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Myth Busters
Absorption Cooling Technology

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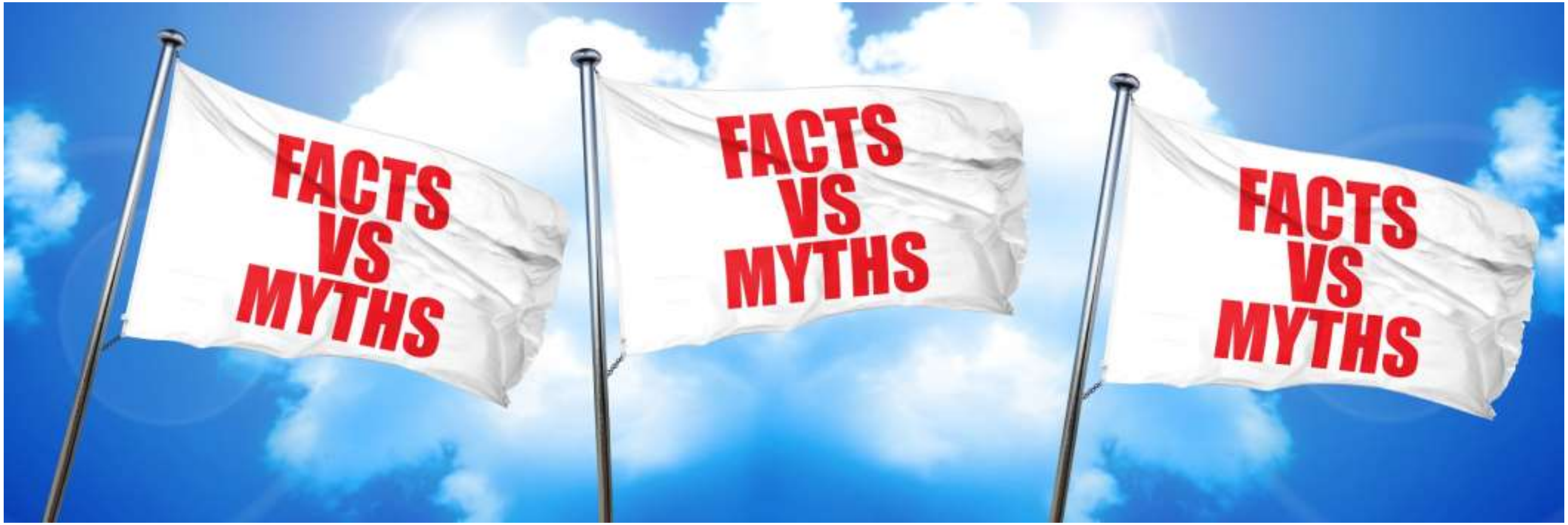
- Hitachi-Johnson Controls A/C Japan
    - Shuichiro Uchida
    - Takashi Nishiyama
    - Shigehiro Doi

Learning Objectives

- Busting Myths About Absorption Cooling Technology
  - Understand the Facts About Technology
  - Break the Stereotype About Technology
  - Shatter Old Misconceptions



Outline

1. Overview of the Technology
2. Myth – Less Efficient
3. Myth – High Cost
4. Myth – Rigid Operational Range
5. Myth – Crystallization A Common Problem
6. District Cooling Applications
7. Innovative Heat Pump
8. Conclusions

Overview of the Absorption Technology

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1. Water as the refrigerant
2. Driven by waste Heat or low cost natural gas
3. Around for last 75 years
4. Thousands of commercial, industrial, marine Applications
5. Helps reduce electrical and water costs, reduced emissions
6. Not reliant on the already congested electric grid
7. Truly green sustainable solution

Myth # 1
Absorption Chillers Are Less Efficient

1. Electric Water-Cooled Centrifugal Chiller COP is ~ 6.5

2. Absorption Chiller COP is ONLY 0.7 ~ 1.4

Myth # 1
Absorption Chillers Are Less Efficient

Facts

1. Driving input energy for an absorption chiller is different than an electric chiller
   1. Electricity for electric chiller
   2. Thermal energy for absorption chiller (generally waste heat so relatively low cost)
2. COP of an electric chiller does not account for generation, transmission and distribution losses (60% ~ 70%) for the electricity

Myth # 1 BUSTED
Absorption Chillers Are Less Efficient

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1. Typical Chiller COPs Assumed

Electric Centrifugal Chiller	Direct Natural Gas Fired Absorption Chiller	Double Effect Steam Absorption Chiller	Single Effect Steam Absorption Chiller
6.5	1.2	1.4	0.7

2. Natural Gas $ 5/MMBTU, Electricity $ 0.15/kWh, Steam $4 per 1,000 lb (450 Kg)

3. Ton-hour Operational Costs (US Cents/ton-hour)

Electric Centrifugal Chiller	Direct Natural Gas Fired Absorption Chiller	Double Effect Steam Absorption Chiller	Single Effect Steam Absorption Chiller
8.12	5.00	3.43	6.86

MMBTU = 1,000,000 Btu

Myth # 1 BUSTED
Absorption Chillers Are Less Efficient

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Example

1. Average US City, Process Cooling Application, 500 Cooling Tons
2. Electricity $ 0.15/kWh, Natural Gas $ 5/MMBTU, Steam $ 4 per 1,000 lb (450 Kg)

	Electric Centrifugal Chiller	Direct Natural Gas Fired Absorption Chiller	Double Effect Steam Absorption Chiller	Single Effect Steam Absorption Chiller
Chiller COP	6.5	1.2	1.4	0.7
Chiller cost of operation (Input Energy)	$ 253,714	$ 169,451	$ 135,181	$ 235,513
Plant cost of operation (Chiller + Pumps + Tower)	$ 330,330	$ 256,071	$ 222,152	$ 316,044

MMBTU = 1,000,000 Btu

Myth # 1 BUSTED
Absorption Chillers Are Less Efficient

- **FACTS**
  - Higher COP (numerical value) of an electric chiller does not necessarily mean it has a lower operating cost compared to an absorption chiller
  - Absorption Chiller can be cost-efficient to operate provided low cost driving heat source is available
  - Efficiency (COP) in combination with input energy cost is the right way to decide the chiller of choice for a facility

Myth # 2
Absorption Chillers Are Very Expensive

1. 500 Cooling Tons

2. Assumed Chiller Prices
    1. Electric Centrifugal $ 150,000 (not considering the cost of electric infrastructure)
    2. Direct Fired Absorption $ 300,000
    3. Double Effect Steam Absorption $ 275,000
    4. Single Effect Steam Absorption $ 250,000

3. First Impression - Absorption Does Not Make Sense

Myth # 2
Absorption Chillers Are Very Expensive

Recollect our example from slide # 8

1. Average US City, Process Cooling Application, 500 Cooling Tons
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Myth # 2 BUSTED
Absorption Chillers Are Very Expensive

1. Even though initial capital cost of an electric chiller is much lower than an absorption chiller, the fact is annual cost of operation of an electric chiller is not necessarily lower than an absorption chiller

2. Simple Payback Compared to Electric Chiller (not considering utility rebates) for this particular example

Direct Fired	Double Effect Steam	Single Effect Steam
2 years	1 year	7 years

1. In many/certain situations, absorption chiller is the right choice over an electric chiller

Myth # 3
Absorption Chillers Not Flexible In Operation

1. Chilled Water Leaving Temperature Must Be Higher Than 5°C (41°F)
2. Chilled Water and Condenser Water Flow Rates Should Not Vary
3. Full And Steady Loads Must Be Maintained
4. Always Operate Closer to the Design Condenser Water Inlet Temperature Typically 29.4°C (85°F)
5. Never Design An Absorption Chiller With Low Chilled/Condenser Flows

Myth # 3 BUSTED
Absorption Chillers Not Flexible In Operation

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FACTS

1. Chilled water leaving temperature can be as low as 4°C (39°F) or even minus 5°C (23°F)
2. Chilled/Condenser water flow rate design range
   1. Flow rate can be changed at 5% per minute up to 50% per 10 minutes
   2. Evaporator 1.3 ~ 2.9 gpm/ton (0.29 ~ 0.65 m3/hour/ton)
   3. Absorber-Condenser
      1. Single Effect 3.0 ~ 8.0 gpm/ton (0.68 ~ 1.81 m3/hour/ton)
      2. Double Effect 2.2 ~ 6.0 gpm/ton (0.49 ~ 1.36 m3/hour/ton)
3. Turndown 100% down to 10% of the design cooling load
4. Design entering cooling water range 20°C (68°F) ~ 37°C (98.6°F)

Myth # 3 BUSTED

Absorption Chillers Not Flexible In Operation

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Myth – not a good idea to design an absorption chiller with low condenser flow

Fact – 4 gpm/ton or 3 gpm/ton or 2 gpm/ton condenser flow is not an issue

Condenser Flow	4 gpm/ton (0.9 m3/hr/ton)	3 gpm/ton (0.68 m3/hr/ton)	2 gpm/ton (0.45 m3/hr/ton)
Capacity (tons)	1000	1000	1000
Chilled Water Inlet/Outlet	12.2/6.7 °C 54/44°F	12.2/6.7 °C 54/44°F	12.2/6.7 °C 54/44°F
Condenser Water Inlet	29.4°C 85°F	29.4°C 85°F	29.4°C 85°F
Condenser Water Outlet	35.1°C 95.1°F	37.1°C 98.8°F	41.1°C 106°F
Pressure drop	58 kPa 19.4 ft wc	42 kPa 14 ft wc	20 kPa 6.7 ft wc
COP	1.42	1.40	1.36

1000 tons, Steam 8 bar(g) 115 psig

Myth # 4
Crystallization – A Common Problem

1. REVIEW THE BASICS

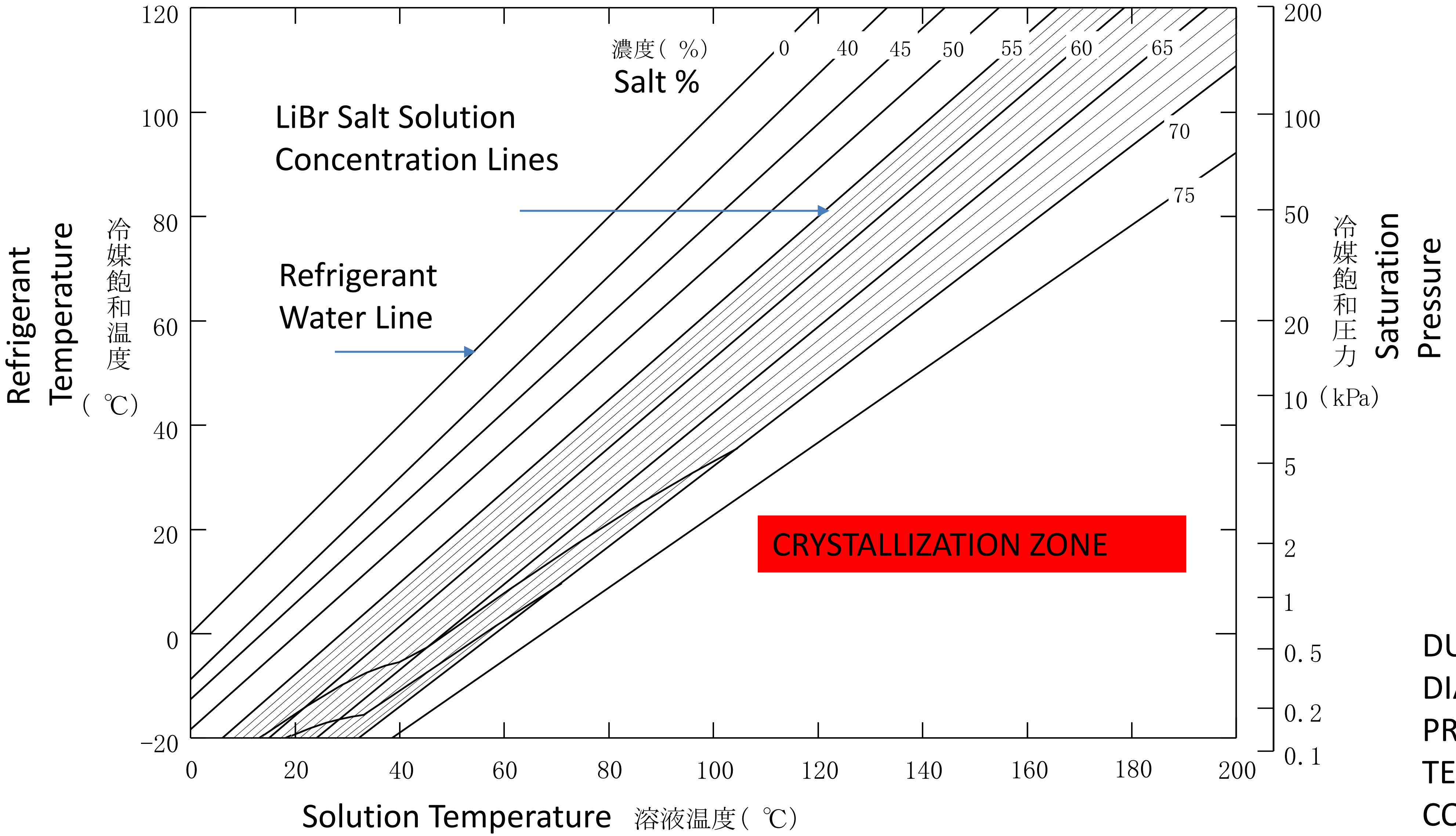
1. Lithium Bromide as a salt solution absorbs refrigerant water vapor
2. Solution concentration means amount of LiBr salt in the solution
    1. 0% solution means 0% by weight salt, 100% by weight water (this is pure refrigerant water)
    2. 54% solution means 54% by weight salt, 46% by weight water

Salt % in Solution	54%	57%	58%	60%	61.5%	63.5%
Crystallization Temperature	-16.1°C (3.02°F)	-3°C (26.6°F)	0.9°C (33.6°F)	10.5°C (50.9°F)	18°C (64.4°F)	26°C (78.8°F)

2. Solution with a higher salt % has a higher probability to crystallize

1. 63.5% solution will crystallize more easily than 61.5% solution
2. 61.5% solution will crystallize more easily than 58% solution

Myth # 4
Crystallization – A Common Problem



DUHRING DIAGRAM – PRESSURE TEMPERATURE CONCENTRATION

Myth # 4
Crystallization – A Common Problem

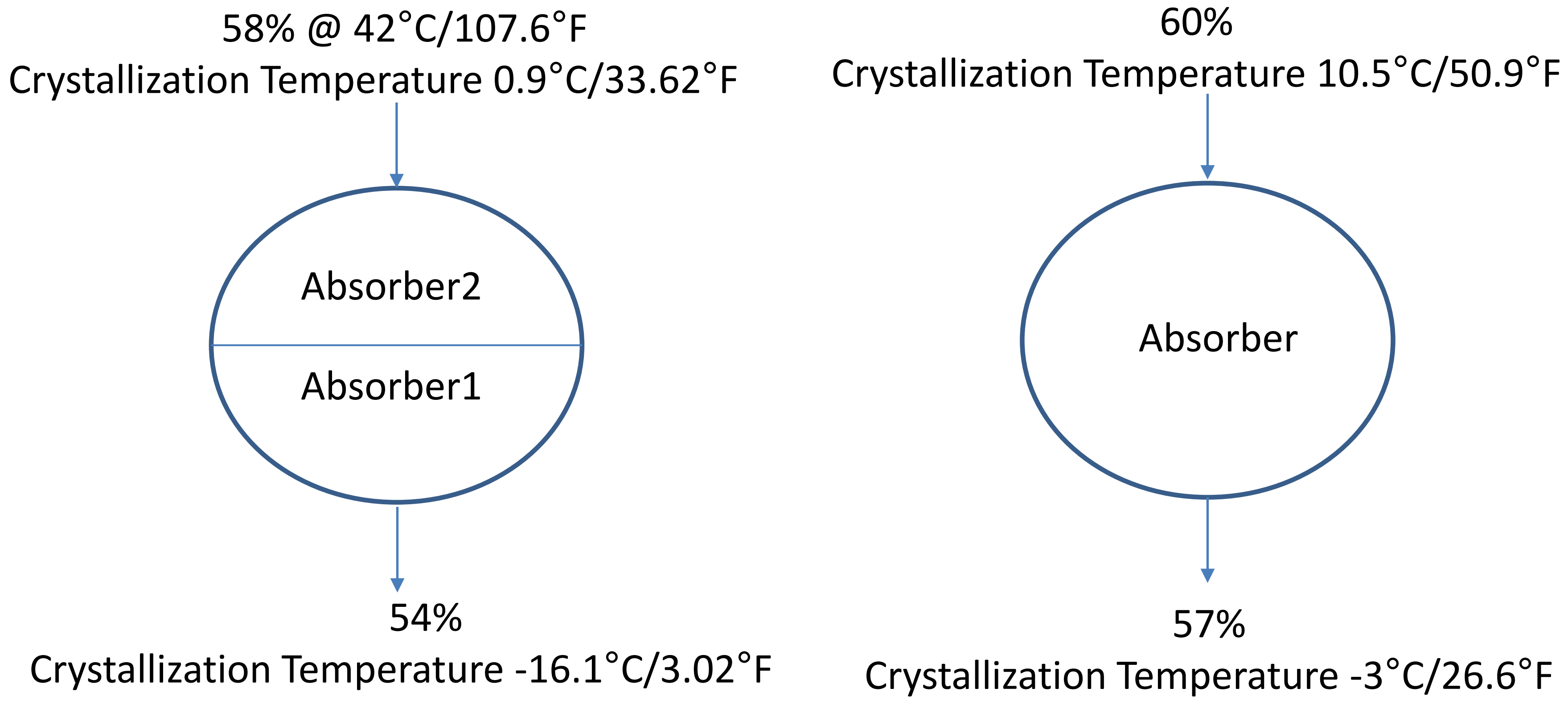
1. Most Common Causes of Crystallization
   - Low condenser water temperature at high cooling loads
   - Air leakage (improper vacuum)
   - Loss of electric power

2. Protect from Crystallization
   - Sophisticated Controls limiting the driving heat input
   - Automatic Purging (vacuum pump operation)
   - Small UPS (uninterrupted power supply) for dilution

3. PREVENT Crystallization (BEST WAY)
   - Design the unit with low salt solution concentrations which are easier to boil
   - Low salt solution concentrations are difficult to crystallize, thus they operate farthest from the crystallization zone

Myth # 4 BUSTED
Crystallization – A Common Problem

Single Effect



VERY DIFFICULT TO GET CRYSTALLIZED

MAY EASILY GET CRYSTALLIZED

ALWAYS DESIGN A CHILLER WITH LOWEST SALT SOLUTION CONCENTRATIONS

Myth # 4 BUSTED
Crystallization – A Common Problem

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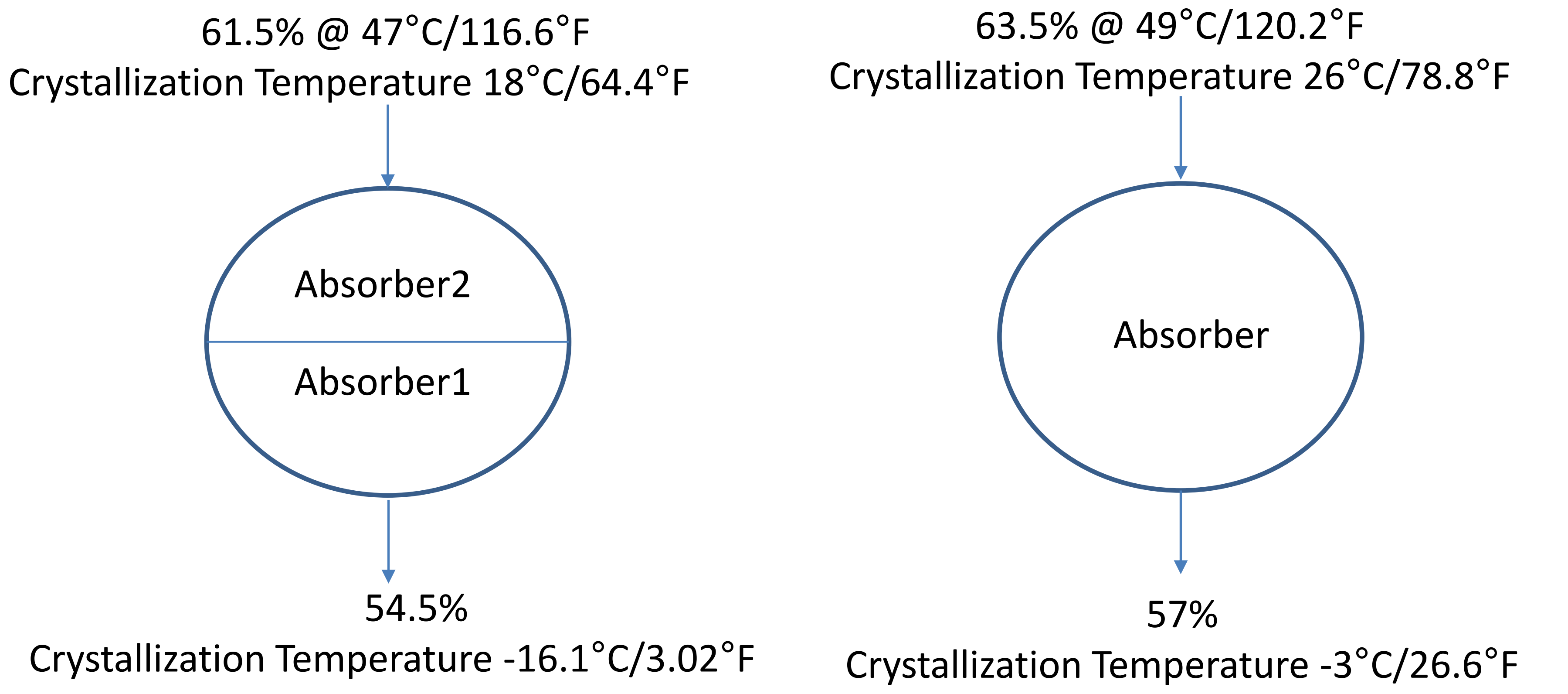
Double Effect



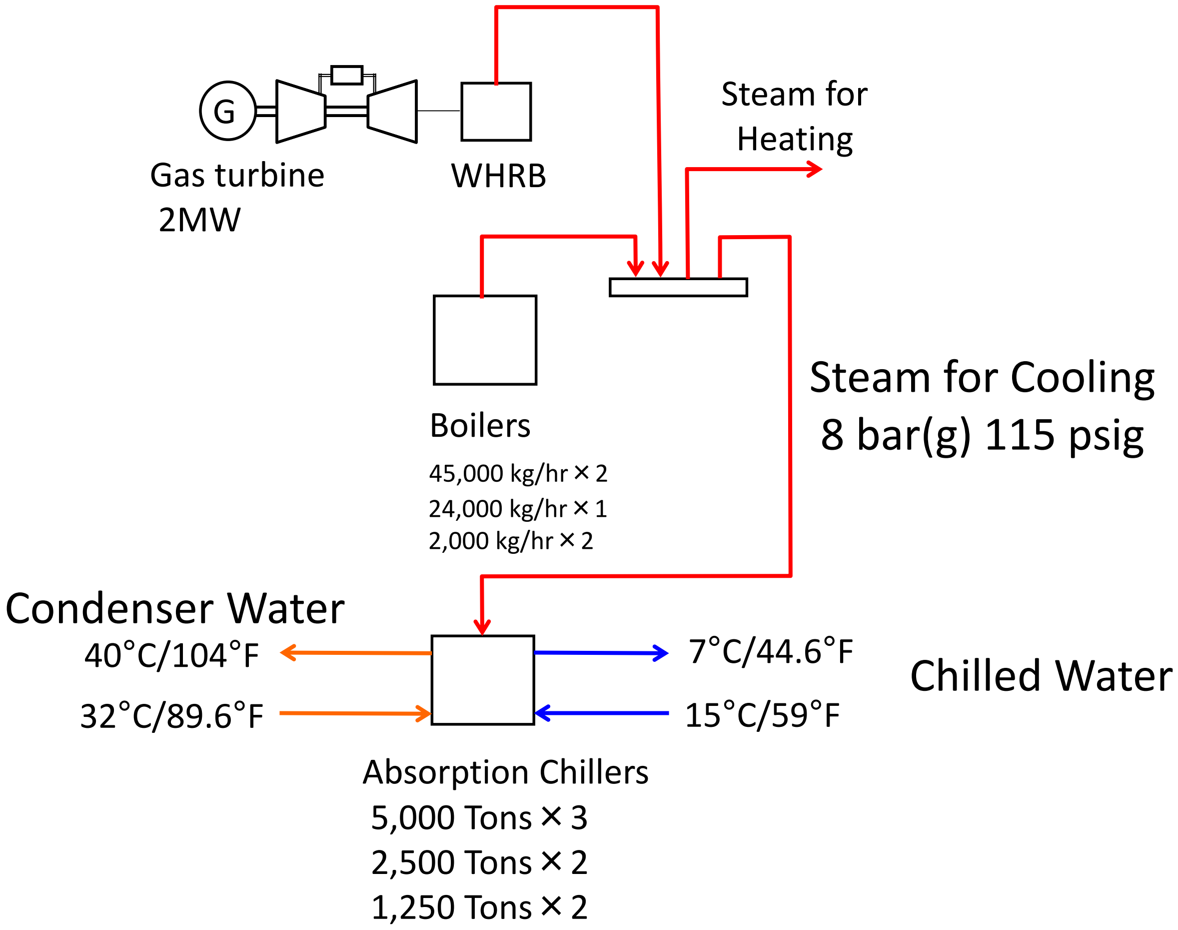
VERY DIFFICULT TO GET CRYSTALLIZED

MAY EASILY GET CRYSTALLIZED

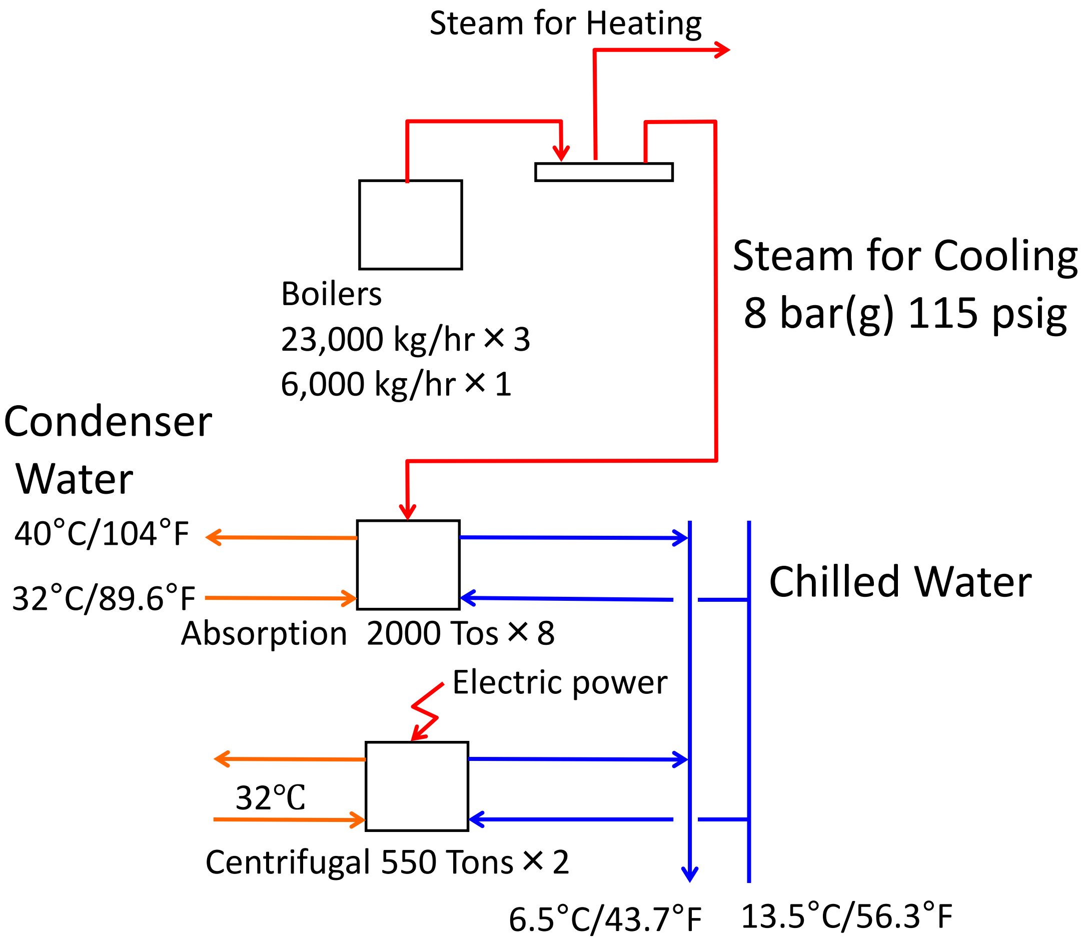
ALWAYS DESIGN A CHILLER WITH LOWEST SALT SOLUTION CONCENTRATIONS

DISTRICT COOLING APPLICATION
22,500 TONS STEAM DRIVEN

SYSTEM INVOLVES STEAM ABSORPTION CHILLERS



DISTRICT COOLING APPLICATION
17,100 TONS STEAM + ELECTRIC



SYSTEM INVOLVES STEAM ABSORPTION AND ELECTRIC CENTRIFUGAL CHILLERS

DISTRICT COOLING APPLICATION
8250 TONS STEAM+ELECTRIC+HEAT STORAGE

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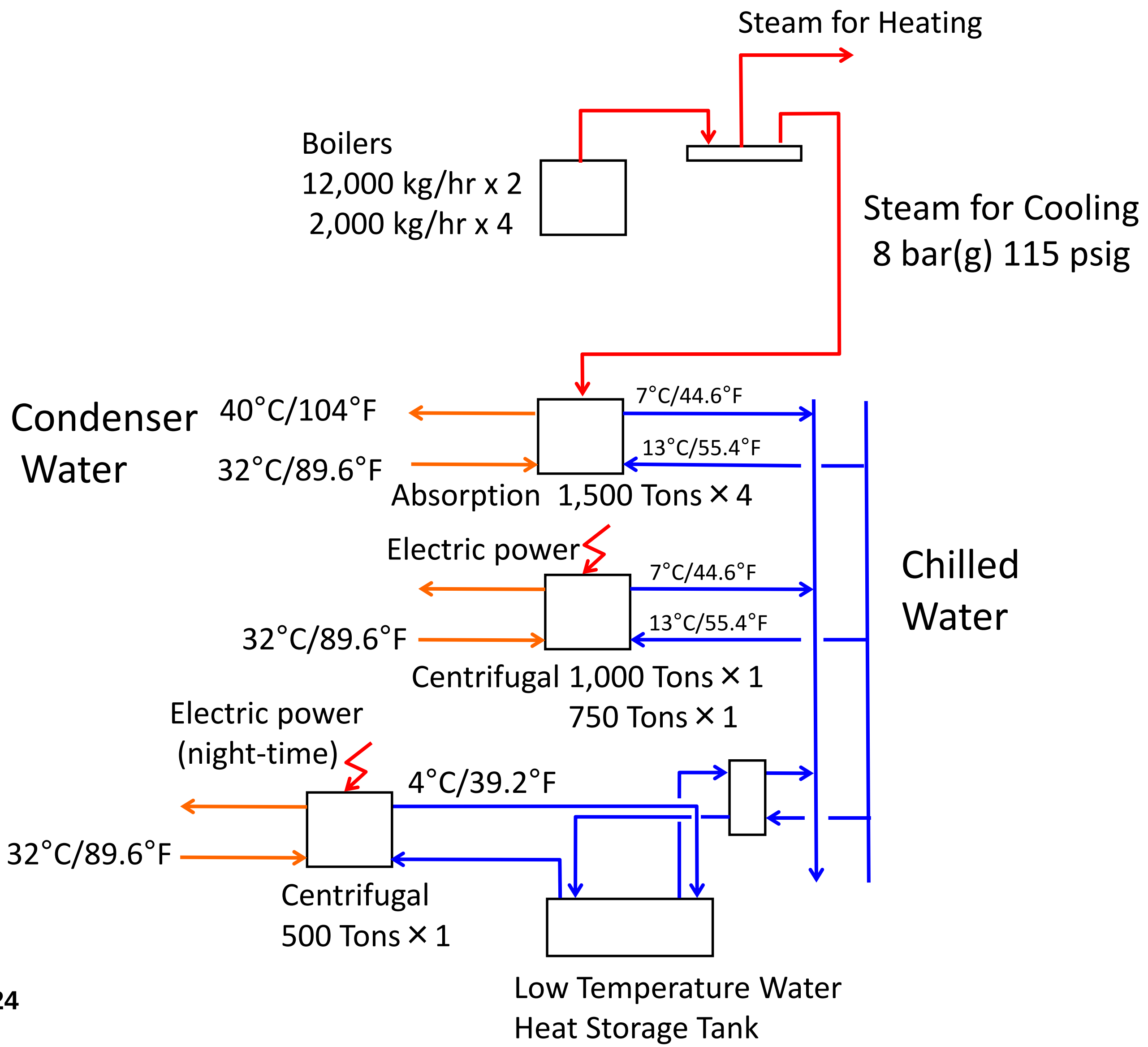
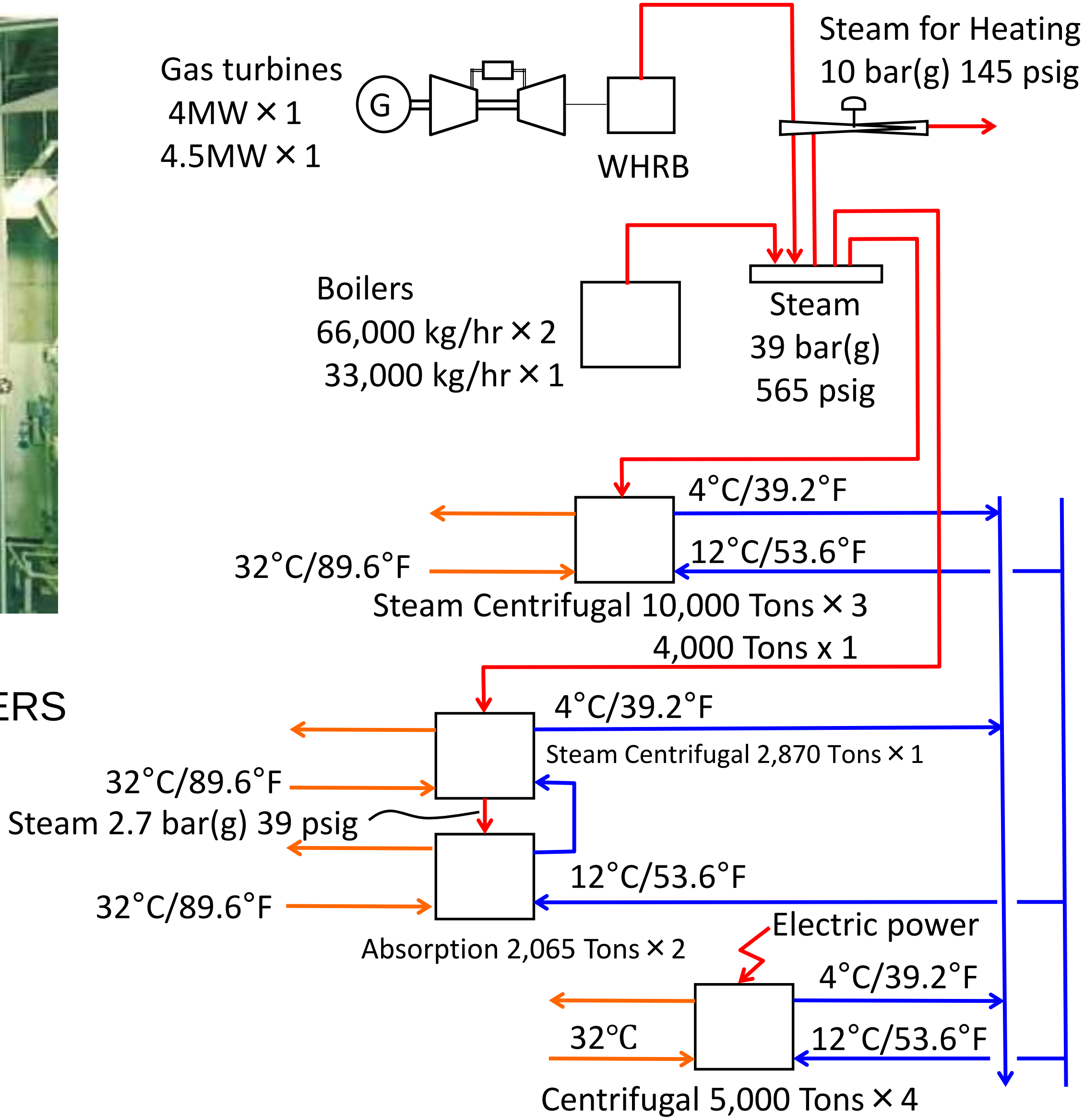
SYSTEM INVOLVES STEAM ABSORPTION,
ELECTRIC CENTRIFUGAL CHILLERS
AND LOW TEMPERATURE WATER HEAT STORAGE

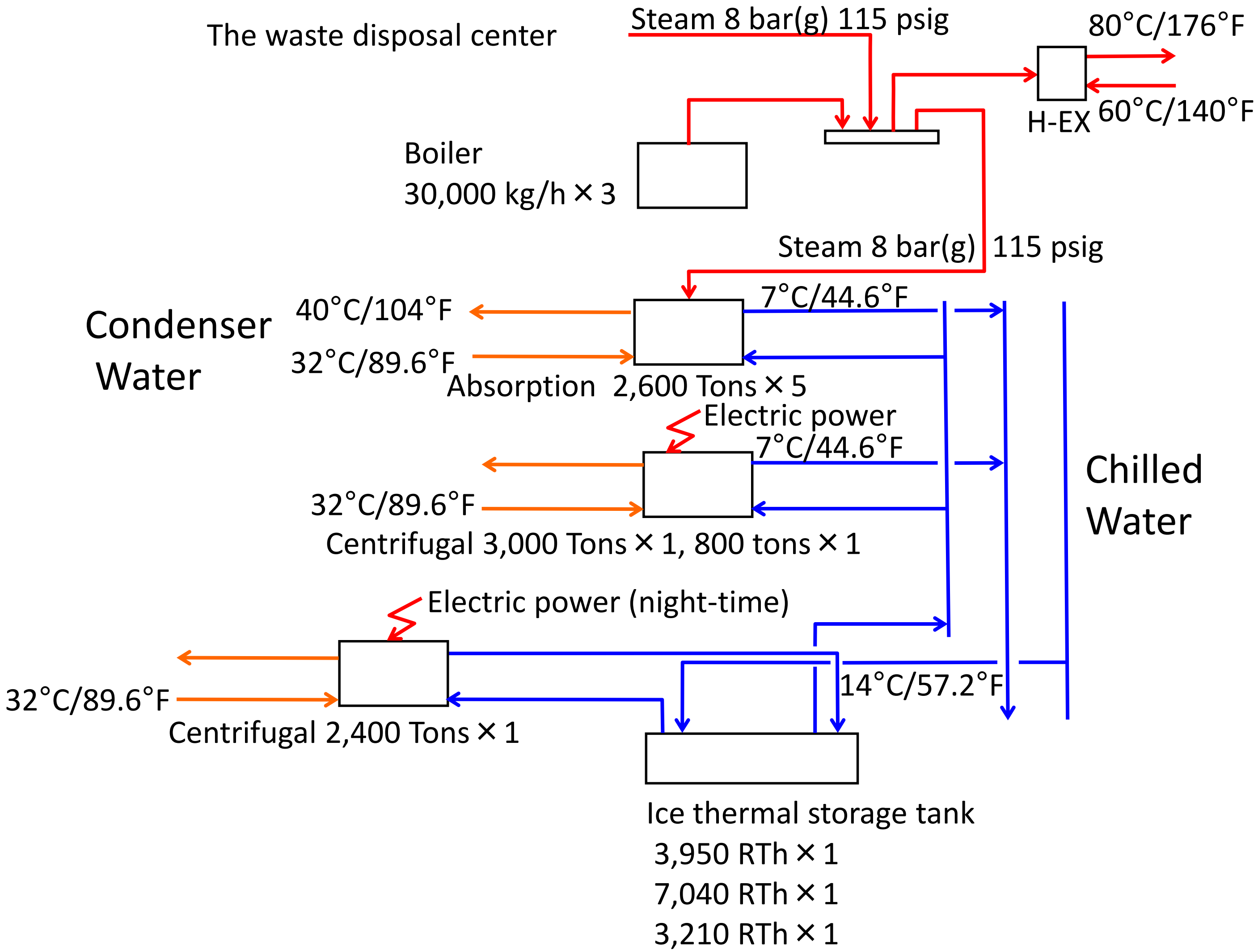


DISTRICT COOLING APPLICATION
61,000 TONS HYBRID SYSTEM

SYSTEM INVOLVES STEAM CENTRIFUGAL,
STEAM ABSORPTION AND ELECTRIC CENTRIFUGAL CHILLERS

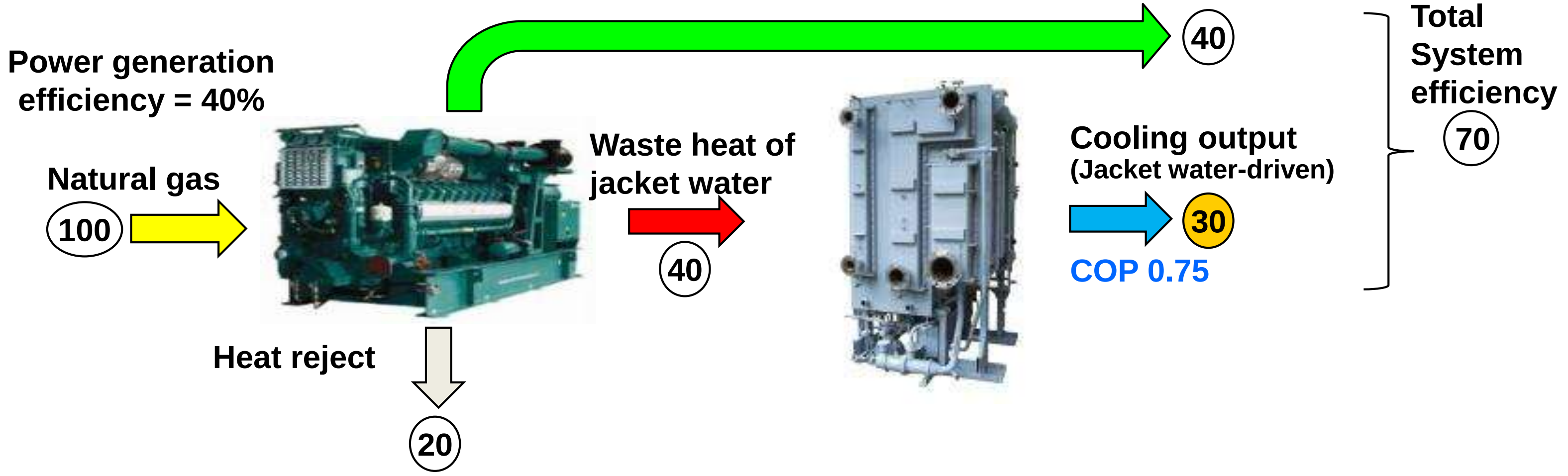


DISTRICT COOLING APPLICATION

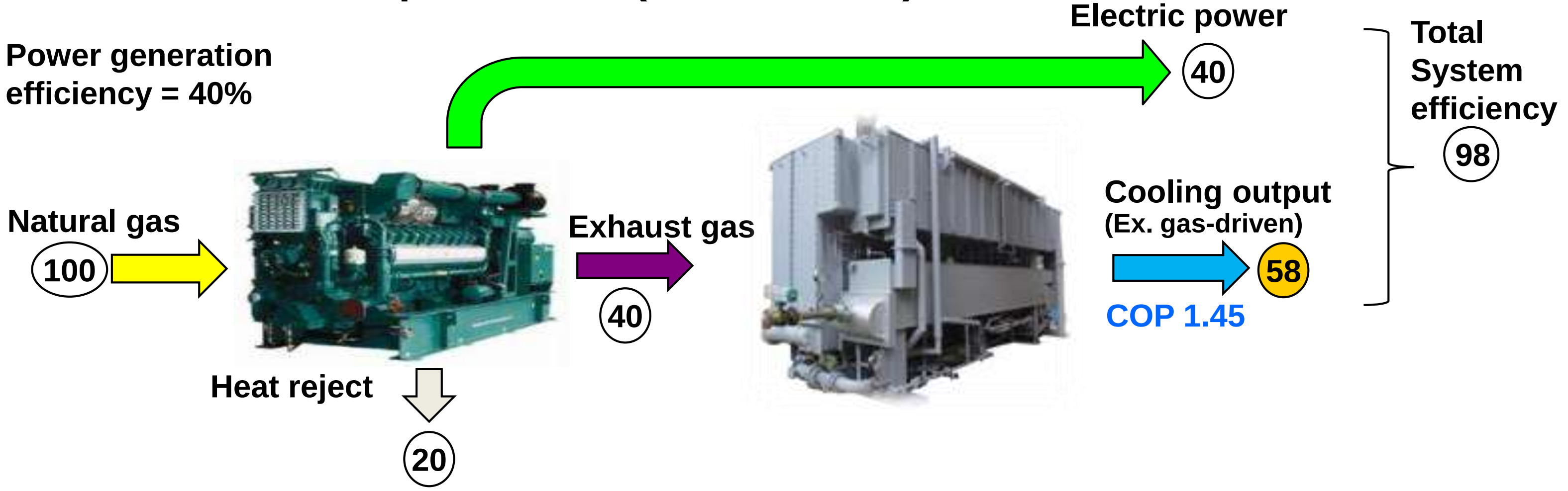


COMBINED HEAT, POWER AND COOLING

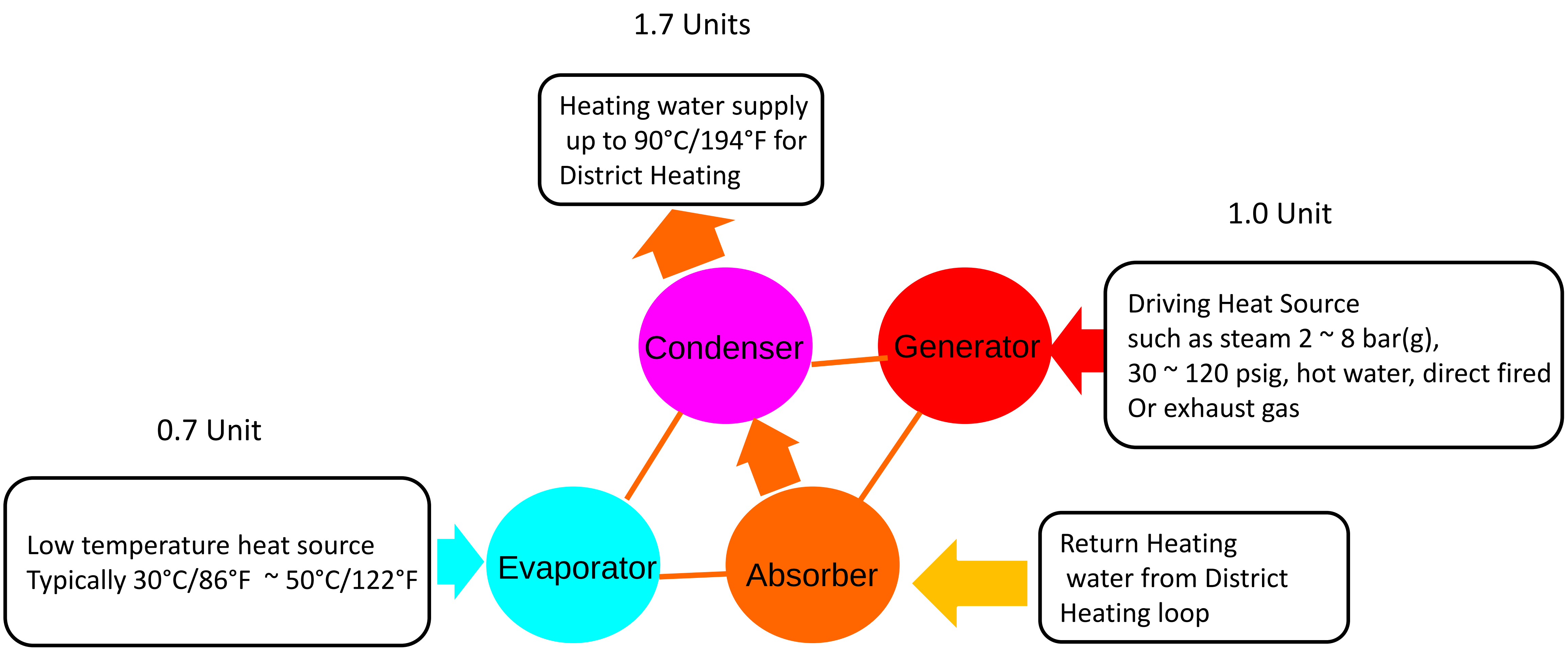
Hot water absorption chiller (Single-Effect)



Exhaust Gas driven absorption chiller (Double Effect)



Innovative Absorption Heat Pump (Type I) Application Heating COP 1.7



Conclusions

1. Decision to use the right chiller technology must be based on first cost, operating cost, maintenance cost and life cycle cost
2. Absorption Chillers have been deployed on large scale basis world-wide since 1950s
3. Variety of applications as chiller, chiller-heater, heat pump
4. Absorption Chiller deserve serious consideration for first choice, if waste heat or low cost heat is available
5. Absorption Chillers help save energy, water and cuts down emissions, helping to achieve climate targets

Questions?