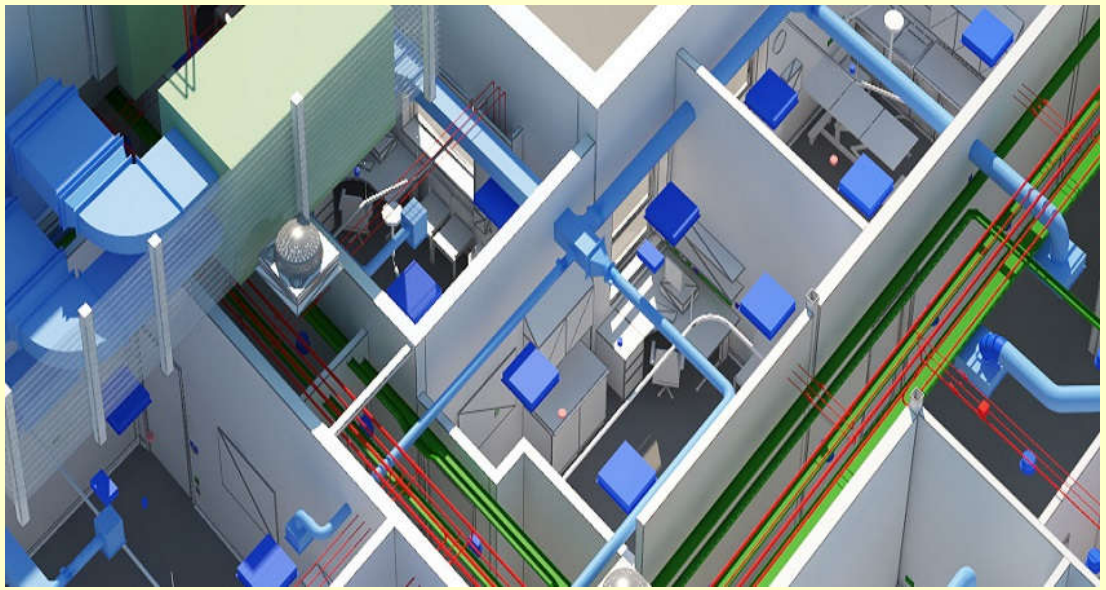

6. HVAC Part 2

6.1 HVAC controls and building management system

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Contents 內容

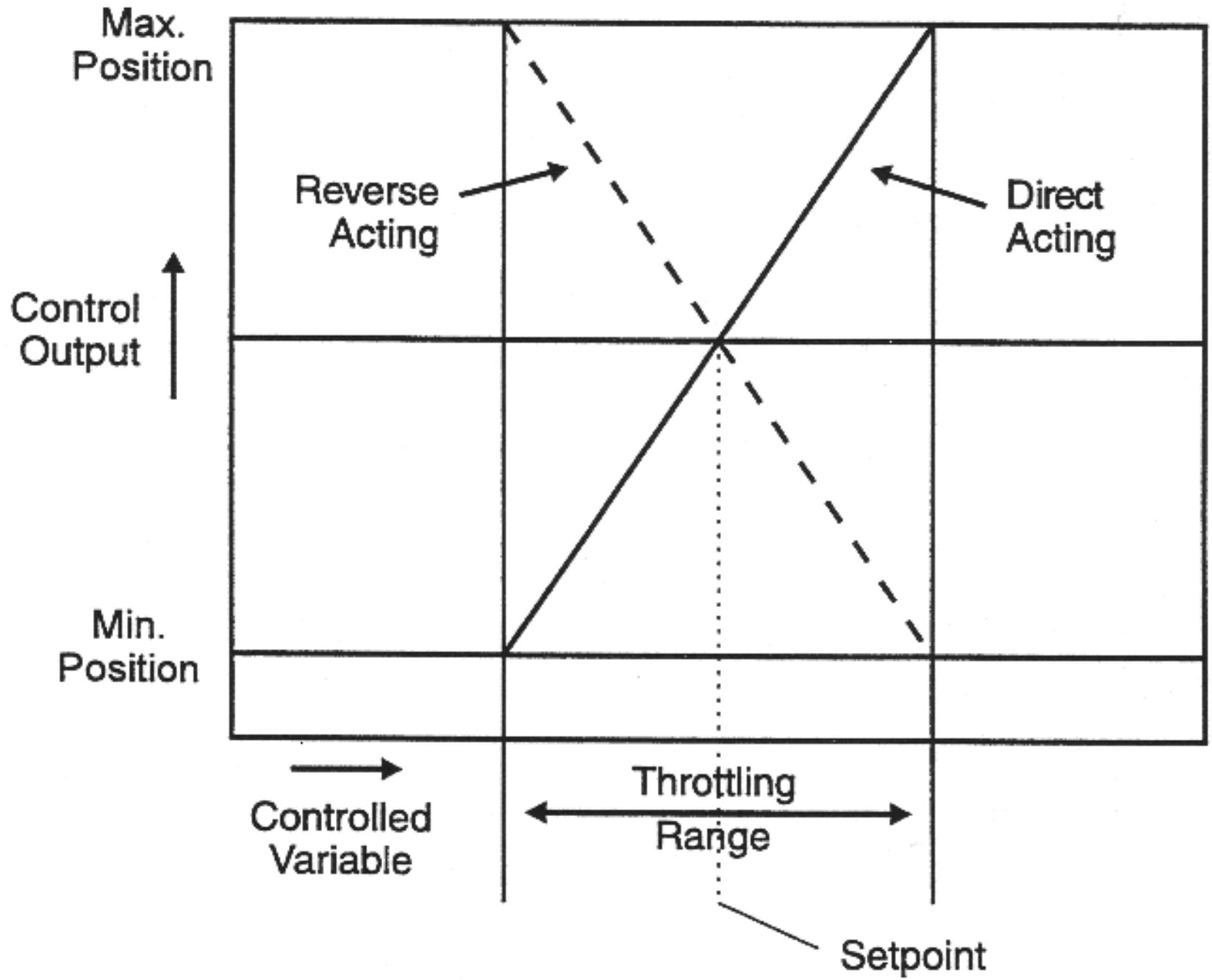
- HVAC controls 暖通空調控制
- System components 系統組件
- Building management system 樓宇管理系統
- Practical examples 實際例子

HVAC controls

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

HVAC controls

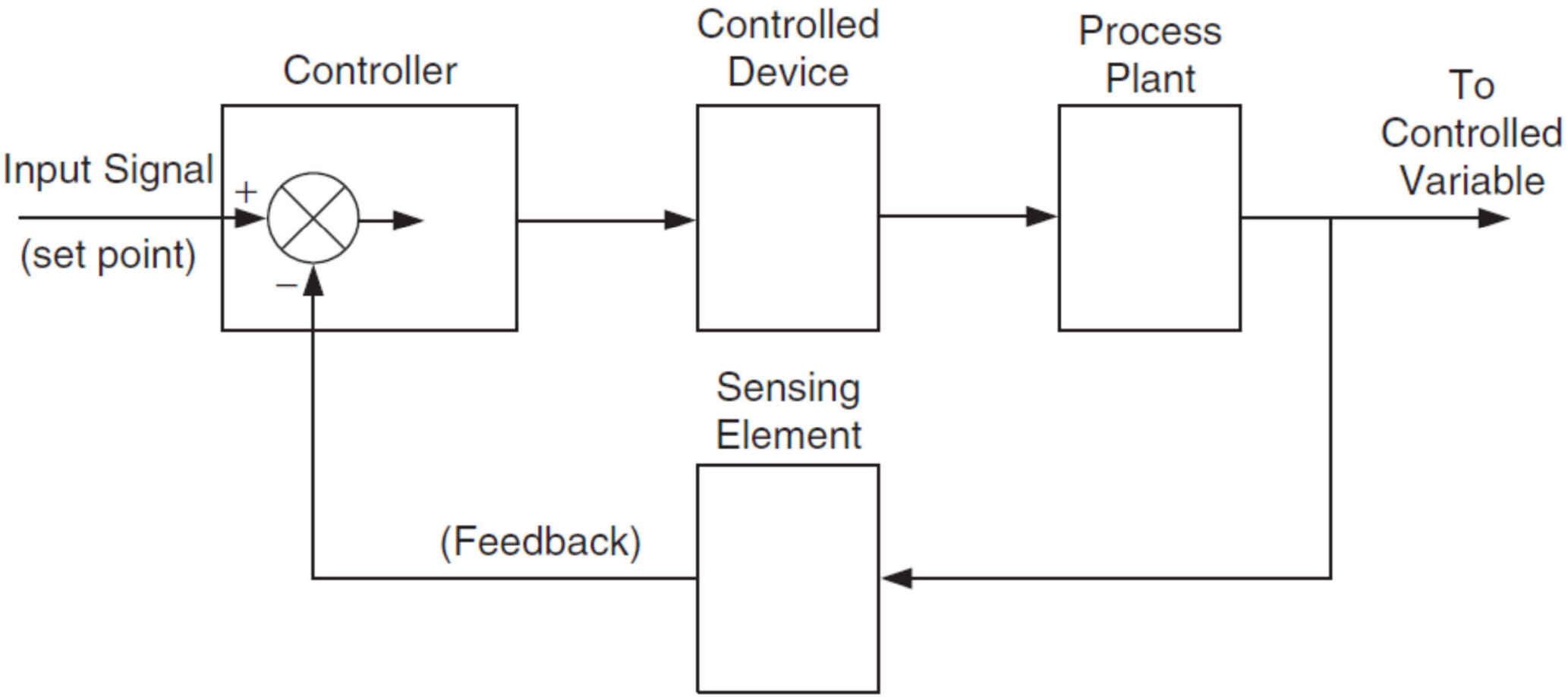
- Definitions and terminology (cont'd) 定義和術語
  - Controlled variable: 控制變量
    - The quantity or condition that is measured & controlled, e.g. temperature, pressure, relative humidity, and flow
  - Setpoint: 設定點
    - The value (desired control point) set at the controller
  - Throttling range: 節流範圍 (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: 死區
    - Range of controlled variable in which no corrective action is taken



Proportional Control 比例控制

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

Basic elements of a feedback control loop
反饋控制迴路的基本要素

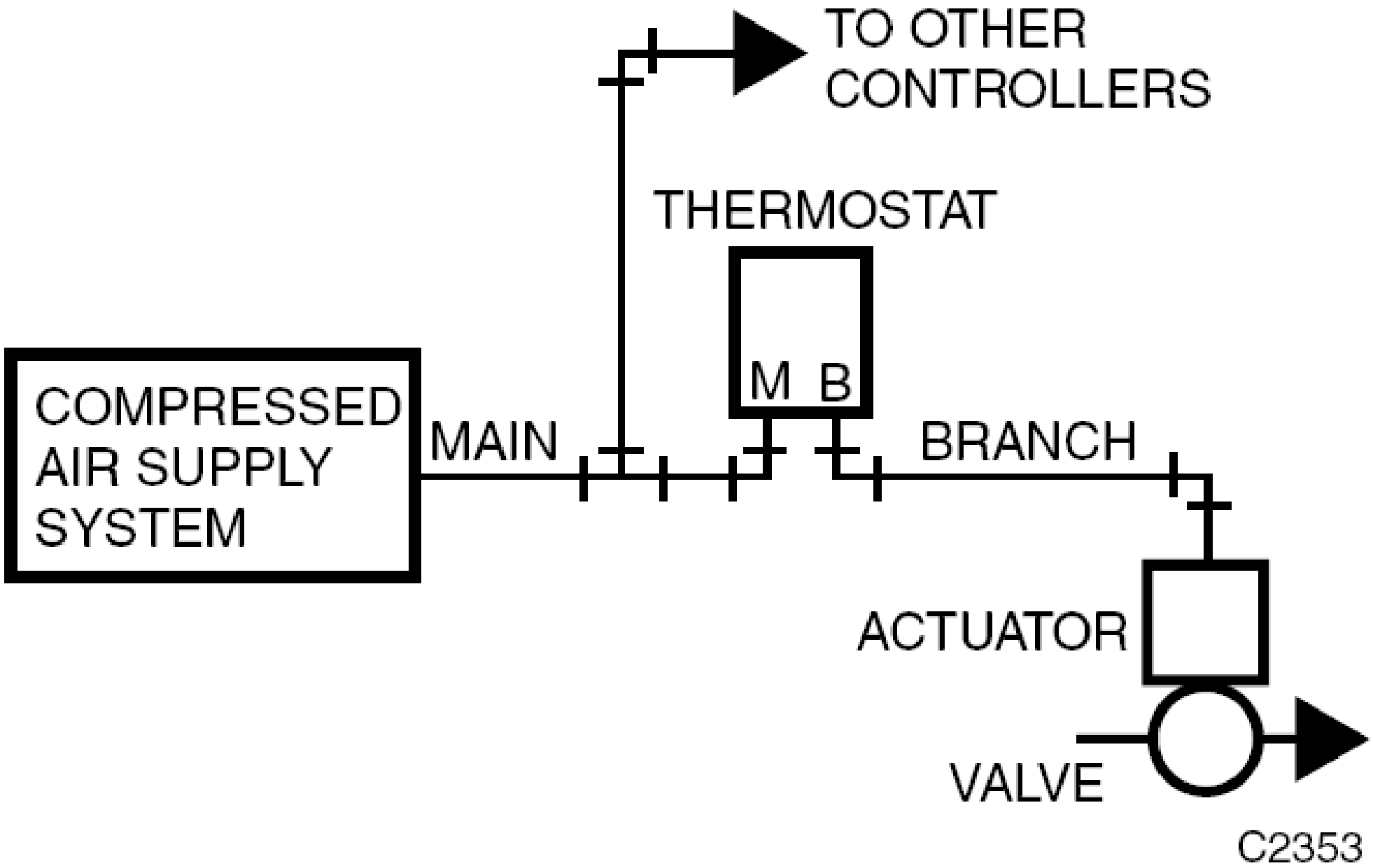


[Source: Montgomery, R. and McDowall, R., 2008. *Fundamentals of HVAC Control Systems*]

HVAC controls

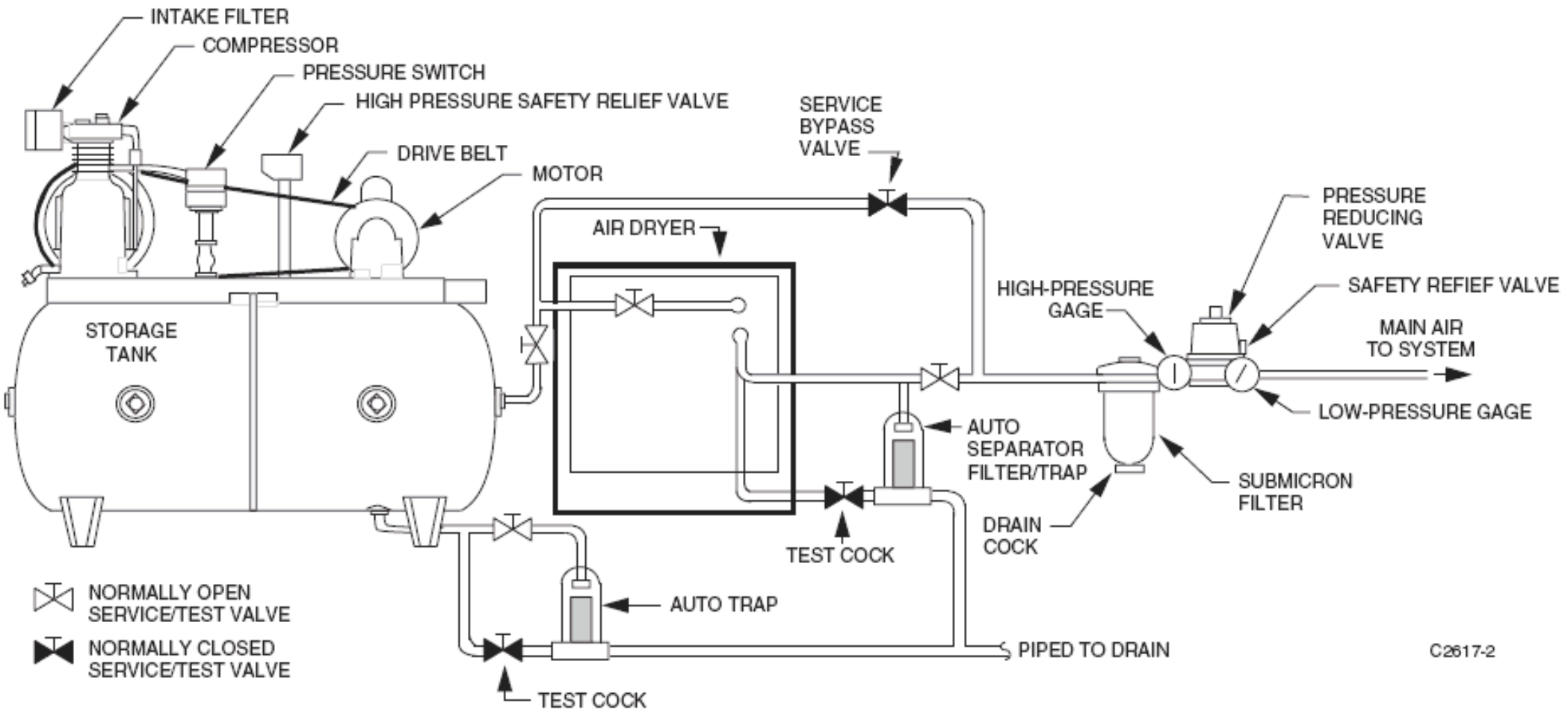
- Pneumatic controls 氣動控制
  - Traditional form of control used in buildings
  - Pneumatic controllers, sensors & actuators
  - Electronic devices may be integrated
- Direct digital control (DDC) 直接數字控制
  - Entered the HVAC industry in late 1980's
  - Use a programmable microprocessor as controller
    - 'Direct' = microprocessor is directly in the control loop
    - 'Digital' = control is accomplished by the digital electronics

Basic pneumatic control system 基本氣動控制系統



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

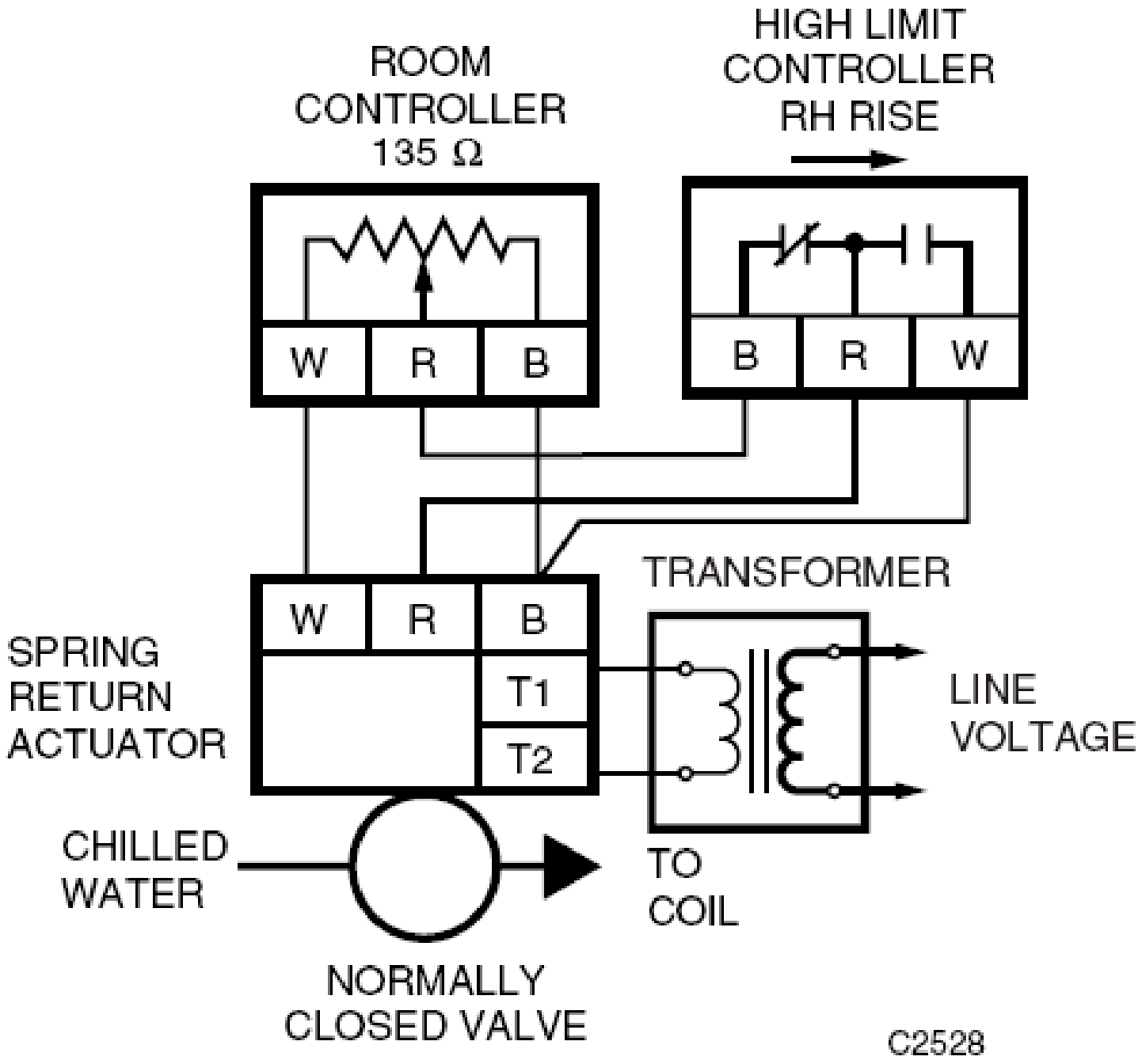
Typical compressed air supply system
典型的壓縮空氣供應系統



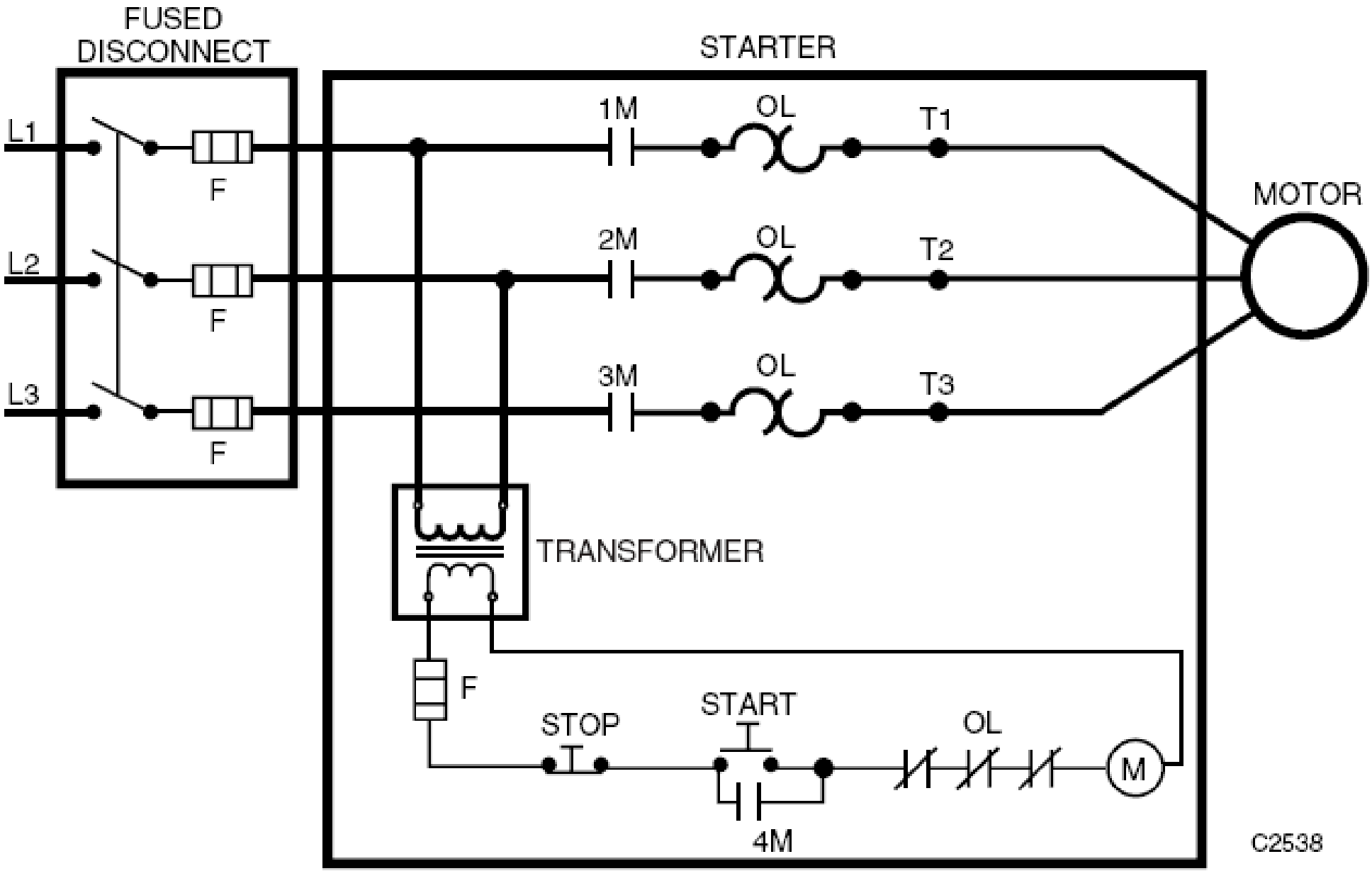
You can hear the sound when the system is operating.
系統運行時，您可以聽到聲音

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

Typical electric control circuit 典型的電氣控制電路



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

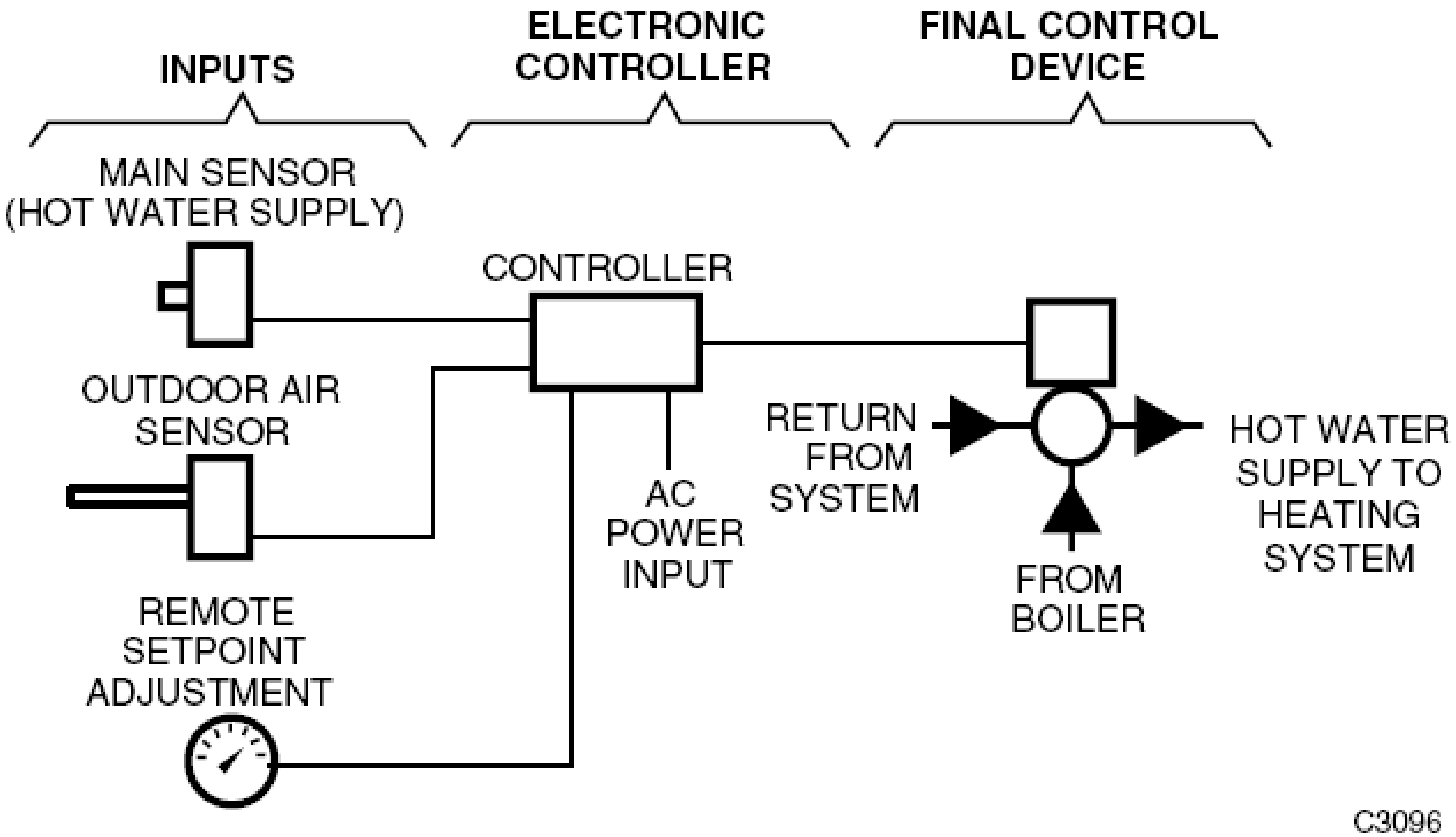


瞬時按鈕啟停電路

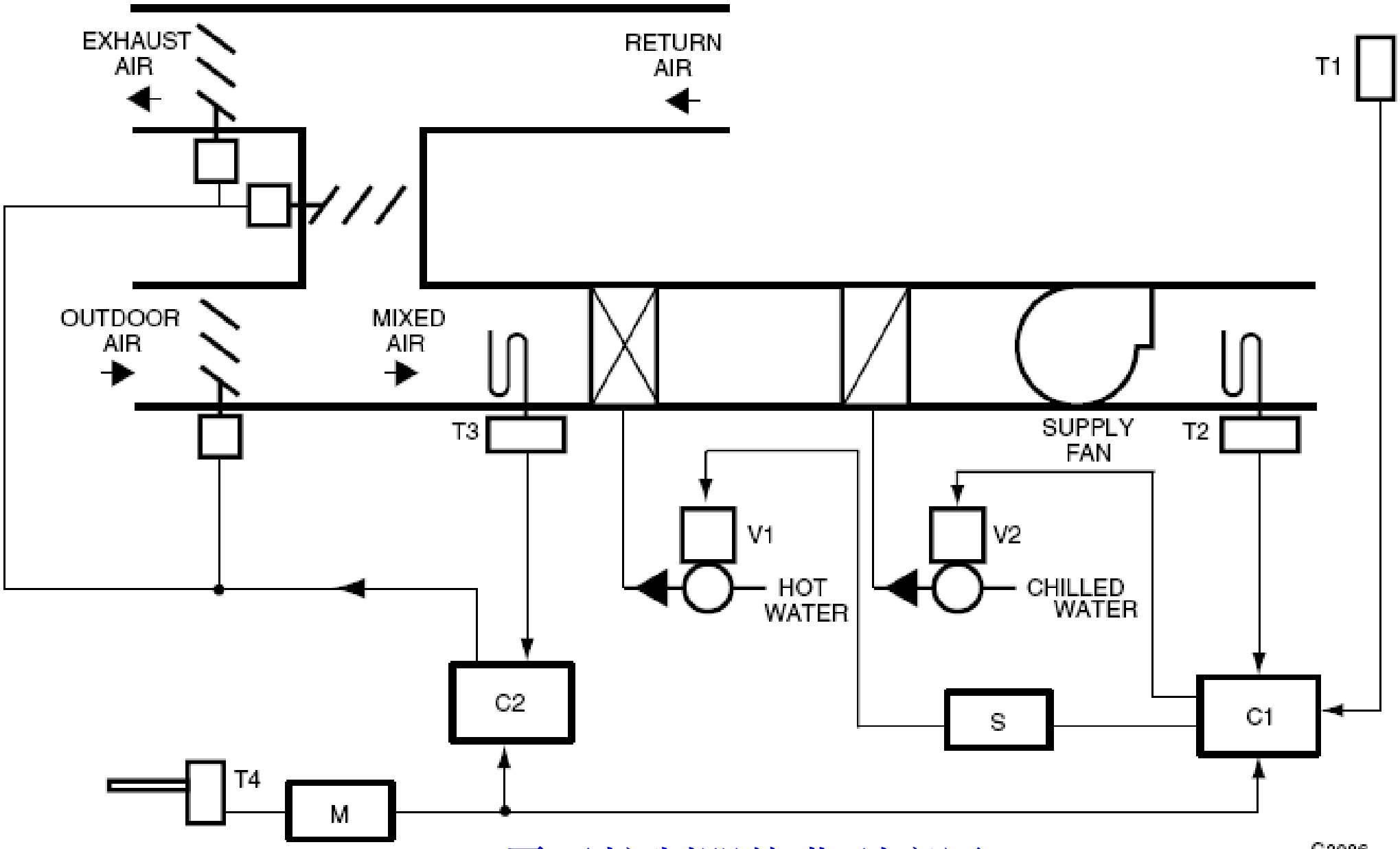
Fig. 35. Momentary Push-button Start-Stop Circuit.

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

Simple electronic control system 簡單的電子控制系統



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



電子控制器的典型應用

Fig. 22. Typical Application with Electronic Controllers.

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

Basic microprocessor/DDC controller 基本微處理器/ DDC控制器

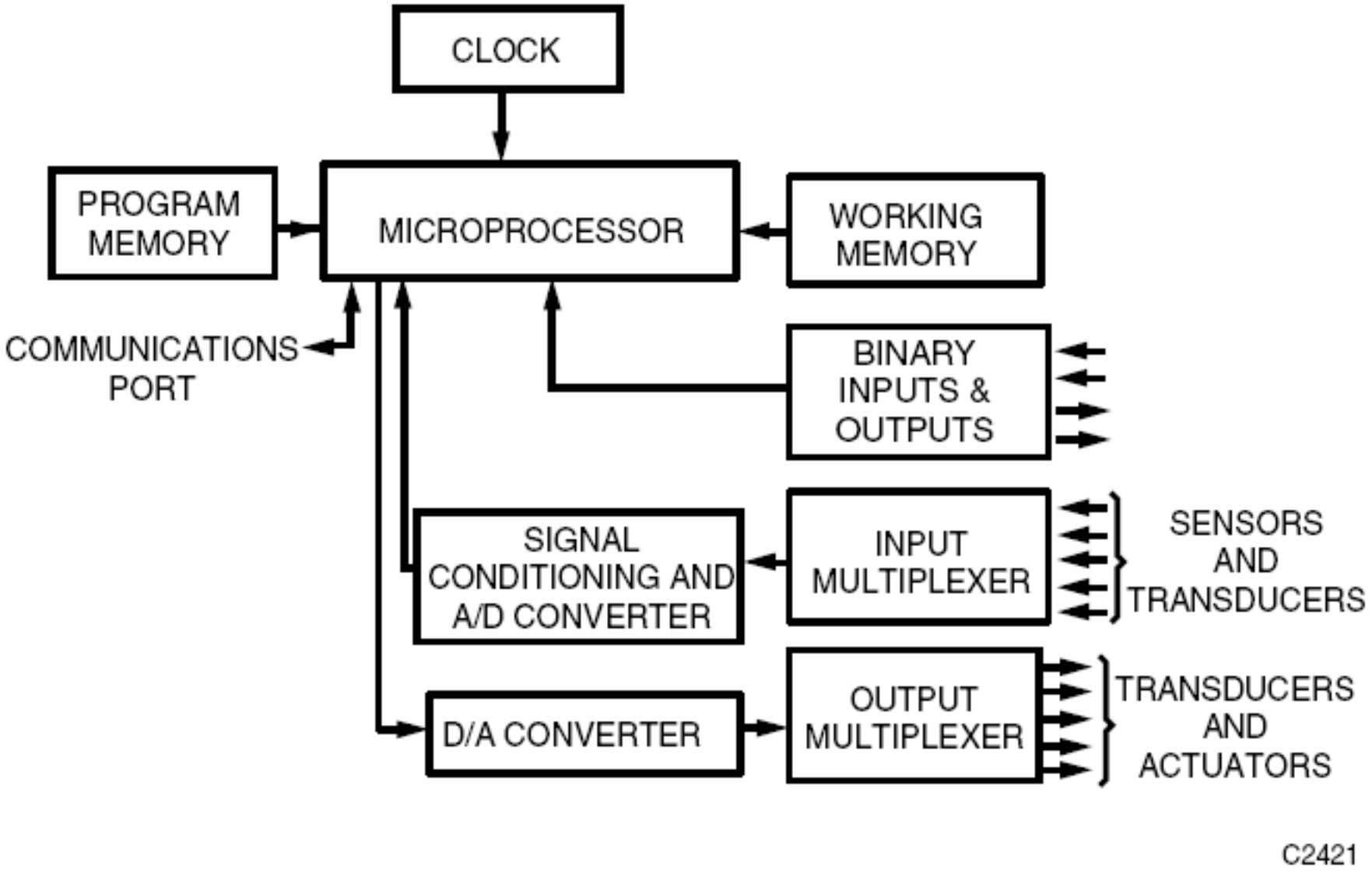
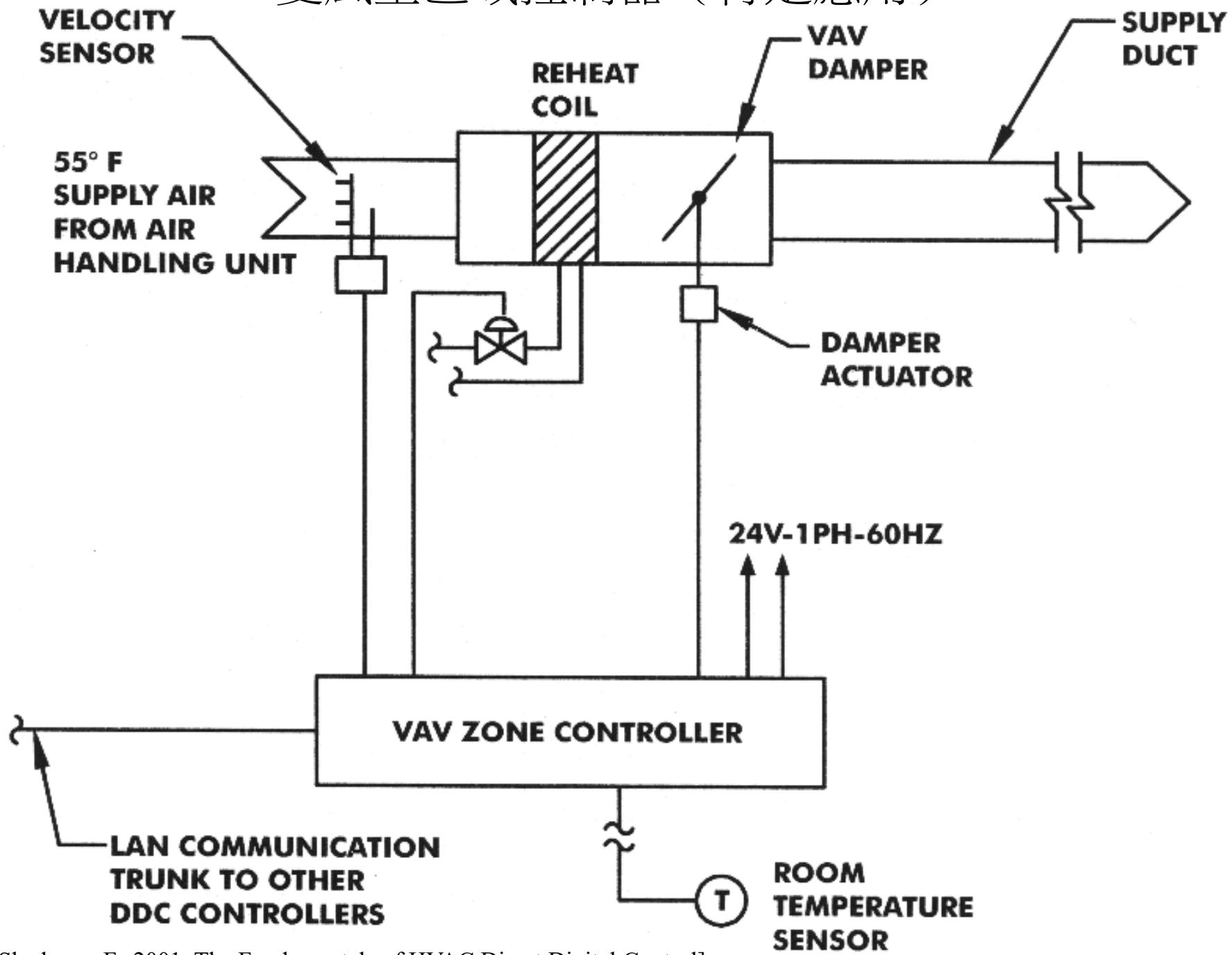


Fig. 3. Microprocessor Controller Configuration for Automatic Control Applications.

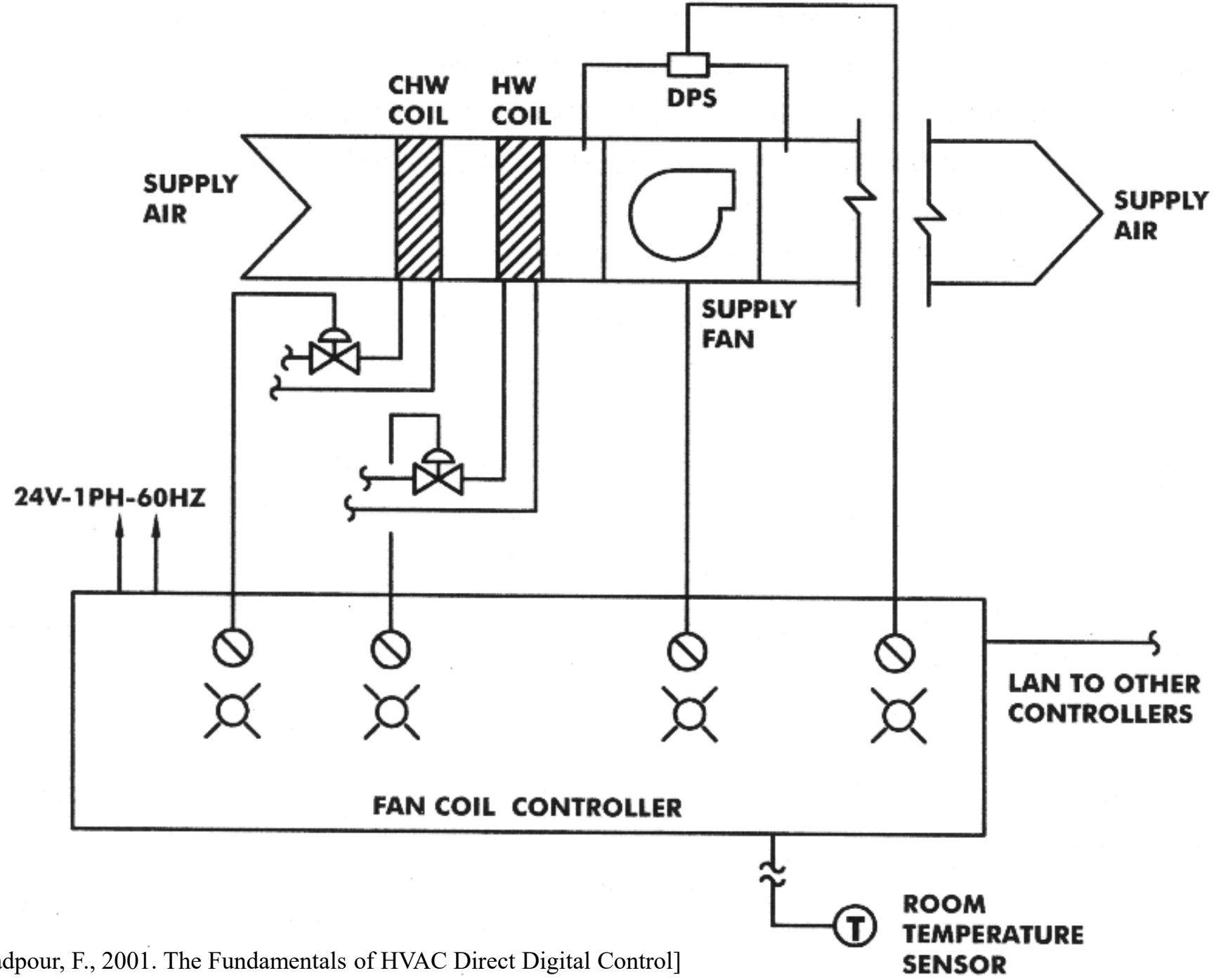
[Source: Honeywell, 1997. Engineering Manual of Automatic Control for Commercial Buildings]

VAV zone controller (application specific)
變風量區域控制器（特定應用）



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

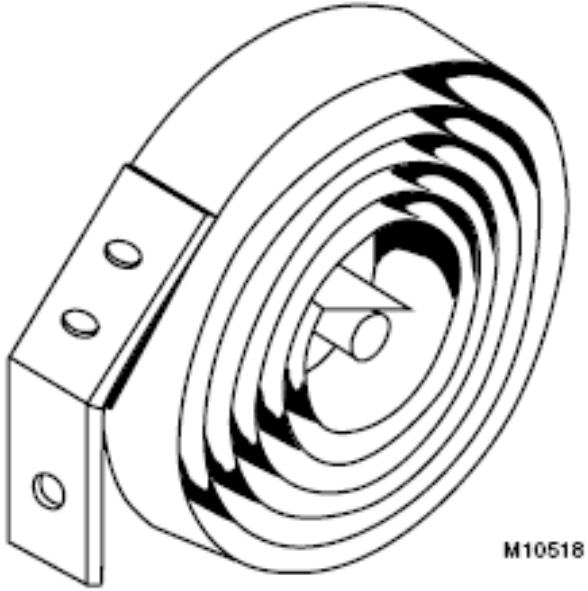
Fan coil controller (application specific)
風機盤管控制器（特定應用）



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

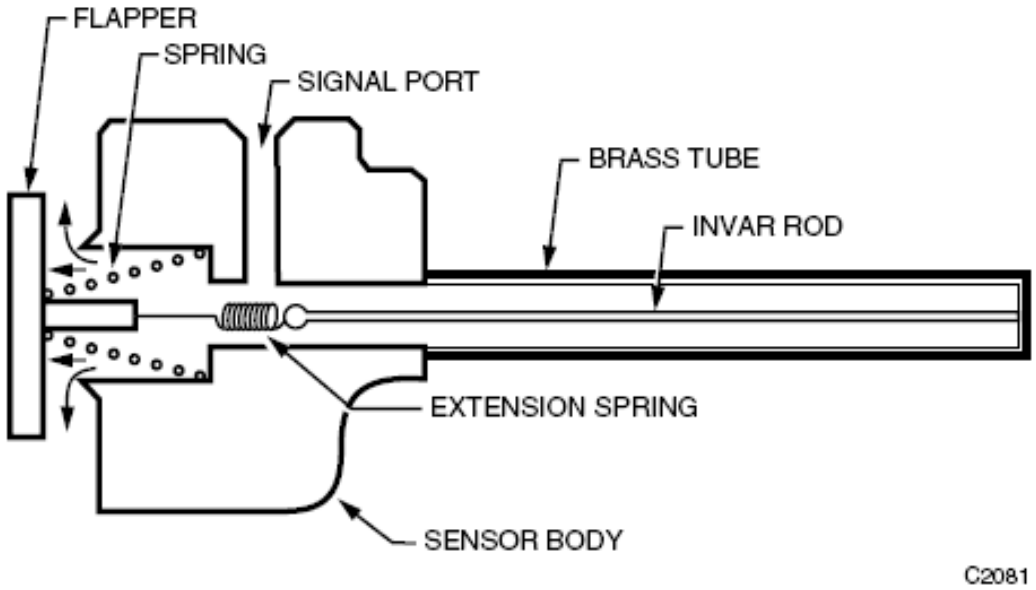
System components

- Control system components 控制系統組件
  - 1. Sensing elements 感應元件
  - 2. Transducers 換能器
  - 3. Controllers 控制器
  - 4. Actuators 執行器
  - 5. Auxiliary elements 輔助要素



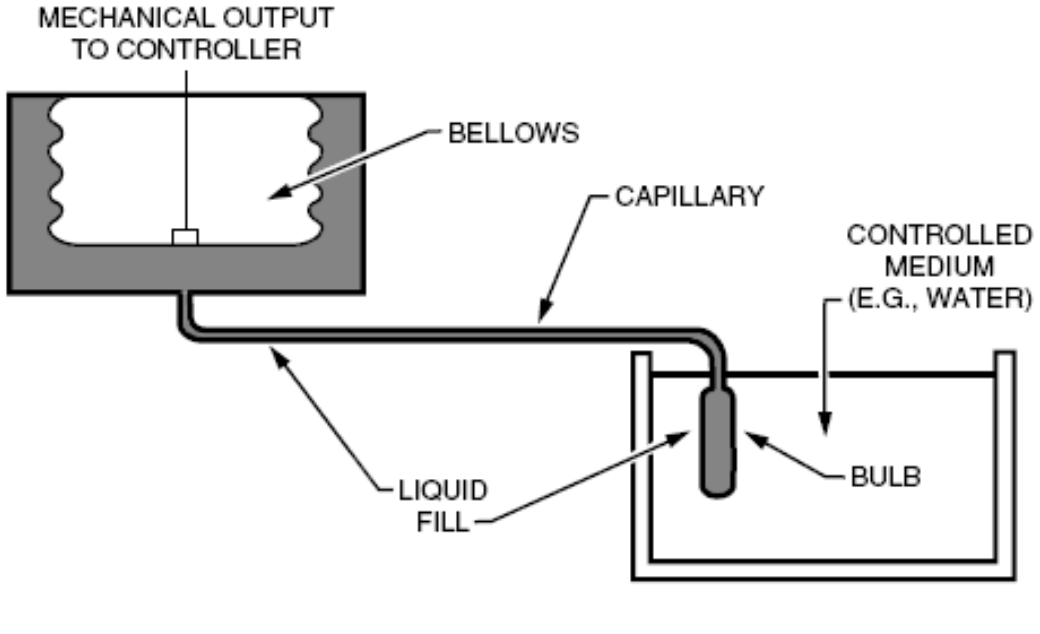
盘绕雙金屬元件

Fig. 49. Coiled Bimetal Element.



桿和管元件

Fig. 50. Rod-and-Tube Element.



典型的遙控球元素

Fig. 51. Typical Remote-Bulb Element.

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

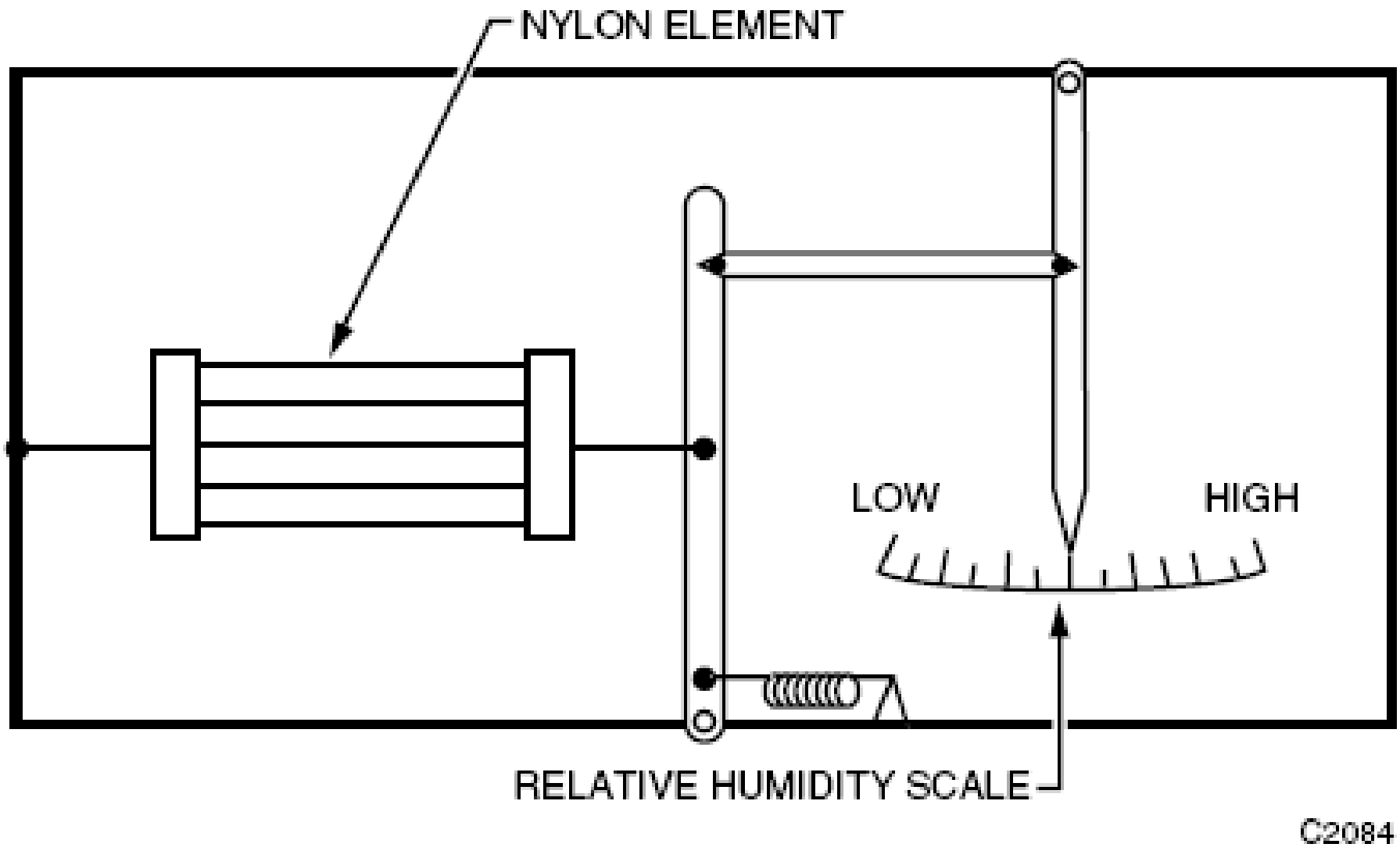


Fig. 52. Typical Nylon Humidity Sensing Element.

典型的尼龍濕度感應元件

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

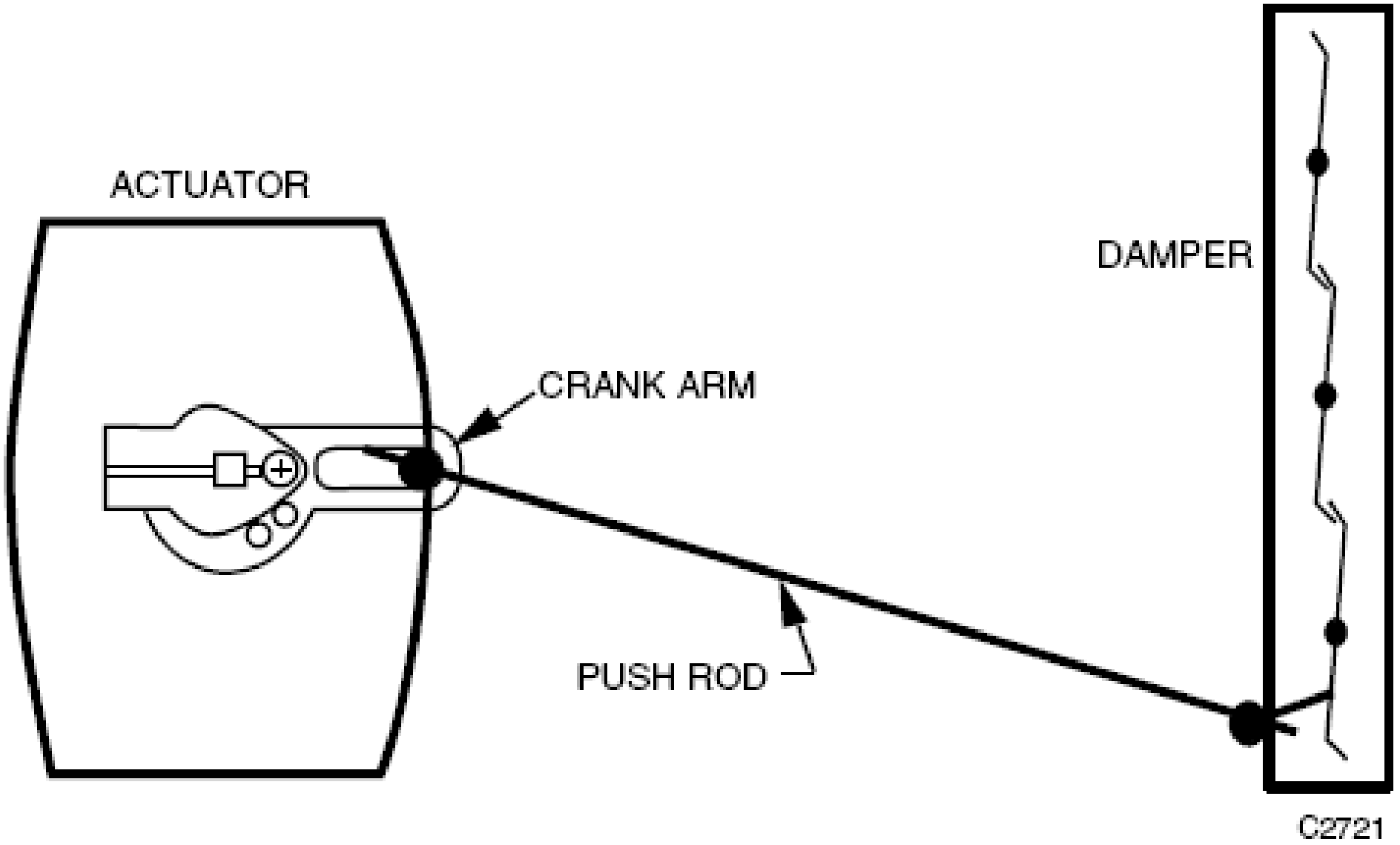
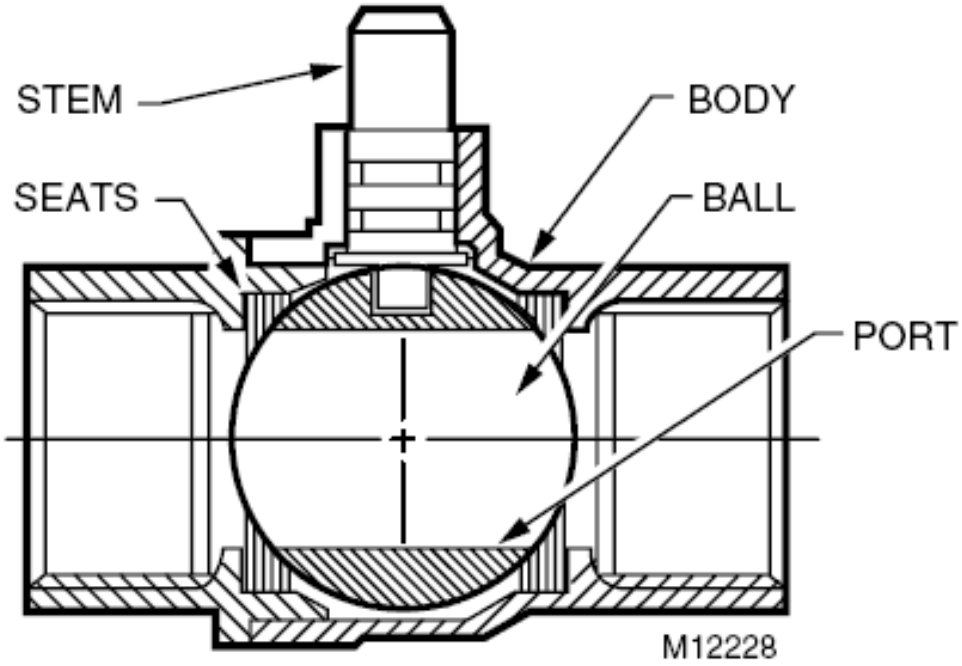


Fig. 56. Typical Electric Damper Actuator.

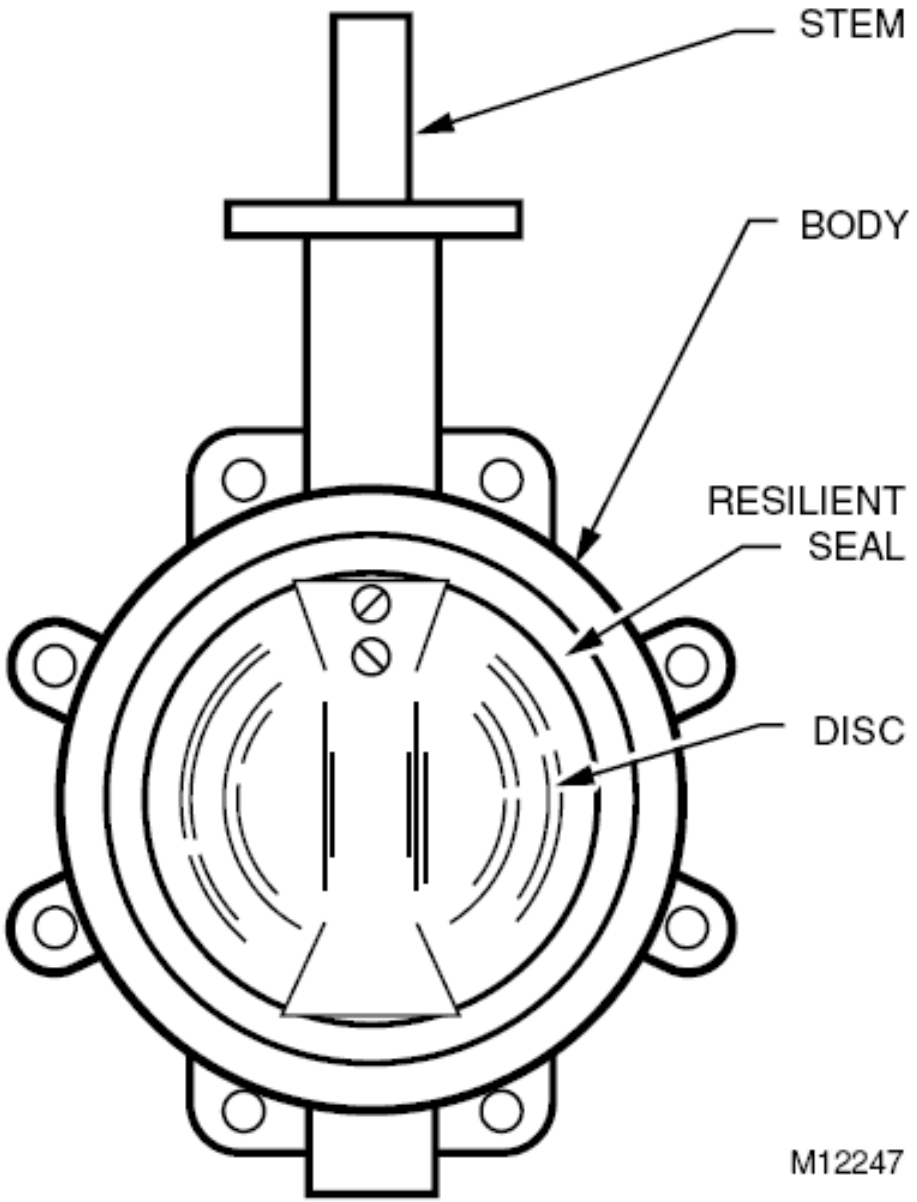
典型的電動風門執行器

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



Ball valve

球閥

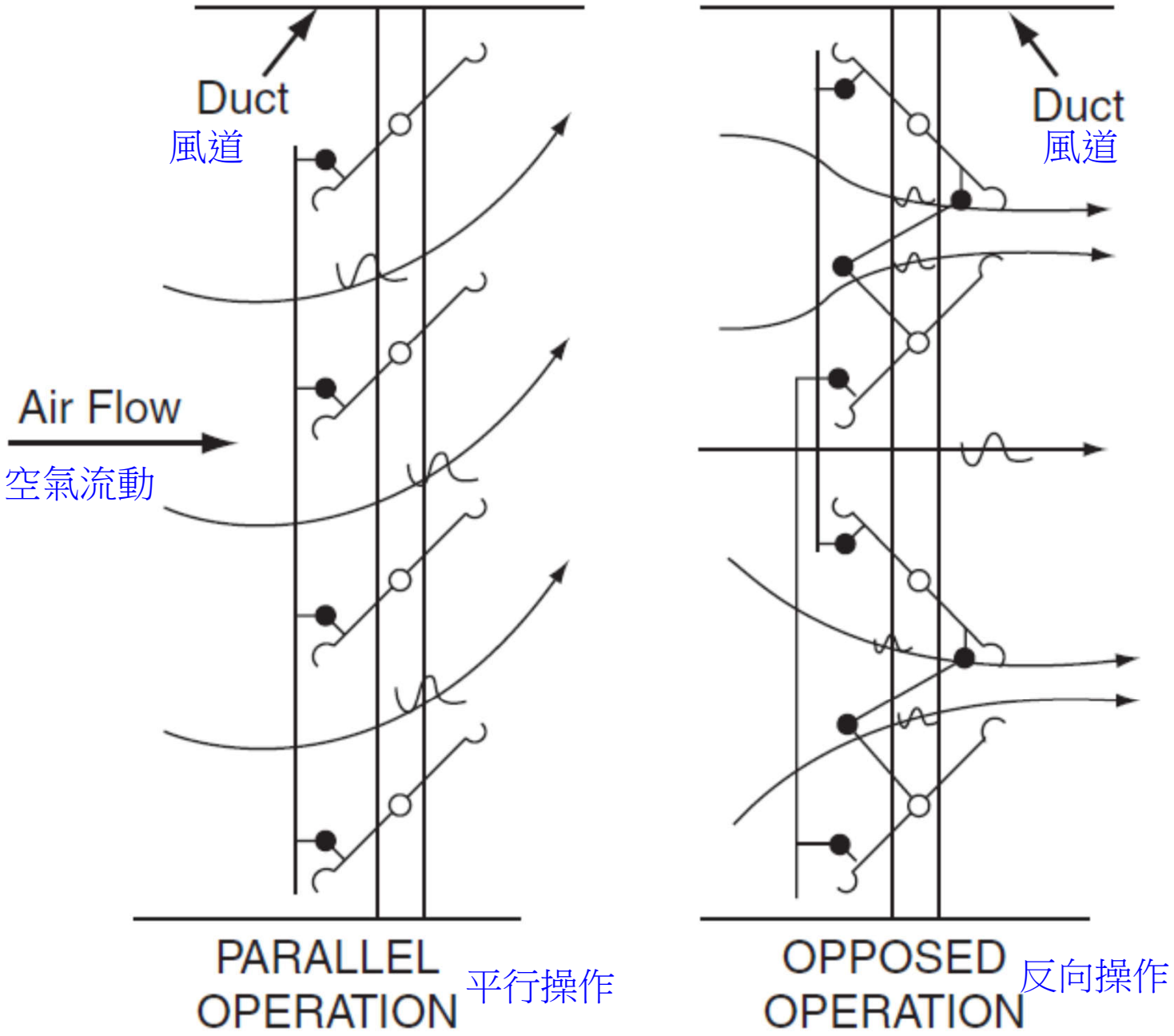


Butterfly valve

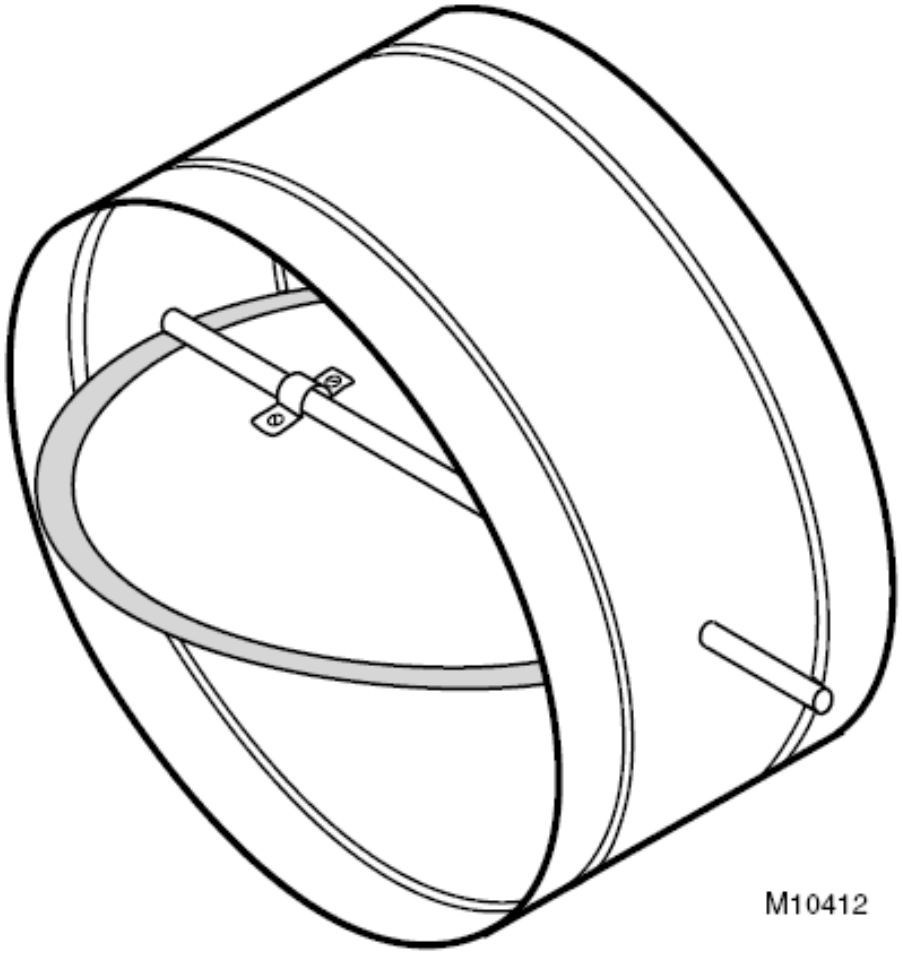
蝶閥

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

Flow pattern through dampers 通過阻尼器的流型



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



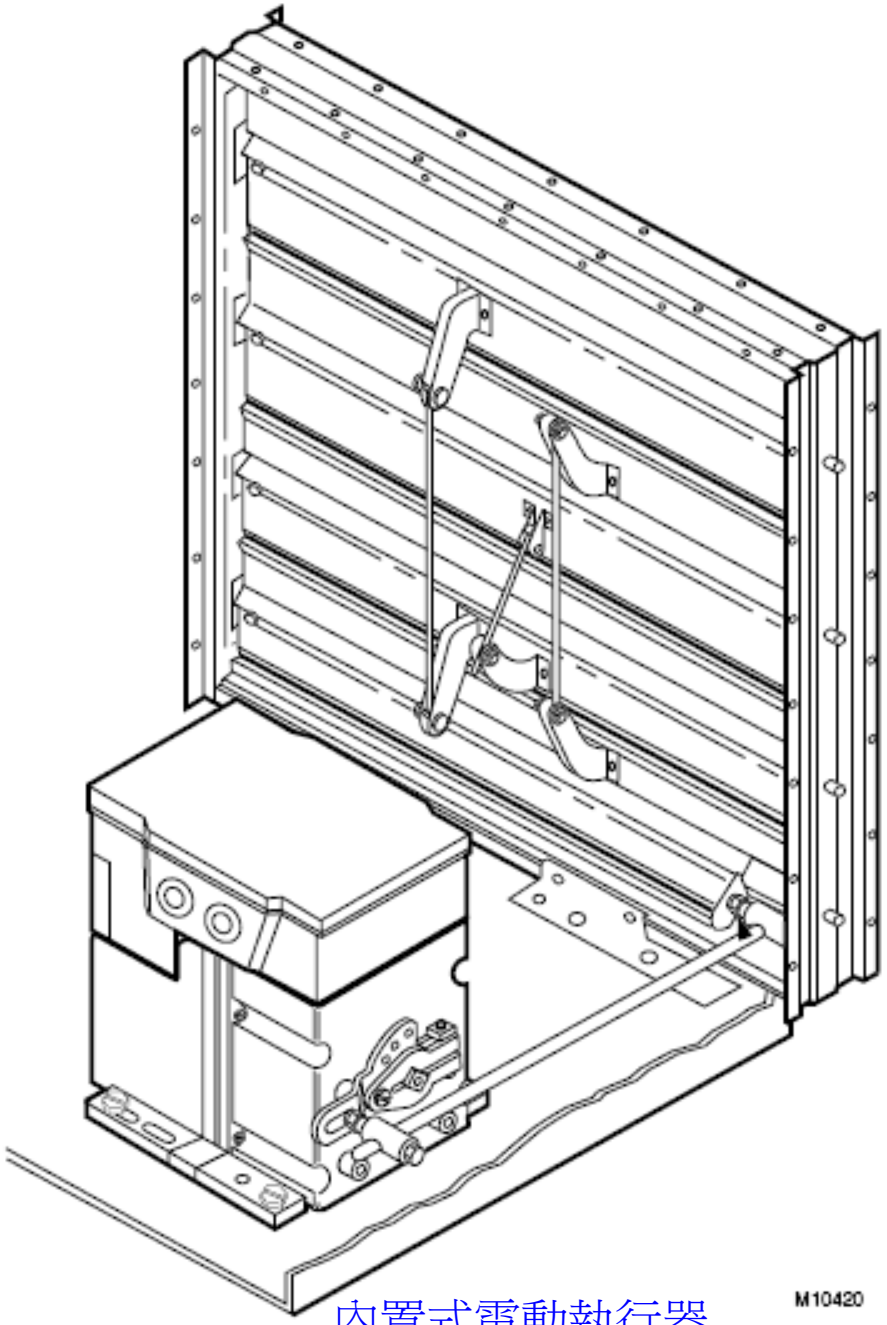
Round damper

圓形阻尼器

Volume control damper (opposed blade)

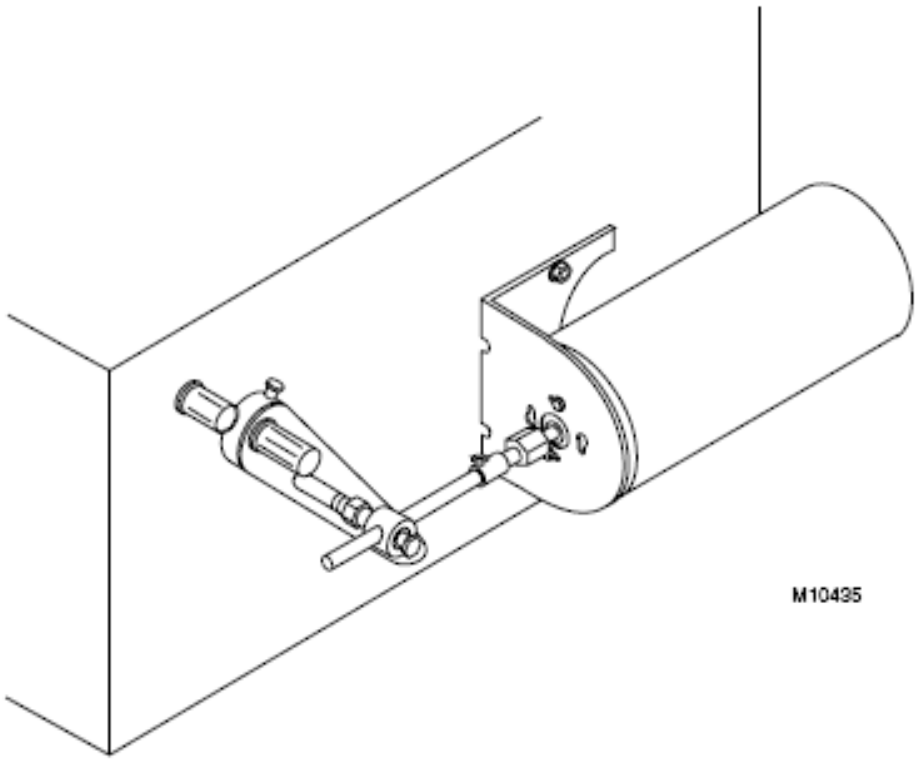
流量控制阻尼器(對置的葉片)

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



內置式電動執行器

Internally mounted electric actuator



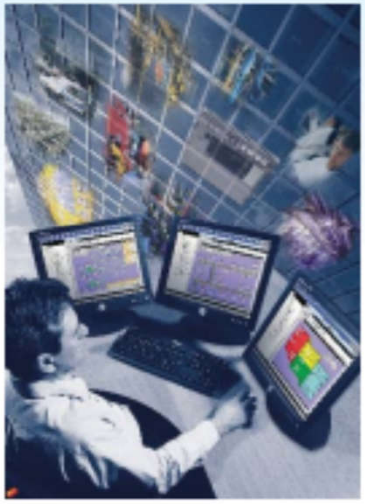
Externally mounted pneumatic actuator

外置式氣動執行器

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

Control core mechanical systems 控制核心機械系統

中央指揮部
Command Central



Air Handlers
空氣處理機組

屋頂設備
Rooftop Equipment

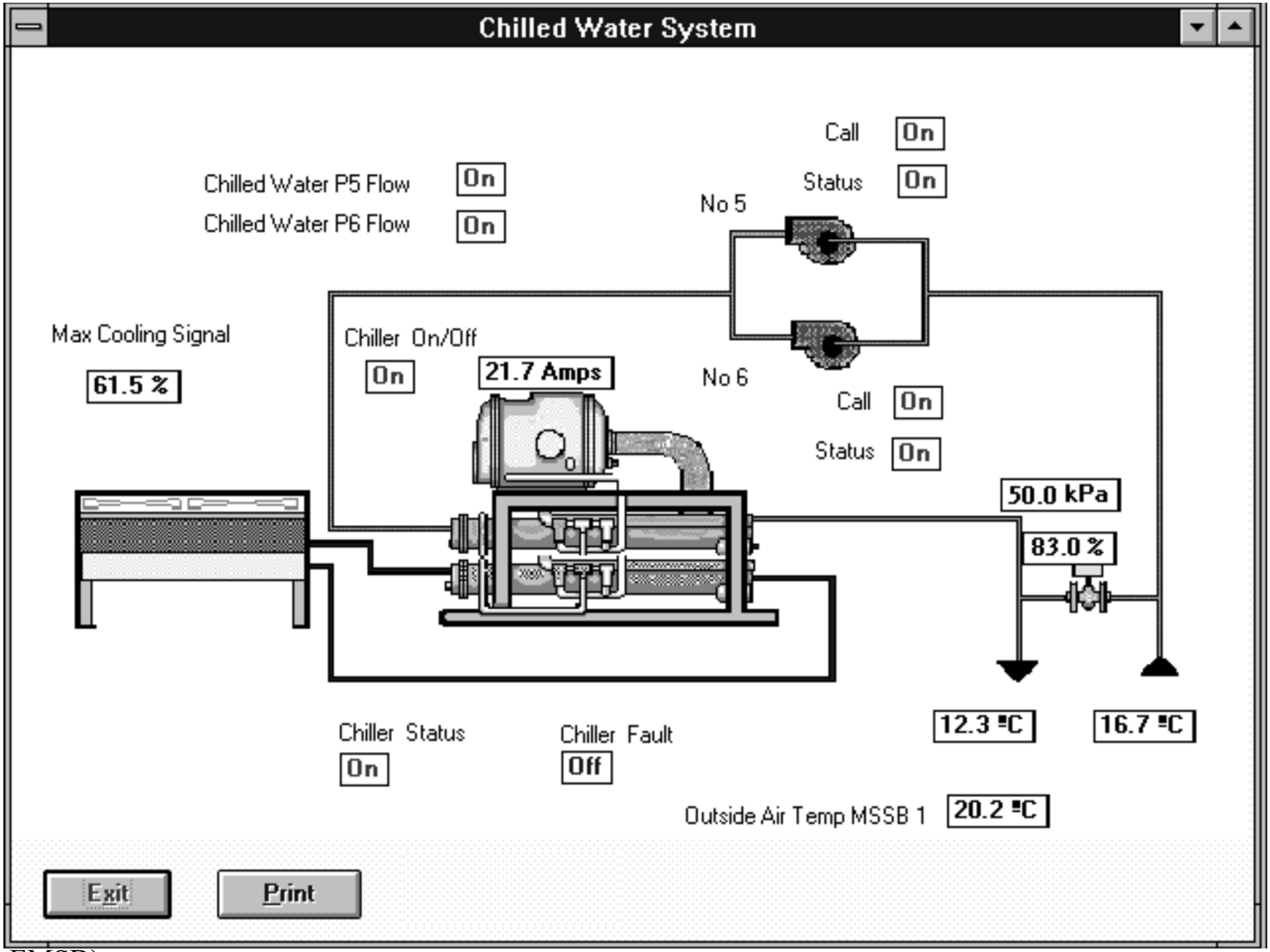
Chillers
Cooing Towers
製冷設備，冷卻塔

Boilers
鍋爐

Fan Coils
Unit Ventilators
VAV Boxes
風機盤管，單元通風機，VAV箱

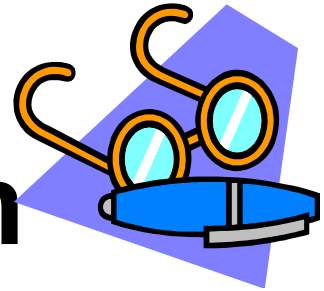
[Source: Johnson Controls]

Building management software for HVAC control & monitoring
樓宇管理軟件，用於暖通空調控制和監視



(Source: EMSD)

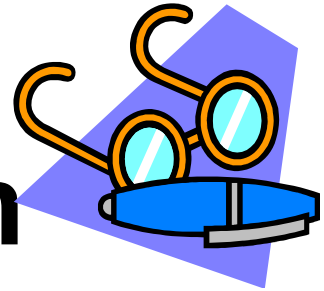
Building management system



樓宇管理系統

- What is building management system (BMS)?
  - It is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment e.g. ventilation, lighting, power systems, fire systems, and security systems
- The aim of BMS is to achieve 目標
  - Safe and comfortable working environment 安全舒適的工作環境
  - Energy saving & efficient operation 節能高效運行，減少時間和成本
  - At reduced time & cost

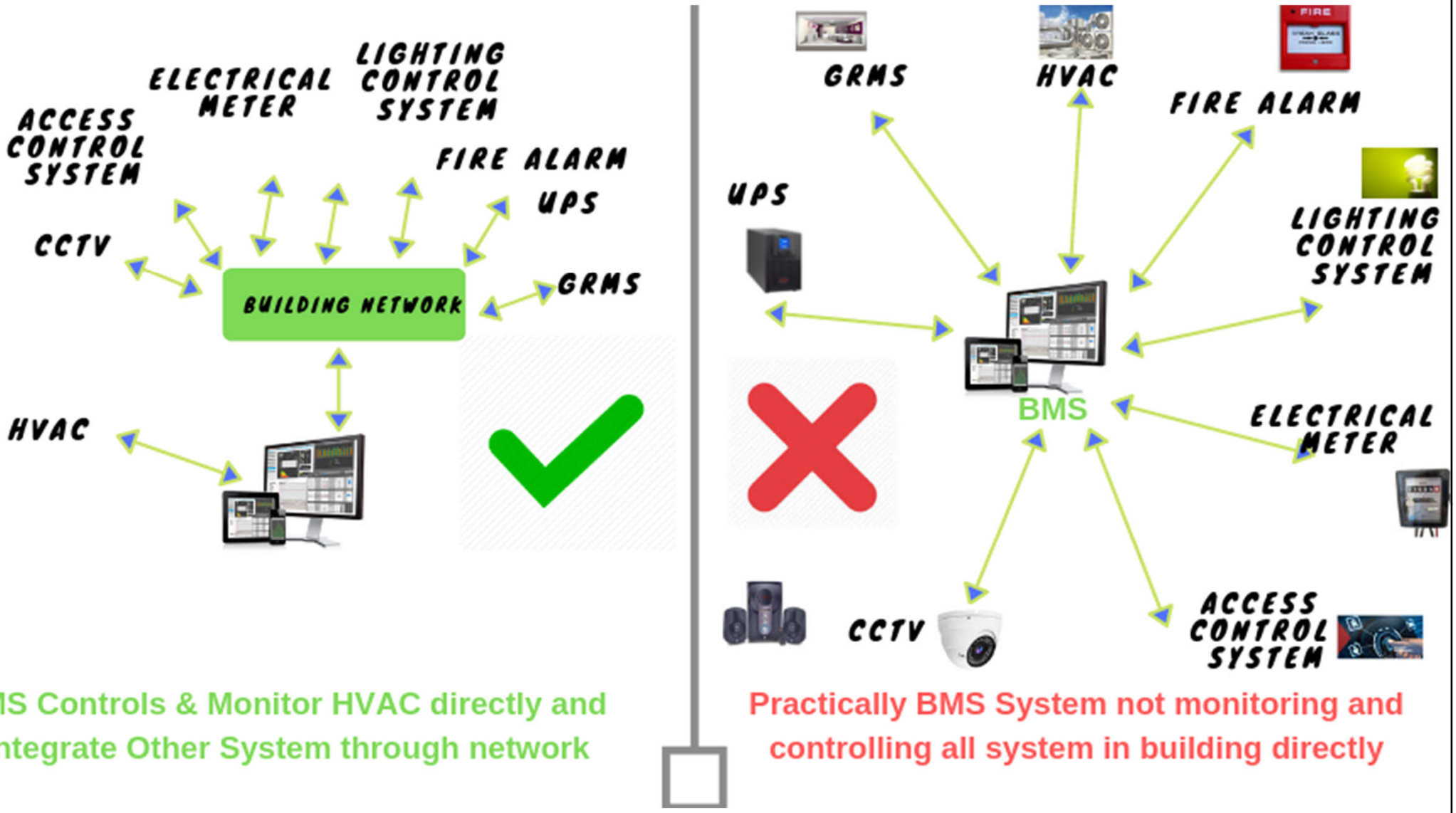
Building management system



- Terminology 術語
  - Building management system (BMS)
  - Building automation system (BAS)

  } Terms used here
  - Building automation & control system (BACS)
  - Building energy management system (BEMS)
  - Energy management system (EMS)
  - Central control and monitoring system (CCMS)
  - Direct digital control (DDC)
  - Intelligent building (IB)

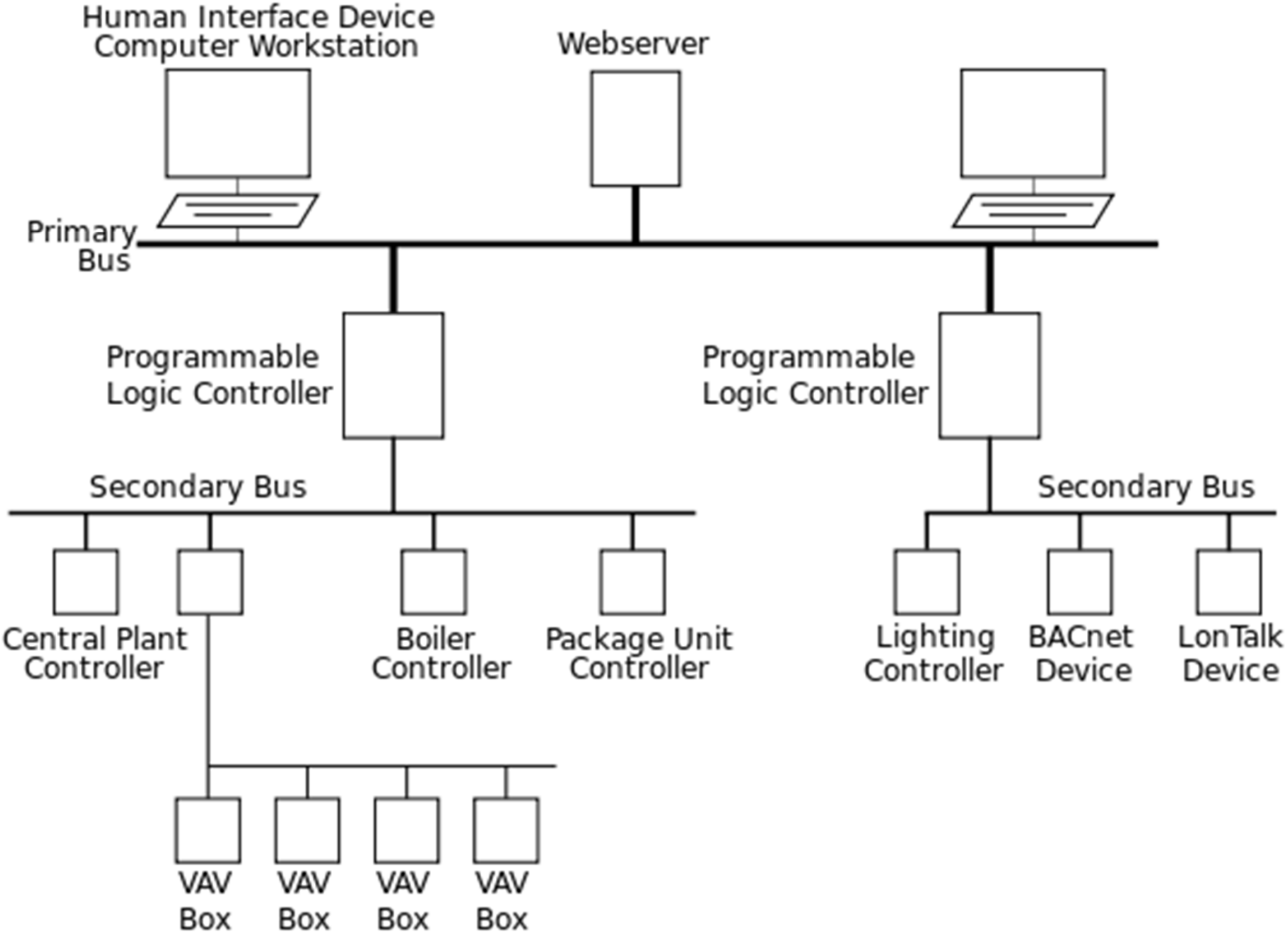
Understand the basic concepts of BMS
了解BMS的基本概念



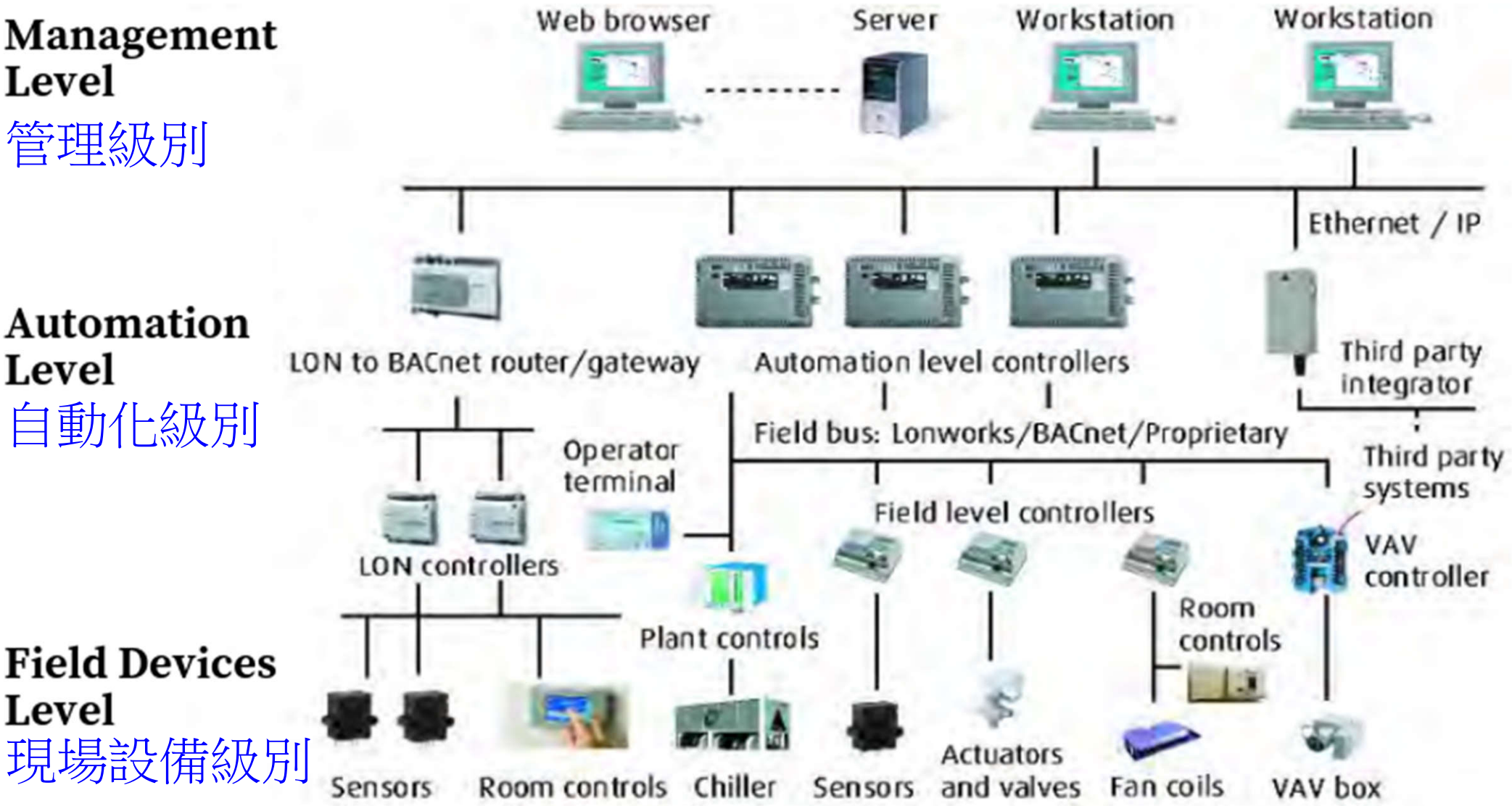
[Source: https://bms-system.com/understand-the-basic-concept-of-bms-system/]

Levels of control in building management system
樓宇管理系統中的控制級別

Diagram to show the typical system architecture of BMS
該圖顯示了BMS的典型系統架構

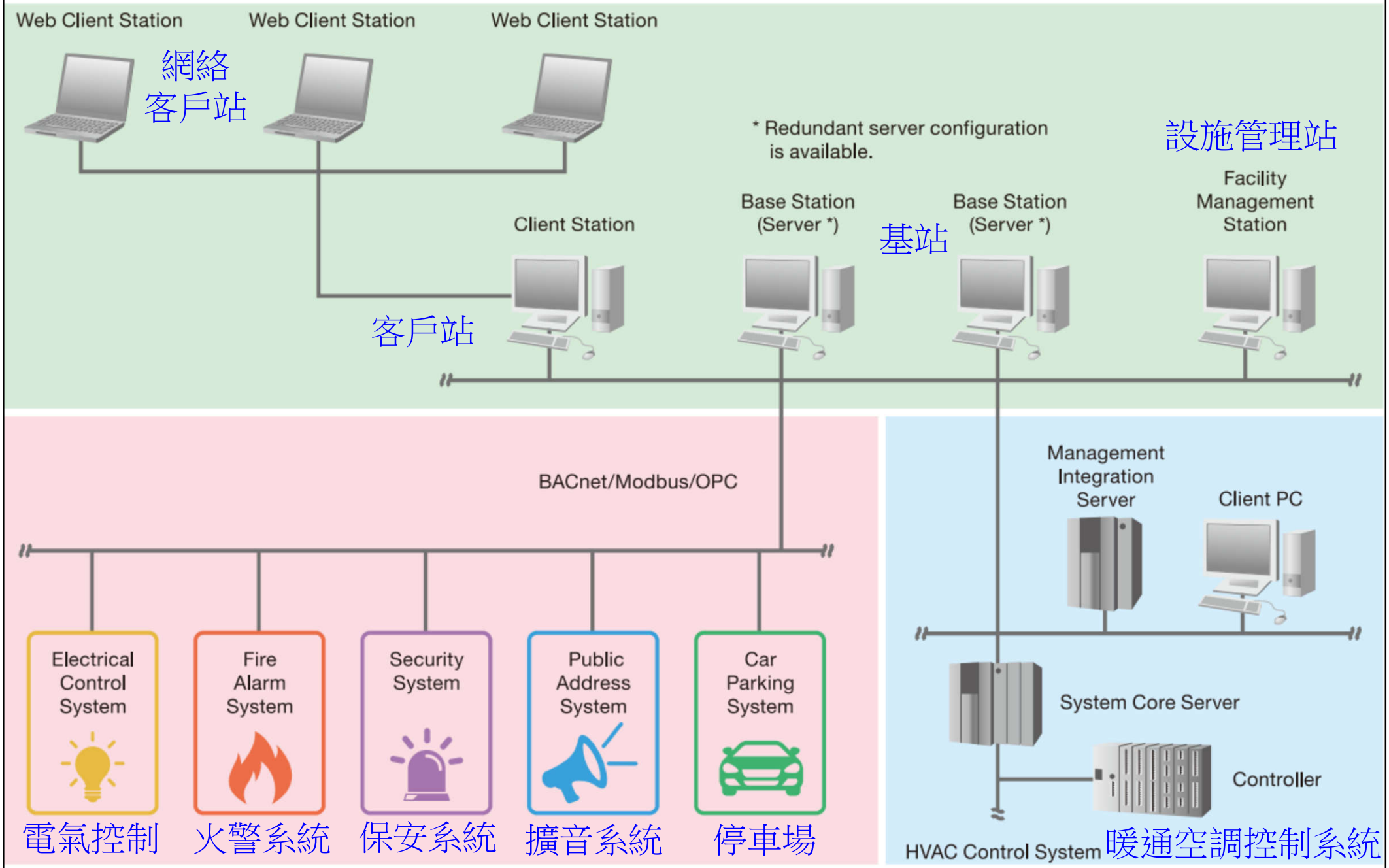


General system architecture and components of BMS
BMS的一般系統架構和組件



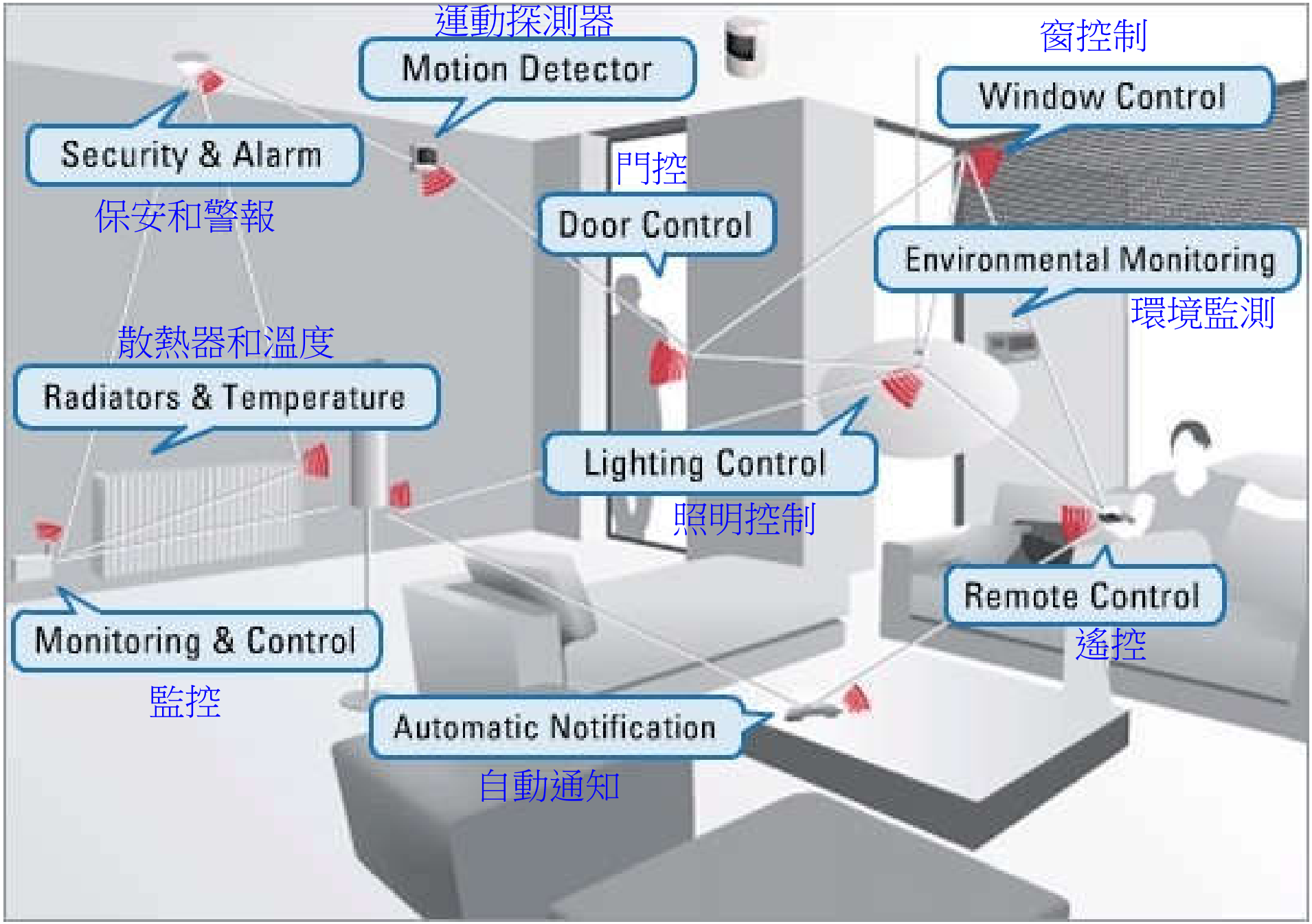
[Source: https://bms-system.com/understand-the-basic-concept-of-bms-system/]

Example of an integrated building management system
樓宇綜合管理系統的示例



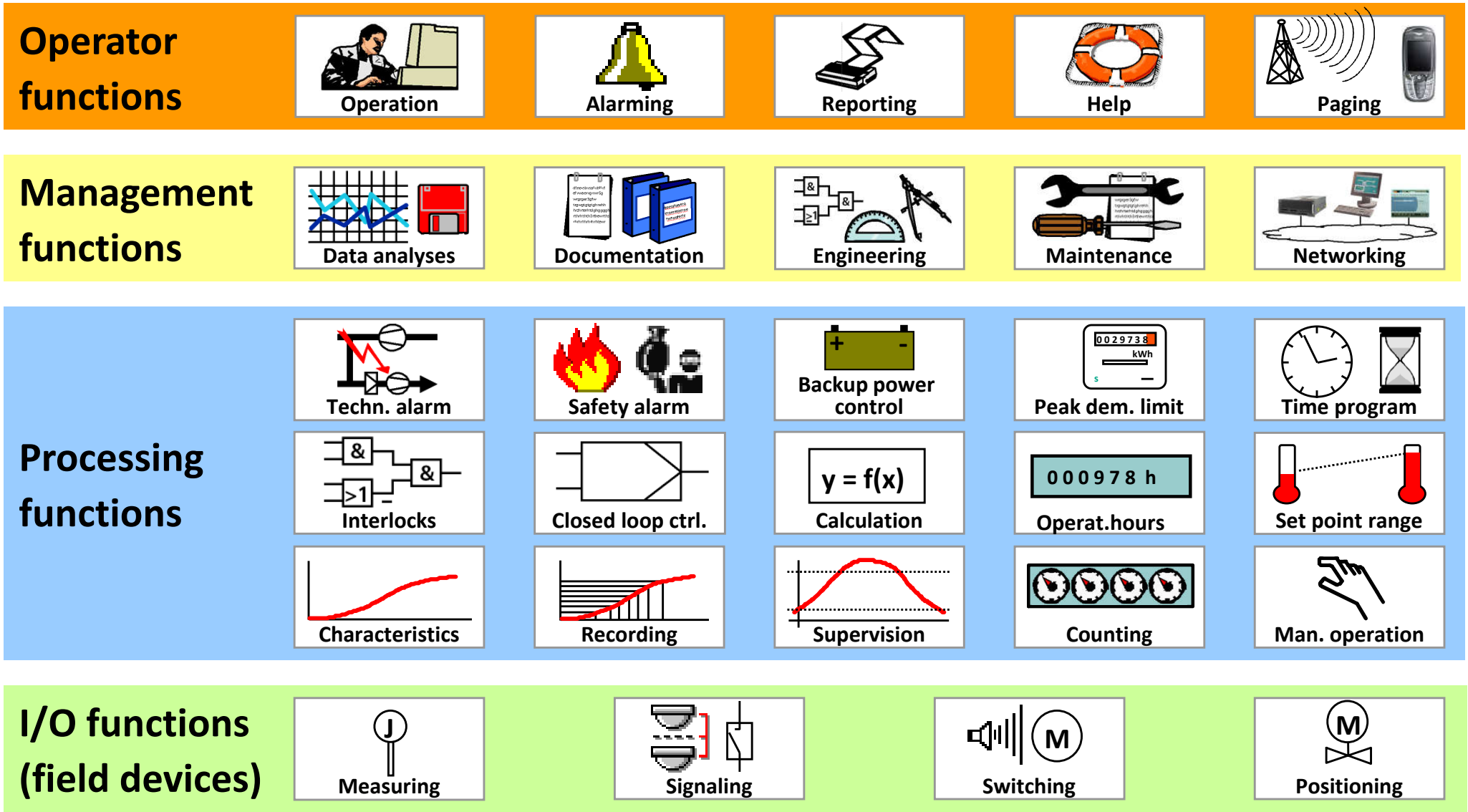
[Source: Azbil Corporation]

Examples of control systems and devices in buildings
建築物中控制系統和設備的示例



[Source: E Source]

Typical functions of building management system
樓宇管理系統的典型功能



[Source: Honeywell]

Example of integrated BMS for building and enterprise
樓宇和企業集成BMS的示例

樓宇系統
Systems

企業系統
Enterprise

MODBUS

XML SQL

HTTP HTML

開放系統框架

OPC FOUNDATION

LEGACY

Open System Framework

ODBC SNMP

JDBC FTP

BACnet

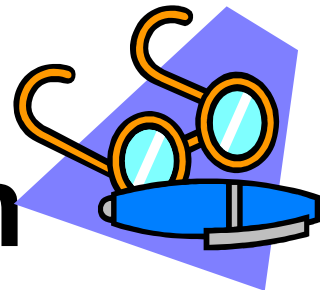
JAVA

SMTP

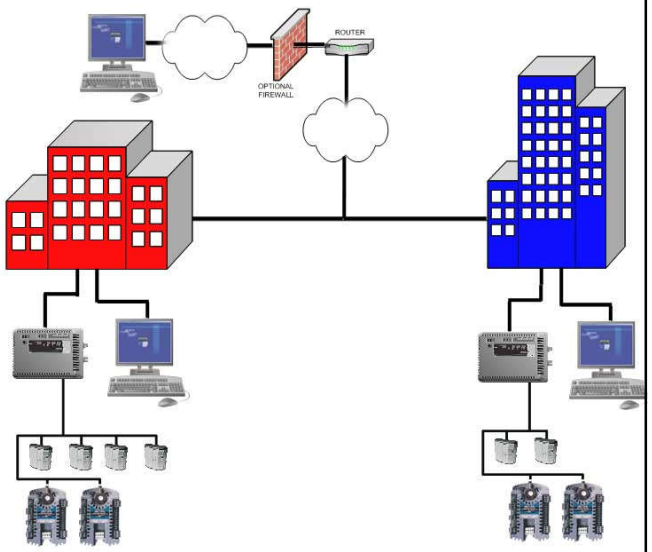
WAP

[Source: Tridium Software Solutions]

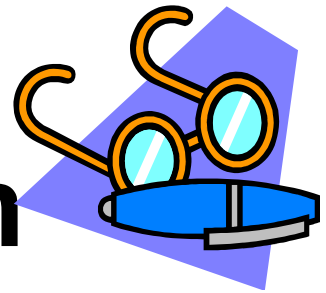
Building management system



- Key elements of BMS: 關鍵要素
  - 1. Hardware 硬件
    - Direct digital controller (DDC)
    - Sensors
    - Actuators
    - Cables to connect sensors, actuators to DDC
    - Human machine interface (HMI) display
    - PC workstation
    - Server to save the extensive database

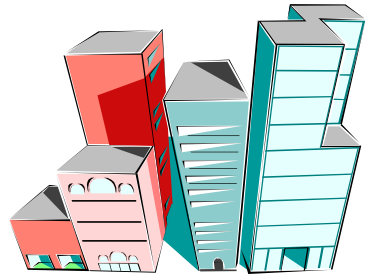


Building management system



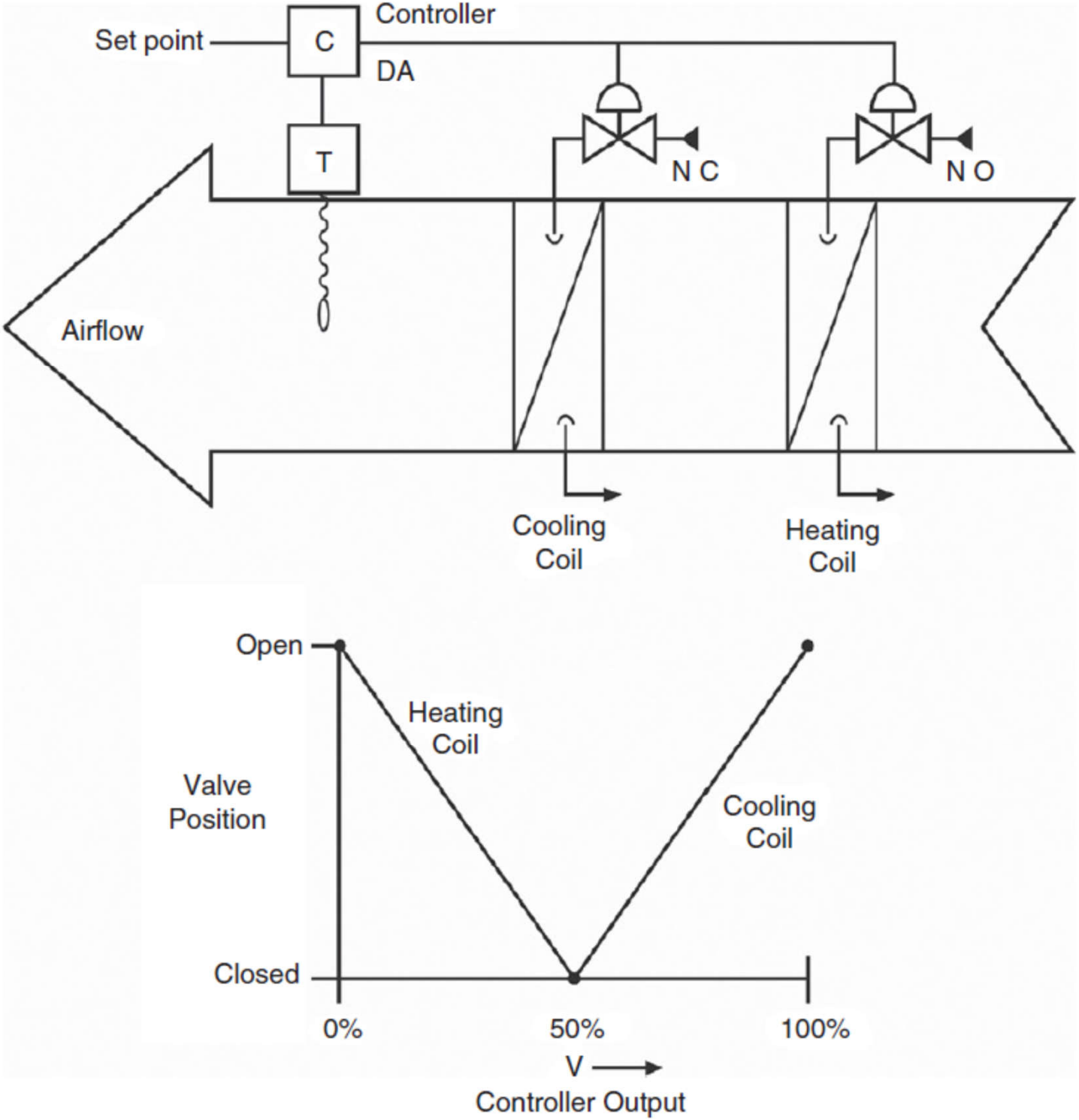
- Key elements of BMS: (cont'd)
  - 2. Software 軟件
    - Programming or configuration tools
    - Graphics or User interface
  - 3. Networking protocols 網絡協議
    - TCP/IP – Transfer control protocols/Internet protocol
    - BACnet – Building automation controller network
    - Modbus
    - LonWorks
    - And numerous protocols available

Practical examples



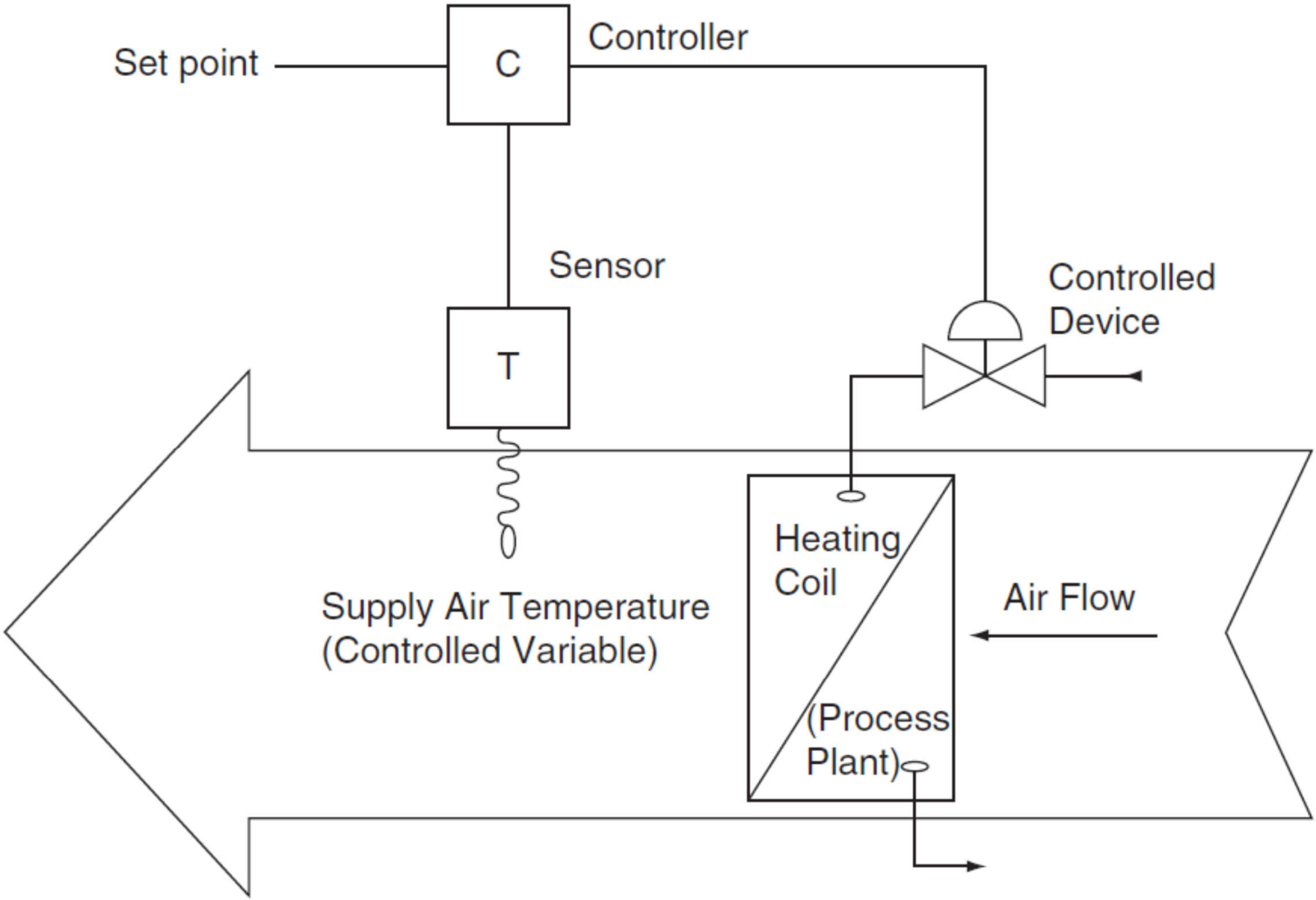
- Basic elements 基本要素
  - Sensor 傳感器
    - Measure some variables, e.g. temperature
  - Controller 控制器
    - Process & compute an output signal
  - Controlled device 受控裝置
    - Act to change the output of the load
- Typical situation for building controls
  - Close loop systems (w/ feedback loop) 閉環系統（帶/反饋迴路）

Example of HVAC controls
暖通空調控制示例



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

Simple heating system 簡單的加熱系統



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

Control system diagram 控制系統圖

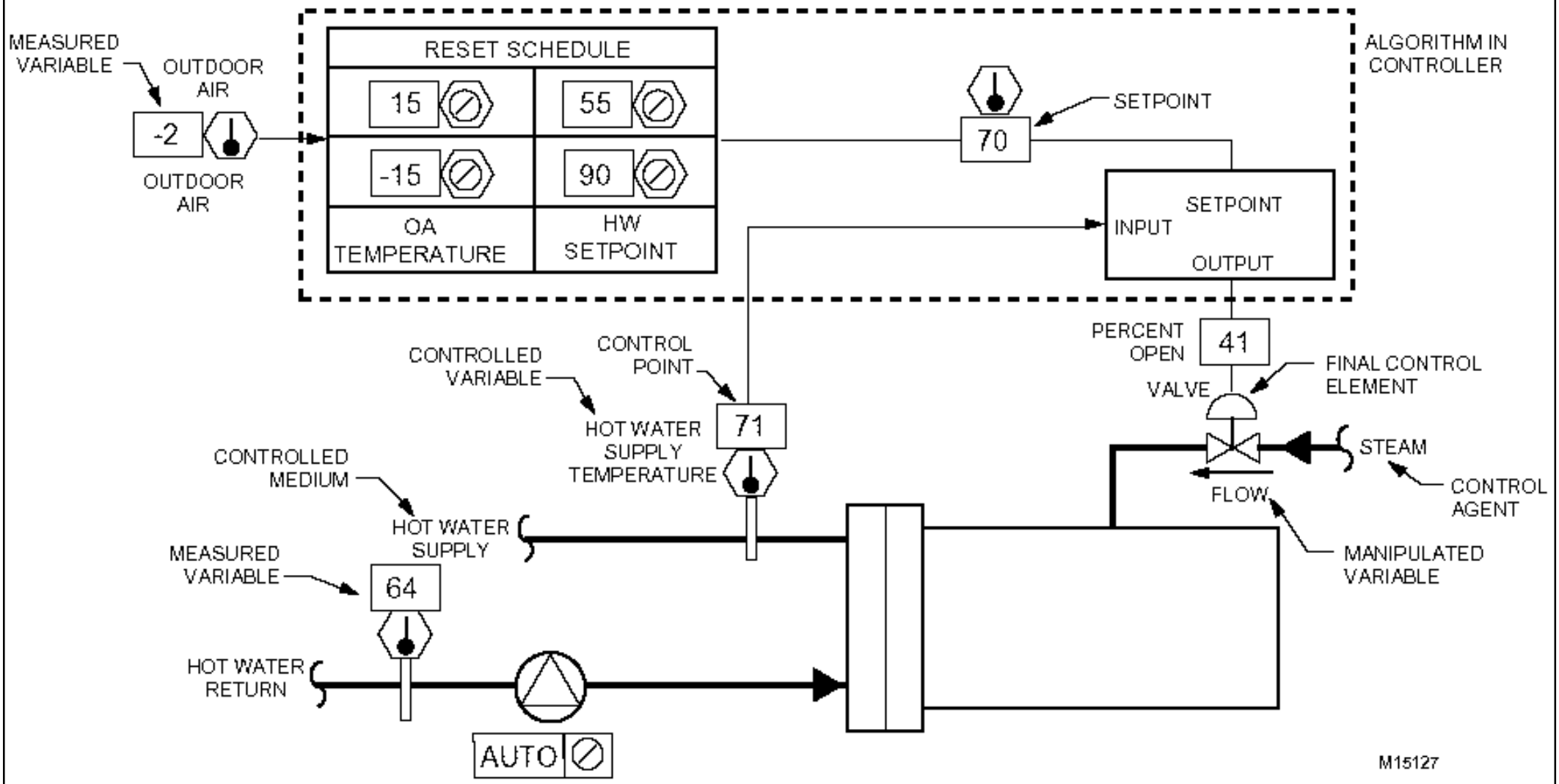
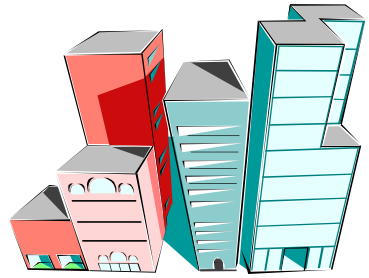


Fig. 1. Typical Control Loop.

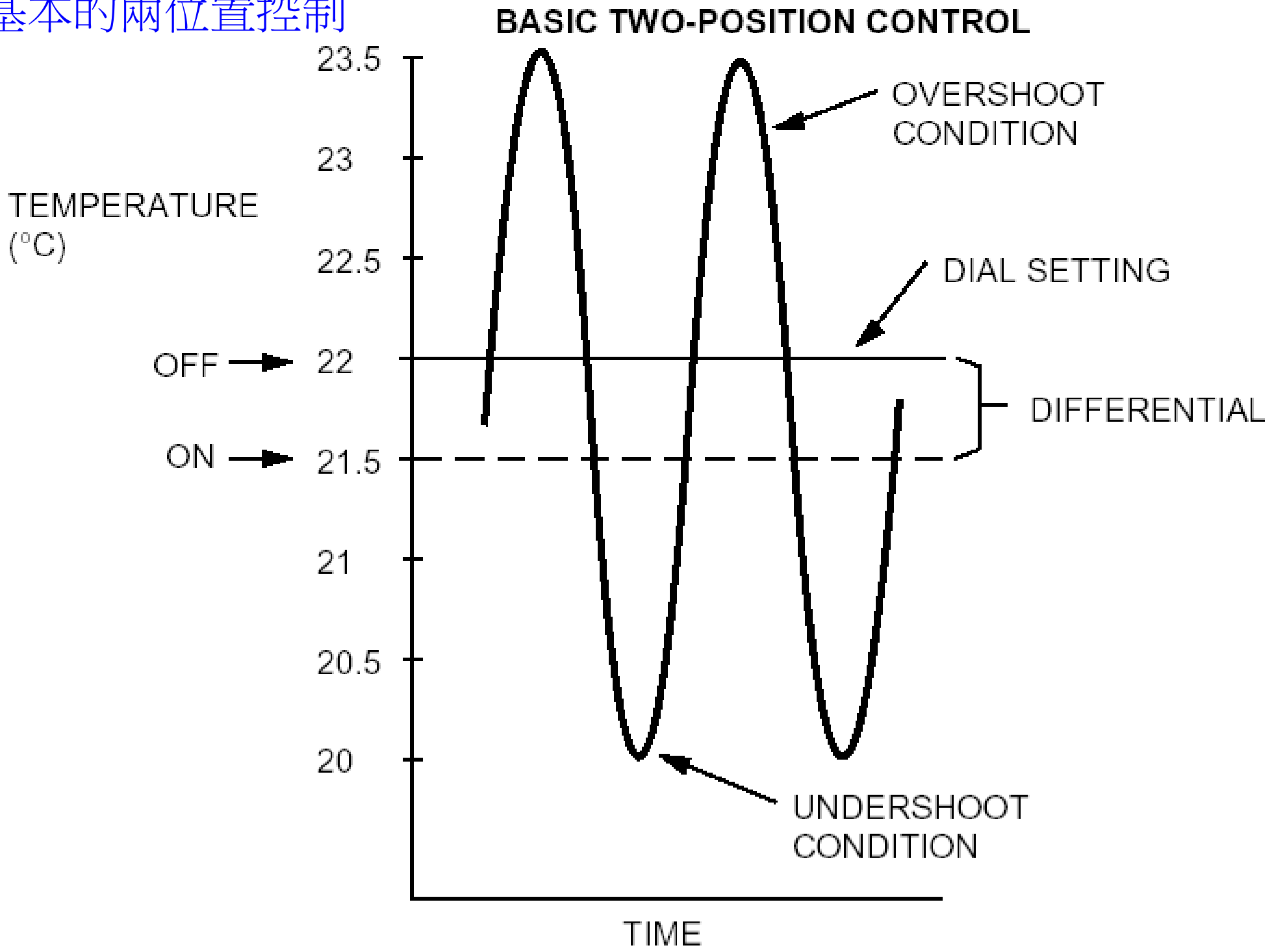
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Practical examples



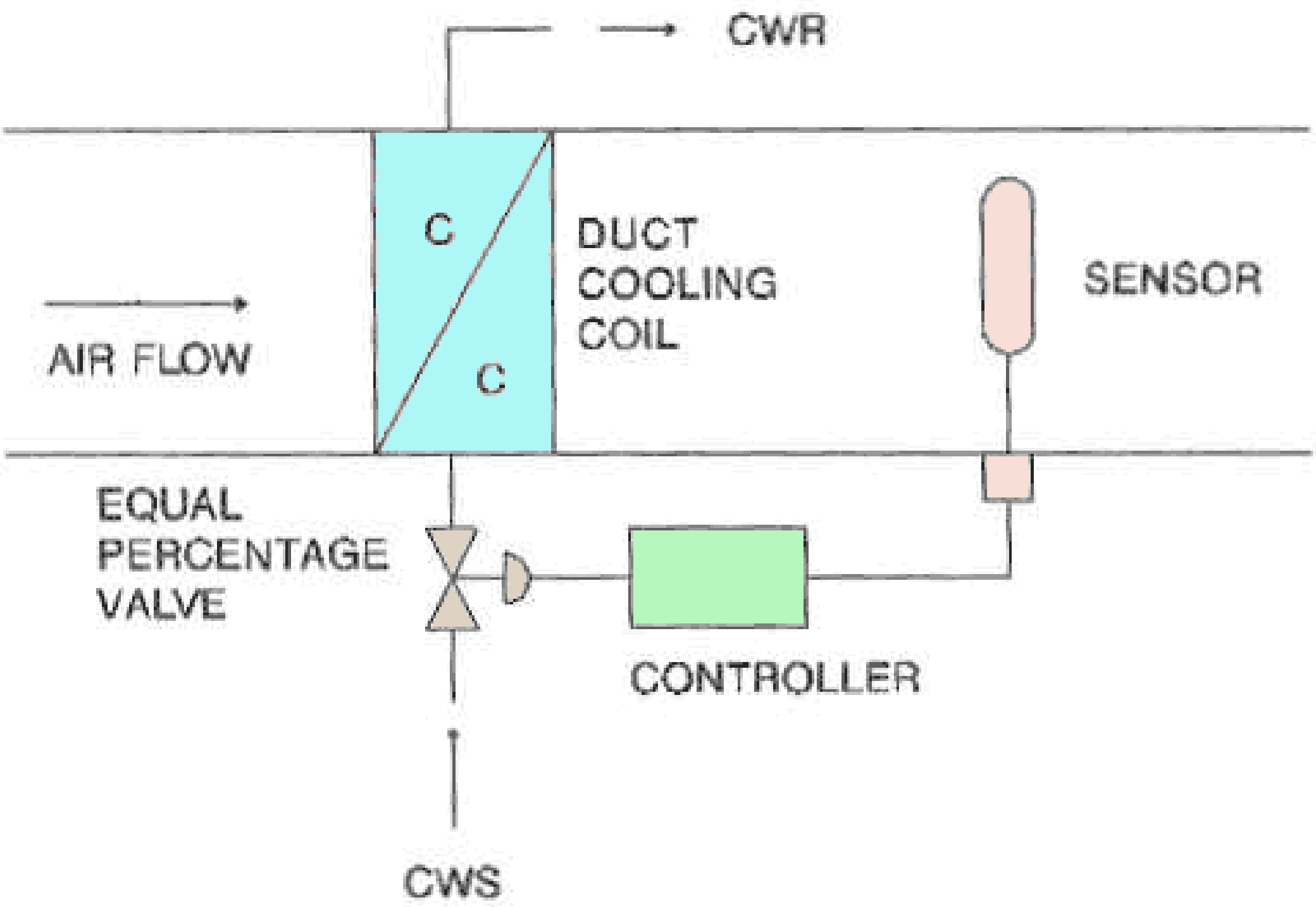
- Control modes 控制方式
  - Two position (on/off) control 兩位置（開/關）控制
  - Proportional control 比例控制
  - Integral control 整體控制
  - Proportional + integral (PI) control
  - Proportional + integral + derivative (PID) control
- Technical terms 技術用語
  - Set points, dead band, throttling range, offset, proportional band, integral time

基本的兩位置控制

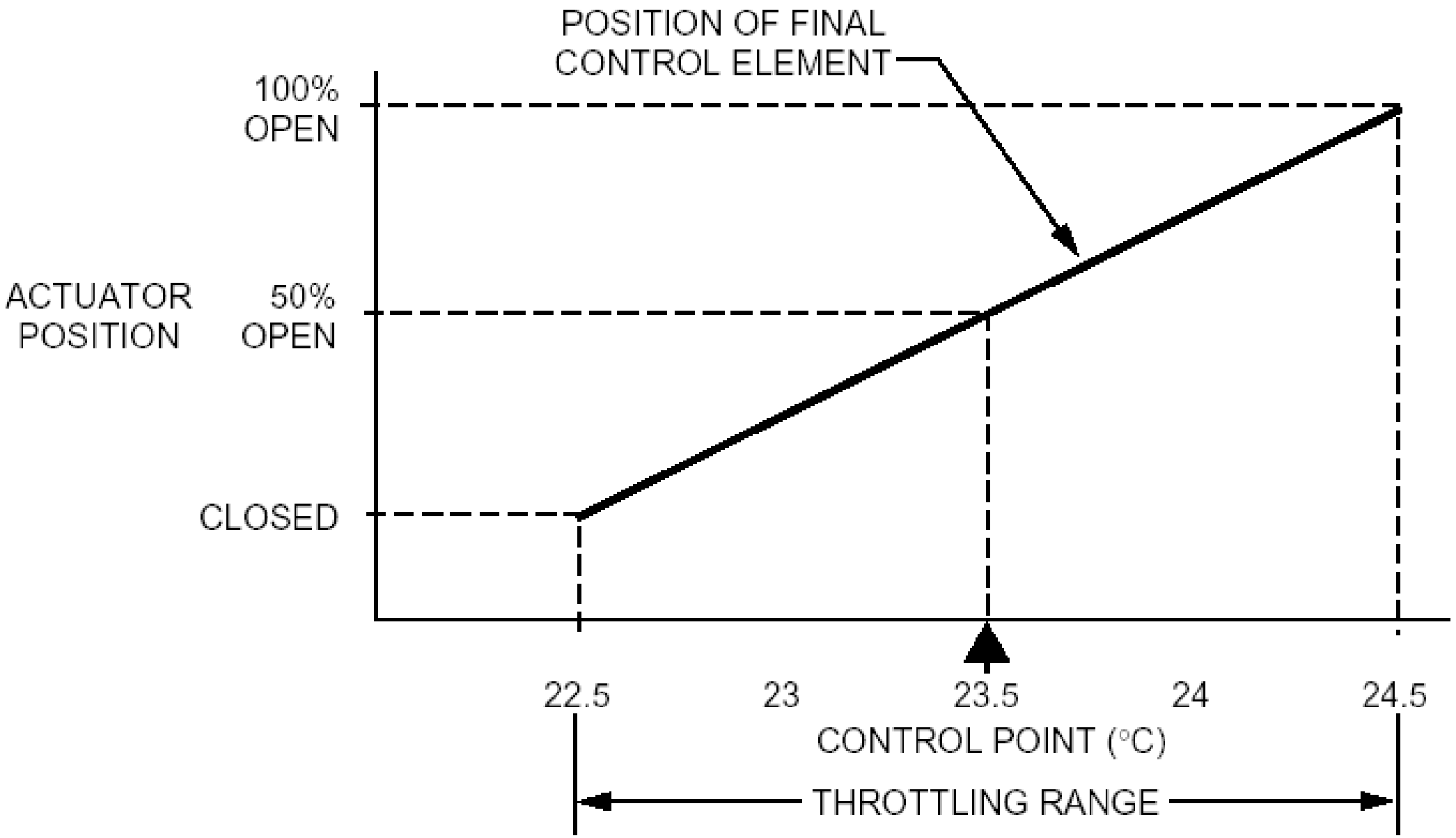


[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Example: Discharge air control system 示例：排氣控制系統

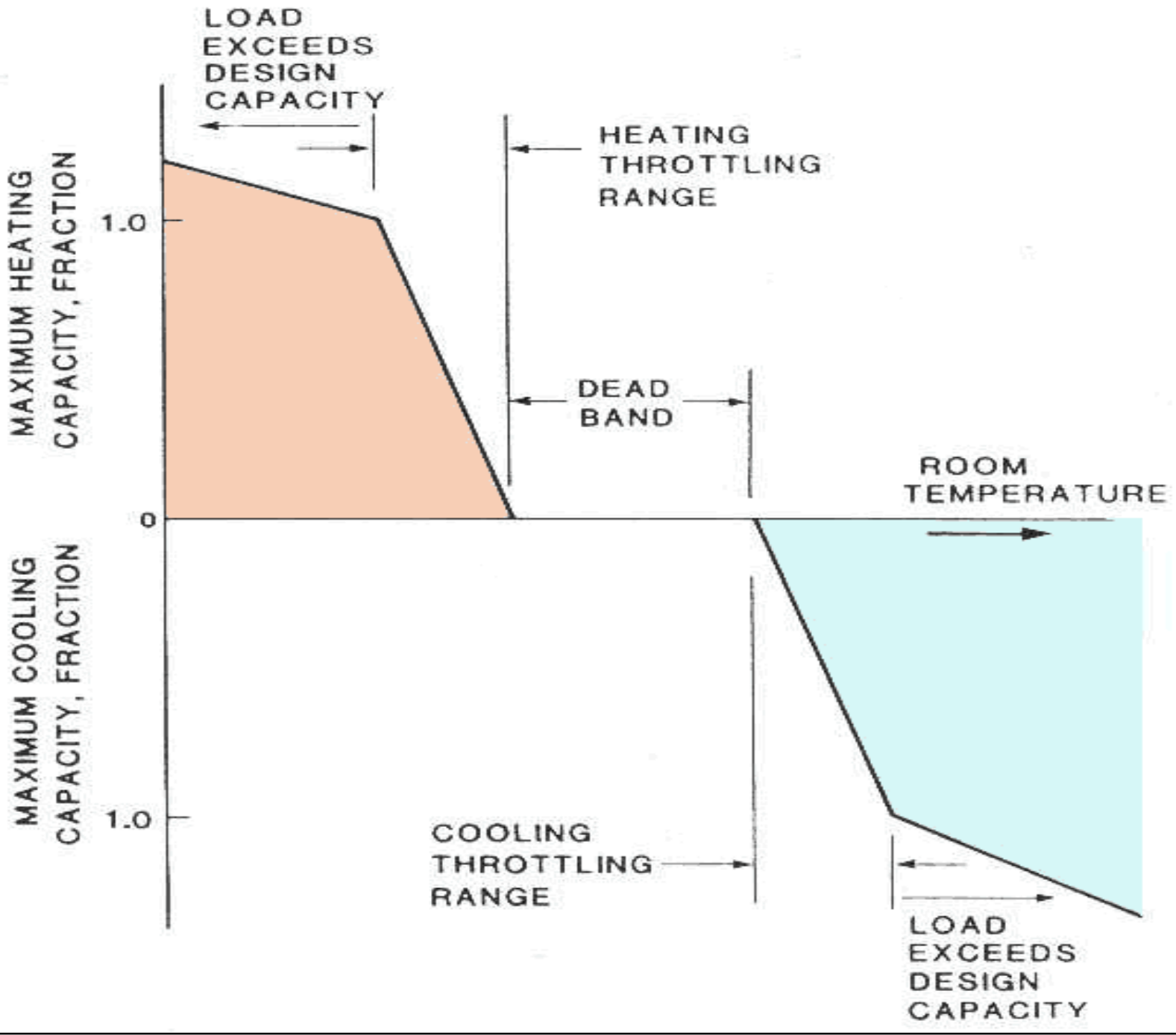


Actuator control diagram 執行器控製圖

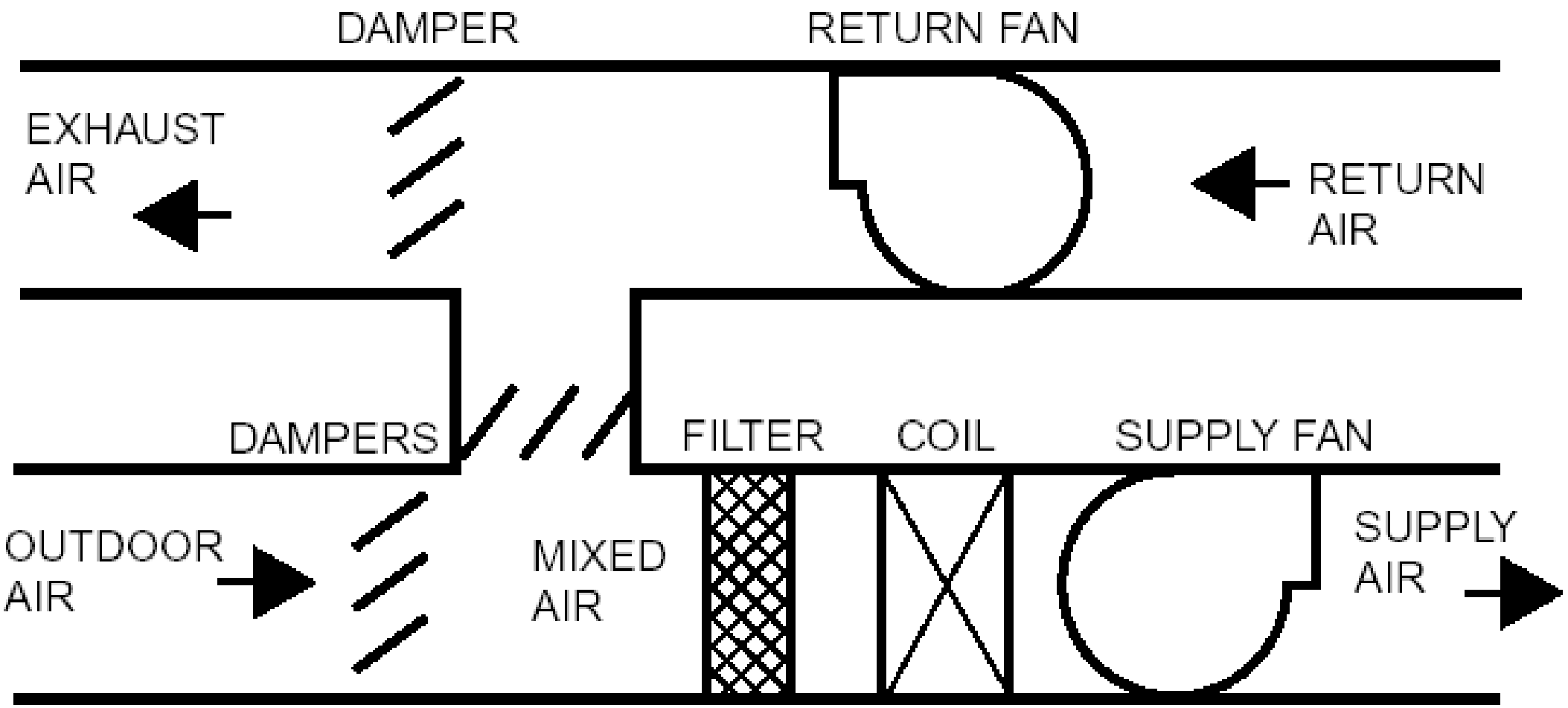


[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Thermostat model of proportional control with deadband and dual throttling range 具有死區和雙節流範圍的比例控制的恆溫器模型



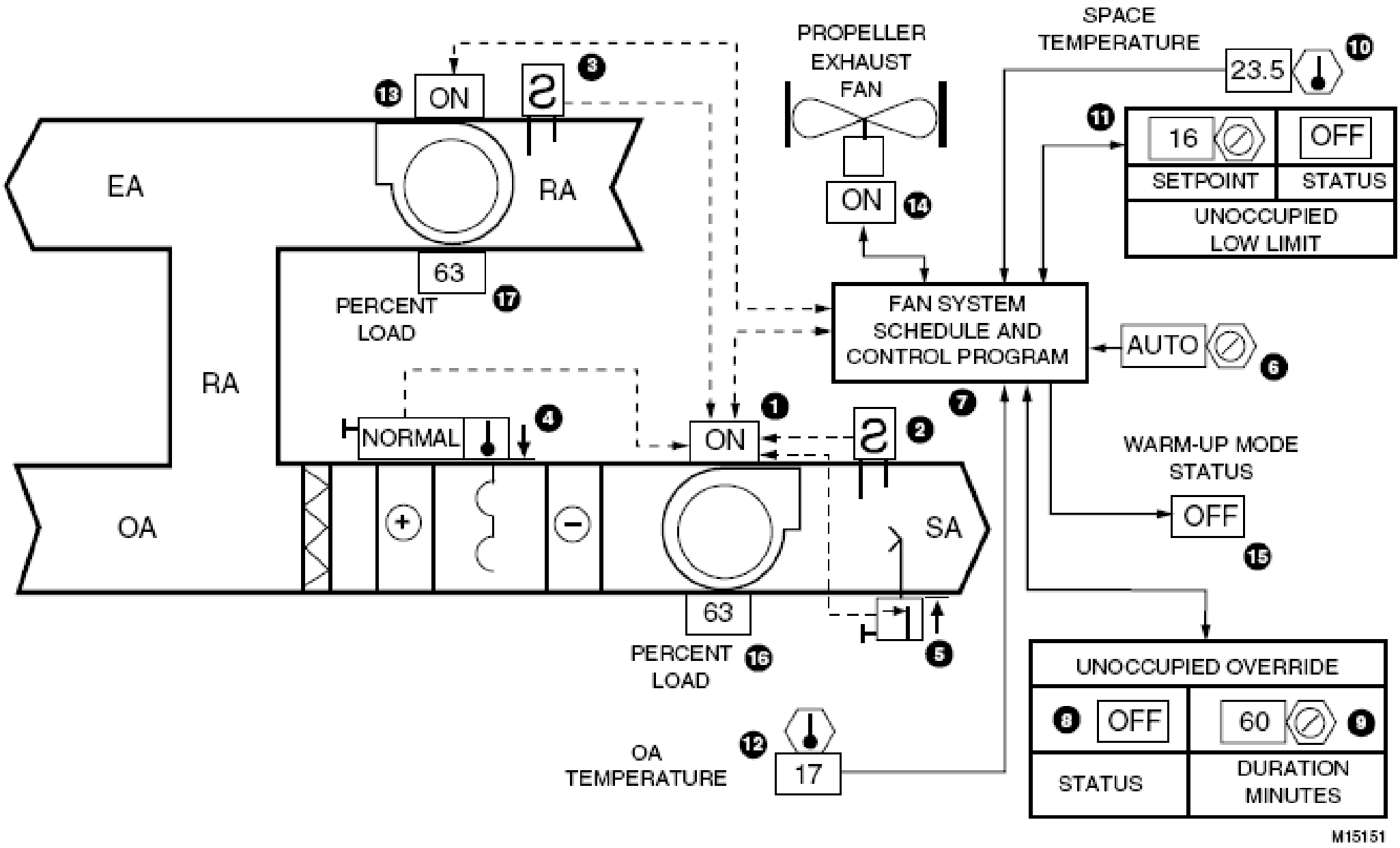
Schematic diagram of a typical air-side system
典型的空側系統示意圖



Can you identify the components when you visit a AHU room?
您在訪問AHU機房時能否識別組件？

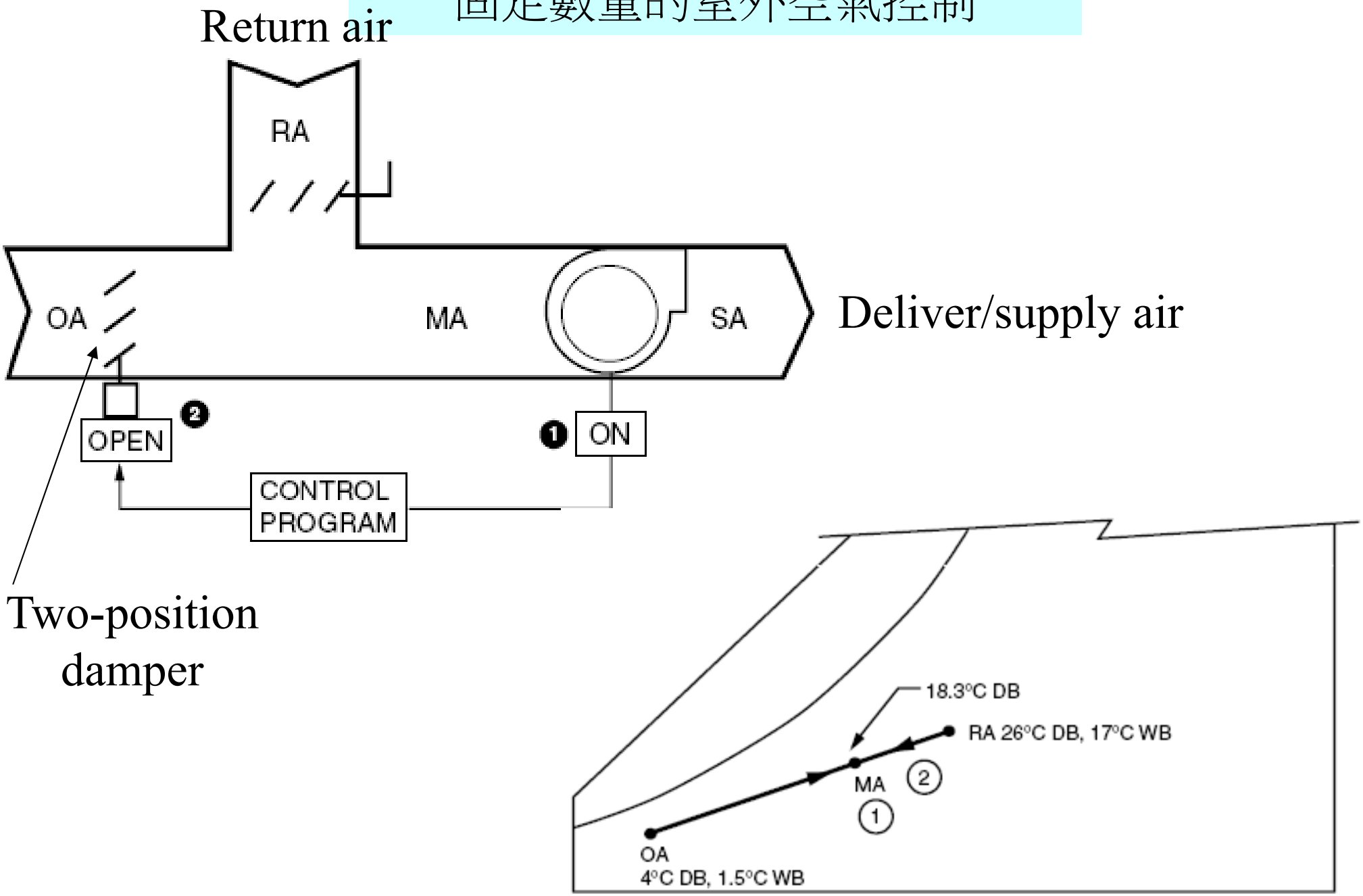
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Fan system start-stop control
風扇系統起停控制



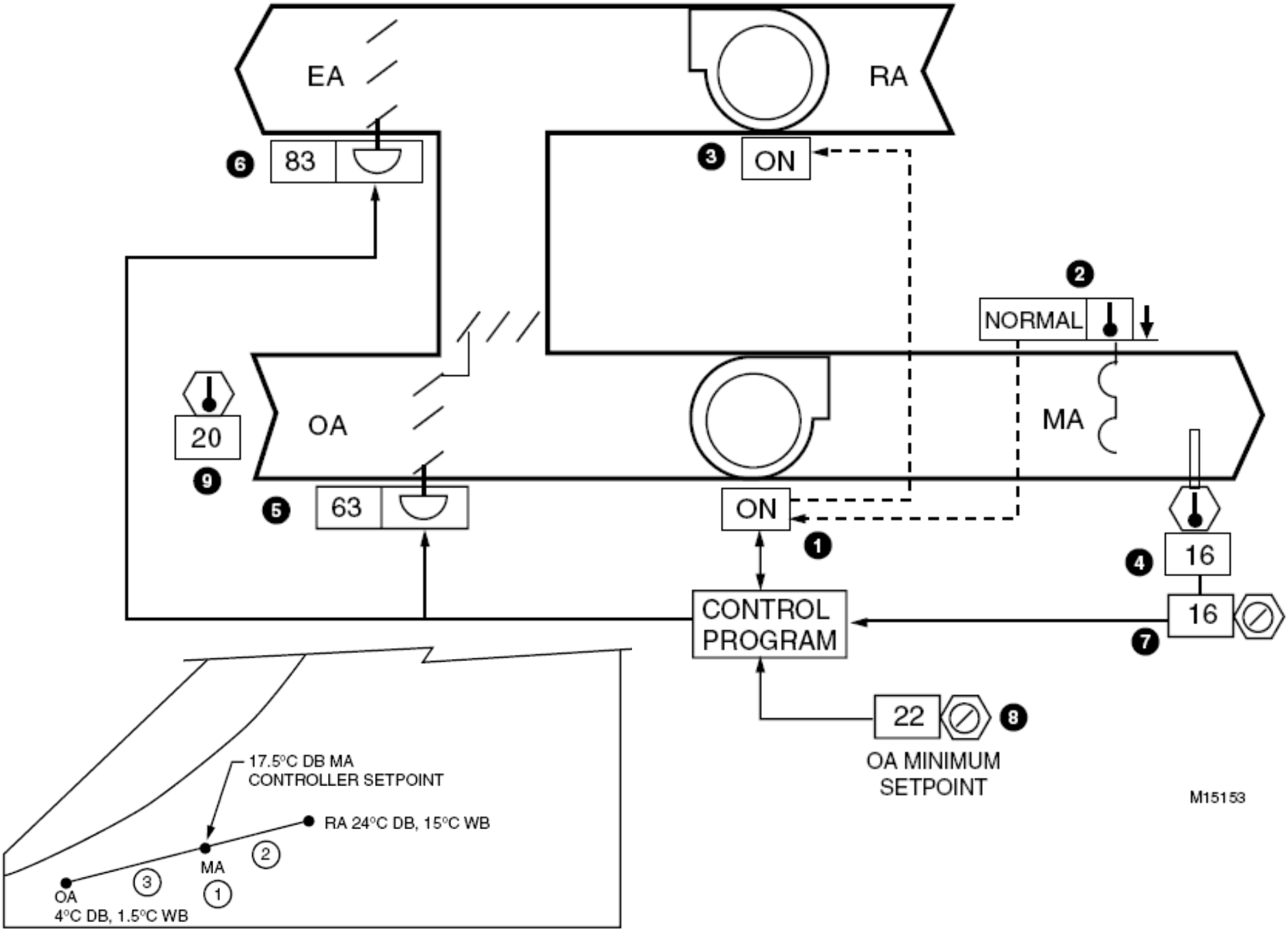
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Fixed quantity of outdoor air control
固定數量的室外空氣控制



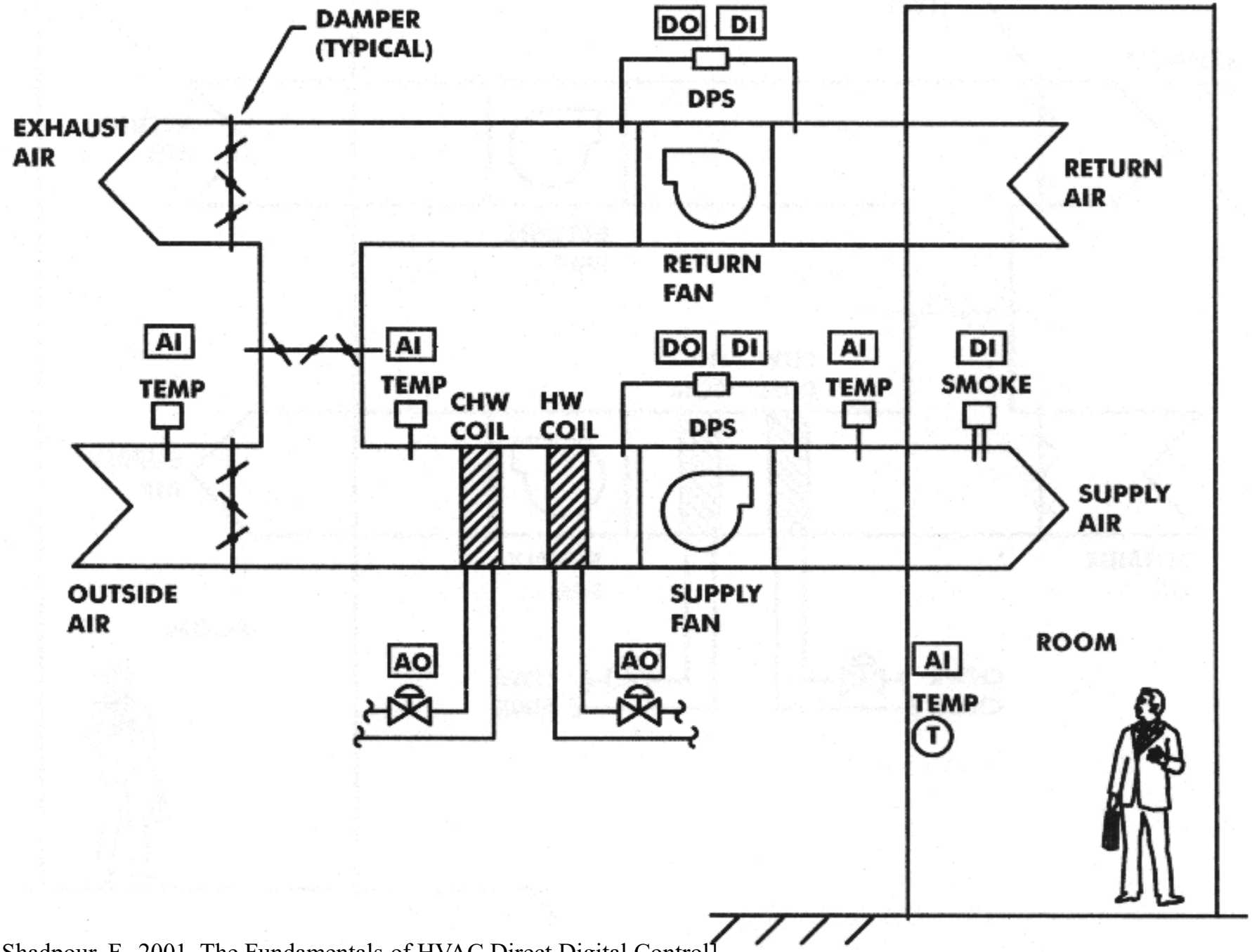
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Mixed air control 混合空氣控制



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

Control point designations for a constant volume single zone AHU
恆定流量單區空氣處理機組的控制點名稱



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

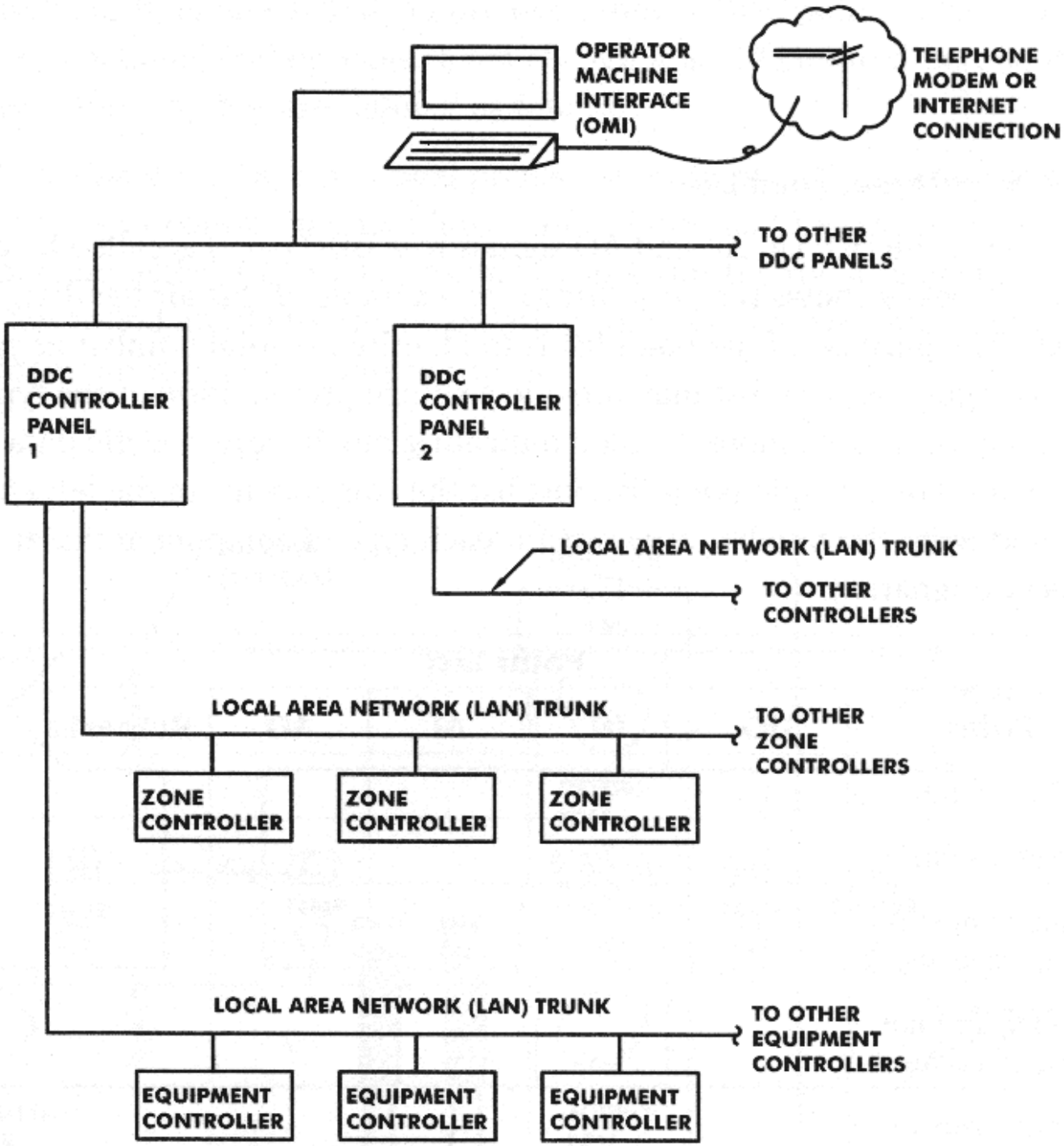
Point list for DDC system DDC系統的點列表

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 DDC系統架構的一個例子



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