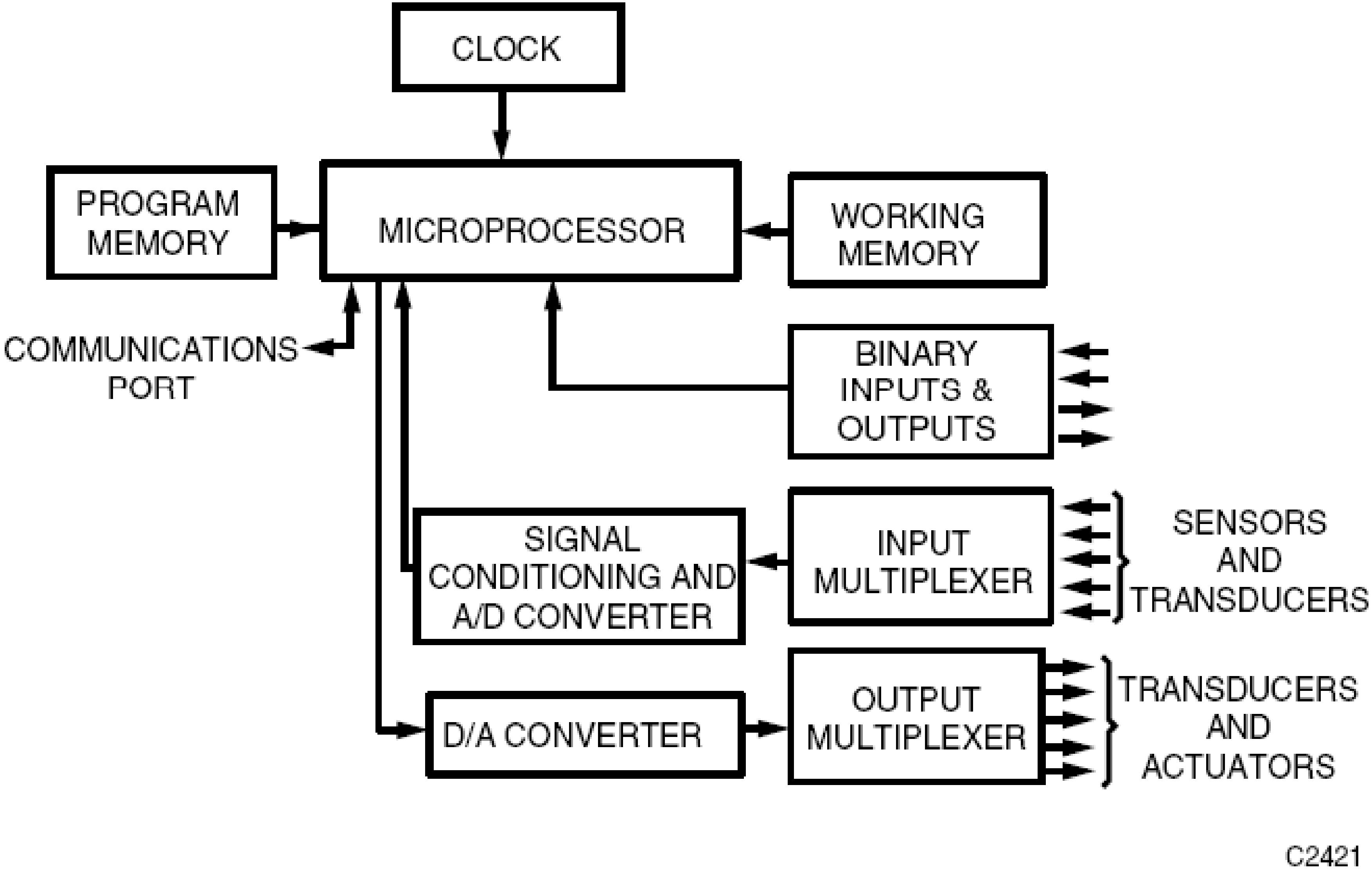



**Fig. 3. Microprocessor Controller Configuration for Automatic Control Applications.**

Basic microprocessor/DDC controller

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

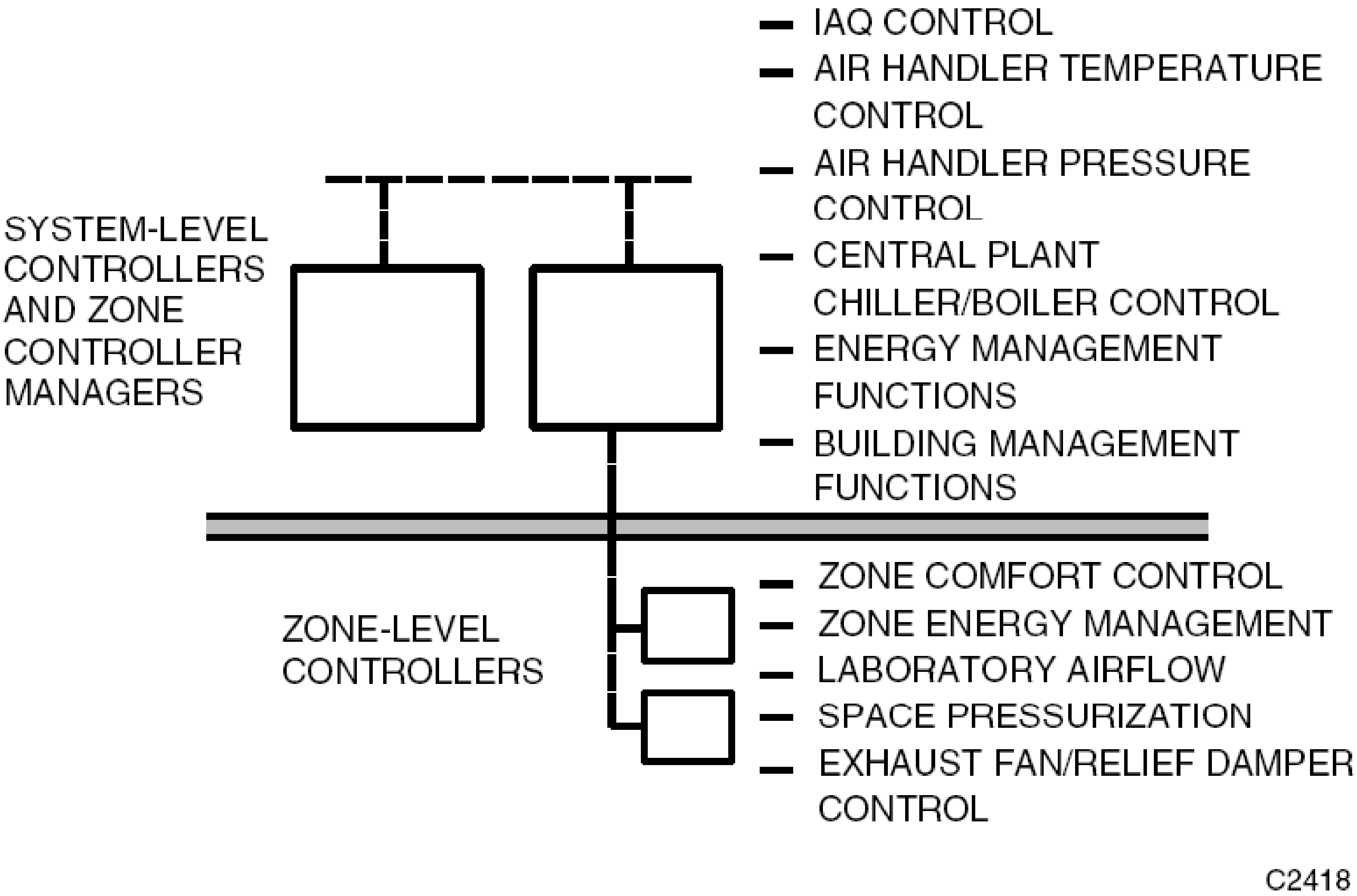



**Fig. 4. Zone- and System-Level Controllers.**

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

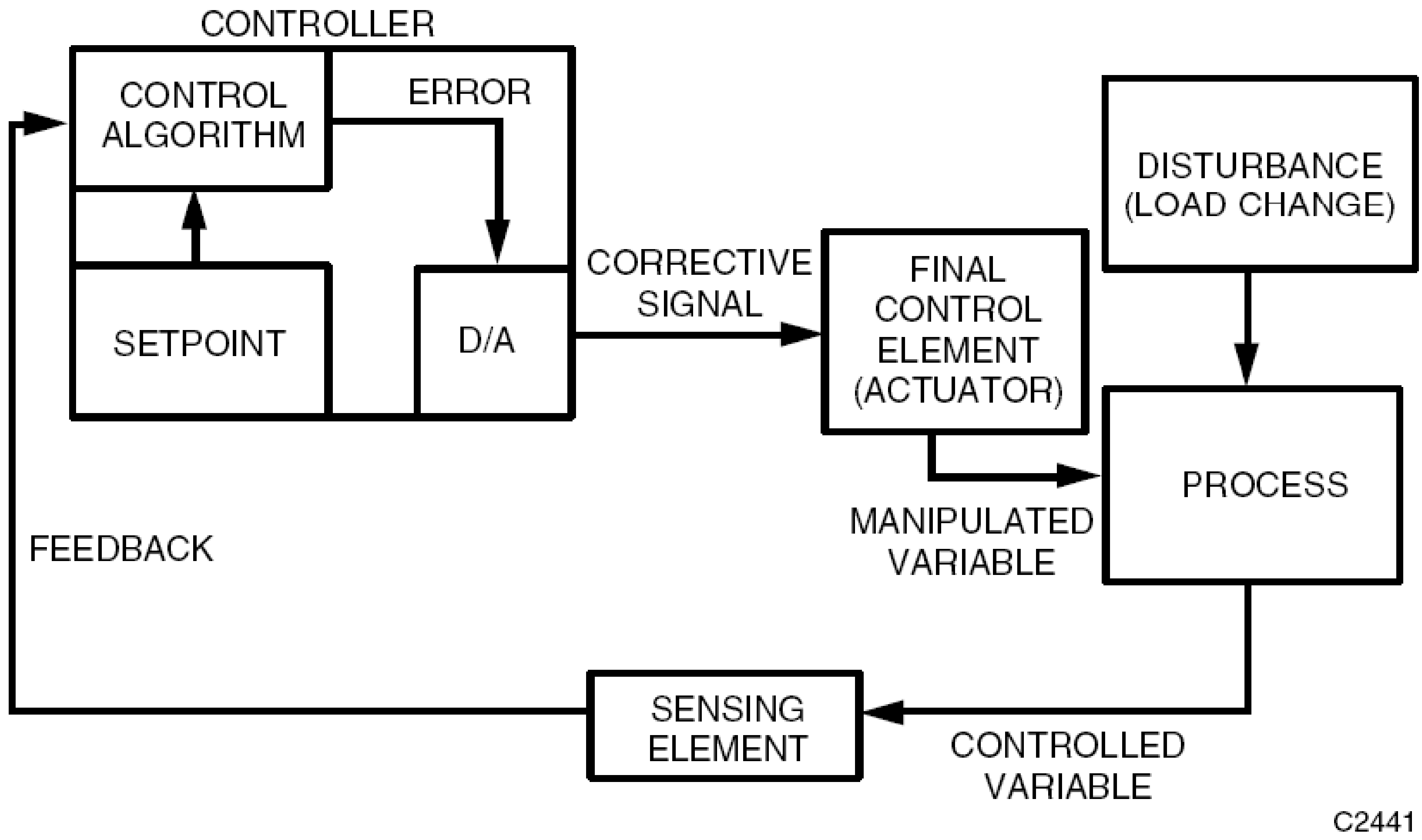



**Fig. 14. Simple Control Loop.**

[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

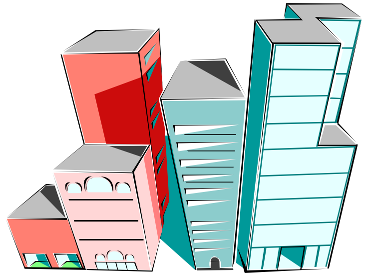
# Select the right type of control for the application

**Table 4. Characteristics and Attributes of Control Methods.**

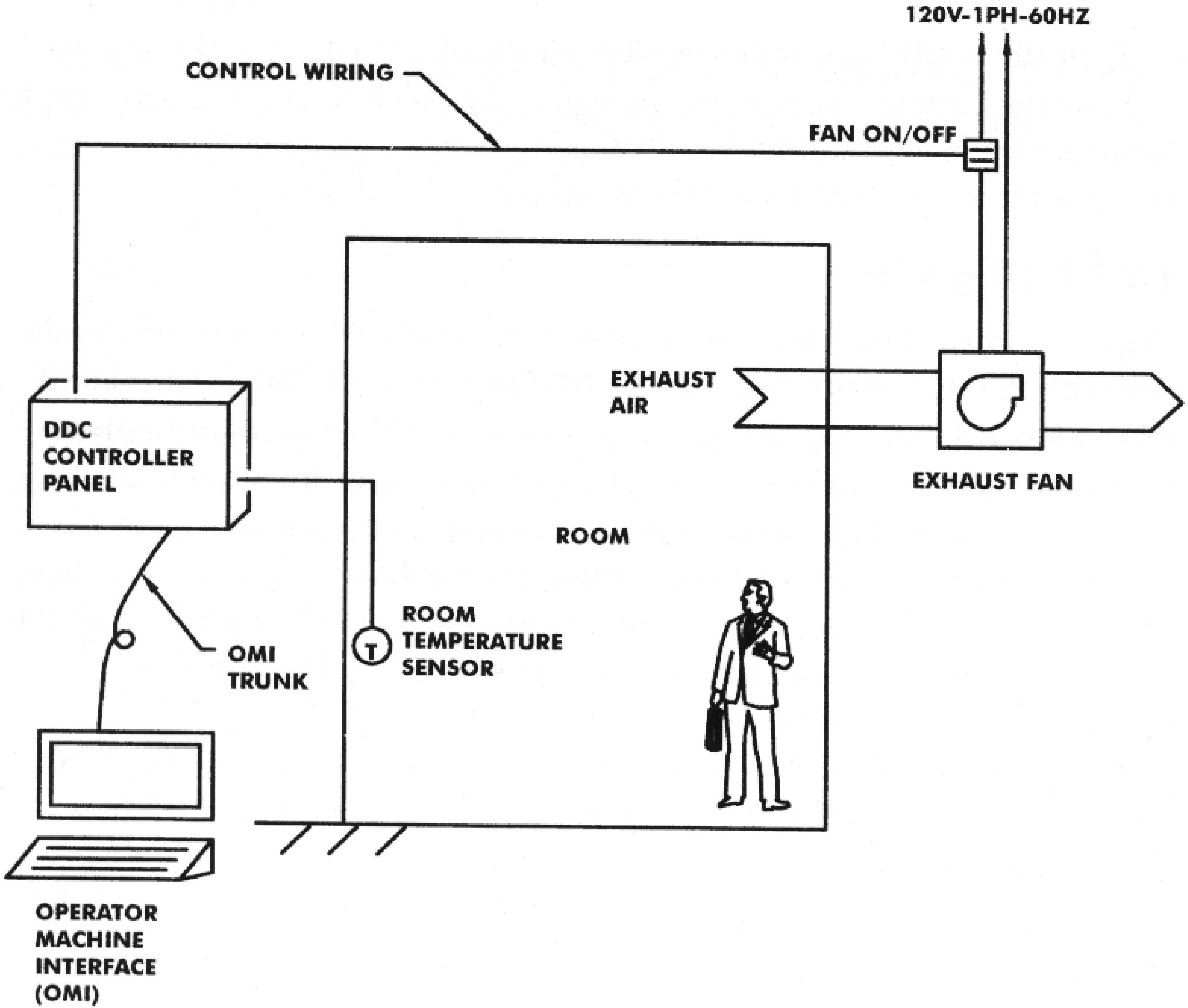
| Pneumatic | Electric | Electronic | Microprocessor |
|---|---|---|---|
| Naturally proportional | Most common for simple on-off control | Precise control | Precise control |
| Requires clean dry air | Integral sensor/ controller | Solid state repeatability and reliability | Inherent energy management |
| Air lines may cause trouble below freezing | Simple sequence of control | Sensor may be up to 300 feet from controller | Inherent high order (proportional plus integral) control, no undesirable offset |
| Explosion proof | Broad environmental limits | Simple, remote, rotary knob setpoint | Compatible with building management system. Inherent database for remote monitoring, adjusting, and alarming. |
| Simple, powerful, low cost, and reliable actuators for large valves and dampers | Complex modulating actuators, especially when spring-return | High per-loop cost | Easily performs a complex sequence of control |
| Simplest modulating control | | Complex actuators and controllers | Global (inter-loop), hierarchial control via communications bus (e.g., optimize chillers based upon demand of connected systems) |
| | | | Simple remote setpoint and display (absolute number, e.g., 74.4) |
| | | | Can use pneumatic actuators |

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

# The Basics



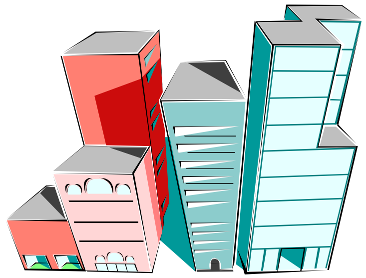
- Design an effective DDC system
  - Simplicity & effective technical communication
- DDC signals
  - Digital output (DO), e.g. command to open a valve
  - Digital input (DI), e.g. status signal from a fan
  - Analogue input (AI), e.g. room temperature
  - Analogue output (AO), e.g. command to modulate a control valve



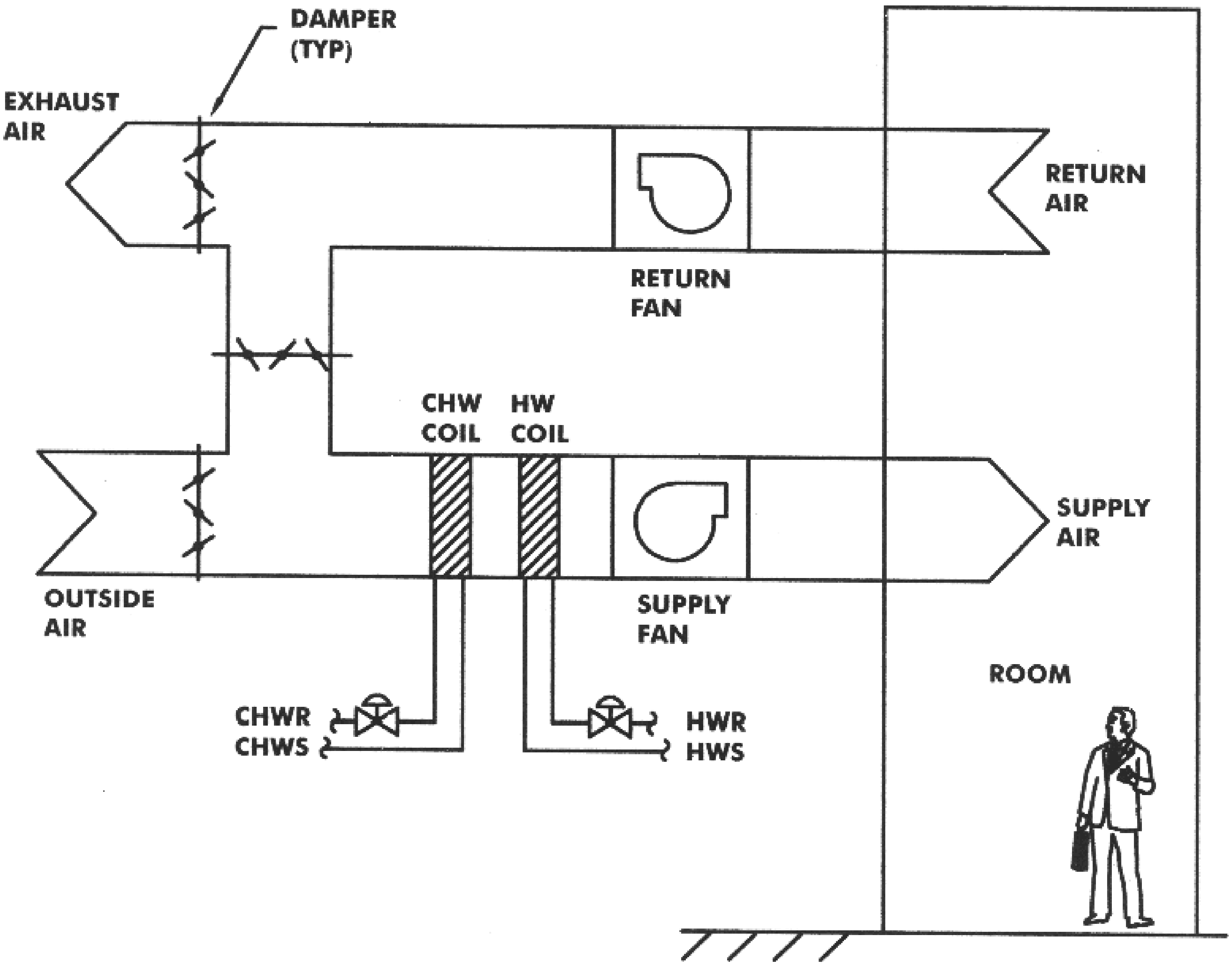

A simple DDC control system

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

# The Basics

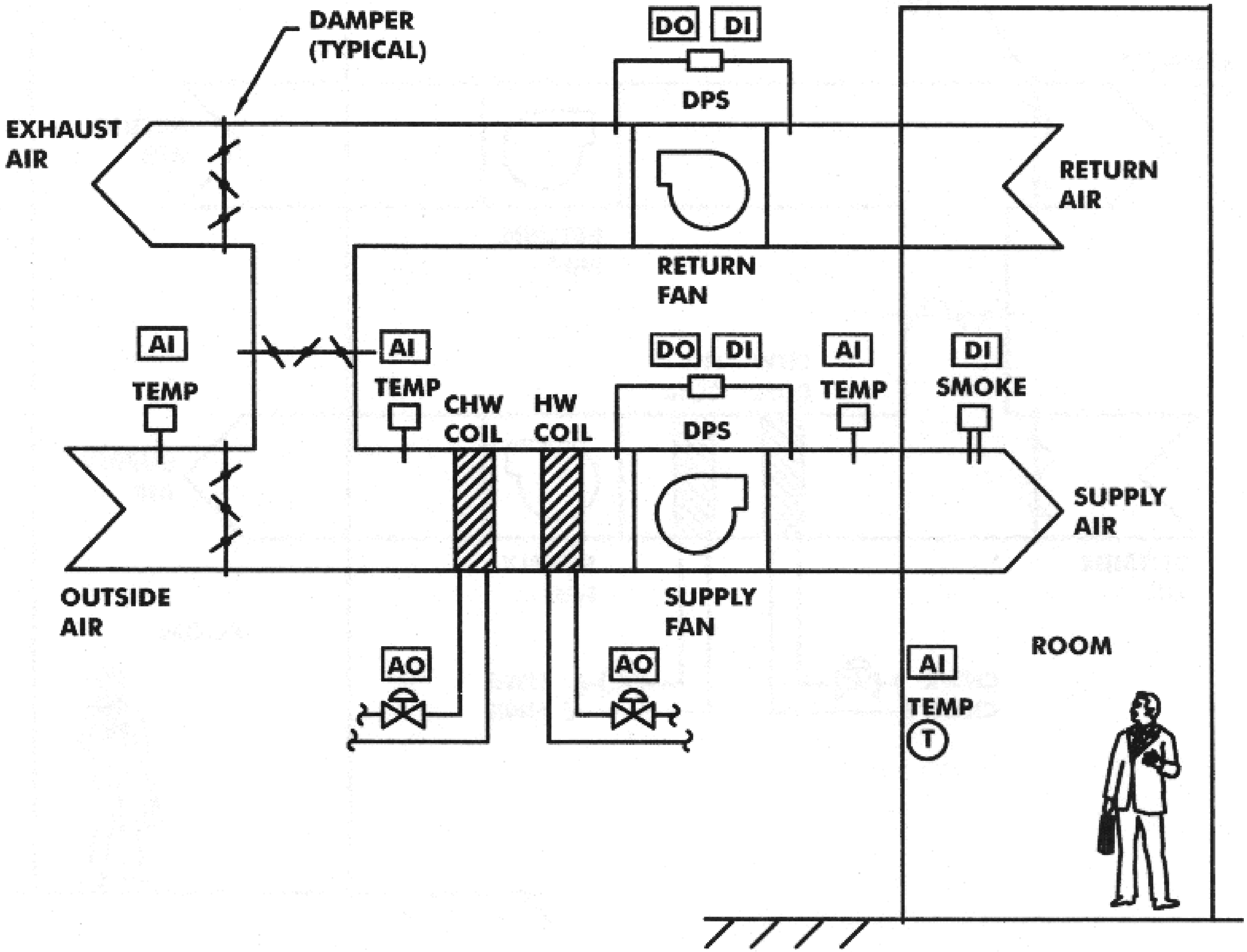


- Six steps of DDC system design
  - System schematic
  - Control point designations
  - Point list
  - DDC system architecture
  - Sequence of operation
  - Specifications
- * It is important to fully understand the HVAC or specific system




System schematic for a constant volume single zone AHU

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



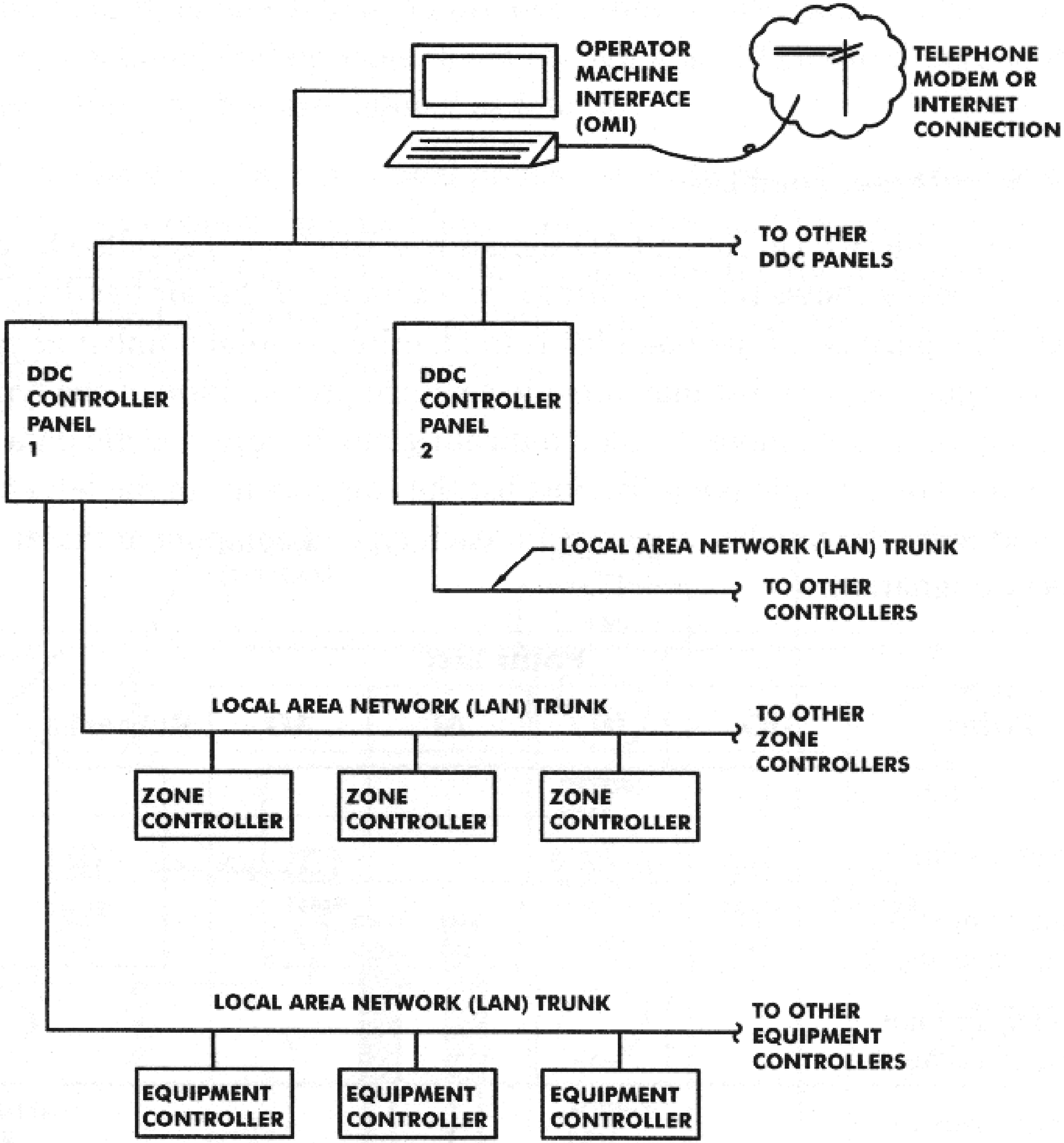

Control point designations for a constant volume single zone AHU

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

| Point List | | | | | |
|---|---|---|---|---|---|
| **Point** | **DO** | **DI** | **AI** | **AO** | **Remarks** |
| Supply fan | 1 | 1 | | | |
| Return fan | 1 | 1 | | | |
| Duct temperature sensors | | | 3 | | |
| Chilled and hot water valves | | | | 2 | |
| Room temperature sensor | | | 1 | | |
| Smoke detector | | 1 | | | |
| Total | 2 | 3 | 4 | 2 | |

Table 1-1: An example of a point list. The purpose of a point list is to identify the total number of each point category.

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




An example of DDC system architecture

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

***Sequence of Operations***

1. *DDC system architecture*
   - a. *The DDC system consists of a local area network of seven DDC panels*
   - b. *Provide the programming and operator machine interface (OMI) through a personal computer. Locate the OMI computer in the facility engineer's office.*
   - c. *Display the following alarm conditions at the OMI computer:*
     - *Supply fan failure*
     - *Return fan failure*
     - *Room air temperature above 78° F or below 68° F designated (adjustable)*
2. *Air handling control*
   - a. *Operate supply fan SF-1 continuously at all times*
   - b. *Operate return fan RF-1 continuously at all times*
   - c. *Modulate chilled water and hot water valves in order to obtain optimum discharge temperature*
   - d. *Reset discharge temperature set point based upon room temperature in accordance with the following table statement:*

| *Room Temperature (° F)* | *Discharge Temperature Set Point (° F)* |
|---|---|
| *65* | *85* |
| *85* | *55* |

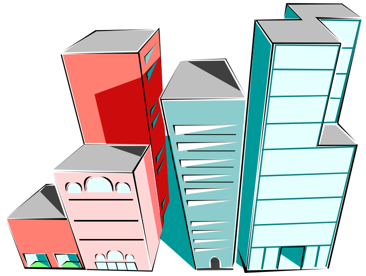
Figure 1-5: An example of sequence of operations.

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

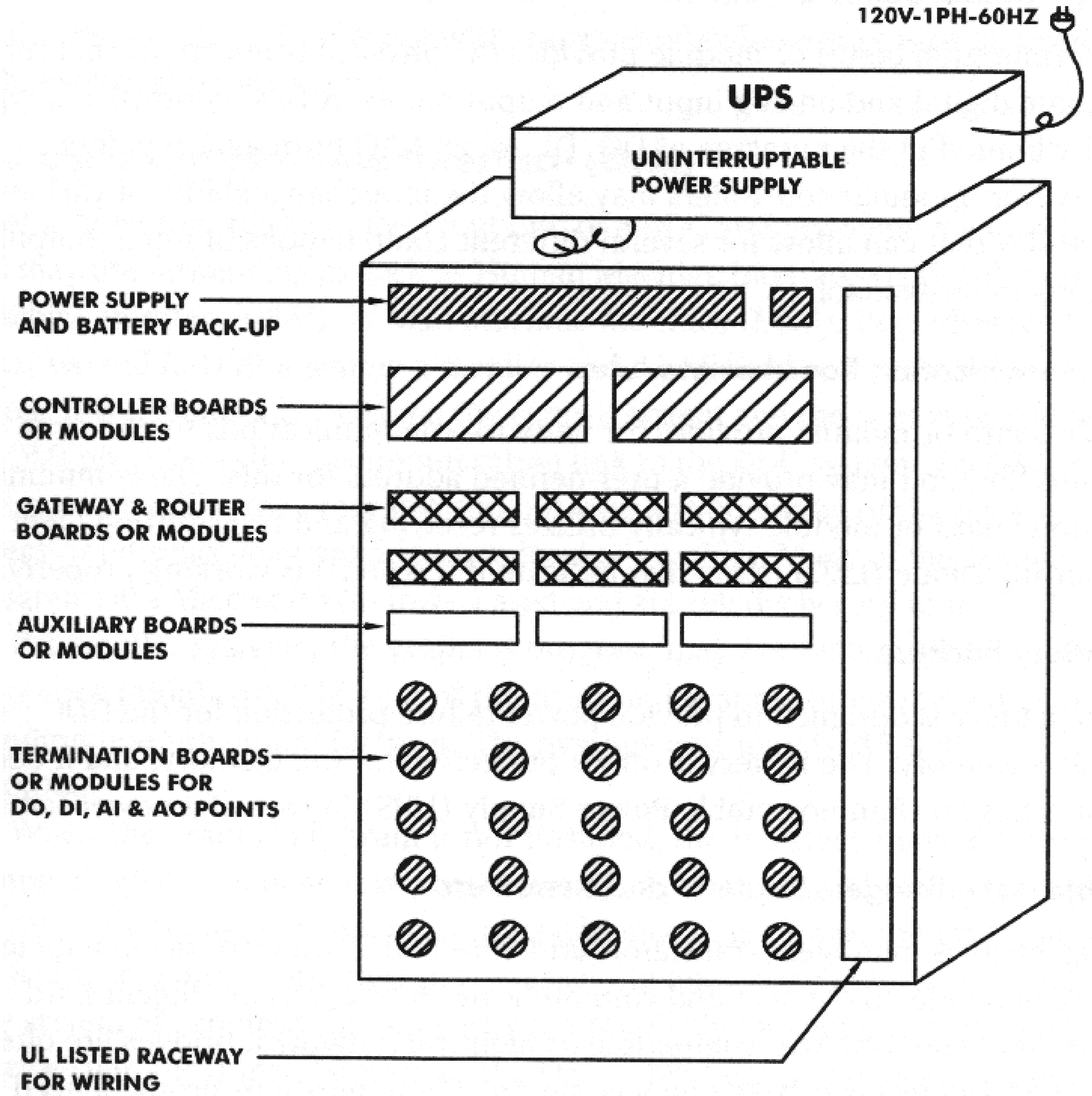
| Show on drawings | Indicate in specifications |
|---|---|
| Location of devices | Quality of components |
| Size of components | Material required |
| Quantity of components | Workmanship |

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

# The Basics



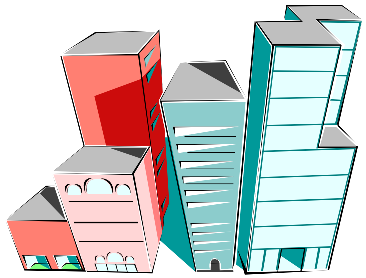
- DDC controller or control panel
  - The “brain” of the system
  - Main components:
    - Power supply
    - Central processing unit (CPU)
    - Terminal board or module
    - Communication board or module
    - Battery back-up
    - Gateways, bridges, routers and repeaters



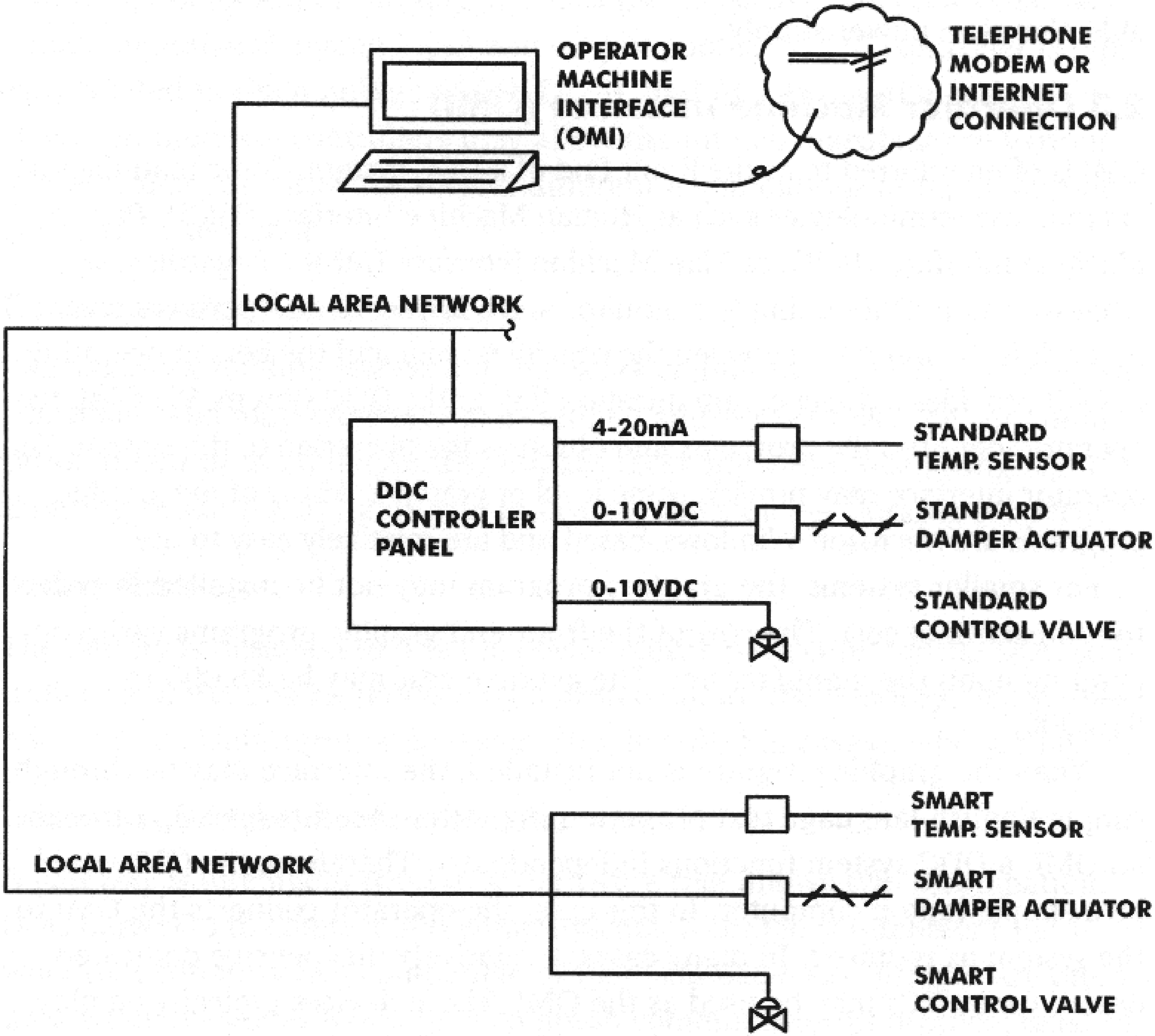

A DDC general-purpose controller

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

# The Basics

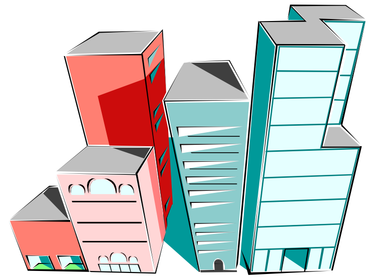


- External components
  - Uninterruptable power supply (UPS)
  - Operator machine interface (OMI)
    - Human-machine or person-machine interface
    - A monitor and a keyboard or a personal computer
  - Smart sensors and actuators
    - Contain intelligence & some form of control capability
    - May transmit/receive signal directly to/from the network

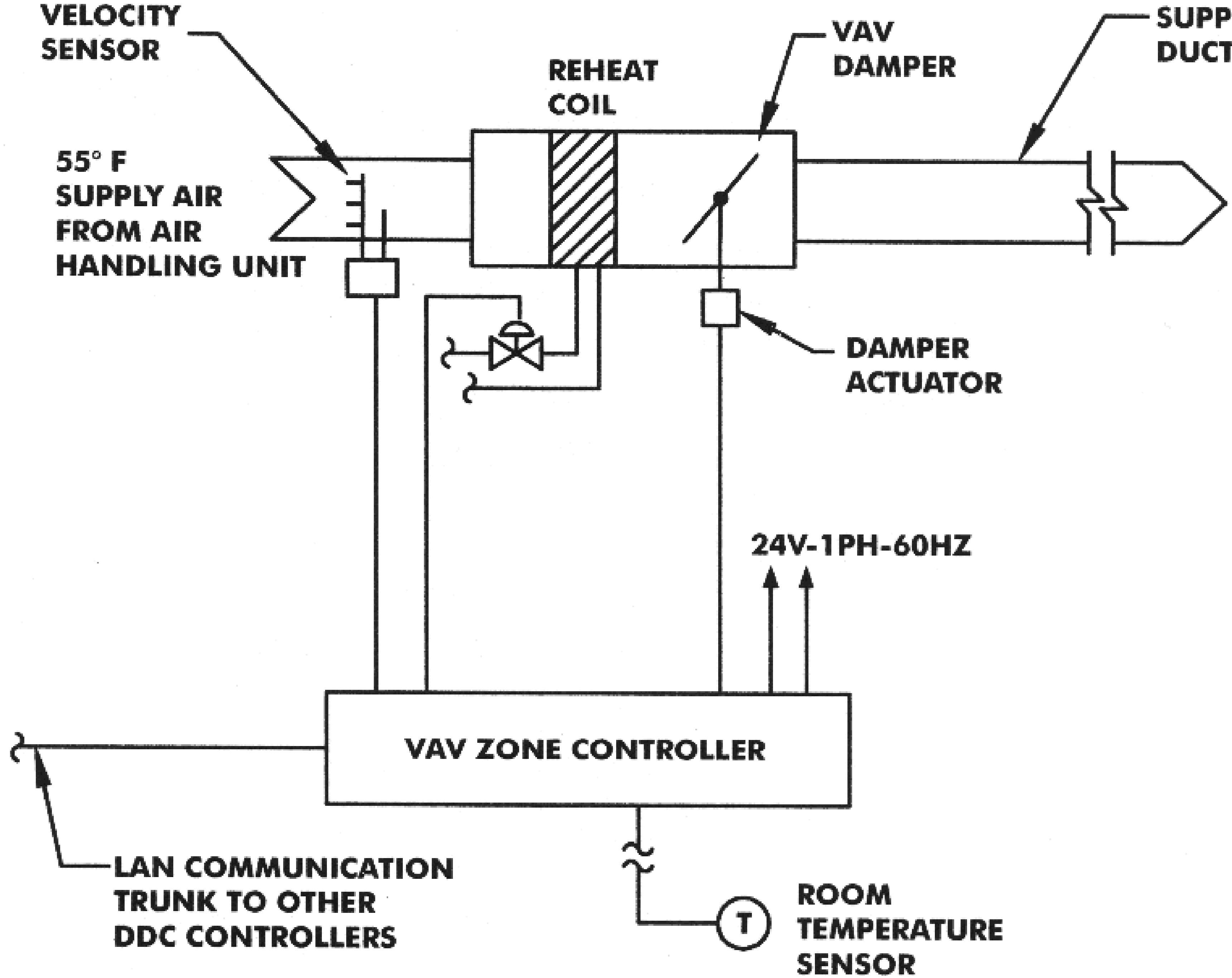



[Source: Shadpour, F., 2001. The Fundamentals of HVAC Direct Digital Control]

# The Basics

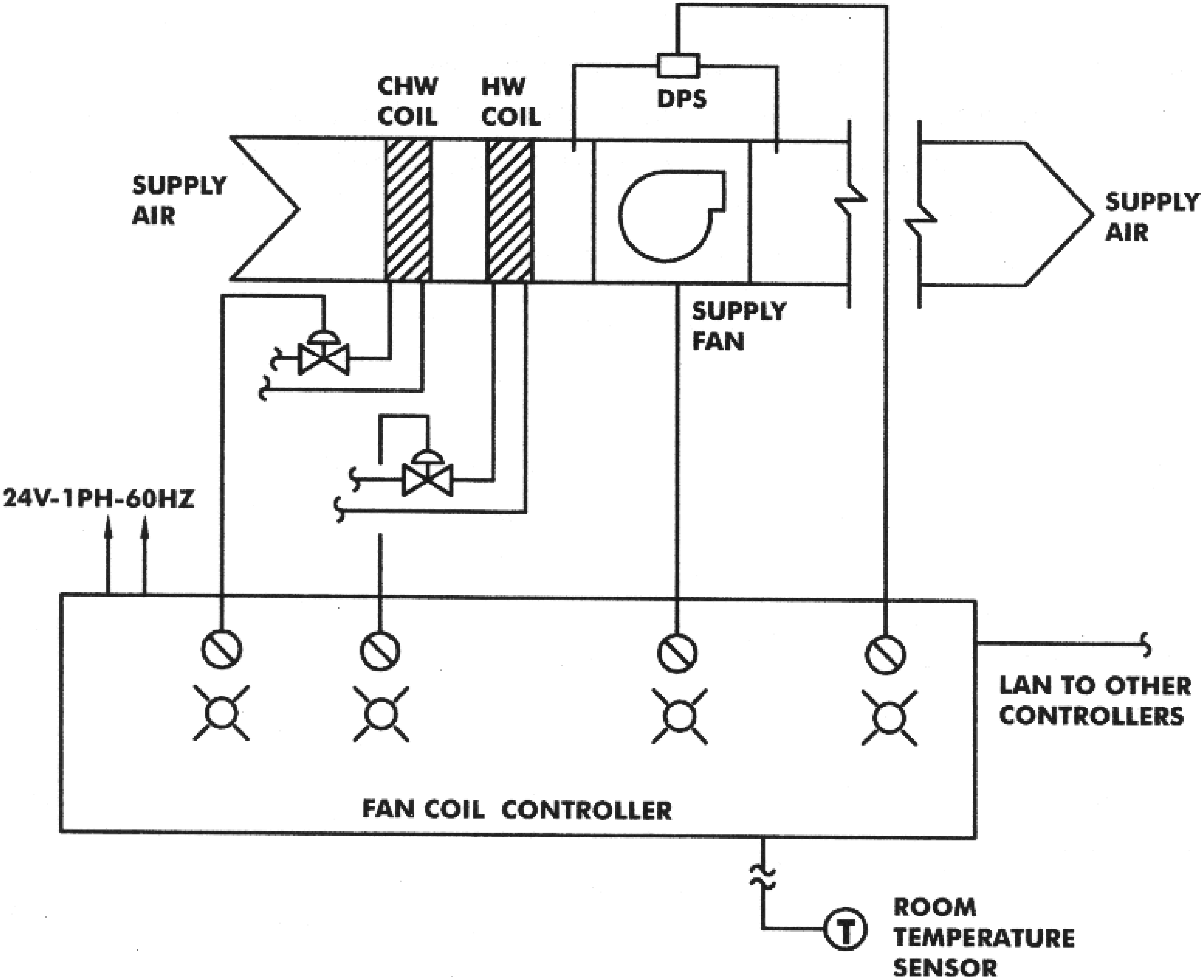


- Major types of DDC controllers
  - 1. Application specific
  - 2. General purpose
  - 3. Programmable logic (for industrial process)
- Selection factors to consider
  - Number of points being monitored & controlled
  - Locations of points being monitored & controlled
  - Application of the system being monitored & controlled



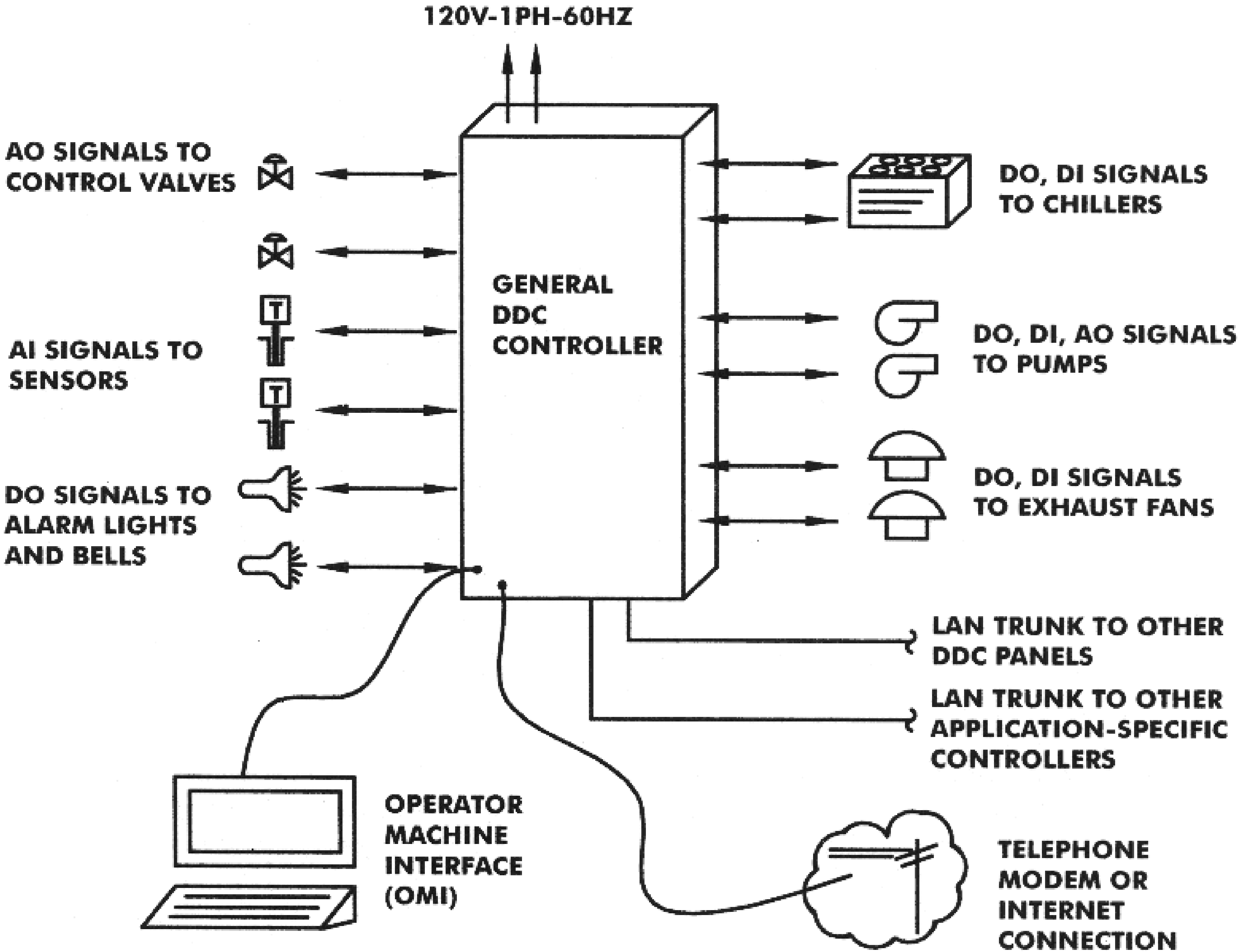

VAV zone controller (application specific)

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




Fan coil controller (application specific)

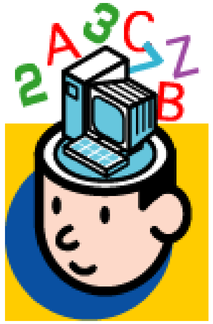
[Source: Shadpour, F., 2001. The Fundamentals of HVAC Direct Digital Control]




General purpose DDC controller

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

# Exercise



- Draw a schematic diagram of a constant volume (CAV) single zone air handling system
- Identify the control point designations & type of signals

- What happens if FIRE happens in the room?
- What are the safety control actions?