



Fundamentals of Refrigeration

Evaporators, Condensers, Expansion Devices
and Accessories



What you will Learn in this Lesson

- Different kinds of evaporators
 - DX, flooded and falling film
- Different kinds of condensers
- Expansion devices
- Refrigeration system accessories

Evaporators

- Heat exchangers that transfer heat from the source that needs cooling to refrigerant
- In ideal cycle evaporator
 - Receives 2 phase refrigerant
 - Boils refrigerant to 100% saturated gas
 - Constant temperature and pressure
 - No internal pressure drops
- Δh is cooling effect for system
- Real evaporators
 - Have internal pressure drops that creates temperature gradient from inlet to outlet
 - Must add superheat

DX Air Coils

- Used in residential, PTACs, WSHPs, minisplits, rooftop units
- Mostly R-410a (replacing R-22)
- Typically, copper tube expanded into aluminum fins
 - Aluminum tube and fin coil uses is starting
- Fins enhanced with ripples, slotting (lancing) etc to improve heat transfer

Microchannel Coil

- All aluminum extrusion
- Limited use as evaporators (so far)
- Condensate management is the issue
 - Condensate gets blown off surface back into airstream

Coil Selection

- User choice
 - Number of circuits
 - Width and height
 - Number rows
 - Number fins per inch
 - Tube material and thickness
 - Fin material and thickness
 - Serpentine
 - Face or row split or interlaced
- Manufacturer choice
 - Tube enhancements
 - Fin design
 - Tube geometry

DX Coil Operation

- Typical
 - Supply air temperature 55 °F
 - Leaving approach = 10 °F
 - SST = 45 °F
- Typical DX coil shows
 - TX valve in vertical position to evenly feed all tubes
 - R-410a enters coil at 45 °F and 145 psia
 - Pressure drop through tubes causes temperature to drop
 - At some point all refrigerant becomes a gas
 - Now on energy is added as superheat
 - Temperature will climb

DX Water Evaporators

- Water evaporators transfer heat from water (brine) to the refrigerant
 - Water undergoes sensible heat transfer
 - Refrigerant undergoes latent heat transfer
- DX water evaporators typical up to about 500 tons
- Two types
 - Plate type
 - Shell and tube
- Typically below dew point
 - Insulated against sweating

Plate Type DX Water Evaporators

- Typically used up through 125 tons
 - Cost effective
 - Not cleanable but ok if chilled water is clean
- Embossed SS plates typically brazed due to pressure
- Vertically mounted
- Refrigerant evenly distributed between plates by internal distributor

Shell and Tube DX Water Evaporators

- Typically used above 125 tons
- Carbon steel shell with copper tubes
- Water in shell
 - Single pass
 - Low PD
- Refrigerant in tubes
 - Low charge
- Tube sheets support tubes and act as baffles to direct water flow over tubes
- Can have multiple circuits
- Distributor built into end of shell to evenly distribute refrigerant to each tube

DX Water Evaporator Performance

- Behave similar to DX air coils
- Refrigerant enters evaporator as 2 phase flow
- Pressure drop through tubes causes temperature to drop
- At some point all refrigerant becomes a gas
- Now on energy is added as superheat
 - Temperature will climb
 - Plate type superheat around 10 °F
 - Shell and tube superheat around 8 °F
- Water is cooled sensibly from 54 °F to 44 °F (typical)
- Low refrigerant charge in DX evaporators makes them good for low ambient applications
 - Not enough refrigerant to freeze tubes
 - Flooded evaporators can freeze tubes – special steps required

Flooded Evaporators

- Similar to DX shell and tube water evaporators
- Refrigerant is in shell
- Water is in tubes
- Used on centrifugals, W/C screw chillers
 - Sometimes on high efficiency A/C screw chillers

Flooded Evaporator

- Engineered tubing
 - Different diameters
 - Material
 - Wall thickness
 - Tube count
- Different water passes (1,2,3 or 4)

Flooded Evaporator Performance

- Very high performance
 - Less than 1 °F superheat
 - Very low refrigerant pressure drop
- Carefully designed to avoid liquid carryover
- Waterside tube velocity important to maintain turbulent flow ($Re > 2300$)
- Since they are built to order, can be tailored for wide range of operating conditions

Falling Film Evaporators

- Similar to flooded evaporator
- Refrigerant circulated into a tray above tubes
 - Passes through holes in tray wetted all the outer surface of tubes below
- Can be mechanically recirculated from bottom of evaporator shell back to tray
- Some designs pour refrigerant from liquid line into tray in a one pass arrangement
- Greatly reduce refrigerant charge vs. flooded design
 - Similar performance

Oil in Evaporators

- Oil coating evaporator heat exchange surface areas has detrimental impact on performance
 - Coats surfaces and acts like an insulator
- Concentrations should be kept under 1% in evaporator
 - Complex oil management technology
 - Not an issue with magnetic bearing chillers

Pressure Ratings

- Most refrigerant pressures require special (ASME) construction
 - R-410a at 45 °F is at 145 psia
- Some products may have pressure relief valve (PRV) that must be field piped to atmosphere
 - Centrifugals
 - Don't run hot water through evaporator!
- Water evaporators also have water side pressure rating
 - Typically 150 psi
 - Optional construction for 300 to 400 psi

Condensers

- Heat exchangers that remove total heat of rejection from system
- In ideal cycle condenser
 - Receives superheated refrigerant from compressor
 - Desuperheats and condenses refrigerant to a saturated liquid
 - Process occurs at a constant temperature and pressure
- Δh is THR
 - Cooling effect plus compressor work
- Real condensers
 - Have internal pressure drops that creates temperature gradient from inlet to outlet
 - Typically include subcoolers
- Some form of mechanical ventilation to cool coils

Air Cooled Condensers

- Used in residential, PTACs, minisplits, rooftop units, A/C chillers
- R-410a (replacing R-22), R-134a
- Fin tube type
 - Copper tube expanded into aluminum fins
 - Aluminum tube and fin coil uses is starting
 - Fins enhanced with ripples, slotting (lancing) etc to improve heat transfer
 - Tubes usually 5/16" to 3/8"

Air Cooled Condensers Cont'd

- Microchannel coils are aluminum extrusion
- All Condenser coils exposed to elements
 - Debris and corrosion
 - Seacoast applications particularly severe
- Special treatments available
 - Blue fin
 - Baked phenolic (Herisite) coating

Air Cooled Condenser Performance

- Typical systems
 - Saturated condensing temperature 20-30 °F > ambient
 - Assuming 95 °F ambient then 115 to 125 °F condensing temperature
- R-410a enters coil at 158 °F and 461 psia
- Saturated Condensing Temperature = 125 °F
 - 33 °F superheat
- Refrigerant is desuperheated, then condensed
- Pressure drop through tubes causes temperature to drop
 - Requires higher inlet temperature

Condenser Coil Fan Systems

- THR passes through HX wall into air stream sensibly heating the ambient air
- HVAC system use forced convection (fans)
 - Most are multiple axial fans
 - Can be fan cabinet

Air Cooled Subcoolers

- Most real HVAC systems use subcooling to:
 - Avoid flash gas in refrigerant line
 - Improve the cooling capacity and hence COP
- Subcooler coil is usually separate coil
 - Saturated liquid refrigerant is drawn off condenser coil and passes through subcooler coil
 - Subcooler coil is either parallel or in front of condenser coil to see coldest ambient air
- Microchannel coils can have tubes pointing down so liquid refrigerant pools at bottom
 - Can be subcooled

Water Cooled Condensers

- Water cooled condenser transfer total heat of rejection from refrigerant to water (brine)
- Used in WSHPs, self contained units, water cooled chillers
- R-410a and R-134a
- Tube in tube type, plate type used with clean condenser water (WSHPs)
- Cleanable tube in tube type or shell in tube type used in self-contained or chillers

Shell and Tube Condenser

- Typically used for all water cooled chillers
- Water is in tubes
- Refrigerant is in shell
- Ends can be removed for tube cleaning
 - Marine water boxes
- Tubes can be copper, cupro-nickel or titanium

Shell and Tube Condenser Performance

- AHRI rates water cooled equipment assuming 85 °F EWT and 3.0 USgpm ton.
 - 85 °F is based on 78 °F ambient wetbulb and a 7 °F approach
- Saturated condensing temperature is around 105 °F rather than 125 °F found in A/C equipment

Shell and Tube Condenser Performance

- Engineered tubing
 - Different diameters
 - Material
 - Wall thickness
 - Tube count
- Different water passes (1,2,3 or 4)
- Gaseous refrigerant around the tubes, condenses falls to the bottom

Subcooling

- Subcooling accomplished by having some condenser tubes submerged in liquid refrigerant at bottom of shell
- Coldest water enters in bottom tubes
- Don't reverse piping connections in field or chiller won't work

Pressure Ratings

- Most refrigerant pressures require special (ASME) construction
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- Some products may have pressure relief valve (PRV) that must be field piped to atmosphere
 - Centrifugals
- Water condensers also have water side pressure rating
 - Typically 150 psi
 - Optional construction for 300 to 400 psi

Evaporatively Cooled Condensers

- Used in rooftop units and chillers
- R-410a and R-134a
- Reject heat at wetbulb temperatures
 - Like cooling towers
- Potentially best efficiency due to low condensing temperature
- Consume water
- Require water treatment
- Popular in dry climates (Southwest, Central CA)

Evaporatively Cooled Condensers

- Hot gas refrigerant passes through condenser coil
 - Steel, SS, copper tubes
 - Desuperheated and condensed
- Water is sprayed on outside of tubes by recirculating pump
 - Draws water from sump at bottom of unit
 - Constant make up just like cooling tower
- Water absorbs heat energy and evaporates at wetbulb temperature
 - 1000 Btu/lb of water evaporated
- Fans are used to draw ambient air through unit
- Subcooling circuit built into bottom of unit
 - Coldest, driest air

Expansion Devices

- Lower pressure from condensing pressure to evaporator pressure
- Meter correct amount of refrigerant based on actual load
- Provide correct amount of superheat
- Ideal process
 - Adiabatic
 - Isentropic
- Real process
 - Heat losses to surroundings
 - Losses to noise, friction etc.
 - Operating envelope covers 0 to 100% capacity and 25 to 100% pressure ratio

Expansion Device Types

- Fixed area restrictor
- Automatic (constant pressure) expansion valve
- Thermostatic expansion (TX) valve
- Electronic expansion valve

Fixed Area Restrictor Expansion Valve

- Carefully formed restrictions placed in liquid line
- Cap tubes
 - Used in residential, PTACs, old WSHPs
- Orifice plates
 - Negative pressure centrifugals (R-123)
 - 17 CFM/ton requires a BIG TX valve
- Economical
 - Don't adapt well to load and lift changes

Automatic Expansion Valve

- Mechanical pressure control valves
- Maintain constant evaporator or valve outlet pressure
- As pressure drops, valve restricts flow
 - Reduced refrigerant flow will absorb heat and build more pressure
- As pressure climbs, valve increases flow
- Does not account for evaporator pressure drop and how that changes with flow changes
 - Low loads will overfeed
 - High loads will starve Evaporator
- Typically not used in HVAC

Thermal Expansion (TX) Valves

- Most common device for HVAC
 - Can manage wide range of loads and pressure ratios
- Maintains nearly constant superheat at evaporator outlet
 - As superheat rises at outlet, TX valve increases refrigerant flow
 - As superheat drops at outlet, TX valve decreases refrigerant flow

Electronic Expansion Valves

- Electromechanical device
- Stepper motor opens and closes valve
 - Meters refrigerant
- Requires a DDC controller to calculate correct refrigerant flow
 - Pressure and temperature transducers
- Very accurate and efficient
- More costly than T-X valve
 - Chillers, large RTUs, HGRH etc.

Refrigerant Piping

- Copper and occasionally steel used for halocarbon refrigerants
- Ammonia reacts with copper
 - Steel piping
- Type L and K approved for ACR (Air conditioning and refrigeration) applications
 - Type M not approved
- Nominal size based on OD
 - Plumbing copper size based on ID
- Nitrogen charges with plugs
 - Keep it dry

Liquid Line Filter Drier

- Installed in liquid line
 - Filters dirt out
 - Desiccant to remove moisture
- Moisture can form carbonic acid in system
- Replaceable core can be serviced without having to cut component out of system
 - Very common if there has been a compressor burnout

Suction Line Filter Drier

- Installed in suction line
 - Filters dirt out
 - Desiccant to remove moisture
- Replaceable core can be serviced without having to cut component out of system
- Less common than liquid line filter driers
 - Used if debris in evaporator a concern
 - Pressure drop due to filter drier in a bad location

Solenoid Valve

- Two position type valve
- When power applied to coil, valve opens almost instantly
- When power is cut, refrigerant pressure drives closed almost instantly
- Can be used for:
 - Staging
 - Pump down
 - Hot gas bypass

Sight Glass

- Installed in liquid line near expansion valve
- Used to identify refrigerant gas in liquid line
 - Gas in liquid line will cause expansion device to not operate properly
 - Strong indicator unit low on charge
- Moisture indicator will change color in the presence of moisture

Auxiliary Side Connector

- Used with hot gas bypass to properly introduce hot gas into inlet of evaporator
- Located between TX valve and distributor
 - Integrates with distributor to evenly distribute hot gas refrigerant to each circuit

Suction Accumulator

- Installed in Suction line
- Separate liquid refrigerant from gaseous refrigerant
 - Used to avoid liquid carryover to compressor
- Common in heatpump applications

Refrigerant Receiver

- Pressure rated storage tanks
- Used if condenser cannot hold entire refrigerant charge
- Used for liquid flood back low ambient systems
- Used if there is a large difference in charge requirement between heating and cooling in heatpump applications

Reversing Valve

- Used with air conditioning/heatpump products to reverse flow through condenser and evaporator

Hot Gas Muffler

- Used to reduce pulsation from compressor
 - Reciprocating
 - Rotary

Shut off valves

- Used to isolate parts of refrigeration system
 - Both sides of condenser to isolate charge
 - Both sides of compressor or filter drier to allow service
- Allow gauges to be connected

Schrader Fitting

- Used to connect pressure gauges to refrigeration system
- Used to charge system
 - Liquid line
- Used to calculate superheat
 - Suction line and external equalization line

End of Lesson

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