BROAD U.S.A. INC.

APPLICATION OF MODERN ABSORPTION "NEW NORMAL" TECHNOLOGY IN CAMPUS DISTRICT ENERGY SYSTEMS WITH LIFE CYCLE ANALYSIS

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At 5B Session: District Cooling & Trigeneration

Agenda

- Basics of Absorption Cycle
- Modern Absorption "New Normal" Technologies
- Case Study of Absorption Technologies Application in Campus Energy District System
- Q&A

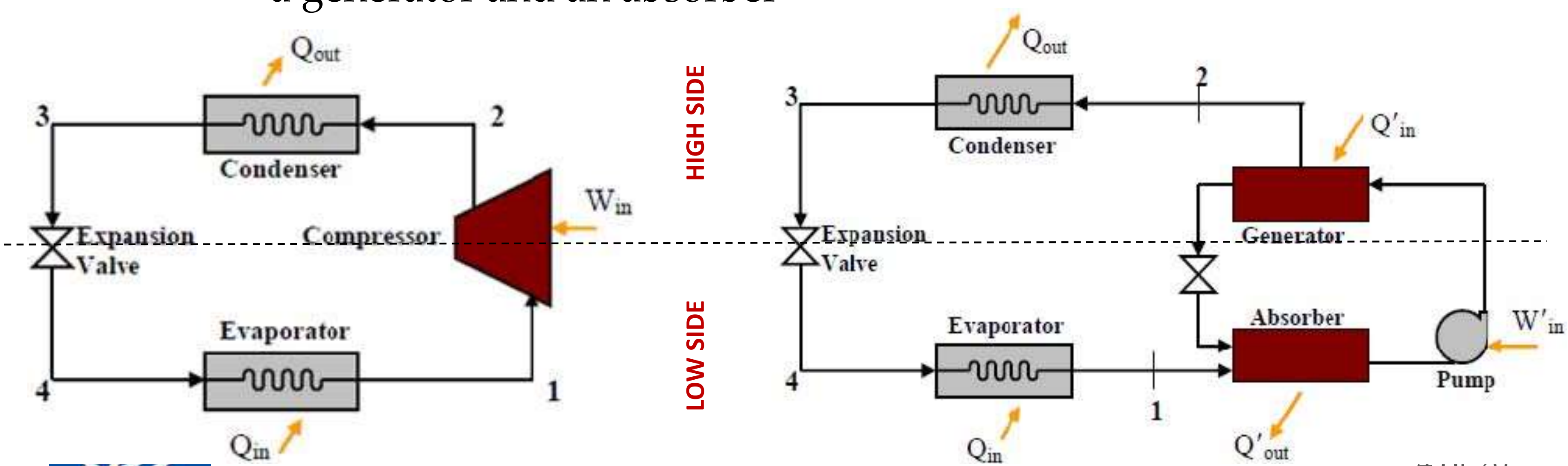
Introduction of Absorption Cycle

How

Burning gas (Steam/Waste heat) produces cooling?

Introduction of Absorption Cycle

- Absorption Cycle
  - Similarity:
    - Heat removal through refrigerant evaporation at low pressure side
    - Heat rejection through refrigerant condensation at high pressure side
  - Differences:
    - VCC uses mechanical compressor to create pressure differences necessary to circulate the refrigerant
    - Absorption cycle uses thermal energy source as the driving force with a generator and an absorber



vapor compression cycle

absorption cycle

Introduction of Absorption Cycle

- Absorption Cycle
  - Refrigerant H_2O and Absorbent Lithium Bromide

Distilled Water

Lithium Bromide (LiBr)

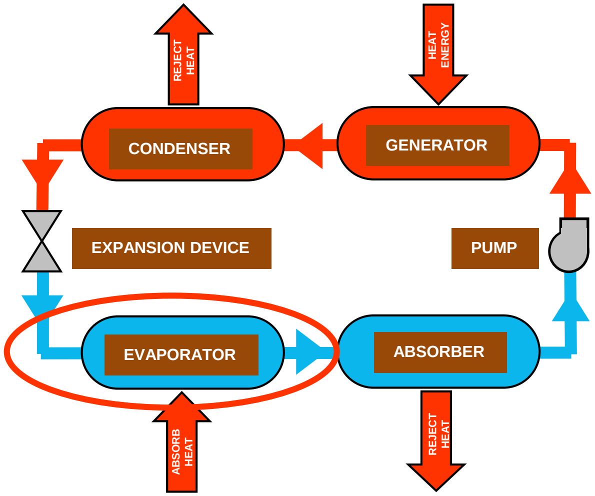
Refrigerant: distilled water R718
- ❑ Stable
- ❑ Nontoxic
- ❑ Low cost
- ❑ Readily available
- ❑ Environmentally friendly
- ❑ High latent heat of vaporization

Absorbent: LiBr
- ❑ High affinity for water
- ❑ Nontoxic
- ❑ In solution, higher boiling point **2309°F** compared to that of water **212°F**
- ❑ Time tested 60 plus years of commercial use in HVAC

Introduction of Absorption Cycle

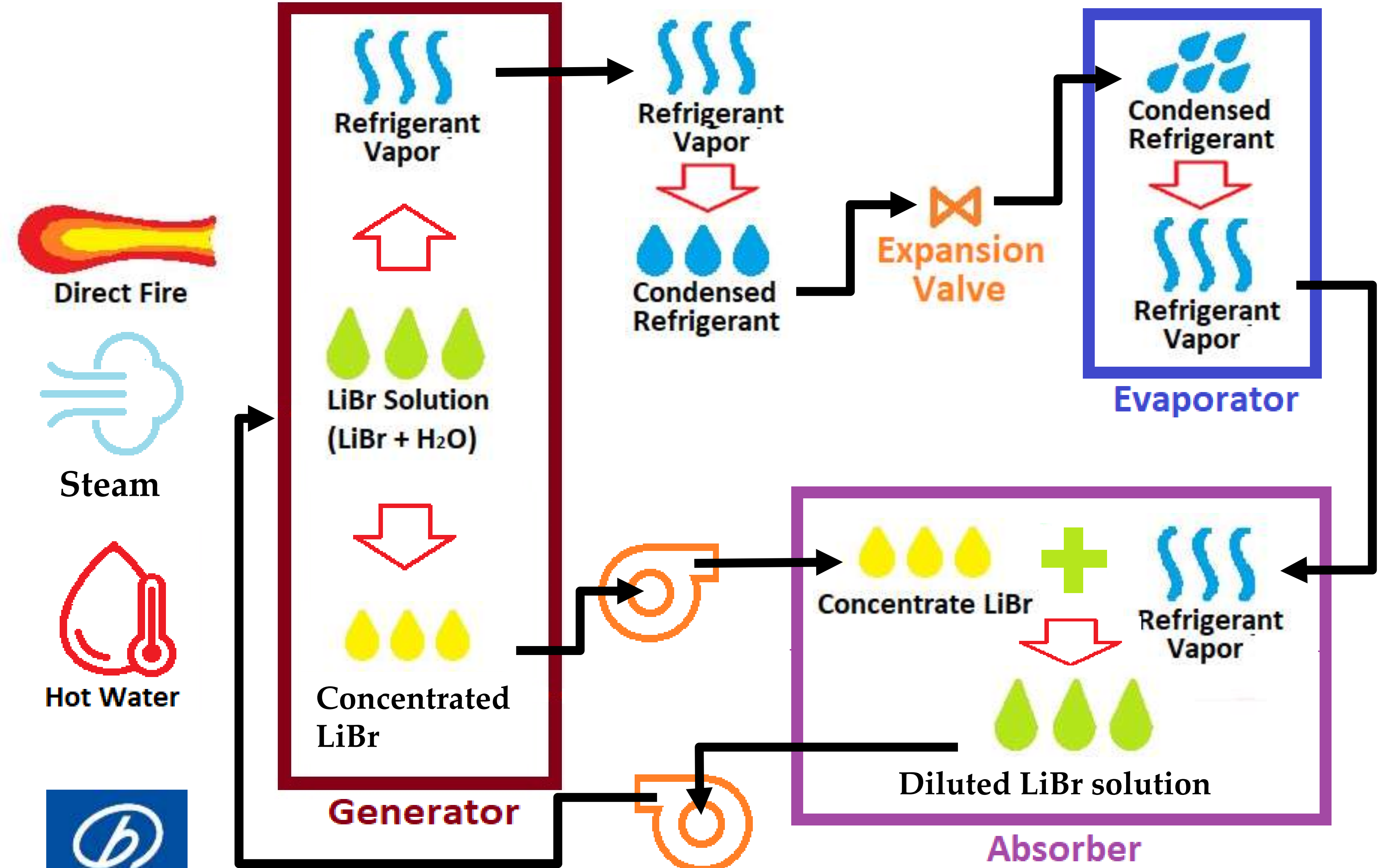
- Absorption Cycle
  - Evaporator with water as refrigerant
    - Refrigerant water sprays on tubes of chilled water system
    - Changes state (boils) and absorbs large amounts of energy
      - Water evaporates at 212°F at 0 psig
      - Water evaporates at 39°F at -14.58psig

Boiling point	pressure
212°F	0 psig (atmosphere pressure)
39°F	-14.58 psig



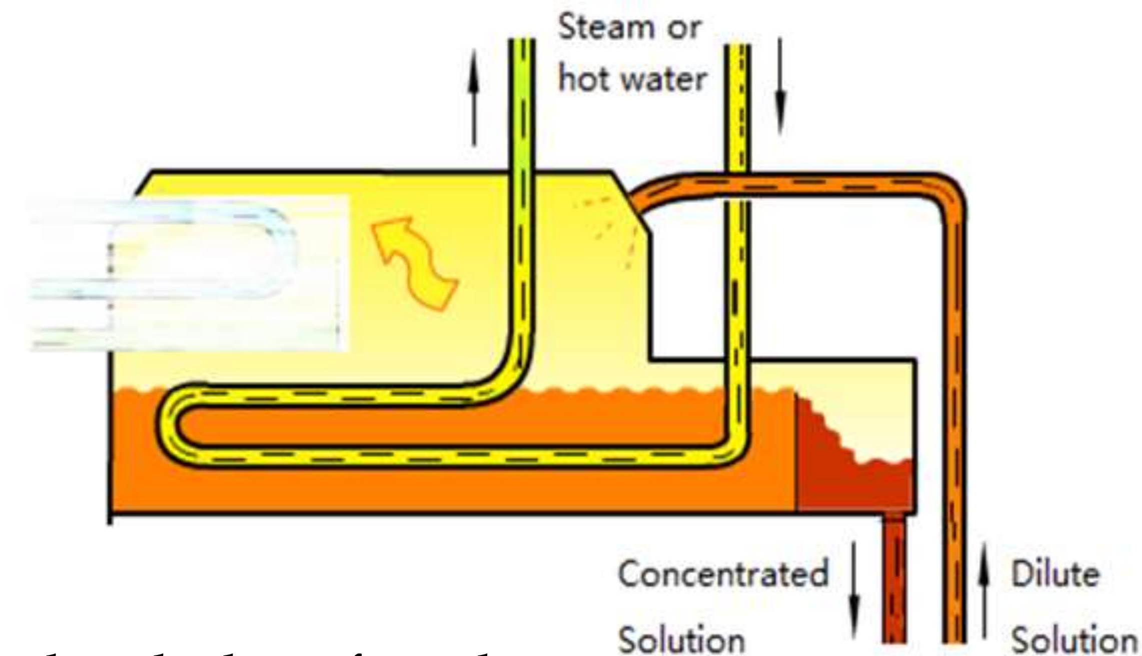
- VCC cycle
  - CFC refrigerant changes state and absorbs large amounts of energy for ex. R134 evaporates at 40°F at 35 psig
- Vacuum, Vacuum, Vacuum for Absorption Cycle!

Working Principle of Absorption Cycle

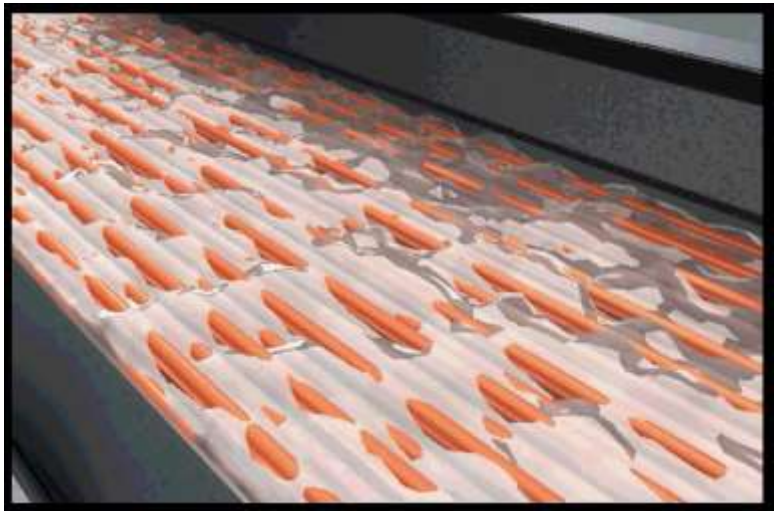


Working Principle of Absorption Cycle

Generator

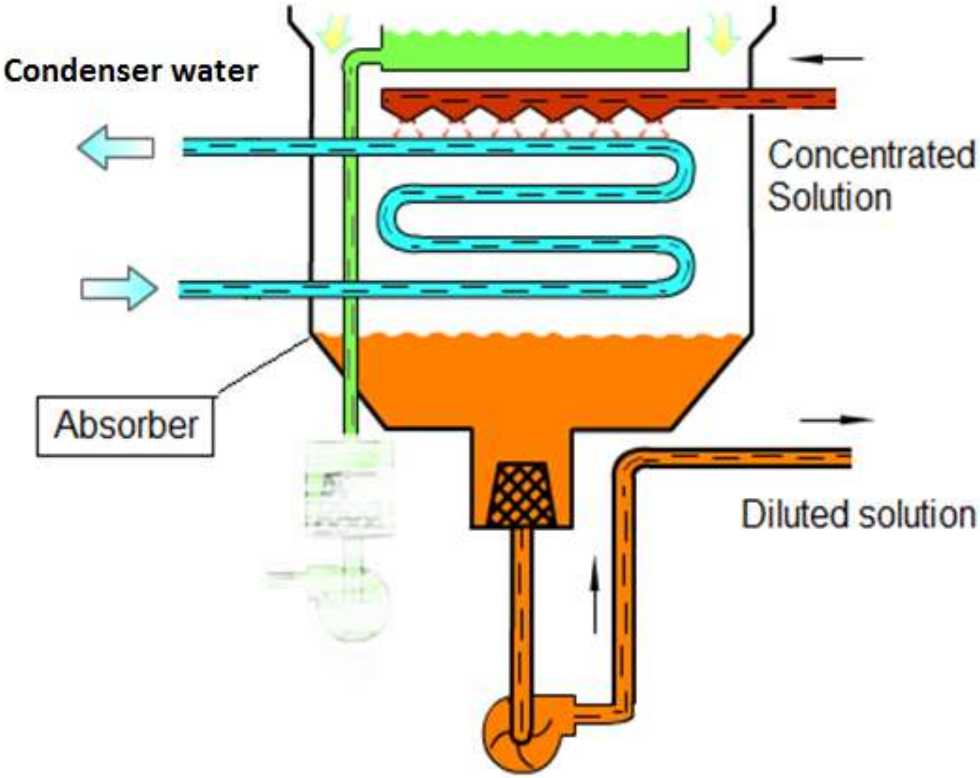


1. LiBr solution absorbs heat from heat source
2. The refrigerant (water) boils and separates from solution
3. The generated refrigerant vapor travels to the condenser



Working Principle of Absorption Cycle

Absorber



1. Refrigerant vapor produced in the evaporator is absorbed by LiBr solution
2. Refrigerant vapor condenses back to liquid
3. Heat generated is rejected to the cooling (condenser) water

Absorption of refrigerant vapor results in low pressure inside the absorber, which induces a continuous flow of refrigerant vapor from the evaporator side.

Modern Absorption Technology – New Normal

- **Corrosion** and degradation of performance was an issue with absorbers in the past
- **Old Absorption technology** requires operators to periodically run a vacuum pump to insure operation and to maintain chilled water set point
- **Oxygen** is the source of corrosion inside an Absorber. If proper vacuum can be maintained for the absorbers life **there is no opportunity** to have corrosion form inside the Absorber.

Modern Absorption Technology – New Normal

- Titanium Tube Material: Best Corrosion Resistant Metal for long life and low life cycle cost

Commercial Production 1960 - 1970 - 1980 - 1990 – 2000 - 2010 - 2020

Time line of Absorption Manufacturing

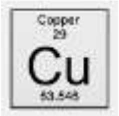
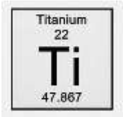
Modern Absorption Technology – New Normal

- “Big Ten”, “State”, “Ivy League” and universities all across North America and Canada are using “Modern Absorption” to lower the cost of proving chilled water on campus

Absorber Factory Testing is now a “New Normal” and the only way to truly guarantee AHRI 560 performance standards.

Why BROAD Absorption Chiller - Technology

- Titanium Tube Material: Best Corrosion Resistant Metal for long life and low life cycle cost

Tube Materials / Solution Media	Pure Copper 	Copper-Nickel 	Stainless Steel 	Titanium 
Chlorine	Resist corrosion under low temp& low concentration	Resist corrosion under low and medium temperature	Resist corrosion differs by types of stainless steel	**No corrosion**
salt water (speed)	1.2 m/s	3.6m/s	5-7m/s	**No limitation**
Ammonia	Serious corrosion	Corrosion	No corrosion	**No corrosion**
Polluted air & water	Corrosion	Slight corrosion	No corrosion	**No corrosion**

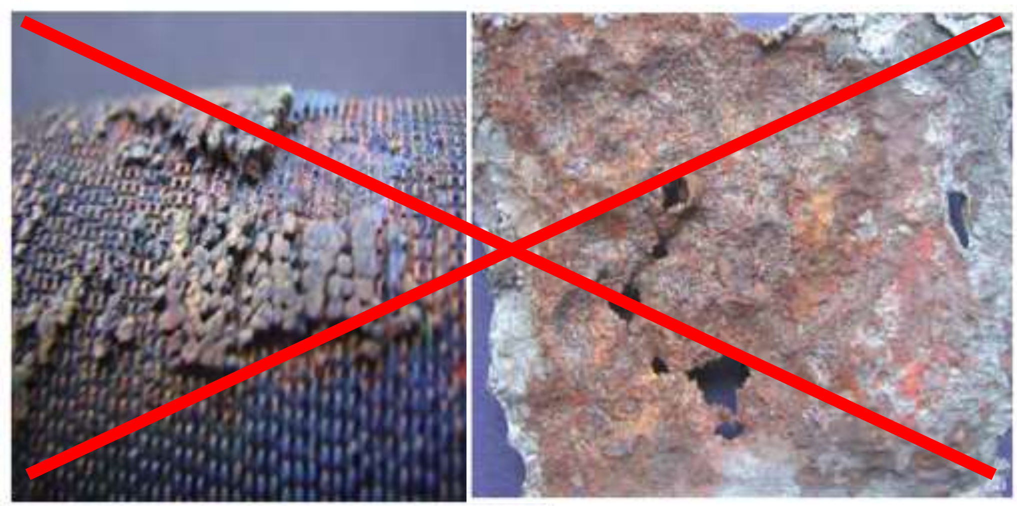
Why BROAD Absorption Chiller - Technology

- Titanium Tube Material: Best Corrosion Resistant Metal for long life and low life cycle cost

Titanium is low density, light weight and high strength **element.**

Titanium does not corrode when exposed to salt water, acid& chlorine….. or in absorber.

A Titanium tube in an Absorbers will likely ***never*** need to be re-tubed



Modern Absorption Technology – New Normal

- Tube selection can be a significant factor to and Absorbers life cycle & should be a considered with each application for use based on project goals and specifics
- As tubes become stronger and less resistant to deterioration wall thickness can be reduced to gain or overcome thermal efficiency differences between material choices
- Less weight can reduce installation costs
- Materials that are stronger and resistant to corrosion will reduce life cycle cost
- Economics of materials and tubes technology changes such as enhancements, cross hatching-rifleling allow for numerous choices for tube selection to improve life cycle costs and the efficiency of the chiller

Case Studies

- Steam absorption chiller application at University of Minnesota

Case Studies

- Steam absorption chiller application at University of Minnesota

Performance Map		Evap Delta T	Lvg Evap	Steam PPH CND Ent. Temp. (deg F)				COP Tolerance		
Load	Tons	deg F	deg F	85	80	75	70	Upper Limit	Lower Limit	Notes
100.0%	1000	18	40					none	ZERO @85F	Non-Standard Application Rating Conditions
100.0%	1000	12	40					none	AHRI 560	Non-Standard Application Rating Conditions
80.0%	800	12	40					none	AHRI 560	Non-Standard Application Rating Conditions
60.0%	600	12	40					none	AHRI 560	Non-Standard Application Rating Conditions
40.0%	400	12	40					none	AHRI 560	Non-Standard Application Rating Conditions
	Average			####	####	####	####			

CND Pump Energy		Evap Delta T	Lvg Evap	CND/ABS Flow (gpm)				CND/ABS dp (ft H20) "dp1"				
Load	Tons	deg F	deg F	85	80	75	70	85	80	75	70	Notes
100.0%	1000	18	40									Non-Standard Application Rating Conditions
100.0%	1000	12	40									Non-Standard Application Rating Conditions
80.0%	800	12	40									Non-Standard Application Rating Conditions
60.0%	600	12	40									Non-Standard Application Rating Conditions
40.0%	400	12	40									Non-Standard Application Rating Conditions
	Average			####	####	####	####					

CHW Pump Energy		Evap Delta T	Lvg Evap	Evaporator Flow (gpm)				Evaporator dp (ft H20) "dp2"				
Load	Tons	deg F	deg F	85	80	75	70	85	80	75	70	Notes
100.0%	1000	18	40									Non-Standard Application Rating Conditions
100.0%	1000	12	40									Non-Standard Application Rating Conditions
80.0%	800	12	40									Non-Standard Application Rating Conditions
60.0%	600	12	40									Non-Standard Application Rating Conditions
40.0%	400	12	40									Non-Standard Application Rating Conditions
	Average			####	####	####	####	*#DIV/0!*	####	####	####	

Hour Bin		Evap Delta T	Lvg Evap	Bin ECWT				Annual	Chiller Energy*	Steam Consumption (lbs)				Incremental CND Pump Energy**	Electric kWh			
Load	Tons	deg F	deg F	85	80	75	70	Total Hours		85	80	75	70		85	80	75	70
100.0%	1000	18	40	80	200	200	100	580		0	0	0	0		0	0	0	0
100.0%	1000	12	40	30	250	200	100	580		0	0	0	0		0	0	0	0
80.0%	800	12	40	0	400	400	400	1200		0	0	0	0		0	0	0	0
60.0%	600	12	40	0	129	150	100	379		0	0	0	0		0	0	0	0
40.0%	400	12	40	0	0	50	75	125		0	0	0	0		0	0	0	0
							Annual Hours	2864										
							Annual Ton Hours	2,397,400										

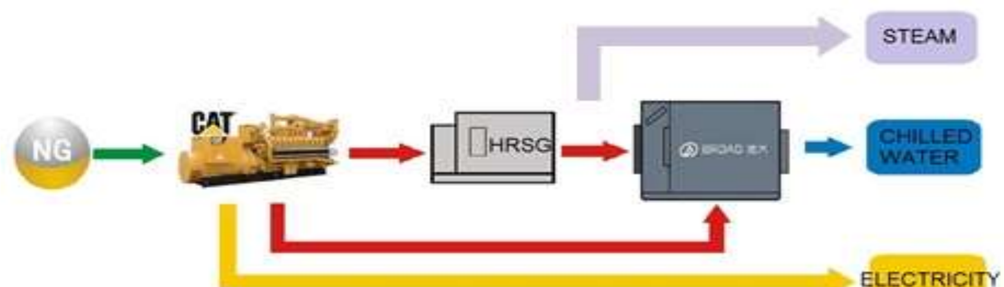
*Hourly Bin Data multiplied by Steam PPH performance Map data

** See Attachment A for kW eqn. kWh computed based on CND/ABS dp and Hourly Bin Data

Case Studies

- Steam and Hot water absorption chiller application at the University of Maryland Upper Chesapeake

EPA Energy Star
CHP award winner



CCHP 2 MW with multi-energy absorption

Case Studies

- Steam and Hot water absorption chiller application at the University of Maryland Upper Chesapeake
  - With an operating efficiency of 75 percent, the system requires approximately 34 percent less fuel than would be used by conventional electricity and steam production, and also avoids emissions of air pollutants, including an estimated 4,700 tons of carbon dioxide annually (equal to the emissions from the generation of electricity used by more than 630 homes). The system saves the University an estimated $300,000 each year.

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THANK YOU!
Q&A

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