Fundamentals of HVAC Control Systems

18, 19, 25, 26 April 2007

Chapter 5
Control Diagrams and Sequences

Design Criteria - I

The control system:

- **Must meet the needs of the process**
- **Should control the process as directly as possible**
- **Must be designed to work with the HVAC system and vice versa**

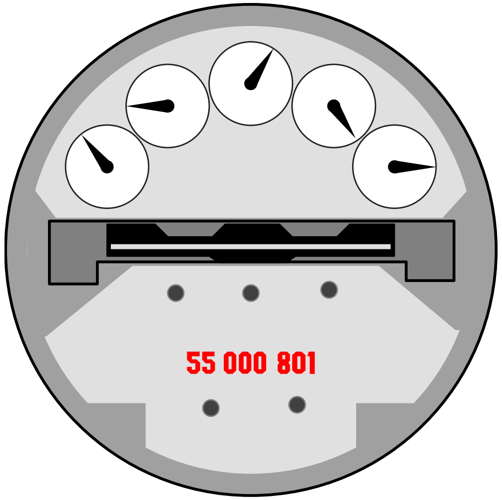
Design Criteria - II

The control system:

- **Should minimize energy consumption while meeting process goals**
- **Must meet the budget**
- **Must be designed for maximum simplicity**
- **Must be easy to understand and maintain**

Aims of HVAC Control System

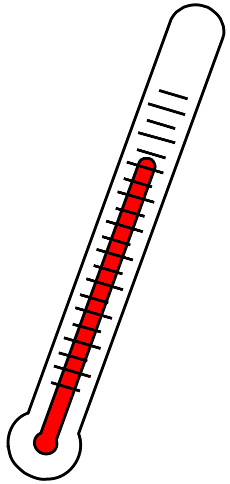
Lower energy cost



Lower operations cost

Increase flexibility

Ensure quality building environment



Key Personnel

- **HVAC system designer**
  - **Responsible for conceptual design, tendering, etc.**
- **Controls vendor sales representative**
  - **Provide advice on control products & features**

Design, etc.

- **Mechanical contractor**
  - **Installation of mechanical parts**
- **Electrical contractor**
  - **Installation of electrical parts**
- **Controls contractor**
  - **Details of control system + part of the installation**

Installation

Typical Installation Tasks

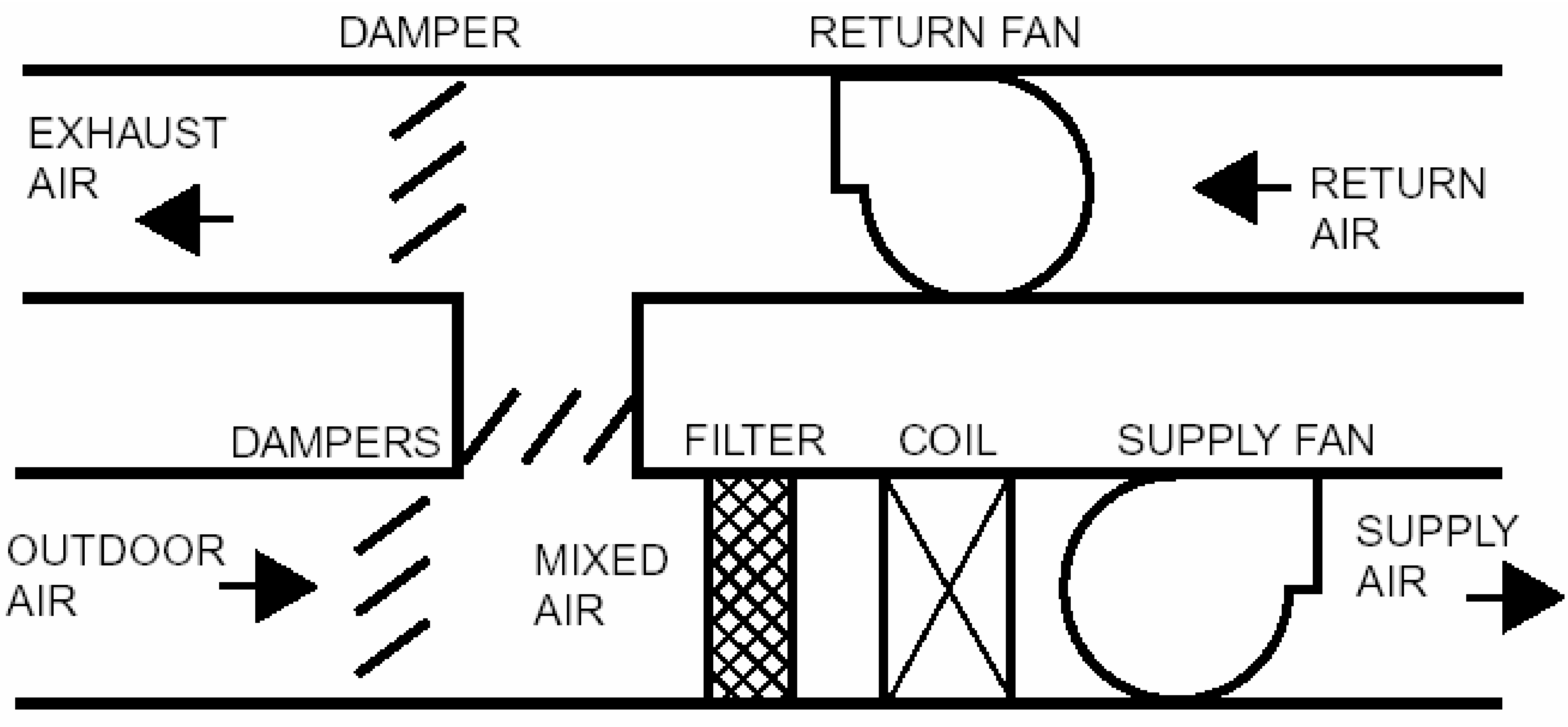
- **Mechanical contractor**
  - **Installation of control valves, dampers, air and water measuring devices**
  - **Provision of control dampers**
  - **Installation of duct mounted smoke detectors**
  - **Provision of variable speed drives**
  - **Provision of starters for package equipment and special machinery (e.g. chiller)**
  - **Provision of starters with thermal overload protection or motors with integral thermal overload protection**

Typical Installation Tasks

- **Electrical contractor (the controls work)**
  - **Motor starters**
  - **Fire alarm and life safety control relays and switches and all smoke detectors**
  - **Wiring and mounting line voltage controls**
  - **Power to control panels**
- **Controls contractor**
  - **Selection of control valves**
  - **Selection of actuators for both valves and dampers**
  - **Control and interlock wiring**

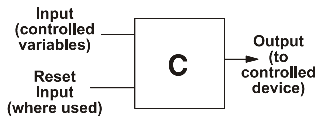
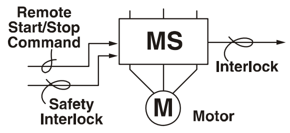
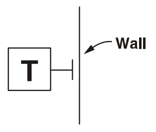
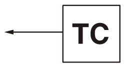
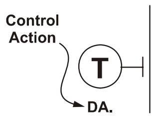
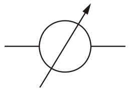
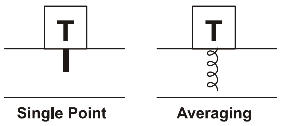
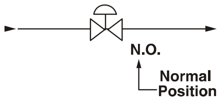
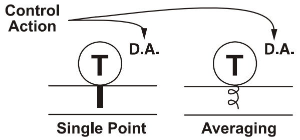
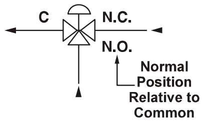
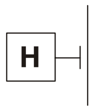
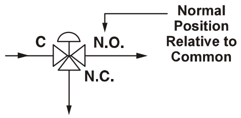
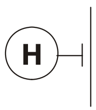
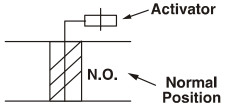
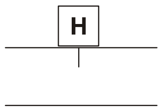
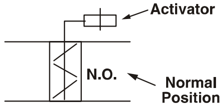
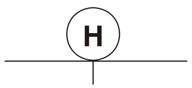
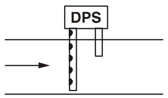
Control Diagrams and Symbols

- **Symbols for HVAC system components**
  - Refer to ASHRAE Fundamentals Handbook 2005 Chp. 37, Abbreviations and Symbols
  - Refer to other local standards or guidelines
  - Usually specified in the contract drawings & documents
- **Generic control diagrams**
  - Using generic symbols to describe and define the requirements of the control system
- **Shop drawings by contractors**
- **Specific hardware control diagrams**

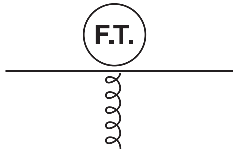
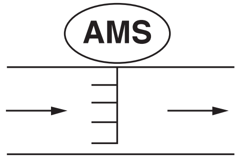
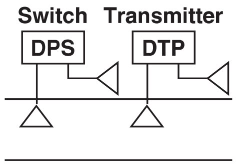
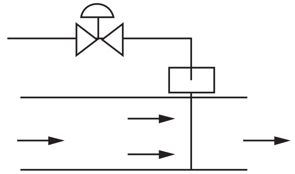
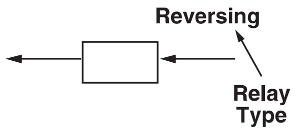
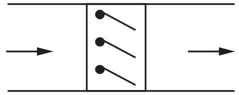
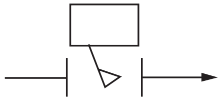
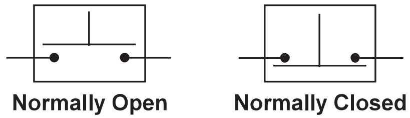
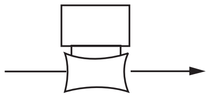
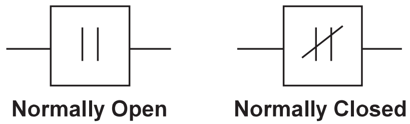


[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Generic Symbols - I

DEVICE	SYMBOL	DEVICE	SYMBOL
Controller		Motor Starter	
Wall Temperature Sensor		Timeclock	
Wall Thermostat		Gradual Switch or Potentiometer	
Duct Temperature Sensor		2-Way Control Valve	
Duct Thermostat		3-Way Mixing Valve	
Wall Humidity Sensor		3-Way Diverting Valve	
Wall Humidistat		Motorized Damper, Parallel Blade	
Duct Humidity Sensor		Motorized Damper, Opposed Blade	
Duct Humidistat		Duct Smoke Detector	

Generic Symbols - II

DEVICE	SYMBOL	DEVICE	SYMBOL
Freeze-stat or Low-limit T'stat		Airflow Measuring Station	
Differential Pressure Switch Transmitter		Steam Humidifier	
General Relay		Backdraft (Barometric Relief) Damper	
Flow Switch (Sail Type)		Momentary Contact Switch	
Flow Meter		Relay	
Well Temp Sensor & Station			

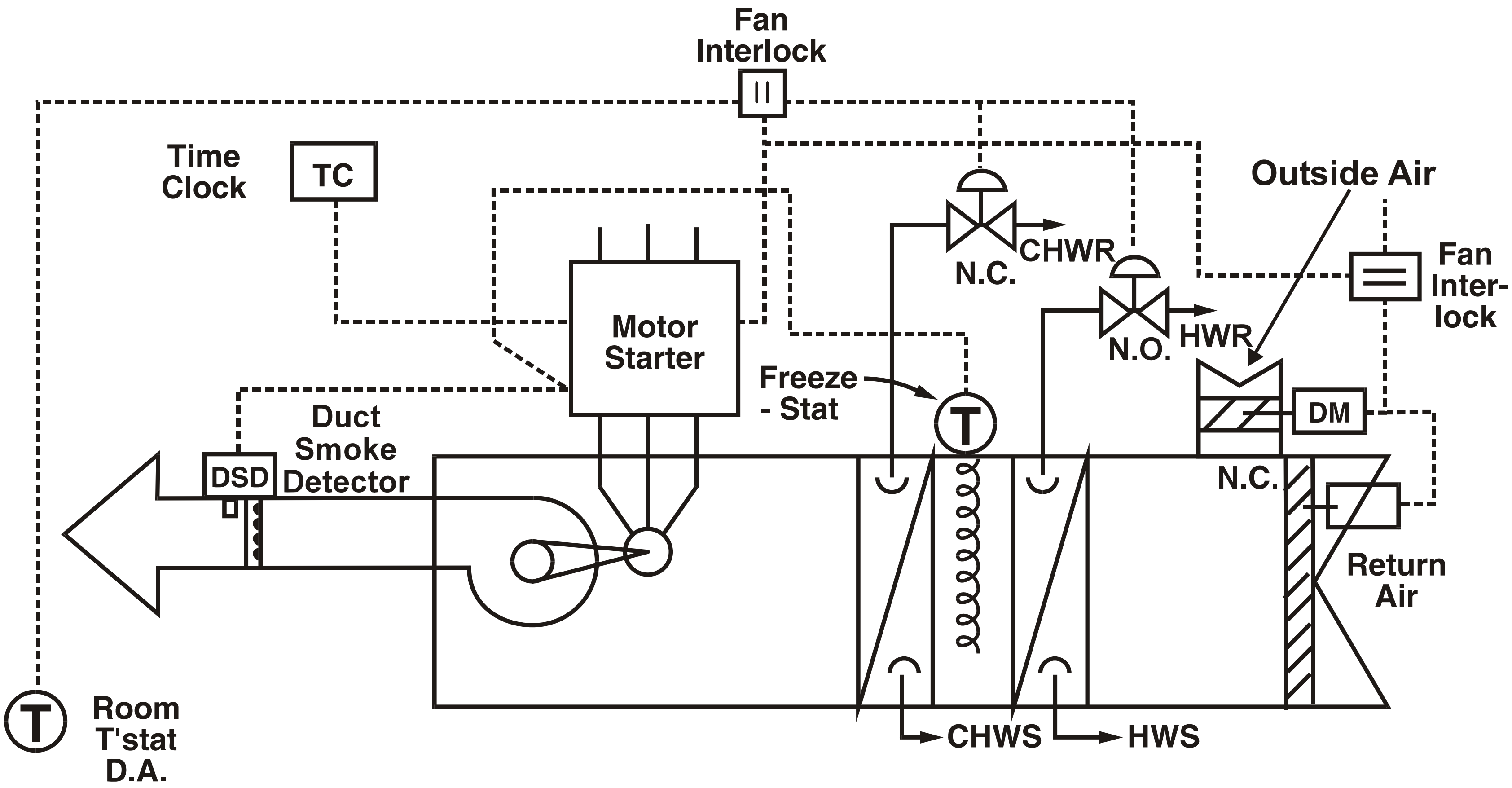
Writing Control Sequences - I

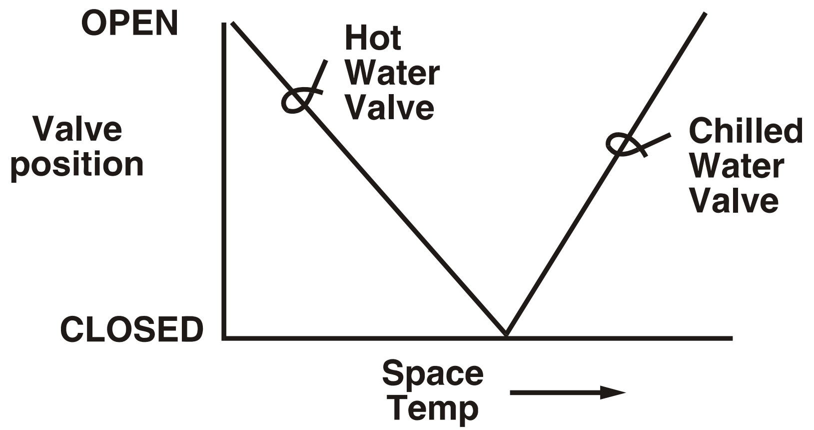
- Break the sequence into logical parts
- Clearly indicate the control point and controlled device and how the setpoint is determined
- Consider using enabling interlocks
- State the required/desired setpoints
- Each variable should be controlled by a single control loop

Writing Control Sequences - II

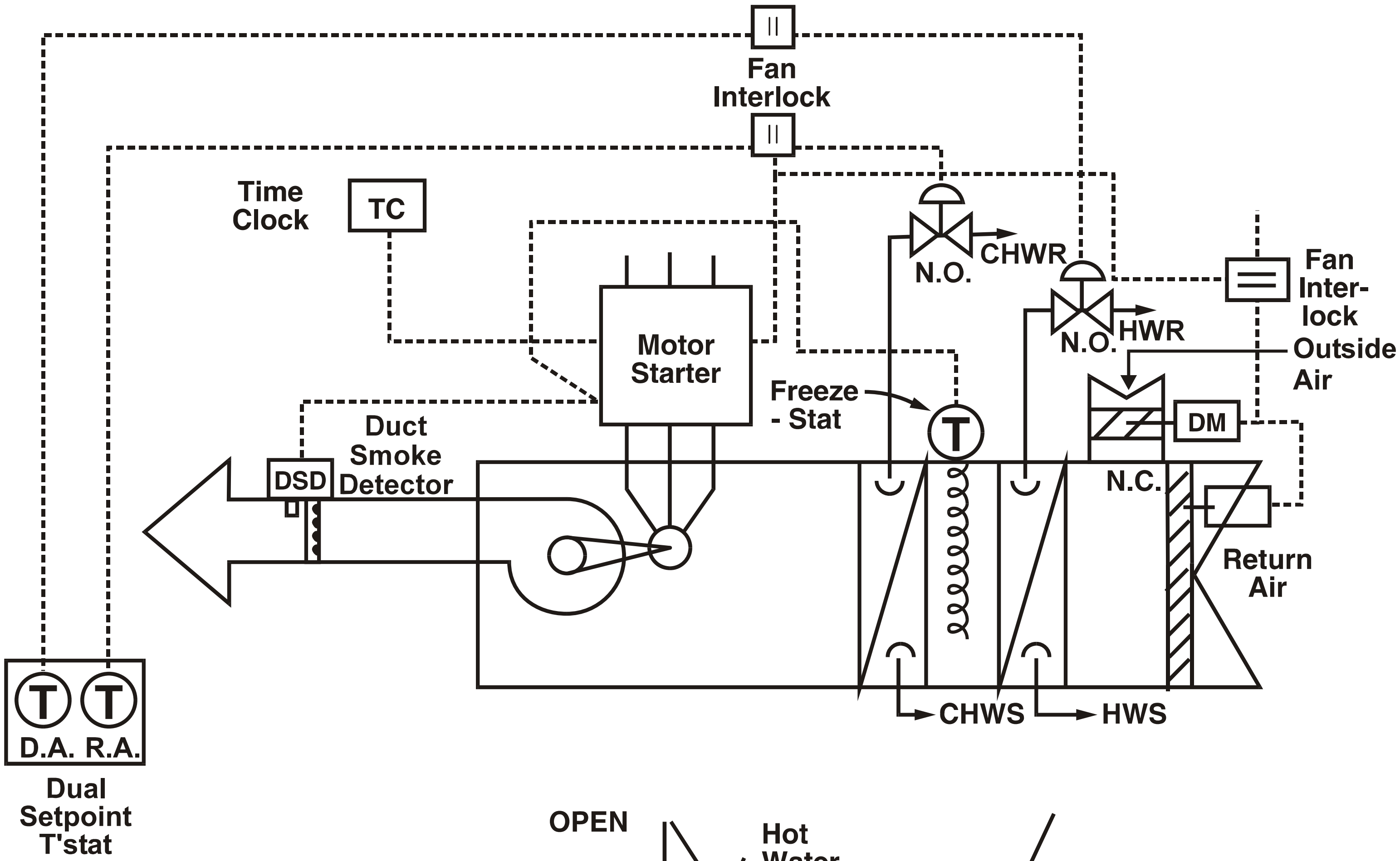
- State how each device should be controlled when the system operates normally, shuts down and in emergencies
- Specify the normal position of important controlled devices
- Control sequences should be as specific as possible
- Simplify control sequences to avoid bugs

Single-Zone Air Handler

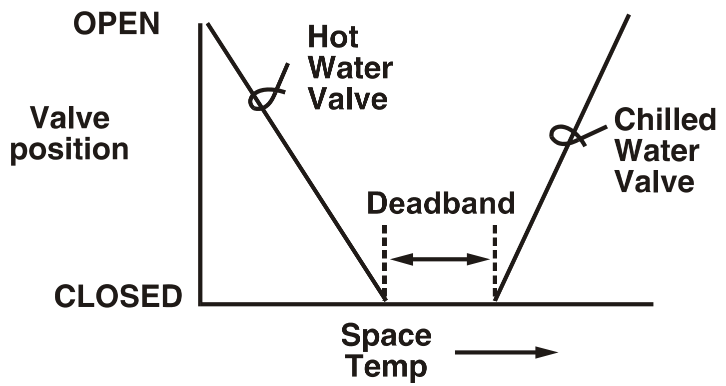




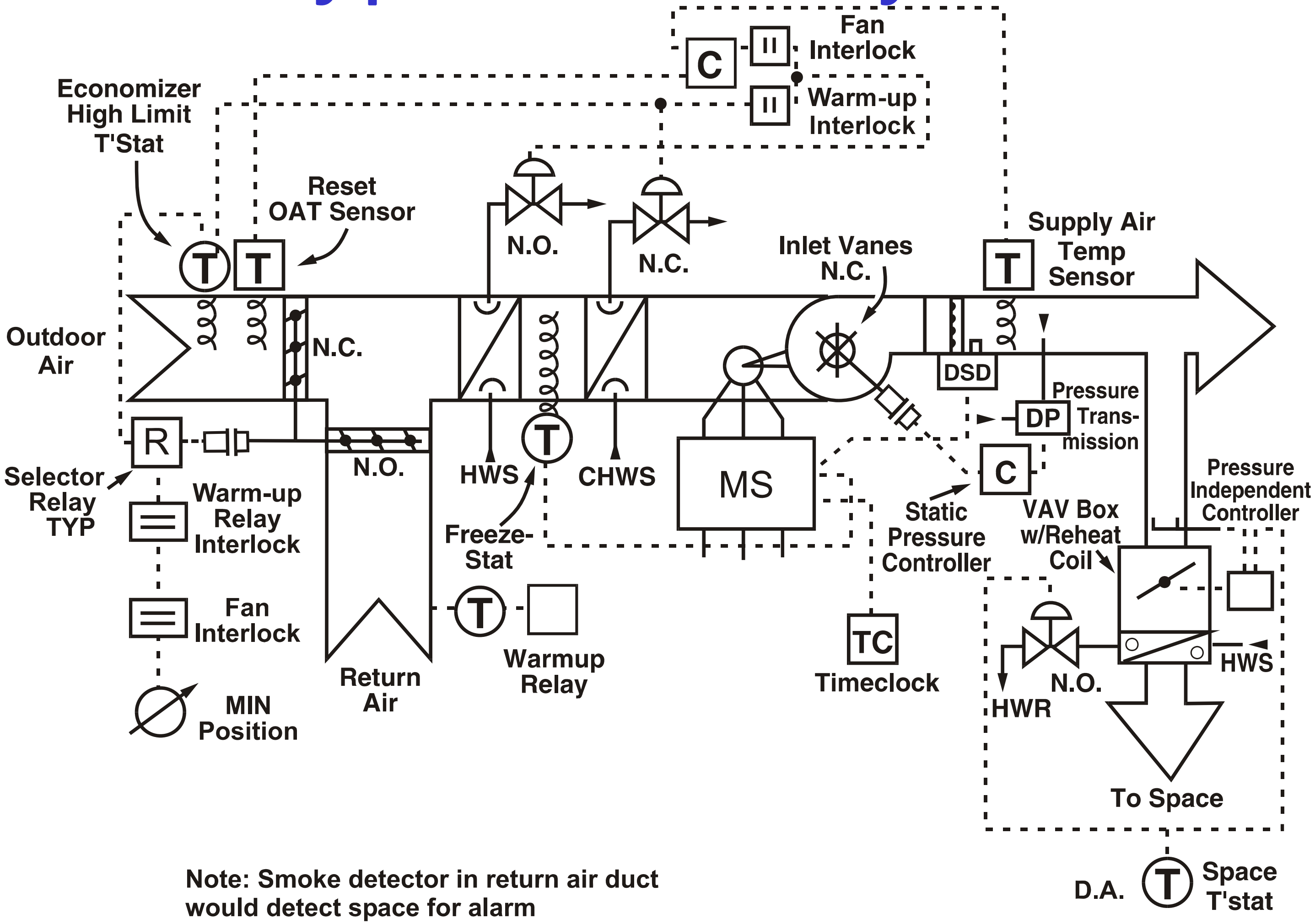
Single-Zone Unit With Dual Setpoint Thermostat



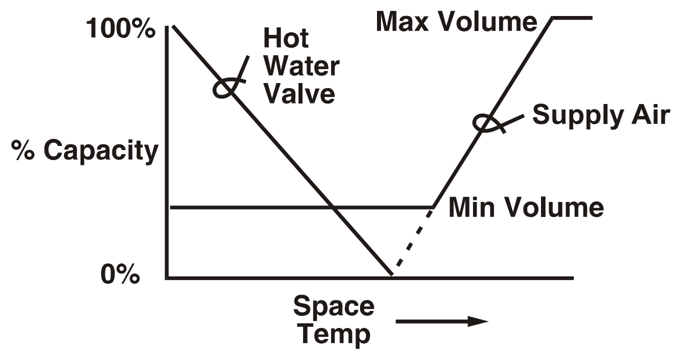
Note: Duct smoke detector in return air duct would detect space for alarm

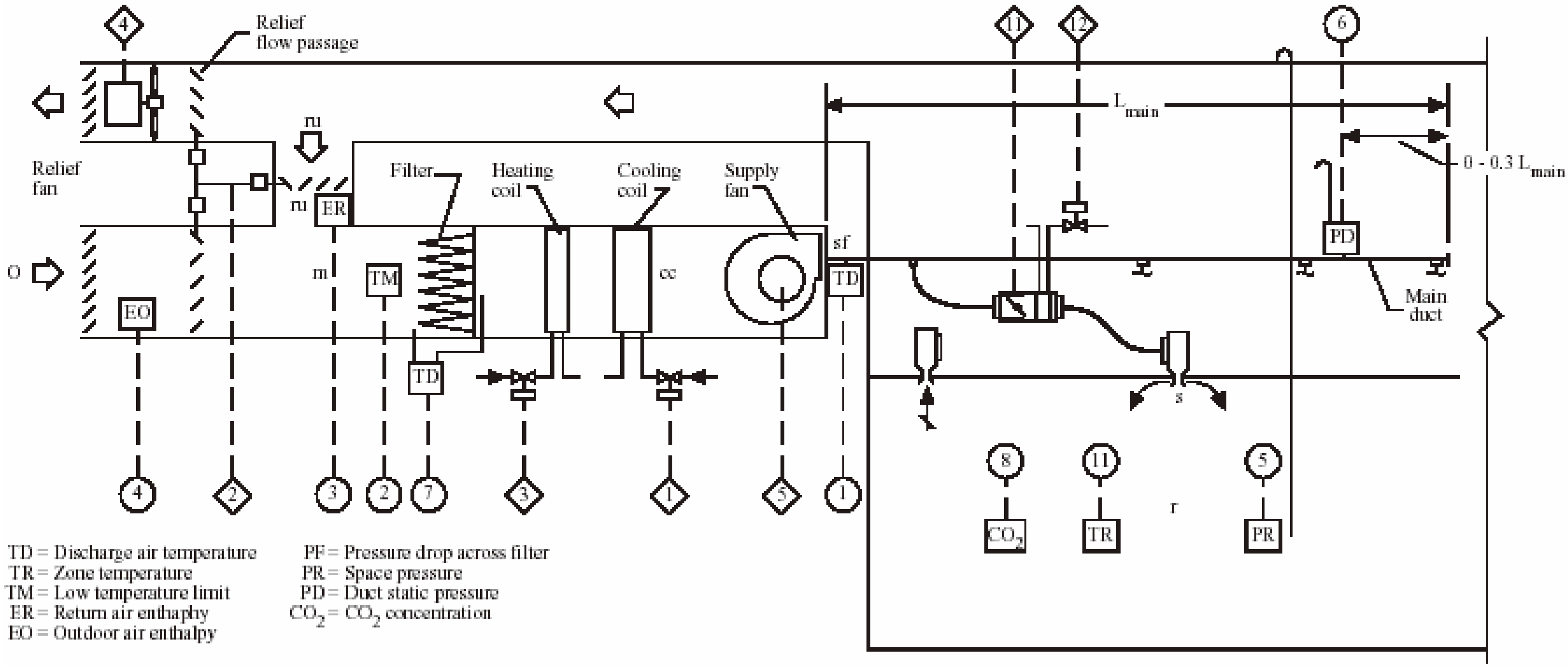


Typical VAV System



Note: Smoke detector in return air duct would detect space for alarm

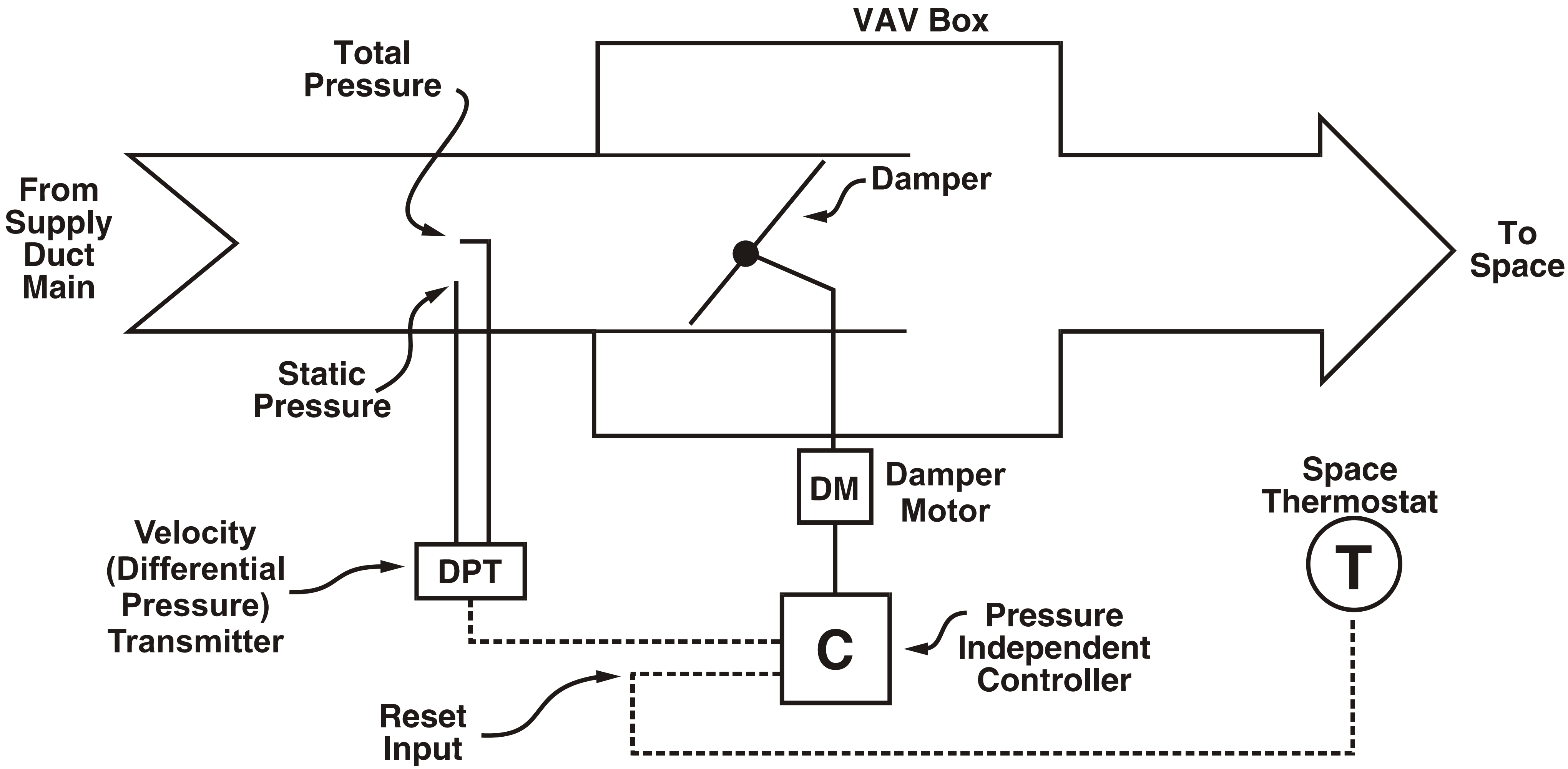




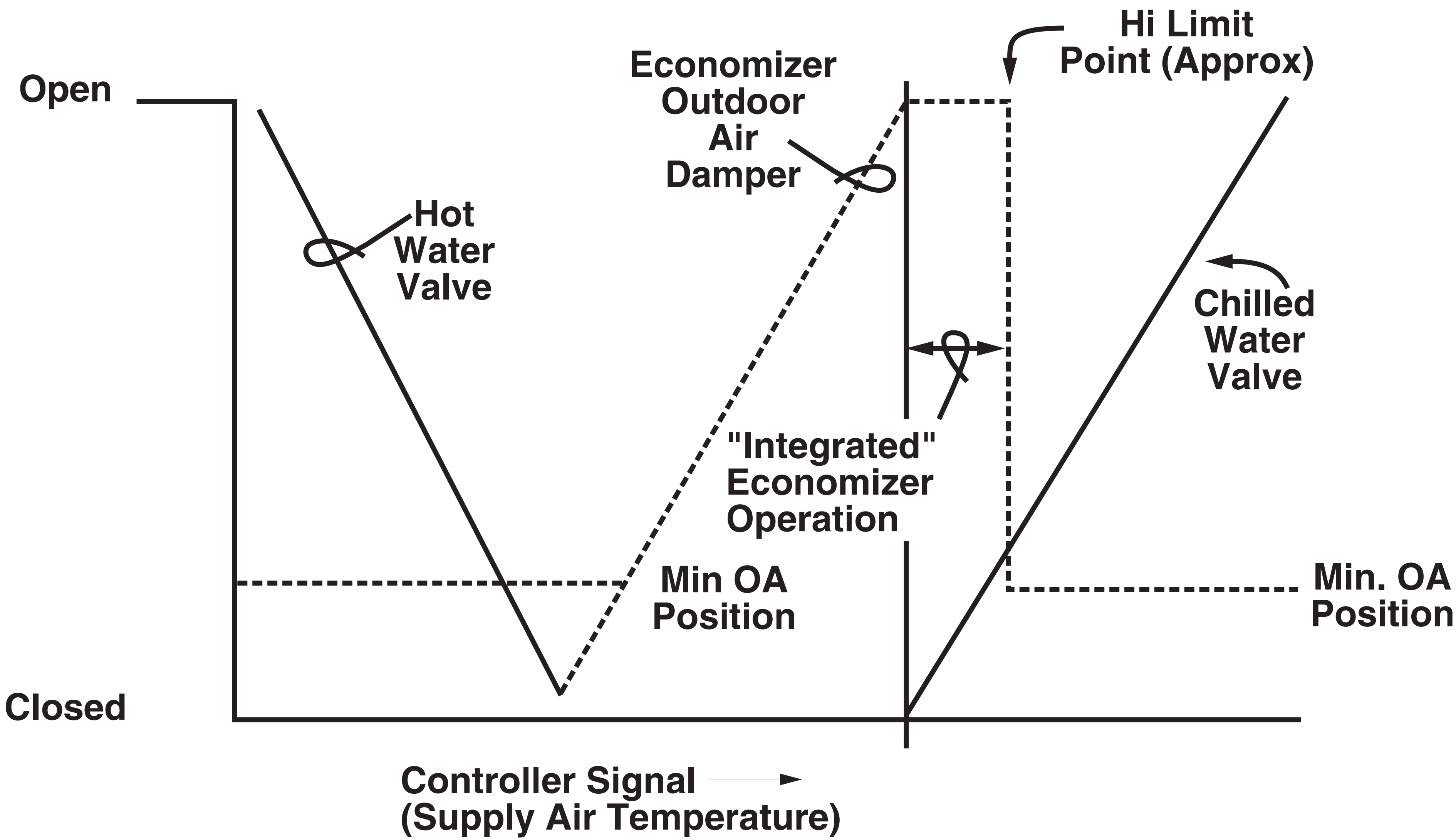
Control diagram of a VAV reheat system for year-round operation

[Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*]

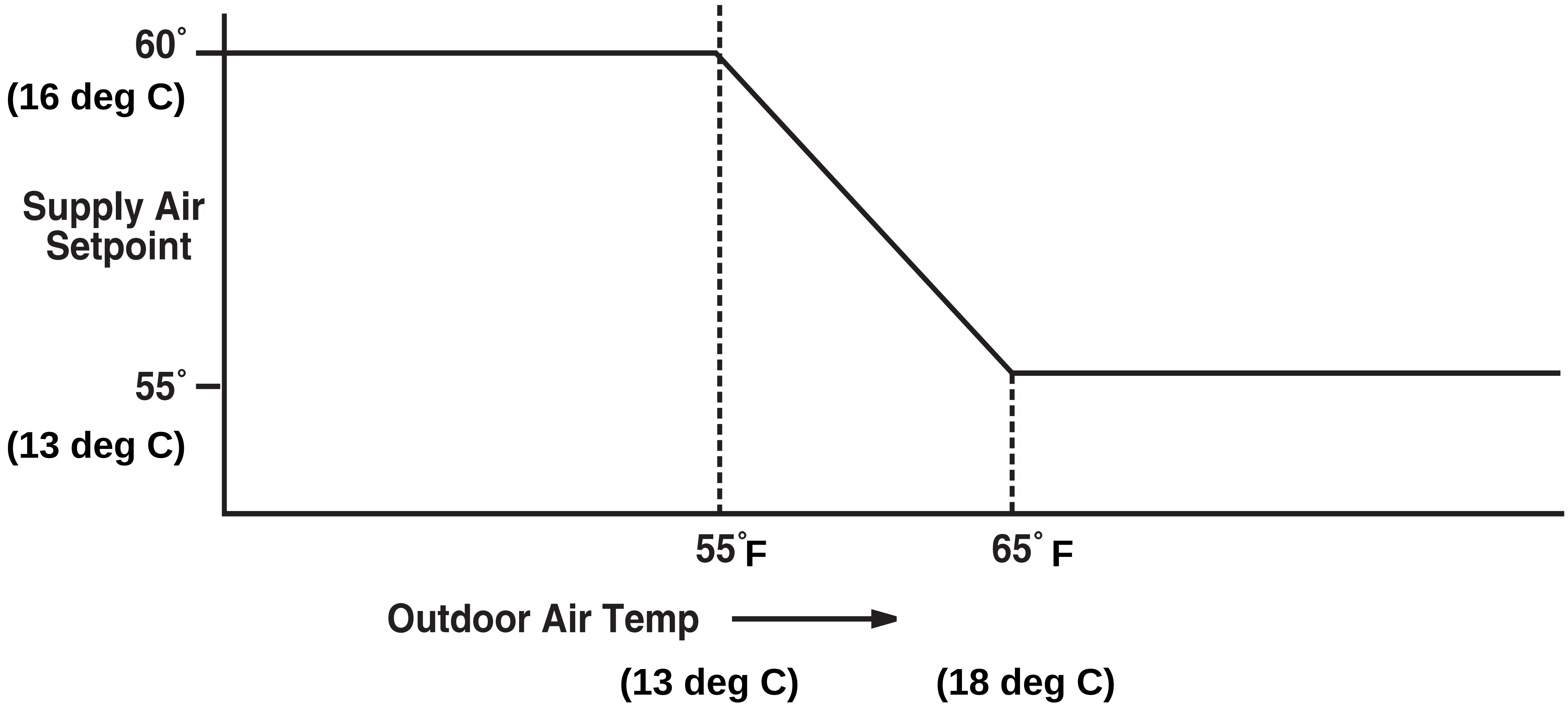
Pressure Independent Control

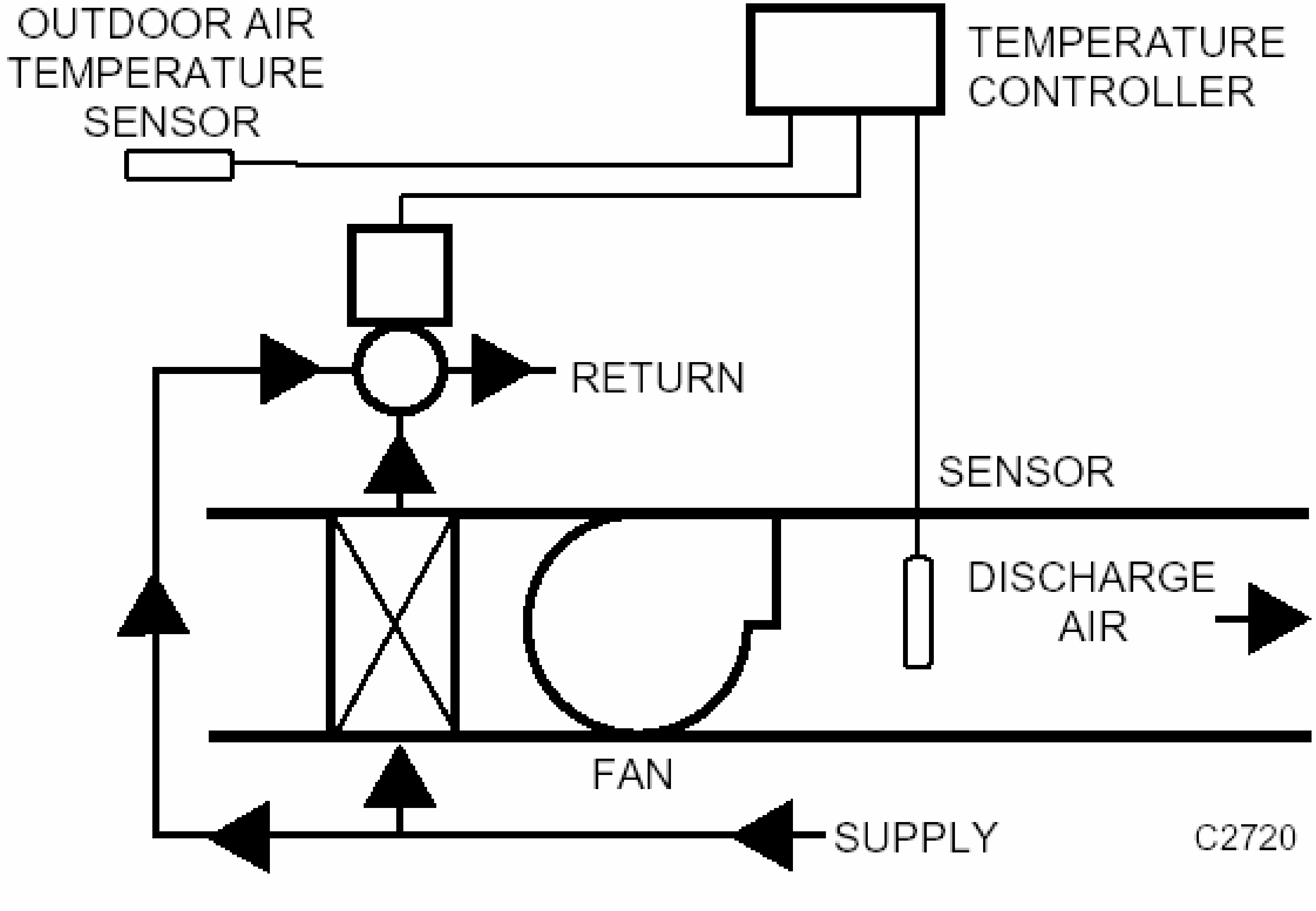


Chilled Water, Economizer and Hot Water Sequencing



Reset Schedule





Discharge air control loop with reset

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

Condition	Outdoor Air Temperature (°C)	Discharge Air Temperature (°C)
Outdoor design temperature	–20	40
Light load	20	20

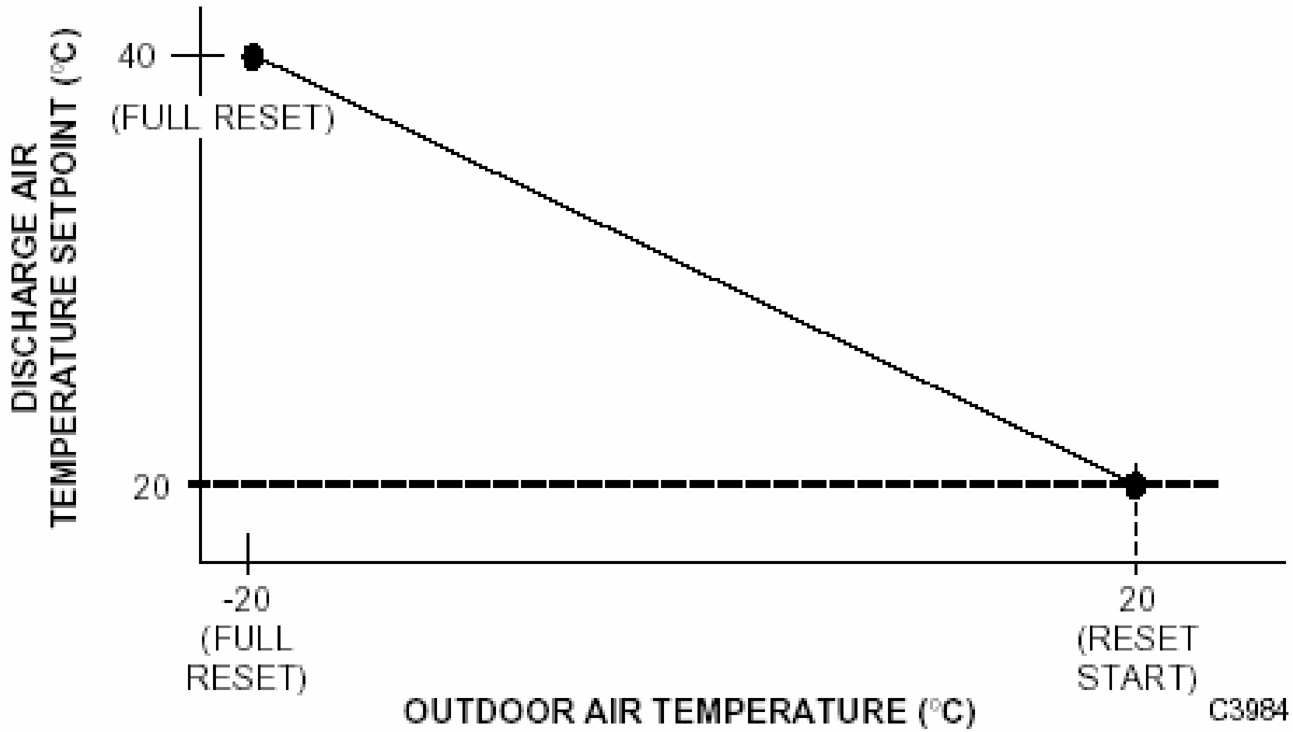
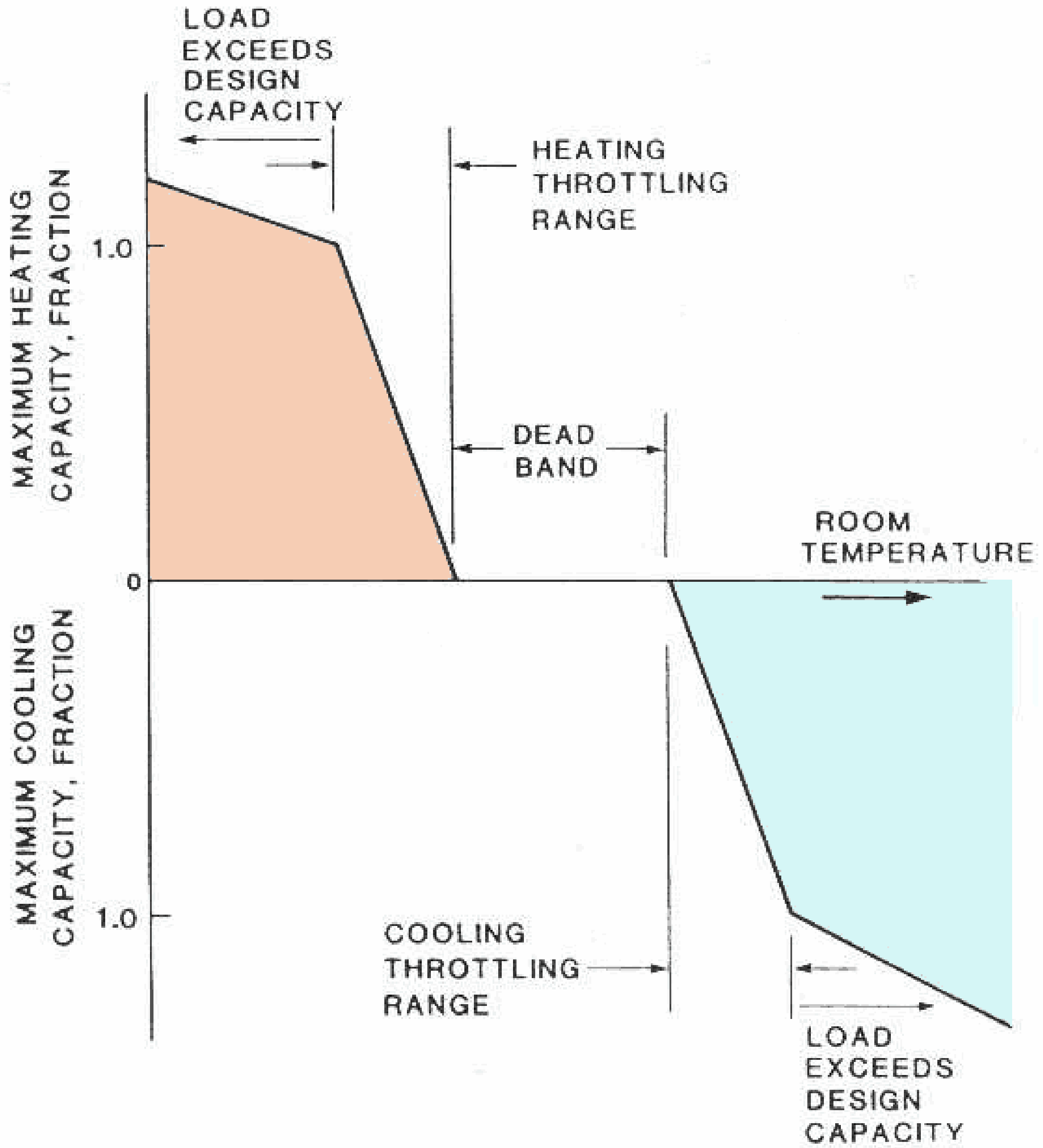


Fig. 34. Typical Reset Schedule for Discharge Air Control.

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



Thermostat model of proportional control with deadband and dual throttling range

Practical Examples for Air Handling System

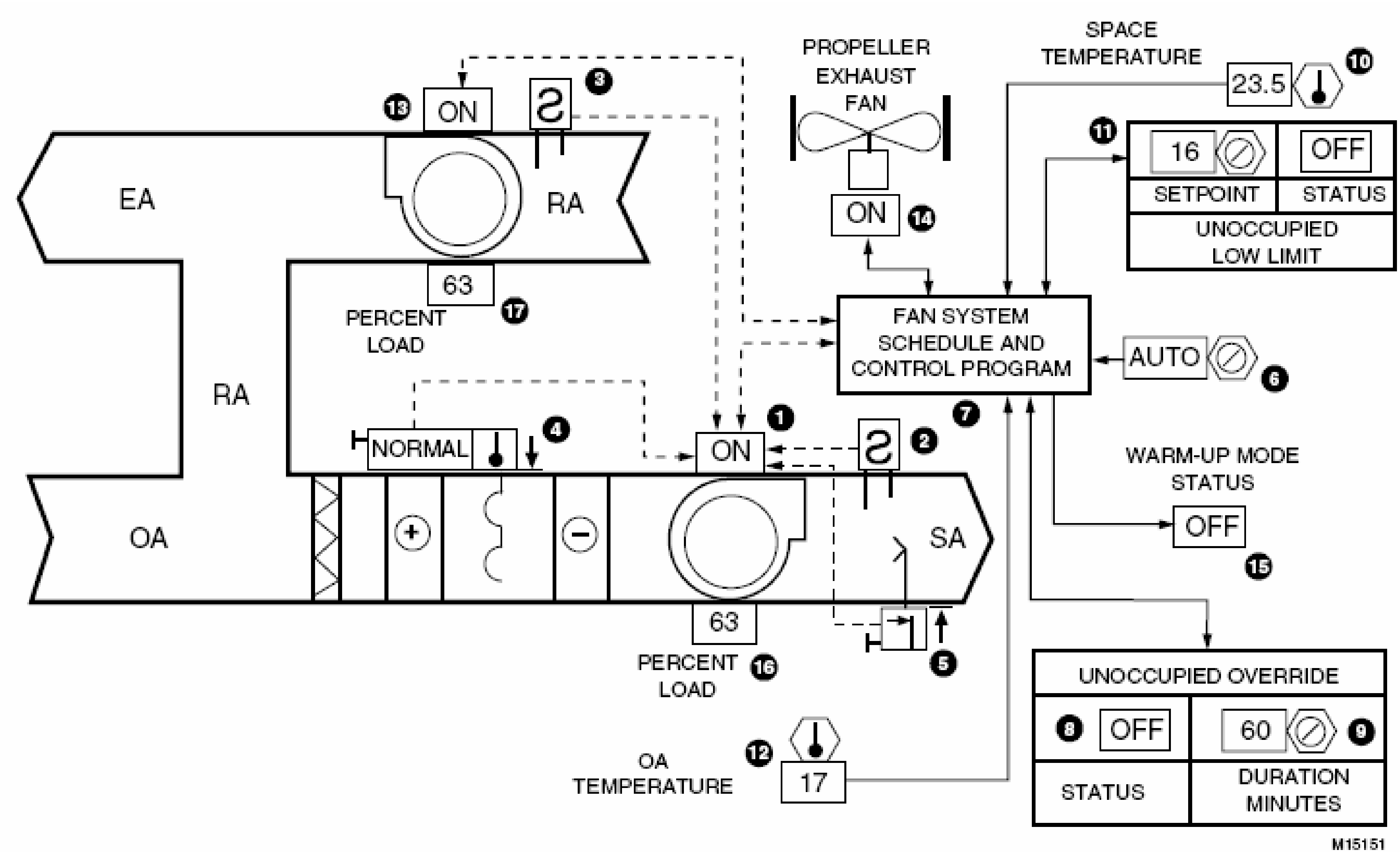
Practical Examples for Air Handling System

- **Reference document:**
  - **Honeywell, 1997. *Engineering Manual of Automatic Control for Commercial Buildings - Heating, Ventilating, Air Conditioning*, SI Edition., Honeywell, Inc., Minneapolis, MN, pp. 201-260.**
- **Air Handling System Control Applications**
  - **Abbreviations and symbols**
  - **Requirements for Effective Control (general guidelines)**
  - **Different HVAC processes**
  - **ASHRAE Psychrometric Charts**

Practical Examples for Air Handling System

- **Typical format and design information**
  - Functional description (w/ diagram)
  - Features
  - Conditions for successful operation
  - Limitations
  - Specifications
  - Psychrometric aspects

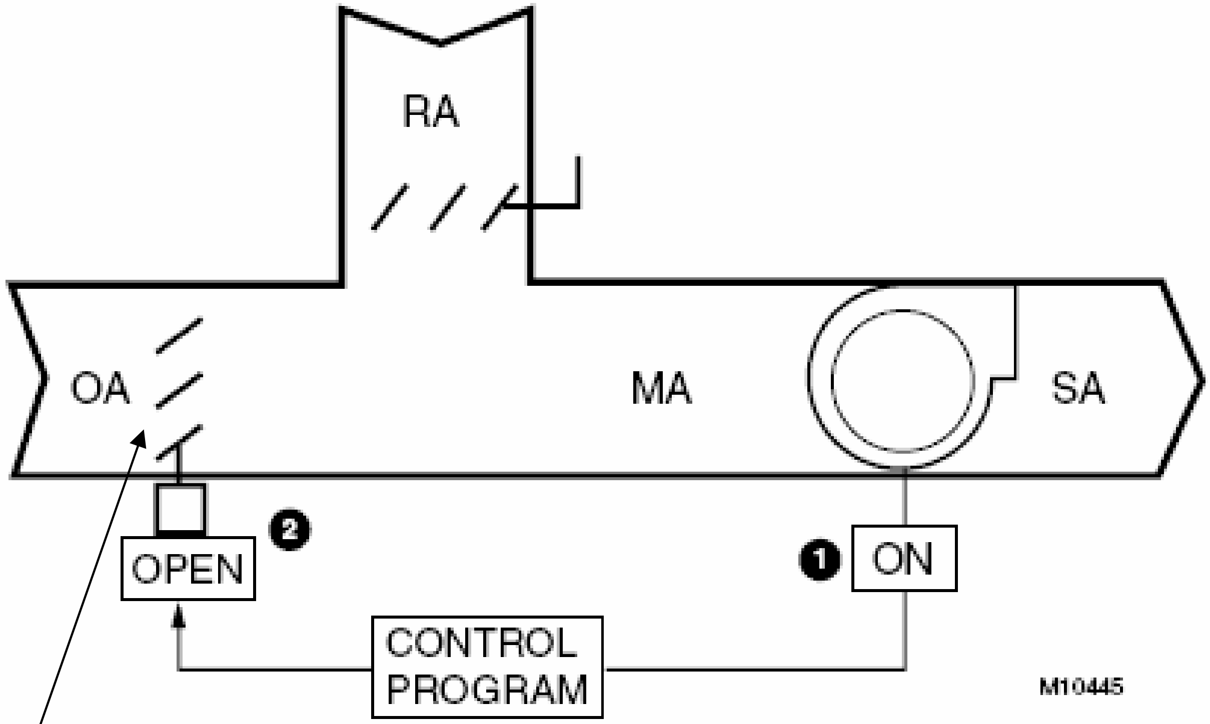
Fan system start-stop control



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

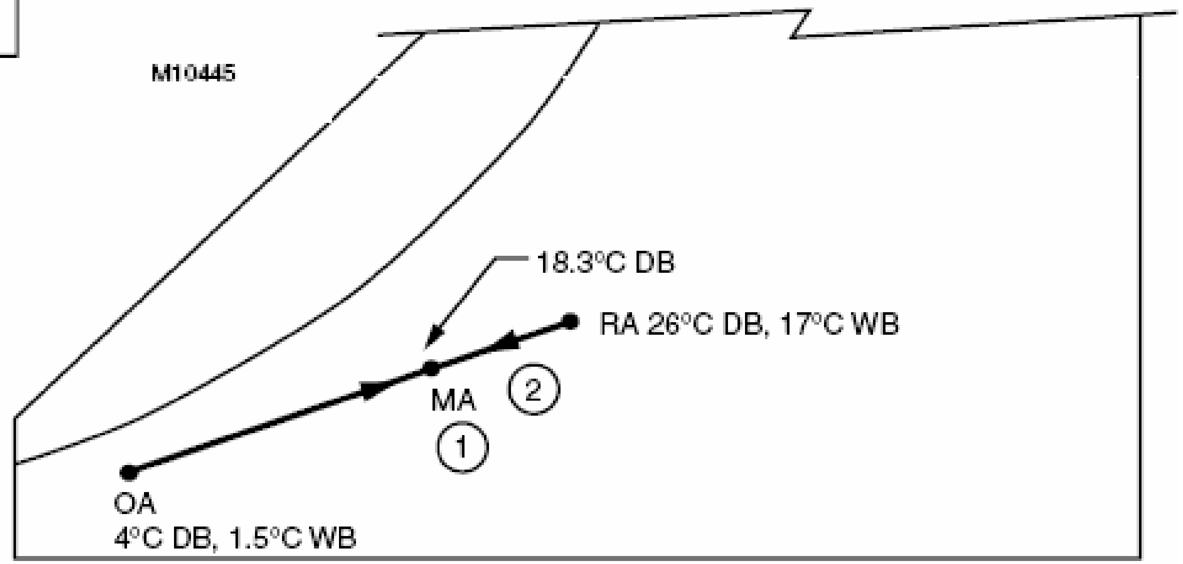
Fixed quantity of outdoor air control

Return air



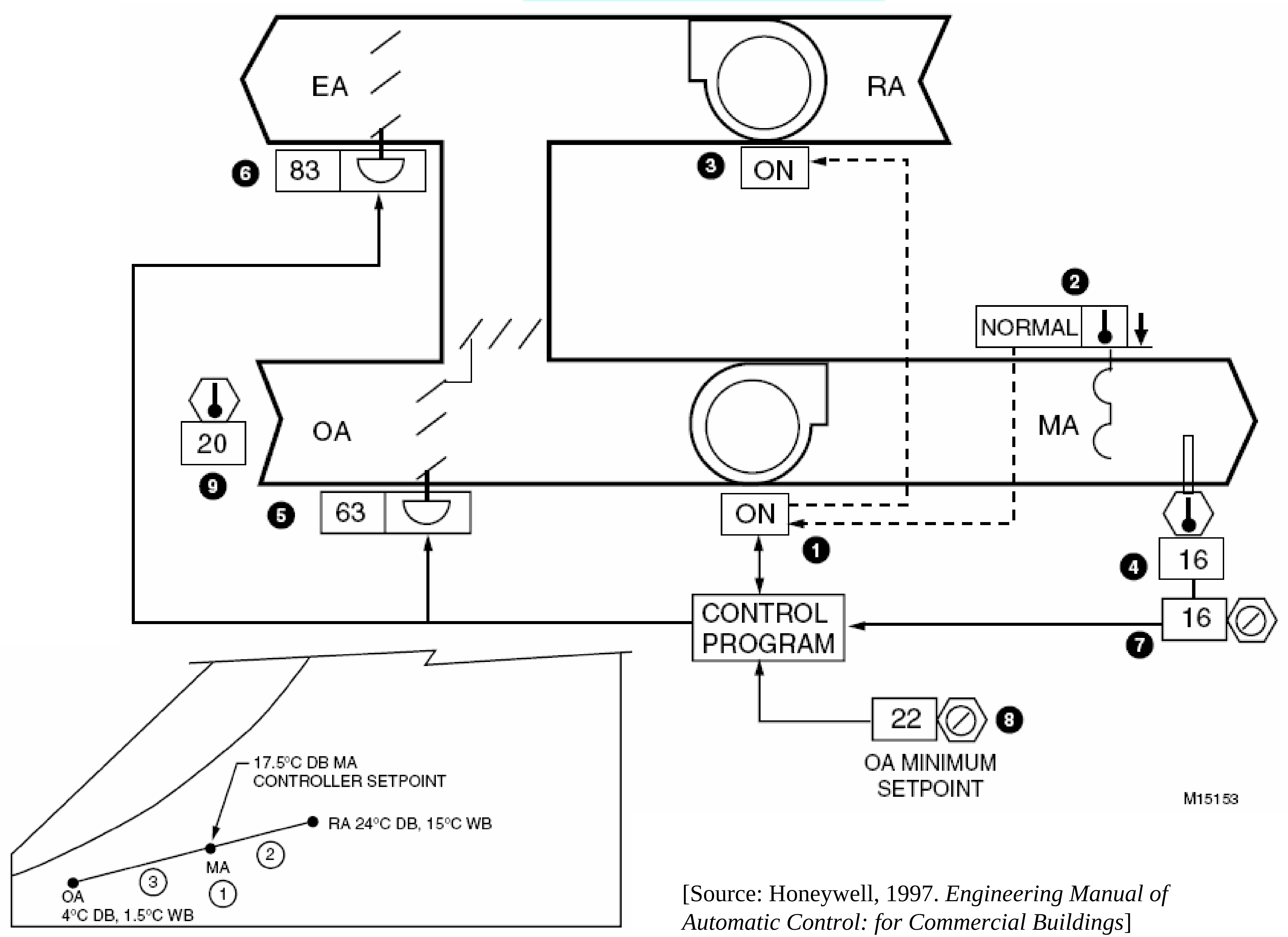
Deliver/supply air

Two-position damper



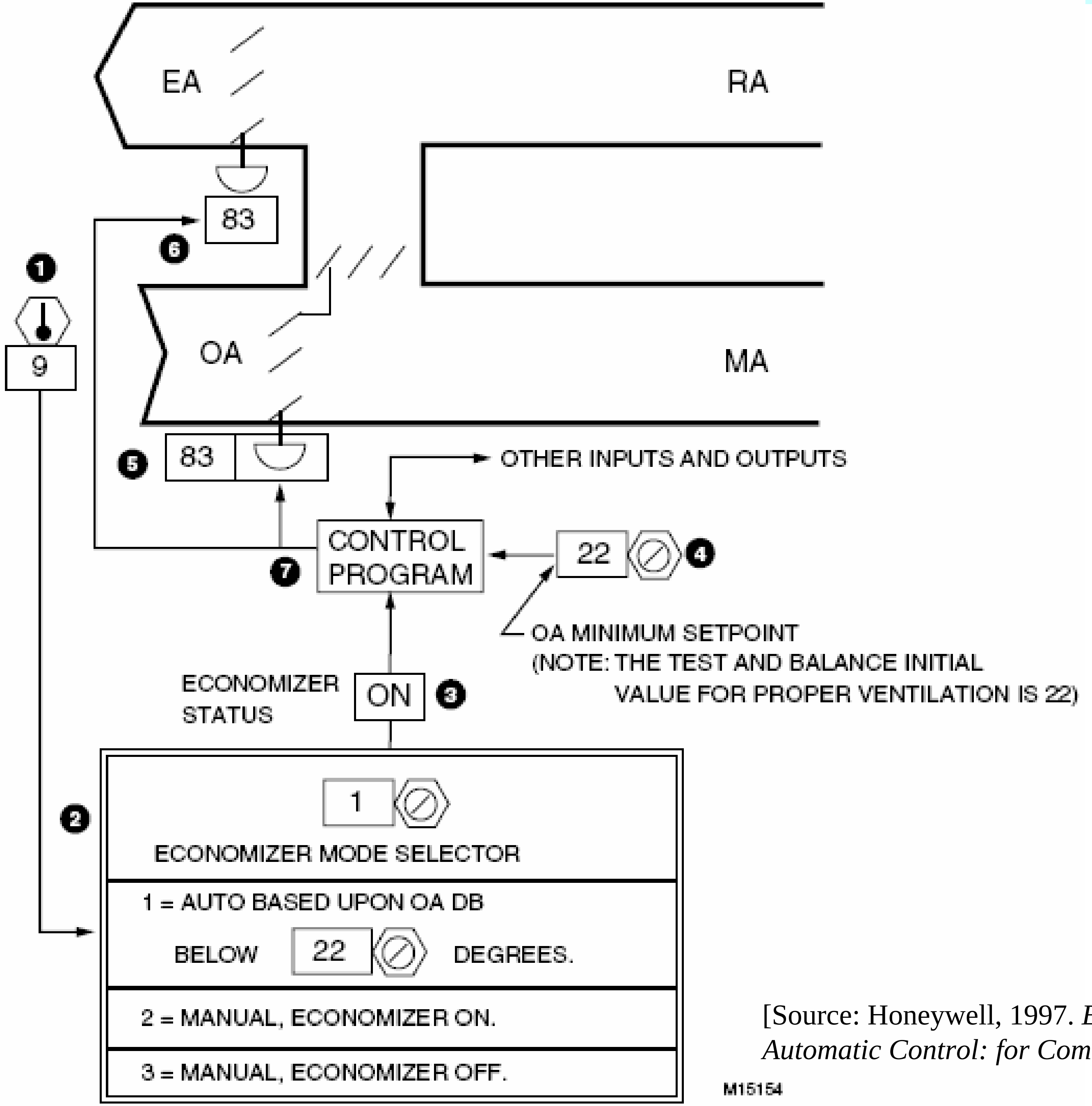
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Mixed air control



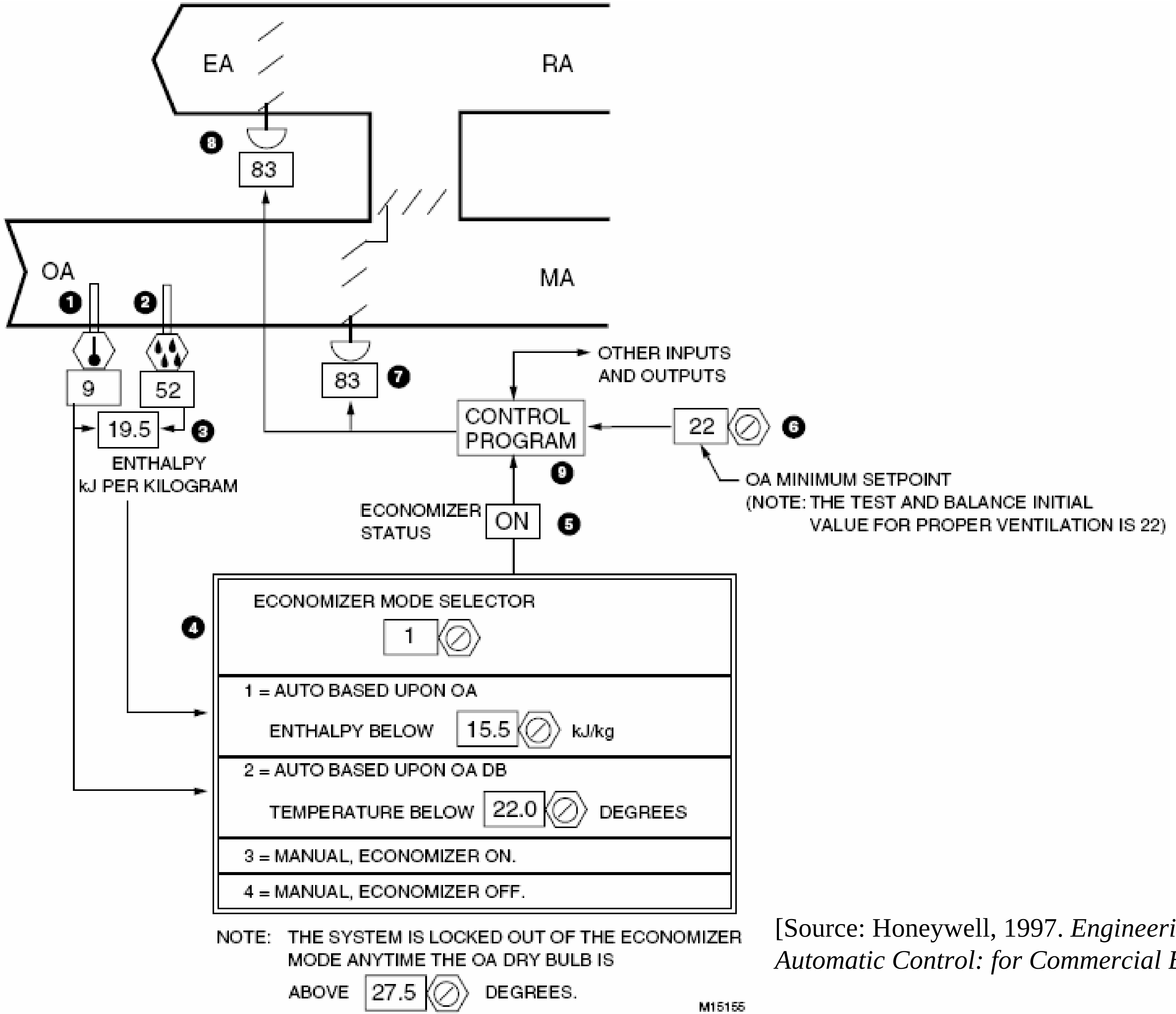
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Economizer cycle control (outdoor air dry bulb)



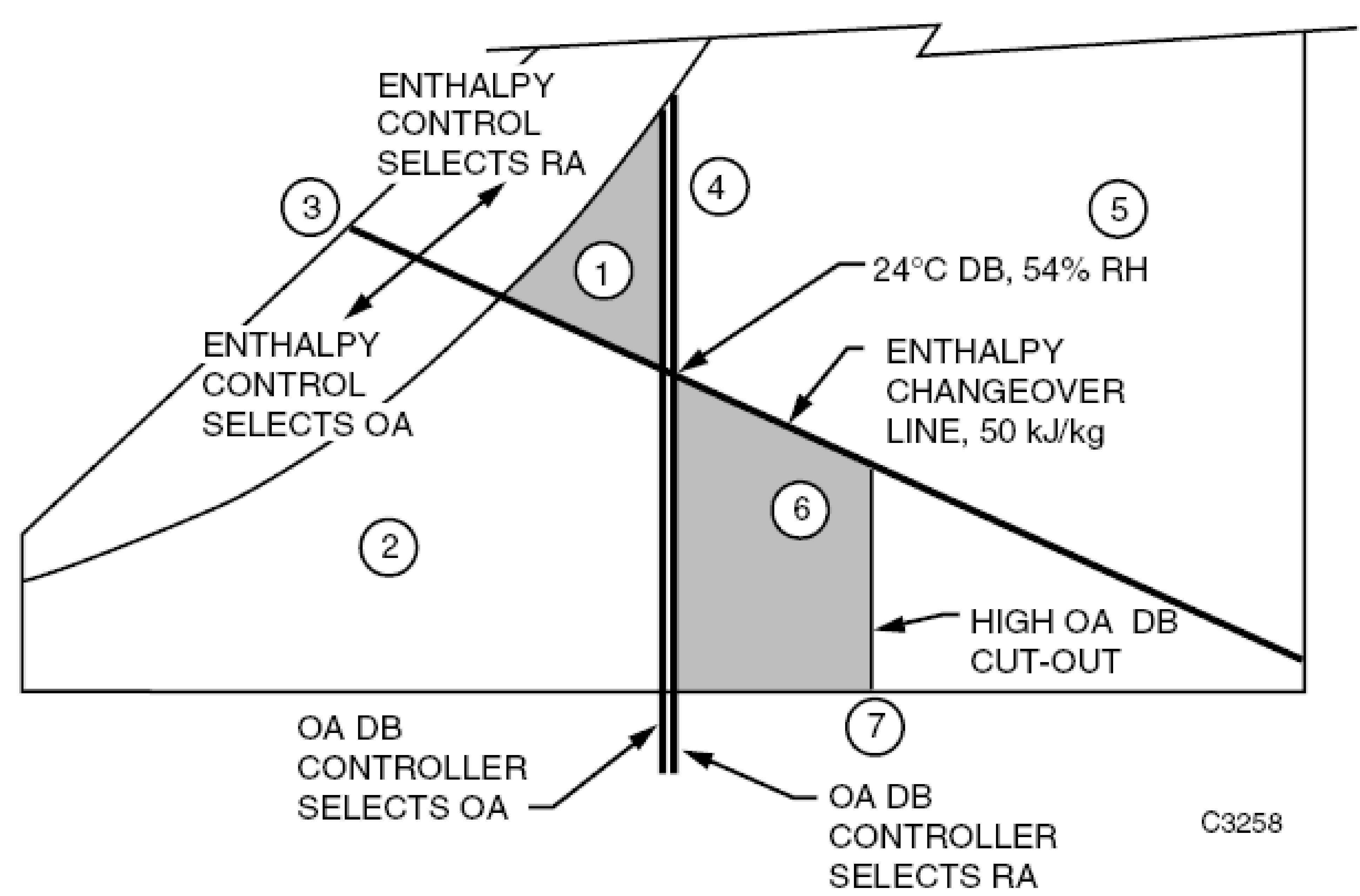
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Economizer cycle control (outdoor air enthalpy)



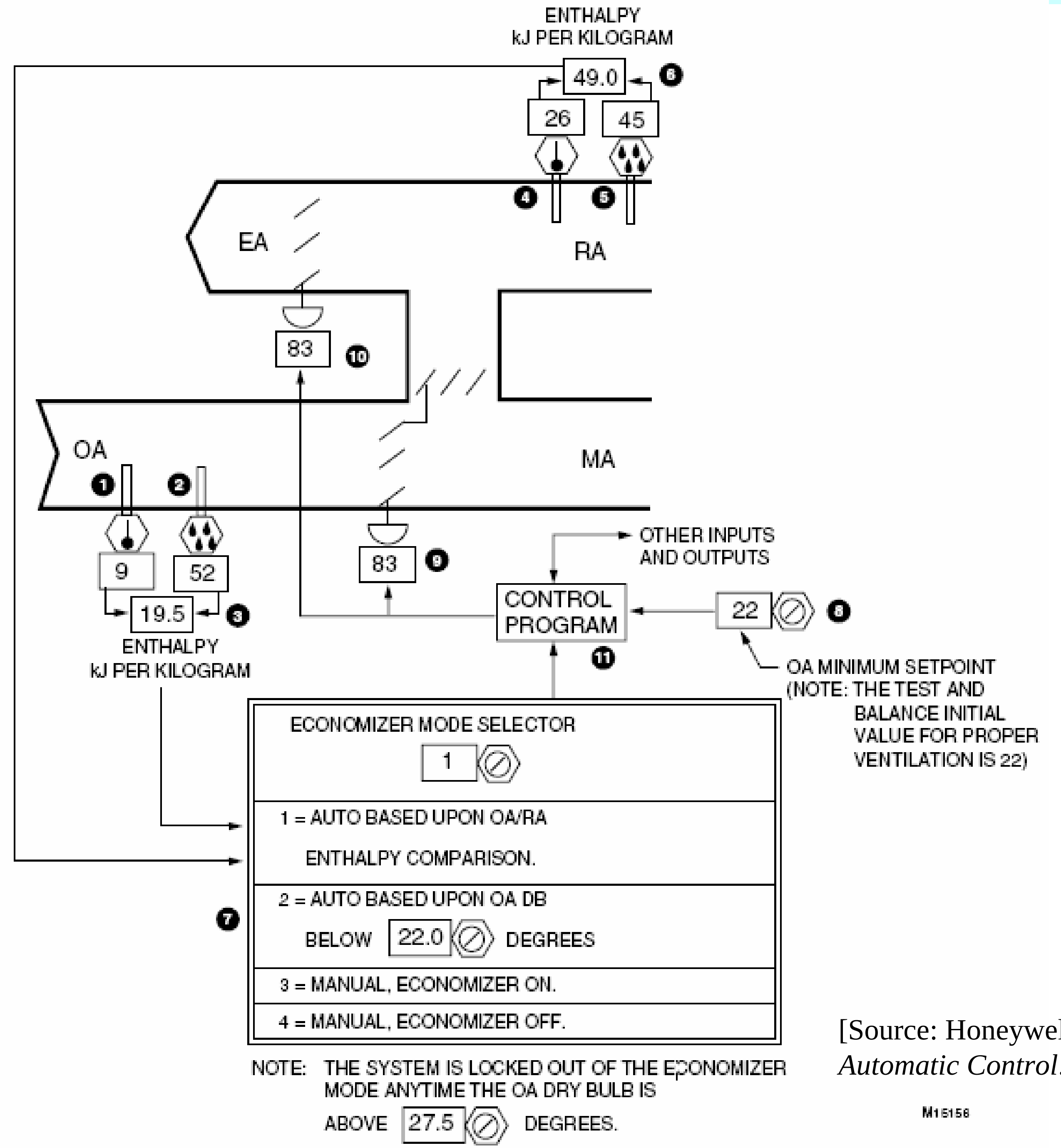
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Economizer cycle control (outdoor air enthalpy)



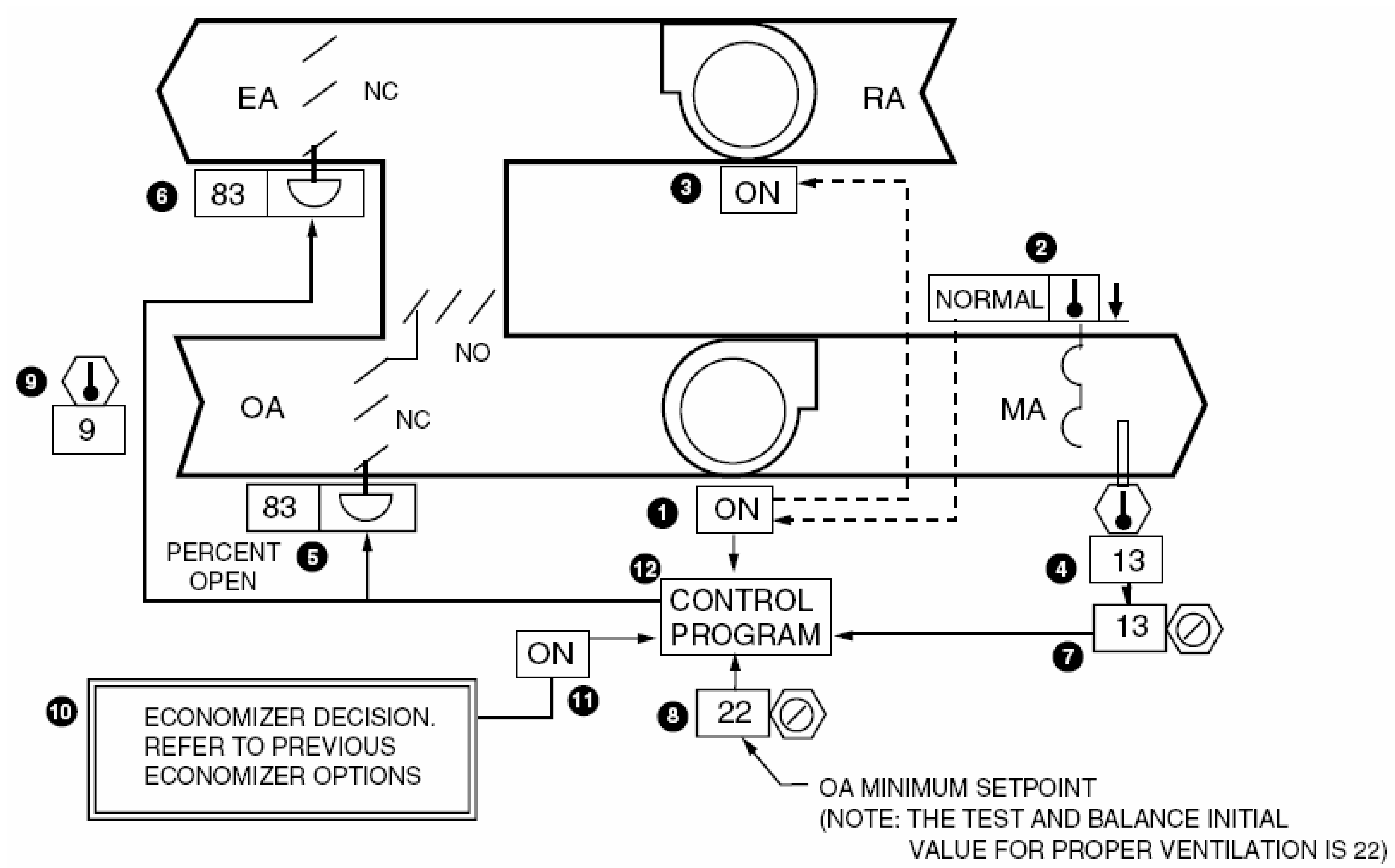
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Economizer cycle control (outdoor air/return air enthalpy comparison)



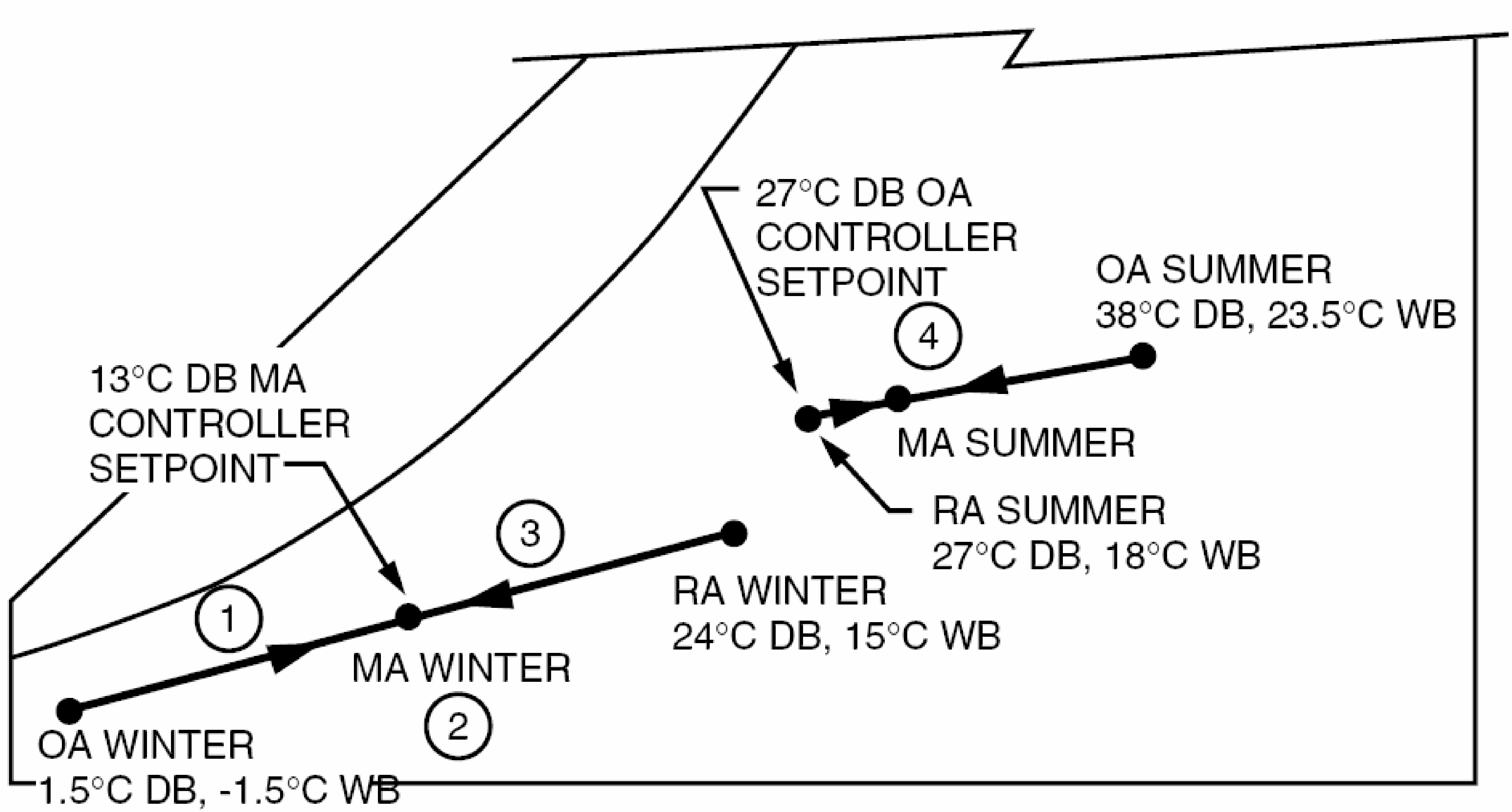
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Mixed air control with economizer cycle



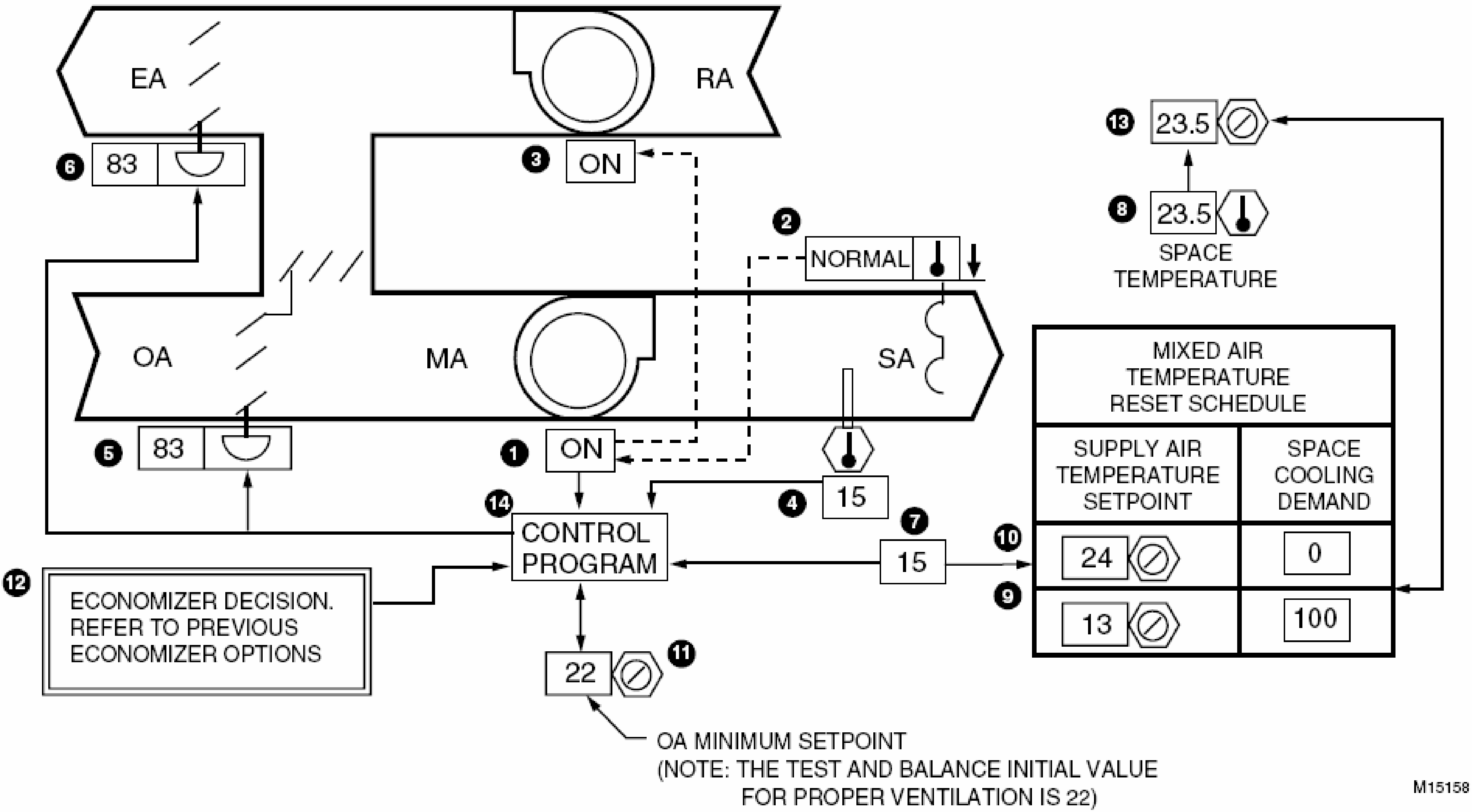
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Mixed air control with economizer cycle



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

Economizer cycle control of space temperature with supply air temperature setpoint reset

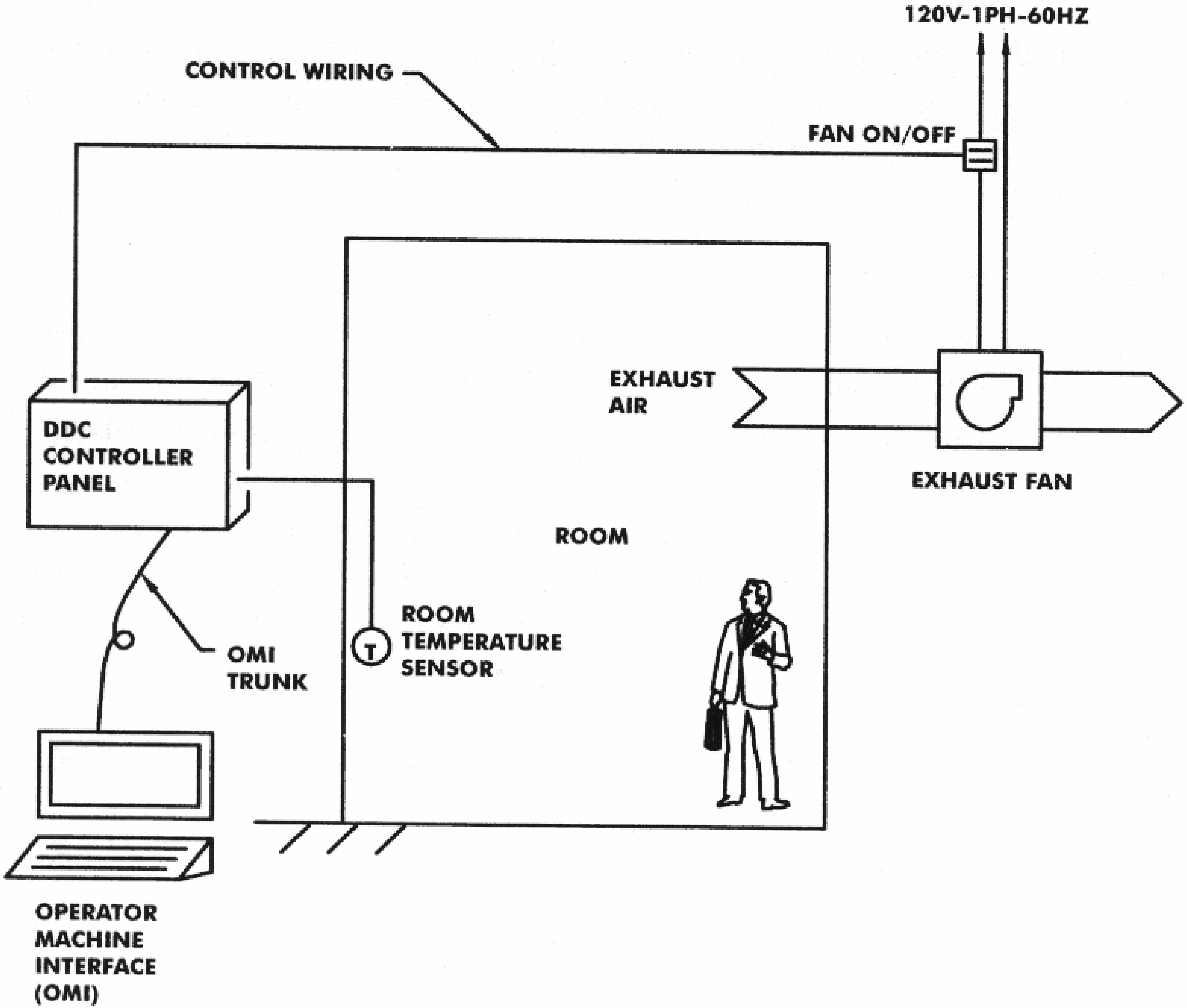


[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Designing Direct Digital Control (DDC) Systems

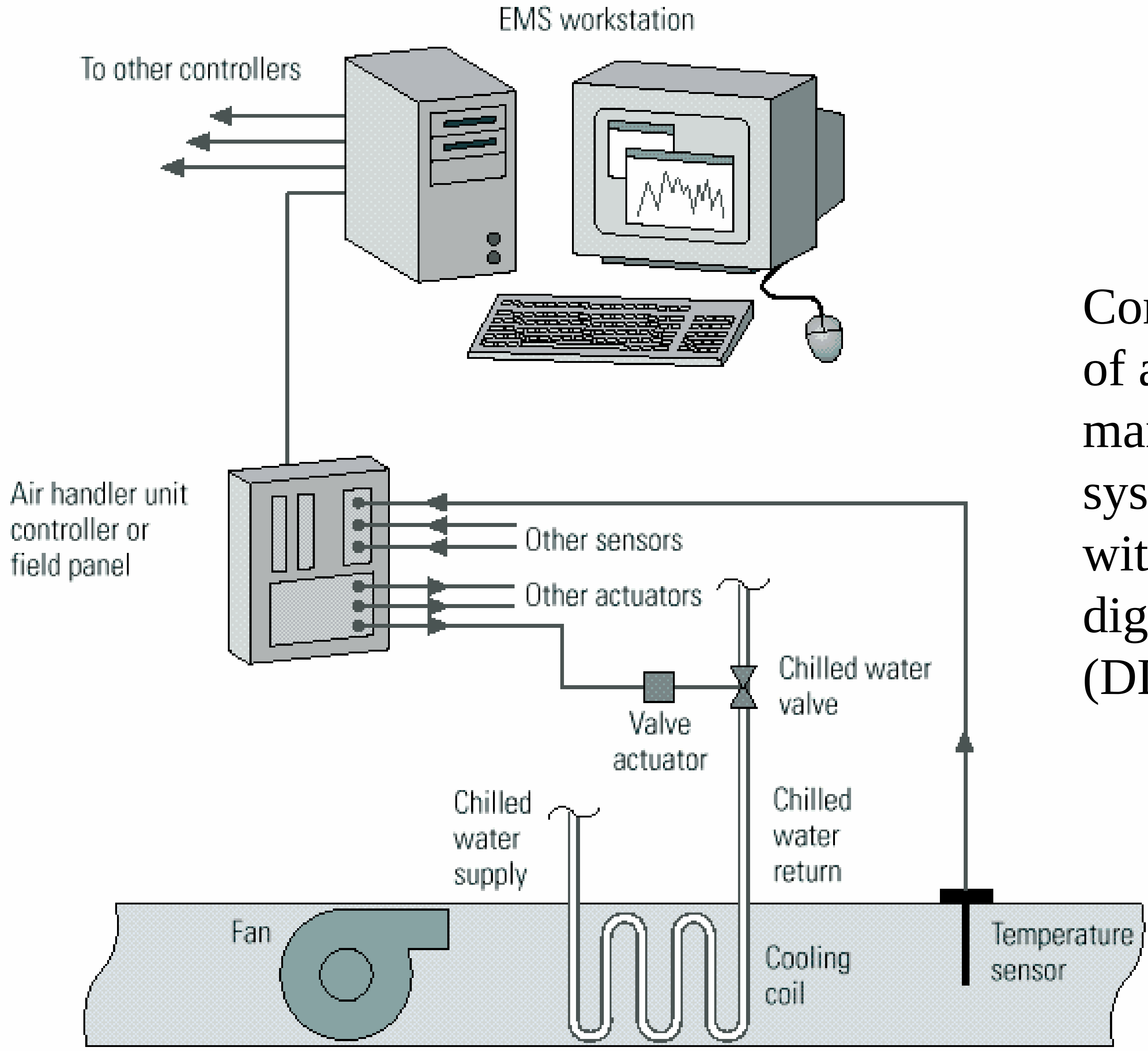
Design DDC systems

- **Design an effective DDC system**
  - **Simplicity & effective technical communication**
- **Types of 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**

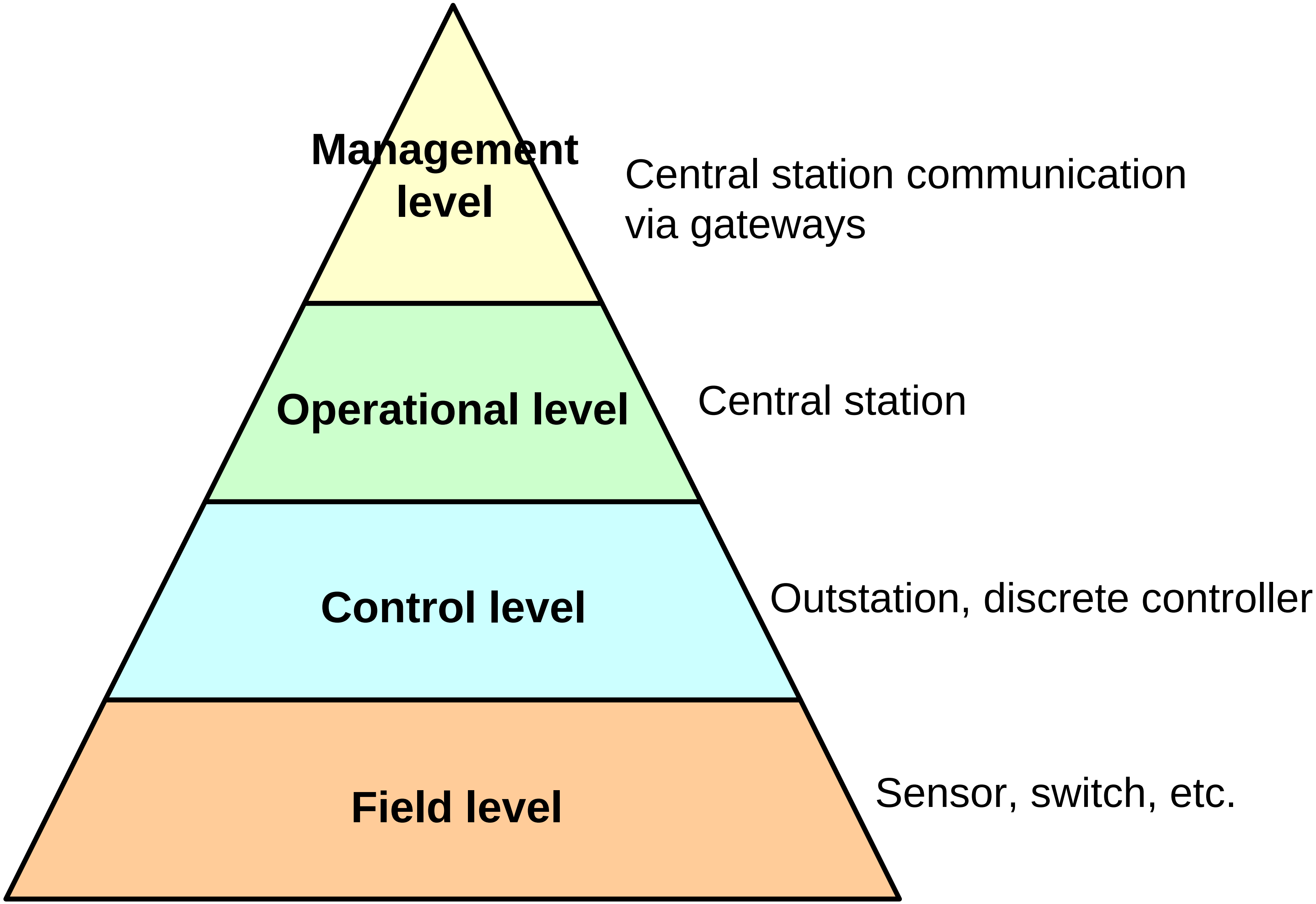


A simple DDC control system

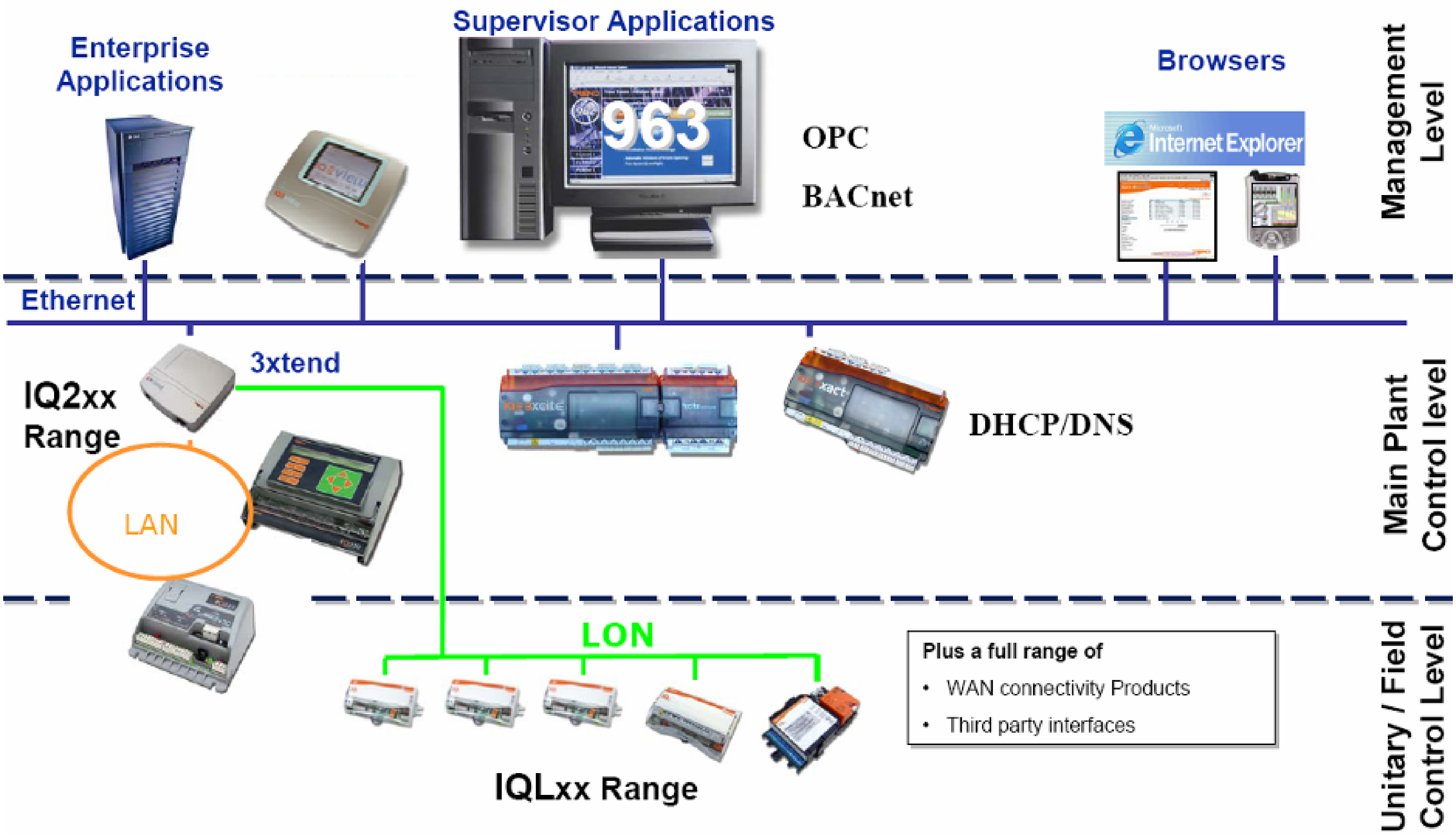
[Source: Shadpour, F., 2001. The Fundamentals of HVAC Direct Digital Control]



Components of a energy management system (EMS) with direct digital control (DDC)



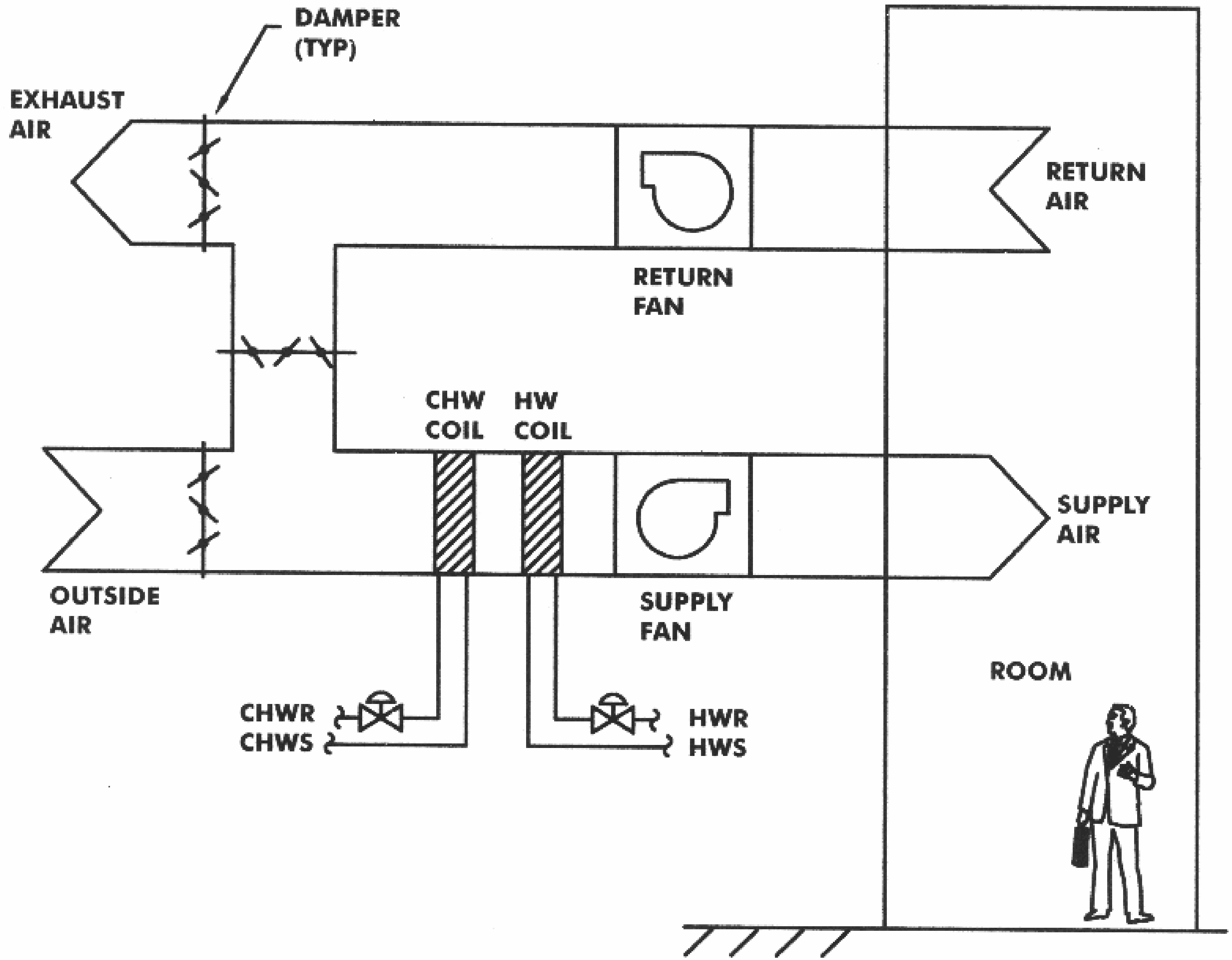
Levels of control in building energy management system



Example of system architecture for building management system

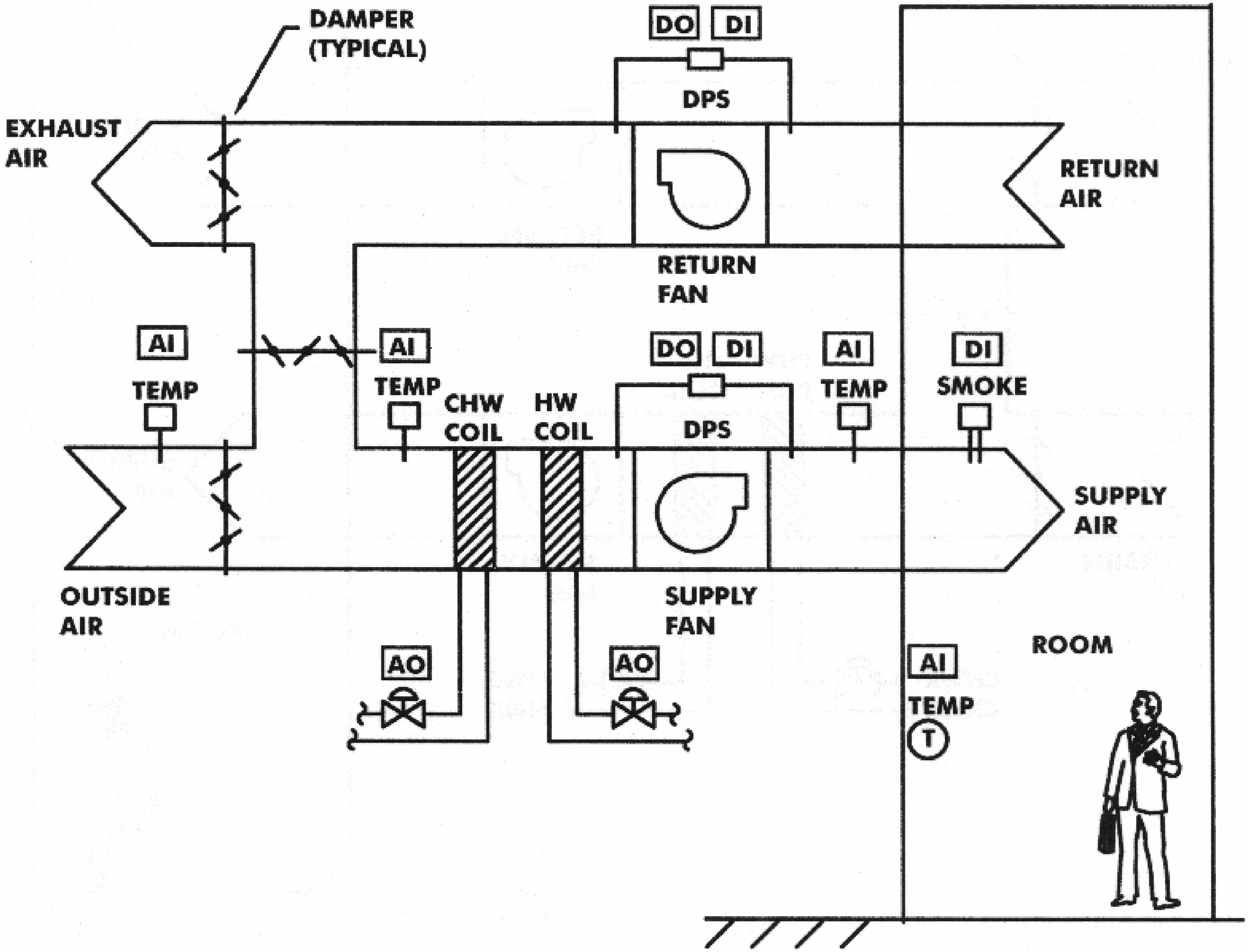
Six steps of DDC system design

- System schematic
- Control point designations
- Point list
- DDC system architecture
- Sequence of operation
- Specifications



System schematic for a constant volume single zone AHU

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



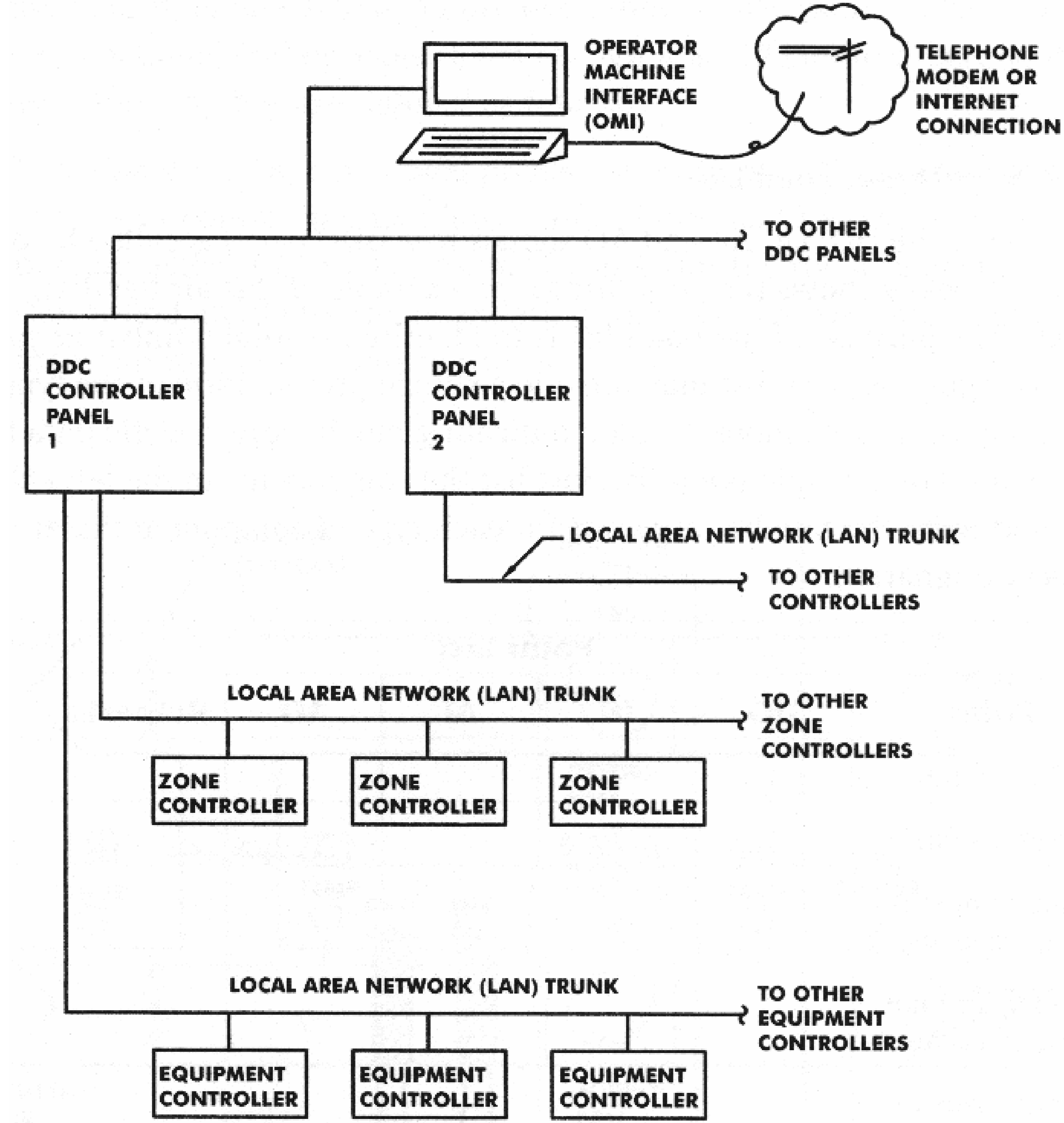
Control point designations for a constant volume single zone AHU

[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	

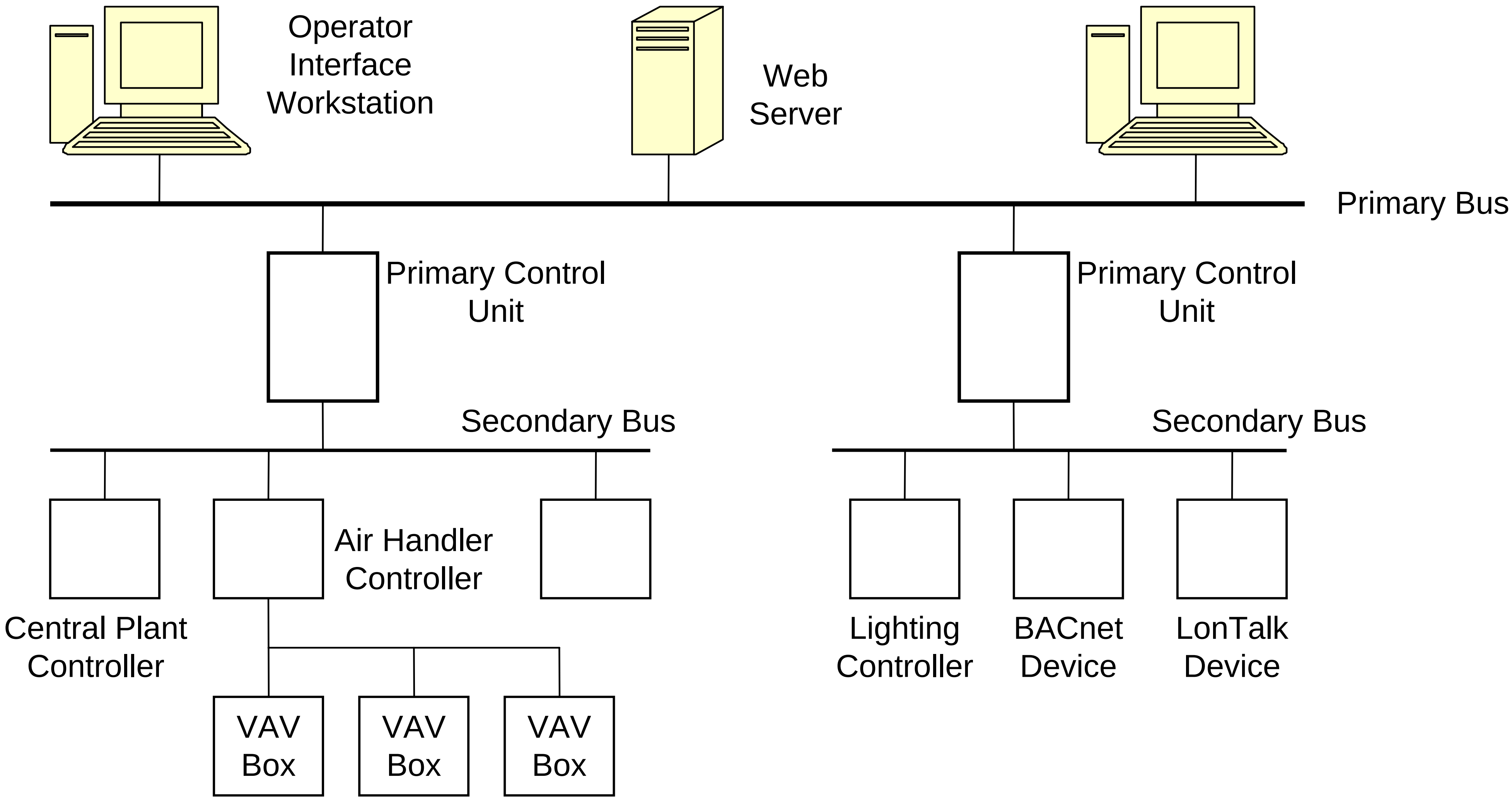
Table 1-1: An example of a point list. The purpose of a point list is to identify the total number of each point category.

[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]



System architecture of building automation system

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]

Useful References

- **Books:**
  - **Honeywell, 1997. *Engineering Manual of Automatic Control for Commercial Buildings - Heating, Ventilating, Air Conditioning*, SI Edition., Honeywell, Inc., Minneapolis, MN.**
    - **http://customer.honeywell.com/Techlit/pdf/77-0000s/77-1200.pdf**
  - **Shadpour, F., 2001. *The Fundamentals of HVAC Direct Digital Control: Practical Applications and Design*, 2nd ed., Hacienda Blue, Escondido, CA.**

Useful References

- **Research papers:**
  - **Hui, S. C. M., 2007. Latest trends in building automation and control systems, In *Proc. of the CAI Symposium 2007 on Intelligent Facility Management and Intelligent Transport*, 28 March 2007, Hong Kong, 10 pages.**
    - **http://web.hku.hk/~cmhui/CAI-2007_SamHui.pdf**
  - **Spitzer, D. W., 2002. Selecting flow measurement devices, *HPAC Engineering*, 74 (12): 52-59.**
- **Website:**
  - **DDC Online [www.ddc-online.org]**