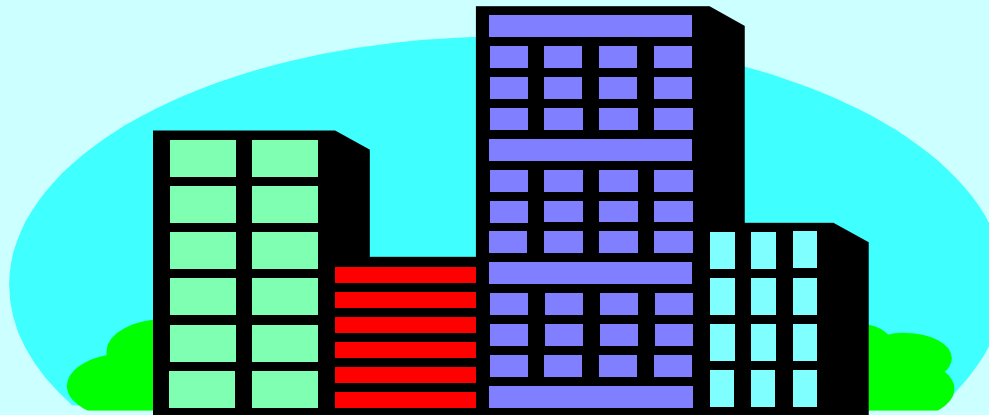


# MEBS6006 Environmental Services I

<http://www.hku.hk/bse/MEBS6006/>



## Introduction

*Dr. Benjamin P.L. Ho*

Department of Mechanical Engineering

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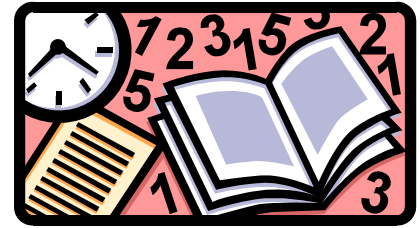
Rm. 5-28 Haking Wong Building

E-mail: [benjamin.ho@hku.hk](mailto:benjamin.ho@hku.hk)



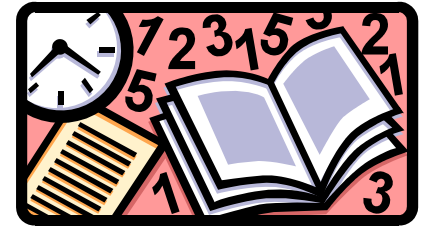
Sep 2011

# Background



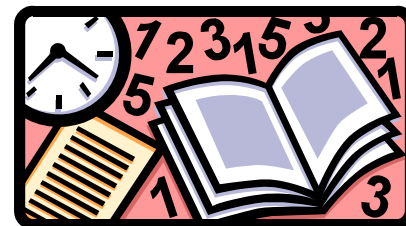
- MEBS6006 Environmental Services I
  - Educational Objectives
    - To enable students to understand the basic principles of design and operation of heating, ventilating, air-conditioning and refrigerating (HVAC&R) systems for environmental control of buildings
    - To enable students to design and select proper HVAC&R systems to serve the desired purpose

# Background

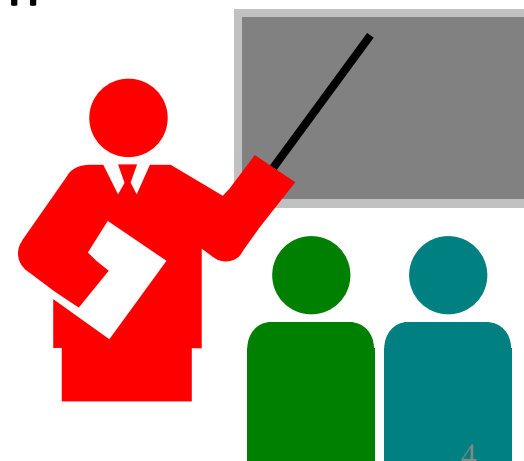


- MEBS6006 Environmental Services I
  - Learning Outcomes:
    - To explain the fundamental principles of HVAC&R systems for environmental control of buildings.
    - To develop skills for design and selection of HVAC&R systems.
  - Assessment: 100% by examination

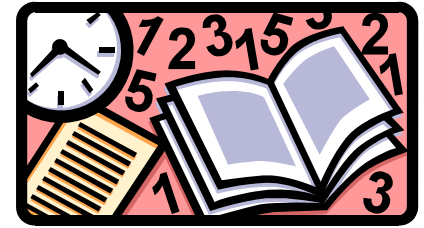
# Background



- These two courses are related
  - MEBS6006 Environmental services I (offered in 2011/12 first semester)
    - Basic principles of HVACR
    - Practical design skills
  - MEBS6008 Environmental services II (offered in 2012/13)
    - System characteristics and operation
    - Analysis and design strategies
- If possible, should study both



# Background



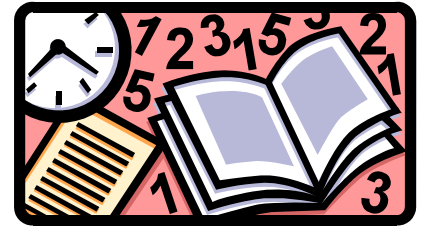
- Study topics of MEBS6006:

- Introduction
- Advanced psychrometry
- Thermal comfort
- Load estimation
- Energy calculations
- Cooling system
- Heating and ventilation system
- Air side system
- Water side system
- Refrigeration

Elementary

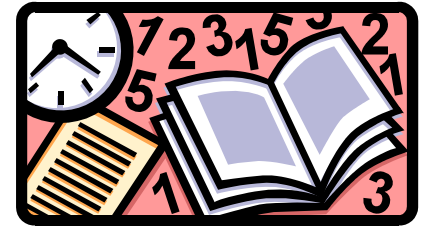
System

# Background

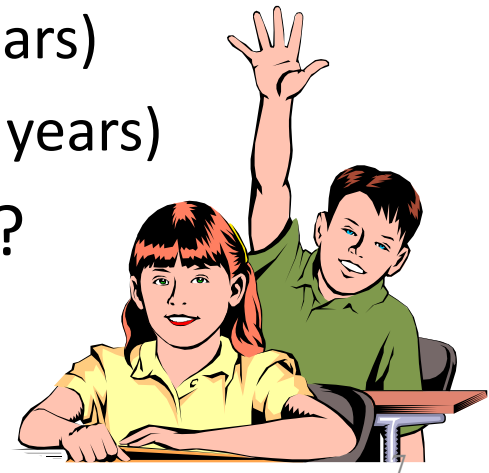


- Assumptions
  - You have basic knowledge of thermodynamics and fluid mechanics
  - You are interested in developing your knowledge and skills in HVAC  
(**H**VAC stands for Heating, Ventilation and Air-Conditioning)
- Focus of this course
  - From basic principles to intermittent level of HVAC design skills
  - Main focus on cooling design and air conditioning

# Background



- Your experience and expectation
  - Raise your hand if you have:
    - Very little knowledge of HVAC
    - Some knowledge of HVAC (e.g. attend courses before)
    - Certain design experience of HVAC (1-3 years)
    - Good design experience of HVAC (4-8 years)
    - Excellent knowledge & experience (> 10 years)
  - What do you expect from this course?
    - Knowledge? Practical design skills?

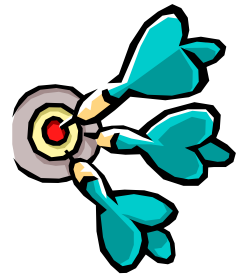


# What is Environmental Services?



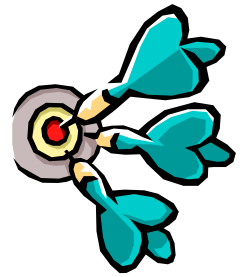


# Environmental Services

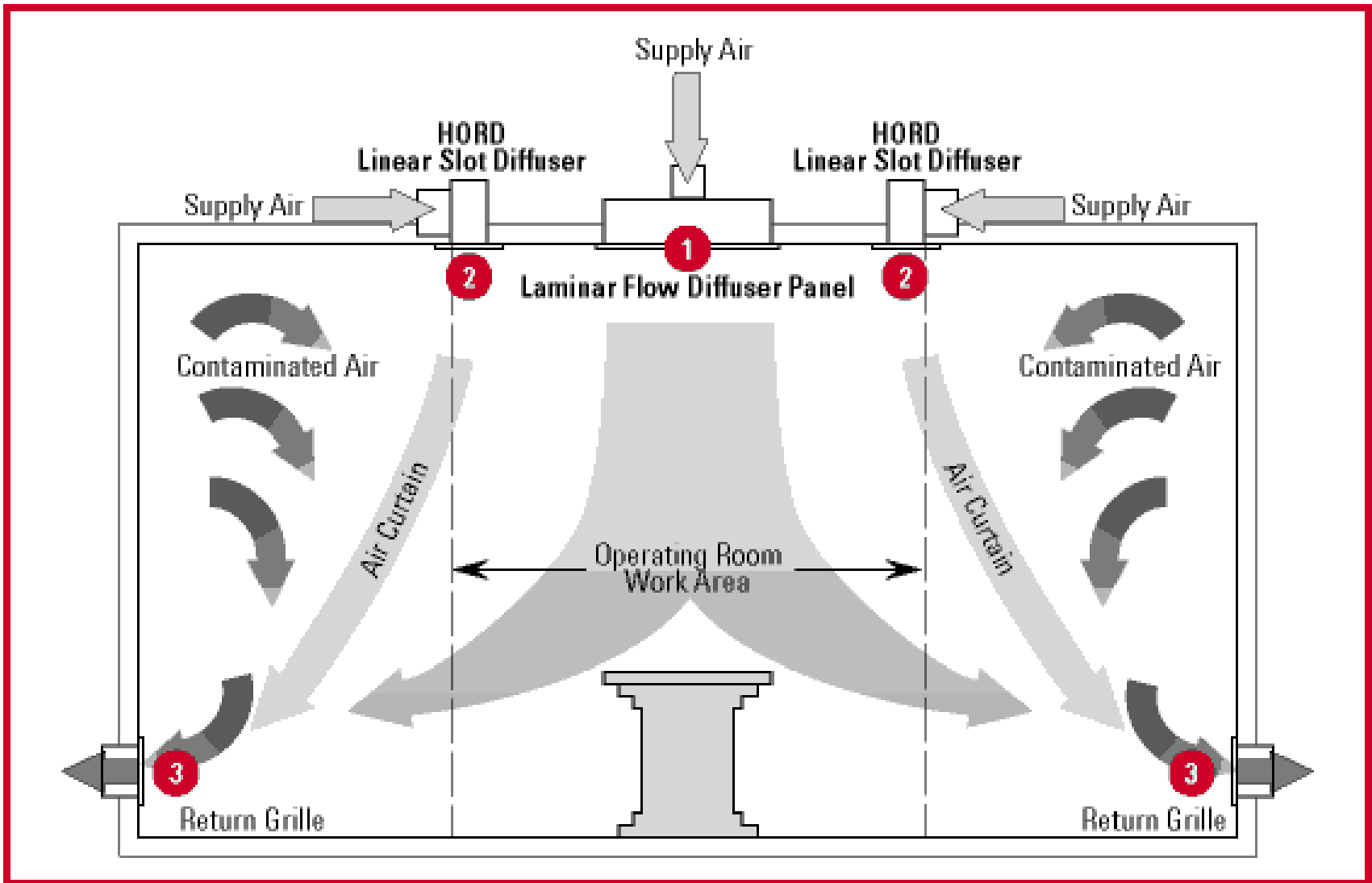


- They are the engineering systems that help to control and maintain the conditions of indoor built environment (in this course, thermal environment is referred to)  
(What is Built Environment? Taking the course MEBS6004 in 2<sup>nd</sup> Semester will let you know more...)
- They are also known as
  - Environmental control systems (ECS)
  - Heating, ventilating, air-conditioning and refrigerating (HVAC&R) systems
  - Heating, ventilating and air-conditioning (HVAC)
  - Mechanical ventilating and air-conditioning (MVAC)
  - Air conditioning and refrigeration (AC&R)

# Environmental Services

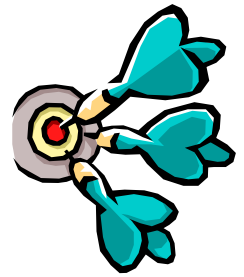


- Importance of HVAC for environmental control in buildings
  - Affect occupant satisfaction, productivity, health and safety
  - Contribute to effective building performance
  - Often form a major part of building construction costs and running costs
  - Affect energy consumption & environmental performance of a building



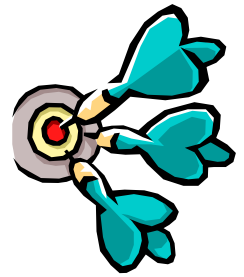
Hospital operating theatre (laminar flow with air curtains)

# Environmental Services



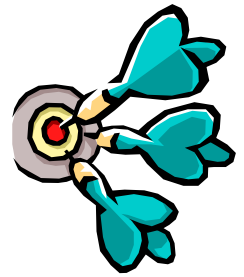
- Practical design strategy: integrated approach
  - AIM to meet the requirements of the people & processes without being excessive & wasteful
    - Energy efficiency, technically & economically sound
  - LINK with the design of building fabric (architectural and structural) to maximize passive design potential
  - BASED on clear understanding of the building, client and end-user needs
  - FOLLOWED by effective commissioning, handover and building management

# Environmental Services



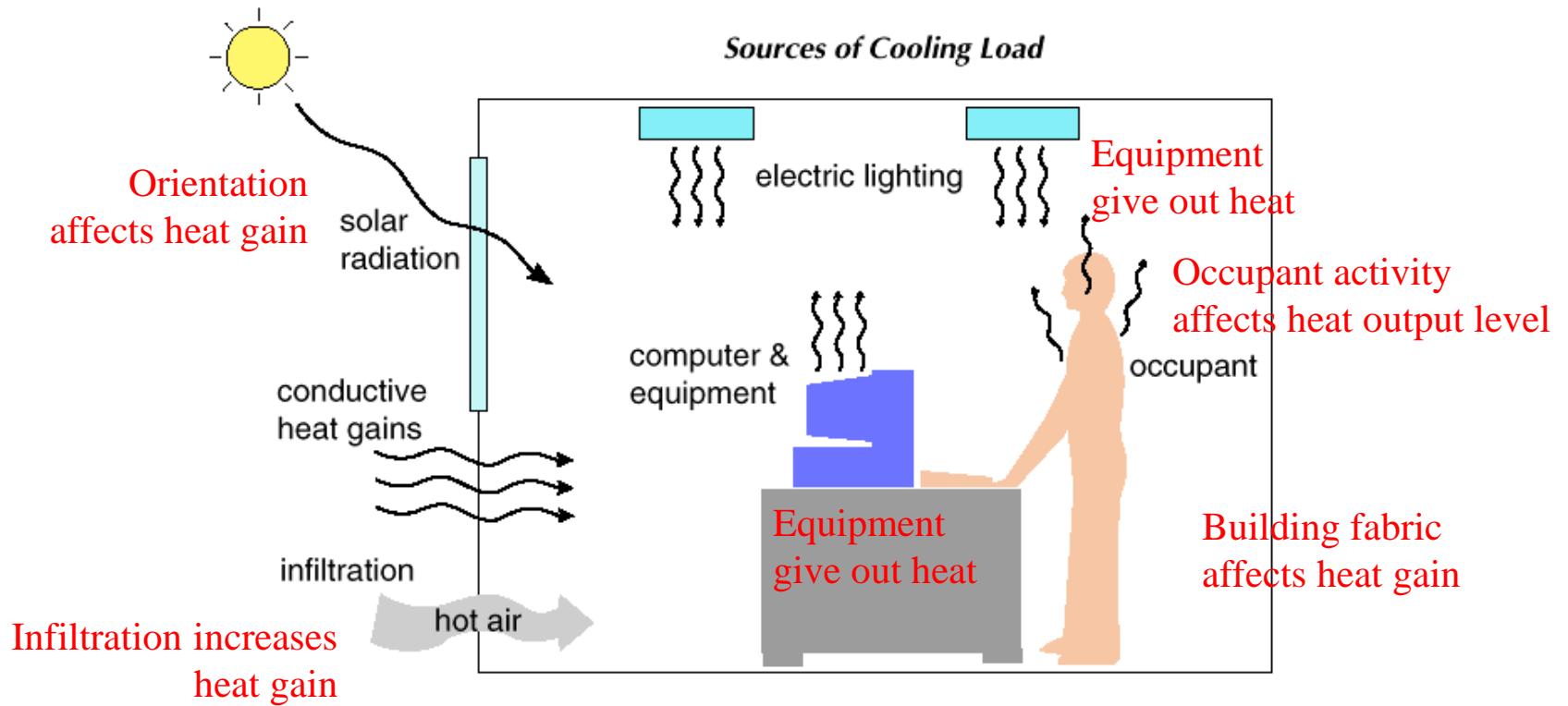
- Establish key performance requirements, e.g.
  - Demands of building occupants & activities
  - Reliability, adaptability & flexibility
  - Maintenance requirements
  - Control quality & complexity
  - Aesthetics, time constraints & security
  - Investment criteria & whole life cycle costs
  - Energy/environmental targets
  - Indoor environmental standards

# Environmental Services

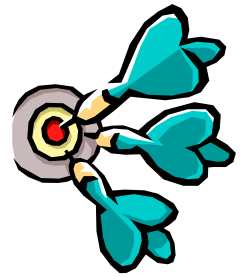


- Interactions

- Building fabric (architectural / structural design)
  - Site orientation & conditions
  - Built form, shading, window performance, thermal mass
  - Thermal insulation, reducing infiltration/air leakage
- Building services elements, e.g.
  - Lighting system & use of daylighting
  - Small power or equipment loads
- Occupants' behavior (human factors)
  - How users behave and react

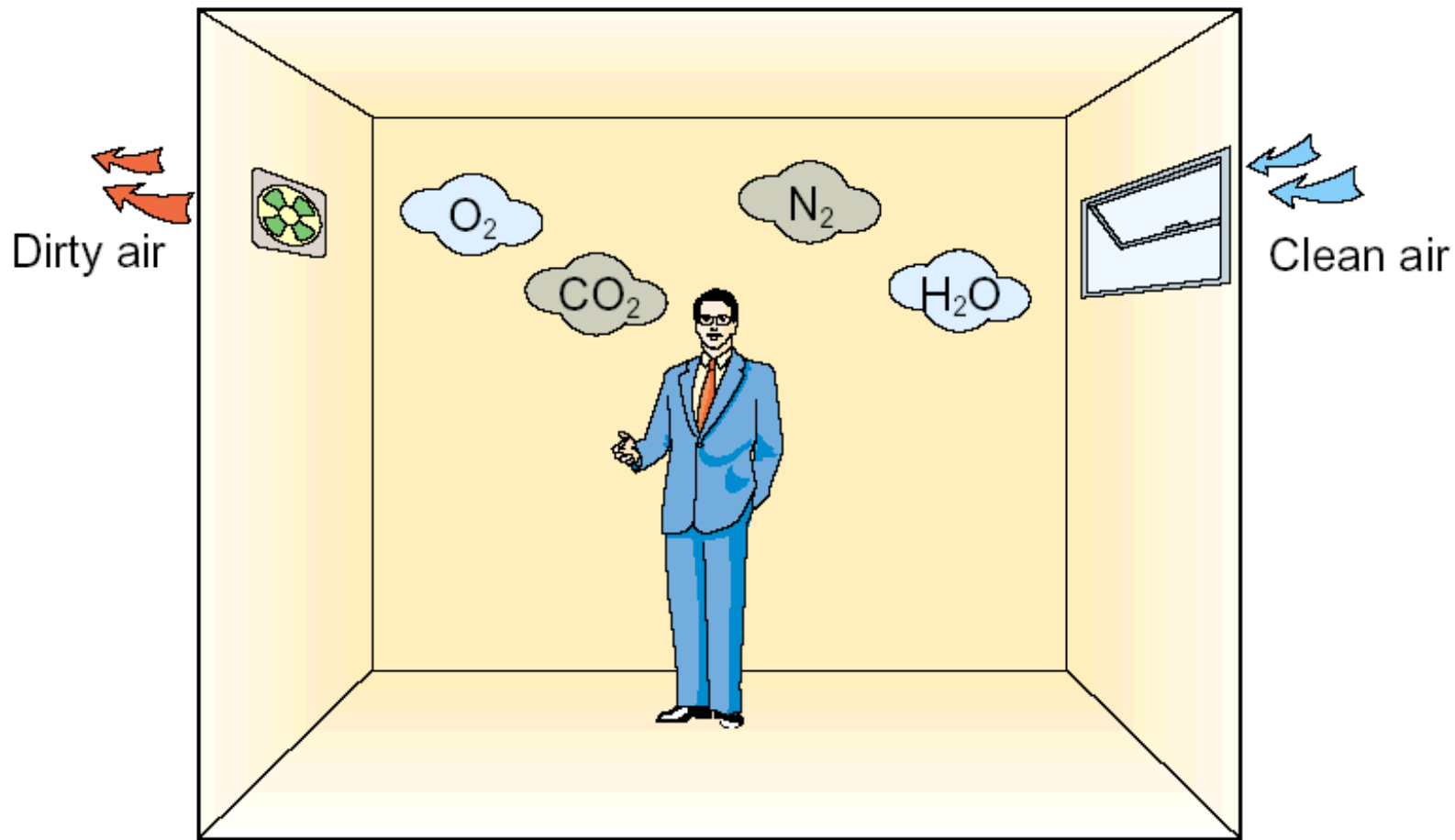


# Environmental Services

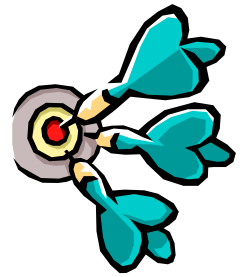


- Understand the purpose of the design
  - To add/remove heat & maintain thermal comfort
  - To control humidity & prevent condensation
  - To provide adequate ventilation for processes
  - To provide adequate indoor air quality by removing and/or diluting indoor pollutants
- Understand the climate
  - Summer: cooling design & dehumidification
  - Winter: heating design & humidification

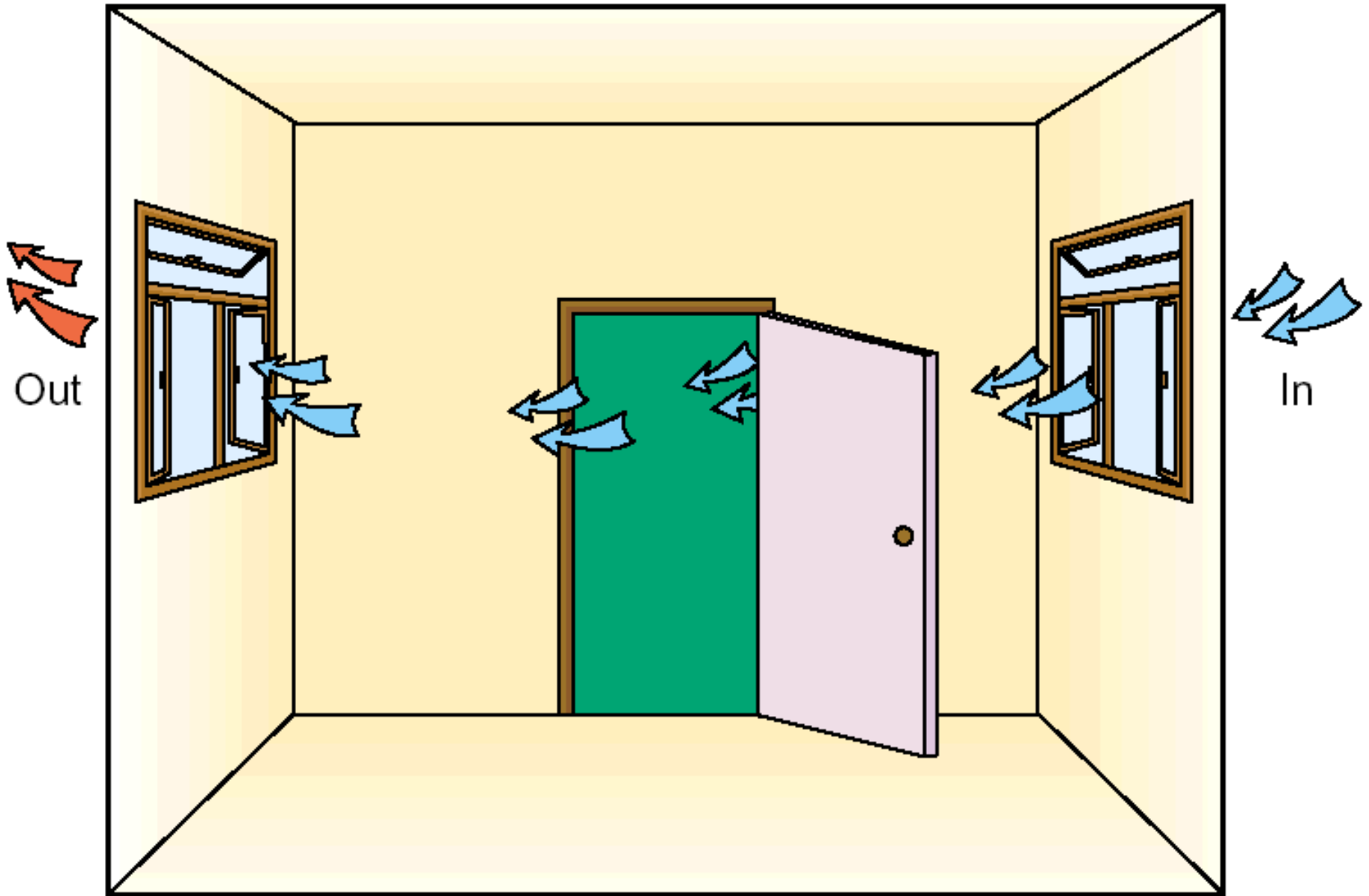




# Environmental Services



- Common ventilation strategies
  - Natural ventilation
  - Mechanical ventilation
  - Comfort cooling
  - Air conditioning (full control of temp./humidity)
  - Mixed mode or hybrid systems
- Further information:
  - *CIBSE Guide B2: Ventilation and Air Conditioning*, Chapter 2

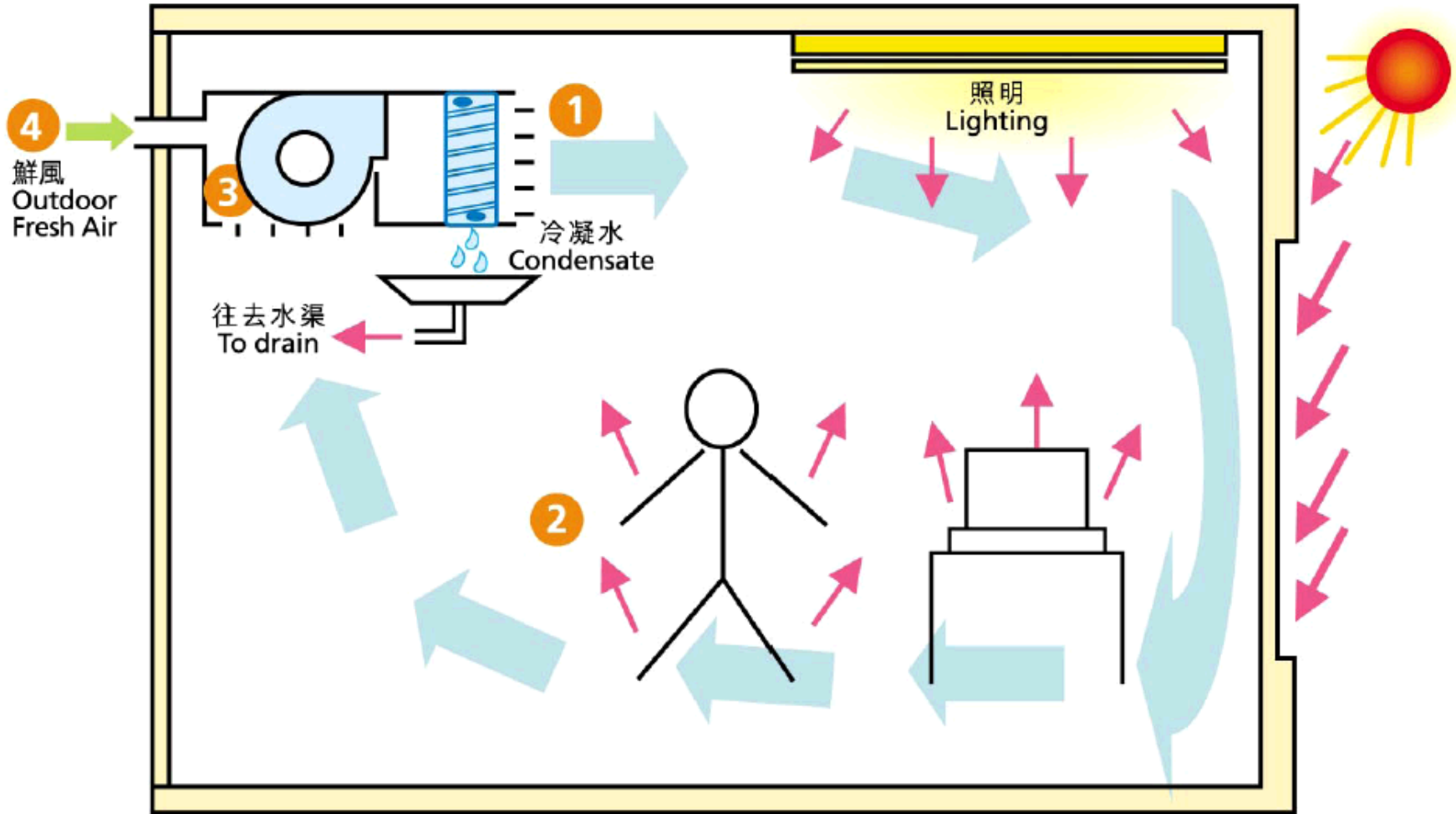


## Cross ventilation

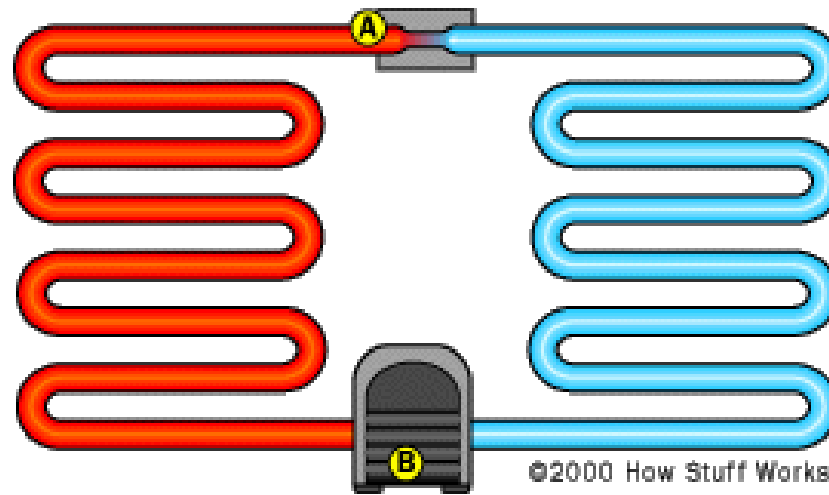
(Source: [www.iaq.hk](http://www.iaq.hk))



冷卻盤管具冷卻及抽濕功效  
Cooling Coil for Cooling & Dehumidification

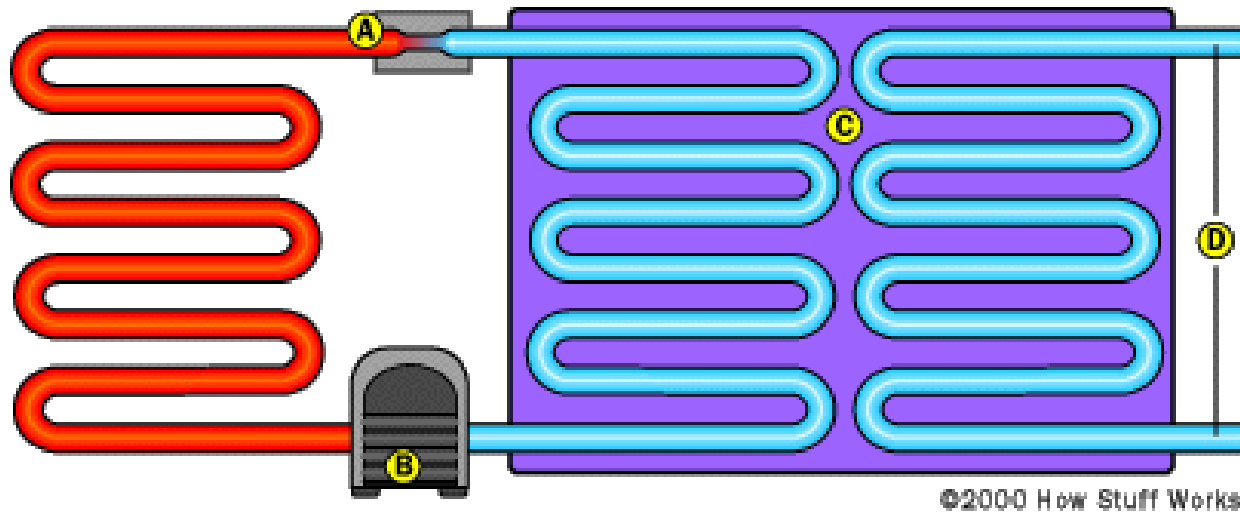


Refrigerant cycle



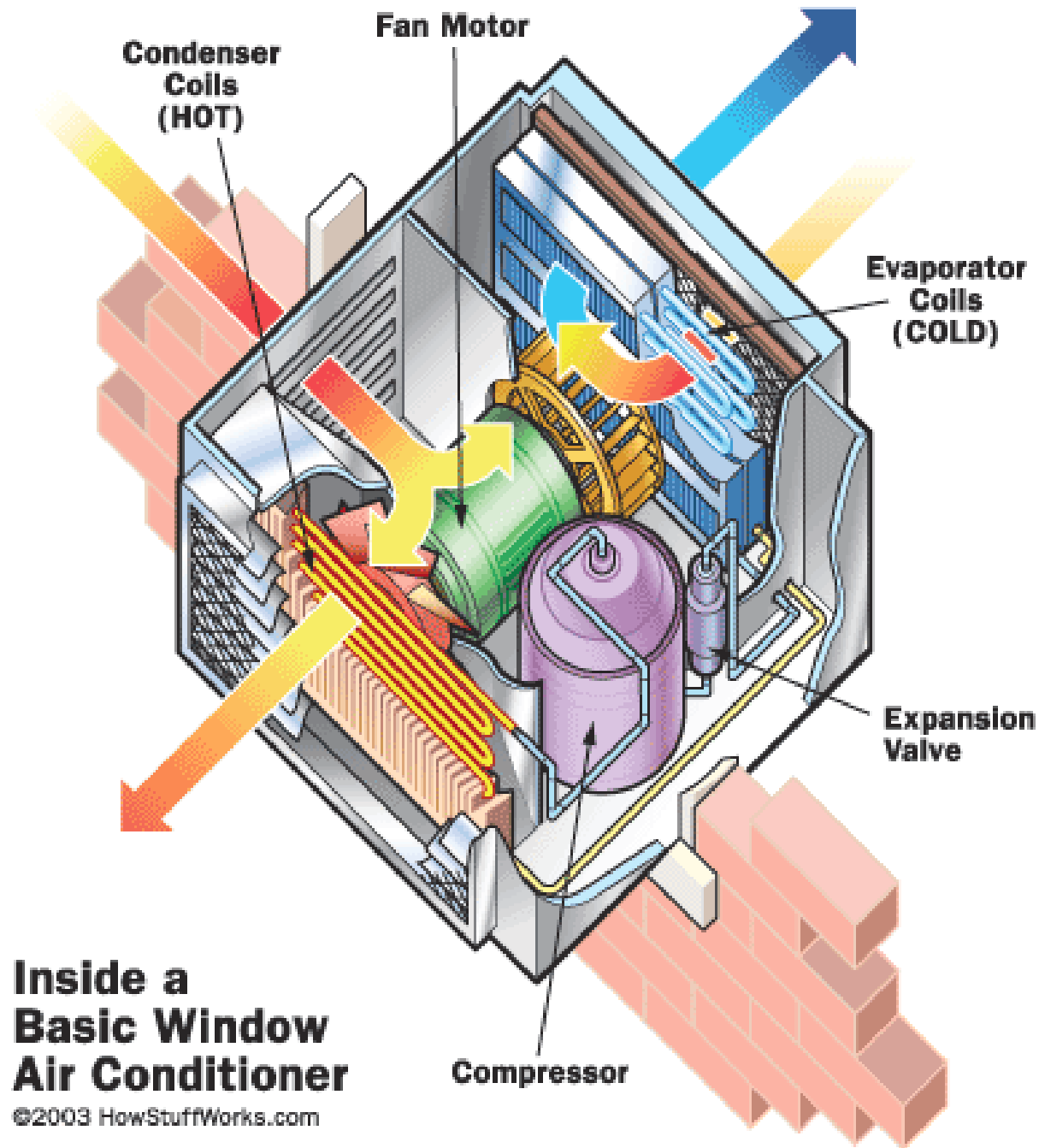
What are the major components?

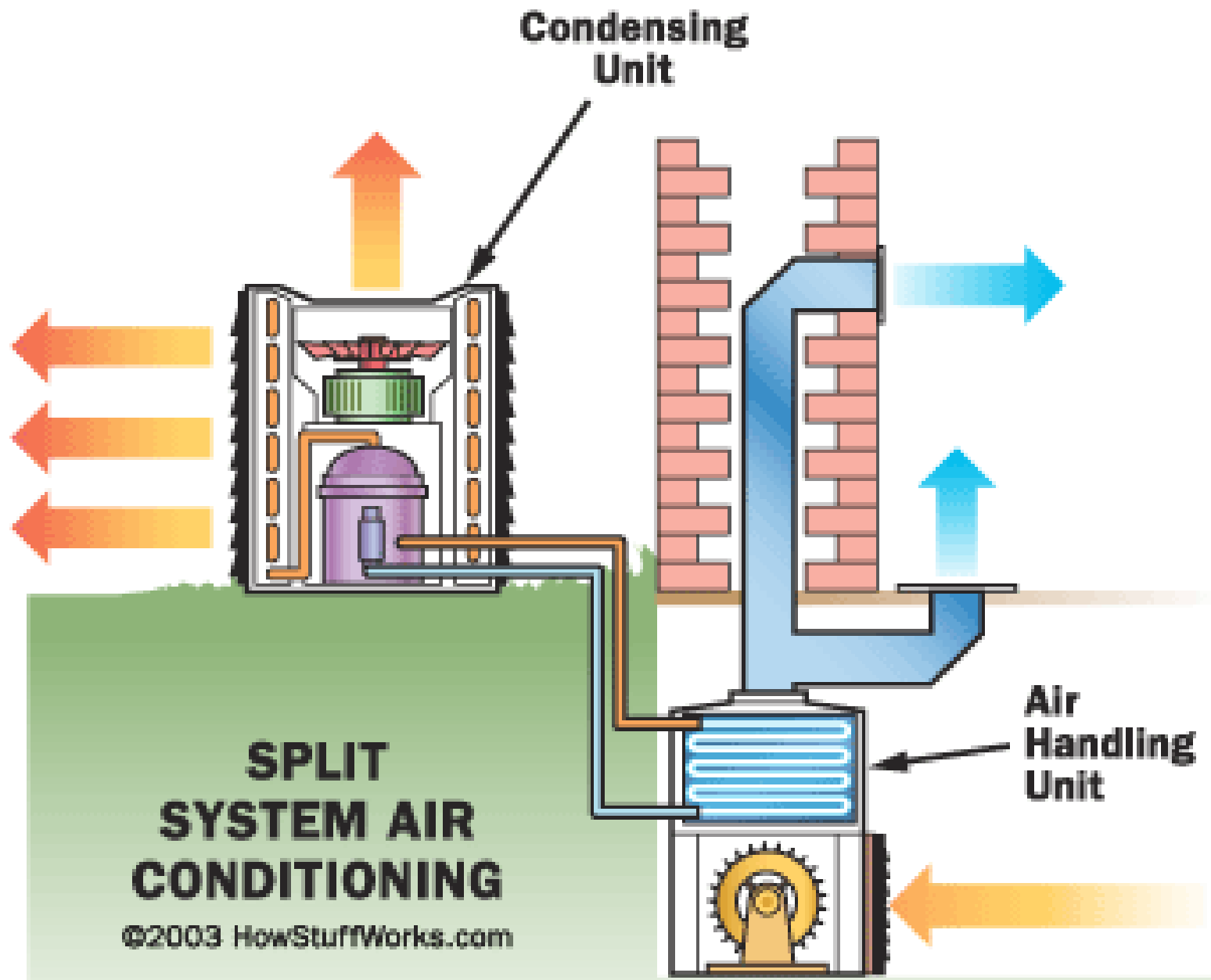
A typical air conditioner



Chilled water system

Air conditioning with a chilled water system





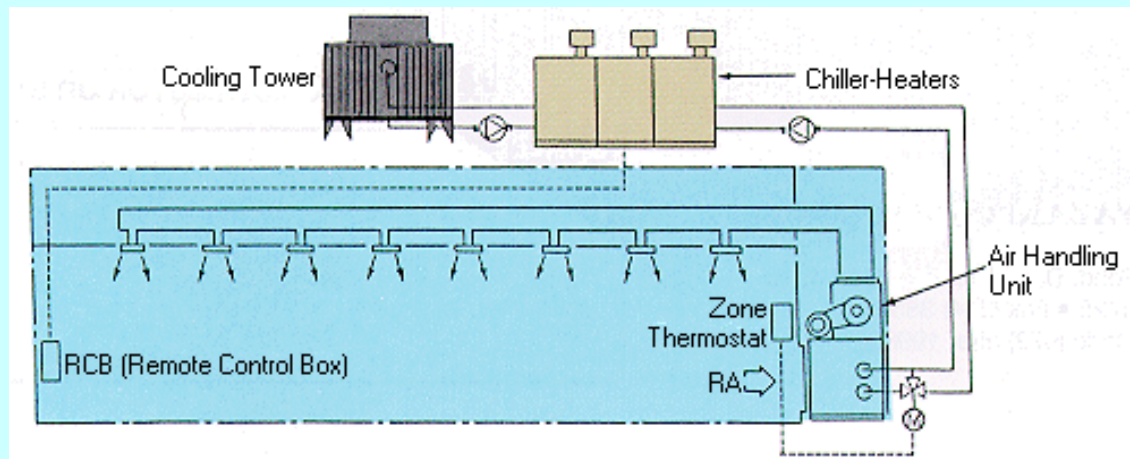
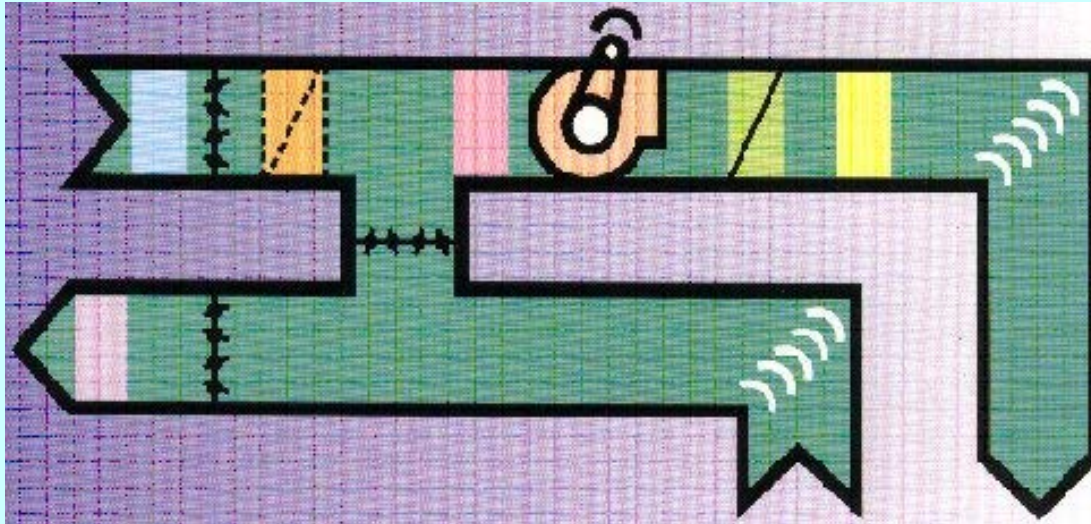
**SPLIT  
SYSTEM AIR  
CONDITIONING**

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(Source: [www.howstuffworks.com/ac.htm](http://www.howstuffworks.com/ac.htm))



# Air Conditioning



# Air Conditioning



- Definition (from ASHRAE\*)
  - Air conditioning is the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space.
    - Basic processes: Cooling and Heating
- Comfort air conditioning
  - To meet comfort requirements of occupants

# Air Conditioning



- Applications of air conditioning:
  - Air conditioning for industrial processes
    - e.g. textile mills, electronics, pharmaceutical
  - Air conditioning of commercial buildings
    - e.g. offices, hotels, retails
  - Residential air conditioning
  - Air conditioning of vehicles (buses, cars, trains, aircrafts, etc.)

# Air Conditioning



- Air Conditioning and Refrigeration
  - No. 10 on the list of the [Greatest Engineering Achievements of the 20th Century]
  - <http://www.greatachievements.org>
    - These cooling technologies have altered some of our most fundamental patterns of living
    - Buildings are climate-controlled & comfortable
    - Fresh foods & milk are kept in refrigerators/freezers
    - Building designs are changed completely
    - Environment for industrial processes are controlled

# Air Conditioning

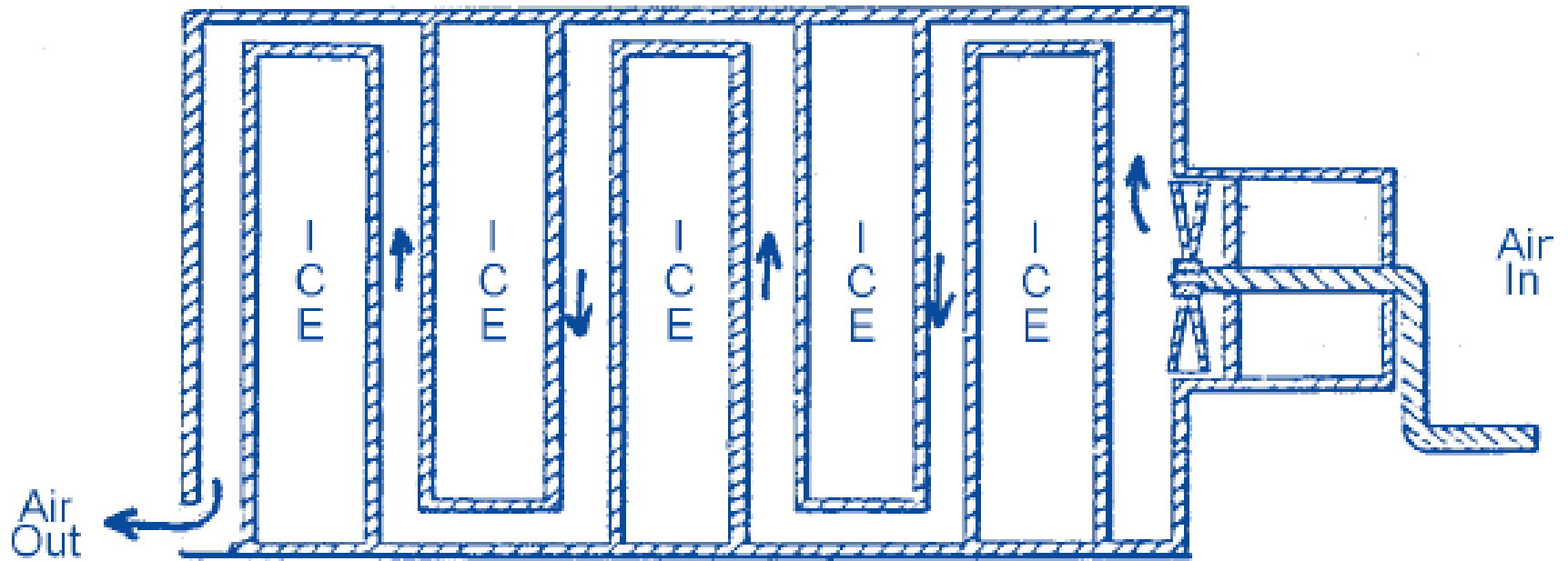


- The History of Air Conditioning

- [www.air-conditioners-and-heaters.com/air\\_conditioning\\_history.htm](http://www.air-conditioners-and-heaters.com/air_conditioning_history.htm)



- 1830: Dr. John Gorrie (ice for cooling hospital rooms)
    - 1881: James Garfield (device w/ melted ice water)
    - Late 19<sup>th</sup> century: “manufactured air” (controlling humidity in textile mills)
    - Early 1900s’: Willis Carrier (designed modern A/C systems for offices, apartments, hotels, hospitals)
    - 1917-1930: movie theatres were kept cool by A/C



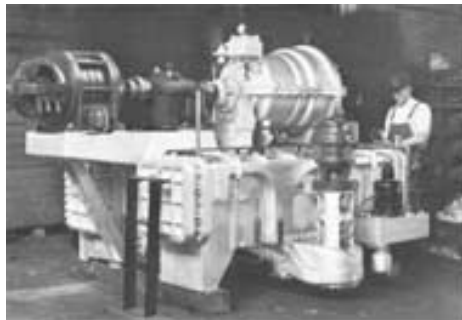
*Figure 1: Shaler's patented cooler for ventilating air, 1865.*

# Air Conditioning



- The Father of Modern Air Conditioning
  - Dr. Willis Haviland Carrier (1875-1950)

- Formed Carrier Air Conditioning Company (1907)
- Published a paper on rational psychrometric formulae in 1911
- Invented and patented many HVAC equipment
- Wrote a well-known air conditioning textbook



# Air Conditioning



- Importance of air conditioning for buildings
  - Change building designs & human adaptation
  - Affect occupant satisfaction, productivity, health and safety
  - Contribute to effective building performance
  - Often form a major part of building construction costs and running costs
  - Affect energy consumption & environmental performance of a building



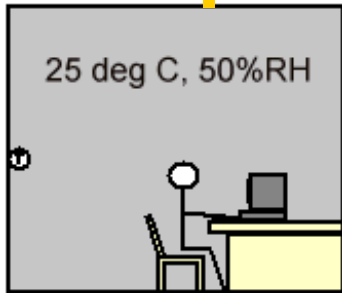
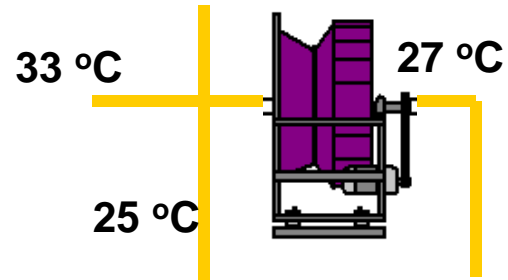
# Air Conditioning



- To understand better, air conditioning system can be divided into five subsystems or loops:
  - Air-side system
  - Chilled water system
  - Refrigeration equipment
  - Heat rejection
  - Controls



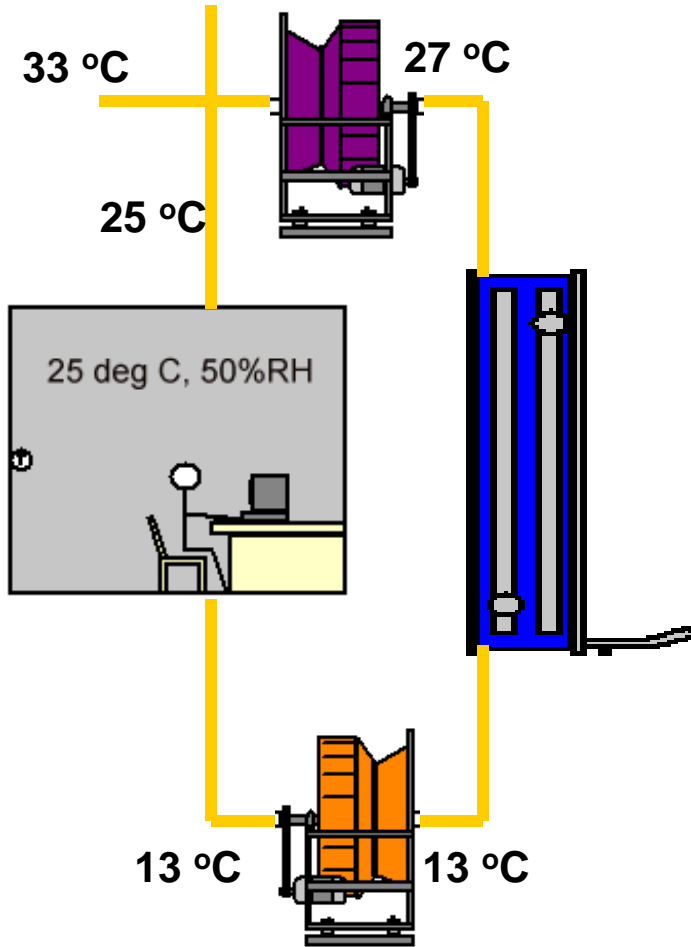
33 °C, 28 °C



Conditioned space



33 °C, 28 °C



In this process

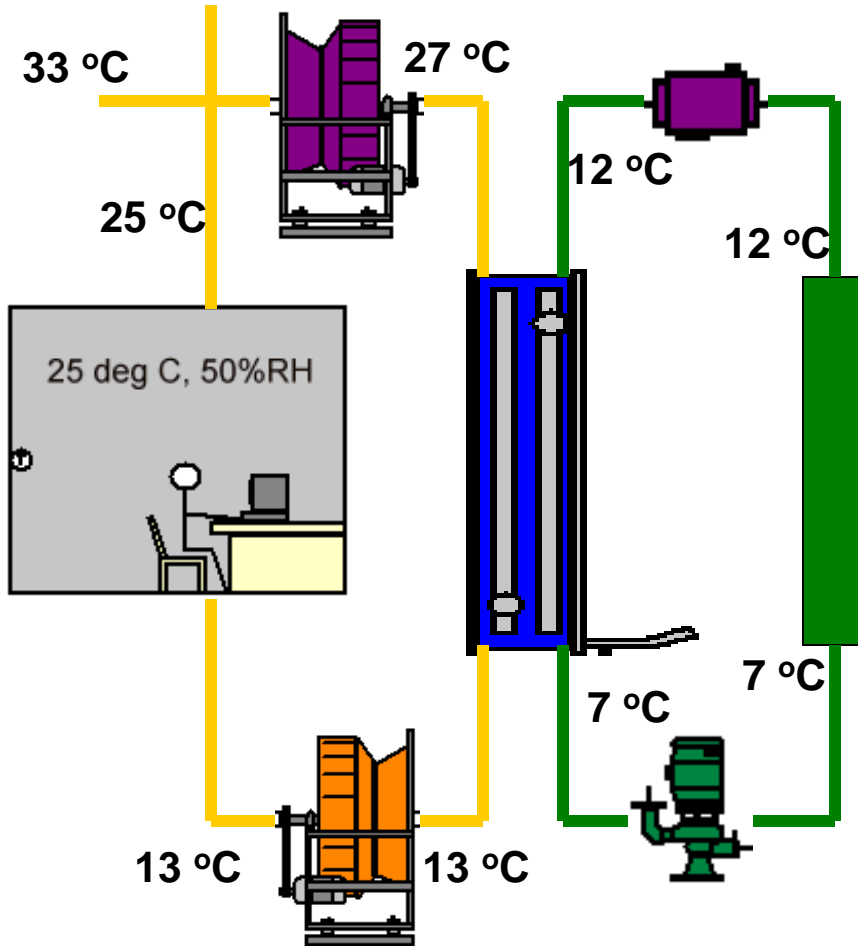
- Some fresh air is mixed with the return air
- Mixed return air is cooled (and dehumidified)
- A circulation and movement of air is maintained
- Heat is transferred from the conditioned space to the equipment – ‘cooling coil’

Air side system



33 °C, 28 °C

## Chilled water system



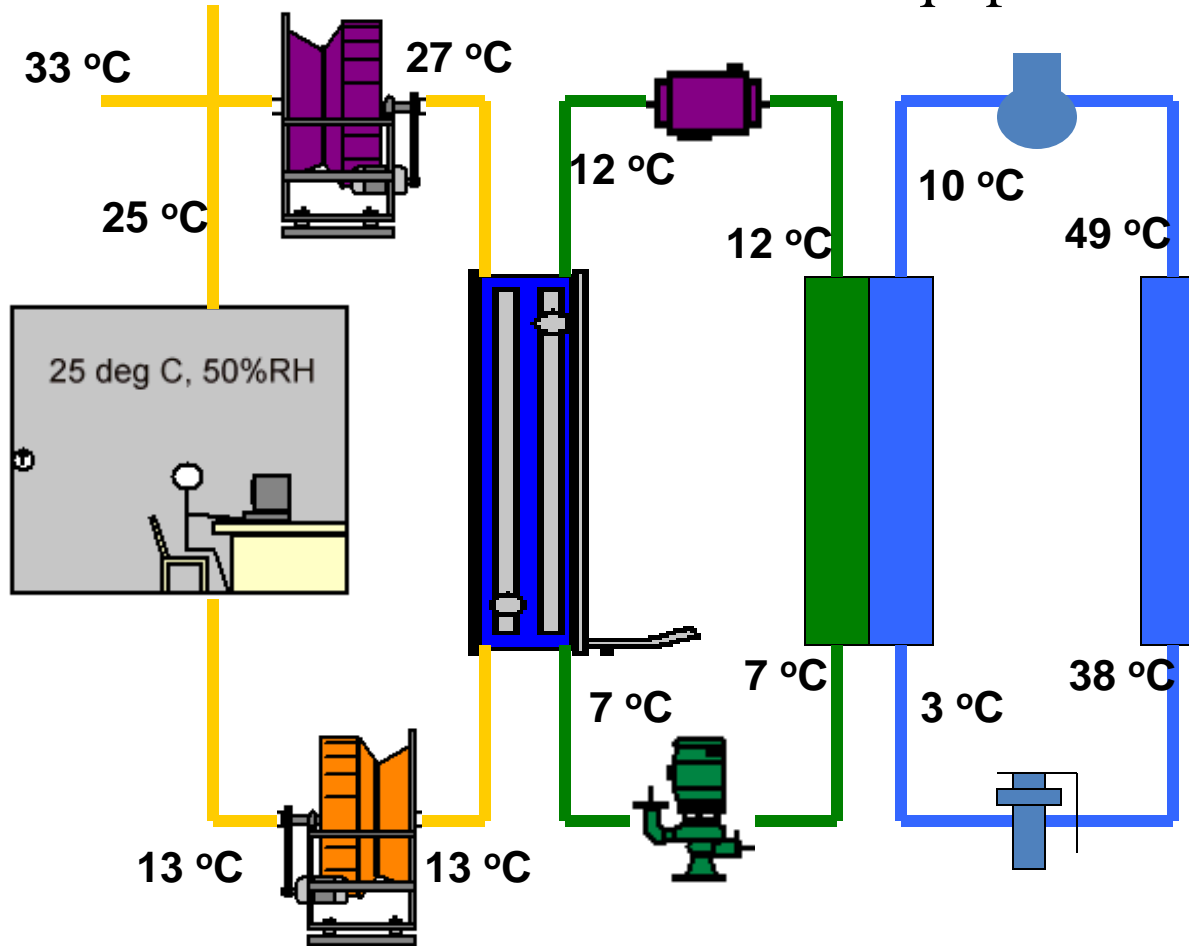
In this process

- Chilled water circulates in the cooling coil and absorbs heat
- The 'heated' chilled water is circulated to another equipment where heat is transferred



33 °C, 28 °C

## Refrigeration equipment



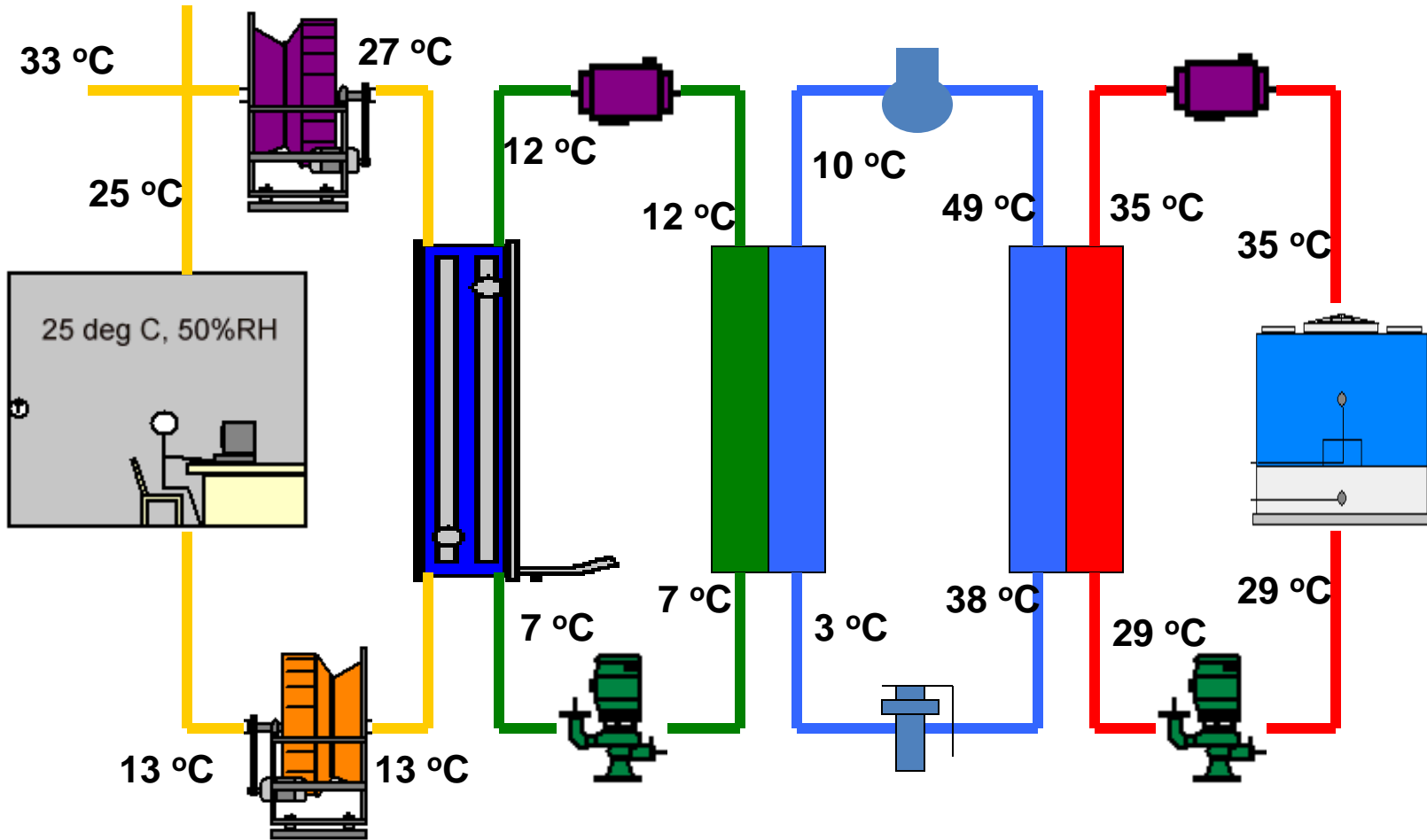
In this process

- Chilled water releases its heat in the refrigeration equipment to another media – ‘refrigerant’
- The refrigeration cycle converts low grade heat to high grade heat



33 °C, 28 °C

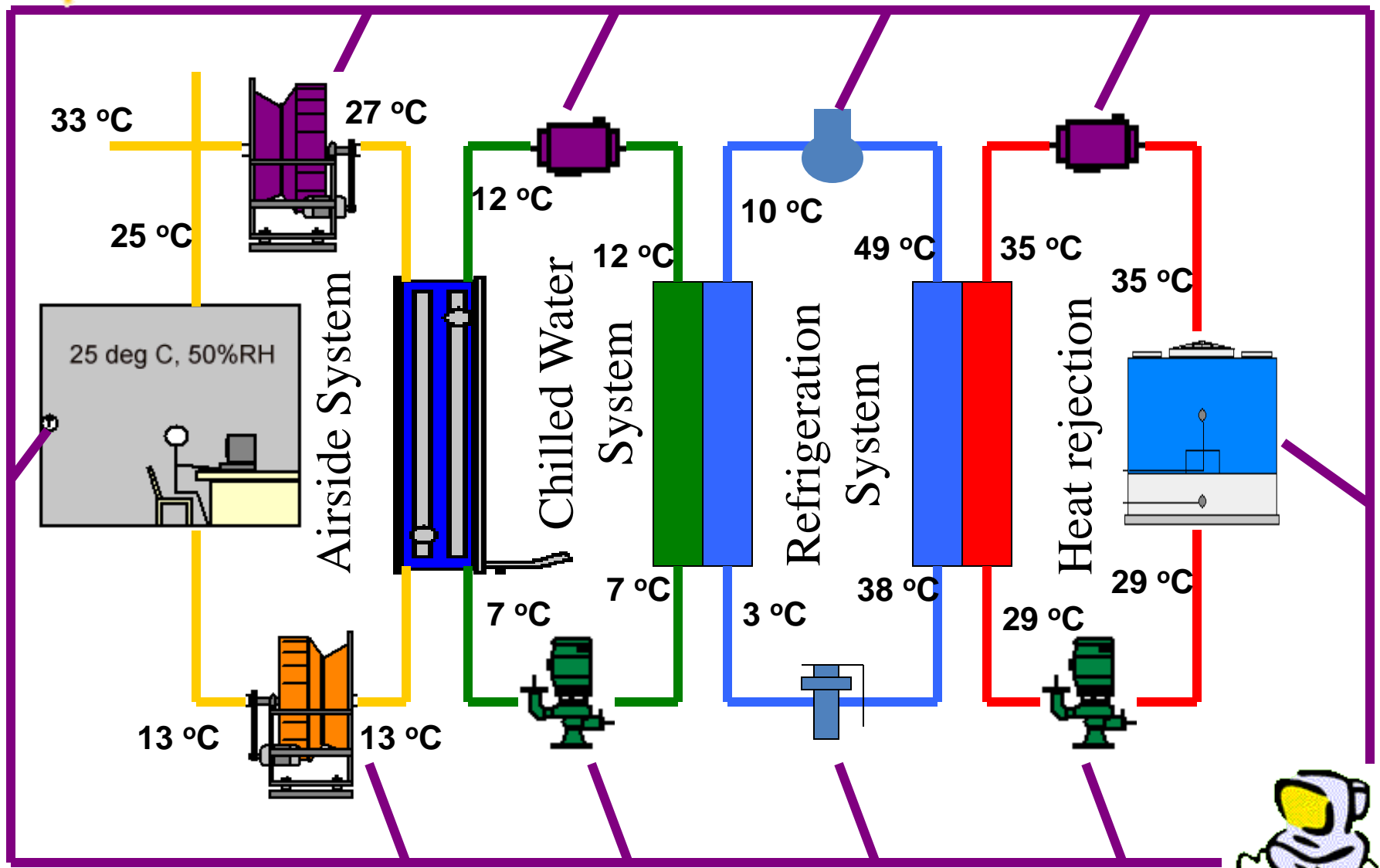
## Heat rejection





33 °C, 28 °C

# Control Loop



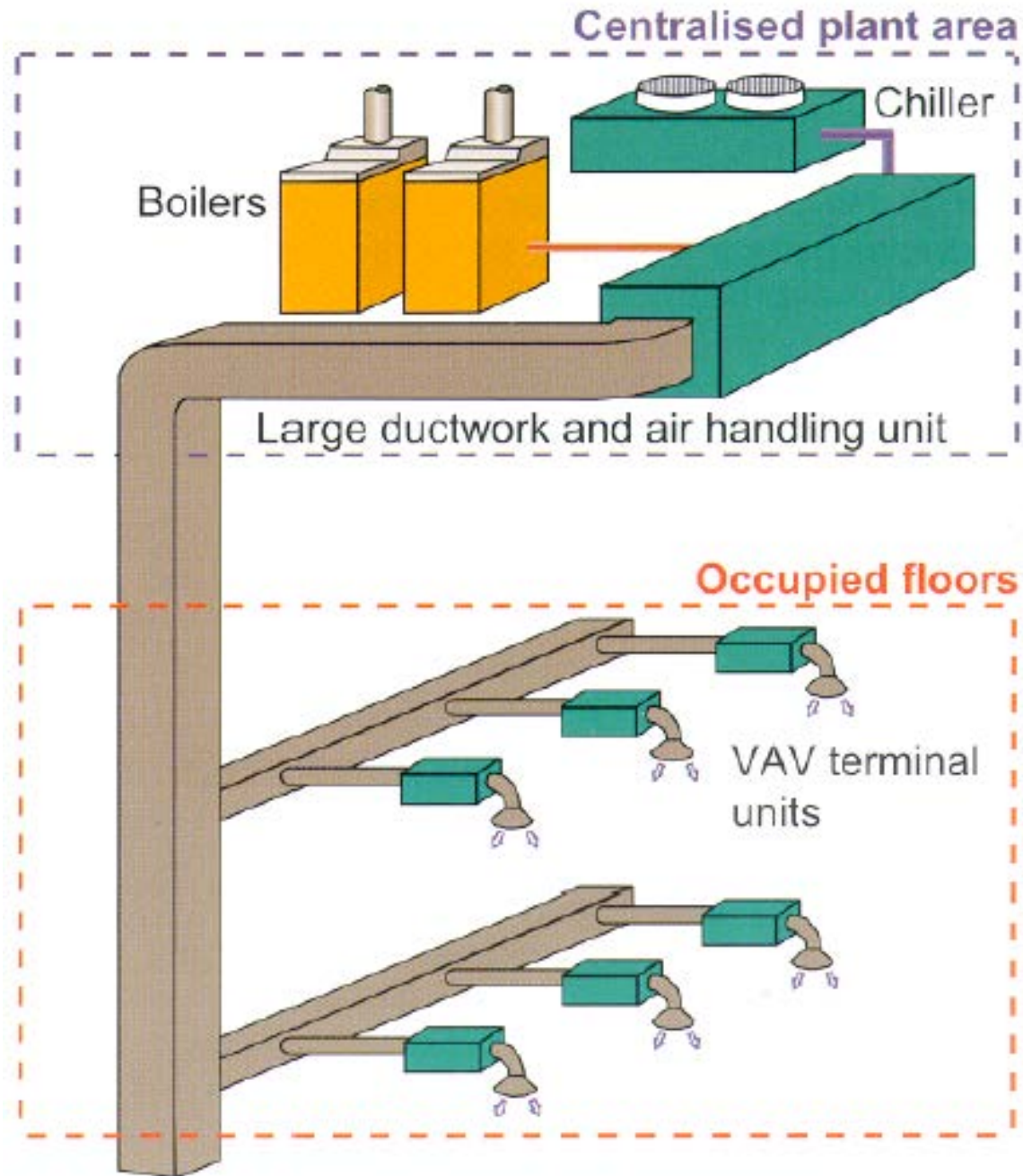
# Air Conditioning



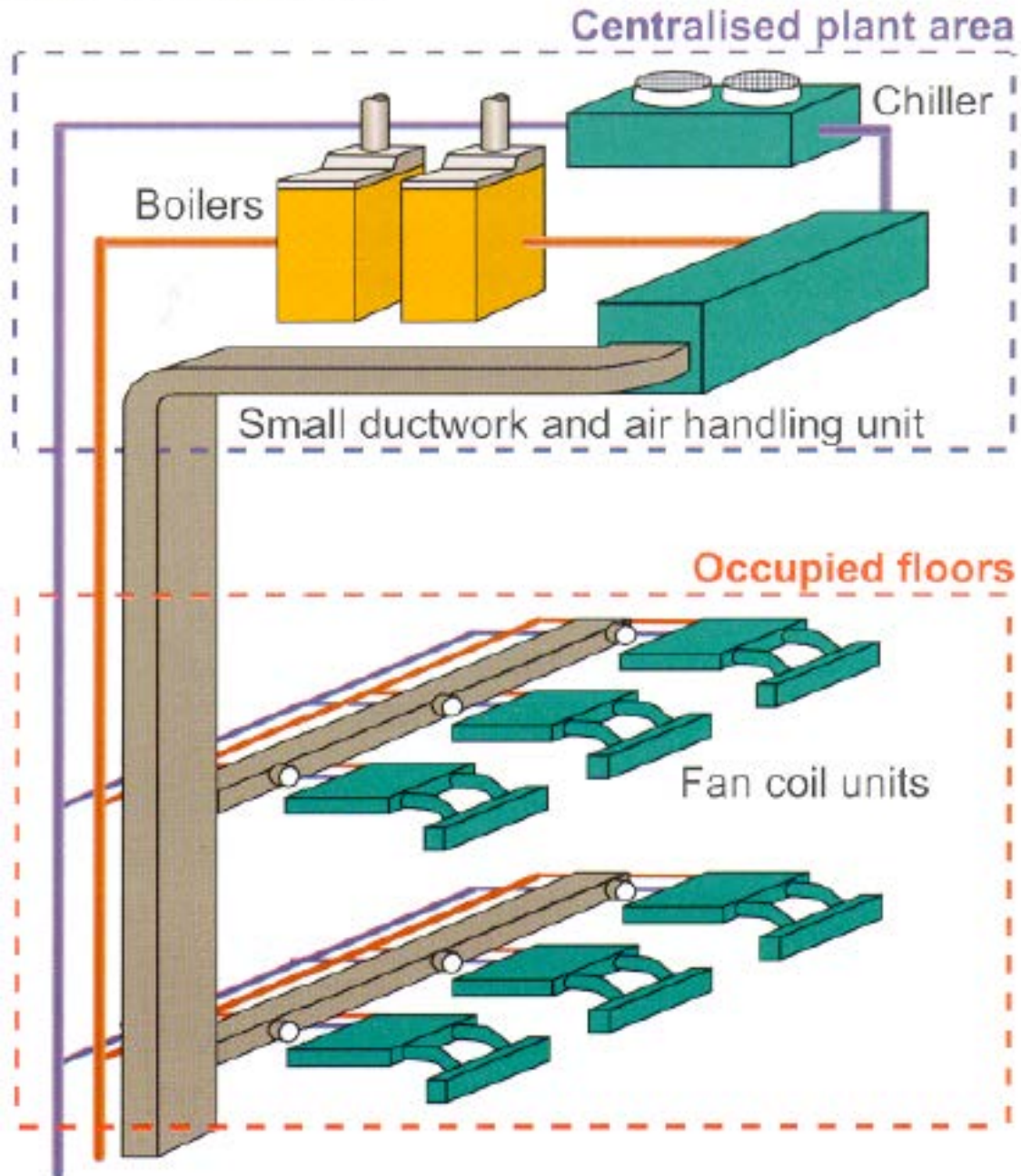
- Three generic types of systems:
  - Centralised all air systems
    - Such as CAV, VAV, dual duct
  - Partially centralised air/water systems
    - Such as FCU, induction units, chilled beams/ceilings
  - Local systems
    - Such as window-type units, split-type packages, VRV/VRF (?)

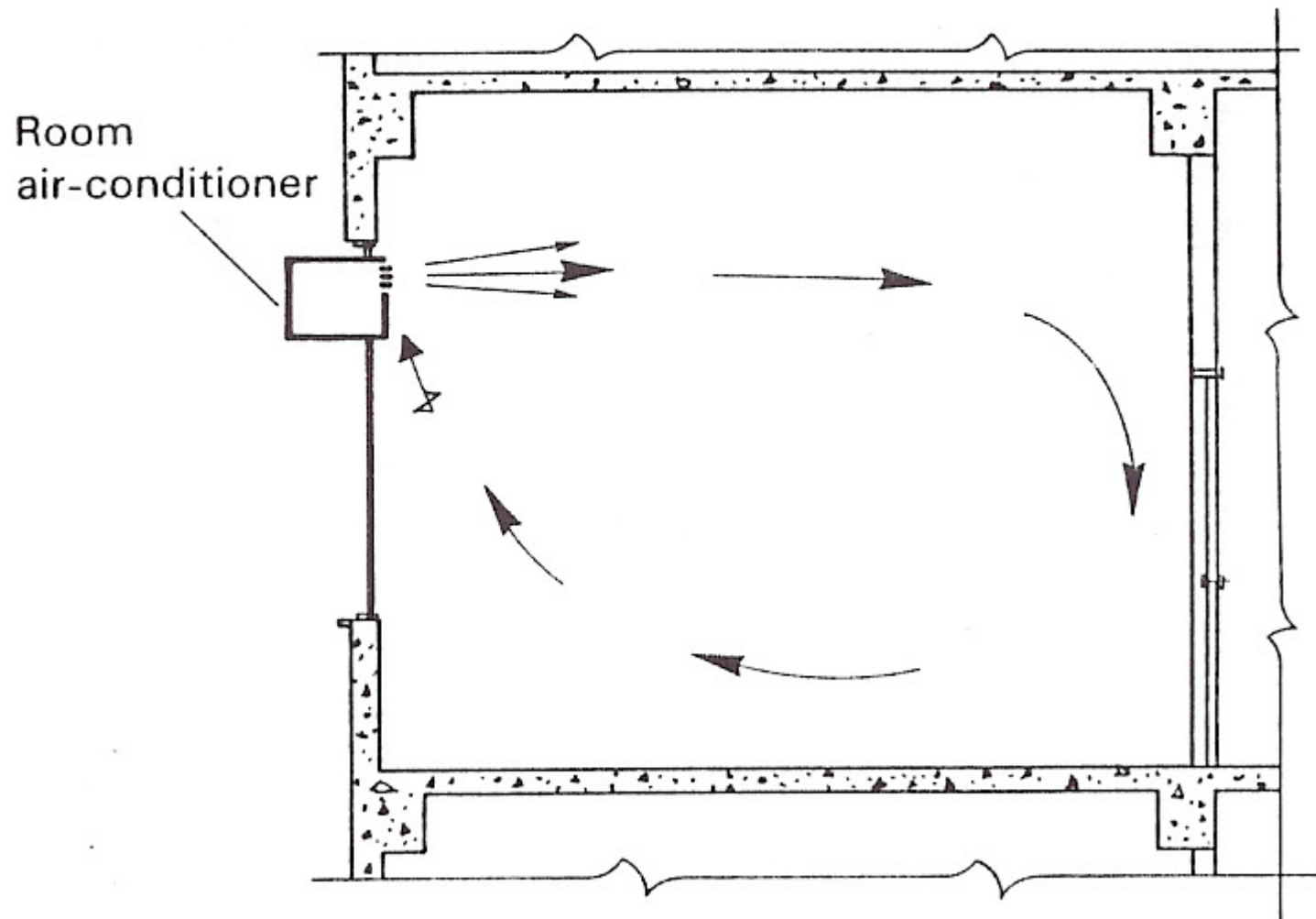


# Centralised air system (VAV example)

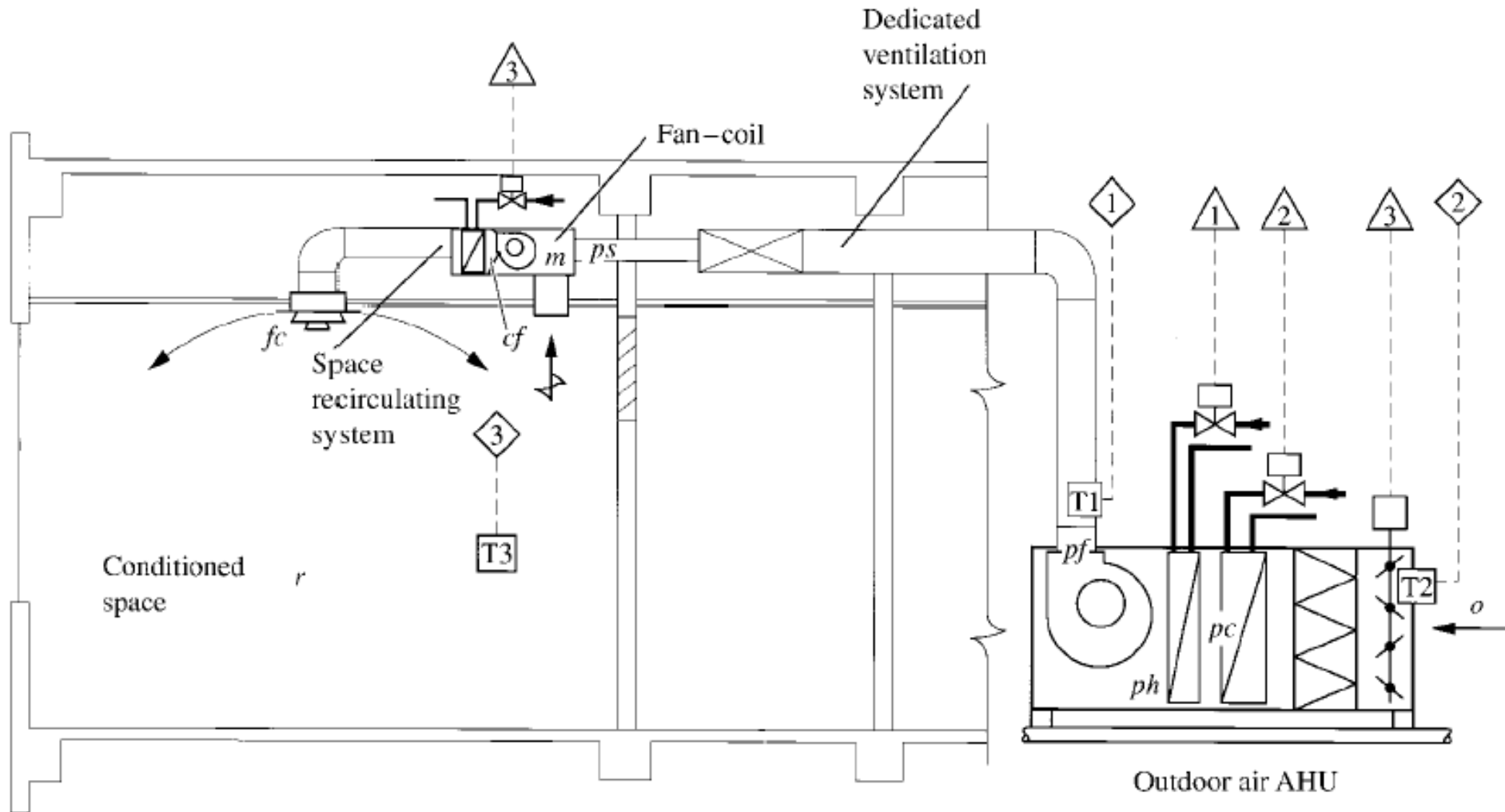


# Partially centralised air/water system (Fan coil example)



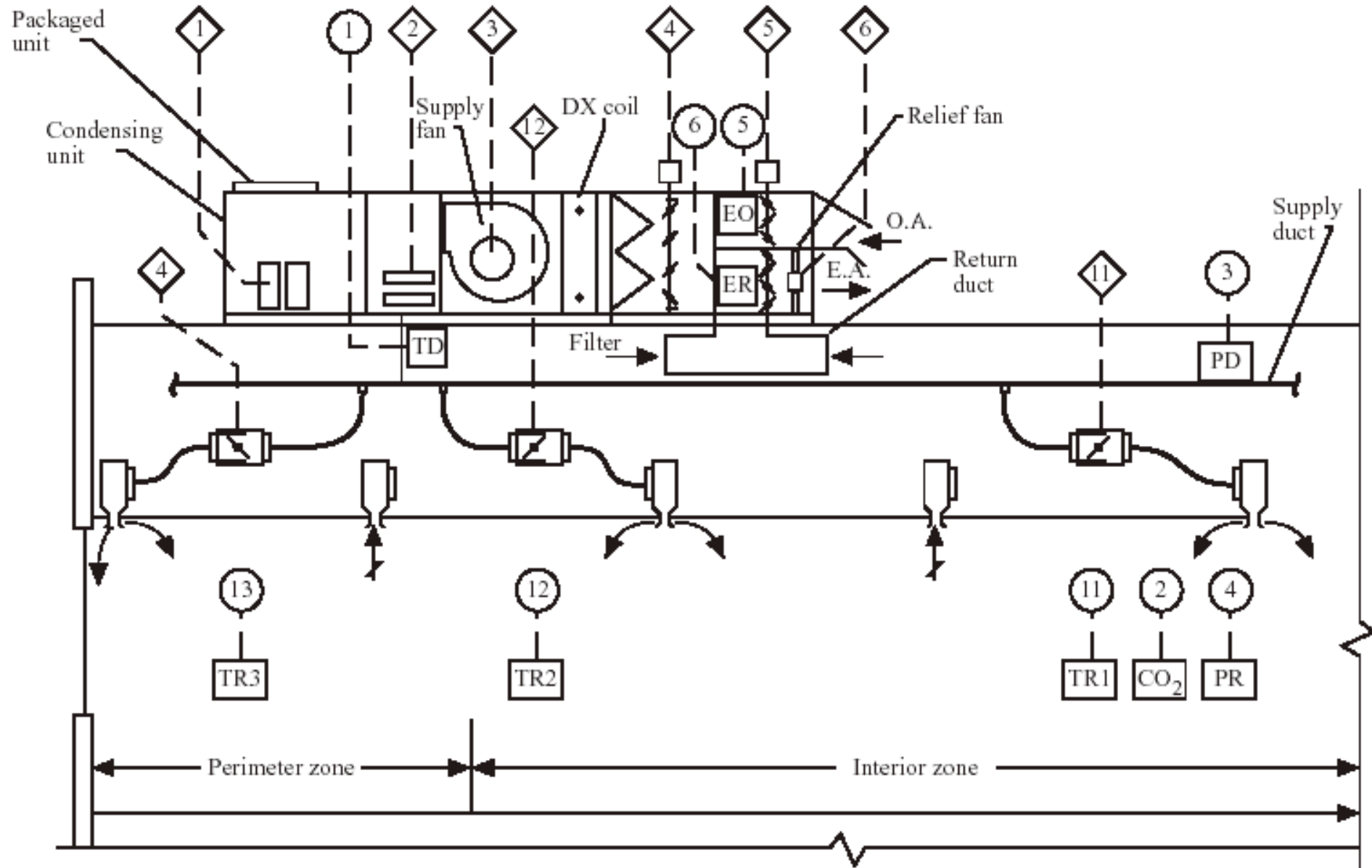


Individual room air-conditioning system

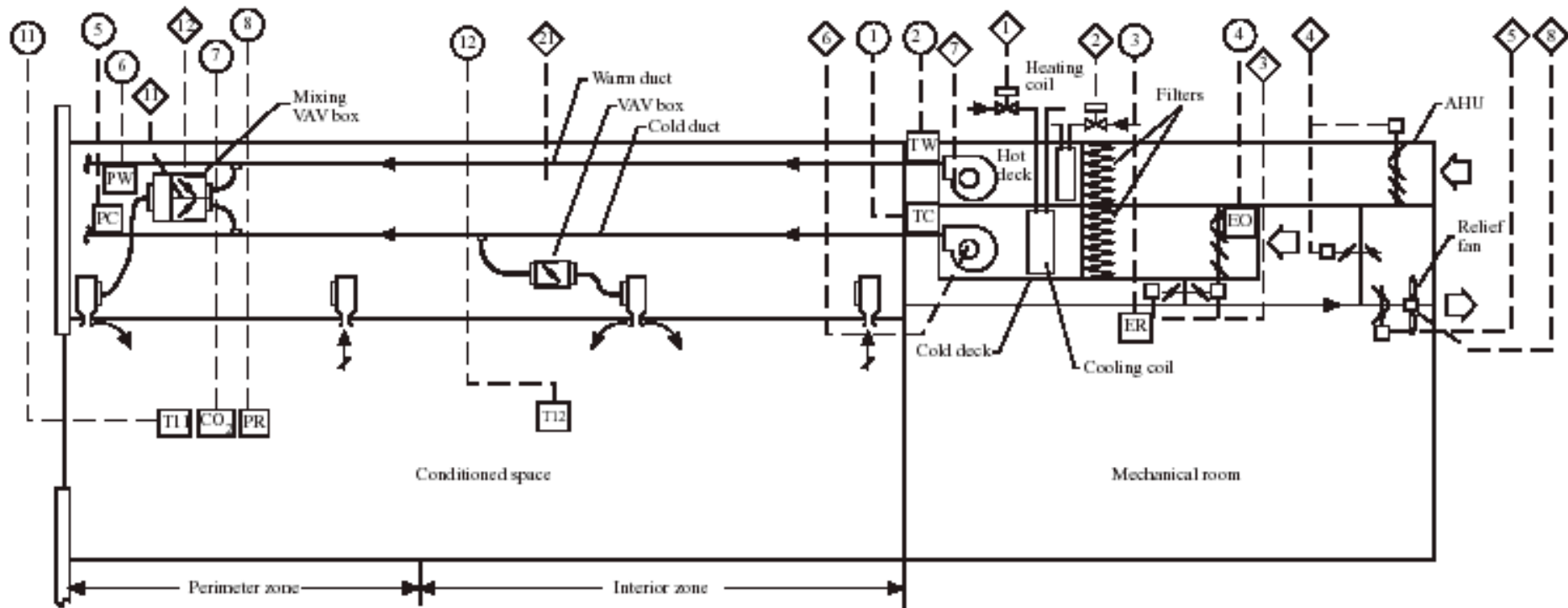


Primary air fan coil unit (PA-FCU) system

# Variable-air volume (VAV) package system



# A dual-duct VAV central system



# Air Conditioning



- Video presentation: Fundamentals of Air Conditioning [video, 24 min.]
  - HVAC systems at Heathrow Airport, Terminal 4, London
    - Basic psychrometric principles
    - HVAC equipment and components
    - Design factors: building, system, climate, economic



Hong Kong International Airport





Stansted Airport, UK



KL International Airport, Malaysia





# ASHRAE

*American  
Society of  
Heating  
Refrigerating &  
Air-conditioning  
Engineers*

# ASHRAE Publications

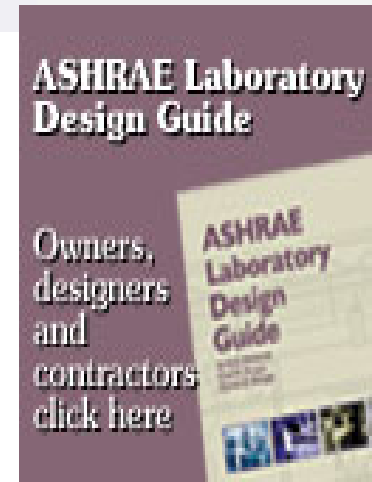
## Handbook



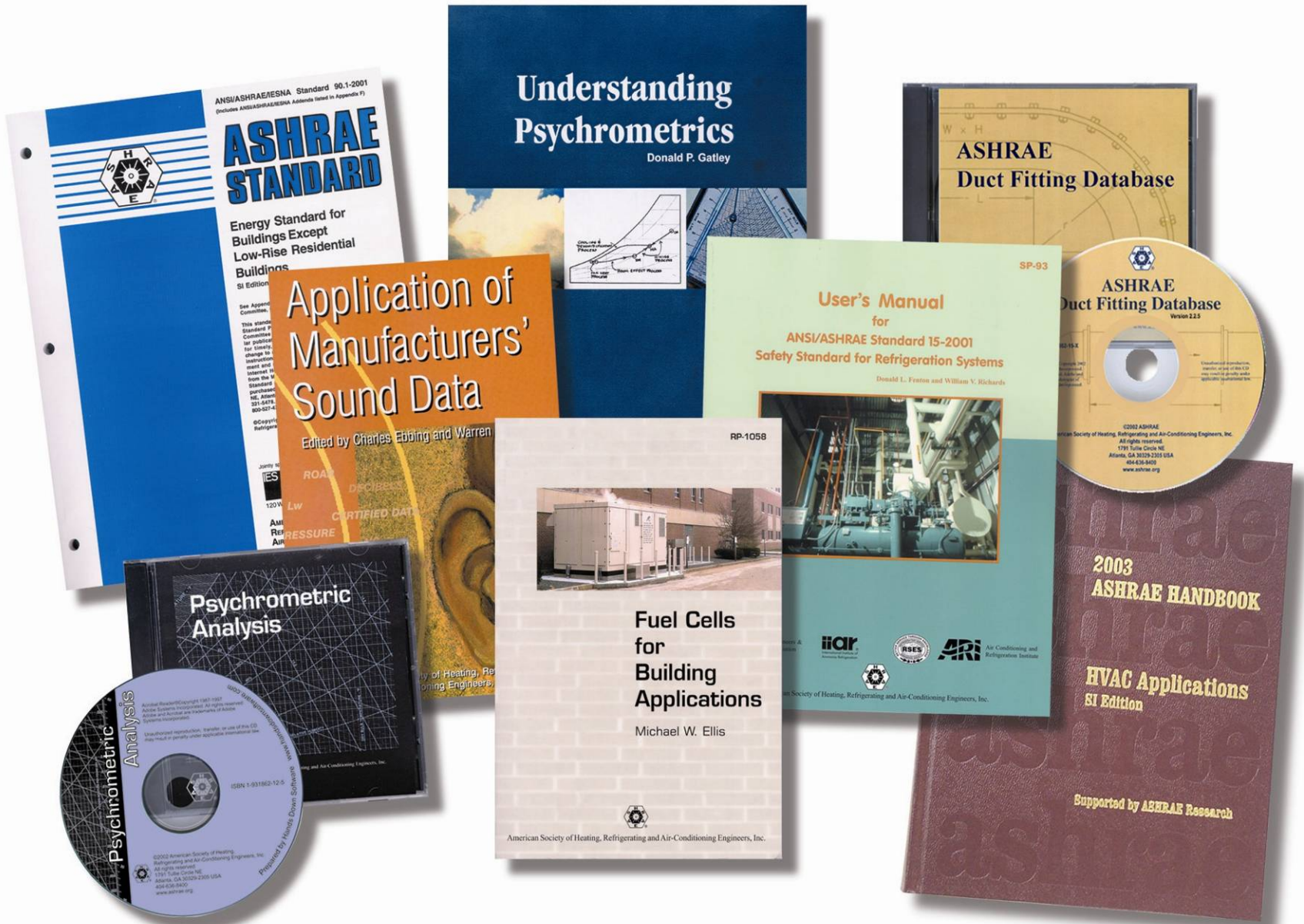
- Handbooks
  - Fundamentals
  - Systems & Equipment
  - Applications
  - Refrigeration
- Journal
- E-newsletters
- Books



## Journal



## Guidelines



(Source: [www.ashrae.org](http://www.ashrae.org))

# Summary of Lecture

- General introduction of Environmental Services – particularly HVAC&R
  - Importance, design strategy, performance requirements
- Introduction of Air Conditioning Systems
  - How heat is extracted, transferred and rejected
  - Various types of air side systems