MECH3023

Building Energy Management & Control Systems

http://www.hku.hk/bse/mech3023

Course Arrangement

- Every Tuesday
  - 16:00 – 17:55 (2 hours)
  - Main Building MB121
- Every Thursday
  - 09:30 – 10:30 (1 hour)
  - Chow Yei Ching Building LG1 Theatre C
- Lecturers
  - Dr. Benjamin P.L. Ho
  - Ir. H.N. Lam
- Teaching Schedule (please refer to the attached)

Course Arrangement

- Assessment
  - 20% in course assessment
  - 10% practical work (2 – 4 March 2011)
  - 70% examination
- In-course Assessment (20%)
  - Quiz before Reading Week (10%)
  - Other assessment(s) by Ir. H.N. Lam (10%)
- Practical Work (10%)
  - Reading Week : 2-4 March 2011 (one day)
  - Laboratory work in groups of 5-6
  - Further details of the arrangement to be announced
- Examination (70%)
  - 3 hour examination
  - Sections A & B, attempt 2 out of 3 questions in each section (tentative)

Subject Objective

- To introduce basic concepts of computer-based integrated monitoring, control and energy management for building services installations
- To study the principles of design and operation of building energy management and control systems (EMCS) and their applications to buildings
- To understand methods of performance analysis of building services systems using building EMCS

Learning Outcomes

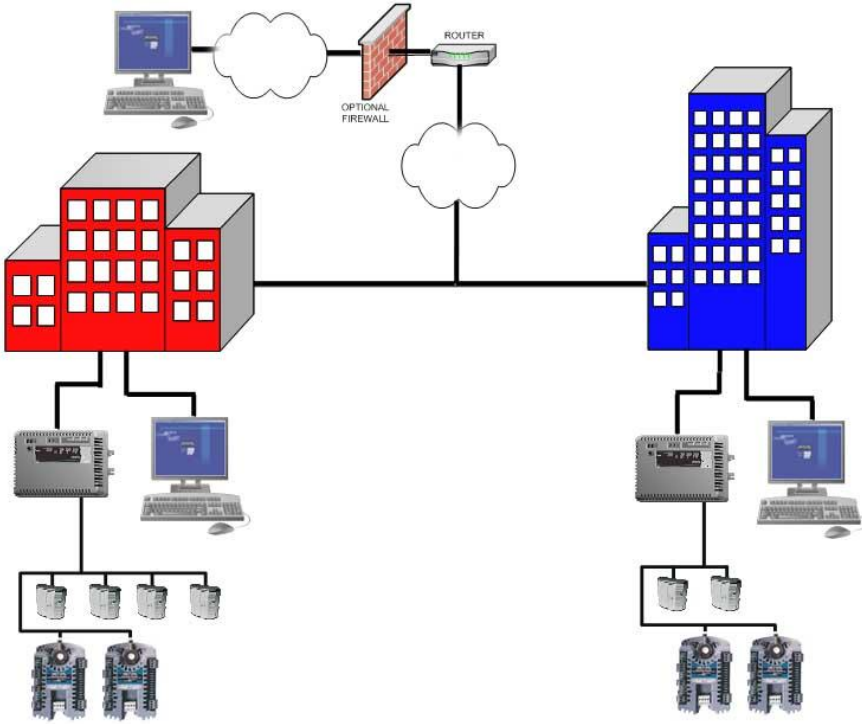
- Know the basic concepts & components of building energy management & control system
- Able to explain the system designs and practical applications for building controls
- Appreciate the recent trends and future development of the management systems for intelligent buildings

Introduction to BAS & ECMS

(MECH3023)

Contents

- References
- Overview
- Control Fundamentals
- Hierarchical Structure



References

- EMSD, 2002. Guidelines on Application of Central Control and Monitoring Systems, Energy Efficiency Office, Electrical and Mechanical Services Department (EMSD), HKSAR Government (www.emsd.gov.hk)
- 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)
- Montgomery, R. and McDowall, R., 2008. Fundamentals of HVAC Control Systems, ASHRAE, Atlanta, GA. (HKU Library)
- Merz, H., Hansemann, T., Hubner, C., 2009. Building Automation – Communication Systems with EIB/KNX, LON and BACnet, Springer (HKU Library)

Introduction to BAS & ECMS

- Overview of BAS / BEMS

Overview

- Commonly used terminology for this subject title
  - Building Automation System (BAS)
  - Building Management System (BMS)
  - Building Energy Management System (BEMS)
  - Energy Management and Control System (EMCS)
  - Energy Management System (EMS)
  - Central Control and Monitoring System (CCMS)
  - Direct Digital Control (DDC)
  - Intelligent Building (IB)

Overview

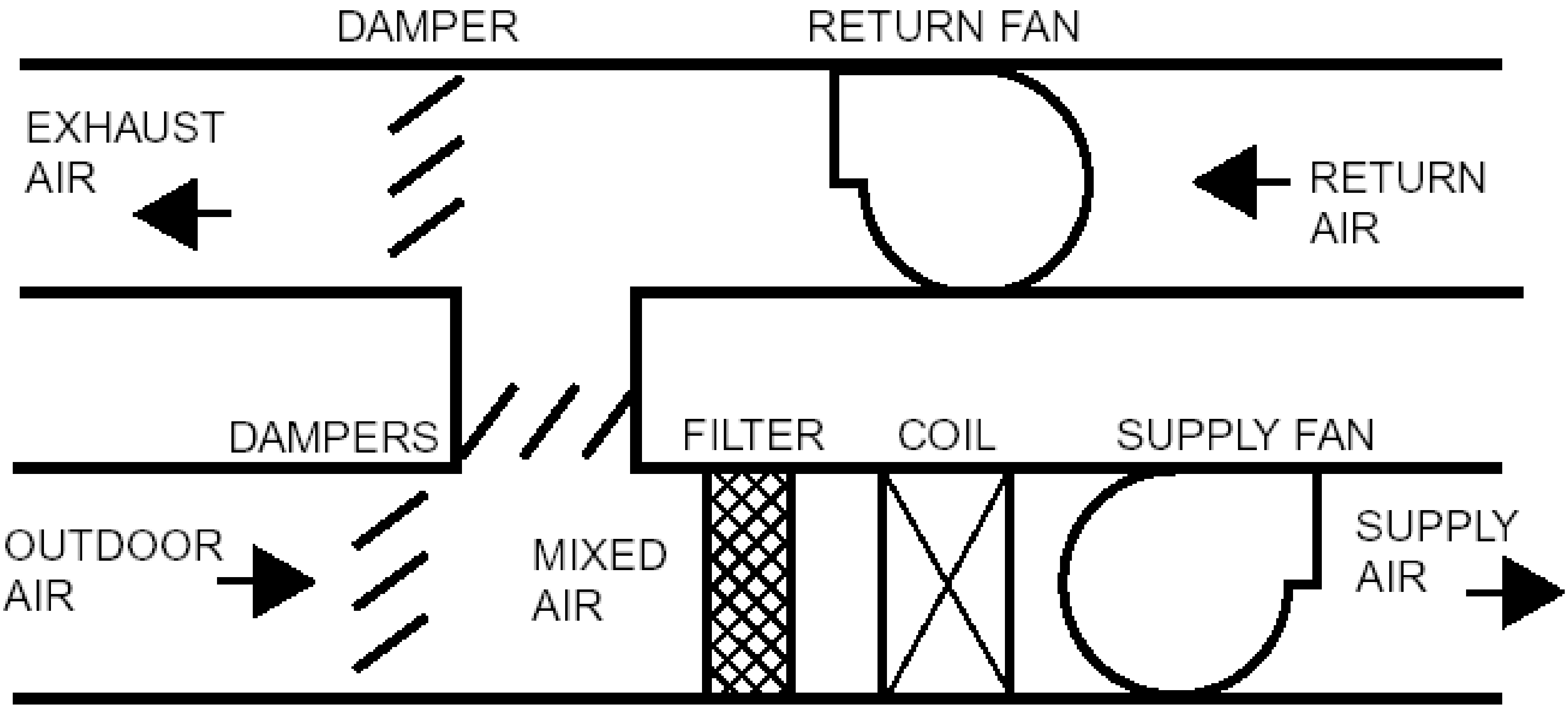
- Building services systems being monitored and/or controlled
  - HVAC (heating, ventilation & air-conditioning)
  - Fire services
  - Plumbing & Drainage
  - Electrical Installations
  - Lighting
  - Lifts & Escalators
  - Security & Communication
- Can you give examples of the Monitoring and Control in these systems?

Discussions

- Consider your home:
  - Can you turn on/off the lamps in the various rooms at one single location? (somewhat like the control console in a hotel room)
  - Can the lamps be dimmed automatically when you watch your favourite movie at your 42" LCD TV?
  - Can the air conditioning be turned on automatically 15 minutes before you reach home?
  - Can any system deodorize the toilet when it gets smelly?
  - Can a system give you ideas how much energy are consumed and the trend of your energy consumption?

- What has to be done to make your home 'automated' and 'intelligent'?

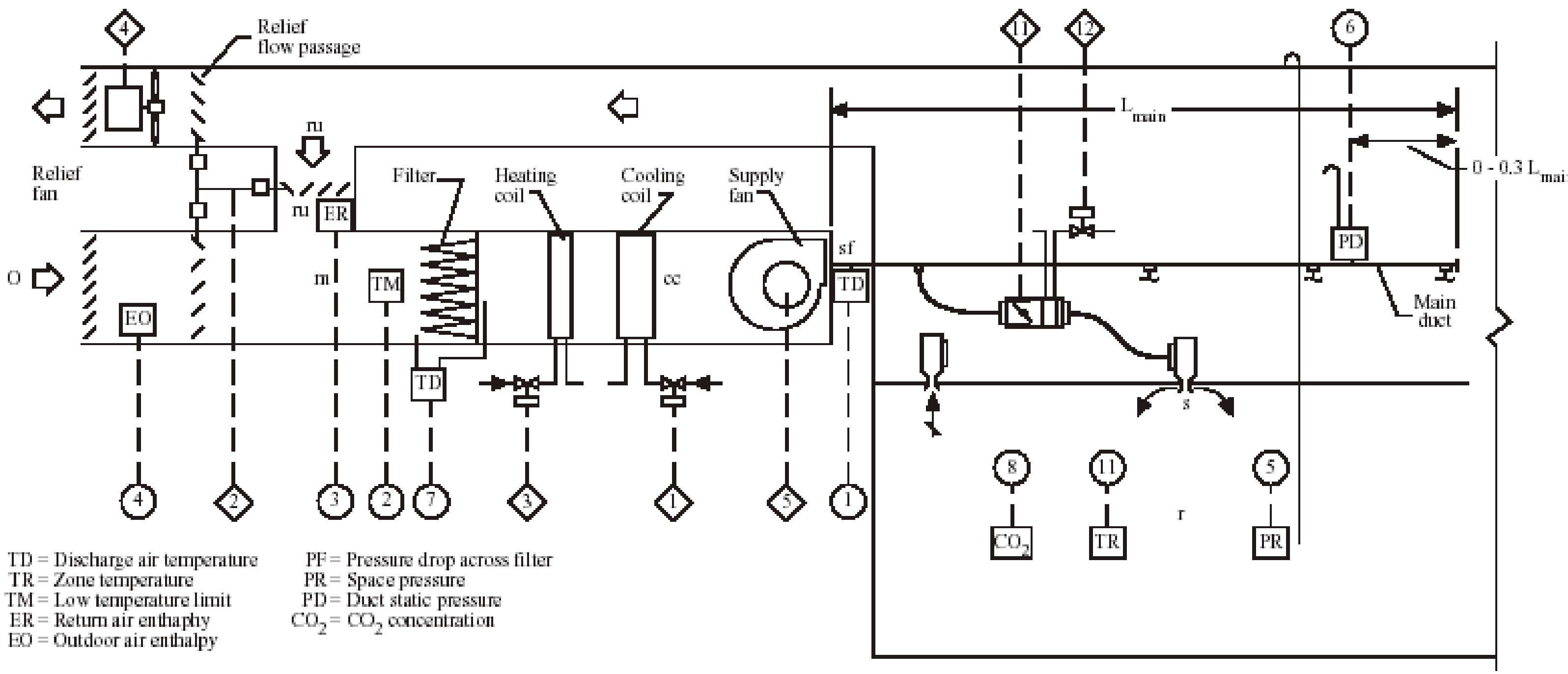
Can you identify the components in this HVAC Air-side System?



Schematic diagram of a typical air-side system

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

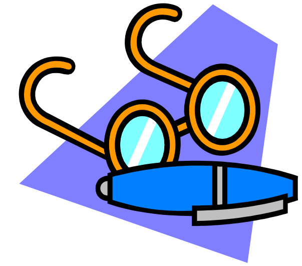
Can you understand all the symbols & abbreviations?



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

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

Overview



- Why use BAS/BEMS?
  - Growing complexity of building systems
  - Demand for more efficient building operation
  - Need to save energy & operating costs
  - Need to increase flexibility & reliability
  - Improve indoor environment & productivity
- Connect BAS/BEMS to major building equipment to
  - Control air conditioning & lighting to save energy
  - Monitor all equipment to improve efficiency of operations personnel & minimize equipment down time

BAS/BEMS can →

- Reduce energy consumption through effective energy management
- Reduce manpower dependence for security and life-safety
- Achieve more accurate maintenance schedules
- Allows for flexibility in system setup
- Facilitate communication of information
- Achieve better workplace automation
- Achieve better facility management

Development History

- Pre-BAS : centralized control and monitoring panels (1950 – 60's)
  - Remote monitoring panels with sensors & switches (hard wire)
  - Pneumatic centralization by the adoption of pneumatic sensor – transmitters
  - Multiplexer systems (wiring reduction)

- 1st Generation : computerized centralized control and monitoring panel (late 60's)
  - Development of modern computer and linking to multiplexers by coaxial cable or two-wire digital transmission
  - Allows programming of controllable devices, automatic reset of analogue outputs, high / low alarm limits
  - Expensive and not easy to use

Development History

- 2nd Generation: BAS based on minicomputer using data-gathering panel (1970's)
  - Use of minicomputers, central processing units and programmable logic controllers
  - Allow for applications in energy management like duty cycle, demand control, optimum start/stop, day/night control, etc

- 3rd Generation : microprocessor-based BAS using LAN (1980-90's)
  - Use of microprocessor and personal computer
  - Use of standalone but integrated microprocessor control stations to control individual plants
  - Control actions done locally while management and optimization done collectively

Development History

- 4th Generation: Open BAS compatible with Internet/Intranet (90's – present)
  - Standardizing interoperability
  - Open protocols
  - Adoption of internet technologies, e.g. IP address, allows BAS to be integrated with enterprise computing networks
  - Convenience of remote control and monitoring
  - Advancement of Information Management

BAS Development is much influenced by the development of control technology, electronic and computing technology, networking and internet technology

Introduction to BAS & ECMS

- Control Fundamentals

Control Fundamentals

- Definitions
  - Automatic control system: A system that reacts to a change or imbalance in the variable it controls by adjusting other variables to restore the system to the desired balance.
  - Controlled Variable: The quantity or condition that is measured and controlled.
  - Controller: A device that senses changes in the controlled variable, execute a control algorithm, and issue a control signal to a Control Device
  - E.g. VAV control system → supply air temperature (controlled variable) → DDC controller (controller) → cooling coil control valve (control device)

Control Fundamentals

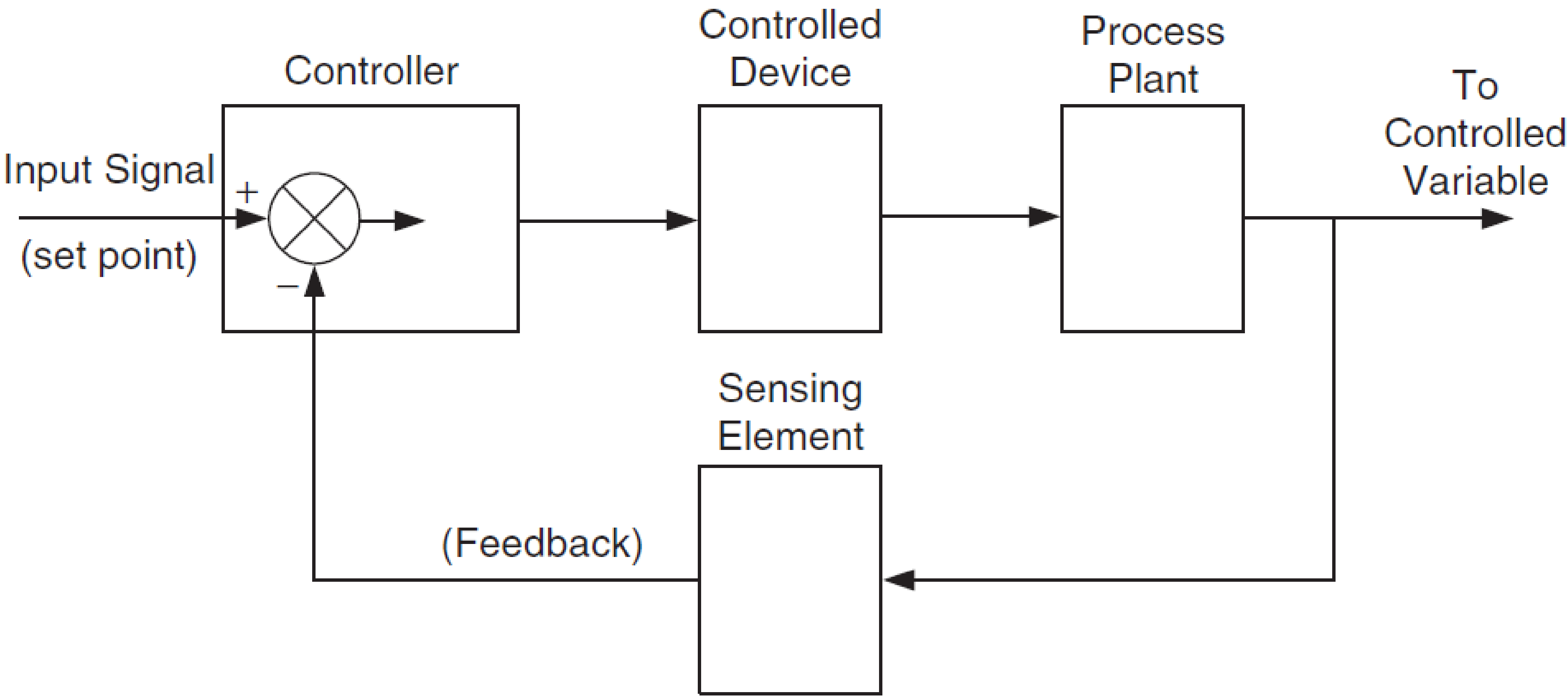
- Pneumatic controls
  - Traditional form of control used in buildings
  - Pneumatic controllers, sensors & actuators
  - Electronic devices may be integrated
  - Use of compressed air to act on the control device

- Direct Digital Control (DDC)
  - 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

Control Fundamentals

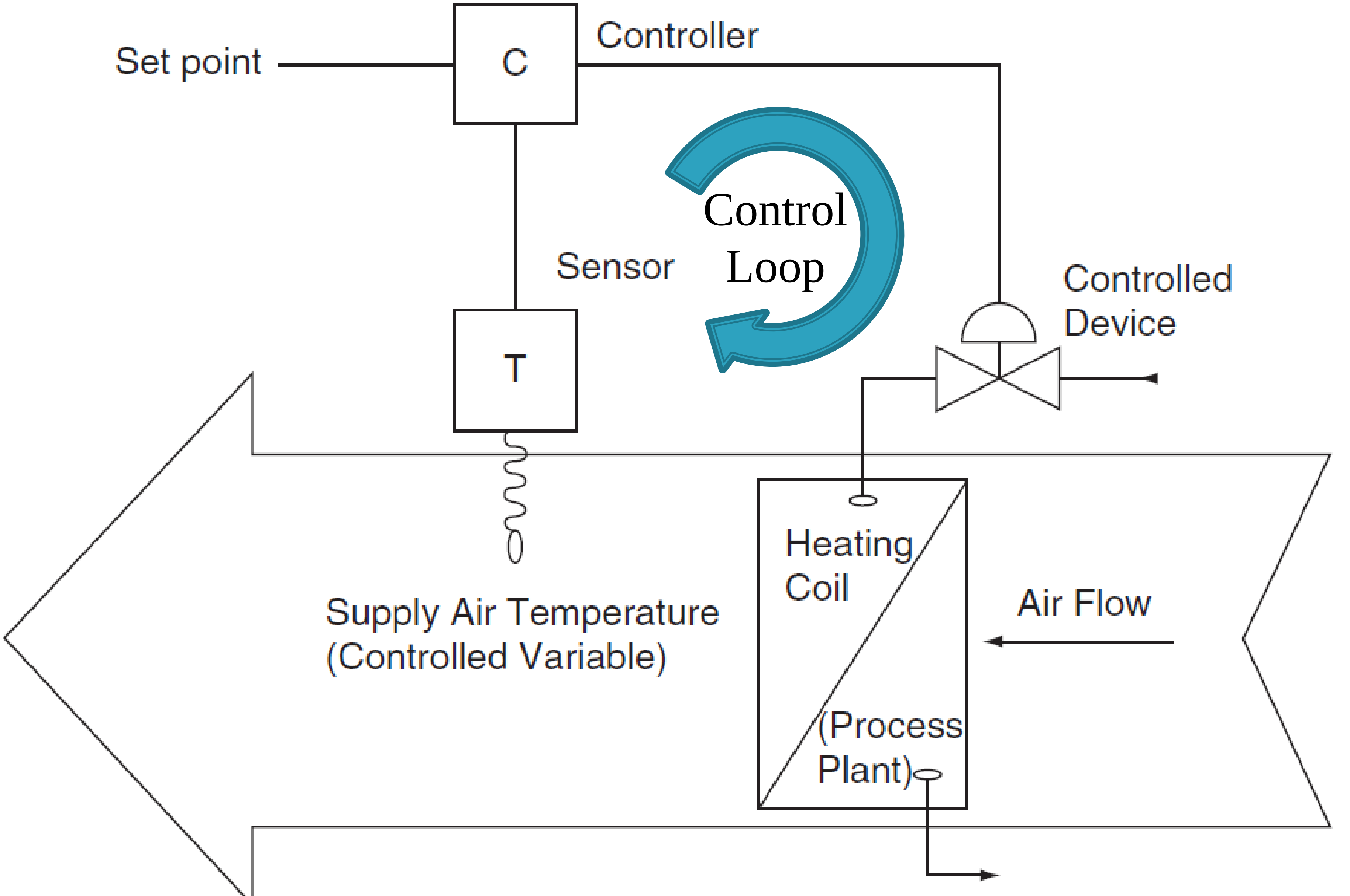
- Basic elements
  - Sensor
    - Measure some variables, e.g. temperature (analog signal)
  - Controller
    - Conversion of analog signal (if any) to digital signal for processing
    - Process a control algorithm & compute an output signal
  - Controlled device
    - Act to change the output of the load
- Typical situation for BAS
  - Close loop systems (w/ feedback loop)

Basic elements of a feedback control loop



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

Simple heating system



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

Control system diagram

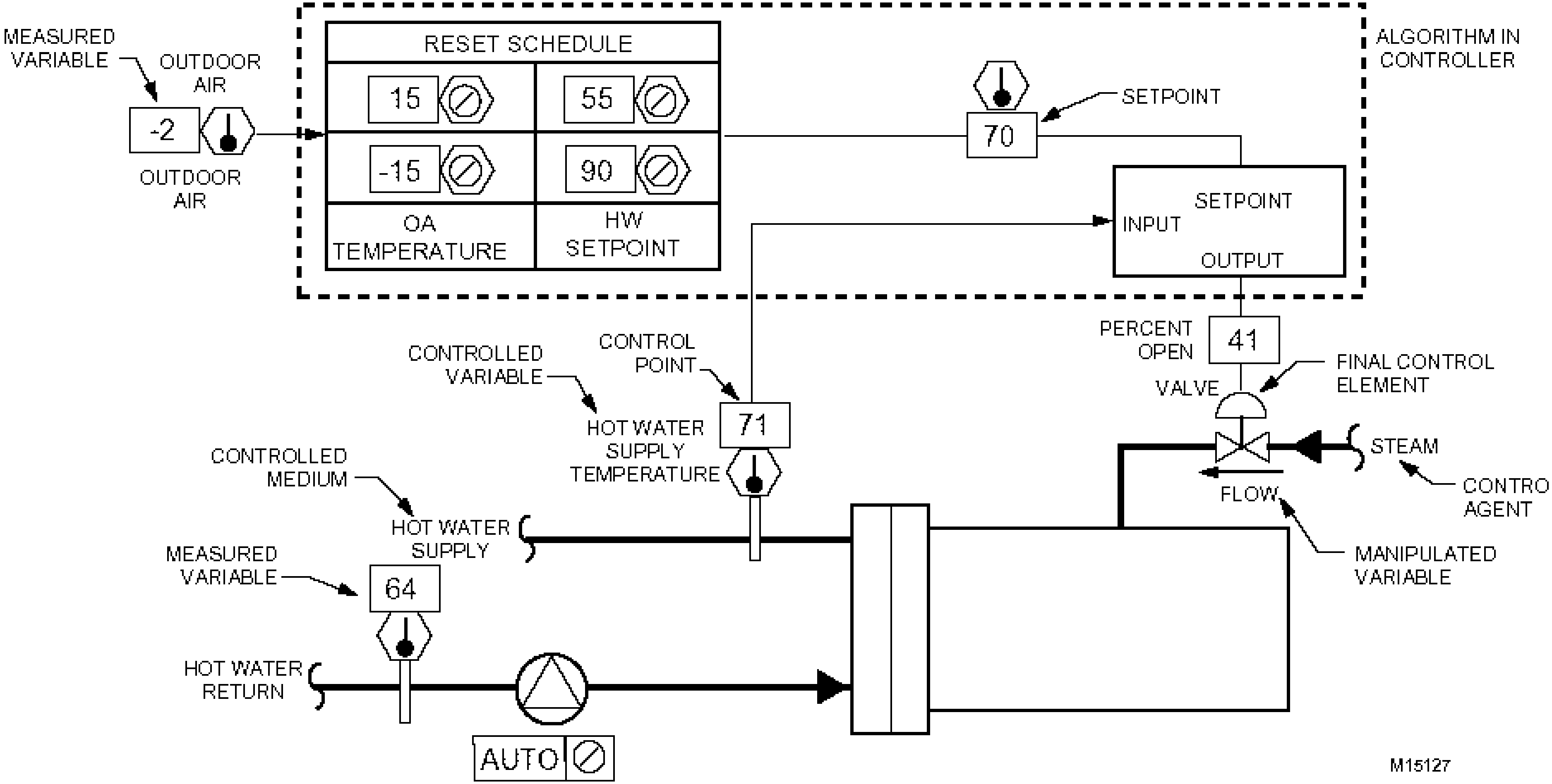


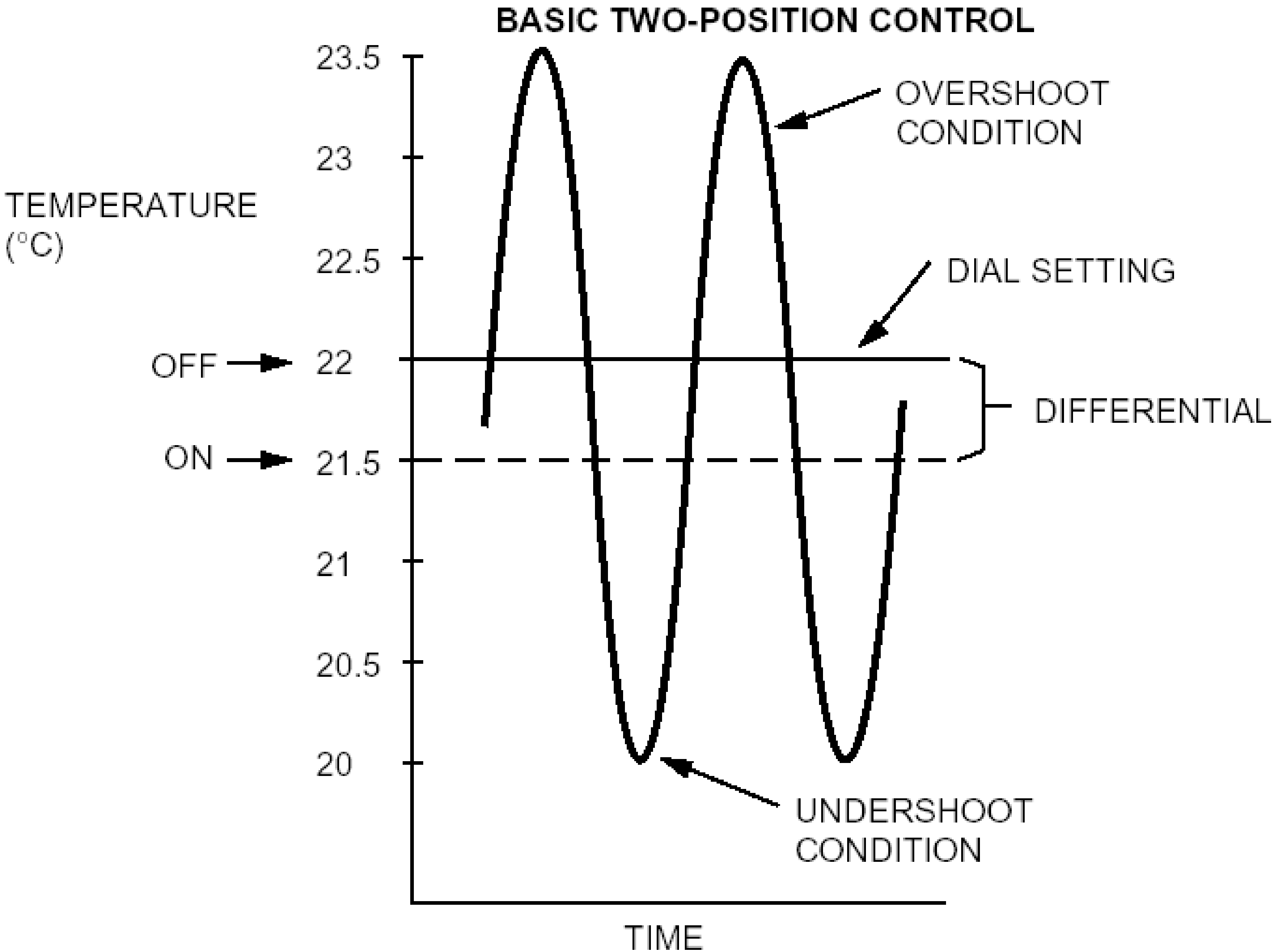
Fig. 1. Typical Control Loop.

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

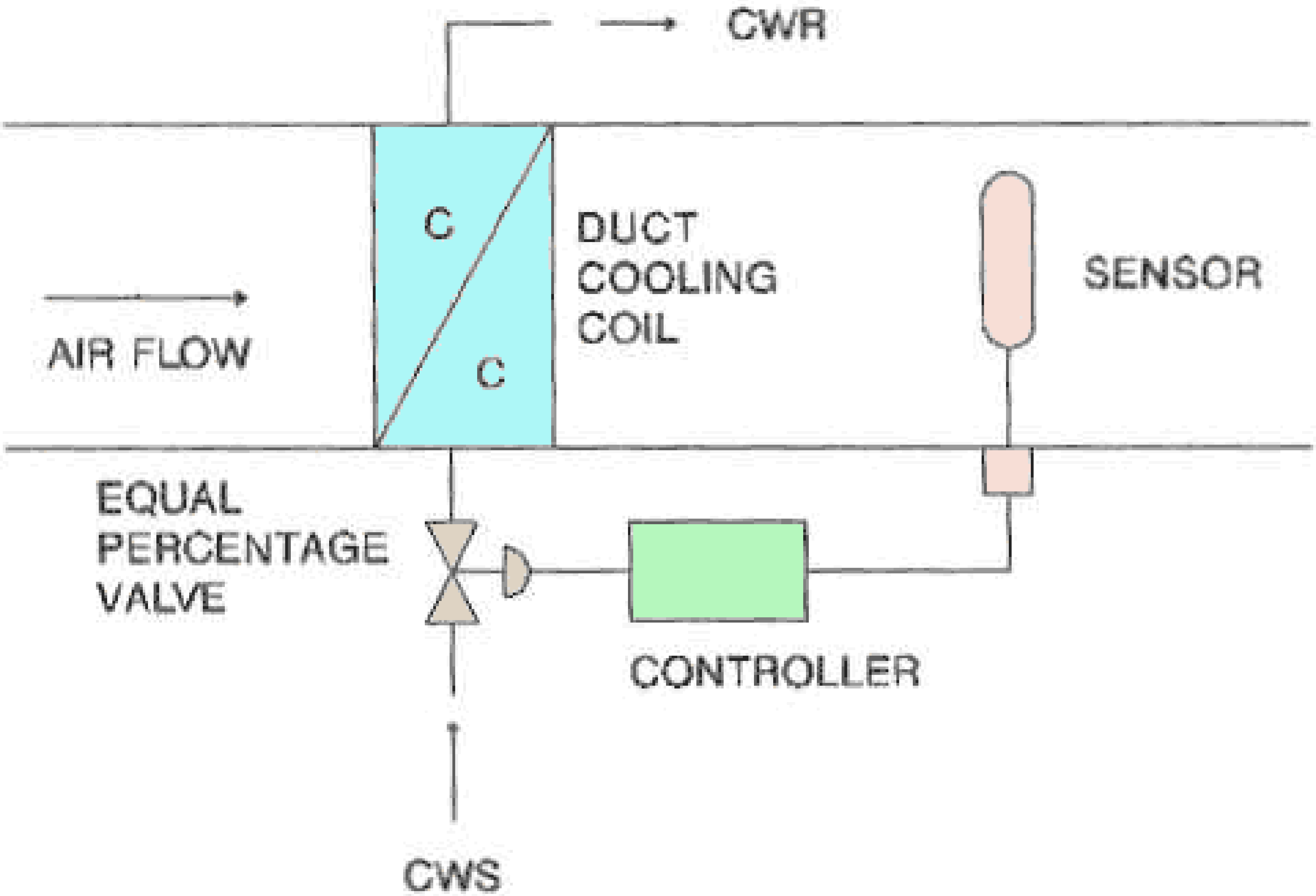
Control Fundamentals

- Control modes
  - Two position (on/off) control
  - Proportional control
  - Integral control
  - Proportional + integral (PI) control
  - Proportional + integral + derivative (PID) control

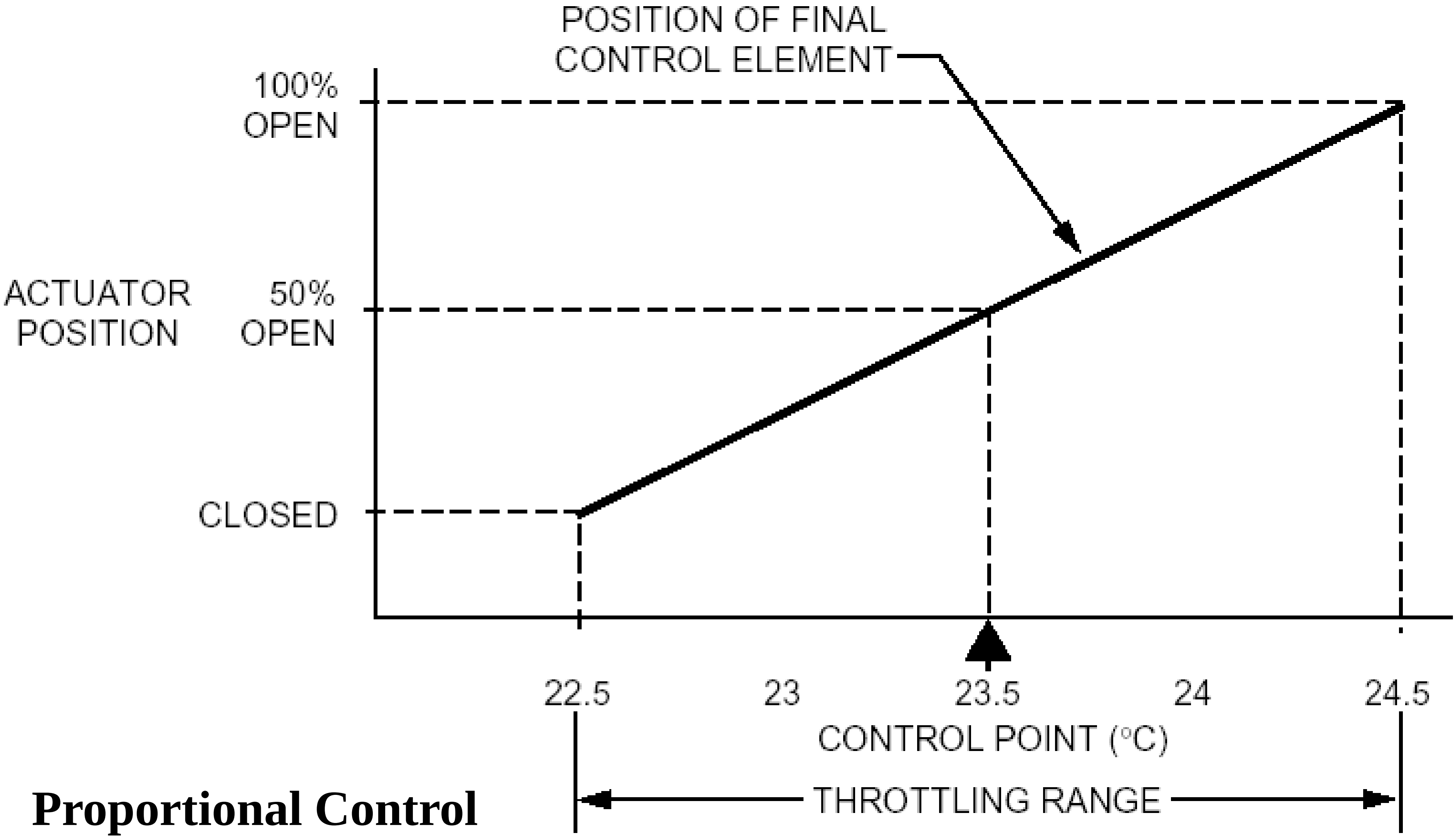
- Technical terms
  - Set points, dead band, throttling range, offset, proportional band, integral time



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

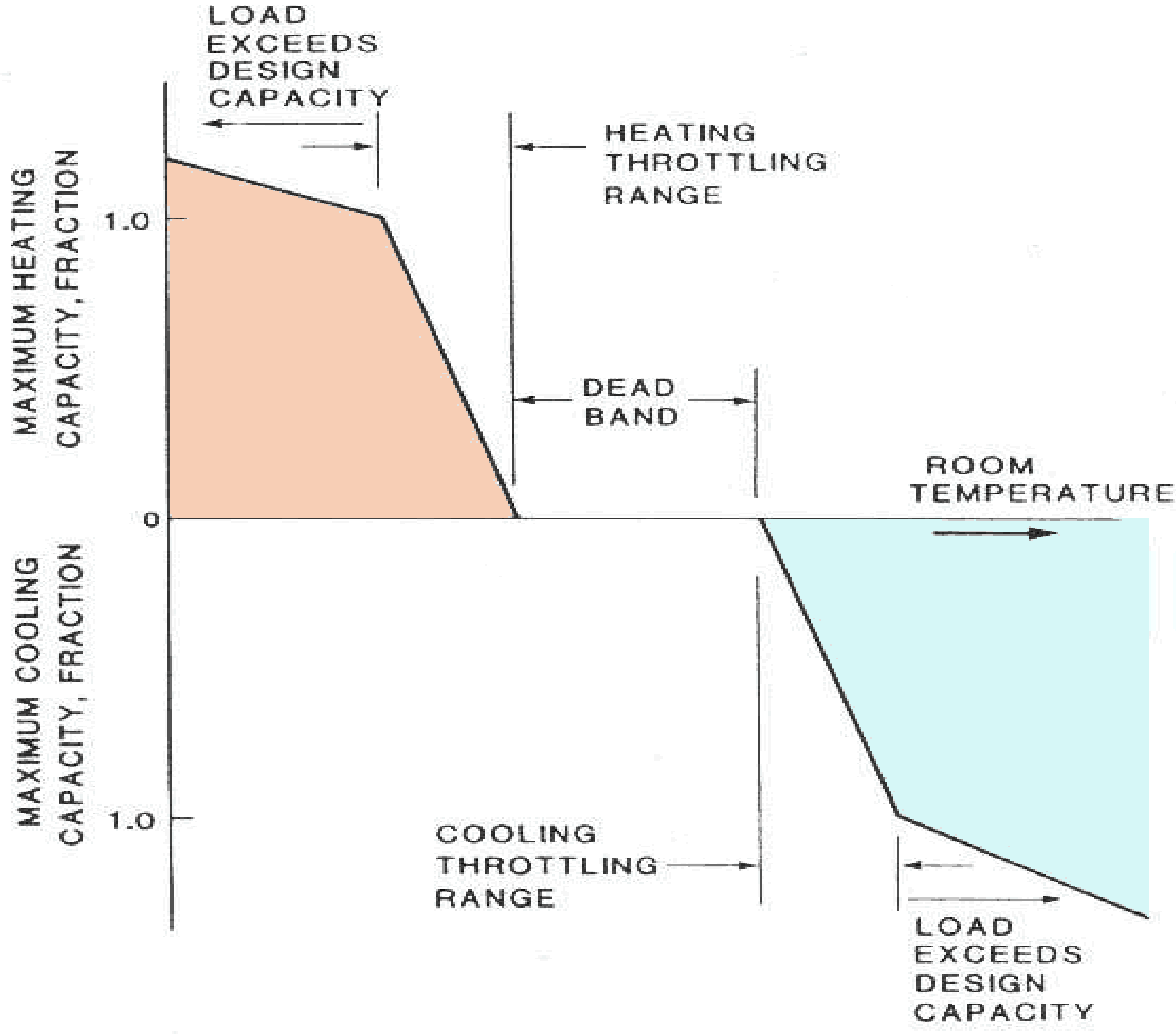


Example: Discharge air control system

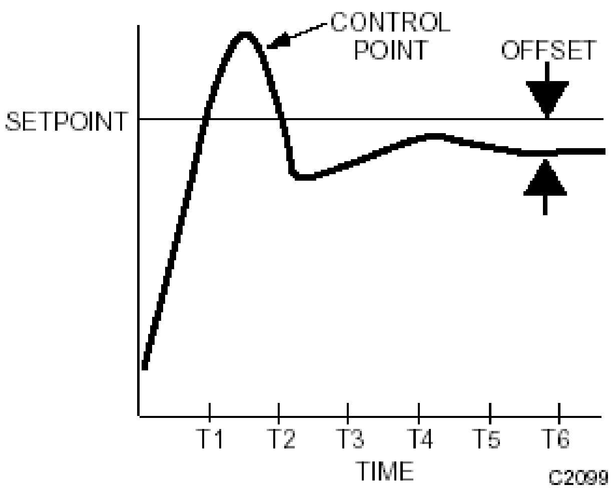


Proportional Control

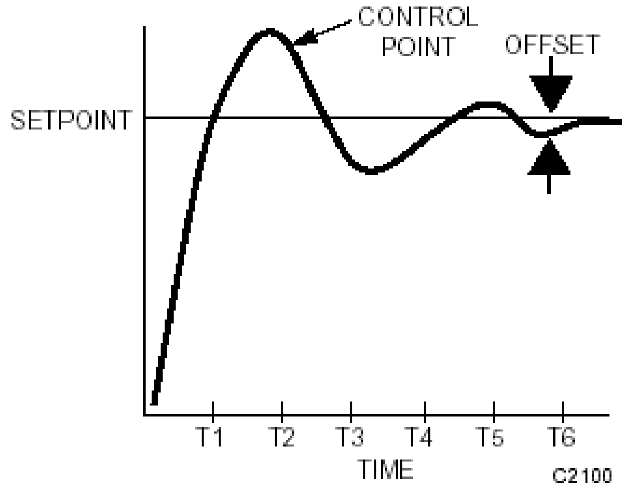
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]



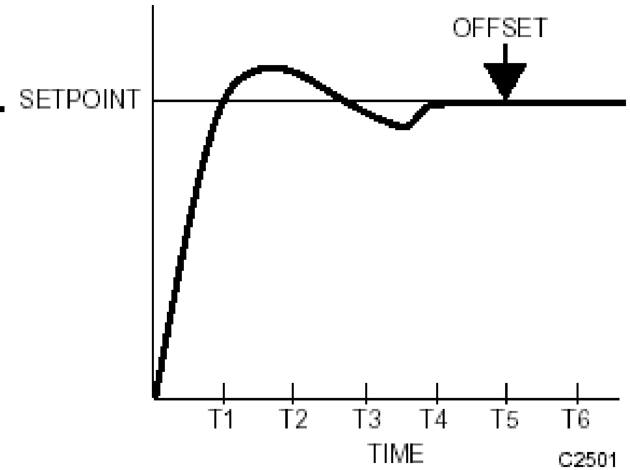
Thermostat model of proportional control with deadband and dual throttling range



Proportional Control



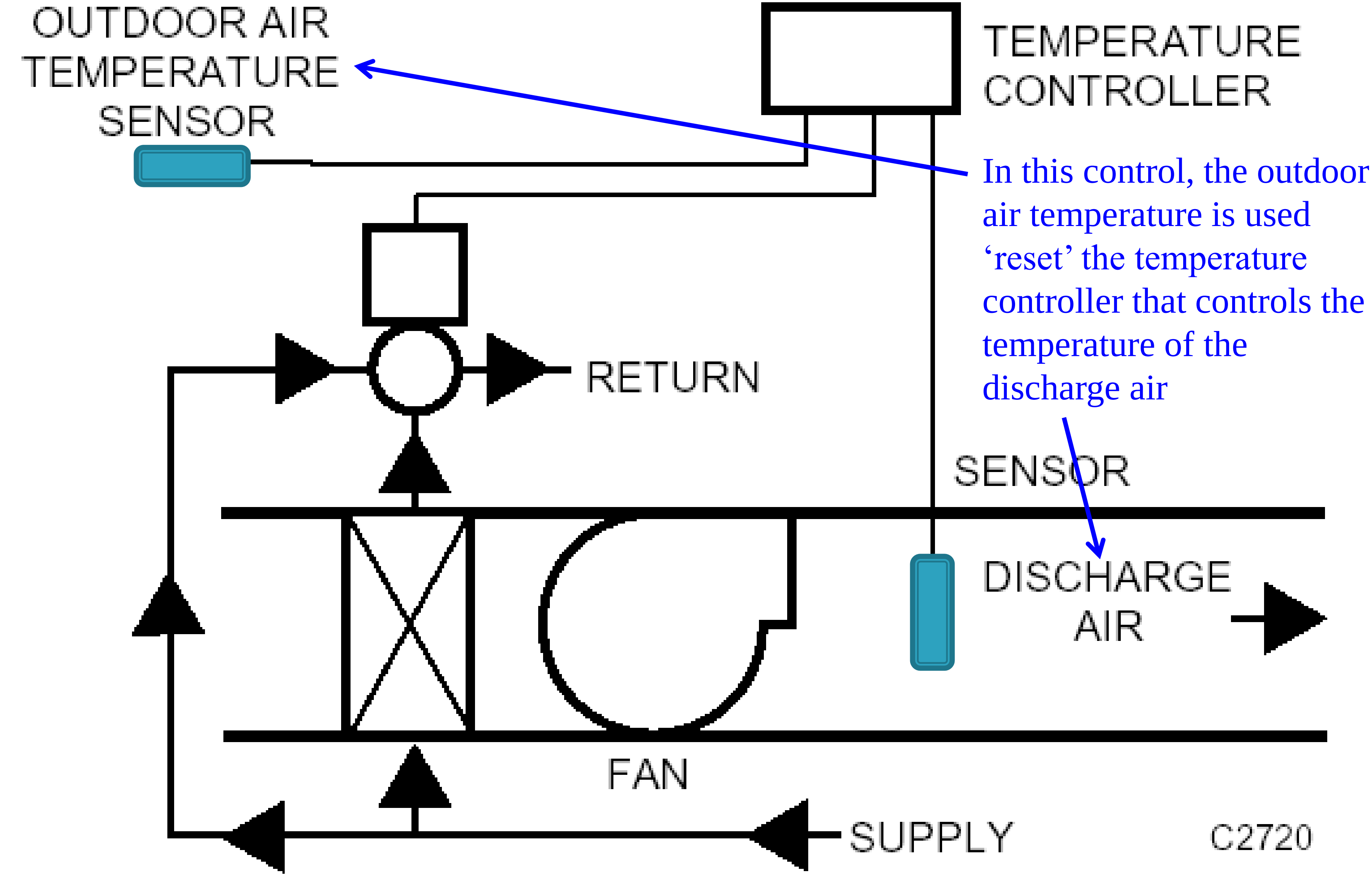
Proportional-Integral (PI) Control



Proportional-Integral-Derivative (PID) Control

$$V = \underbrace{KE}_{\text{Proportional}} + \underbrace{\frac{K}{T_1}\int E\,dt}_{\text{Integral}} + \underbrace{KT_D\frac{dE}{dt}}_{\text{Derivative}} + M$$

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



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

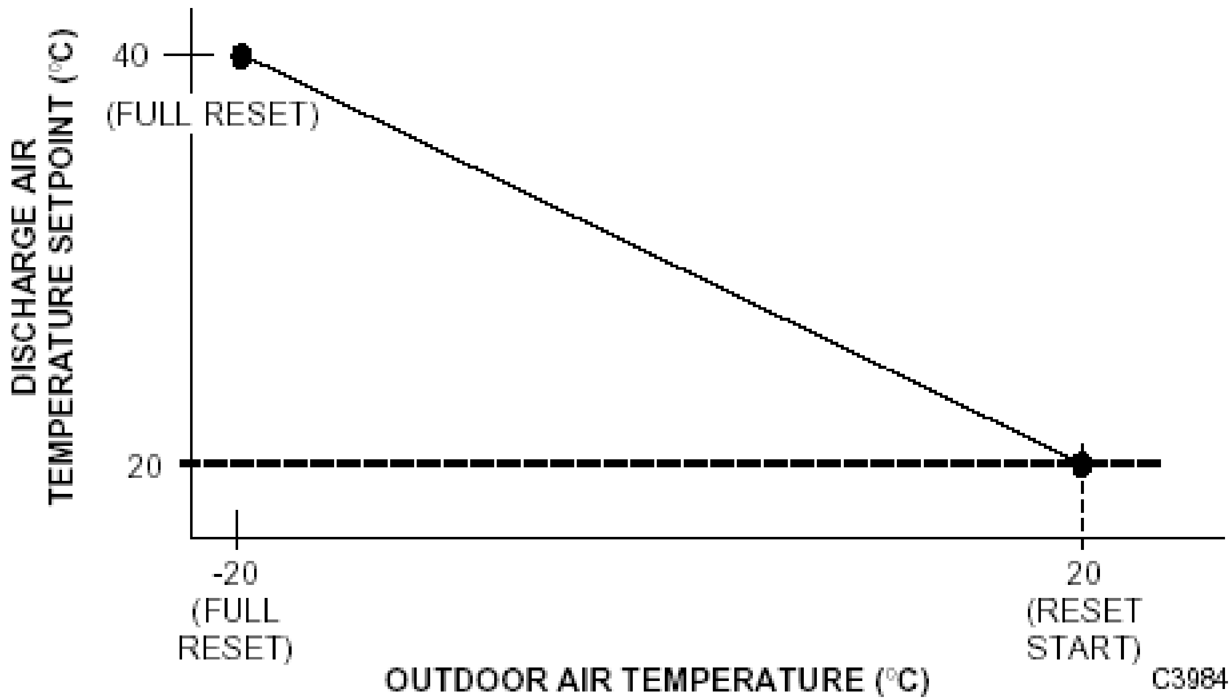


Fig. 34. Typical Reset Schedule for Discharge Air Control.

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

Control Fundamentals

- Choice of control mode
  - Degree of accuracy required; amount of offset
  - Type of load changes expected
    - Including amplitude, frequency & duration
  - System characteristics
    - Such as no. & duration of time lags, speed of response
  - Expected start-up situation
- In general, use the SIMPLEST mode

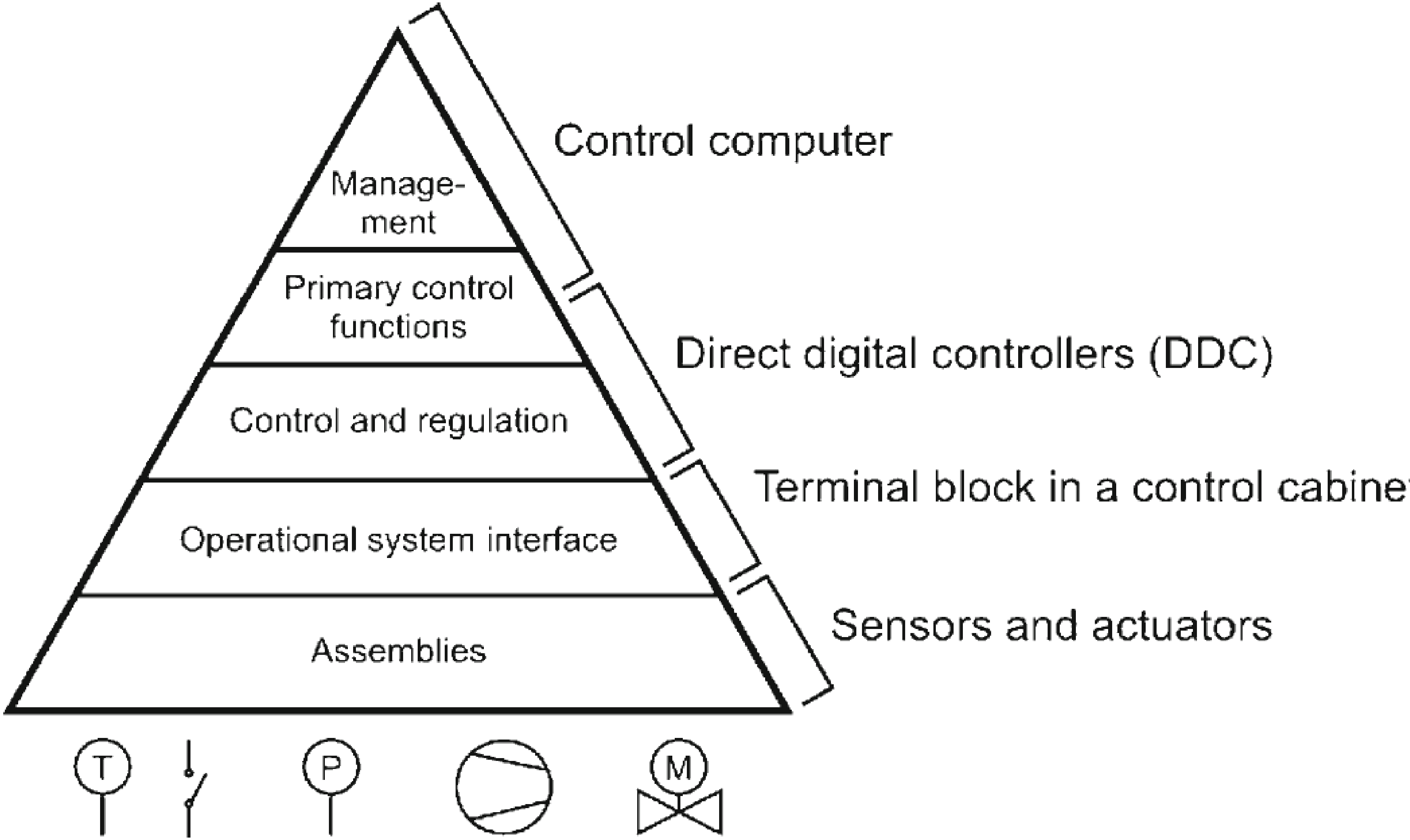
Recommended control modes for HVAC system

Application	Control mode
Space temperature	P, PID
Mixed air temperature	PI, Enhanced PID
Coil discharge temperature	PI, Enhanced PID
Chiller discharge temperature	PI, Enhanced PID
Air flow	PI (use wide proportional band & a fast reset rate), PID
Fan static pressure	PI, Enhanced PID
Humidity	P, possibly PI for tight control
Dewpoint temperature	P, possibly PI for tight control

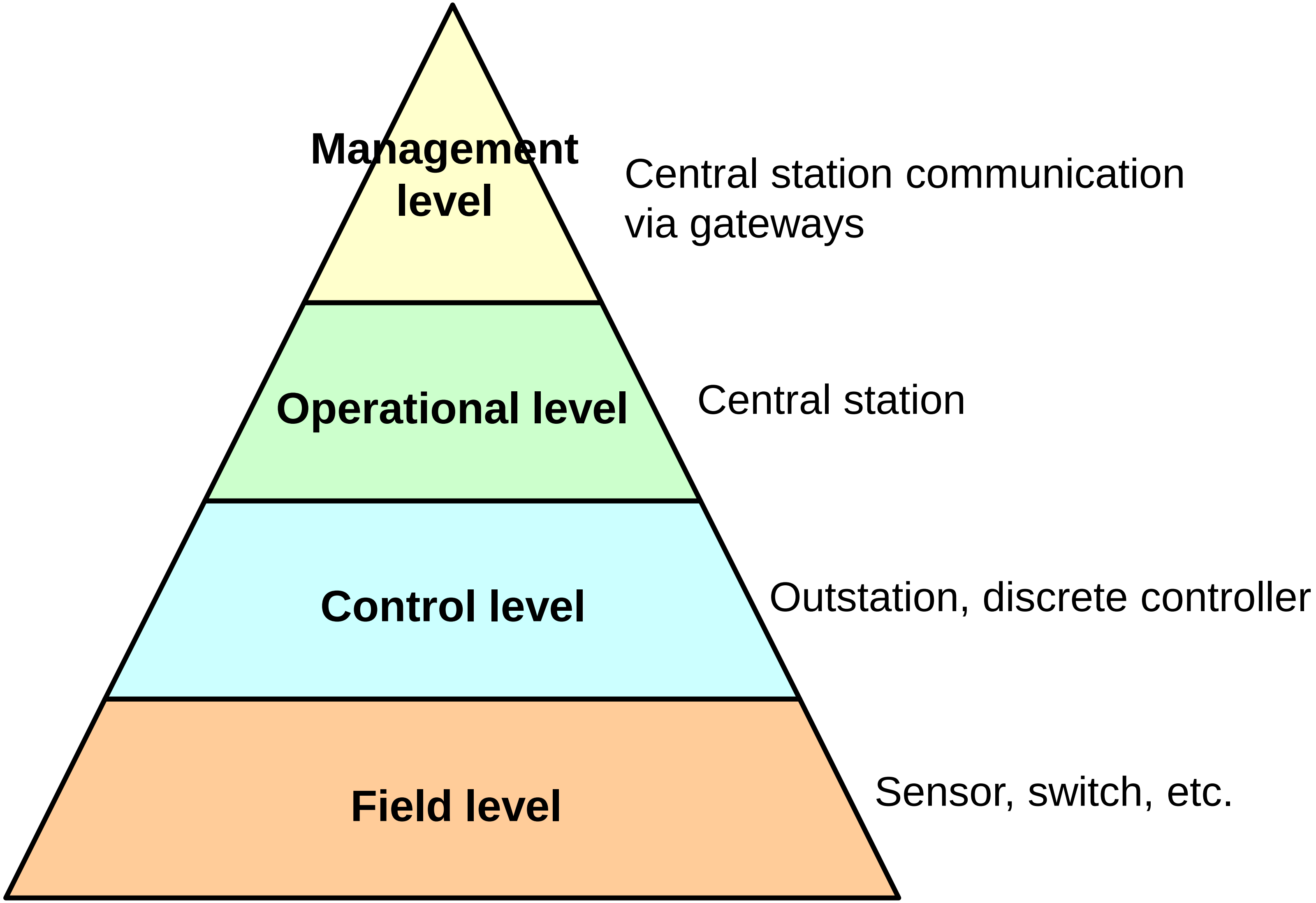
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Introduction to BAS & ECMS

- Hierarchical Structure of Building Automation

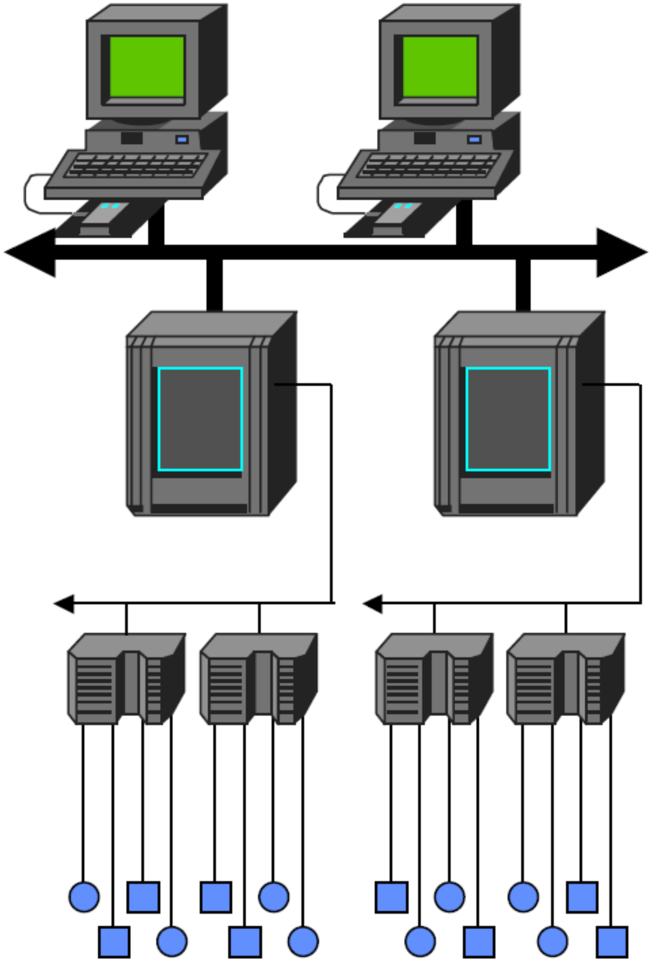


The hierarchical structure in building automation



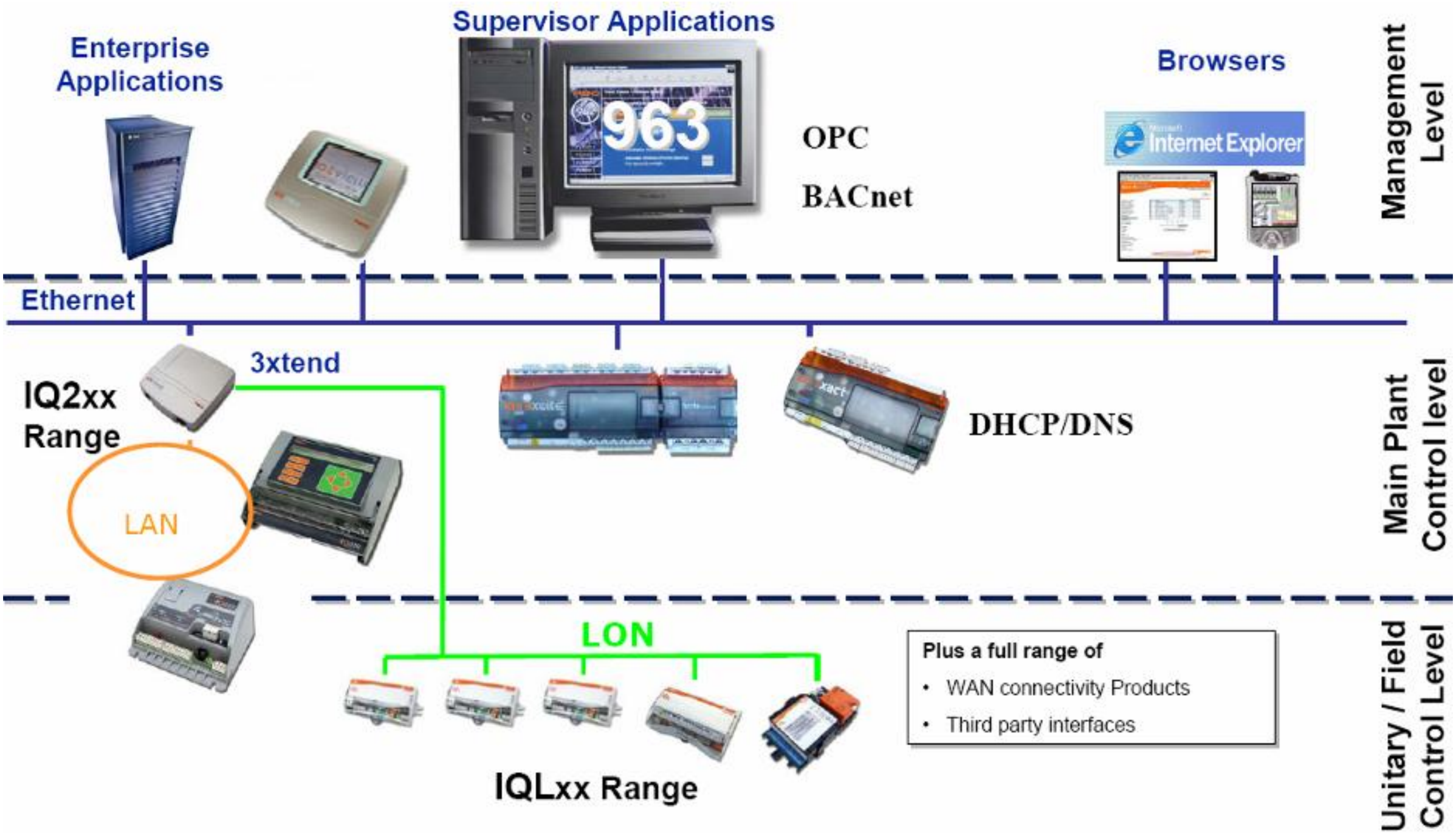
4 Levels of Control in BAS

Layers of BAS characterized by



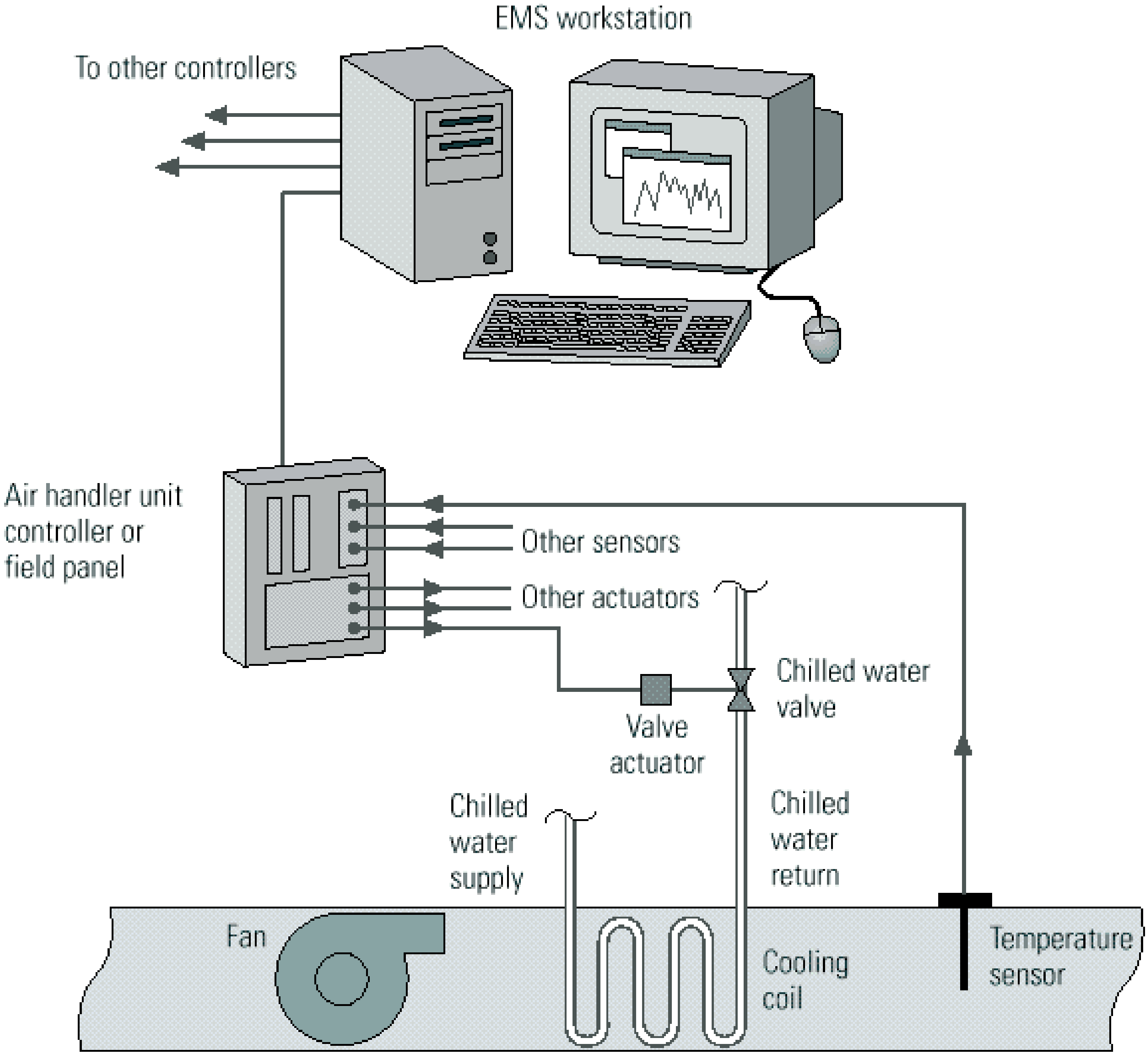
- Management Layer
  - Operator workstation
  - GUI
  - Data Archiving
- Automation Layer
  - System controller
  - Supervisory control
  - BAS features
  - Data collection
- Field Layer
  - DDC Controller
  - Connect to sensors/actuators
  - Equipment level interlocks
  - Control loops

Layers defined by European Standardization Committee



Example of system architecture for building management system

[Source: Trend Control Systems]


EMS workstation
To other controllers
Air handler unit
controller or
field panel
Other sensors
Other actuators
Chilled water
valve
Valve
actuator
Chilled
water
supply
Chilled
water
return
Fan
Cooling
coil
Temperature
sensor

Disadvantages of missing layers

- Combining the field layer and the automation layer result in a system with poor fault tolerance
  - each controller to connect to a large number of points
- Combining the automation layer and the management layer reduces system reliability and limits the expandability of system
- BAS with collapsed architectures (i.e. two layers) should only be considered for very small systems

Typical procedure for a BEMS project

- Initial concept
- Information retrieval
- Candidate buildings & system selection
- Field survey
- Design (sometimes in a performance based specification for design and built)
- Prepare contract documents
- Tendering
- Contract
- Installation & training
- Acceptance
- Operation & maintenance

BEMS system design are usually carried out by consultants, control companies & HVAC contractors