



Fundamentals of Refrigeration

Energy Recovery, Heatpumps, HGBP and Controls



What you will Learn in this Lesson

- Energy recovery
 - Hot gas reheat
 - Liquid subcooling
 - Desuperheater
 - Heat recovery chillers
- Hot gas bypass
- Heat pumps
 - Reverse cycle
 - Defrost
 - Low temperature (cascaded systems)
- Refrigerant controls

Energy Recovery

- Refrigeration systems convert low grade heat energy into high grade heat energy
 - Generally to move heat from indoors to outdoors
- If simultaneous heating and cooling occurs
 - Opportunity for energy recovery
- Can take the form of
 - Hot gas reheat
 - Subcoolers
 - Desuperheaters
 - Heat recovery
 - Heatpumps

Hot Gas Reheat

- Second coil downstream from DX cooling coil
- Coil is parallel with condenser coil
- Used to reheat air once it has been cooled enough to lower humidity to desire level
 - For make up air, the air is now too cold for space
- Used in RTUs, DOAS, WSHPs
- Can be “on-off” or “modulating”
- Effectively “free heat”
- No impact to refrigeration circuit performance
- Small penalty for coil APD

Liquid Subcooling

- Supermarket RTUs
- Psychrometrically same as HGRH
- Hot liquid refrigerant from condenser heats air and subcools refrigerant
 - Subcooling coil piped in series with condenser coil
- Subcooling can be as much as 40 °F resulting in 15% efficiency improvement
- At part load reheat and subcooling effect drop
 - Good to have secondary reheat source
 - Supermarkets use reheat from refrigeration racks

Desuperheater

- Desuperheaters heat water by de-superheating the hot gas from the compressor
 - Installed between compressor and condenser
- Not a lot of energy but the temperatures are very high
 - 140-160 F refrigerant gas

Desuperheater

- Used in residential geothermal WSHPs and A/C chillers
- Often used to preheat domestic hot water in residential applications

Heat Recovery Chiller

- Huge amounts of low grade heat from chiller plant
 - 10,000 ton plant produces 150,000,000 Btu/h
- Only 95 °F (low grade)
- Can raise condenser to 105 – 100 °F
 - Better grade heat
 - Used for domestic hot water preheat, VAV box reheat, snow melting, etc.

Heat Recovery Chiller (Cont'd)

- Split condenser
- Separate water loops through condenser
- One set connected to cooling tower
 - Sized for chiller capacity
- One set connected to heat recovery system
 - Closed loop (clean)
 - Can be less than the rated chiller capacity
- Both condenser loops must be at the same temperature to get heat recovery
 - *“If you want heat recovery, then raise the cooling tower water temperature”*

Heat Recovery Chiller (Cont'd)

- Raising the condenser temperature lowers chiller efficiency
- Typically still cheaper than heating with natural gas or electricity

Hot Gas Bypass

- Re-circulates discharge gas from compressor back around to suction side to artificially load compressor
 - Traditionally connected to ASC at distributor (upstream of evaporator)
 - Can be introduced into suction pipe but great care must be taken to avoid damaging compressor
- Used to avoid short cycling compressor at part load
- Wastes significant energy
 - Power draw remains constant at whatever it is when the HGPPB valve opens regardless of actual cooling load
- Not allowed by ASHRAE Standard 90.1
- May be required for some industrial applications with fast changing loads

Heatpumps

- Air conditioners move heat from where you don't want it to where you don't care
- Heat pumps move heat from where you don't care to where you do want it
- System controller is moved from the cold side to the hot side
- Some units have two control points (**Dual Mode**) so they can run in heating or cooling mode
 - Requires piping connections to be changed external to the unit
- Reverse cycle heat pump can change refrigerant flow direction so the unit can operate in either heating or cooling without connection changes

Heatpump Performance

- Templifier can produce up to 160 °F hot water (high grade heat) from a low grade source
 - Condenser water from chiller plant
 - Return chilled water
 - Geothermal
- Controller is installed in discharge hot water side
 - Stages unit to maintain hot water supply temperature setpoint
- Heatpumps can heat air as well as water
 - RTUs, residential units, WSHPs, etc.

Heatpump Performance

- $\text{COP} = \frac{Q_{\text{Total Heat of Rejection}}}{W_{\text{compressor}}}$
 - Typical COP between 2 and 6 depending on lift required
- R-410a Critical point is 160.44 °F so not a good choice for heatpumps
- R-134a, CO₂ more common
- Condensing boiler COP = 0.9
 - Heatpump technology is very GREEN!

Reverse Cycle Heatpumps

- Reverse refrigerant flow direction to reverse heat flow direction
 - Can operate as heaters or coolers without changing external connections
- WSHPs, small RTUs, residential, minisplits, VRV etc

Defrost

- As soon as the coil surface temperature reaches 32 °F
 - Moisture in air will start freezing on evaporator coil
 - Water will freeze in water evaporator
- Almost all heatpump systems have some form of defrost
 - Those that don't will lockout near freezing – PTHPs
- Defrost systems can be;
 - Electric heat
 - Hot gas (reverse cycle)
- Simple control based on time
- Complex control based on performance

Low Ambient Operation

- The larger the lift, the poorer the COP
 - Geothermal
 - 140 °F Domestic Hot Water
- Positive displacement compressor are preferable
- Cascaded systems can be used to create large lifts
 - Can use different refrigerant in the two cycles
 - Common in supermarket refrigeration
 - Industrial refrigeration

Refrigeration Controls

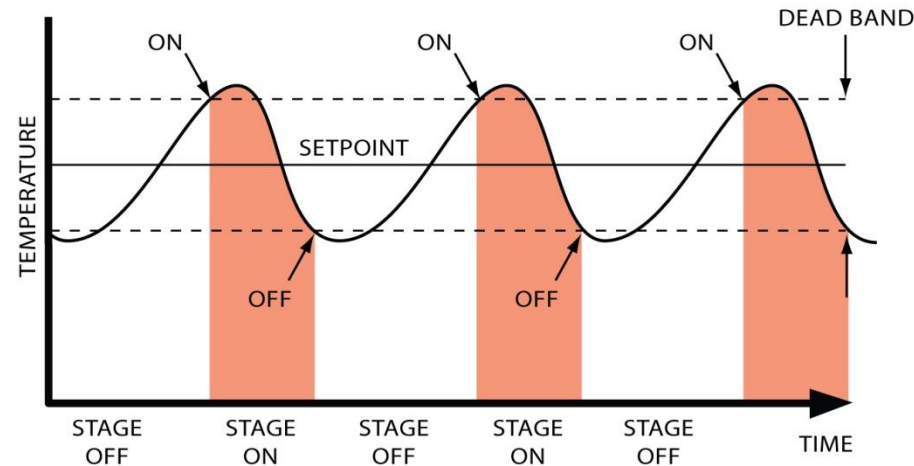
- Primary goal is to match capacity of refrigeration system to the load
 - Heating or cooling
- Match discharge temperature to setpoint
 - Chilled water
 - Supply air temperature
 - Space air temperature
- Use DDC controller (computer)
 - Digital I/O
 - Analog I/O

Refrigeration Controls

- Human interface panel
 - Thermostat
 - Small display
 - Touch screen
 - Computer terminal
- Operator inputs setpoints
 - Sees operating conditions
 - Alarm conditions
 - Operating conditions at time of alarm
 - Trend logging
- Interface with BAS
 - BACnet, LonMark, Modbus

On-Off Capacity Control

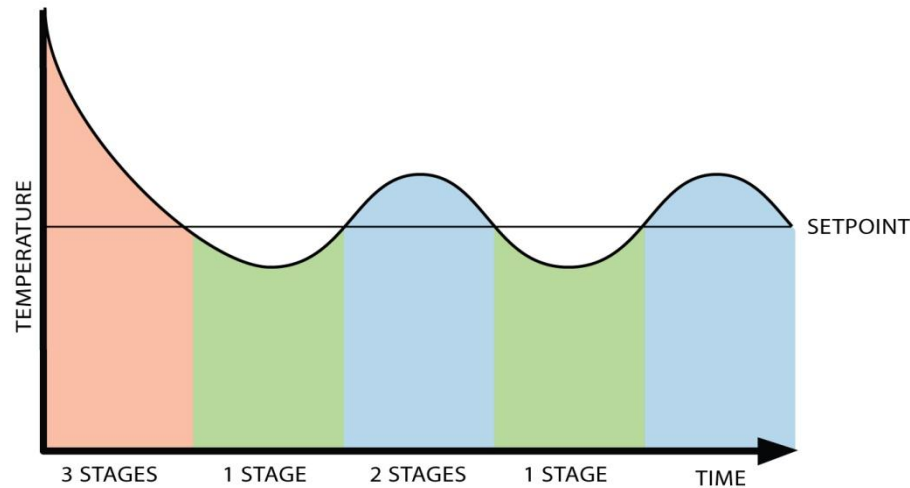
On-Off Control



- Single stage units (PTACs, WSHPs, residential, small RTUs etc.)
- Basic Thermostat
 - Need flywheel effect of building system to avoid cycling
- Part load capacity by cycling equipment on and off over time
 - 50% capacity is delivered by operating 50% of the time
- Poor control, not energy efficient

Staged Capacity Control

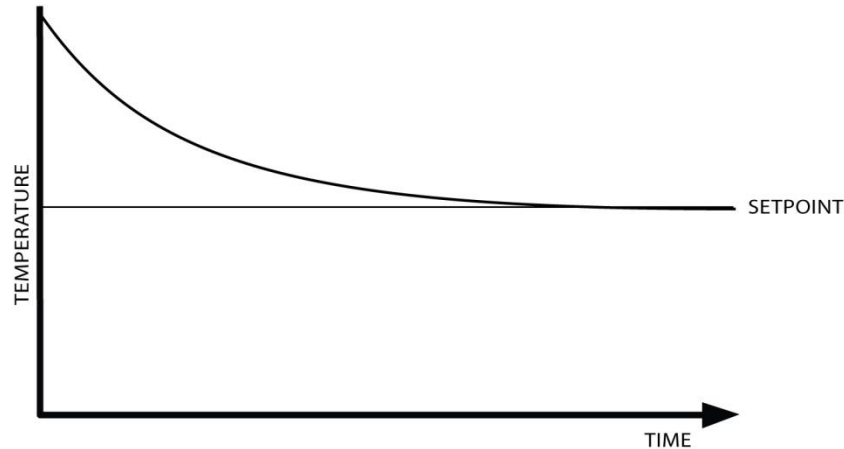
Staged Control



- Multi-stage units (RTUs, Self Contained, Scroll Chillers etc)
- Temperature sensor connected to DDC controller
 - Measure space temperature and compare to setpoint
 - Use Proportional – Integral – Derivative (PID) control
- Unit stage capacity levels will not likely match load so unit will cycle above and below setpoint
- Good control, good energy performance

Modulating Capacity Control

Modulating Control



- Modulating units (Screw chillers, centrifugal chillers, inverter scroll products)
- Temperature sensor connected to DDC Controller
 - Measure space temperature and compare to setpoint
 - Use proportional – integral – derivative (PID) control
- Unit capacity (within operating envelope) can directly match load
- Excellent control, best energy performance

Capacity Control

- DDC controller will do one of the following to change capacity
 - Stage a compressor on (close a contactor)
 - Power on/off an unloader (scrolls, screws, recipis)
 - Adjust a slide valve (screw)
 - Adjust inlet guide vane angle (centrifugal)
 - Change compressor speed (inverter)

Pumpdown

- Pump down is used at the end of a compressor cycle to remove as much refrigerant in the evaporator as possible
 - Common with reciprocating products
 - Not common with scroll products
- At end of compressor cycle
 - DDC controller closes liquid line solenoid valve (de-energizes it)
 - Compressor runs and pulls the refrigerant out of the evaporator
 - Runs until the low pressure switch opens – compressor stops
- Recycling pump down
 - If any refrigerant leaks into the evaporator and build the pressure up to the point where the low pressure cutout switch makes – compressor starts and pulls the gas out

Reverse Cycle Control

- Solenoid device
- Can be normally cooling
 - In cooling mode with no power
 - Typical of commercial units
- Can be normally heating
 - In heating mode with no power
 - Typical of residential units
- To reverse modes unit controller will:
 - Stop unit in current mode
 - Wait a fixed amount of time to allow pressures to equalize
 - (un) Power reversing valve
 - Start compressor

Refrigeration Safeties

- Protect equipment and occupants
- Safety code issue
 - UL 1995
 - ASME
 - ASHRAE Standard 15
- High pressure safety
 - Small compressors usually have internal bypass
 - Usually fuse plug – fails at preset pressure
 - Pressure switch wired directly to compressor control circuit
 - Open/closed
 - May automatically reset or require manual reset
 - Pressure transducer wired to DDC controller
 - Controller will shut unit down in pressure reading is too high

Refrigeration Safeties

- High Pressure Safety (Cont'd)
 - Pressure Relief Valves (PRV)
 - Typically used on centrifugal chillers
 - Open at preset pressure
 - Release refrigerant until pressure level is safe, then close
 - Vent to atmosphere (Standard 15)
 - Can be on evaporator and condenser
 - Rupture Disks or plugs
 - Disks used on R-123 centrifugals
 - Plugs used on small products (WSHP, PTACS etc)
 - Rupture at preset pressure level
 - Release all the refrigerant
 - Disks can be on evaporator and condenser
 - Vent to atmosphere (Standard 15)

Refrigeration Safeties

- Low pressure safety
- Protect unit from freezing up
 - Possibly slugging compressor
- Suction line temperature or pressure sensor
 - Temperature sensor is cheaper so more common on small products
 - Attached to suction line
 - Used on small products (WSHPs, PTACS etc)
 - Stops compressor if low temperature setpoint is reached
 - Typically auto resets (may have a limited number of times it will reset)
- Suction pressure transducer
 - Used on more sophisticated products (centrifugal, screw chillers, large RTUs etc)
 - Measures refrigerant pressure and DDC controller identifies risk
 - May try corrective action

Compressor Protection

- Compressor is heart of system
- DDC controllers usually include
 - Start to start or stop to start time delays to avoid cycling
 - Brown out protection (voltage drop)
 - Phase loss or reversal protections
 - Over current or inrush current protection
 - Motor winding thermal overload protection (centrifugals)

Oil Management Controls

- DX products let oil flow with refrigeration circuit
 - Limited safeties
 - Crankcase heaters
- Centrifugals can have complex oil management systems
 - Oil heating
 - Oil cooling
 - Oil flow pressure sensor (proof of oil flow)

Refrigerant Head Pressure Control

- DDCs can manage condensing system to maintain the desired condensing (head) pressure
- Stage on-off fans
 - Based on ambient (poor) or head pressure (good)
- Control variable speed fans
 - Usually based on head pressure
- Manage liquid flood back system
 - Complex and usually only used on advances systems operating in very cold weather
- Manage cooling tower system to maintain desired condenser water temperature (chillers)

End of Lesson

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