Air Conditioning and Water Treatment

A basic presentation about all the different types of Air Conditioning Systems, and where water treatment is needed and how it’s done

Scott Yollis, CFM
Goals of this presentation

• How Air Conditioning works, the basic principals
• Common Air Conditioning strategies for different building types
• The different types of AC hardware, and what they do
• HVAC configuration alternatives
• Water treatment, why we need it, where it is used, how it works
What your tenants think air conditioning is

• Most don’t know a register from a return
How air conditioning works

• It’s all about moving heat cost effectively and efficiently
• Cooling systems move heat, most heating systems create it
• Air Conditioners take heat from one place and put it in another
• The simplest example is a Window Air Conditioner.

<table>
<thead>
<tr>
<th>Inside of the house is cooled</th>
<th>Outside of the house is heated</th>
</tr>
</thead>
<tbody>
<tr>
<td>The AC Unit pumps heat from inside the house</td>
<td>to the air outside the house</td>
</tr>
</tbody>
</table>
Heat is usually moved in two ways

• Evaporative cooling using water
• Evaporative cooling using refrigerants

• When liquids evaporate the vapor takes heat away
  • Called the latent heat of vaporization
  • The latent heat of vaporization for water is: 1 calorie = 4.186 J. Latent heat of vaporization of water = 539 cal/g = 2256 kJ/kg. Latent heat of fusion of water = 79.5 cal/g = 333 kJ/kg. Specific heat of water = 1 cal/g = 4.19 kJ/kg.
  • The latent heat of refrigerants is less, but the concept it the same

When a wet shirt evaporates it is using evaporative cooling
What is a refrigerant?

• A refrigerant is a substance that is used in Air Conditioners to move heat from one place to another by being evaporated and condensed in places where it is desirable to move the heat.

• Ideally refrigerants are:
  • Environmentally friendly, (ozone layer and people)
  • Compatible with the materials used inside Air Conditioners
  • Not too expensive
  • Efficient to use
Don’t refrigerants destroy the ozone layer?

• Older refrigerants like R-12 were chlorinated hydrocarbons, CFC’s, that scientists told us were damaging the ozone layer
• Those refrigerants are no longer made
• They were replaced by other refrigerants, HCFCs like R-22 and even that is being phased out by 2020.
• R-22 is now replaced by RS-44b (R453a)
• New equipment uses more environmentally friendly refrigerants
• Many new refrigerants are blends of chemicals
  • Blends can get out of balance if there is a leak in the system
  • R-4414 is 54.8% propane, 36.1% butane, 3.1% ethane and 6% isobutane

Scott Yollis CFM for IFMA
An evaporative cooler, (swap cooler)

- Air blows though wet materials, evaporating some of the water, which cools the remaining water and air passing by it cools the air
  - Works well in dry climates, not well with humid or recycling air
  - Many homes, warehouses, big open buildings like Home Depot
AC units using refrigerants

• Use force to pressurize and evaporate the refrigeration inside them
  • When the refrigerant is a gas and pressure is added to make it into a liquid, heat is released.
  • When it’s liquid and pressure is removed so it can evaporate it, it cools down
• Refrigerated Air Conditioning has 4 major parts
  • The compressor, which pressurizes the refrigerant to condense it
  • A Hot Coil where the hot gas is pressurized and turns into a liquid
  • A valve which limits how much liquid goes to the Evaporator
  • An Evaporator Coil where liquid refrigerant is allowed to evaporate, making it very cold
The refrigerant cycle
Other types of heating and cooling

• Absorption systems use Ammonia for the refrigerant
  • Often uses in large buildings like food warehouses and processing
  • Ammonia is very hazardous, few good technicians
  • Can be powered with fuels other than electricity, like gas, propane or oil

• Passive AC systems use creative physics to cool buildings
  • Very cost effective, but often marginally effective in warm climates

• Thermocouple cooling & heating is usually restricted to refrigeration
  • Not hazardous, no moving parts, not too efficient. Never used on buildings
Passive heating and cooling

The Conrad Hilton Foundation is an excellent example
What about heat?

• Boilers usually provide heat in big buildings
  • Building boilers are not associated with domestic water heaters
  • Hot water from them is circulated to places that need heat
  • Most are powered by natural gas, some propane, some electric, (expensive)
  • The largest boilers are highly regulated
    • In Calif boilers over 2,000 btu are highly regulated by the AQMD
    • High pressure boilers over 5 hp 15 psi require specially licensed operators in LA

• Solar panels sometimes provide heat
  • Usually solar panel heat needs to be backed up by other heat sources

• In other parts of the country geothermal heat is sometimes used
AC components for small buildings

• Swamp coolers and window air conditioners that we covered
• Condenser units, (stand alone condenser coils, usually outside)
• Evaporator units, (“split system”, evaporator coils in the building)
• Compressor, (refrigerant pumps, “split system”, in condenser units outside)
• Heater, (usually gas, sometimes electric, usually indoors)
• “Package Unit”, (gas heat and refrigerated AC all in one unit)
  • Usually outside, sometimes in attics
• Heat pump, (an air conditioner that also runs in reverse to provide heating)
  • Heat pumps cost more to provide heat then gas heaters, but less than electric heating
  • A good alternative when gas is not available
• Thermostat, (the AC controls, located in the occupied spaces)
Condenser units

• Usually placed outside the building so they can release heat to the air
• Often on the roof or adjacent to the building
• They only release heat, they do not add or remove building air
• Many, but not all have compressors built into them
Package units

• Heating and Cooling in one big box
• Usually gas heating in this part of the country
• Provides appropriately heated and cooled air flow, (forced air)
• Recycles up to 90% of the air it gets from inside
Compressors

- Electric pumps that turn refrigerant gas to a liquid with pressure
  - Hermetic reciprocal is most common small pump,
Evaporators

• Where the liquid refrigerant from the condenser evaporates and cools
• Air that is going into occupied spaces passes thought the evaporator
• It can be outside in an air handler, or inside in air boxes
• Air is cooled down to about 20 degrees below the room temperature
Typical control system for small buildings

• Usually just wall mounted thermostats
  • Most control several rooms, often that causes problems
  • Sometimes sensors are added to help vary support to different rooms
  • Many can be programed, new ones can even have wifi
HVAC components for larger buildings

• Swamp coolers and sometimes Ammonia systems that we covered
• Cooling towers, (evaporate water to provide cool tower water)
• Chillers, (refrigerants move heat from tower water to chilled water)
• Boilers, (provide hot water to heat the building)
• Pumps, (move hot and cold water from one place to another)
• Air Handlers, (move air from one place to another, usually in ducts)
• Heating & Cooling Boxes, (blow air past hot/cold coils to cool spaces)
• Control systems, (thermostats to very automated computer controls)
• Humidifier and Dehumidifier equipment
• Small areas like computer rooms often use small building AC systems
  • Doing so allows primary building AC to be turned off during non working hrs
Cooling towers

• Like giant swamp coolers but for cooling the water in them
• The cooling is all done by evaporating water
• 80% of the water used in a big building can be evaporated in them
• Costs much less per btu of cooling than refrigerated cooling
• Efficiency is highly dependent on outside temperature and humidity
• Often on roofs or close to the building, they must have fresh air
• Generally economical for AC loads over 200 tons
• Require constant and precise water treatment
• Some are hardscape structures
Typical cooling towers
Typical chiller, (water cooled)
How a centripetal chiller works

• A high speed fan that forces the refrigerant gas outward under so much pressure that it turns into a liquid
• It uses a heat exchanger to pass heat from refrigerant to tower water
Chillers

• Use refrigeration to remove heat from the chilled water loop and put it back into the air. Large building water cooled chiller diagramed below.
Chiller, typical air cooled

• Uses a refrigerant loop to cool water, rejects the heat into the air
• Not as efficient as water cooled chillers which use cooling towers
• Can be large or small
How air cooled chillers work
The big trade off, evaporative vs air cooled

- Evaporative cooling, less expensive to operate but uses lots of water
  - Not appreciated where water is at a premium
  - Can use 80 to 90% of the water used at a facility, just to cool the building
    - Some of the water used is discharged down the drain, (blowdown)
  - In dry years it can be almost impossible to meet water rationing requirements
- Air Cooled is more expensive to operate, uses much more power
  - Doesn’t consume fresh water or generate wastewater, (blowdown)
  - Uses much more electricity, so where power is at a premium it’s not good

There is no right answer, just options and ramifications
Boilers

• Most use natural gas, because it’s the most economical than electric
• Water from them is piped to where heat needs to be added
• Boilers over 5 hp or 15 psi are highly regulated in LA
• Boilers over 2,000 btu require AQMD Permits.
  • Boilers under 2,000 btu don’t even if you de-rate a larger boiler
Hydronic heating and cooling

- Heating by passive conduction using water coils
  - Usually in the floor, mostly used for heat
  - Can use a floor or wall mounted radiator
  - It is generally more efficient than ducted or forced air systems
    - It doesn’t waste energy moving air
    - It doesn’t require large air ducts which take up a lot of space
  - It does not provide fresh air or exhaust, only heat
    - It doesn’t meet fresh air requirements, they must be addressed some other way
  - It’s very slow to heat or cool a building
  - Buildings are in generally in a heating or cooling mode at any one time
  - Can easily use heat from solar panels
Hydronic heating
Typical pumps
Air handlers
Air delivery

• Make up air must be delivered to all occupied spaces
  • A closet, a computer room, & even a walk in freezer can be unoccupied space
  • **Ductless heating and cooling** may be used in unoccupied spaces
  • Offices, lunch rooms, open areas, everywhere people spend time, is occupied
  • Obviously avenues for exhaust also must be provided
  • In large buildings variable speed fans balance air pressure
  • Stack pressure effects also must be considered especially in multi story bldgs

• There are many ways to calculate the fresh air requirement for a space
  • In offices 15 CFM per person, assuming there are no contaminants
  • If there are contaminants they must be kept below hazardous thresholds
  • Demand control systems are allowed that base flow on CO2 levels

**EXCEPTIONS ABOUND**, the rules are complicated

**Fun fact, if you don’t have any way to provide fresh air, you can’t occupy the building**
Heating and cooling boxes

• Use hot and cold water, sometimes electric heating coils to heat and cool the air.

• They meter the air and or hot and cold water to maintain your temp
Computerized Control Systems

• Can schedule, operate, and report on all HVAC activities including faults
  • Most offer remote access, must overcome security concerns first
  • They require custom programs which can be costly to modify
  • The more sensors and zones the more expensive to buy and maintain
Thermostats in big buildings

• Can be electronic or pneumatic, pneumatic is the most popular
  Pneumatic requires a compressor
• Often connected to the computer controls
• Can directly control a box or not
• Many can’t be controlled locally
• Many are only sensors
• If you hear them hiss, they are pneumatic
Stand alone supplemental refrigeration
Ductless heating and cooling

- Commonly provided where more fresh air is not needed
- Many provide heating and cooling
- They do not provide any fresh air
- Easy to install because the supply piping is very small
- Great for computer rooms, or to add supplemental capacity
- Can be in the ceiling or on the wall
CRAC Systems

- Short for **Computer Room AC**
- Also includes Humidity control, prevents static & moisture problems
- Often includes 2 independent sides for redundancy
- Often has it’s own power with back up provisions
- Often they only recycle air since they are not occupied spaces
- Recycling air also minimizes the energy required
- Some fire systems aren’t people friendly, so the rooms must be sealed
- Sealing computer rooms is also a good idea because they are very noisy
- The AC and power designs get complicated, (another presentation)
Humidity control

• Adding moisture to the air for comfort and to stabilize materials
  • People don’t like to be too dry or too moist, even food has an ideal range
  • Museums, archiving centers, even wood floor gyms, want stable humidity
  • Condensation and static control for equipment

Humidifiers

De-Humidifiers
Humidifier types, (mobile, in duct, direct space)

- Ultrasonic
- Electrode steam
- Boiler
- Misting nozzle
- Impeller
Dehumidifiers

• Remove excessive moisture from the air
  • Used when air conditioned air humidity control is not adequate
  • Used to help provide extremely stable humidity controlled environments
  • Used to provide ultra dry environments, often needed in manufacturing
    • Can easily maintain a -75°F dew point

• The king of dehumidification in this area is Munters
HVAC strategies & configuration alternatives

Goals:

• Provide consistently comfortable temperatures, humidity & fresh air
• Design to provide the AC as economically as possible
• Operate as economically as possible
• Operate and maintain to maximize equipment life
• Include appropriate redundancy where necessary
Thermal Storage

• Usually freezing water at night when power costs less
Air can be delivered conditioned... or not

• **Economizers** can often cool a building with fresh outside air

• Many buildings in warmer parts of the country count on cooling most parts of the building most of the time
  • They cool ALL the air in their air handlers and then reheat it if they need to when it gets to the area it’s delivered
  • Air is cooled even when the weather is cold and MOST of the building needs to be warmed up because none of the building can be cooled if they don’t

• Buildings in cold places might deliver warm air all the time

• Some switch between heating and cooling seasonally

• Some provide heating & cooling to all rooms all year long on demand

**THERE IS NO RULE, THEY CAN DO WHATEVER THEY WANT**
Temperature and humidity

- OSHA recommends office temperature control in the range of 68-76° F and humidity control in the range of 20%-60%

- According to an OSHA interpretation letter, "office temperature and humidity conditions are generally a matter of human comfort rather than hazards that could cause death or serious physical harm. OSHA cannot cite the General Duty Clause for personal discomfort."
  - Most buildings automatically end up about 46% RH in the Summer
    - Cooling coils bring air down to about 45°F, then warm to 72°F, resulting in 38%RH
      - 45°F air loses all the water it can’t hold, and when it warms up has lower humidity
  - Most buildings can’t maintain 20% unless they add humidity in the Winter, few do
PSYCHROMETRIC CHART
Normal Temperature
I-P Units
SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
Relative humidity and dew point

• **The relative humidity** is the amount of water vapor the air is holding right now as a percentage of what it would be holding if it were saturated, (holding as much as it can suspend as a gas). If you increase the temperature the amount of water vapor the air can hold increases, so the relative humidity decreases.

• **The dew point** is the temperature at which a given sample of air will have a relative humidity of 100 percent. If the temperature goes any lower some of the water will condense

Interesting fact, the best way to measure dew point is with a dew cup
Sensible vs Latent Heat

• Sensible heat is heat gained or lost without a change of state
  • Conductive heat, warmed or cooled by contact

• Latent heat is a gain or loss used to evaporate or condense
  • Moisture from people or most outside air that must be condensed by the AC
  • Changing the state takes a lot of energy but does not change the temperature
  • Latent heat loads can consume a lot of energy and your AC capacity

• People emit sensible latent heat, both need to be removed by AC

AC units are much more efficient when the humidity is not high
### The heat load from people

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total Heat (Btu/H)</th>
<th>Sensible Gain/Person</th>
<th>Latent Gain/Person</th>
<th>Low Radiant %</th>
<th>High Radiant %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seated in theater</td>
<td>225</td>
<td>105</td>
<td></td>
<td>60</td>
<td>27</td>
</tr>
<tr>
<td>Seated in theater, night</td>
<td>245</td>
<td>105</td>
<td></td>
<td>60</td>
<td>27</td>
</tr>
<tr>
<td>Seated, very light work</td>
<td>245</td>
<td>155</td>
<td></td>
<td>60</td>
<td>27</td>
</tr>
<tr>
<td>Moderately active, office work</td>
<td>250</td>
<td>200</td>
<td></td>
<td>58</td>
<td>38</td>
</tr>
<tr>
<td>Standing, light work, walking</td>
<td>250</td>
<td>200</td>
<td></td>
<td>58</td>
<td>38</td>
</tr>
<tr>
<td>Walking, standing</td>
<td>250</td>
<td>250</td>
<td></td>
<td>58</td>
<td>38</td>
</tr>
<tr>
<td>Sedentary work</td>
<td>275</td>
<td>275</td>
<td></td>
<td>49</td>
<td>35</td>
</tr>
<tr>
<td>Light bench work</td>
<td>275</td>
<td>475</td>
<td></td>
<td>49</td>
<td>35</td>
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<tr>
<td>Moderate dancing</td>
<td>305</td>
<td>545</td>
<td></td>
<td>49</td>
<td>35</td>
</tr>
<tr>
<td>Walking 3 mph, light machine work</td>
<td>375</td>
<td>625</td>
<td></td>
<td>49</td>
<td>35</td>
</tr>
<tr>
<td>Heavy work</td>
<td>580</td>
<td>870</td>
<td></td>
<td>54</td>
<td>19</td>
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<tr>
<td>Heavy machine work, lifting</td>
<td>635</td>
<td>965</td>
<td></td>
<td>54</td>
<td>19</td>
</tr>
<tr>
<td>Athletics</td>
<td>710</td>
<td>1090</td>
<td></td>
<td>54</td>
<td>19</td>
</tr>
</tbody>
</table>
Heat loads from other sources

• Lighting
  • The less efficient the more AC you need to compensate for heat it generates

• Computer Equipment
  • Some is much more efficient than others

• Windows
  • Conduction and radiant heat especially if single pane, window coverings help
  • Transmission when the sun is out

• Printers, Copiers, kitchen equipment and other equipment
HVAC zones

• Heat, cooling and fresh air must be delivered where it’s needed without depriving or overwhelming areas on the same thermostat.

• Window and exterior wall zones must have their own controls
  • They are strongly affected by the weather and the sun
  • Top floors often require more cooling & heating because of conductive loads.

• Offices & conference rooms vary their loads depending on occupancy
  • They often need separate controls which will self-adjust to occupancy

• Offices can’t become conference rooms without adding AC capacity

• Additional heat loads from other equipment must be considered
HVAC zone considerations
The supply must match the load

When the control system and or capacity can’t match the load with appropriate heating and cooling, you get very unhappy people

• Unfortunately the nature of the business is there will always be some unhappy people
• The best you can do is try and design in enough controls and zones to allow you to avoid over or under heating or cooling one part of a zone in order to satisfy another part of a zone that has one control point
• Whenever moves or renovations are considered it’s OUR JOB to consider and point out AC load ramifications
When does the AC need to change?

• Whenever you are adding loads that will exceed the existing capacity
  • Making or using offices for conference, meeting or lunch rooms
    • Must consider the capacity of the existing supply
    • You might need to add a new box
    • Should consider an independent thermostat for that room, so it doesn’t effect others
  • If you decide to add a lot of equipment to a room
    • Printer rooms or computer rooms or closets must have enhanced AC their own controls
  • If you decide to wall off a common area for privacy or security
    • They need their own AC and air supply, and probably their own control
    • They might require their own box
  • If you open up an area, or remove a wall
    • You might be joining two incompatible AC systems, they might fight each other
Water treatment

• Protects people
  • Impedes the propagation of dangerous pathogens like Legionella

• Prolongs the life of equipment
  • Slows down biological damage like corrosion prevents clogging up the system
  • Prevents scale from forming an insulating layer of minerals on vital equipment
  • Anodes minimize metal loss from vital equipment

• Saves water and energy
  • Prevents scale from bonding to AC components at high levels of concentration
    • Scale reduces the efficiency & is very difficult to remove, it drives operating costs way up
Biological water treatment

• We add chemicals to the water to kill undesirable biologicals
  • Bacteria, fungi, zooplankton, and phytoplankton or algae, even ostracods
  • Chemicals must be strong enough for control but not environmental hazards
  • We often try to switch between biocides to minimize acquired immunity

• Treatment goes in all wet environments
  • Tower water, chilled water, boiler water, open and closed loops
  • Most of the water and chemicals go into the tower water because that is an open loop that is constantly replenished

The most common mistake made by new water treatment techs is adding too much biocide at once, usually when a container is getting low so they can switch to a new one. That causes massive foaming, requires foam inhibitors
Good and bad biological treatment
Corrosion related water treatment

• Several types of chemicals are added to water to protect the equipment
  • Passivating (Anodic) Inhibitors: These chemicals form a protective oxide film on the metal surface which is not only tough, but, when damaged, quickly repairs itself
  • Adsorption Inhibitors: These are organic compounds containing nitrogen, such as amines, or sulfur or hydroxyl groups. Due to the shape, size, orientation, and electrical charge of the molecule, they will attach to the surface of the metal, preventing corrosion

Corrosion can tremendously shorten the life of a equipment
Corrosion in a chiller
Precipitation inhibitors

**Precipitating Inhibitors:** Precipitating inhibitors form complexes with the minerals that are insoluble at the higher pH and, thus, precipitate them out of the water

- These save water and money and without them much more water would need to be flushed down the drain to prevent scale from building up on vital equipment surfaces
- The amount of make-up water is reduced significantly as the number of cycles is increased from 2 to 6. However, there is only a further 5% reduction in make-up water as the number of cycles is increased from 6 to 10, and only a further 2% reduction as it is increased to 20. Therefore, in most cooling tower applications, cycles of concentration is maintained between 5 and 10 and deposition inhibitors are added as necessary. While lower cycles represent loss of more water and treatment chemicals, the amount of treatment chemicals required tends to go down with cycles, and 5-10 cycles usually represents a good balance point.
Scale in a chiller
Tricks to save water and chemicals

• Good water treatment to increase the cycles of concentration
  • As a pervious slide shows, that becomes fruitless if too extreme and puts your equipment at risk

• “Blow then flow”
  • To keep the cycles of concentration from getting too high most companies drain out some of the tower water that has highly concentrated minerals in it, and then backfill. To save chemicals drain first than add new chemicals to with the new water. That way less chemicals are flushed down the drain

• Automated water treatment
  • Quite common, some based on time, and others measure and maintain a concentration that is acceptable.
Unusual water treatment methods

• Zero blow down
  • Some companies do it, but it’s a lot of work and a big risk to the equipment for a minimal additional water savings

• Ozone treatment
  • Replaces biocides and reduces the scale potential. I can’t argue with things that work but it’s not common and like with zero blow down, you have a lot to lose by using unconventional processes to protect some of your most expensive assets

• Using reclaimed water instead of potable water
  • Requires extensive pretreatment to remove excess minerals and ammonia. Ammonia is corrosive to HVAC components

• Electronic galvanic control
  • Uncommon
Anodes

• Sacrificial anodes are magnesium or zinc that are added inside components like chillers to protect them from corrosion
  • The magnesium and zinc have a higher potential to corrode than the base metal itself. In this system, metal bars are strategically installed on tube sheets or baffles. The sacrificial anodes corrode instead of the equipment, and are periodically replaced
  • They need to be replaced when they get too small to be effective
Water treatment effectiveness must be measured

- Coupon Racks expose samples of metal that have documented weights, to the water, and damage to them is analyzed
  - Metal loss of less than 2.0 mils per year for mild steel and copper metal loss less than 0.1 mils per year is acceptable. Nothing lasts forever.
Rule of thumb

“The company is not as important as the tech”

• All the large companies have good and bad techs, the trick is to get them to give you a good one and keep them
• The turn over in most water treatment companies is awful and those companies tend to want to train new staff at your account, (not good)
• Even small companies can be very good. Your company is a much more important client for a small company than they might be at a much larger company with much larger and “more important” clients

Many small companies are started by fantastic techs who left big companies
It’s easy to pay for good work and be cheated

• The company you hire to do your water treatment is unlikely to tell you if they are not doing a good job

• You have a tremendous amount to lose if they do a bad job
• They can save themselves a lot of money by
  • Not adding enough chemicals
  • By not spending enough time at your account to do the job well
  • By not giving you techs who know what little problems look like before they turn into big and very expensive problems.

It’s a very good idea to have an independent company inspect their work
Questions?

This presentation only hit the highlights, there is a lot more

• I can be contacted at any reasonable time
• Mention you attended an IFMA seminar so I don’t cut you off

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