ENERGY SOLUTIONS CENTER

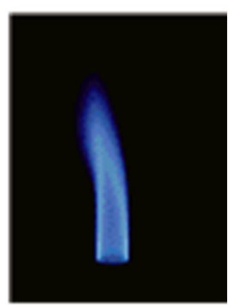
Track: Commercial Natural Gas
Unit #5: Natural Gas Cooling

An overview of Cooling Technologies for Commercial Facilities

Mr. Eric Burgis, Energy Solutions Center

Presentation Outline

- Terminology
- Market Overview
- Reducing Cooling Costs
- Cooling Basics & Science
- System components
- Natural Gas Cooling Equipment
- Natural Gas Cooling Economics & Emissions
- Commercially Available Products



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Gas Air Conditioning Terminology & Market Overview

Cooling System Terminology

- HVAC – Heating Ventilating and Air Conditioning (System)
- Ton of Refrigeration – Approximately equal to the cooling power of 2000 pounds of ice melting in a 24-hour period
  - The value is defined as 12,000 BTU per hour, or 3,517 watts
- Gas Heat Pump (GHP) – Uses natural gas as the energy that drives the heat pump
- Coefficient of Performance – (COP) is the ratio of the heat removed from the cold reservoir to input work (Output ÷ Input)
- SEER = BTU/hr ÷ Watts for Unitary Systems
- KW/Ton for Electric Chillers

Cooling System Terminology

$$COP = \frac{\text{Cooling Produced (Btus/Hr or kW)}}{\text{Heat Input (Btus/Hr or kW)}}$$

$$\frac{12{,}000}{8{,}000} = 1.5\ COP$$

$$SEER = \frac{\text{(Btus/Hr)}}{\text{Watts}} \qquad \frac{12{,}000}{2{,}344} = 5.1\ SEER$$

Remember 1 kW = 3,412 BTU

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Natural Gas Cooling Market Overview

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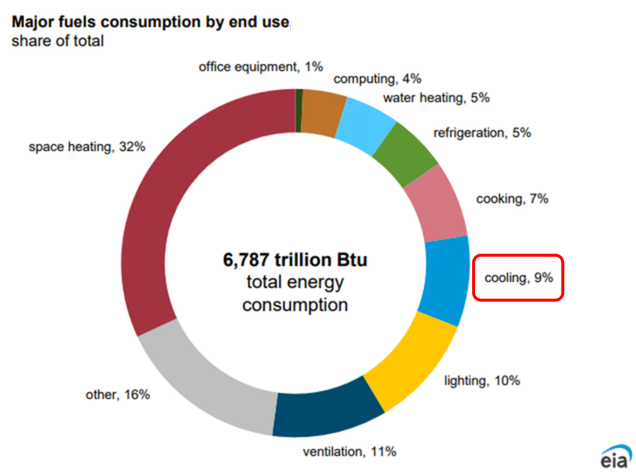
Commercial Building Overview

- U.S. commercial buildings used 6,787 trillion British thermal units (TBtu) of all major fuels: 4,081 TBtu of electricity, 2,300 TBtu of natural gas, 305 TBtu of district heat, and 101 TBtu of fuel oil
- Total floorspace in commercial buildings has increased but energy consumption is not, meaning intensity (consumption per square foot) decreased.
- Together, electricity and natural gas account for about 94% of energy consumed.
- Electricity intensity is higher in hotter climates, and natural gas intensity is higher in colder climates.
- Commercial buildings spent $141 billion on energy in 2018, averaging $1.46 per square foot.

EIA CBECS: https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS%202018%20CE%20Release%202%20Flipbook.pdf

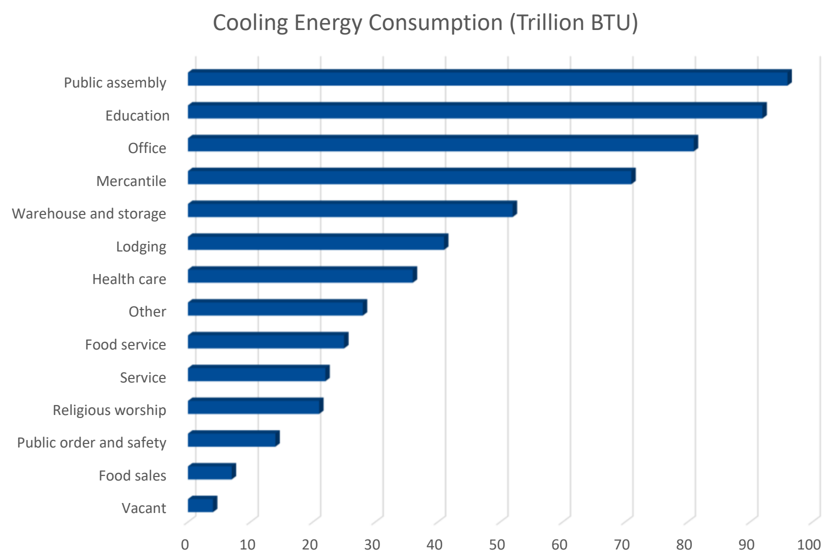
Energy Use in U.S. Commercial Buildings



Data source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*
Note: Btu = British thermal units

EIA CBECS: https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS%202018%20CE%20Release%202%20Flipbook.pdf

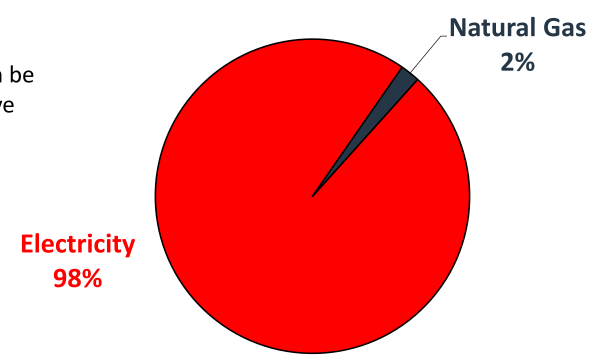
Energy Consumption for Comfort Cooling by Business Activity



Source: EIA CBECS Table E1

Energy Used for Comfort Cooling

Most buildings use electric air conditioning today, but electric can be more expensive than the alternative



https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS%202018%20CE%20Release%202%20Flipbook.pdf

Useful Life for Cooling Equipment

Equipment Type	Medial Life - Years
Air Conditioners	
Through-the-Wall	15
Water-Cooled Package	15
Rooftop	15
Packaged Chillers	
Reciprocating	20
Centrifugal	23
Absorption	23
Heat Pumps	
Air-to-Air	15
Water-to-Water	19

ASHRAE: https://www.naturalhandyman.com/iip/infhvac/ASHRAE_Chart_HVAC_Life_Expectancy.pdf

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Reducing Cooling Costs

Base Load Operation vs. Summer Peaking

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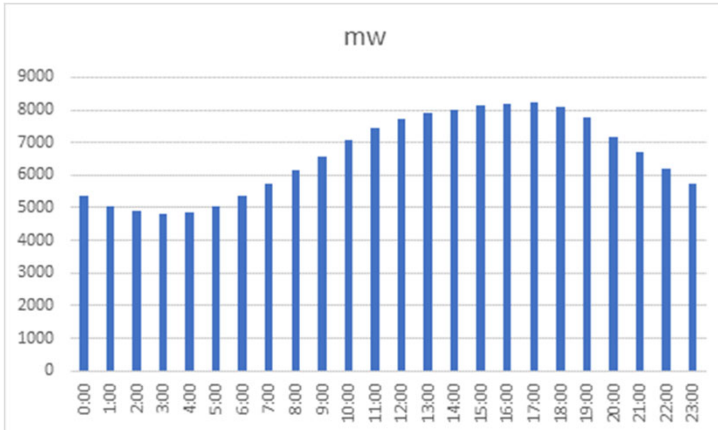
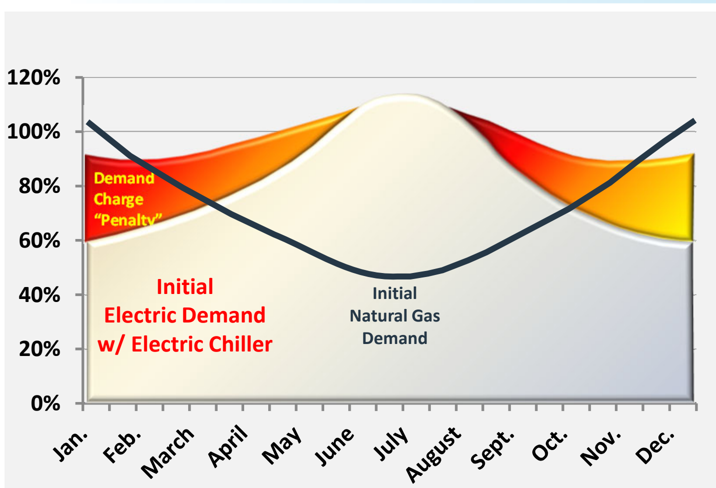
Daily Electric Load Profile- Summer Day

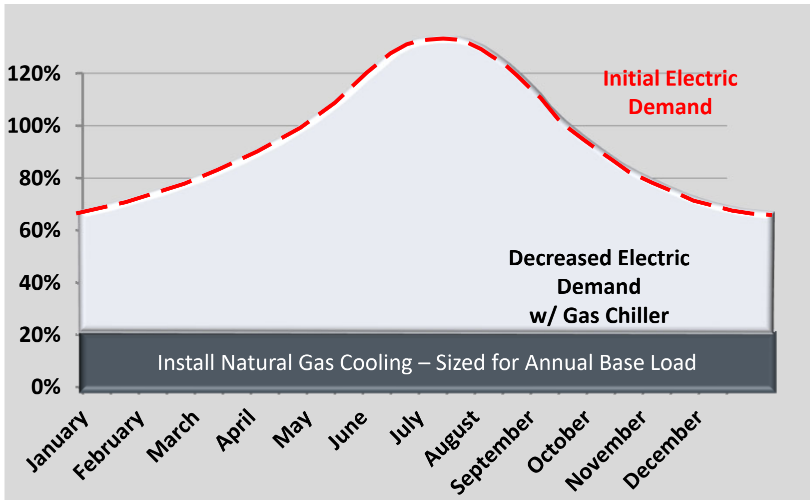


Sample for one day in August for one region of the PJM

Energy Demand Profiles
Gas Chiller – Annual Base Load



Energy Demand Profiles – Gas Chiller for Annual Base Load



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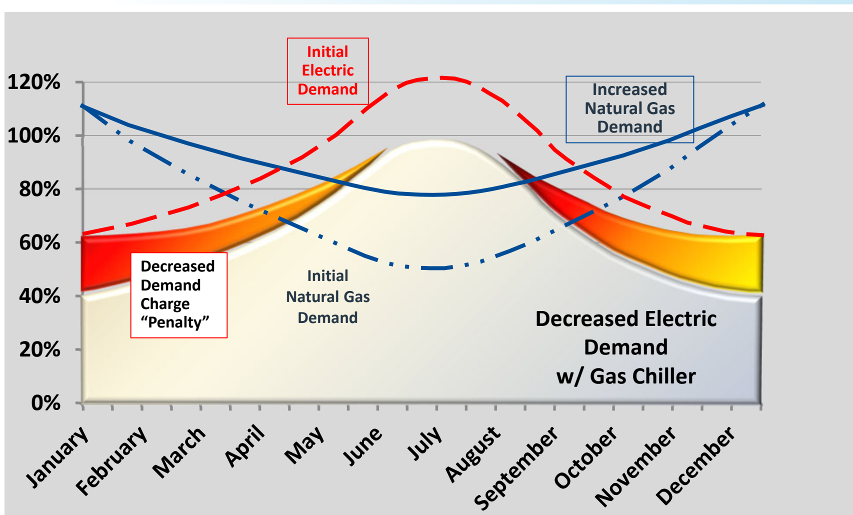
Energy Demand Profiles – Gas Chiller for Annual Base Load



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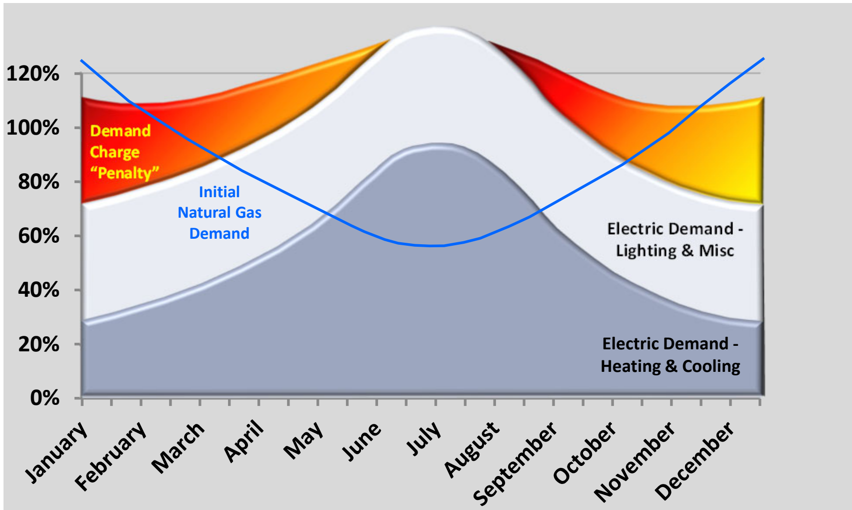
Energy Demand Profiles – Gas Chiller for Summer Peak



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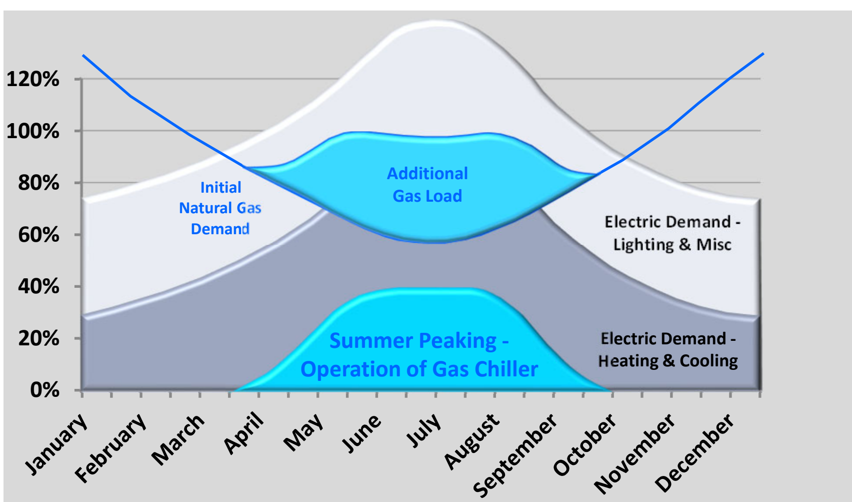
Gas Cooling
Summer Peaking Operation



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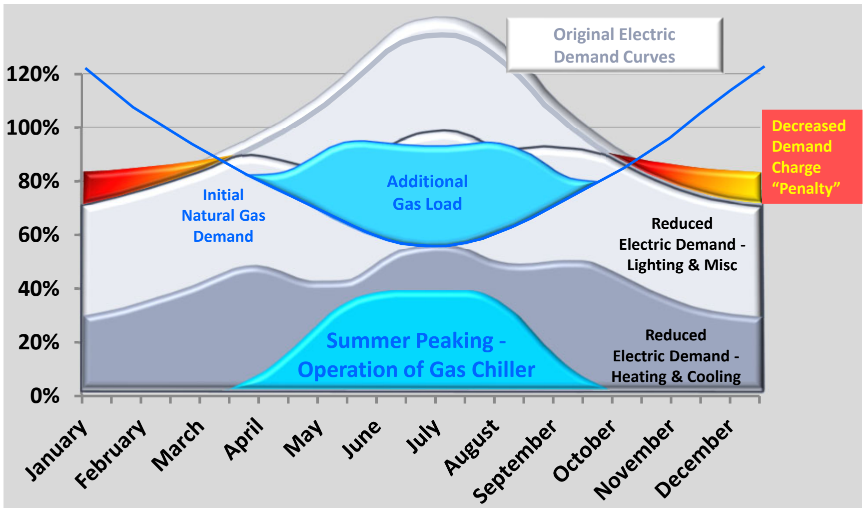
Energy Demand Profiles
Gas Chiller Summer Peak



Cooling Basics & Science

Chemistry provides us with the Modern Gas Law

PV=nRT or re-written **T= PV/nR**.

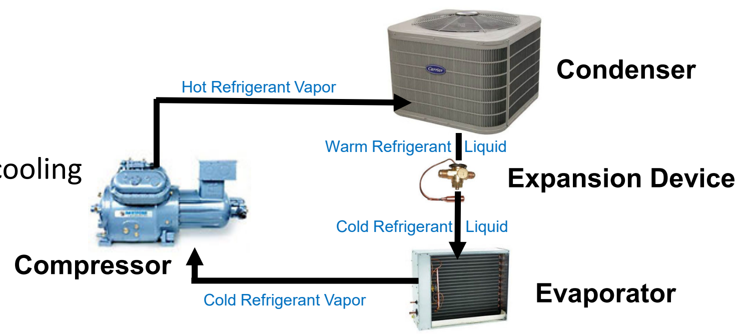
Temperature = (**P**ressure X **V**olume) / nR

R is a gas constant and n is related to the refrigerant

In short, if the pressure and volume rise, the temperature increases and vice versa

Cooling System Types

- Vapor Compression - uses a compressor to provide cooling
  - Reciprocating compressor
  - Screw compressor
  - Centrifugal compressor
  - Scroll compressor
- Absorption - uses heat to provide cooling
  - Single effect
  - Double effect



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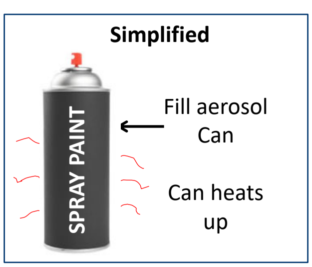
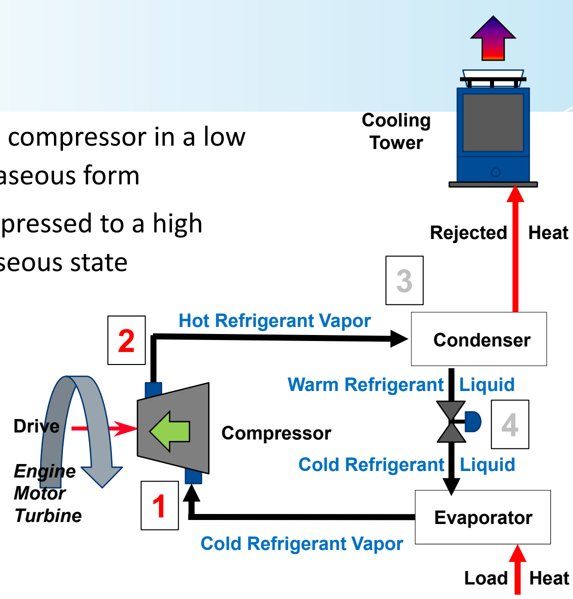
Vapor Compression Cycle

- **Step 1:** Refrigerant enters the compressor in a low pressure, low temperature, gaseous form
- **Step 2:** The refrigerant is compressed to a high pressure and temperature gaseous state





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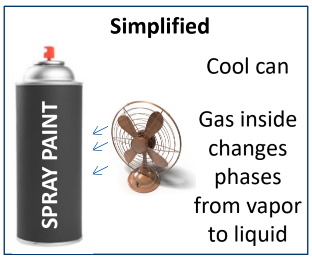
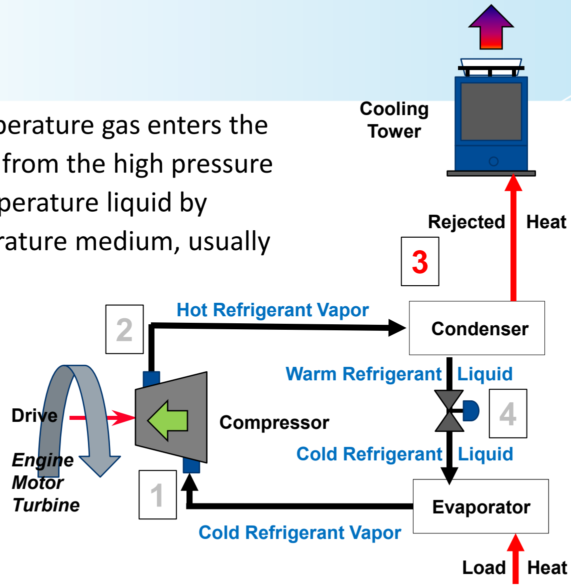
Vapor Compression Cycle

- **Step 3:** The high pressure and temperature gas enters the condenser where it changes phase from the high pressure and temperature gas to a high temperature liquid by transferring heat to a lower temperature medium, usually ambient air





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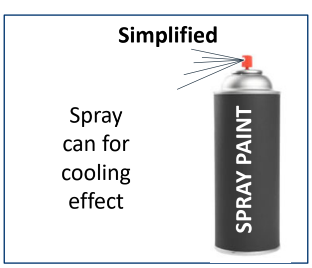
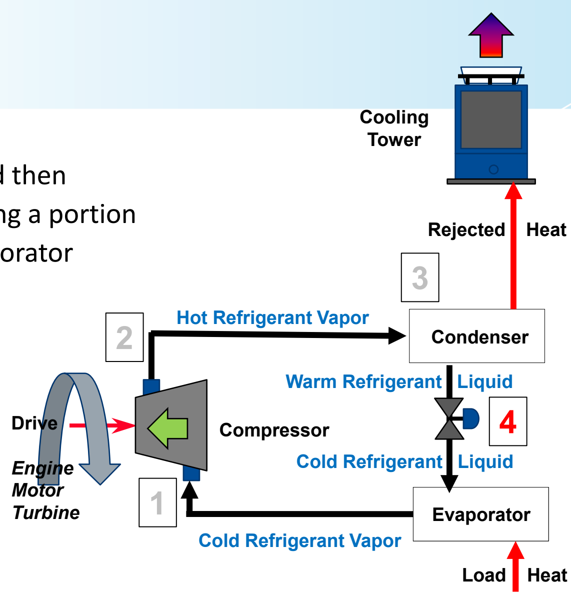
Vapor Compression Cycle

- **Step 4:** The high temperature liquid then enters the expansion device allowing a portion of the refrigerant to enter the evaporator





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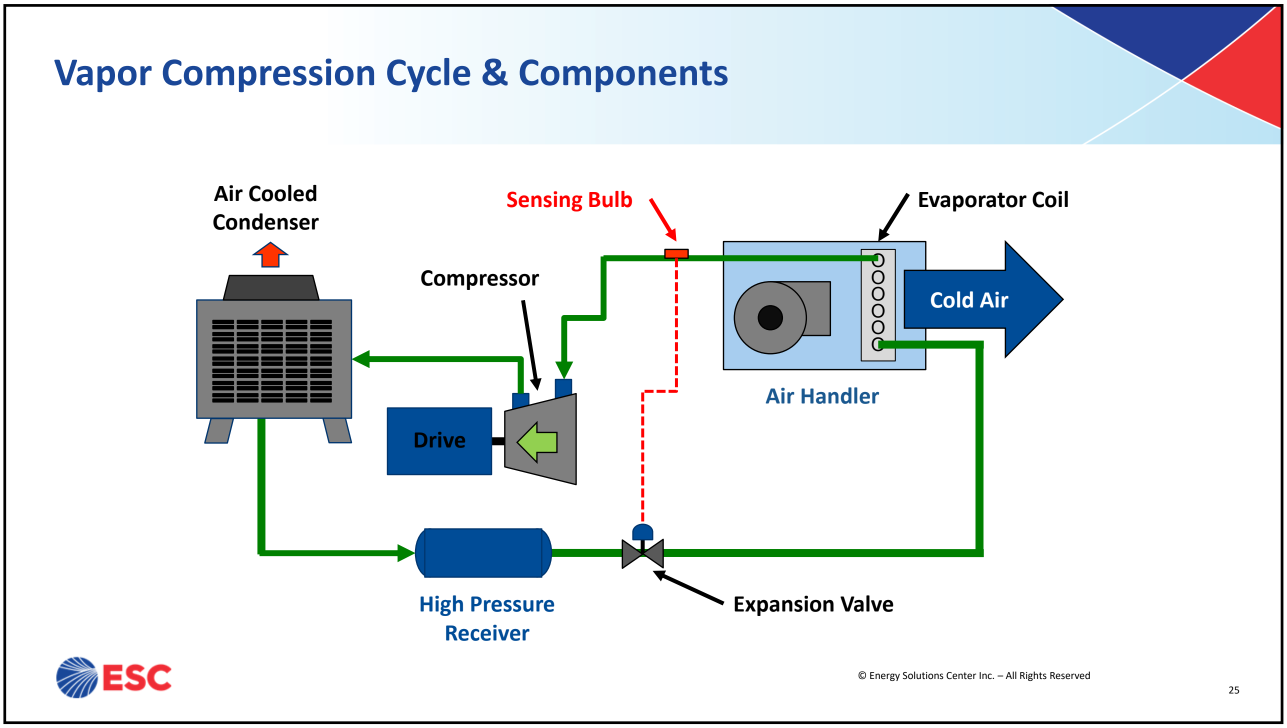
Vapor Compression Cycle & Components
Air Cooled Condenser
Sensing Bulb
Evaporator Coil
Compressor
Cold Air
Air Handler
Drive
High Pressure Receiver
Expansion Valve
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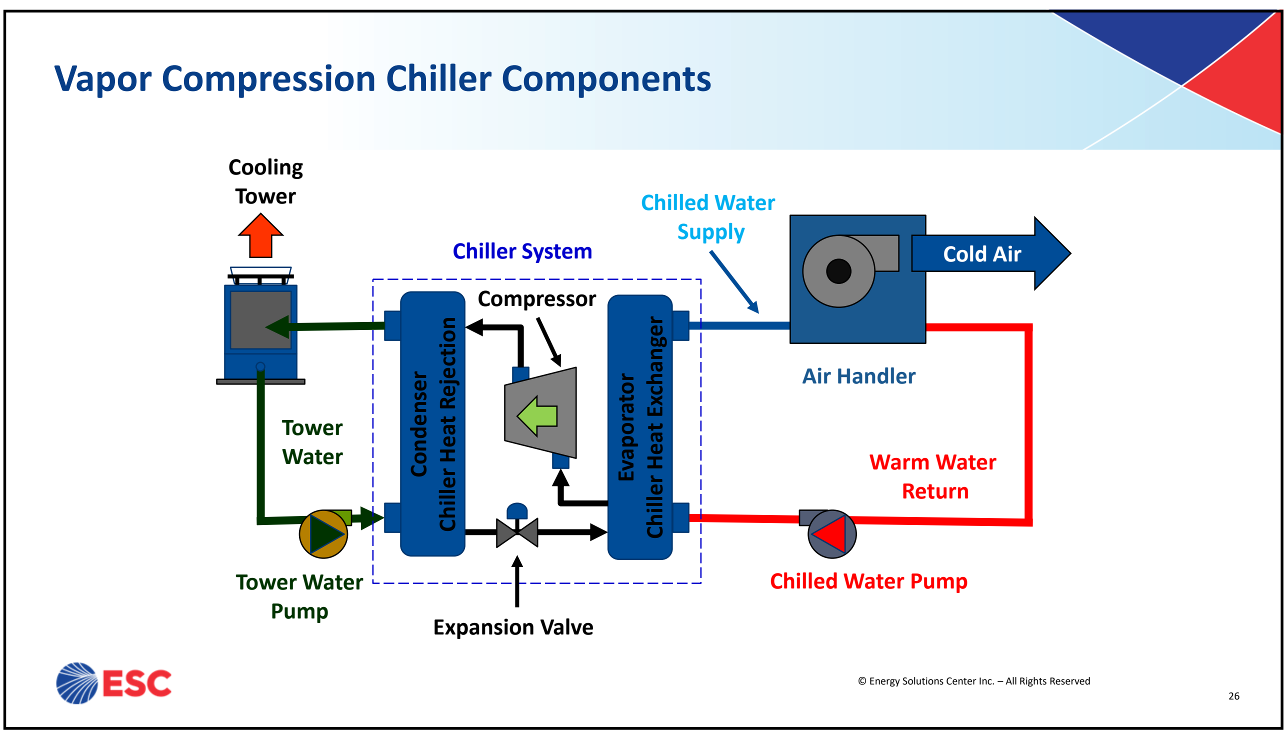
Vapor Compression Chiller Components
Cooling Tower
Chilled Water Supply
Chiller System
Cold Air
Compressor
Condenser
Chiller Heat Rejection
Evaporator
Chiller Heat Exchanger
Air Handler
Tower Water
Warm Water Return
Tower Water Pump
Chilled Water Pump
Expansion Valve
ESC
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Direct Expansion Systems

- In a direct-expansion (DX) unitary system, the evaporator is in direct contact with the air stream
- The cooling coil of the airside loop is also the evaporator of the refrigeration loop
- The term "direct" refers to the position of the evaporator with respect to the airside loop

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System Components

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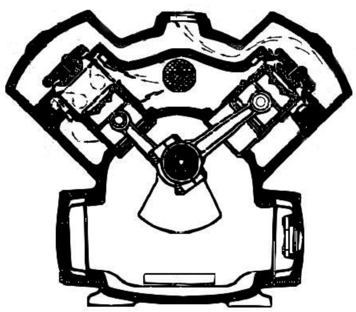
Vapor Compression Systems

Reciprocating compressor

- A positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure
- The intake gas enters the suction manifold, then flows into the compression cylinder where it is compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged



- The compressor is essentially a pump
- It pumps heat from the cold side to the hot side of the system
- The heat absorbed by the refrigerant in the evaporator must be removed before the refrigerant can again absorb latent heat

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Reciprocating Compressor

- To change phases from vapor to liquid the refrigerant gives up the latent heat of vaporization that it absorbed in the evaporator by cooling and condensing it in the condenser
- Due to the relatively high temperature of the cooling medium, the only way to make the vapor condense is to compress it

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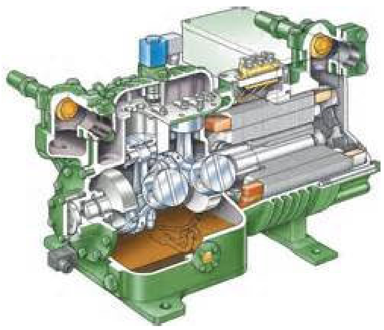
Reciprocating Compressor Types

Hermetic

- Compressor-motor assembly contained in a welded steel case, typically used in household refrigerators, residential air conditioners, smaller commercial air conditioning and refrigeration units



Reciprocating Compressor Types

Semi-hermetic

- Compressor-motor assembly contained in a casting with no penetration by a rotating shaft and with gasketed cover plates for access to key parts such as valves and connecting rods

Reciprocating Compressor Types

Open Drive

- Compressor only with shaft seal and external shaft for coupling connection to belt - or direct-drive using as electric motor or natural gas engine

Vapor Compression Systems

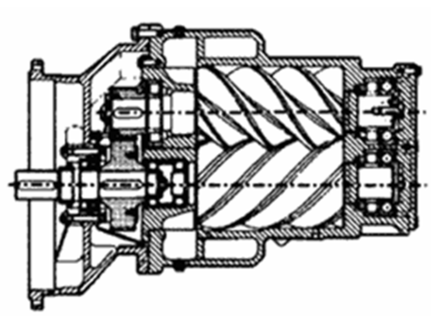
Rotary screw compressor

- Are also positive displacement compressors
- Two meshing screw-rotors rotate in opposite directions, trapping refrigerant vapor, and reducing the volume of the refrigerant along the rotors to the discharge point

- Within the compressor body there are two screws with mating profile – a female and a male screw; female having concave inlets and the male with convex helical inlets

Rotary Screw Compressor

- Screws rotate in opposite directions with the female screw receiving the driving power and transmitting this power to the male screw through a set of synchronization gears
- Refrigerant is drawn into the inlet port and fills up the space between the screws and is compressed



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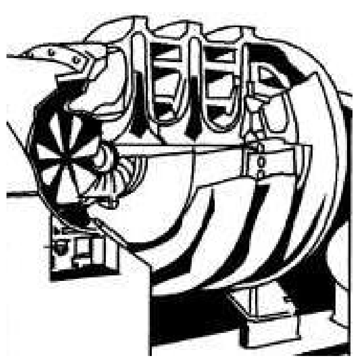
Vapor Compression Systems

Centrifugal compressor

- Centrifugal compressors are dynamic compressors
- The compressors raises the pressure of the refrigerant by imparting velocity or dynamic energy, using a rotating impeller, and converting it to pressure energy



- Centrifugal compressors are higher in speed than rotary screw or reciprocating compressors
- They have fewer rubbing parts
- Are relatively energy efficient

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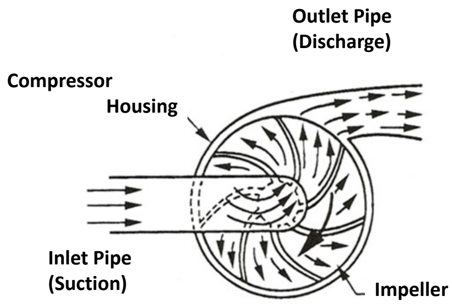
Vapor Compression Systems

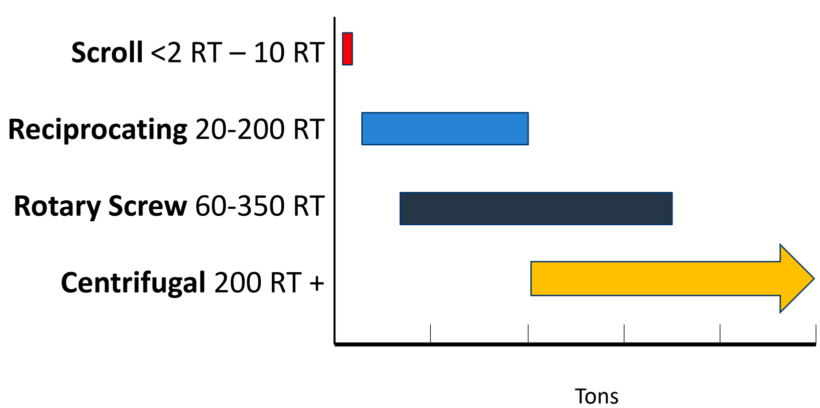
Scroll compressor

- Scroll compressors are positive displacement
- The compressors raises the pressure of the refrigerant by imparting velocity or dynamic energy, using a rotating impeller, and converting it to pressure energy



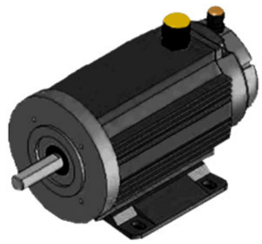
- A scroll compressor uses two interleaving scrolls to pump, compress or pressurize the refrigerant
- These devices are known for operating more smoothly, quietly, and reliably than conventional compressors
- The compression process occurs over approximately 2 to 2½ rotations of the crankshaft
- The efficiency of scroll compressors is slightly higher than that of a typical reciprocating compressor

Compressor Size Ranges



Drive Options

- Electric motor
  - Constant speed
  - Variable Speed Drive (VSD)
- Natural Gas Engine
- Absorption
- Steam Turbine



Electric Motor

- Converts electrical energy into mechanical energy
- Electric motors operate through the interaction of magnetic fields and current-carrying conductors to generate force

- Shaft power is used to turn the compressor
- Constant speed of 1,800-3,600 RPM
- Direct coupled to compressor or to gear box for higher speed applications

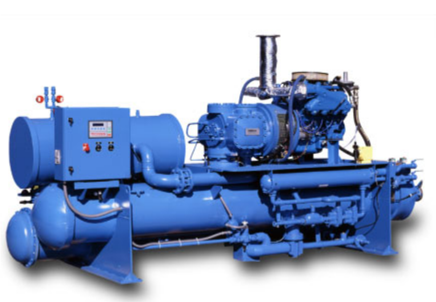
Variable Speed Drive

- Uses an internal or external variable frequency controller to convert input power (AC) to direct current (DC) that can be directly used in a DC motor or inverted back to AC and frequency varied off 60HZ to control speed
- Allows for “soft start” capabilities

- Can match speed and load capabilities
- Energy efficient motor
- External VFDs can be added to most electric motors

Other Drivers

Natural Gas Engine



Absorption

Steam Turbine

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Expansion Devices (Valves)

- Controls the amount of refrigerant flow into the evaporator – a metering device
- Uses a temperature sensor to regulate a stepper motor or sensing bulb filled with a similar gas as in the system that causes the valve to open against the spring pressure in the valve body as the temperature on the bulb increases

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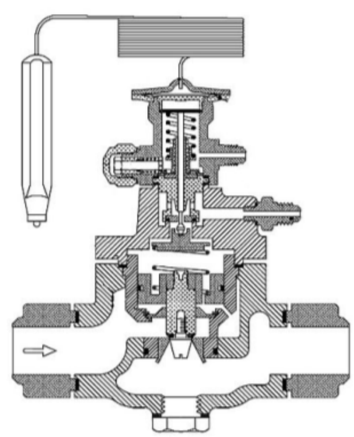
Thermal Expansion Valve

- Key element to the refrigeration cycle
- During the refrigeration cycle high temperature liquid enters the expansion valve where the TX valve allows a portion of the refrigerant to enter the evaporator
- The valve limits the flow into the evaporator



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Electronic Expansion Valve

- Key element to the refrigeration cycle
- During the refrigeration cycle high temperature liquid enters the expansion valve where the EX valve allows a portion of the refrigerant to enter the evaporator
- The valve limits the flow into the evaporator

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Condensing Systems

- Air cooled condenser
  - Vapor compression systems
- Water cooled – tower
  - Vapor compression and absorption systems

*Small scale (residential and small commercial) available as air cooled units

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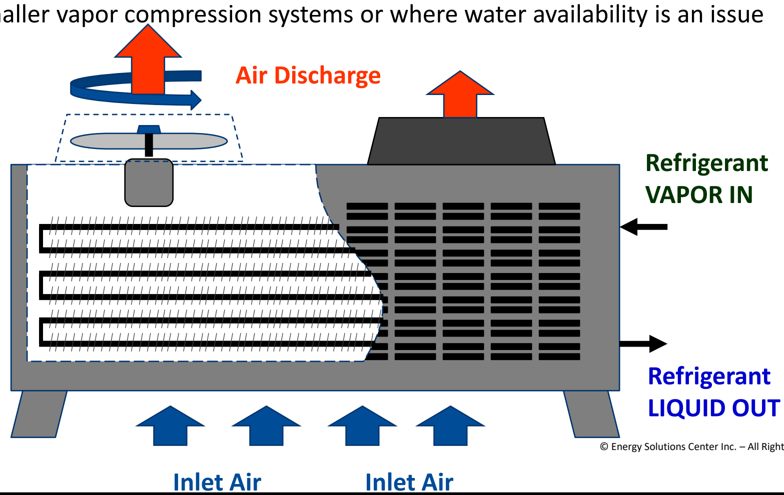
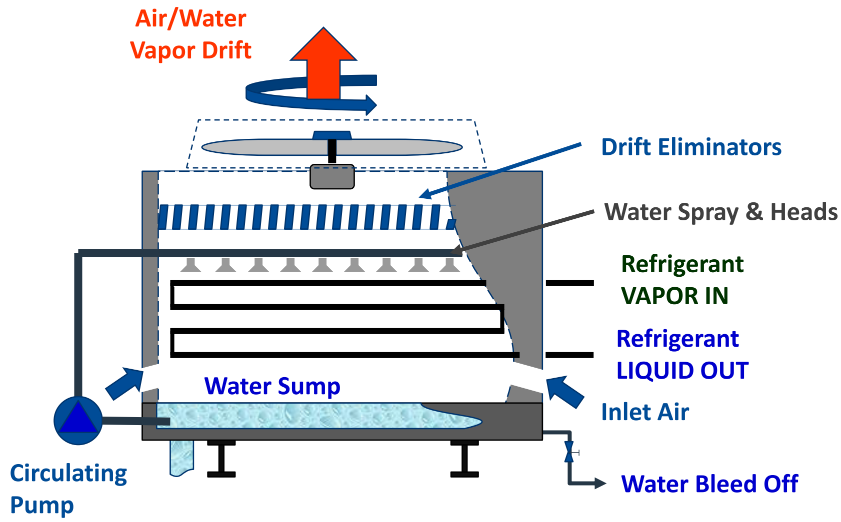
Air Cooled Condenser

- Heat rejected to the atmosphere via finned tubes and fans
  - Similar to the outside unit on a residential system
- Best suited for smaller vapor compression systems or where water availability is an issue



Water Cooled – Tower System

- Heat rejected to the atmosphere via bare tubes, water spray and fan
- Best suited for larger vapor compression systems and absorption chillers



Gas Cooling Equipment

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Absorption Cooling

- Heat drives system
- Often best choice when:
  - Electric demand charges are high
  - Electricity use rates are high
  - Summertime natural gas prices are favorable
  - Limited electric service available
  - Recoverable heat is available

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Absorption Cooling

- The thermodynamic cycle of an absorption chiller is driven by a heat source – a chemical process rather than a mechanical process.
  - steam, hot water, or combustion as heat source
- Compared to electrically powered chillers, an absorption chiller has very low electrical power requirements
  - ~15 kW combined consumption for both the solution and the refrigerant pumps

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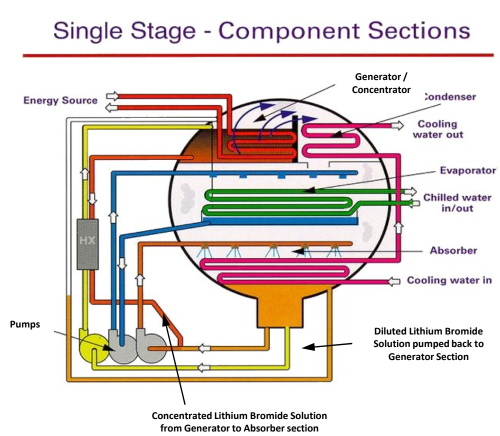
Absorption Cooling – How It Works

- “Thermal compressor” replaces electric compressor
  - Generator • Pump
  - Absorber • Heat Exchanger
- Typically uses water (refrigerant) and non-toxic lithium bromide (absorbent) solution – eliminates CFCs
  - Smaller units use ammonia and water
- More efficient and potentially lower operating costs than electric vapor compression chillers – particularly when using recovered heat
- Double-effect achieves even greater efficiency



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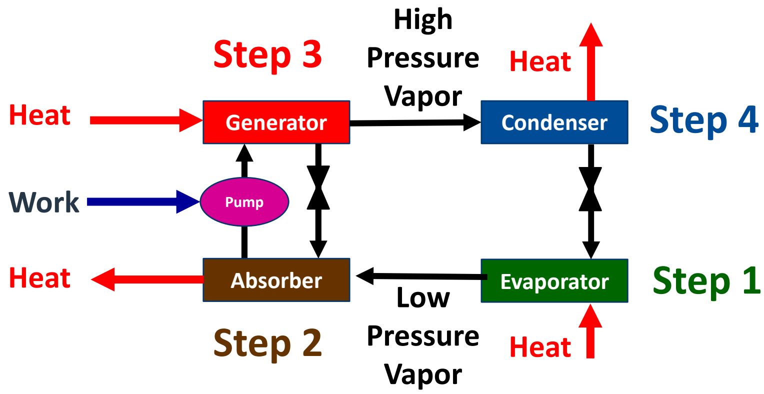
The Absorption Cycle Overview



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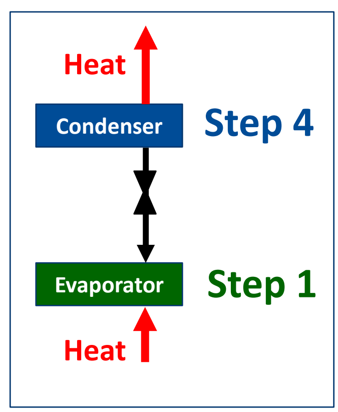
The Absorption Cycle – Step 1

- Cycle begins when the refrigerant leaves the condenser as a high-pressure liquid. On the way to the evaporator, the refrigerant flows through an expansion valve that drastically lowers the operating pressure. Once inside the evaporator (step 1), heat is absorbed and the low-pressure liquid "boils" and is vaporized.



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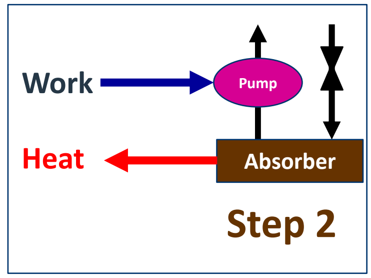
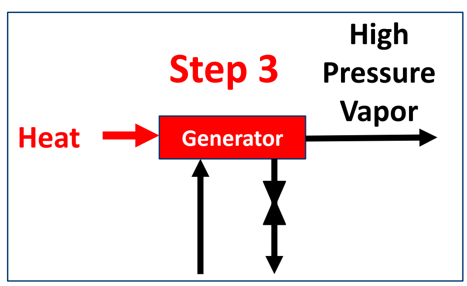
The Absorption Cycle – Step 2

- The absorption process uses vaporization to produce a cooling effect, but the work restoring the refrigerant is done differently than the vapor compression cooling cycle. The vapor returning to the absorber, (step 2) is absorbed by a liquid (an "absorbent") just as alcohol absorbs water. The resulting solution can then be pressurized by a simple motor-driven pump.



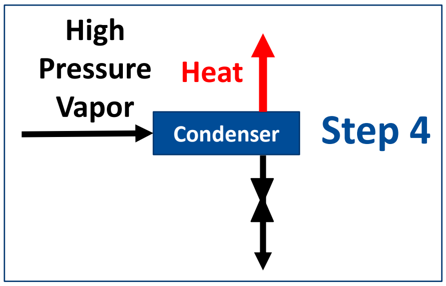
The Absorption Cycle – Step 3

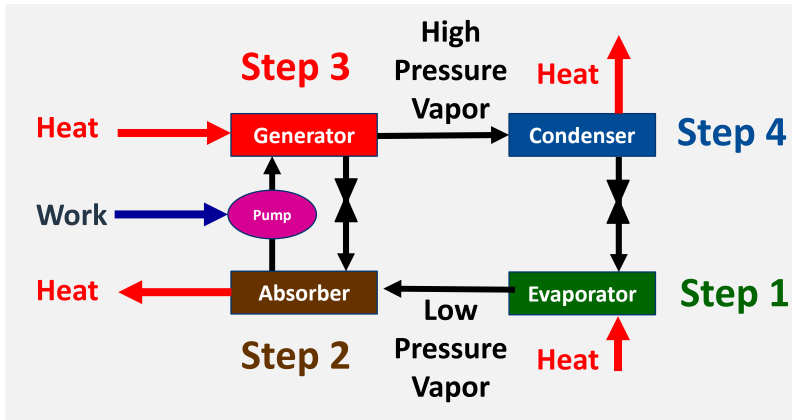
- Then, by using a gas-fueled generator (boiler) (step 3) to heat the solution, the two fluids can be separated. The liquid absorbent is cycled back to pick up more refrigerant.



The Absorption Cycle – Step 4

- The high pressure refrigerant vapor is condensed to a liquid releasing its heat to the outdoors (step 4) and sent back to the evaporator to produce more cooling.





Advantages of Absorption Cooling

- Heat, domestic hot water, and cool with the same unit
- Usually lower operating costs
- Safe, quiet and dependable operation
- Reliable, low maintenance
- Direct-fired absorber has a smaller footprint than an electric chiller and separate boiler
- Initial costs offset by energy savings

Absorption Cooling Issues

- Heat input requirements are large
- Typical COP is often 0.7 (single-effect) to 1.4 (double-effect)
- Requires a slightly larger cooling tower than a vapor-compression chiller (about 30% larger, but depends on COP)
- Absorption units excel where cheap, high-grade heat or waste heat is readily available

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Natural Gas Absorption Cooling

- Sizing – several tons to over 3000 tons
- Types
  - Heat recovery – e.g., CHP system
  - Hybrid systems (½ gas cooling, ½ electric cooling)
  - Chiller (cooling only)
  - Chiller/heater
  - Single or double effect systems, or combination
  - Direct & indirect fired
  - Air Cooled & water cooled
  - Absorption heat pumps

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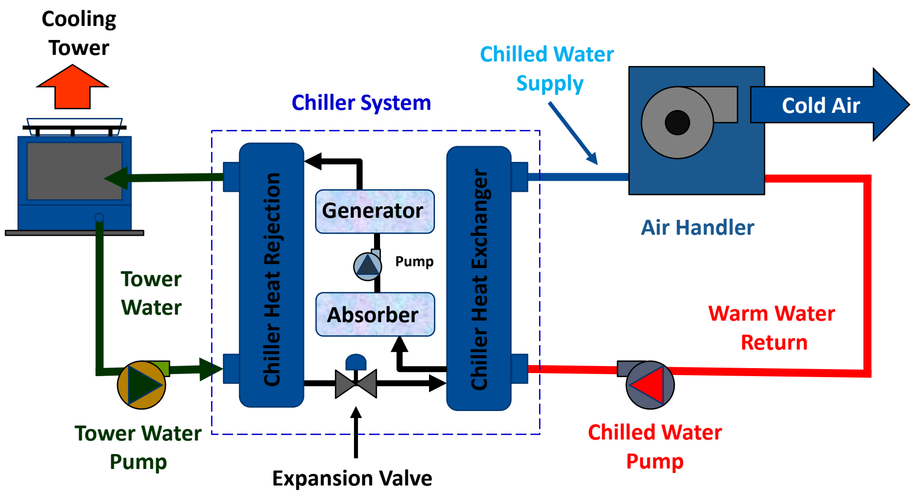
Basic Absorption Chiller Cycle

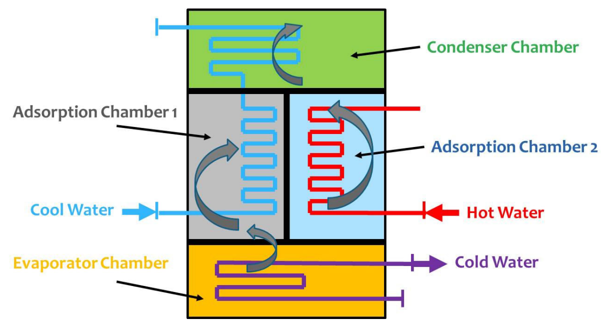


Adsorption Chillers

- Adsorption works with the interaction of gases and solids
- The molecular interaction between the solid and the gas allow the gas to be adsorbed into the solid
  - The adsorption chamber of the chiller is filled with Silicagel/H20 or Zeolith/H2O (sorbent)
  - The sorbent creates an extremely low humidity condition that causes the water refrigerant to evaporate at a low temperature
  - As the water evaporates in the evaporator, it cools the chilled water

Adsorption Chillers

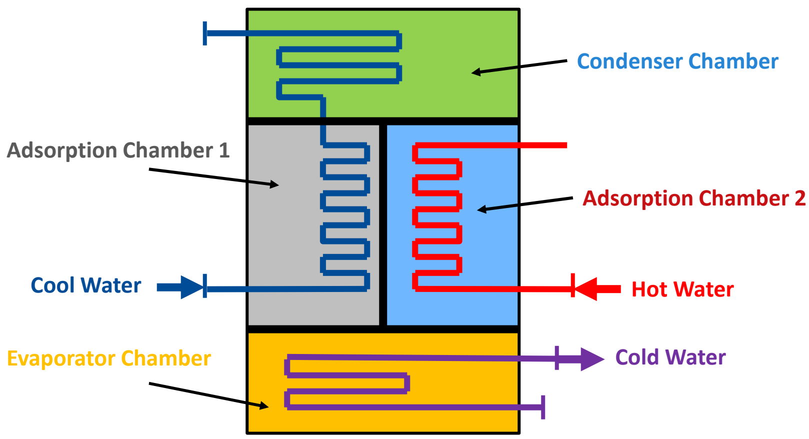
- The adsorption chiller has four chambers – an evaporator, a condenser and two adsorption chambers
- All four chambers are operated at nearly a full vacuum
- These systems are less common than Absorption



Adsorption Chillers

- The machines consist of two sorbent compartments– one evaporator and one condenser
- Using hot water from an external heat source the sorbent in the first compartment is regenerated
- The sorbent in the second compartment adsorbs the water vapor entering from the evaporator
- Compartment 2 has to be cooled in order to enable a continuous adsorption

Adsorption Chiller Cycle



- Due to the low-pressure conditions in the evaporator, the refrigerant is transferred into a gas phase by taking up the evaporation heat from the chilled water loop thereby producing the useful "cold"
- If the sorption material in the adsorption compartment is saturated with water vapor, the chambers are switched over in their function

Engine Driven Chillers

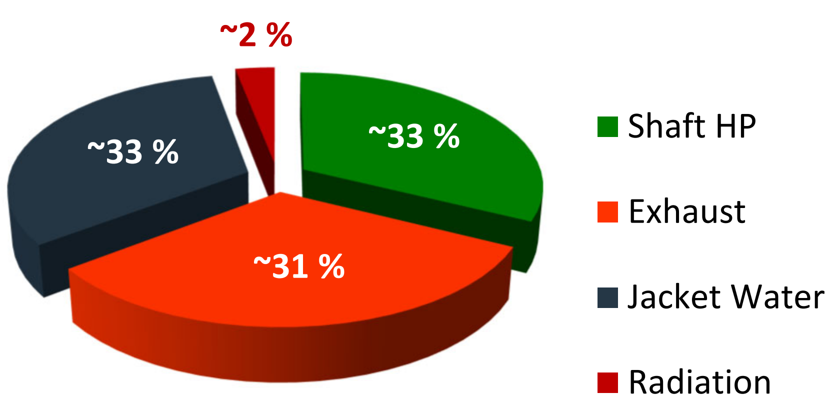
- Engine replaces electric motor in an electric refrigeration compressor
- Primarily used for reciprocating, and screw compressor systems
- Offer variable speed capability (just like an electric VFD)
    - Can run at 20% capacity without loosing efficiency

Engine Drives

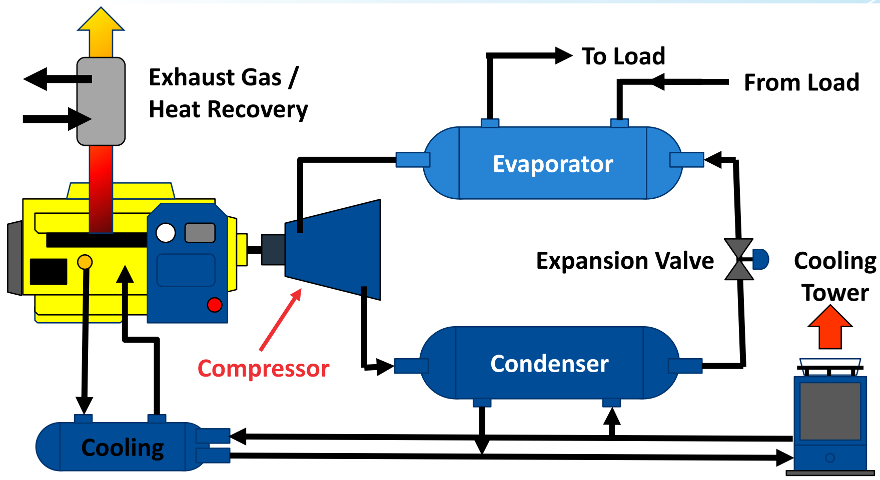
- Primary types – automotive derivative and industrial grade
- Can be dedicated design for natural gas
- Produce shaft speed between the ranges of 900-3600 RPM
- Offer excellent heat recovery options

- Engine maintenance is critical for reliability and life expectancy
  - Oil/Filter changes
  - Valve adjustments
- Engine "overhaul" necessary between 20,000-40,000 full-load hours of operation

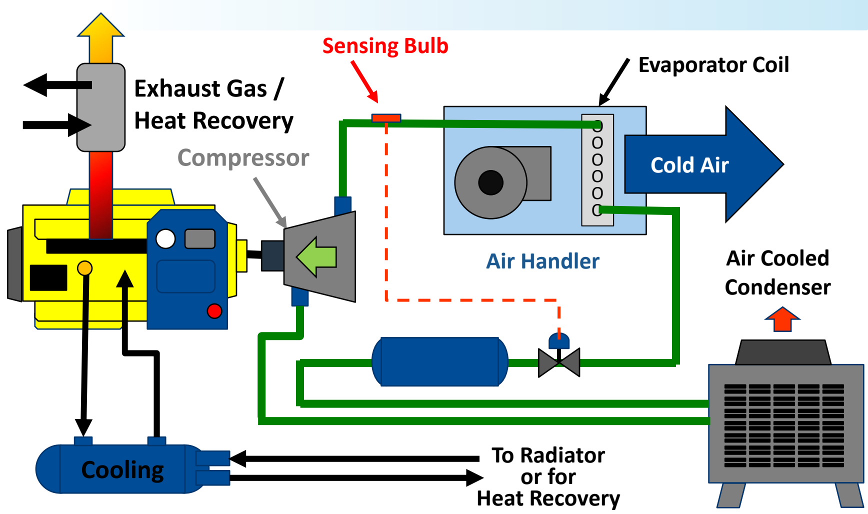
Engine Energy Balance



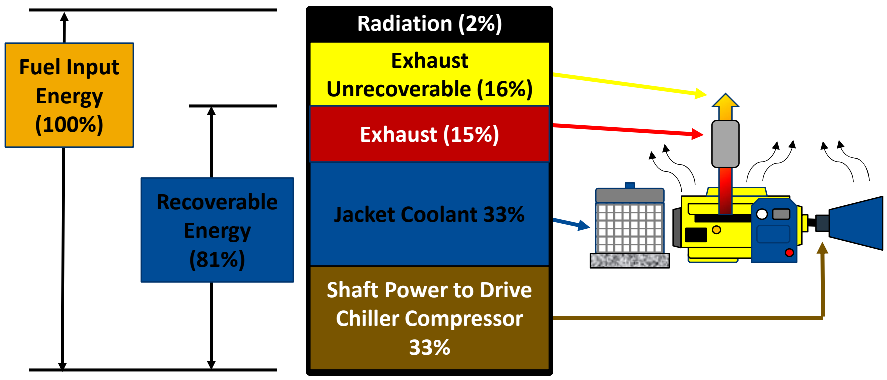
Engine Driven Chiller with Heat Recovery Options



Direct Expansion System



Engine Fuel Use and Heat Recovery



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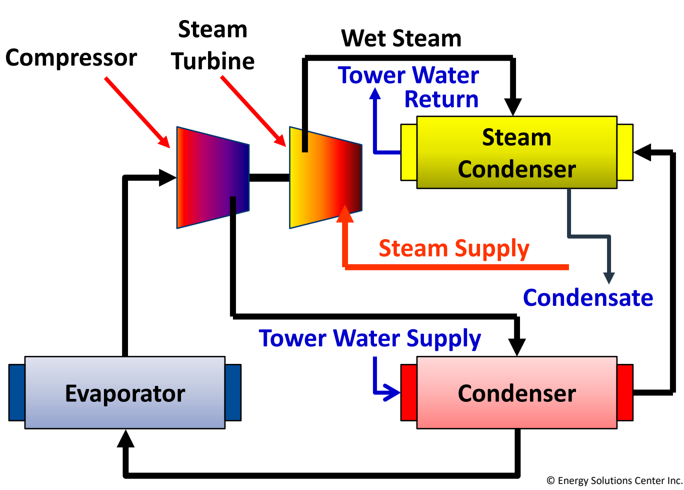
Steam Turbine Driven Chillers



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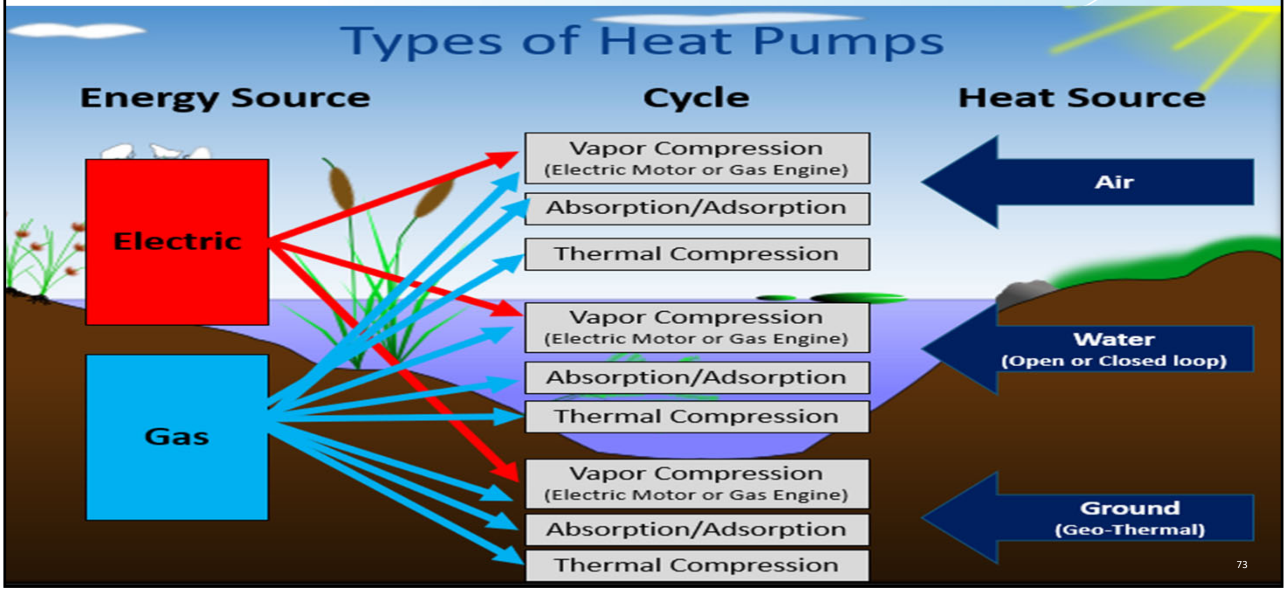
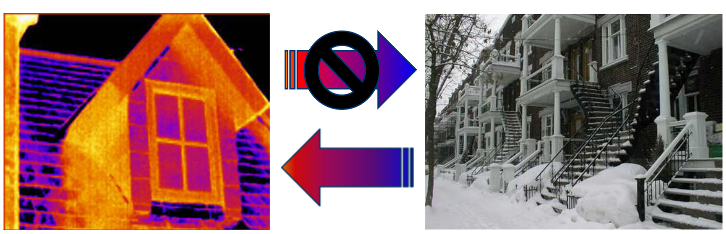
Heat Pumps



How Heat Pumps Work
How they "trick" nature

Thermodynamic Laws
Heat flows naturally from a **higher-temperature** region
to a **lower-temperature** region



Indoor : 72ºF (22ºC)

Outdoor: -8ºF (-22ºC)

Heat Pump
They "trick" nature by using **low-temperature** heat (outdoor) and transferring it to a **high-temperature** region (indoor)

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Types of Heat Pumps

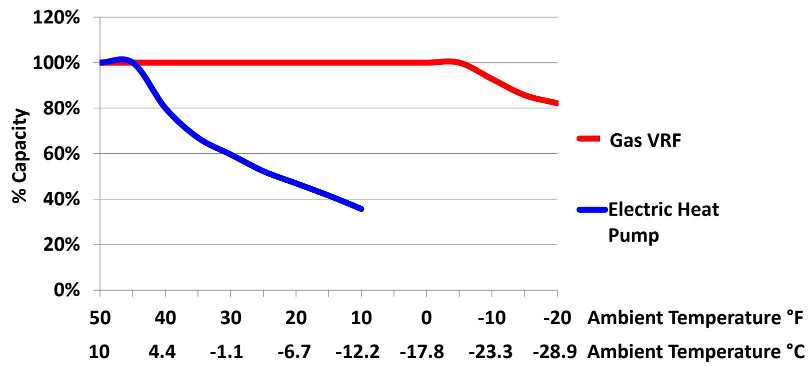
- Air Source
- 'Geothermal'
  - Ground Source
- Water Source
  - Closed loop
  - Open loop
- Gas fired
  - Absorption
  - Engine Driven



Engine Driven Heat Pumps

- Similar to electric heat pumps
- Electric motor replaced with a natural gas driven engine
- Excellent part load efficiencies
- Multiple zone capable
- Heating efficiency equivalent to 140%

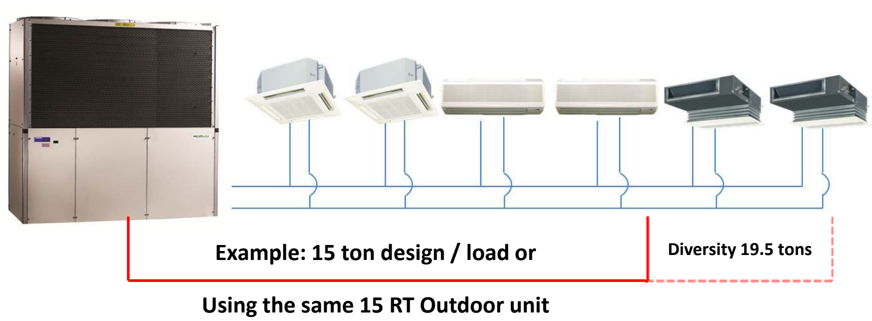
Gas Heat Pump
Low Temperature Performance



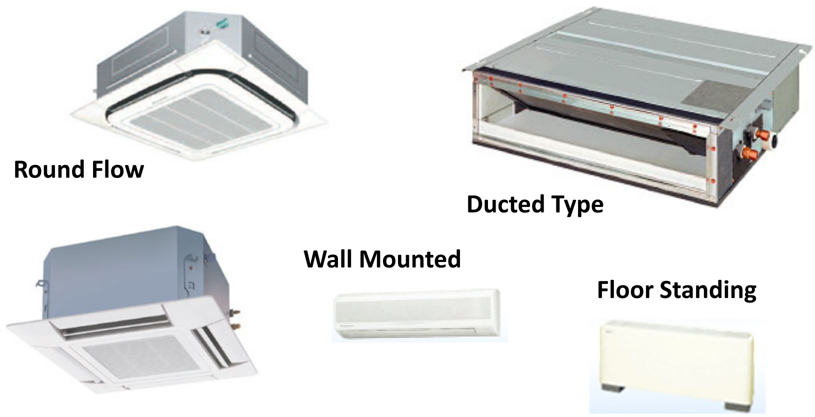
Typical of other Gas Heat Pumps

Flexibility Design & Diversity

- Multiple zones – any combination of ducted or ductless air handlers



Indoor Air Handlers



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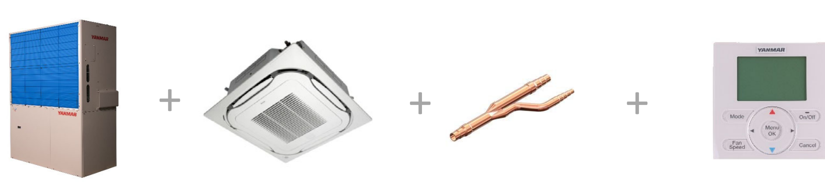
Variable Refrigerant Flow (VRF)

VRF is a modular, commercially applied air conditioning and heating system that distributes refrigerant from the outdoor unit to multiple indoor units, providing efficiency, comfortable individual user control and reliability in one flexible package.

Gas Heat Pump VRF Systems are built on 4 basic product elements



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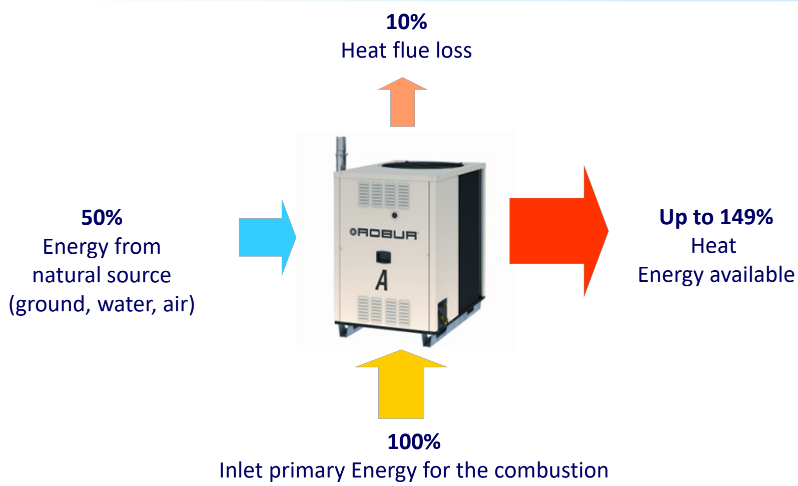
What is a Gas Absorption Heat Pump?

- Small gas fired boiler (traditional combustion)
  - 95,500 BTU/HR input
- Produces **HOT** up to 149°F (65°C) or **COLD** water down to 37°F (2.8°C)
- Hydronic product
  - Piped into hydronic loop just like a hydronic boiler

Achieving >100% Thermal Efficiency



Absorption Heat Pump
Heating Efficiency Comparison

Heating Product Category	Maximum Thermal Efficiency
Non-Condensing Boilers	~83%
Condensing Boilers	99%
Gas Absorption Heat Pumps	~140%

Hybrid Chiller Applications

- Incorporate electric & gas chillers into a combined chiller plant
  - Install both unit types into system
    - Typically 50% electric & 50% gas capacities
  - Base load chiller based on utility costs or time of day
  - Ideal for facilities that have minimal electrical service

- Incorporate into a CHP application to utilize recoverable heat
- Utilize excess steam capability or off-season boilers

Economics & Emissions

A detailed Cost Analysis or Life Cycle cost analysis is essential for evaluating any Cooling project at a facility.

Using the real energy costs associated with the cooling technology is critical.

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Gas Cooling & GHP Tool

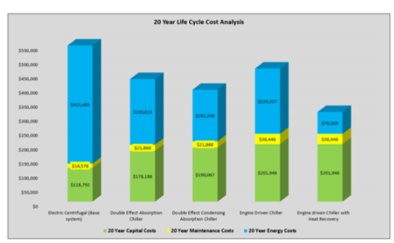
GasAir Conditioning | ESC Energy Solutions Center

Home   Market Segments   Resources   Technologies   Contact Us

Tools to assist you

Here you will find a links to valuable tools to design and evaluate a natural gas cooling system.

Large & Small Tonnage Excel Tool
Calculates savings from natural gas vs electric cooling
Life cycle cost analysis & emissions calculations
CLICK HERE TO OPEN EXCEL TOOL



https://gasairconditioning.com/general-resources/tools/

ESC

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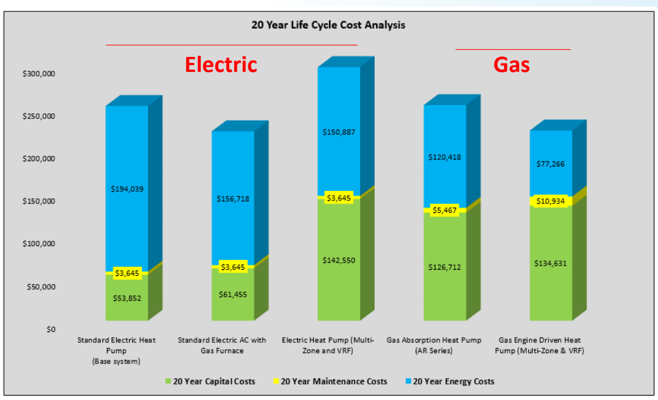
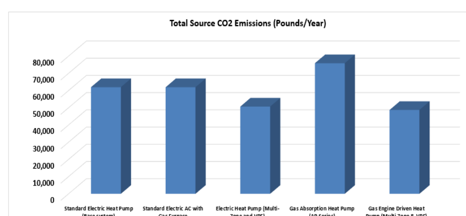
Back of Envelope Analysis
(ESC's Commercial Building Consortium)

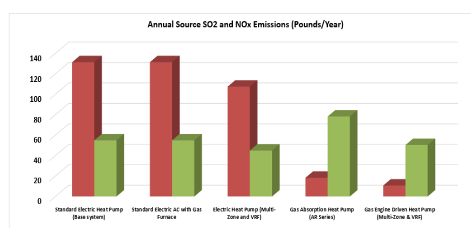
Natural Gas vs. Electric Cooling Analysis

	Standard Electric Heat Pump (Base system)	Standard Electric AC with Gas Furnace	Electric Heat Pump (Multi-Zone and VRF)	Gas Absorption Heat Pump (AR Series)	Gas Engine Driven Heat Pump (Multi-Zone & VRF)
Total Size System Installed (Tons)	20	20	20	20	20
Total Installed Cost	$34,000	$38,800	$90,000	$80,000	$85,000
Electric Cost	$7,986	$6,450	$6,210	$945	$576
Natural Gas Cost	$0	$0	$0	$4,011	$2,604
Maintenance Cost	$150	$150	$150	$225	$450
Total Energy & Maint Costs (/year)	**$8,136**	**$6,600**	**$6,360**	**$5,181**	**$3,630**
Savings vs. Base System	Base	$1,536	$1,776	$2,955	$4,506
Incremental Cost vs Base System	Base	$4,800	$56,000	$46,000	$51,000
Simple Payback (Years)	Base	**3.13**	**31.53**	**15.57**	**11.32**
20 Year Positive Cash flow	Base	**$29,718**			**$28,705**
Net Present Value	Base	**$16,882**	**-$12,848**	**$25,799**	**$58,484**
Internal Rate of Return	Base	**34%**	**-2%**	**4%**	**8%**
20 Year Capital Costs	$53,852	$61,455	$142,550	$126,712	$134,631
20 Year Maintenance Costs	$3,645	$3,645	$3,645	$5,467	$10,934
20 Year Energy Costs	$194,039	$156,718	$150,887	$120,418	$77,266
20 Year Life Cycle Cost	**$251,536**	**$221,818**	**$297,082**	**$252,596**	**$222,830**

Heat Pump Energy Analysis (<100 tons)

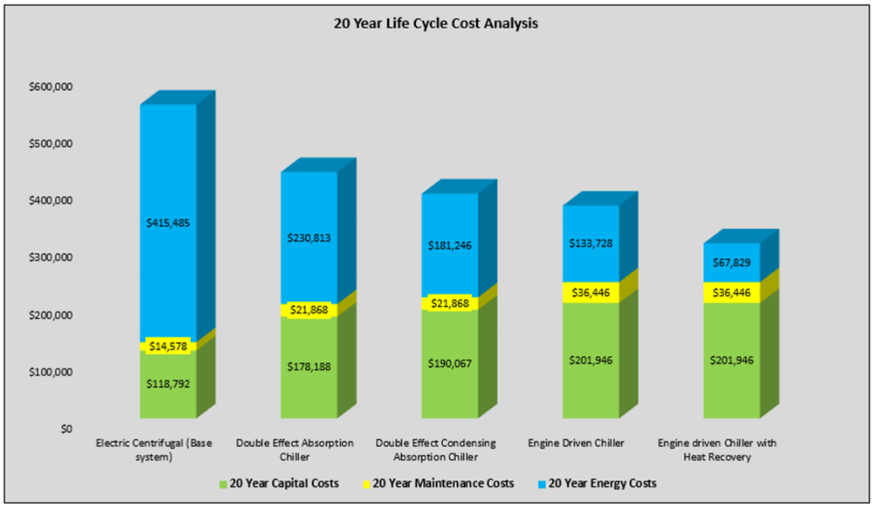






Assumptions:
Electric - $.15/KW, no demand charge, Gas = $.70/Therm
20 Tons of cooling for 6 months per year
1500 full load hours cooling & 1500 hours heating

Large Chiller Life Cycle Cost (=> 100 Tons)



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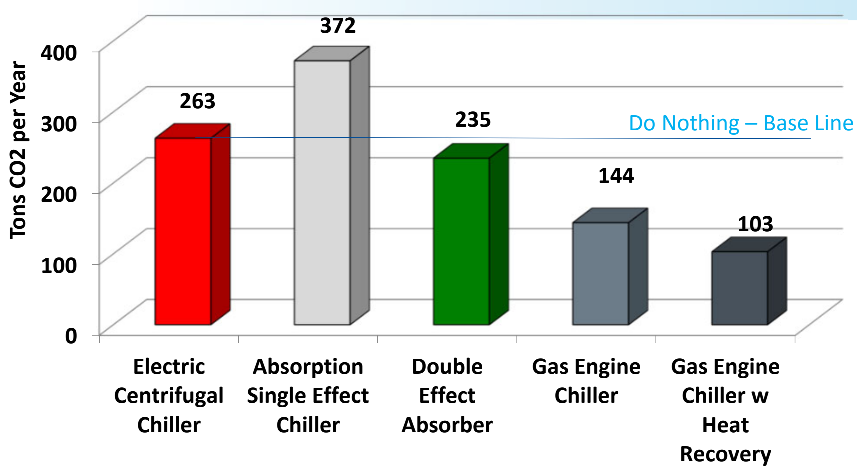
Chiller Annual CO2 Emissions



Using ESC Cooling payback tool for 200 Tons running 2000 cooling hours per year.

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Economic Analysis

- Use available economic evaluation tools (www.gasairconditioning.com) check with manufacturers or others
- Understand the concepts and principles of the economic analysis
- Know the projects "real" costs
- Do your economics make financial sense?

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Gas Cooling Products

- Engine Driven Chillers
- Absorption / Adsorption
- Steam Turbine Chiller
- Heat Pumps

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Engine Driven Chillers

- **Air-Cooled Chiller**
  - Hybrid Gas-Electric 100 Tons
    - Full load COP = .9
    - COP with Heat Recovery = 1.4
    - IPLV COP = 1.52
- **Water Cooled Chiller**
  - STx 150 & 200 Tons
  - DTx 300, 250, 400 Tons
  - Jacket water heat recovery up to 230°F (110°C)
    - Full load COP = 1.6 – 1.7
    - COP with Heat Recovery = 2.1 – 2.2
    - IPLV COP = 2.6

Absorption Chillers

Manufacturer	Size/Tons	Special Features
Broad USA	30-2600	Multi-Fuel Capable
Carrier Corporation	100-680	Steam or hot water fired
Cention Corporation	40-650	Can be waste heat fired from exhaust
Energy Concepts	15-150	Available as a heat pump
Robur Corporation	5-25	Link into 25 ton units. Heat pump
Thermax (Trane)	10-2000	Steam, Hot Water, Thermal Fluid, or gas fired
Yazaki	5-200	Gas or hot water fired
York	120-1350	Steam, Hot Water or Direct Fired

Broad U.S.A.

- BROAD USA
- Direct / Indirect Fired Chiller/Heater
- 30 - 3,300 Tons
- NO CFC's
- High Efficiency Models

BROAD U.S.A. INC.

http://www.broadusa.com

Broad U.S.A. – Single Stage Absorbers

BDH, Hot Water
- 30-1800 Tons
- 160-220 F Hot Water
- **Cooling only**

BDE, Exhaust Driven
- 30-1163 Tons
- 450-600 F
- **Cooling only**

BDS, Steam
- 30-2000 Tons
- 6-60 PSI
- **Cooling only**

Broad U.S.A. – 2 Stage

BZ Model, Direct Gas Fired
•Capacity: 30-3300 ton
•Gas Pressure: 2.3-7.3 Psi (Standard)
•Dual Fuel Burner (Gas and Oil, Low NOx, <10ppm)
•**Cooling / Heating / Domestic Hot Water**

BS Model, Steam Driven
•Capacity: 30-3300 ton
•Steam Pressure: 60 – 150 Psi
•Chiller Come With Steam Valve
•**Cooling Only**

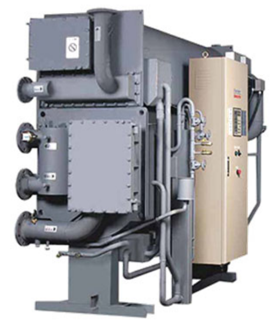
Broad U.S.A. – 2 Stage

BE Model, Exhaust Driven
•Capacity: 40-3300 ton
•Exhaust Pressure Drop: 3 – 8 Inch W.C.
•Exhaust Temperature: 536-990F
•**Cooling / Heating Only**

BH Model, Hot Water Driven
•Capacity: 30-3300 ton
•Hot Water Temperature: 280 – 356 F
•Provides Hot Water Valve
•**Cooling Only**

Carrier (Sanyo)

- Carrier Chiller/Heater
- Hot Water & Steam Fired
- 75 - 1,323 Tons
- Models include:
  - 16LJ: Single Effect, Hot Water, 75-575 Tons
  - 16NK: Double Effect, Steam, 98 – 1323 Tons
  - 16TJ: Single Effect Steam, 100 700 Tons



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Energy Concepts

- Absorption 15 - 150 tons
- Heat Pumps (absorption based)
- Custom systems to 15,000 tons
- Simultaneous heat and cooling, or refrigeration
- Co-produce hot water
- Air or water cooled (ammonia water)

100

Robur

- Direct-Fired Chillers & Heat Pumps
- 4 to 5 ton units packaged to 25 tons
- Ammonia water system
- Low temp units available
- Air cooled systems
- Single phase power

http://www.robur.com/chillers

ROBUR

Thermax (Trane)

- Thermax Chillers
- Direct, Hot Water & Steam Fired
- Products
  - Steam 50 – 2000 Tons
  - Hot Water 10 – 2000 Tons
  - Exhaust fired 50 – 2000 Tons
  - Direct fired 40 – 1500 Tons
- International Sales & Service Programs

THERMAX

http://thermax-usa.com/

Yazaki

- Yazaki Absorption Chillers
- Direct Fired Gas (Chiller-Heater)
  - CH-K: Double effect, 30-100 Tons
  - CH-MG: Double effect, 150 & 200 Tonss
- Water Fired: WFC-S, Single effect, 5, 10, 20, 30 & 50 Tons

YAZAKI ENERGY SYSTEMS, INC.

http://www.yazakienergy.com/

York

- YHAU-C: Single Effect, 30 - 2000 Tons
- YHAU-CW: Double Effect, 120 – 4000 Tons
  - Natural Gas or HP Steam fired
- YHAU-CG Chiller/Heater 30-1600 Tons

https://www.york.com/commercial-equipment/chilled-water-systems/absorption-chillers

Steam Turbine Chiller

YORK
INSTALL CONFIDENCE

- 1.2 Coefficient of Performance (COP) using excess steam
- Provides opportunity to Integrate waste steam into a "mechanical" cogeneration system
- Can provide cooling, heating, dehumidification

York Turbine Driven Chiller

- Utilizes steam to drive refrigeration compressor
- Excellent use for heating boilers in the summer months
- Sizes 700 – 2800 Tons
- Variable speed capability
- Uses traditional vapor compression refrigeration cycle

Gas Heat Pumps (GHP) for Commercial Buildings

- Engine Driven
- Absorption Heat Pumps

Company	Type	Technology	Best Applications	Status	Heat Sizes	Cooling Sizes
Anesi	Heating, Water Heating	Absorption	Residential, Commercial	Commercially available	10,000 to 140,000 BTU/h	Future cooling 1-4 tons
Blue Mountain Energy	Heating, Cooling, Water Heating	IC Engine	Residential, Commercial, Industrial	Commercially available, 5 & 11 Ton, field testing others	91,000 to 410,000 BTU/h	5, 8, 11, 15, and 30 Tons
boostHEAT	Heating, Water Heating	Thermal Compressor	Residential	Field test 2023	68,000 BTU/h	n/a
Broad USA	Heating, Cooling, Water Heating	Absorption	Commercial, Industrial	Commercially available	962,000 BTU to 57,800,000 BTU/h	30 to 3,968 Tons
Energy Concepts	Heating, Cooling, Water Heating	Absorption	Commercial, Industrial	Commercially available	396,000 to 40,000,000 BTU/h	20 Tons to 2,000 Tons, down to -50ºF
HeatAmp	Heating, Water Heating	Adsorption (Chemisorption)	Residential	Field test 2023	Up to 50,000 BTU/h	n/a
Robur	Heating, Cooling, Water Heating	Absorption	Residential, Commercial	Commercially available	120,000 BTU/h	5 Tons
ThermoLift	Heating, Cooling, Water Heating	Thermal Compressor	Residential	Field demos	55,000 to 75,000 BTU/h	3 Tons
Thermax	Heating, Water Heating	Absorption (Waste heat fired)	Commercial, Industrial	Commercially available	835,035 to 136,484,680 BTU/h	n/a
Yanmar	Heating, Cooling, Water Heating	IC Engine	Residential, Commercial, Industrial	Commercially available	108,000 to 198,000 BTU/h	8, 10, 12, and 14 tons
York	Heating, Water Heating	Absorption (Waste heat fired)	Commercial, Industrial	Commercially available	10,000,000 to 24,000,000 BTU/h	n/a
Vicot	Heating, Water Heating	Absorption	Residential, Commercial	Commercially available. Resid. units: Field Trial	68,000 BTU to 290,000 BTU/h	n/a

Key: Residential, Commercial, Industrial, Heating, Cooling, Water Heating

ESC

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GHP: Blue Mountain Energy (Engine driven)

- 8, 11 & 15 Ton units available
- Ducted or Ductless Options
  - Ductless Units ideal for Zoning
- Air-cooled condensing in packaged unit
- Cooling COP of 1.23
- Heating COP of 1.40

BLUE MOUNTAIN ENERGY

ESC

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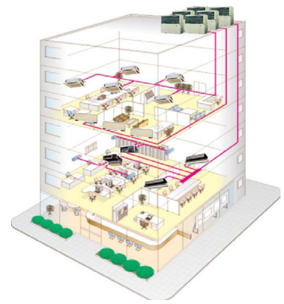
GHP: Yanmar (Engine driven)

2 Pipe Systems

Manufacturer / Model			YANMAR NNCP096J	YANMAR NNCP120J	YANMAR NNCP144JN	YANMAR NNCP168JN
Capacity	Cooling Capacity	RT	8	10	12	14
		kW	28	35	42	49
	Heating Capacity	BTU	108,000	135,000	160,000	198,000
		kW	32	40	47	58
	Low Temp / Cold Temp Heating	BTU	114,300	145,000	152,000	162,000
		kW	33	42	45	47

3 Pipe System

Manufacturer / Model			YANMAR NFCP168JN
Capacity	Cooling Capacity	RT	14
		kW	49
	Heating Capacity	BTU	198,000
		kW	58
	Low Temp / Cold Temp Heating	BTU	162,000
		kW	47



YANMAR

ESC

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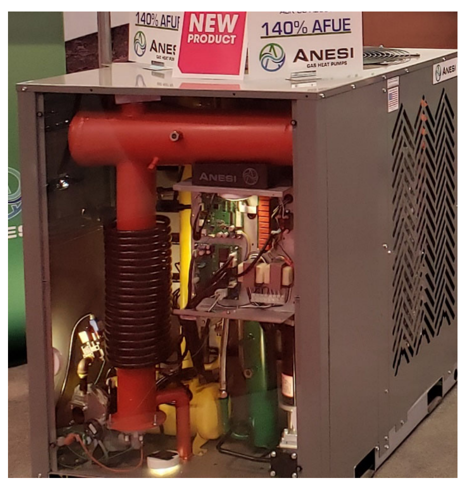
GHP: Anesi (Absorption - Stone Mountain Technologies)

Heating

- 80,000 Btu/hr GAHP
- 140,000 Btu/hr GAHP

ANESI



ESC

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Anesi: 80,000 BTU/Hr (example)

COP:	1.45 (@47°F, HHV) *std rating point*
	1.20 (@ 0°F, HHV)
AFUE:	140%
Capacity (output):	80,000 BTU/hour
Min. Ambient Temperature:	minus 40°F
Refrigerant:	NH_3 / H_2O
Global Warming Potential:	None
Modulation Ratio:	4:1
Max Supply Temp (steady):	140°F
NOx Emissions:	SCAQMD compliant (<14 ng/j)
Venting:	Direct outdoors
Dimensions:	44”H x 34”W x 48”D
Weight:	<600 lbs.

ESC

140,000 BTU/Hr model also available

GHP: Broad USA – Heat Pump

- Heating capacity 962 MBH to 48,186 MBH direct fired or steam
- ~170% heating efficiency

BROAD U.S.A. INC.

ESC

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GHP: Broad USA Absorption Heat Pump

Absorption heat pump is based on lithium bromide absorption technology

Uses heat as the driving source to recover the heat from the low-temp heat source

Provides mid-temp and high-temp water for process or heating

It transfers heat from low temperature to high temperature.

Driving Source: Natural gas, Biogas, Steam, Hot water, Exhaust gas

Main Application:

Central heating, **B**uilding heating, **P**rocess heating

Heating up to **203℉**

Heating COP: **1.7~2.4**

113

GHP: Energy Concepts (Absorption)

- 15-300 Tons, custom built absorption heat pumps
- Cooling or refrigeration
- 160°F (71.1°C) hot water at 1.5 COP

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GHP: Homy / Vicot (Absorption)

- **Heating and water heating:** ~ 65 MBH and 290 MBH models
- **Efficiency up to 140%**
- **Carbon Reduction:** 45% less energy consumption compared to common boilers and furnaces
- **Stepless burner control:** a solution for heating load instability
- **Refrigerant:** Ammonia with 0 GWP & 0 ODP
- **Low electricity consumption :** Using no compressor
- **Long Life Expectancy :** Less moving parts
- **Low noise level**: around 54 dB for a 65 Kw GAHP
- **Cold Climate Equipment:** Maintain Desired Capacity and Efficiency at Very Low Ambient Temperatures -22°F **(-30°C)**
- **Modular installation**

HOMY BUILDING SOLUTIONS
VICOT

115

GHP: Homy / Vicot

Residential

Model: V20

Capacity: 68 MBH GAHP

Application: Heating/Domestic

Small homes, houses

Commercial

Model: V65:
Capacity: 221 MBH GAHP

Model: V85
Capacity: 290 MBH GAHP

Combo Type (Higher Capacities)

Combination of GAHP and a Condensing boiler

Model: V140
290 MBH GAHP
+187 MBH BOILER

116

GHP: Robur Corporation (Absorption)

- GAHP Systems
  - Air-source water-ammonia absorption heat pumps
  - Up to 149°F (65°C) hot water available
  - Single phase power requirements
  - Can be linked using single or multiple controllers

ROBUR®
caring for the environment

ESC

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Robur Corporation

GAHP A Air-Source Heat Pump (Heating Only)

GAHP AR Air-Source Reversible Heat Pump (Heating, Cooling and Supplemental DHW)

GAHP W LB Water Source Heat Pump Geothermal Applications (Heating, Cooling and Supplemental DHW)

GAHP W Water Source Heat Pump (Simultaneous Heating, Cooling and DHW production)

118

GHP: Thermax Heat Pump (Absorption)

- Type I
  - COP 1.65 – 1.75
  - Up to 90 °C (194 °F)
- Type II (Heat Transformer)
  - Upgrade waste heat

THERMAX

http://thermax-usa.com/heat-pump.php

119

GHP: York – Heat Pump (Absorption)

- YHAP-C Absorption Heat Pump
- Up to 194°F/90°
- COP up to 1.7
- Also offers Type II GHP

YORK®

https://www.york.com/commercial-equipment/chilled-water-systems/absorption-chillers

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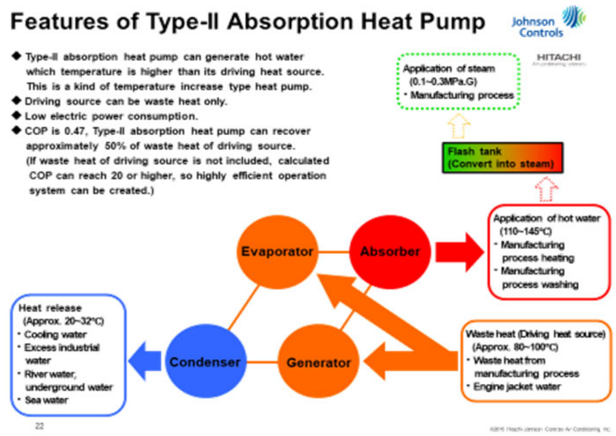
Type II Absorption Heat Pump (Heat Transformer)

- Upgrade waste heat from lower to higher temperature.
- Delivery temperature up to 320 °F (160 ° C), typically with a lift of 122 °F
- Typically for industrial applications
- Heat driven
- COP ~ .5



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Thank you …