AIR-CONDITIONING SYSTEMS AND APPLICATIONS

Abdullah Nuhait  Ph D.
King Saud University
AIR-CONDITIONING SYSTEMS

• Earliest air conditioning system used only for heating (winter)
  • Provided heated air for comfort
  • Provided ventilation
  • Using simple ductwork and control

• In later time, addition of cooling, dehumidification, and/or humidification provide all year round air conditioning

• Air conditioning:
  • Control of temperature, moisture, cleanliness, air quality, and air circulation in space as required by occupants, process, or product
AIR-CONDITIONING SYSTEMS

• No simple answer on how to select HVAC systems

• General factors to be studied when selecting HVAC systems
  • Performance and capacity requirements
  • Spatial requirements
  • First cost
  • Operating costs (energy, maintenance, labor, supplies of spare parts)
  • Reliability
  • Flexibility
  • Maintainability
APPLICATIONS

• Air conditioning systems found in many applications:
  • Residences
  • Public buildings (mosques, auditoriums, gymnasiums, swimming pool)
  • Office buildings
  • Educational facilities (Schools and universities)
  • Health care facilities (Hospitals)
  • Hotels
  • Stores and shopping centers
  • Manufacturing facilities
  • Ships
  • Trains
  • Airplanes
  • Submarines
  • Restaurants
  • Environmental control for survival (underground shelters)
APPLICATIONS

- Underground shelter
APPLICATIONS

• Office buildings
  • Occupancy varies considerably
  • Interior and exterior spaces (zones)
  • Conference room
  • Private room
  • Waiting room
  • Lighting makes sizable part of cooling load (4-7 w/ft²)
  • Office equipment
  • 8:00am – 5:00pm working hours
  • Supply outdoor air for ventilation
APPLICATIONS: Office buildings
APPLICATIONS : Office buildings
APPLICATIONS: Office buildings
APPLICATIONS: Office buildings
APPLICATIONS: Office buildings
APPLICATIONS: Office buildings
APPLICATIONS

- Schools
  - Occupancy varies (universities)
  - 8:00am-3:30pm teaching time
  - Exterior spaces (zones)
  - Auditorium
  - Libraries
  - class rooms
  - Lighting (2.5 W/ft²)
  - Supply outdoor air for ventilation
  - Every class room zone by itself
APPLICATIONS: Schools
APPLICATIONS

- Hospitals
  - Internal load
  - Restriction on air movement between various departments
  - Air quality
  - Humidity (30-55%)
  - Patient rooms (same as hotel)
  - Waiting room
  - 24 hours, 7 days/week working hours
  - Supply outdoor air for ventilation
  - Surgical department (100% outdoor air), use of HEPA filter
  - Nursery (newborn)
APPLICATIONS: Hospitals
APPLICATIONS: Hospitals
APPLICATIONS: Hospitals
APPLICATIONS

• Extended care centers
  • Patients no longer require hospital facilities
  • Similar to hotels
APPLICATIONS: Extended care centers
APPLICATIONS

• Stores
  • Small stores
    » Large glass area in front
    » Use unitary AC equipment
  • Supermarkets
    » Large glass area in front
    » Most of supply air in front
    » Refrigeration equipment
• Department stores
• Shopping centers (malls)
APPLICATIONS: Stores
APPLICATIONS

• Hotels
  • Single room with toilet and bath adjacent to corridor
  • Single story, low-, or high-rise
  • Multipurpose facilities
    » Gymnasium
    » Meeting room
    » Auditorium
    » kitchenettes
  • Use of FCU system or unitary
  • Use of AC systems require least space because of competitive hotel business
  • Guest rooms frequently unoccupied (use diversity factor)
APPLICATIONS: Hotels
APPLICATIONS: Hotels
APPLICATIONS

• Manufacturing facilities
APPLICATIONS: Manufacturing facilities
AC SYSTEMS

Air-Conditioning Systems can be categorized into six types:

- All-Air Systems
- Air-Water Systems
- All-Water Systems
- Unitary Air Conditioners
- Heat Pump Systems
- Heat Recovery Systems
AC SYSTEMS

- HVAC Systems share common basic elements
- HVAC Systems differ in physical appearance and arrangement
- HVAC Systems differ in manner in control and operation
AC SYSTEMS: complete system

Schematic of a typical commercial HVAC system
AC SYSTEMS: four type of piping systems
AC SYSTEMS: complete system

Air conditioning and air distribution systems (shown in previous slide) have means:

- To heat air
- To cool air
- To humidify air
- To dehumidify air
- To clean air
- To distribute air to various conditioned spaces in a zone
- To admit outdoor air
- To exhaust air
AC SYSTEMS: Cooling

• Removing space load using cooling fluid:
  
  – Cooling fluid supplied to cooling coil (heat exchanger) in air handler

  • Fluid may be liquid (used in commercial applications)

  • Fluid may be mixture of liquid and vapor (refrigerant)

    – Liquid cooled by chillers

      » Chiller cooled by air (air cooled) or water (water cooled)

  • Pumps used to circulate liquid through piping

  • Liquid cooling equipment may be at remote location
AC SYSTEMS: Heating

- Balancing space loss using heating fluid:
  - Heating fluid supplied to heating coil in air handler
    - Fluid usually hot water provided by boiler at remote location
    - Fluid may be steam provided by boiler at remote location
    - Water may be heated using steam with heat exchanger (converter)
  - Fuel for boilers can be natural gas, liquefied petroleum gas (LPG), fuel oil, solid fuel such as coal or wood
  - Heating can also be provided by direct electrical heating or refrigerant (heat pump)
AC SYSTEMS: Humidification

- Adding moisture to space using humidifier:
  - Humidifier supplied
    - With atomized water
    - with water vapor supplied by steam boiler
    - with water vapor supplied by small special steam-generating device
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Central system design involves:
  - Determination of individual zones to be air conditioned
  - Selection of type of HVAC equipment
  - Location of HVAC equipment

- HVAC equipment location:
  - In basement
  - On roof
  - In surface area
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Thermal zone (zone)
  • Conditioned space under control of single thermostat
  • In special cases: zone humidity controlled by humidistat

• Thermostat control device:
  • Senses temperature
  • Sends correcting signal if that temperature not within some desired range
  • Thermostat location in spot free from local disturbances
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Uniform temperature experienced in spaces
  - With large open areas
  - Small external heat gain (loss)
    - Theaters, auditoriums, department stores, public buildings
    - Interior zones fairly uniform in large commercial buildings
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

Spaces with rigid requirements for

- Cleanliness control
- Humidity control
- Temperature control
- Air distribution

- Usually isolated as separate zones within larger building
  - Served by separate systems
  - Furnished with precision control

» Surgical operation rooms: all-air systems used
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• In spaces such as:
  • Large office buildings
  • Factories
  • Large department stores

• Practical considerations require:
  • Multiple zones
  • Multiple installation of central systems

• In case of tall buildings:
  • Each central system may serve two or more floors
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Large installation such as:
  • College campuses
  • Military bases
  • Research facilities

• Served by central plants:
  • Chillers provide chilled water through piping system to entire facilities
  • boilers provide hot water or steam through piping system to entire facilities
  • Piping located underground

• Used diversity factor to adjust for actual capacity of equipment
  • All buildings not be in full use at same time

  » Capacity of equipment lower than sum of maximum requirement of all buildings
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- For large installations with low diversity factor
  - Central plants allow designs with much smaller total capacity
  - Provide lower capital (first) costs than isolated systems located in each individual building
  - Greater efficiency (lower operating cost)
  - Less maintenance cost
  - Lower labor costs
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Selection and arrangement of various system components by designer when
  - User’s of building needs studied and evaluated carefully
  - Zones defined
  - Loads calculated
  - Air requirement computed
  - Type of overall AC system determined
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Equipment should be suitable
  - For particular application
  - Sized properly
  - Accessible for easy maintenance
  - No more complex in arrangement and control than necessary to meet design criteria

- Economic trade-off between initial investment and operating costs must be kept in mind all time

- Ductwork and piping systems make up significant part of AC systems costs
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Central system components can be grouped into five categories:
  • Air handlers and fans
  • Heating sources
  • Refrigeration devices
  • Pumps
  • Controls and instrumentation

• Familiarity with components of HVAC systems may produce optimum design
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Air-handling equipment
  - Shown general arrangement for commercial central system
  - Components available in sub-assembled sections (field assembled)
  - Completely assembled by manufacturer
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Simplified schematic of air handler shows:
  • Fans
  • Heating and cooling coils
  • Filter
  • Humidifier
  • Controlling dampers
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Fans located downstream of coils
  - Called draw-through configuration
    » Used for single zone system

- Photograph of air handler for single zone shown in next slide
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Draw-through air handler
  - Used for single zone system
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Several zones to be served by single air handler
  - Heating and cooling coils may be placed in side-by-side (parallel) arrangement
    - Heating coil called hot deck
    - Cooling coil called cold deck
  - Fan location in front of coils
    - Fan arrangement called blow-through configuration
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Discharge area of air handler may be divided to serve several zones
- Separate temperature control in each zone
- Air handler may be used without dampers in dual-duct system
- Shown in next slide, one typical of cooling, heating, preheat coils
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Finned –tube type coil
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- One type of humidifier used in commercial air handler
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Typical centrifugal fan used in air handler
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Typical unit-type air filter used in air handler
- Bag filters
- Gas removal
- Particulate removal
  - Check pressure drop
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Heating equipment: boilers

• Boiler considered pressure vessel
  
  • Designed to transfer heat to fluid (water)
  
  • Classified on basis:
    » Of working pressure and temperature
    » Fuel used
    » Shape and size,
    » Steam or water

• Constructed to meet ASME Boiler and Pressure Vessel Code
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Refrigeration equipment

• Basic components:
  • Compressor
  • Condenser
  • Evaporator
  • Expansion valve
  • Control system
AC Refrigeration equipment: chillers (air-cooled, water-cooled)
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Compressor major energy-consuming component in HVAC

• Compressor performance and reliability is significant

• Types of compressors used:
  • Reciprocating
  • Scroll
  • Screw
  • Centrifugal
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Water-cooled chillers reject heat atmosphere through cooling tower
  - One type of cooling tower
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Pumps and piping
  • Centrifugal pump used in HVAC system for:
    » Primary chilled water
    » Secondary chilled water
    » Hot water
    » Condenser water
    » Steam condensate return
    » Boiler feed water
    » Fuel oil
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- HVAC piping system consists of two groups:
  
  - Primary piping (main equipment)
    - Fuel lines
    - Refrigerant piping
    - Steam
    - Water
  
  - Secondary piping (air-handling system) throughout building
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Control and instrumentation

- Load in building varies with time

  - Needs control to modulate output of HVAC system to satisfy loads

  - Properly designed control system maintains good indoor air quality and comfort

- Controls energized in variety of ways:
  - Pneumatic
  - Electric
  - Electronic
  - Combination
  - Direct digital control (DDC)
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Control and instrumentation – continue

- Necessary elements:
  - Sensor (thermostat)
  - Controller (thermostat)
  - Controlled device (valve)
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

• Electric solenoid valve (on and off)
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Two-way, direct-acting control valve with pneumatic actuator and positioner
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

- Two-way control valve with electric actuator
AC SYSTEMS AND AIR DISTRIBUTION SYSTEM

All-air system

• By supplying air to conditioned space:
  • Provides complete sensible heating and humidification (winter)
  • Provides complete sensible and latent cooling (summer)

• No additional cooling required at zone

• All-air system can be used in all HVAC systems for comfort and process work (industrial AC)
All-air system

- All-air system used in buildings that:
  - Requiring individual control of conditioned space
  - Having multiplicity of zones:
    » Office buildings
    » Schools and universities
    » Laboratories
    » Hospitals
    » Stores
    » Hotels ships
    » Clean room
    » Computer room
    » Hospital operation rooms
    » Textile factories
All-Air System

- Single zone (constant air volume)
  - System components
All-Air System (constant volume)
All-Air System (constant volume) - control
All-Air System chilled water AHU (constant volume)
All-Air System chilled water AHU (constant volume) - control
All-Air System

- Reheat (constant air volume) system
  - Modification of single-zone constant-volume system
  - Permit zone control for area of unequal loadings
All-Air System

- Variable-air-volume system
  - Varying load by regulating volume of supplied air
All-Air System: indoor AHU fan powered VAV system
All-Air System: indoor AHU fan powered VAV system (control)
All-Air System: water cooled self-contained air conditioner fan powered VAV system
All-Air System: water cooled self-contained air conditioner fan powered VAV system (control)
All-Air System: roof-top air conditioner VAV system with reheat
All-Air System: roof-top air conditioner VAV system with reheat (control)
All-Air System: roof-top air conditioner VAV system
All-Air System: roof-top air conditioner VAV system (control)
All-Air System: chilled water AHU (outdoor) - VAV system (thermal storage)
All-Air System: chilled water AHU (outdoor) - VAV system (control) - (thermal storage)
All-Air System

- Dual-duct (double-duct) system
  - Supplies warm air through one run and cold air through the other
  - Temperature controlled by mixing warm and cold in proper proportions
  - Installed in office buildings, hotels, hospitals, schools, large laboratories, …etc
  - Control will reset cold air supply to highest temperature acceptable and hot air supply to lowest temperature acceptable
All-Air System

- Dual-duct system
All-Air System

- Dual-duct system – Control system
All-Air System

- Multi-zone system
  - Provides single supply duct for each zone
Air-water System

• Both air and water distributed to each space
  • To perform both cooling and heating

• Water has greater specific heat and density than air (reduced amount of air)
  • Less building space needed
  • Pumping HP less than fan HP

• Commonly used in:
  • Office building
  • Hospitals
  • Hotels
  • Schools
  • High-rise building (to save space)
Air-water System

- Water side consists of
  - Pump
  - Piping
  - Coils

- Schematic of air-water induction used in air-water system
Air-water System

• Typical fan-coil unit used air-water system
Air-water System – unit ventilator
Air-water System - control
All-water System

- All-water systems use fan-coil and ventilator units
- Cooling and dehumidification provided by circulated chilled water
- Similarly heating provided by circulated hot water
- Humidification provided by separate humidifier for each room
Unitary Air Conditioner

- Unitary air-conditioning equipment
  - Factory-matched components (fan, coils, filters, etc.)
  - Packaged (single)
  - Split (two units connected in field)
  - Air cooled (condenser)
  - Water cooled (condenser)
Unitary Air Conditioner

- Typical of large commercial packaged
Unitary Air Conditioner

- Schematic of roof-top packaged
Unitary Air Conditioner

- Schematic of room air conditioners
Unitary Air Conditioner

- Typical of packaged terminal air conditioner
Unitary Air Conditioner for hotel
Heat Pump Systems

- Refrigeration equipment used for cooling and heating
Heat Recovery Systems

- Recovering heat from warm exhaust air (winter) by fresh air
- Cooling fresh air by cool exhaust air (summer)
Heat Recovery Systems

- Schematic of air-to-water-heat-recovery system
Heat Recovery Systems

- Schematic of rotating heat exchanger
Heat Recovery Systems

- Schematic of air-to-air heat-recovery system