Webinar # 3

Absorption 101
Lithium Bromide-Water Cycle

Rajesh Dixit

Johnson Controls

November 15th, 2018

Welcome to the IDEA Webinar Series

- The webinar will start promptly at 1:00pm ET (Boston time) and is scheduled to last sixty (60) minutes; including time for questions.
- All lines are muted during this webinar with exception to the panelists.
- If you are having problems with video or audio, please send a note via the Chat Box function on the right side. Click the Chat box and choose – “Chat privately to Cheryl Jacques (host)”. Or call to IDEA at +1-508-366-9339. .
- Questions to Presenters: Please enter your Questions in the Q&A box at the lower right of the screen. These questions will be moderated and addressed as time allows. We plan to handle Q&A at the conclusion of the presentation.
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Efficient Energy for Smarter Cities
DECEMBER 9-11, 2018 – ATLANTIS, THE PALM – DUBAI, UAE

CampusEnergy2019
February 26 - March 1, 2019 | New Orleans, LA | Hilton New Orleans Riverside

IDEA2019
The Energy for More Resilient Cities
110TH ANNUAL CONFERENCE & TRADE SHOW | June 24-27
David L. Lawrence Convention Center and The Westin Convention Center | Pittsburgh, PA

Speaker and Moderator

Speaker:
Rajesh Dixit
Director – Global Product Management
Johnson Controls York PA

Moderator:
Rob Thornton
IDEA President & CEO

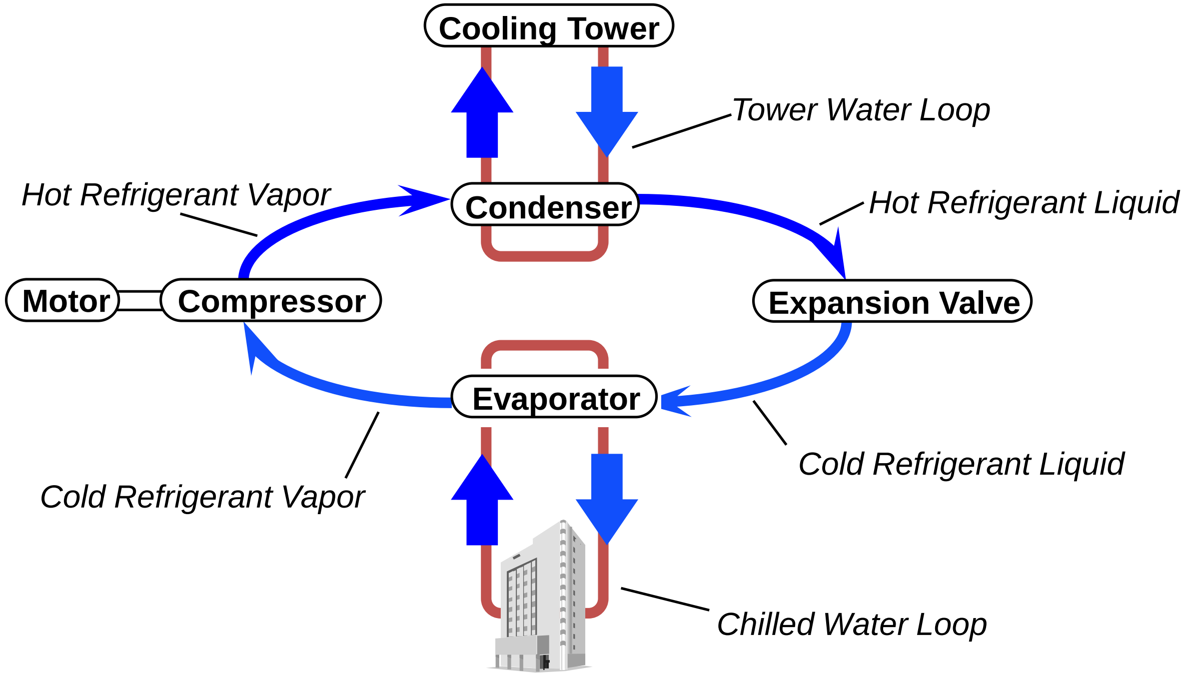
Learning Objectives

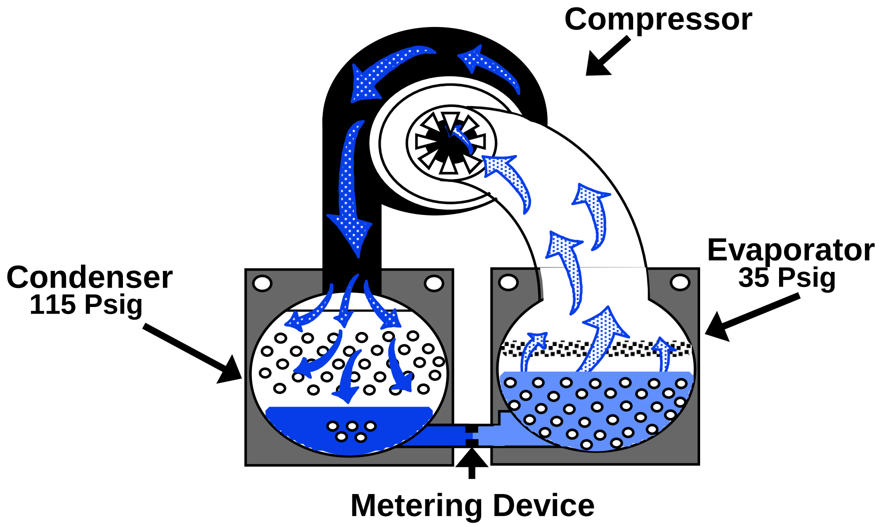
- Understand how an absorption chiller works
- Overview of different types, performance

Outline

1. Fundamentals
2. How it works, Fluids
3. Types
4. Operational Range
5. Performance
6. PTX Diagram – Crystallization
7. Various Cycles
8. Conclusions

Conventional Vapor Compression Cycle





Boiling Point of Water

Atmospheric Pressure
0 psig
14.7 psia
760 mm Hg (abs)
29.92 in Hg (abs)

Liquid turns to vapor

212 ° F

100 ° C

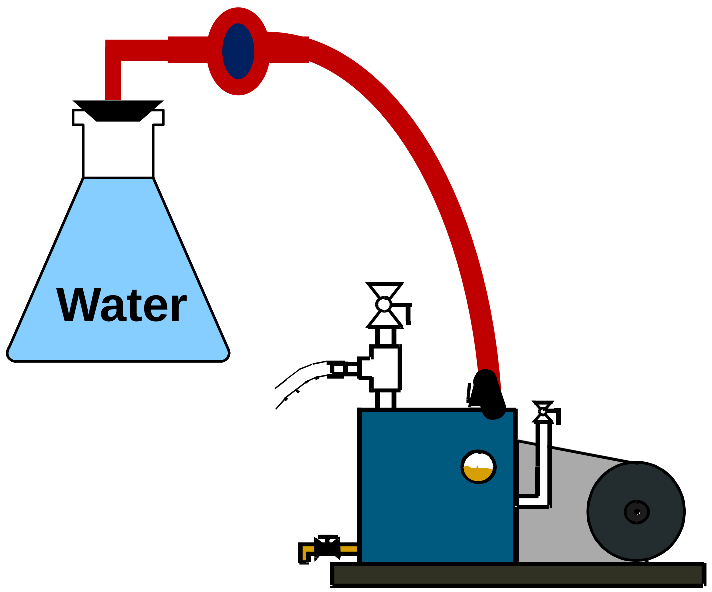
Water Pressure and Temperature Relationship

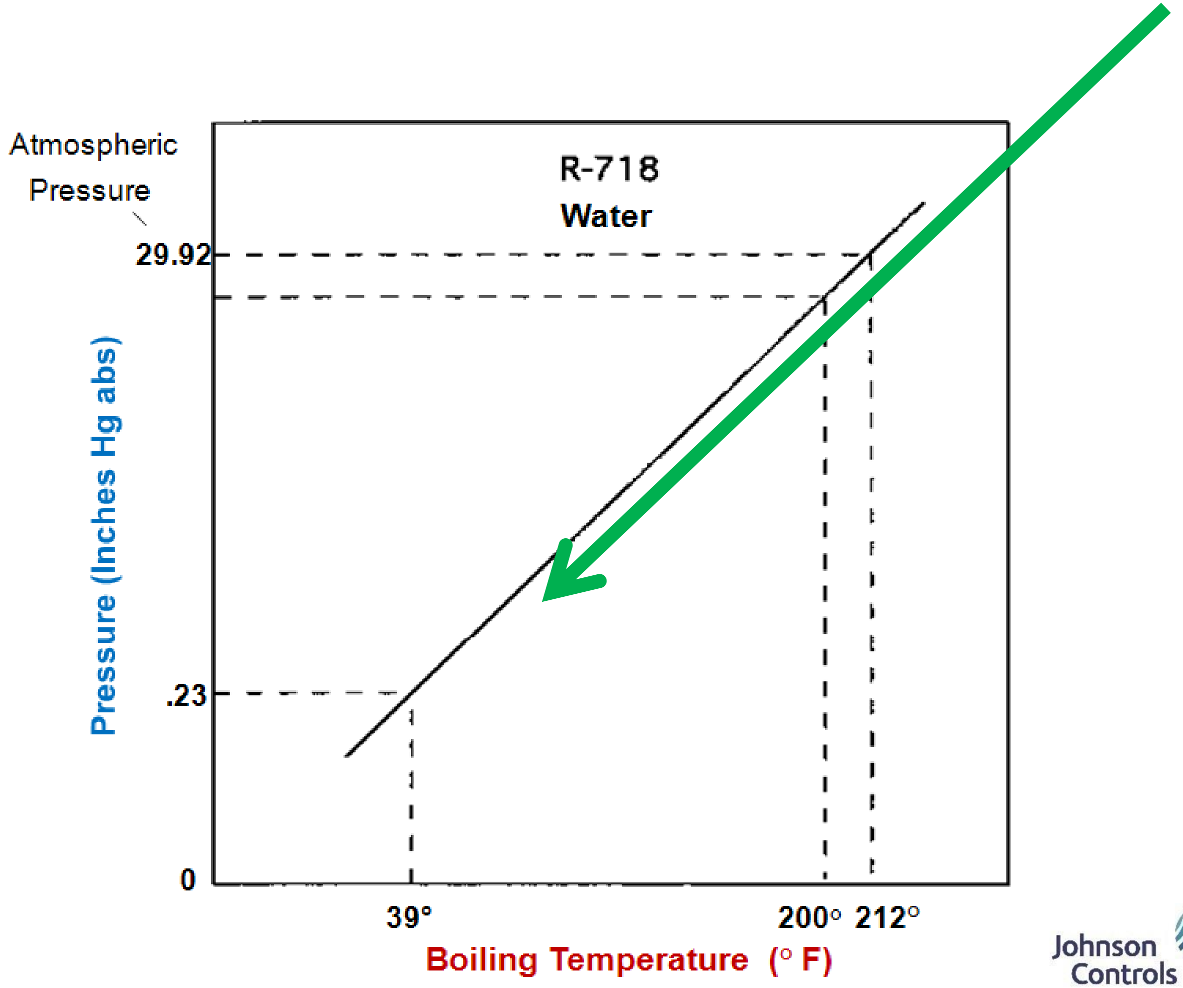
- **Sea Level**
  - 0 PSIG **or** 14.7 PSIA **or** 760 mm Hg (abs) **or** 29.92 in Hg (abs)
  - 212° F boiling point
- **Pike's Peak**
  - 14,000 ft above sea level
  - 165° F boiling point

	PSIG	PSIA	"Hg (g)	" Hg (abs)	mm Hg (g)	mm Hg (abs)
Perfect Vacuum	-14.7	0	-29.92	0	-760	0

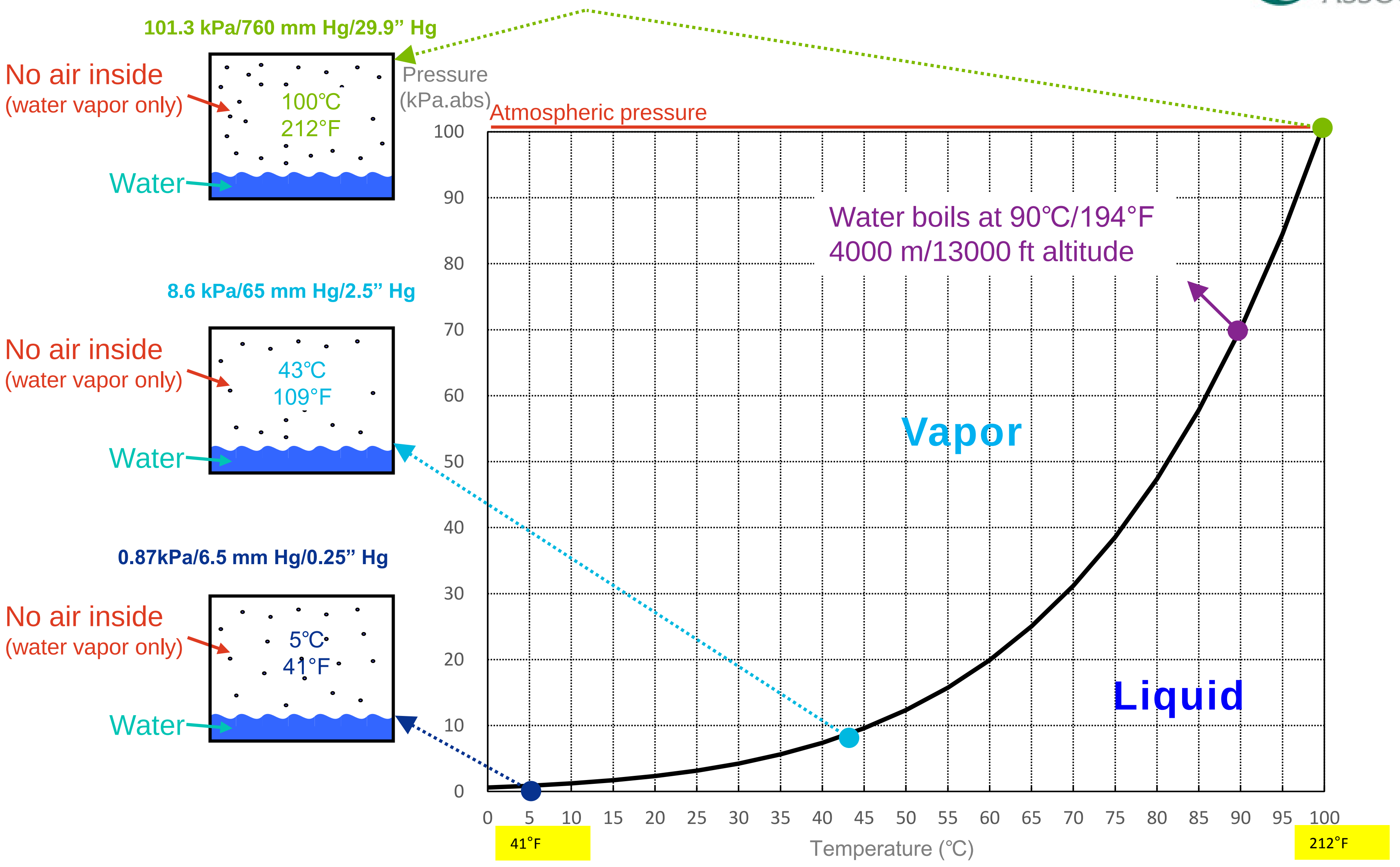
Water Pressure and Temperature Relationship

With the help of a Vacuum (Purge) Pump , the non-condensable gases(air) are taken out, this reduces the pressure to 1/100th of atmospheric. At this low pressure (deep vacuum), the boiling point of water drops to 3.9°C (39°F).



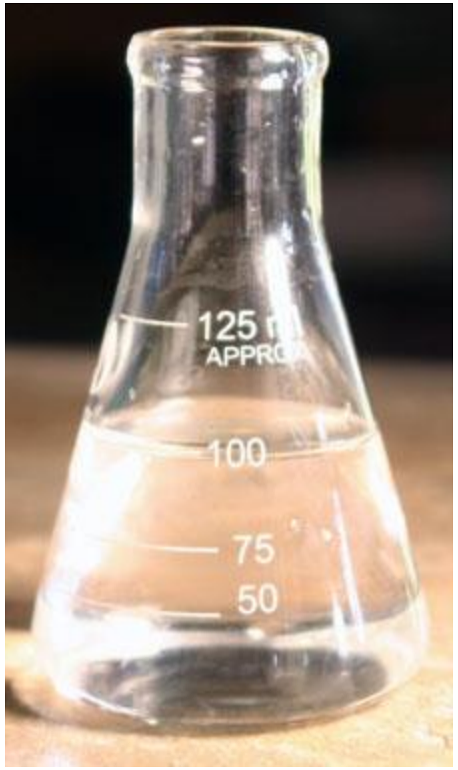


De-ionized Water as the Refrigerant



De-ionized Water as the Refrigerant R-718

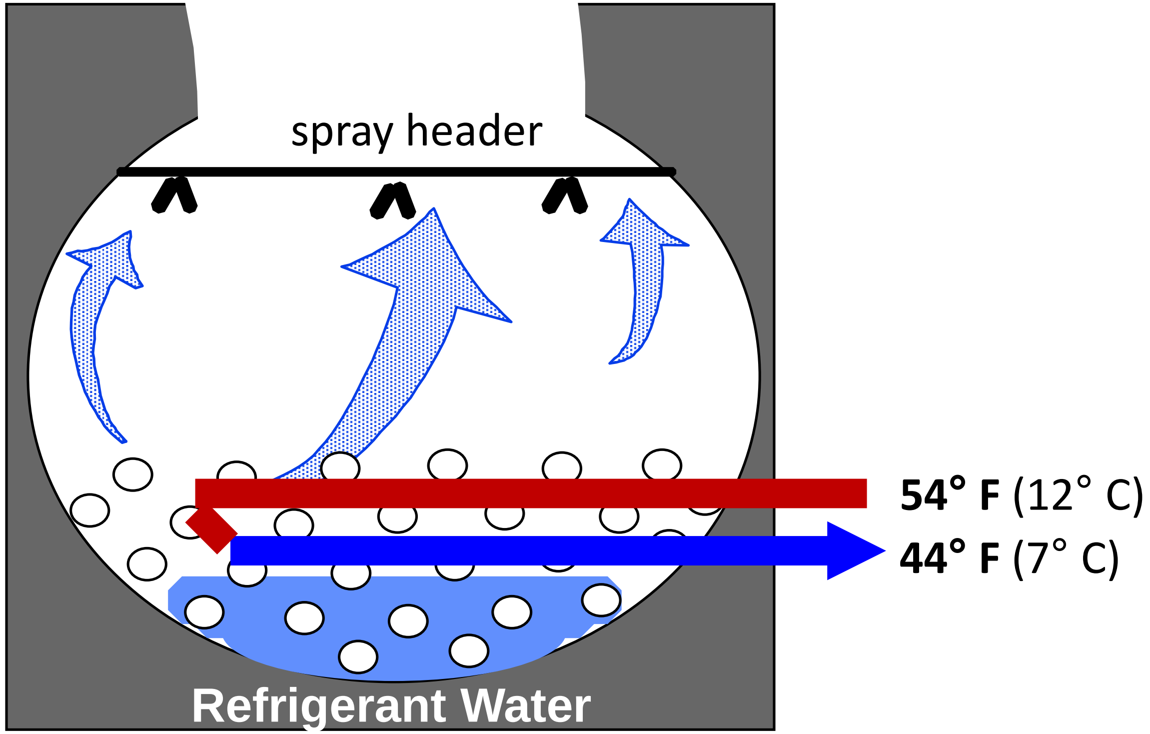
- Stable
- Non-toxic
- Environmentally Friendly
- Low Cost
- Latent Heat of Vaporization 1000 Btu/lb
- Can be easily absorbed and separated



Evaporator

Refrigerant Water (R-718) will boil @ 39° F (3.9° C) in a deep vacuum

6 mm Hg (abs) <u>or</u> 0.23 inches Hg (abs)



Evaporator and Absorber

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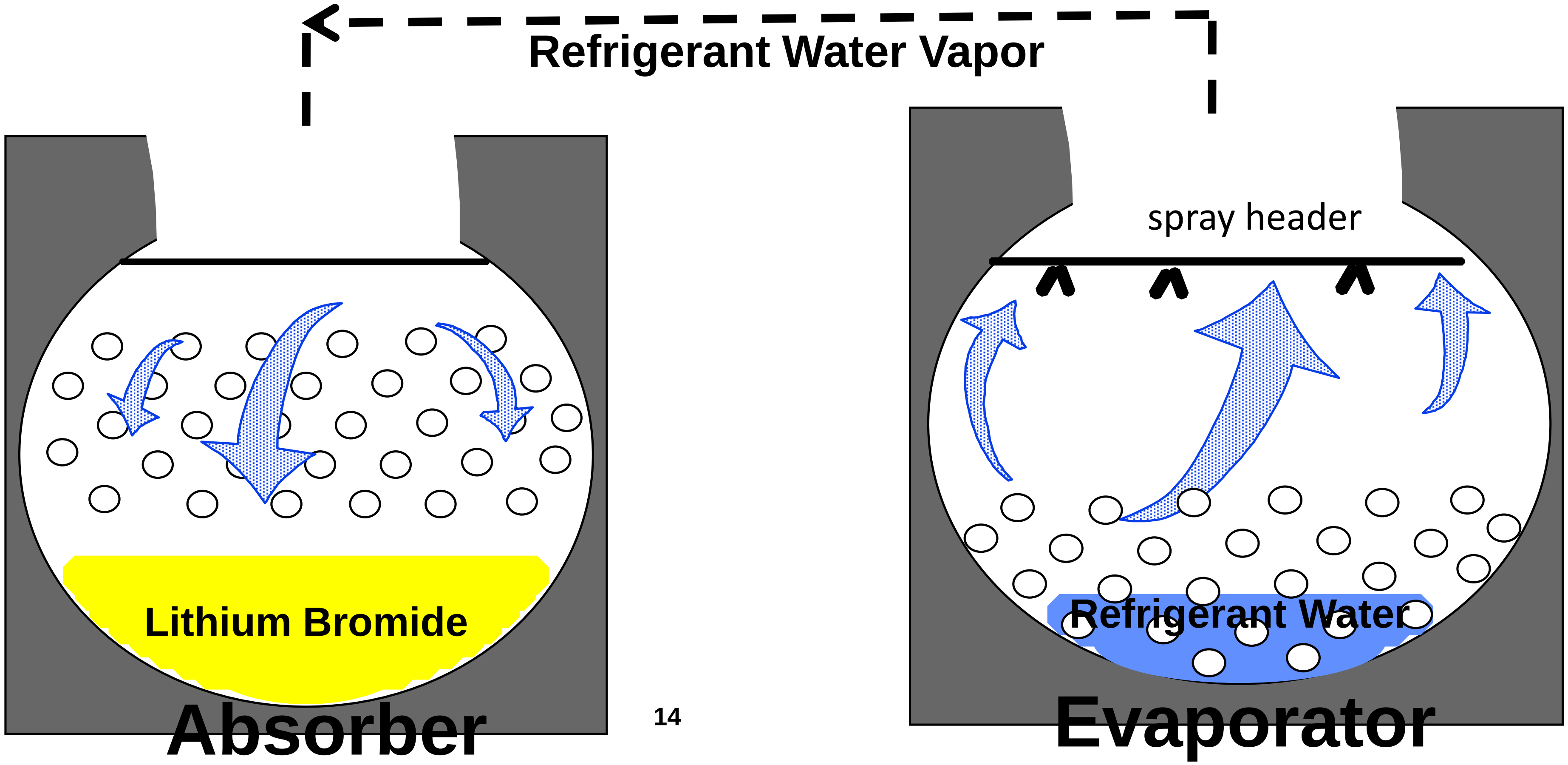


Lithium Bromide as the Absorbent

- LiBr – similar to NaCl (Salt)
- High affinity for water
- Molecular weight 86.856 (Li 8%, Br 92%)
- High boiling point
- Non-toxic (but don't drink/eat)
- Odorless
- Typically 53% ~ 55% (by weight) solution
- Inhibited with a corrosion inhibitor
- Octyl alcohol added as a surfactant

Evaporator and Absorber

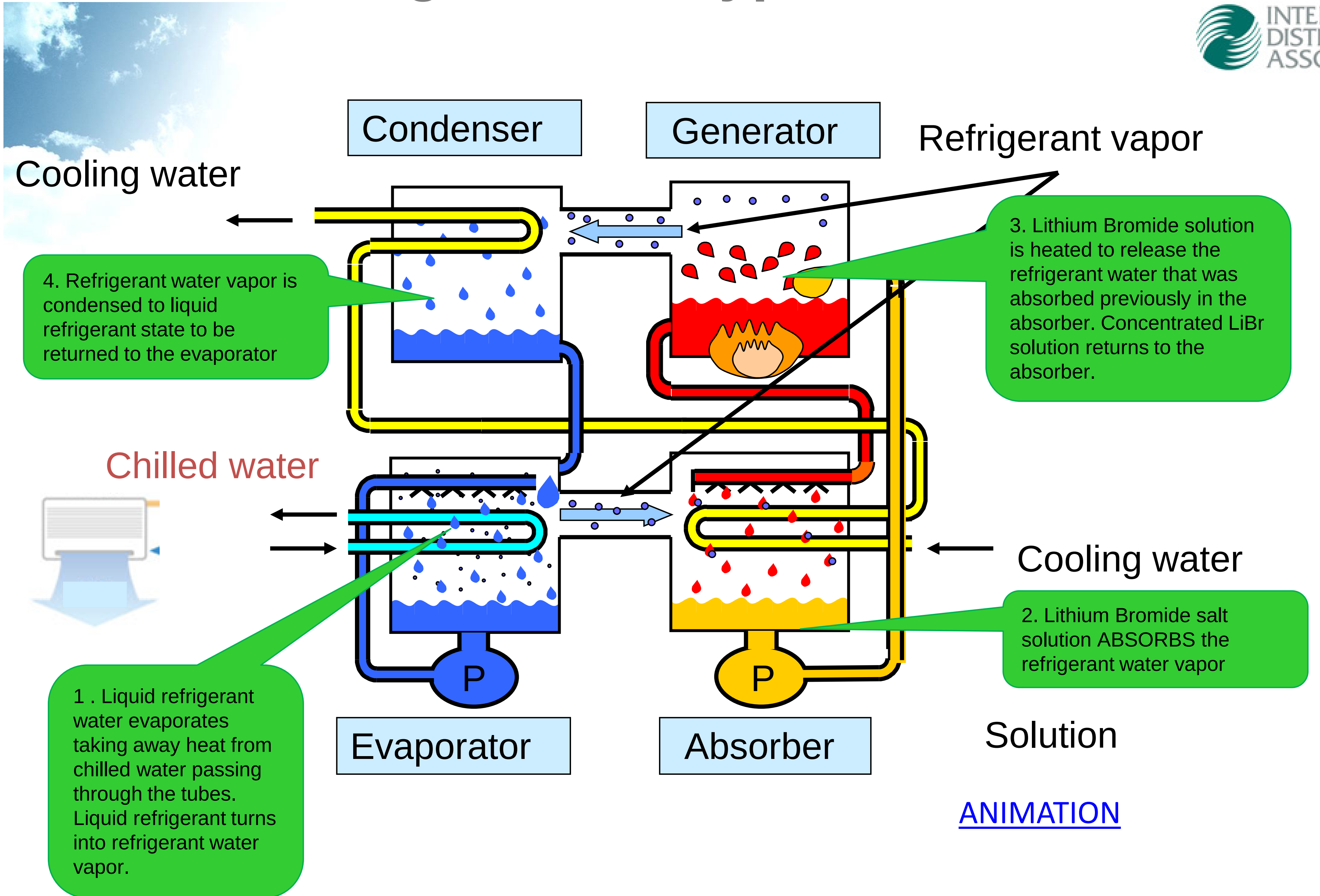
	5℃ 41°F	40℃ 104°F	60℃ 140°F
Water	0.87kPa 6.5 mmHg	7.3kPa 55 mmHg	20.4kPa 153 mmHg
40% LiBr Solution	0.47kPa 3.5 mmHg	4.0kPa 30 mmHg	10.7kPa 80 mmHg
60% LiBr Solution	0.07kPa 0.5 mmHg	0.69kPa 5.2 mmHg	2.3kPa 17 mmHg

The inside pressure goes up as the ambient temperature goes up.

In the LiBr solution case, the pressure is lower than that of water.

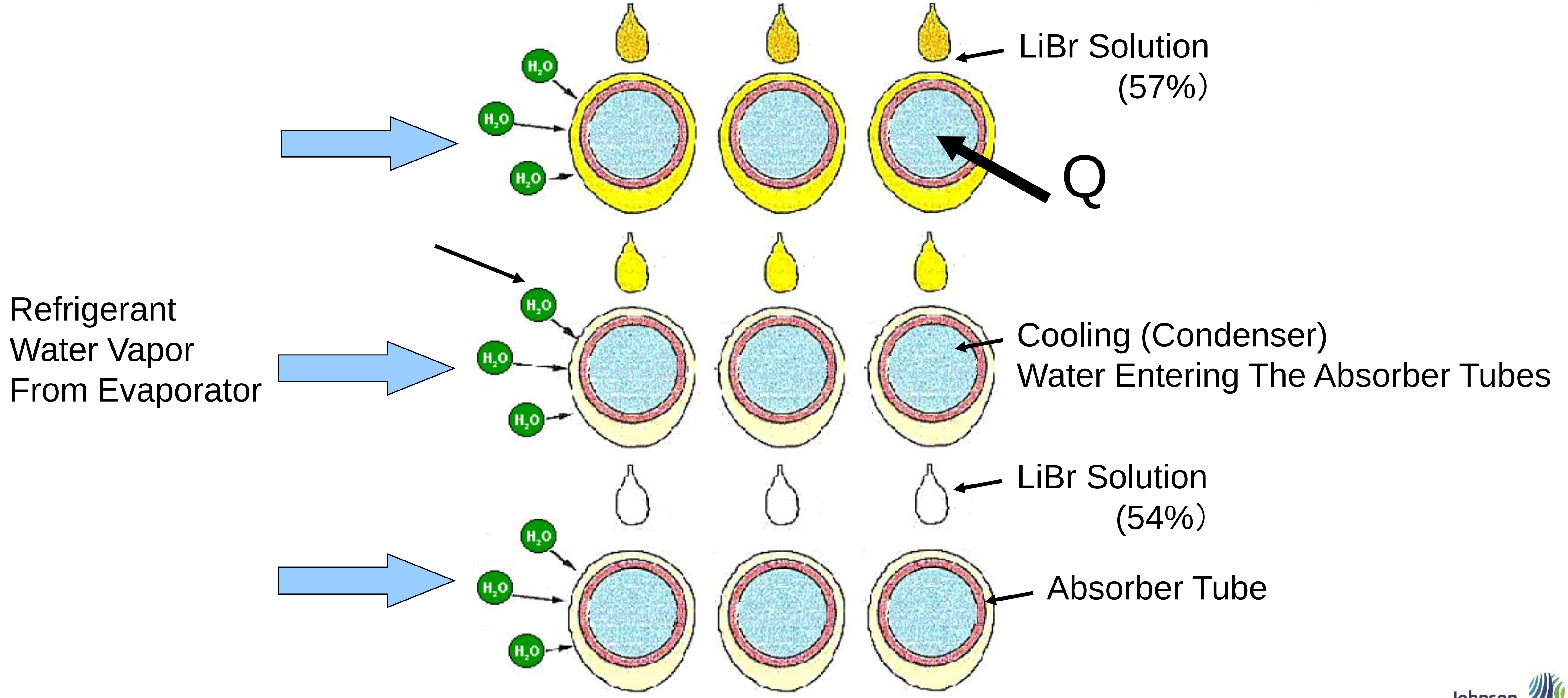
Notice the difference in vapor pressure between two boxes 0.87 kPa (6.5 mmHg) and 0.69 kPa(5.2 mmHg)

How it works – Single Effect Type

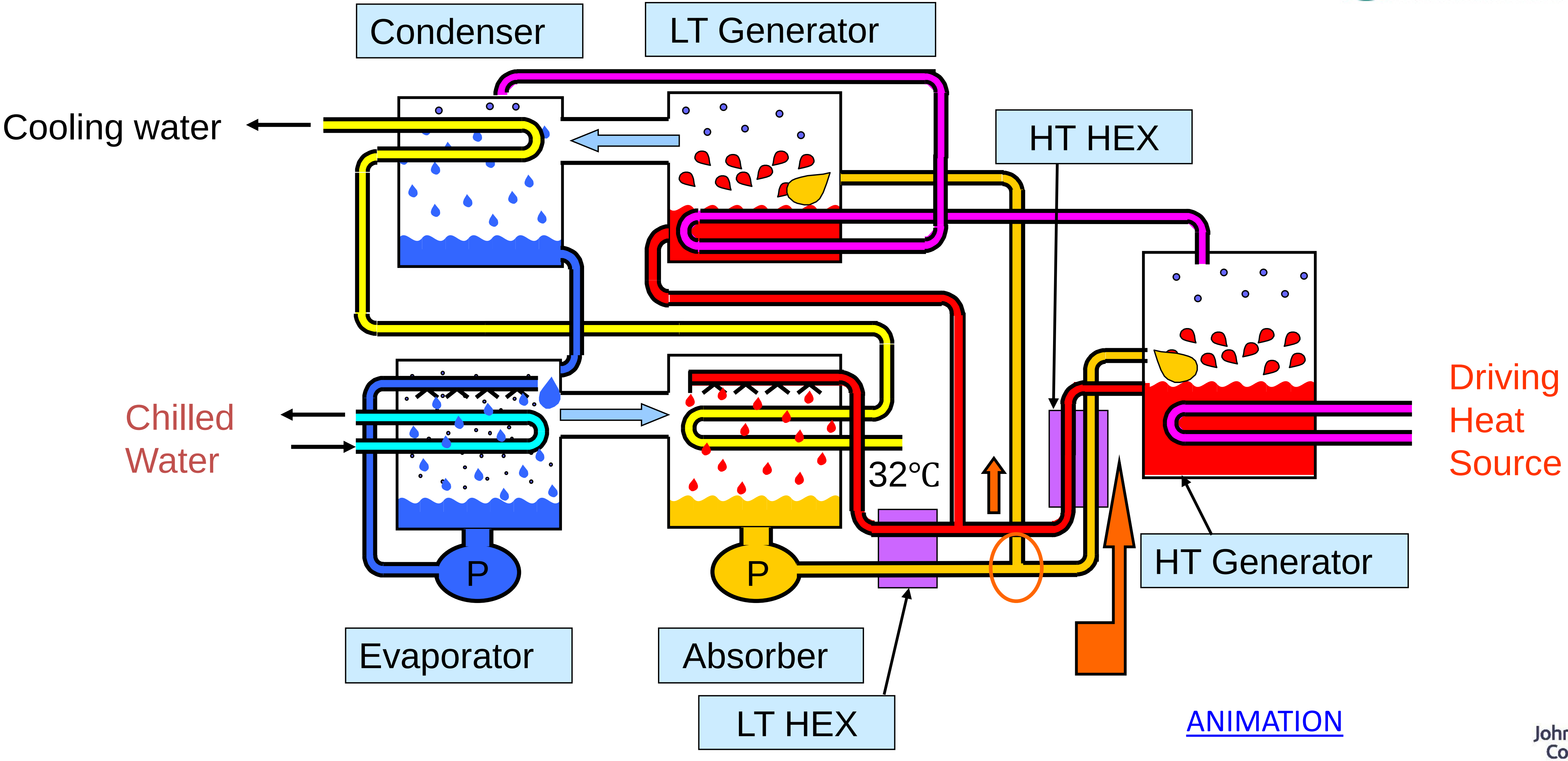


[ANIMATION]

The Absorption Process

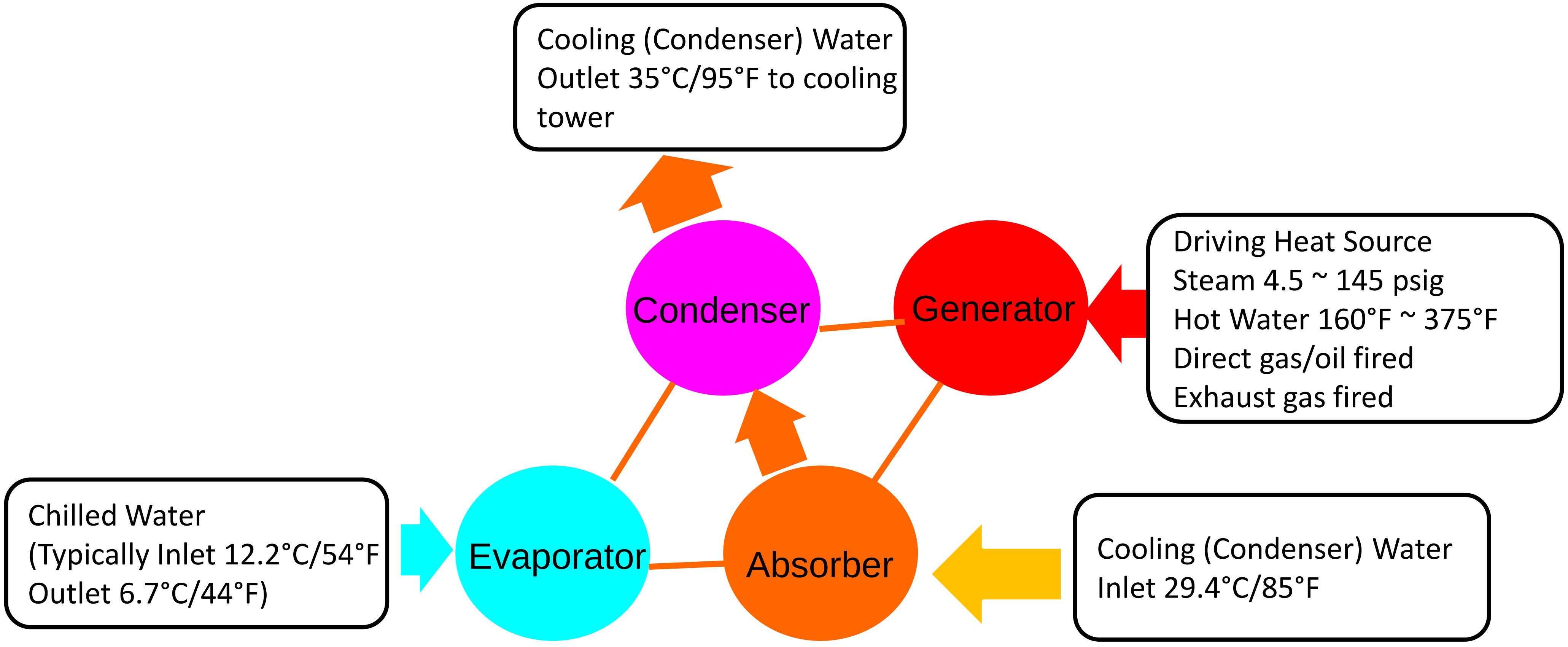


How it works – Double Effect Type



ANIMATION

Four Basic Components
Chiller Mode



Types

1. Single Effect or Double Effect
2. Direct Fired or Indirect Fired (hot water, steam, exhaust gas)
3. Water cooled or air cooled

Typical Operational Range

	Single Effect	Double Effect
Chilled Water Outlet °F	39.2°F ~ 68°F 4°C ~ 20°C	39.2 ~ 68°F 4°C ~ 20°C
Chilled Water Flow Rate	1.3 ~ 2.9 gpm/ton 0.29 ~ 0.65 m^3/hr/ton	1.3 ~ 2.9 gpm/ton 0.29 ~ 0.65 m^3/hr/ton
Cooling (Absorber-Condenser) Flow Rate	3.0 ~ 8.0 gpm/ton 0.68 ~ 1.81 m^3/hr/ton	2.2 ~ 6.0 gpm/ton 0.49 ~ 1.36 m^3/hr/ton
Cooling (Absorber-Condenser) Inlet °F	68 ~ 98.6°F (20°C ~ 37°C)	68 ~ 98.6°F (20°C ~ 37°C)
Steam Inlet Pressure	4.4 ~ 43.5 PSIG 0.3 ~ 3 Bar(g) 15,500 Btu/ton 14.8 lb/hr/ton 6.7 kg/hr/ton	29 ~ 145 PSIG 0.3 ~ 10 Bar(g) 8,700 Btu/ton 8.5 lb/hr/ton 3.9 kg/hr/ton
Hot Water °F (in case of hot water driven)	Up to 320°F (160°C)	Up to 370°F (180°C)
Direct Fired Input Energy		10,000 Btu/ton

COP
1000 Tons, Typical AHRI Conditions

Type of Chiller	Design COP	IPLV (COP)	Electrical Consumption kW/Ton
Electric Centrifugal	6.5	10.7	0.542
Single Effect Steam	0.78	0.81	0.01
Double Effect Steam	1.37	1.56	0.01
Direct Fired (HHV)	1.2	1.51	0.01

Heat Rejection To Cooling Tower

SINGLE EFFECT	DOUBLE EFFECT
29 MBH/ton	21 MBH/ton

1 MBH = 1,000 Btu

Impact of Cooling Water Inlet Temperature Typical 1000 Tons Double Effect Steam

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Cooling Water Inlet F	85	87	89	91	93
Cooling Water Outlet F	95.4	97.4	99.4	101.4	103.4
Cooling Capacity Tons	1000	1000	922	868	739
COP	1.37	1.35	1.35	1.35	1.35
Steam lb/hr	8,514	8,668	7,992	7,524	6,406

Chilled Water 54/44 F, 2.4 gpm/ton
Cooling water 4.0 gpm/ton
Steam 115 PSIG
Chilled/Cooling Water fouling factors 0.0001/0.00025

Values may vary with manufacturer

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Impact of Cooling Water Flow Rate 1000 Tons

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Cooling (Condenser) Water Flow Rate	Single Effect Absorption COP 0.77	Double Effect Steam Absorption COP 1.37	Electric Centrifugal COP 6.5
3.6 gpm/ton	85/100.3 F		
3.0 gpm/ton	85/103.4 F	85/98.8 F	85/94.3 F
4.0 gpm/ton		85/95.4 F	

Chilled Water 54/44 F, 2.4 gpm/ton
Chilled/Cooling Water fouling factors 0.0001/0.00025

Values may vary with manufacturer

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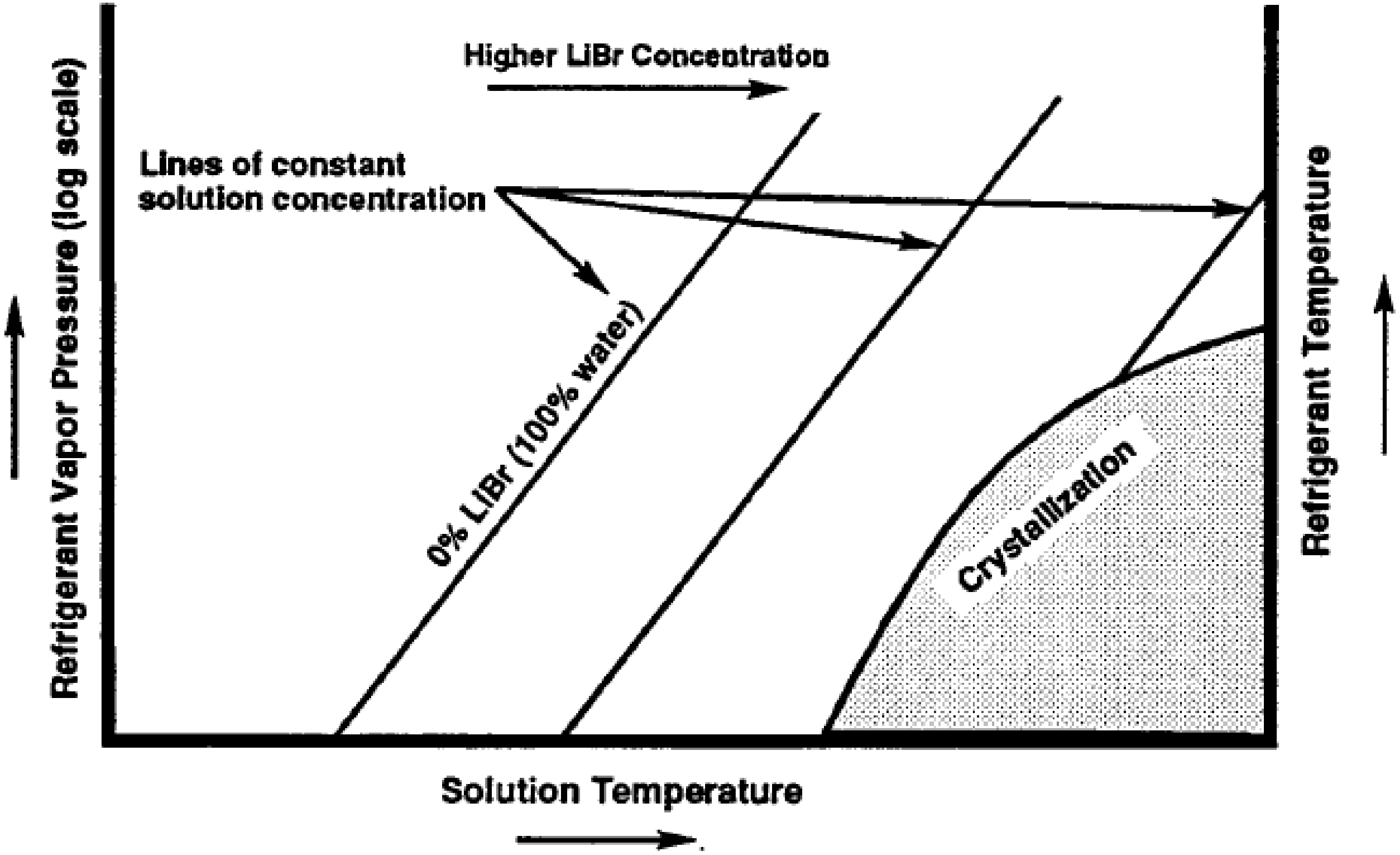
Impact of different tube materials

Evaporator	Absorber	Condenser	Cooling Capacity %
Copper	Copper	Copper	100
Copper	CuNi 90:10	CuNi 90:10	93
CuNi 90:10	CuNi 90:10	CuNi 90:10	87
Copper	Titanium	Titanium	89
SS316	SS316	SS316	82

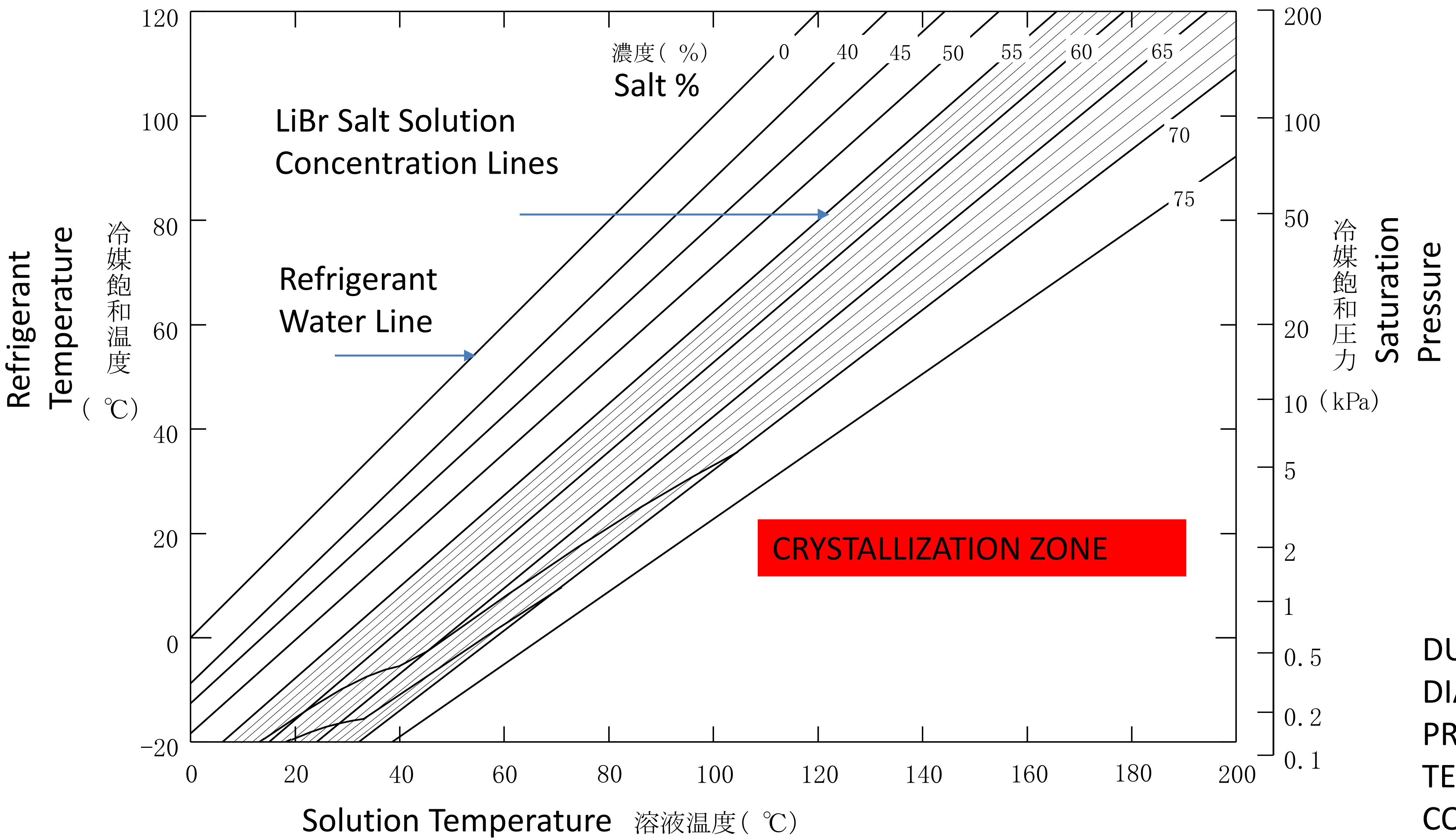
Values may vary with manufacturer

Pressure Temperature Concentration (PTX) Duhring Diagram



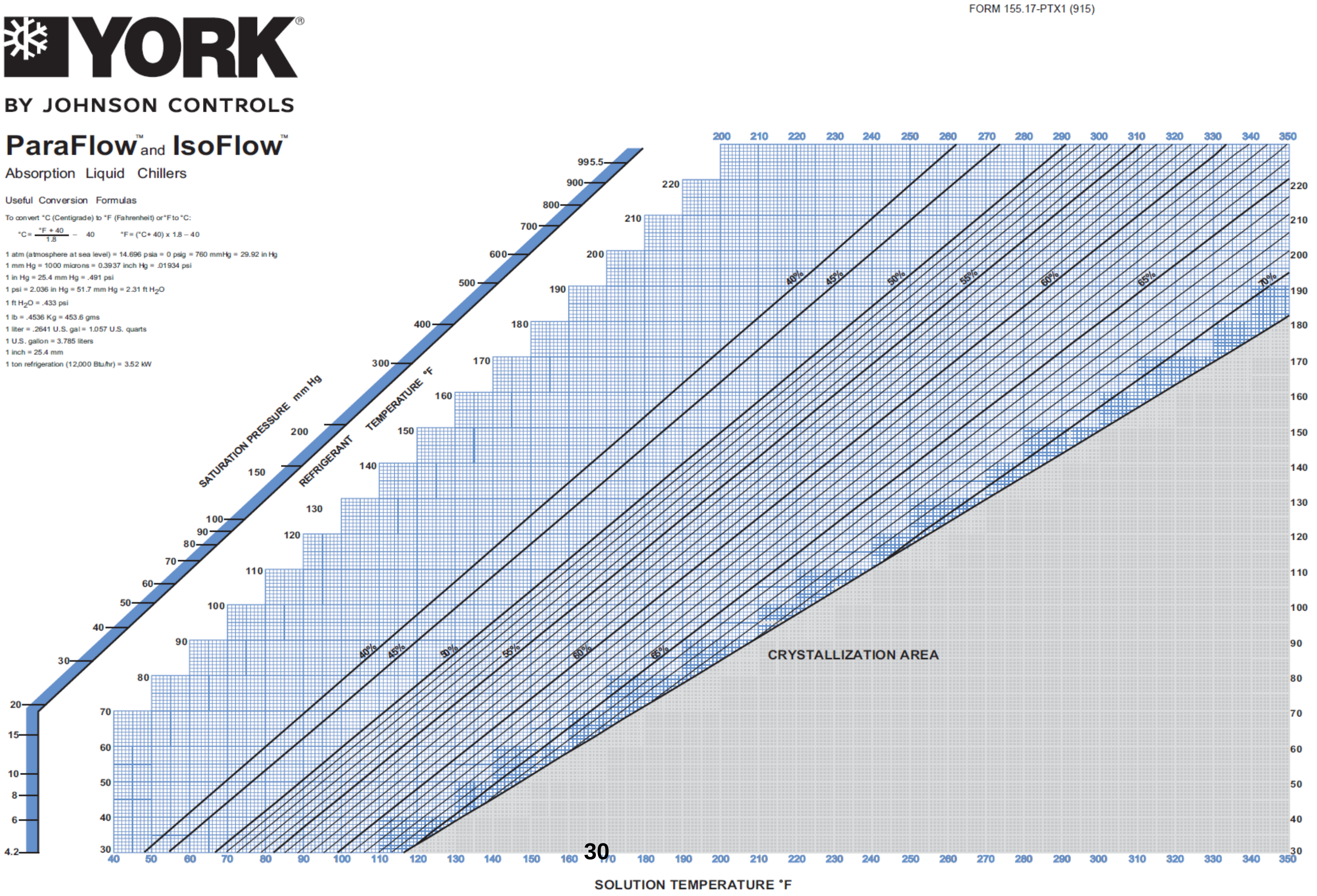
Source: ASHRAE Application Guide

PTX Diagram



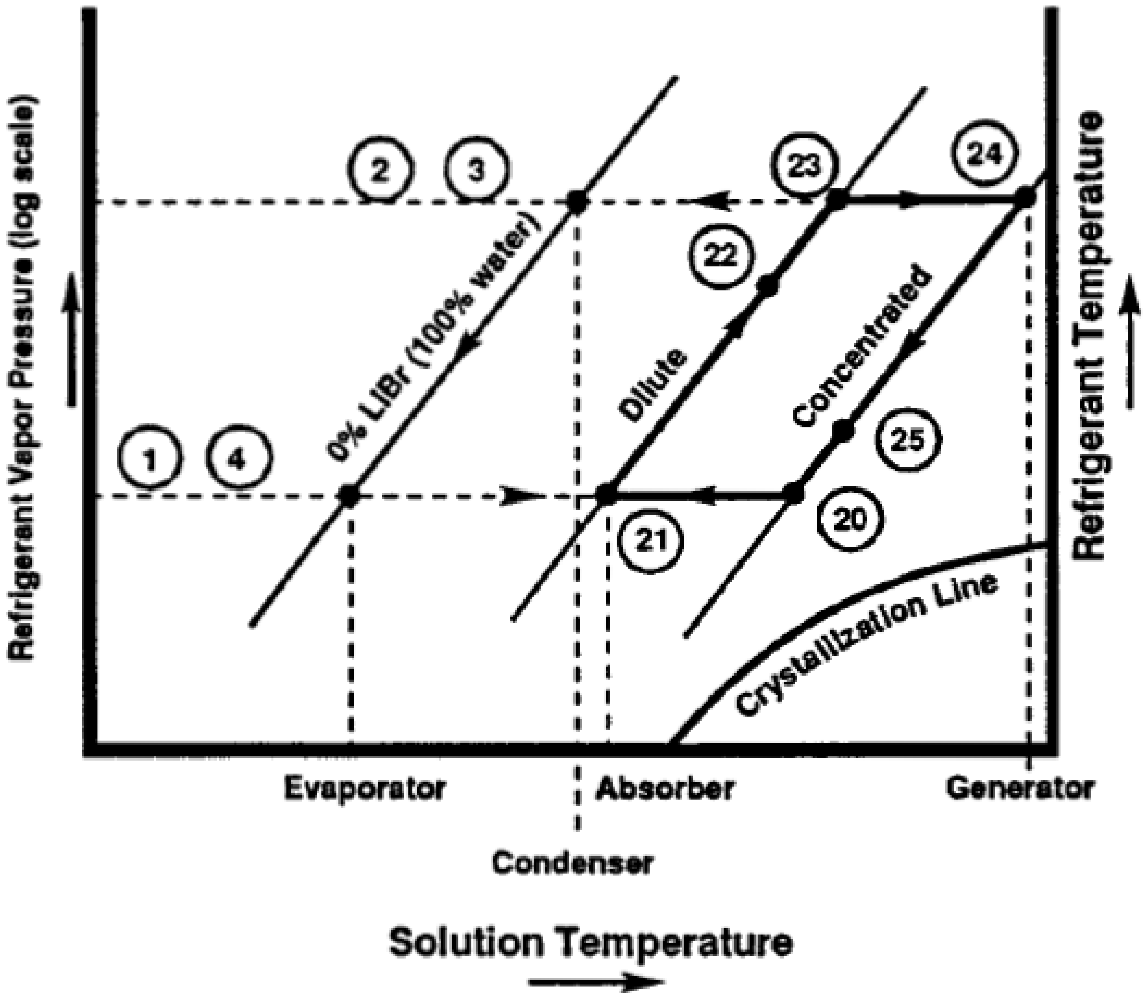
DUHRING DIAGRAM – PRESSURE TEMPERATURE CONCENTRATION

PTX Diagram



FORM 155.17-PTX1 (915)
YORK
BY JOHNSON CONTROLS
ParaFlow™ and IsoFlow™
Absorption Liquid Chillers
Useful Conversion Formulas
To convert °C (Centigrade) to °F (Fahrenheit) or °F to °C:
$°C = \frac{°F + 40}{1.8} - 40$ $°F = (°C + 40) \times 1.8 - 40$
1 atm (atmosphere at sea level) = 14.696 psia = 0 psig = 760 mmHg = 29.92 in Hg
1 mm Hg = 1000 microns = 0.3937 inch Hg = .01934 psi
1 in Hg = 25.4 mm Hg = .491 psi
1 psi = 2.036 in Hg = 51.7 mm Hg = 2.31 ft H_2O
1 ft H_2O = .433 psi
1 lb = .4536 Kg = 453.6 gms
1 liter = .2641 U.S. gal = 1.057 U.S. quarts
1 U.S. gallon = 3.785 liters
1 inch = 25.4 mm
1 ton refrigeration (12,000 Btu/hr) = 3.52 kW
SATURATION PRESSURE mm Hg
REFRIGERANT TEMPERATURE °F
995.5
900
800
700
600
500
400
300
200
150
100
90
80
70
60
50
40
30
20
15
10
8
6
4.2
40% 45% 50% 55% 60% 65% 70%
CRYSTALLIZATION AREA
SOLUTION TEMPERATURE °F
40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350

SINGLE EFFECT @ FULL LOAD



Source: ASHRAE Application Guide

SINGLE EFFECT @ PART LOAD

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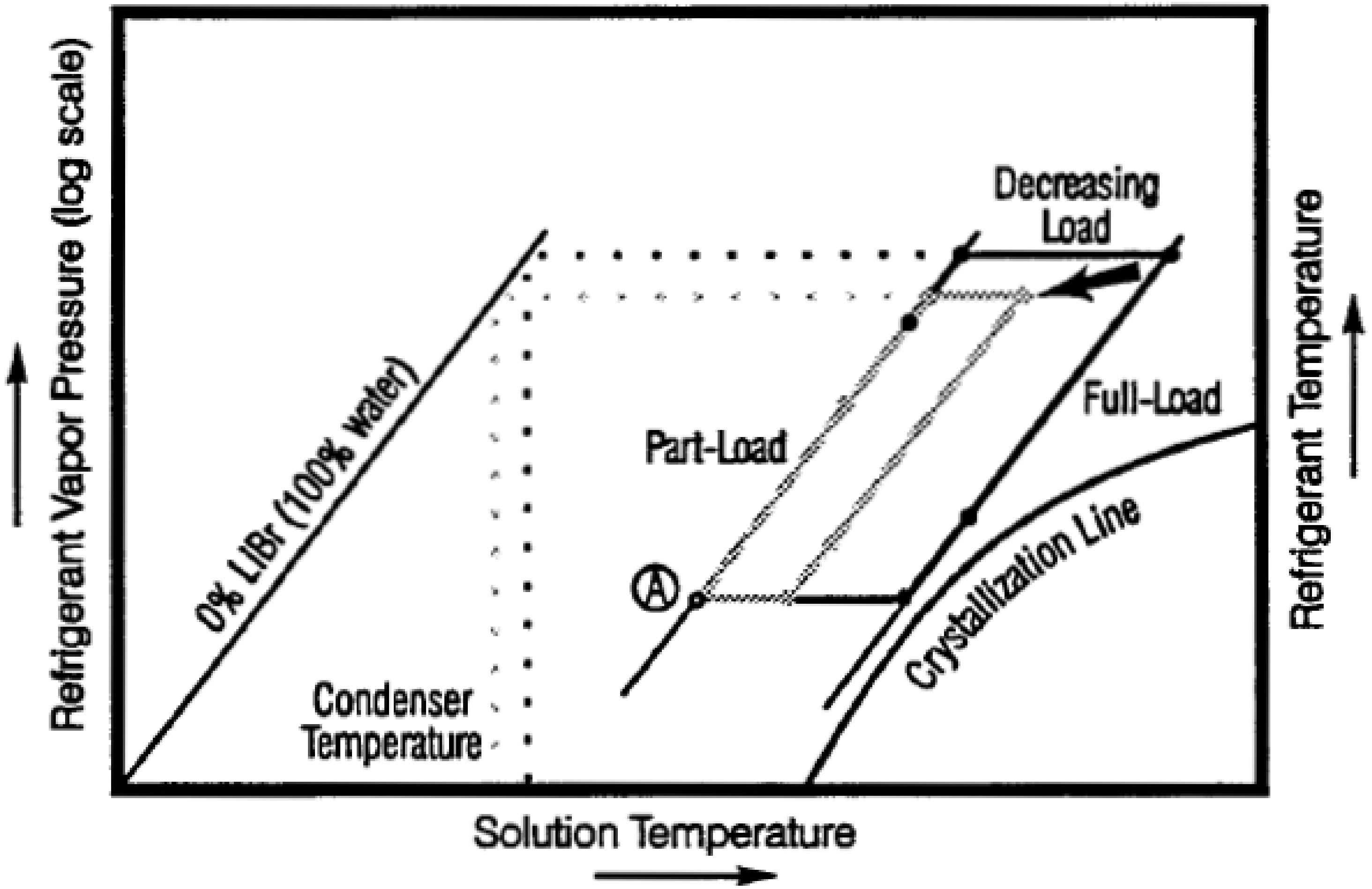

Source: ASHRAE Application Guide

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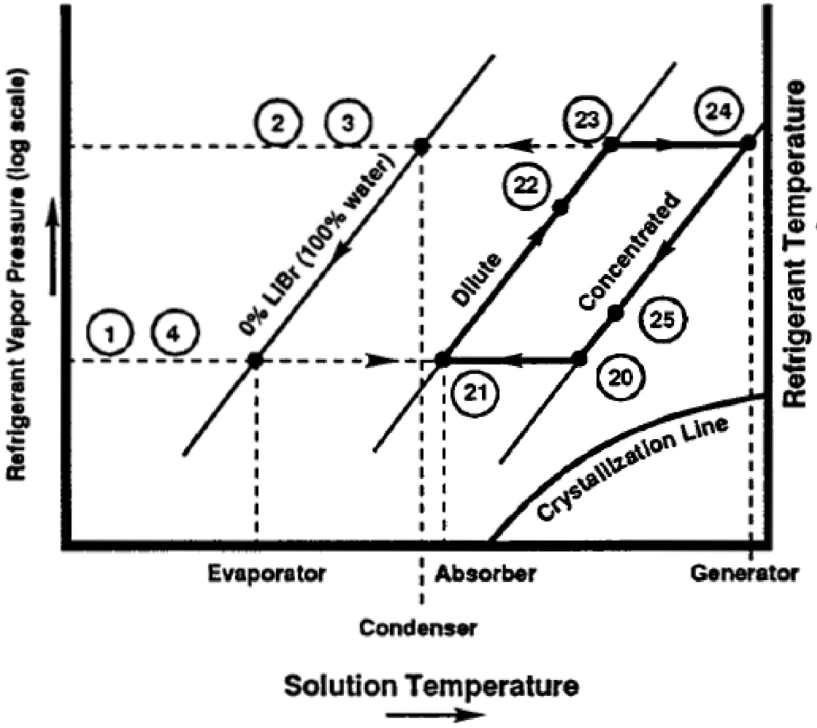
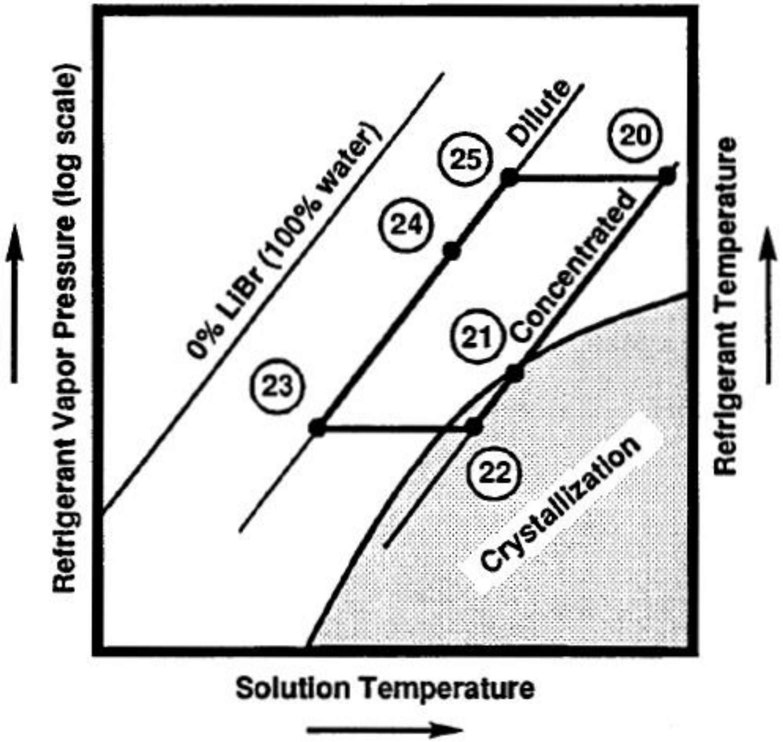
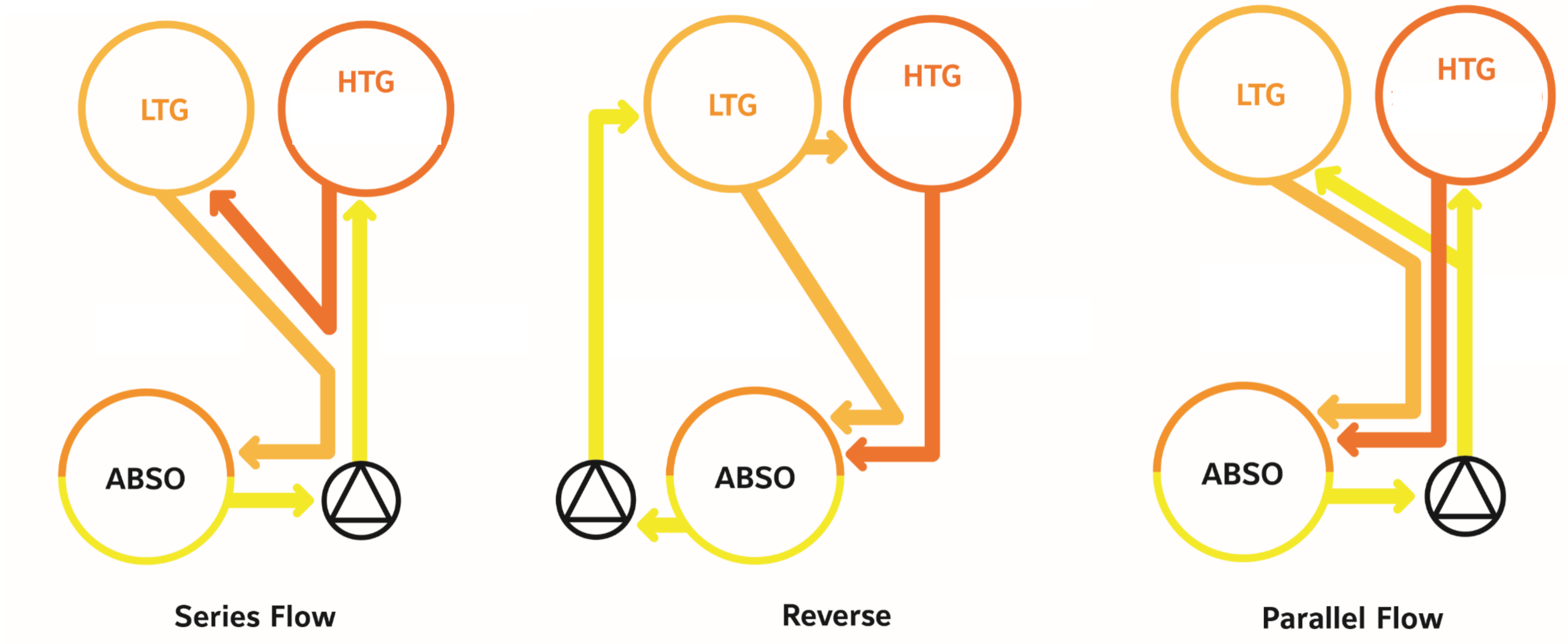
CRYSTALLIZATION



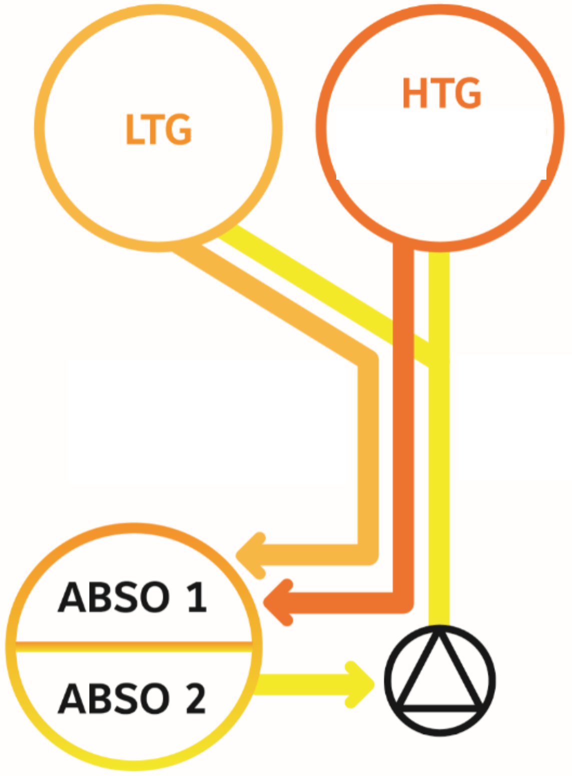


Source: ASHRAE Application Guide

Various Cycles
Series Reverse Parallel



Parallel Flow Cycle
With 2-Step Evaporator Absorber



2-Step and Parallel

Select the cycle that offers:

1. The Lowest Pressure (P)
2. The Lowest Temperature (T)
3. The Lowest Concentration (C)

Conclusions

1. Water as the refrigerant – zero ODP and GWP
2. Very few moving parts – quiet and vibration free
3. Select the cycle with the lowest P, T and Salt Concentration %
4. Variety of applications
5. Driven by waste heat, low cost natural gas, renewable energy
6. Negligible electric consumption (reduced electric utility costs)
7. Fast payback
8. Saves energy, water and cuts emissions (Truly Sustainable)

Acknowledgements

- Johnson Controls – Hitachi, Japan

Thank you for attending

be-chillersolutionsmarketing@jci.com

http://york.com/absorption-chillers

Questions?