HVAC Equipment for Large Buildings
Objective

- Identify types of HVAC systems and equipment used in non-residential applications and to point out energy conservation features/opportunities.
- First look at types of systems: (1) all air, (2) air and water, (3) all water, (4) other.
- Next look at the individual equipment components out of which systems are built.
- Finally examine some general HVAC energy conservation principles.
All-Air: Central Air System

- Name implies a single-zone system.
- **Operation**: A single system that supplies HVAC needs of a single zone by delivering conditioned (hot or cool) air.
- **Advantages**: control simplicity
- **Disadvantages**: No variation of supply conditions throughout zone, constant air volume (fixed cfm) regardless of load, often cheaper and more comfortable to let larger central unit supply several zones.
Central Air System

Exhaust Air

Return Air Fan

Filter

Heating Coil

Cooling Coil

Humidifier

Outside Air

Flow Control Dampers

From zone

Supply Air Fan
Central Air Example- Rooftop Units
All-Air: Reheat System

- **Operation**: Multi-zone. Air is chilled and sent to mixing boxes serving each zone. Air is partially reheated (using steam, hot water or electricity) to satisfy the exact requirement for each zone.

- **Advantages**: Close control of conditions in each zone; large, efficient central unit can cool air.

- **Disadvantages**: Constant air volume (fixed cfm). ENERGY GLUTTON- energy first used to cool, then more energy wasted to reheat air.

- This type of system is still very common and was very popular until recently.
Reheat System

Exhaust Air

Return Fan

Outside Air

Filters

Cooling Coil

Supply Fan

Terminal Reheat Units in Each Zone
Disadvantage of Constant Air Volume Systems

- Significant savings result if air flow is modulated to meet actual load because fan power required is proportional to the cube of the flow rate:

  \[ \frac{hp_1}{hp_2} = \left(\frac{cfm_1}{cfm_2}\right)^3 \]

- If the air flow rate is cut in half, the fan power is reduced to one-eighth!

- A constant air volume system doesn’t give that option- we need a **variable air volume** (VAV) system.
All-Air: Variable Air Volume System

- **Operation**: Central cool air is sent to VAV boxes at each zone. VAV boxes meet varying load by varying flow rate with *dampers*. Reheat often used for control.

- **Advantages**: Zone control, much lower fan power and heating/cooling energy use.

- **Disadvantages**: Requires good diffuser design for good air distribution at varying flow rates; sometimes noisy; terminal reheat option is still wasteful of energy, but VAV reduces this loss.
Variable Air Volume System

Exhaust Air

Outside Air

Return Fan

Filter

Heat

Cooling Coil

Supply Fan

Return Air

Supply Information

VAV Units

VAV Boxes
All-Air: Dual-Duct System

- **Operation**: Central system provides both warm and cool air supply to each zone through pair of ducts. Conditions at each zone are met by mixing cold and warm air in a mixing box.

- **Advantages**: Precision zone control to zones having widely varying needs.

- **Disadvantages**: ENERGY GLUTTON- both cools then heats air; often designed for constant volume operation. Requires two ducts running to each zone (separate by good insulation!). Dual duct was once very popular, used less now.
Dual-Duct System

Exhaust Air

Return Fan

Return Air

Heat and Humidifier

Hot Deck

Outdoor Air

Preheat Coil and Filter

Supply Fan

Cooling Coil

Mixing Boxes

Cold Deck
Air and Water Systems

- It is cheaper to circulate water than air because pumping costs are lower (recall work = $-\int v dP$). Also, water pipes take up much less space than air ducts, which makes architect happy.

- These systems often operate by providing minimum flow of conditioned ventilation air to each zone. Full load is met using chilled or heated water (or steam) circulated from central supply (chiller, heat pump or boiler).

- Many variations, but we will look at only two.
Air and Water: Air-Water Induction System

- **Operation**: Centrally conditioned air is supplied to each unit at relatively high pressure. Flow of primary air draws secondary air flow through water coil to provide additional cooling or heating.

- **Advantages**: Normally less expensive than all-air.

- **Disadvantages**: Induction unit can be noisy. Gives less control over comfort conditions and results in less air cleaning.
Air-Water Induction System

- Primary Air
- Balancing Damper
- Nozzles
- Secondary Coil
- Condensate Pan
- Induced Air
- Mixed Air
Air and Water: Fan Coil System: Operation

- Each zone has one or more fan coil units that pull in air at bottom over a filter, pass the air over a coil containing chilled or heated water, and blow air out top of unit into the room.
- Varying load met by varying blower speed or water flow in coil.
- Ventilation air, often conditioned, may be supplied through a separate ceiling diffuser.
- Fan coil units are used to heat and cool much of Hardaway Hall (not this room, however).
“2-, 3- and 4-Pipe” Systems

- Fan coil unit supplied by a 2-, 3- or 4-pipe system.
- A 2-pipe system consists of a supply line and return line. It can either heat or cool, but not both at the same time. Often takes hours to switch from heating to cooling, so flexibility is poor—too hot on warm winter days, etc.
- A 3-pipe system consists of hot and cold supply lines, plus return. Can switch quickly between heating and cooling, but only one at a time.
- A 4-pipe system has hot and cold supply and return—can heat some zones while cooling others.
Air and Water: Fan Coil System

- **Advantages**: Inexpensive, usually give occupants good, individualized control over their environment.

- **Disadvantages**: Requires high maintenance; 2-pipe systems are fairly complicated to "switch over," so this system is not flexible enough to provide comfort during rapid weather changes; units often need individual human control and not well-suited for automatic control.
Typical Fan Coil Unit

1. Finned tube coil
2. Fan scrolls
3. Filter
4. Fan motor
5. Aux. condensate pan
6. Coil connections
7. Return air opening
8. Discharge air opening
9. Water control valve
Fan Coil Unit

Wall Fan Coil Unit

Ceiling Fan Coil Unit
All Water Systems

- These systems operate by providing chilled and/or heated water to zone units (typically fan-coil units), but ventilation air is supplied by infiltration or by fresh air inlet vents at the fan coil unit itself.
- This is really the system that Hardaway has- no forced fresh air ventilation.
- Fresh air requirements for new construction and renovation won’t allow systems without forced ventilation in the future- if you get a construction permit, it’s got to comply with code.
All Water System

- Cooling Coil
- Heating Coil
- Filter
- Outdoor Air
- Floor
- Fan
- Drain Pan
- Mixing dampers
- Recirculated Air

Note: This is a 3 or 4-pipe system
Air-to-Air Heat Recovery

Air-to-air heat recovery heat exchangers become increasingly important as fresh air ventilation requirements continue to increase.
Recuperative Air-to-Air HX

This Trane heat recovery unit (top) uses a “heat wheel” (left) to capture waste heat from the exhaust air leaving and transfer it to incoming fresh air.
Energy Conservation Rules for HVAC System Operation

1. Heat to the lowest temperature possible, cool to the highest temperature possible (particularly applicable when trying to improve efficiency of a reheat or dual-duct system). Thermo-dynamically speaking, generate as little entropy as possible, entropy generation is lost work (and dollars).

2. Avoid heating or cooling if it’s not needed. Use "setback" thermostat control for night, weekends, off-hours.
Energy Conservation Rules for HVAC System Operation

3. Understand and **maintain** the system. There are energy consultants *getting rich* from "shared savings" right now simply by assuring that their client's building is operating as it was designed. This may seem like a trivial point, but most buildings are NOT operated as designed with fully functional components. (Have you checked your tire air pressure recently?)
Energy Conservation Rules for HVAC System Operation

4. Design/modify pumping and fan/blower systems so that no more fluid is circulated than is actually needed at any given instant.

5. If equipment is not needed, turn it off. Design controls so that equipment operates only when needed.
Energy Conservation Rules for HVAC System Operation

6. Use "free cooling" if possible. Many buildings with year-round core air conditioning fail to use cool outside air for A/C. Can use air directly or to chill water and circulate chilled water.

7. Take advantage of free heating opportunities. This includes using heat recovery equipment in air exhaust ducts and using heat removed from core areas to warm spaces adjacent to the envelope of large buildings in the winter.
Grilles and Filters - Used to remove particulate larger solid debris from air flows. Grilles and filters get dirty, resulting in an increased $\Delta P$ across them. More fan power is required to overcome this increased $\Delta P$ or lower flow results. These items require regular dedicated maintenance.
Fans

- **Fans** - Used to move air. Efficient blade, transmission and motor combinations should be used and well maintained.

- Ability to operate efficiently at part load is highly desirable and becoming more common.
Heat Exchangers

- Include condensers and evaporators in refrigeration equipment, water and steam coils in air handlers.
- Typically are finned tube heat exchangers with water, steam or refrigerant in tubes, air passing over the outside.
- Outdoor surfaces get dirty and should be cleaned periodically. Surfaces containing water can suffer from biofouling or scaling, both of which greatly reduce the rate of heat transfer.
Heat Exchanger Examples

Trane Absorption Chiller

Cooling Coil

Heating Coil
Ducts

- Carry air to and from conditioned space. Can leak if poorly sealed, can lose excess heat if poorly insulated.
- Ductwork can become partially blocked by trash, etc., reducing flow, increasing heat transfer.
- Ductwork can be a site for microbial growth if air is excessively humid (Sick Building Syndrome).
- Ducts contain **dampers** to direct and modulate air flow.
Pumps and Piping

- **Pipes** - Used to carry water, steam and refrigerant. Can suffer from fouling, scaling, corrosion/leakage, excessive heat loss.

Compressors

- Compress refrigerants in vapor-compression refrigeration cycle.
- Small tonnage: reciprocating (piston) and scroll compressors; medium tonnage: reciprocating, screw (rotary helical) and centrifugal compressors; large tonnage: centrifugal compressors. Most compressors over 250 tons or so are centrifugal compressors.
- Compressors also require regular maintenance.
Small Compressors

Scroll Compressor Principle

Hermetic Reciprocating Compressor
Refrigerants

- Working fluids of vapor-compression refrigeration cycle- usually CFC's or HCFCs.
- Recent legislation requires:
  1. Capture/recycling of CFC/HFC's when repairing equipment by authorized personnel.
  2. Rapid phaseout of CFC's (now) and fairly rapid phaseout of HCFC (~2010).
- Item 2 requires substitution for R-11 and R-12 in existing equipment. Screw, centrifugal and small reciprocating compressors mostly use R-22, an HCFC.
Chillers

- A chiller produces chilled water (for circulation through coils to condition air). There are two major types of chillers:
- Vapor-compression cycle chiller (conventional) essentially the same as an air conditioner or heat pump in cooling mode, except the cold Freon in the evaporator is used to chill water rather than cool air.
- Chillers can use reciprocating (smallest), screw, or centrifugal (largest) compressors.
Centrifugal Chiller
Absorption Chiller

- Absorption chiller uses the absorption cycle, where a cooling effect is generated from a heat energy input (rather than a work input).
- Low temperature applications use ammonia/water, HVAC applications typically use a lithium bromide/water working fluid.
- This type of chiller is less competitive unless there is a source of essentially free waste heat available, or very low fuel prices can be arranged.
Cooling Towers

- Large A/C systems use water rather than air to cool the condenser.
- At summer peak conditions, the water typically enters condenser at 85°F and is heated up about 15°F.
- The water is evaporatively cooled in the cooling tower by breaking it into small droplets, exposing it to rapidly moving air and collecting the cooled water.
Cooling Towers (Cont’d)

- A cooling tower uses fans, pumps and piping that must be maintained.
- Tower serves as a good site for the growth of *Legionella* bacteria and other potentially dangerous biological microbes, so water must be regularly treated.
Boilers

- Produce hot water or steam for heating through the burning of fossil fuel.
- Boilers have heavy maintenance requirements and can be sources of major energy waste.
- We’ll discuss boilers in more detail soon.
Controls and Energy Management Systems

- Senses outdoor and indoor conditions and automatically adjusts the HVAC system to produce the desired indoor conditions.
- System must sense temperatures, pressures and humidities, transmit these to a central location where they are used to initiate control responses, and then transmit signals back to the valves, dampers, fans, pumps to achieve the desired conditions.
Control systems are usually fairly complicated and often poorly understood by maintenance personnel, consequently they often work improperly, resulting in energy waste.