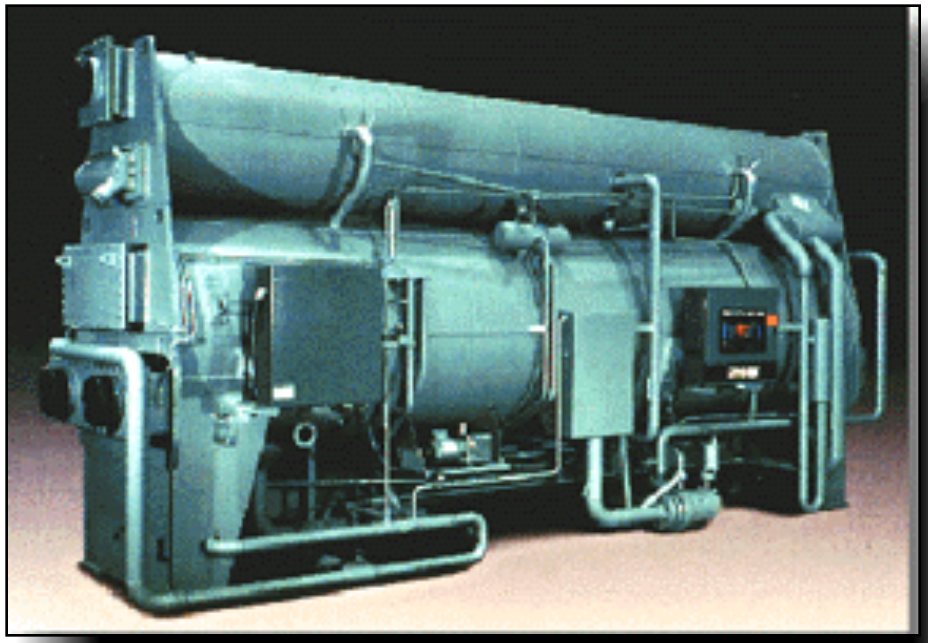
Basic Absorption Training Course



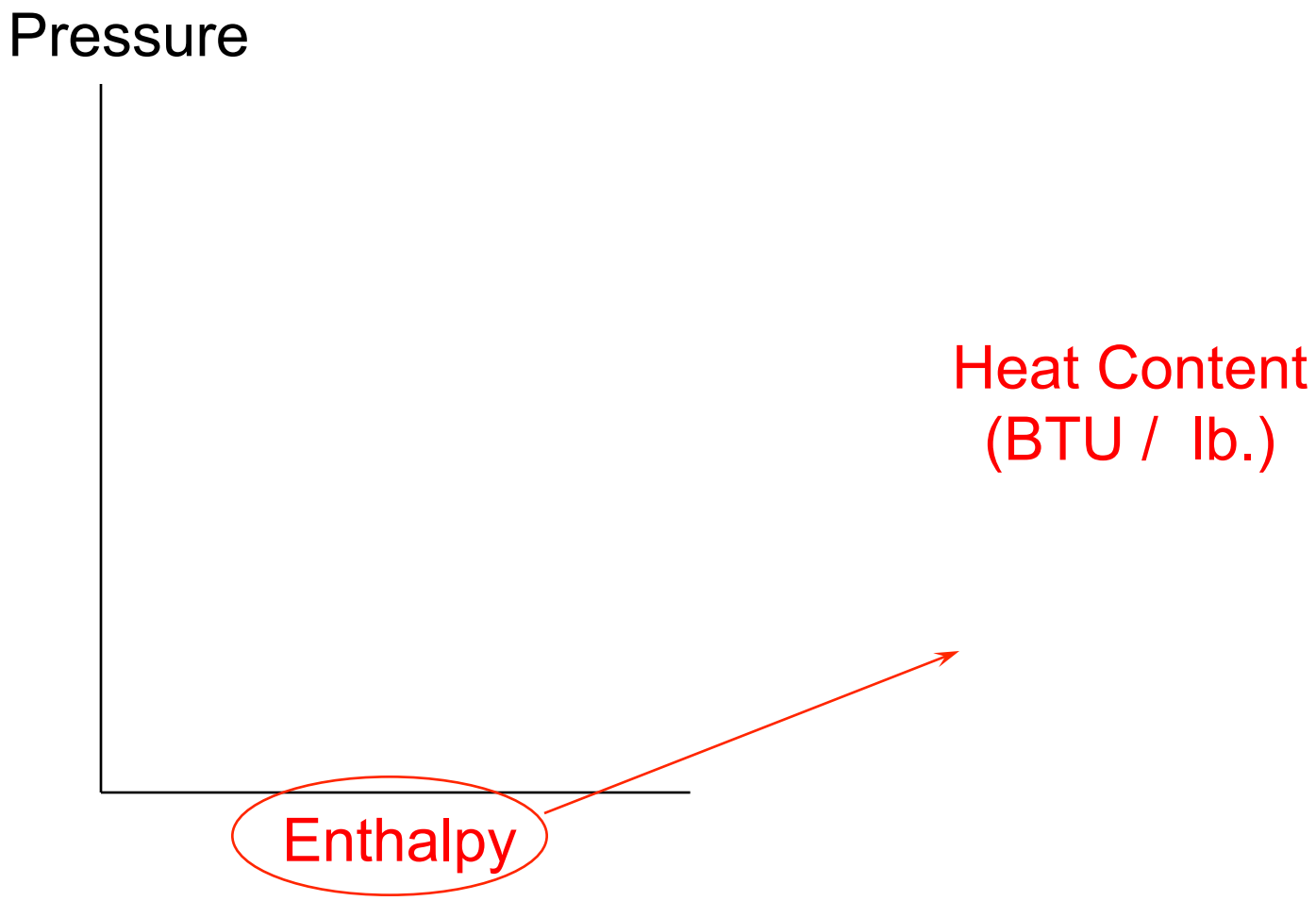
Robert Smith, Yo

Service Training Department

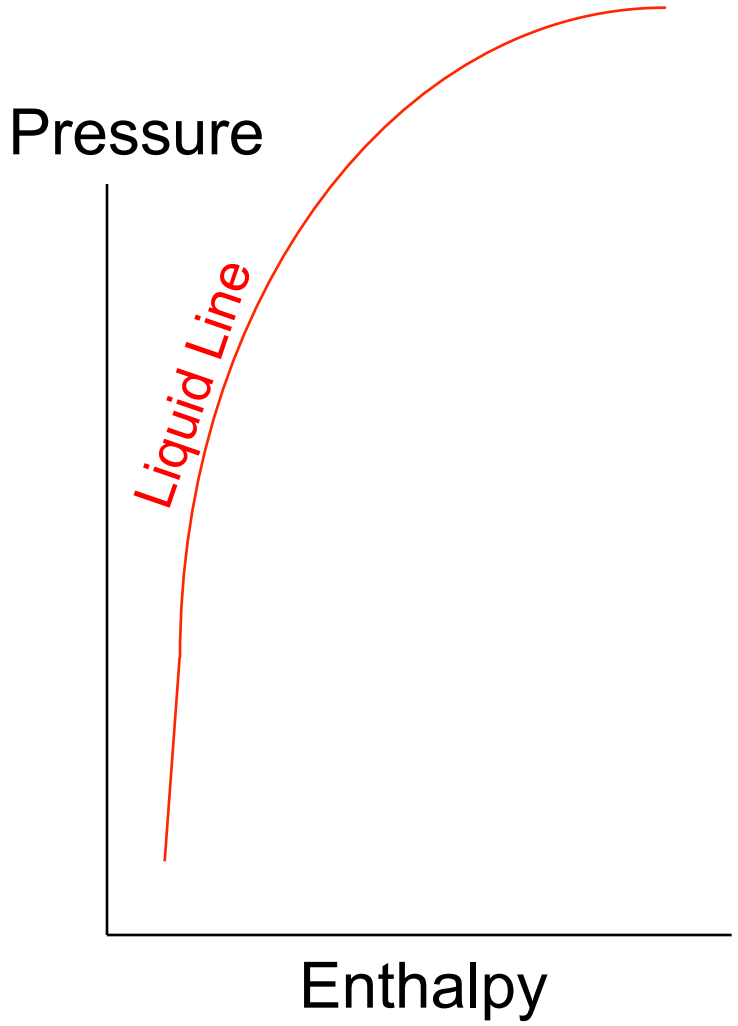
Absorption Cooling Basics

Pressure - Enthalpy Chart

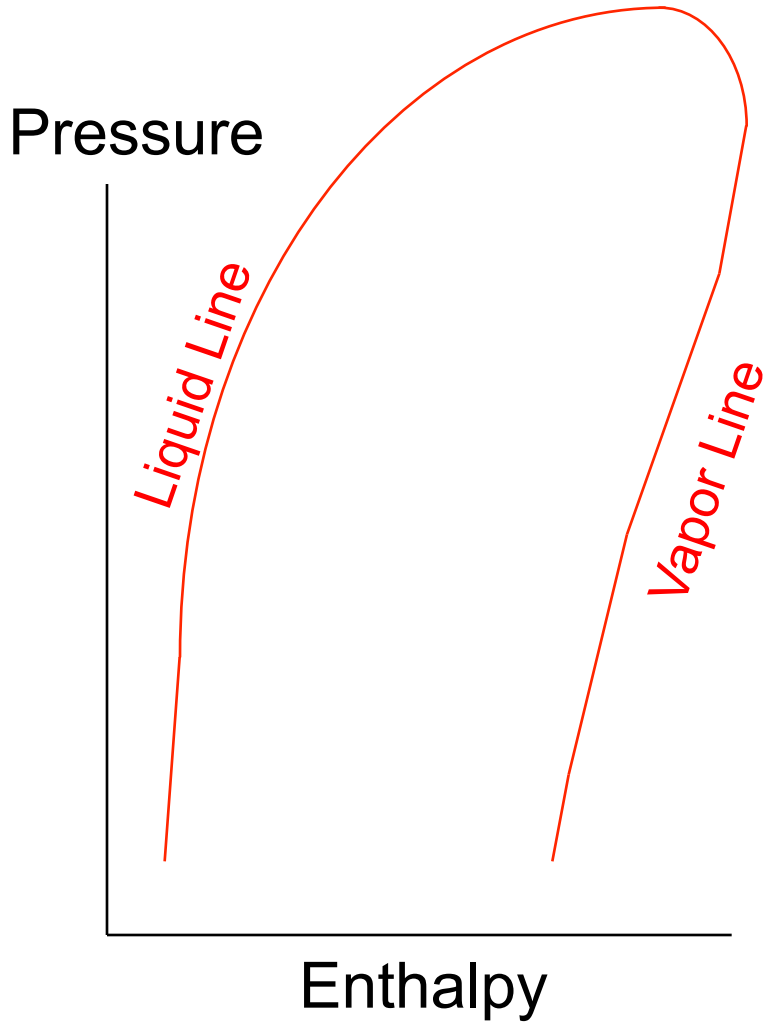
Pressure - Enthalpy Chart



Pressure - Enthalpy Chart



Pressure - Enthalpy Chart



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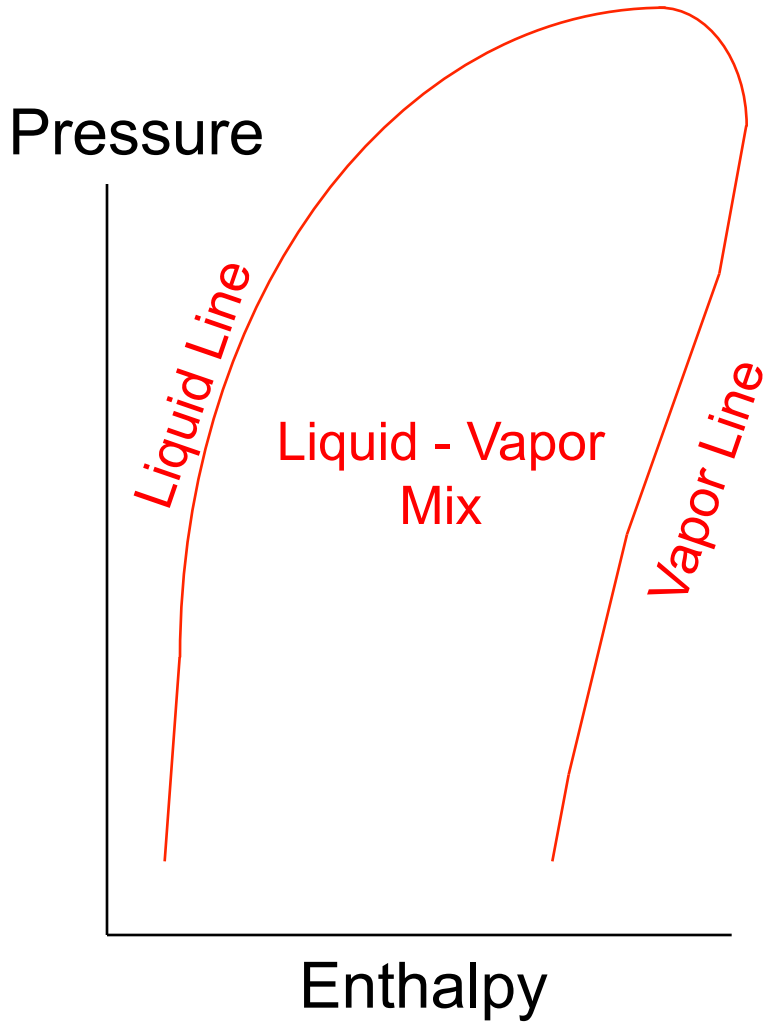

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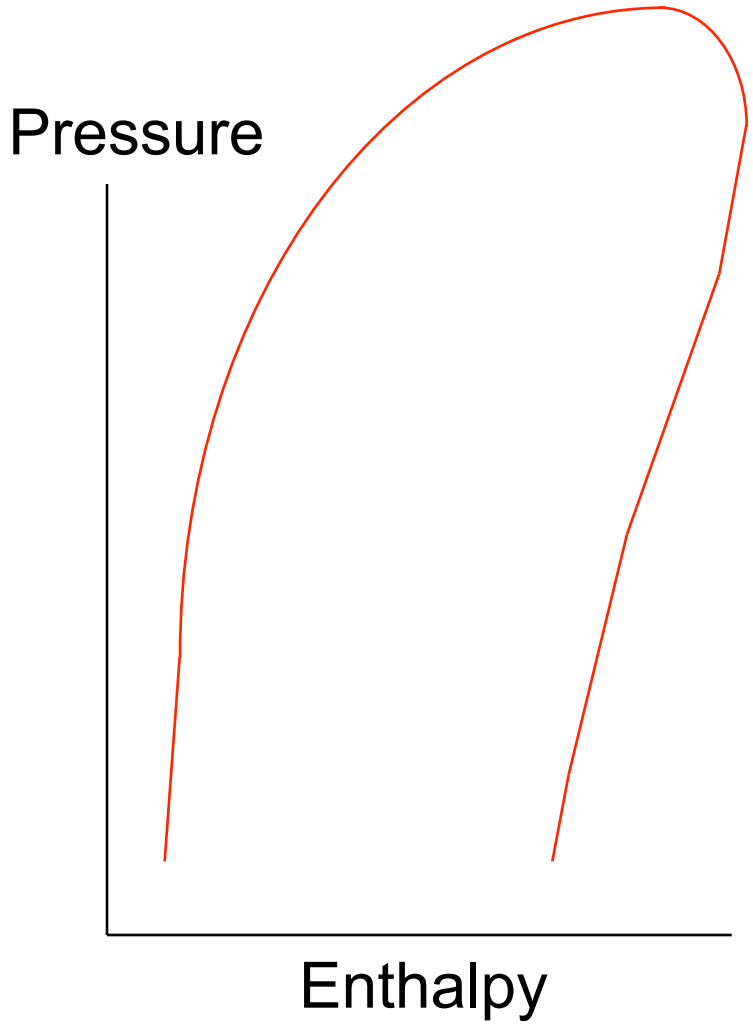
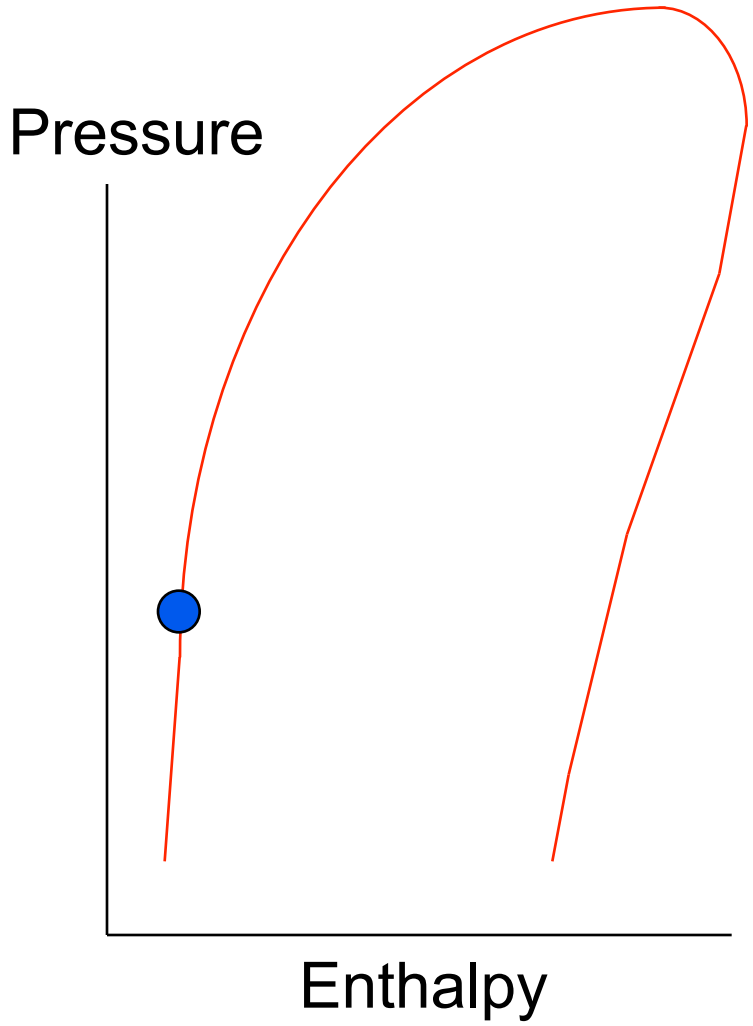


Pressure - Enthalpy Chart



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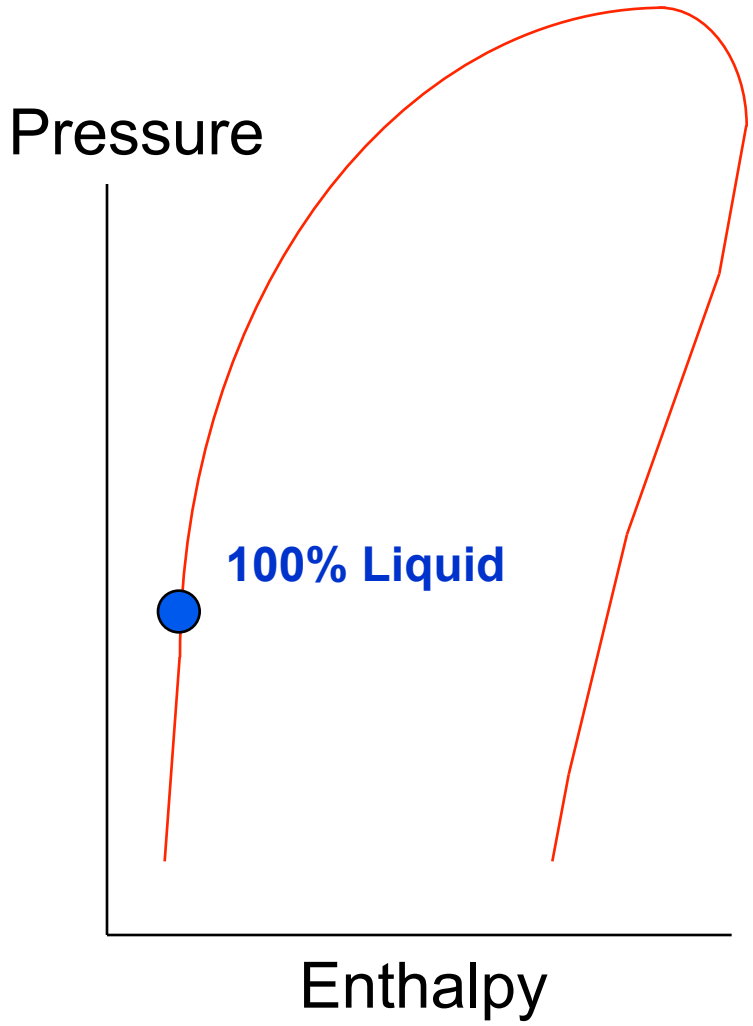

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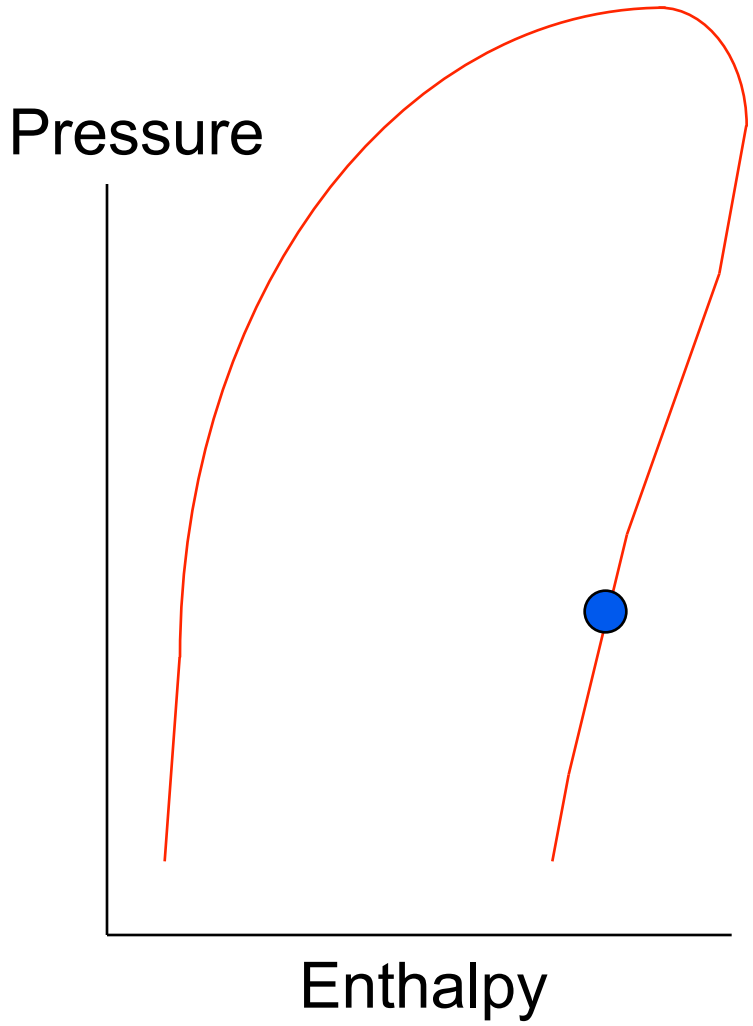

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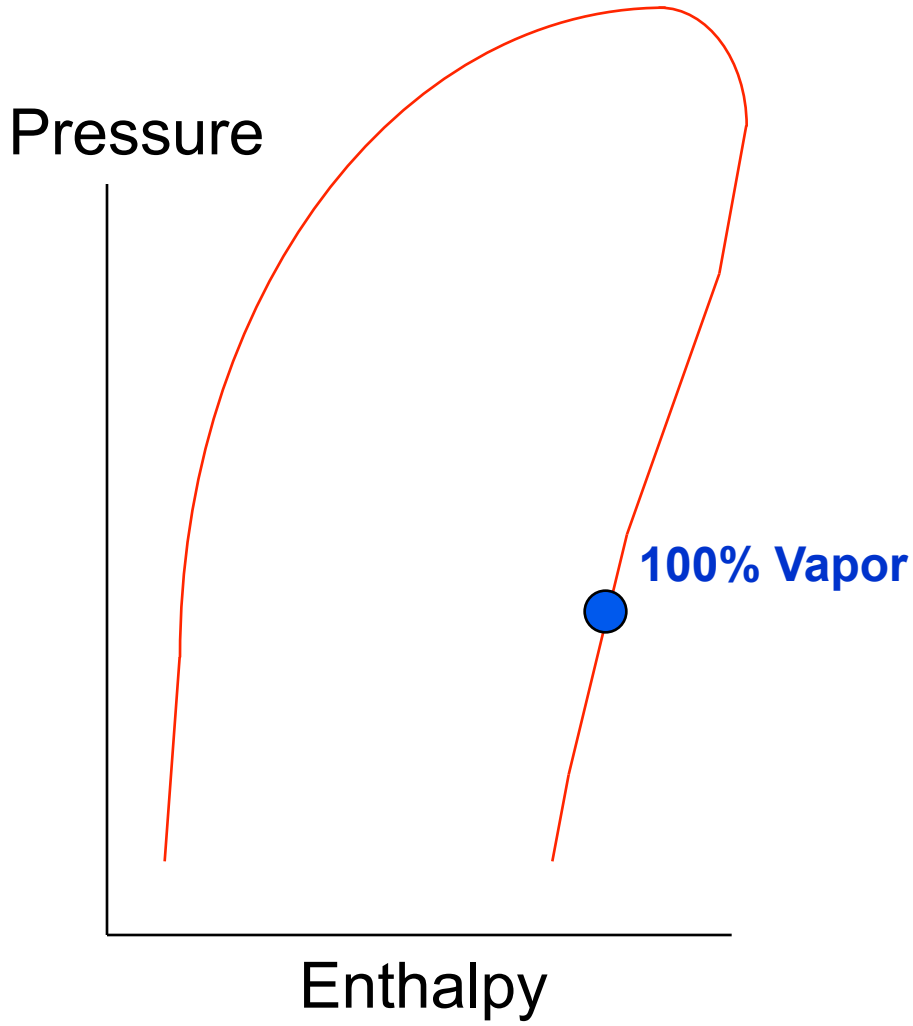

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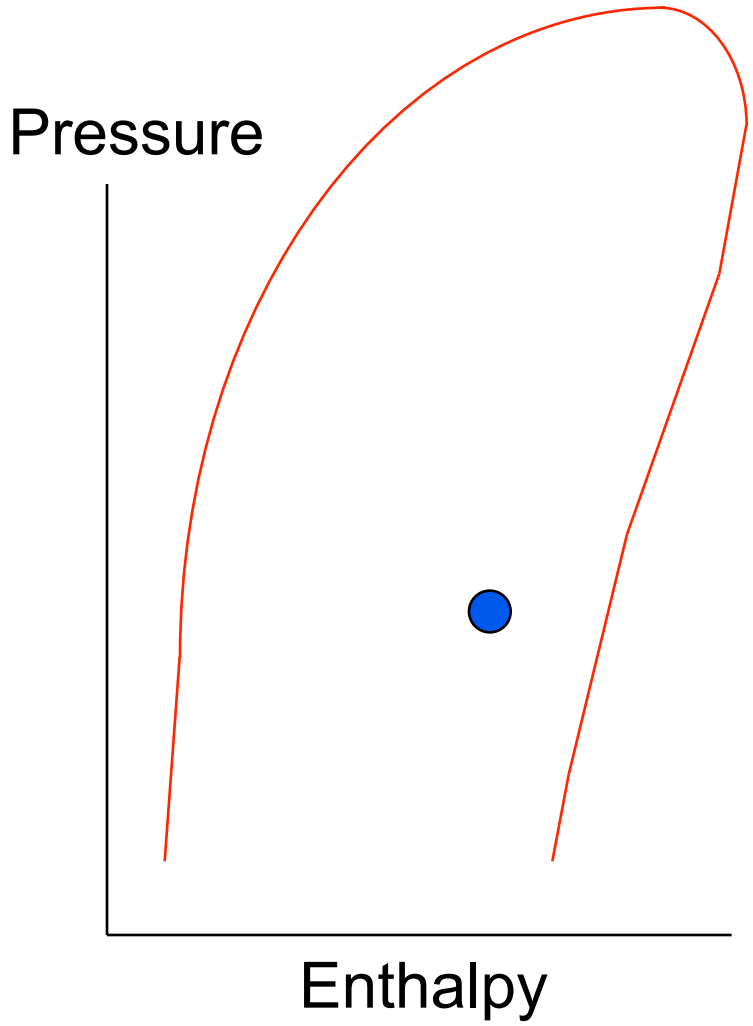
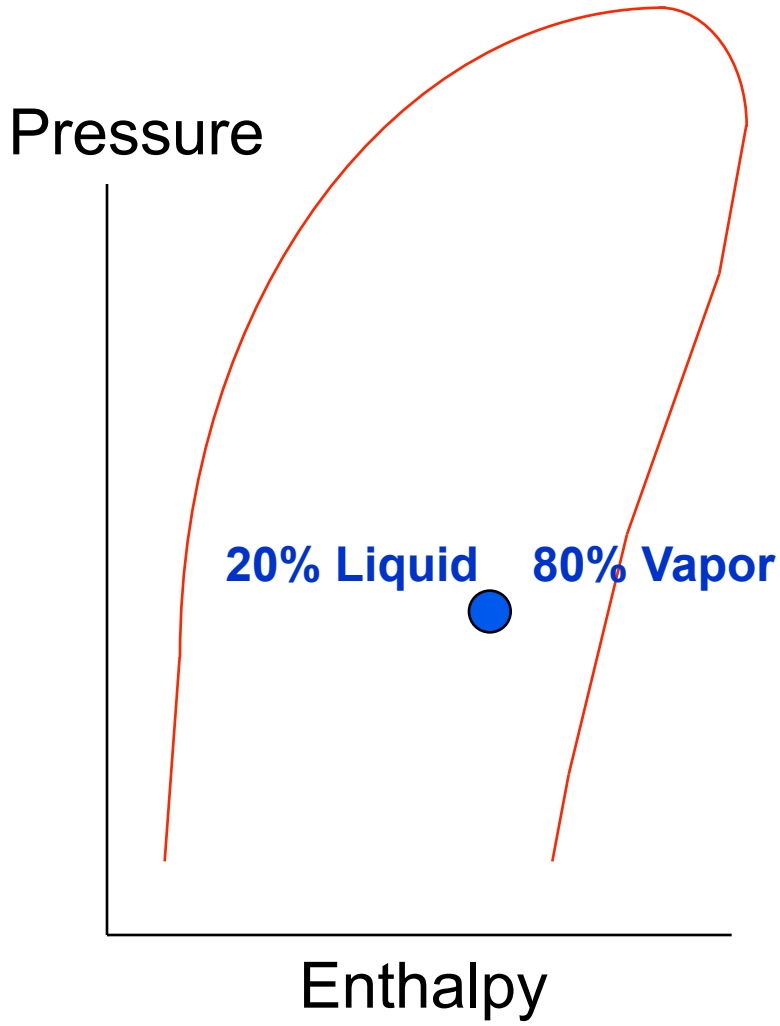
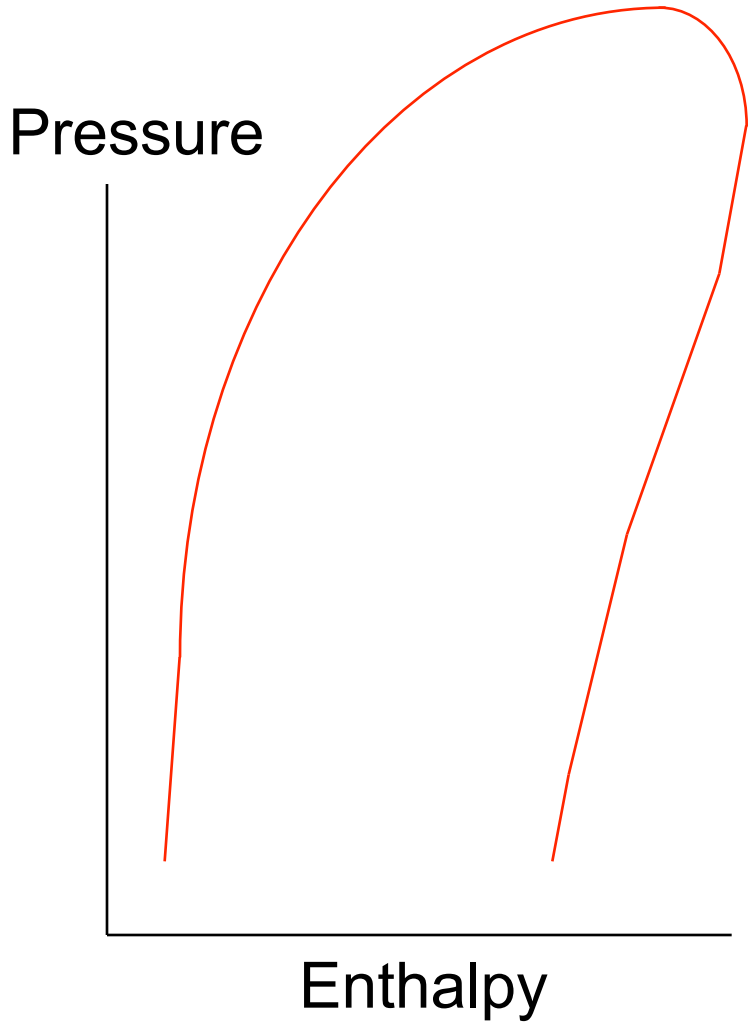


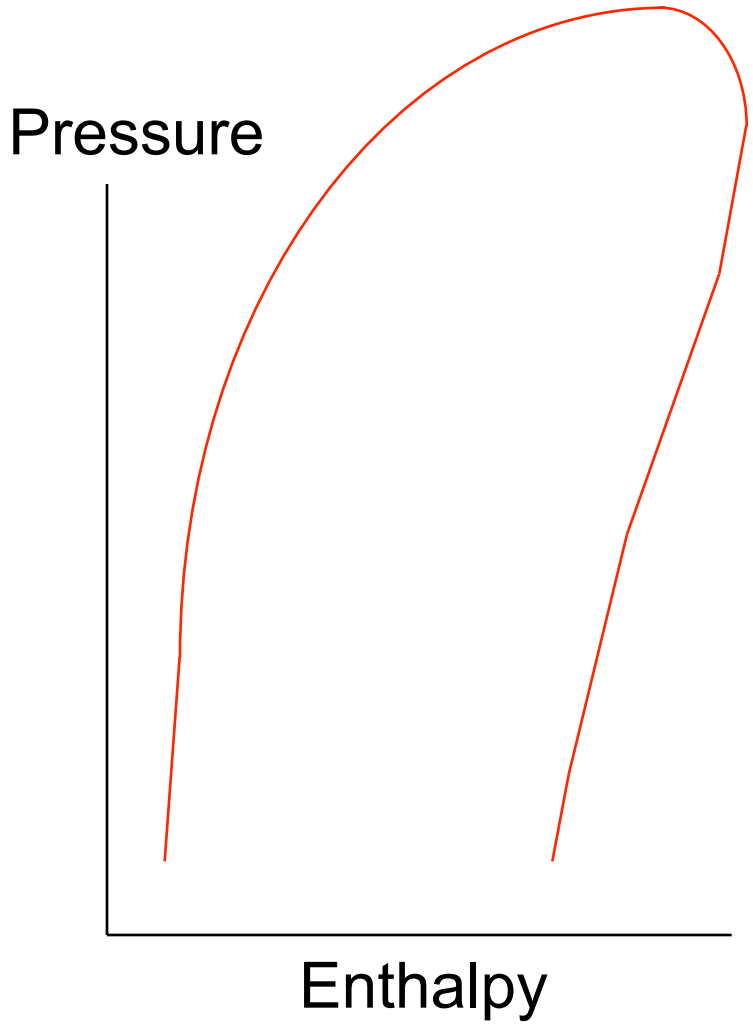
Pressure - Enthalpy Chart



Pressure - Enthalpy Chart

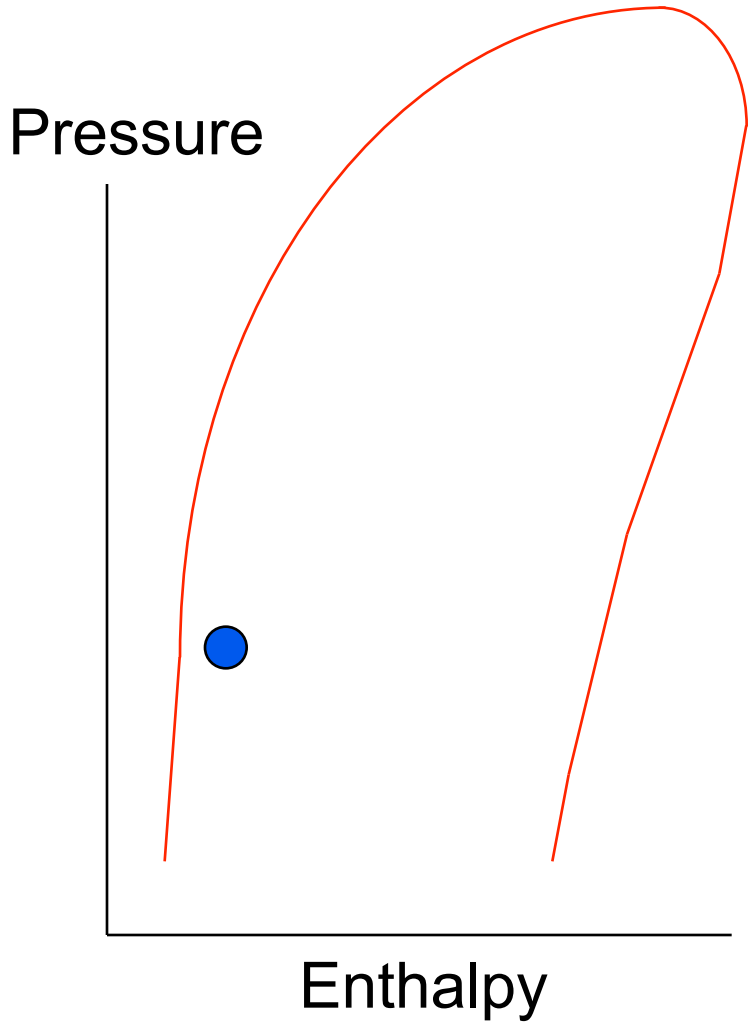


Pressure - Enthalpy Chart



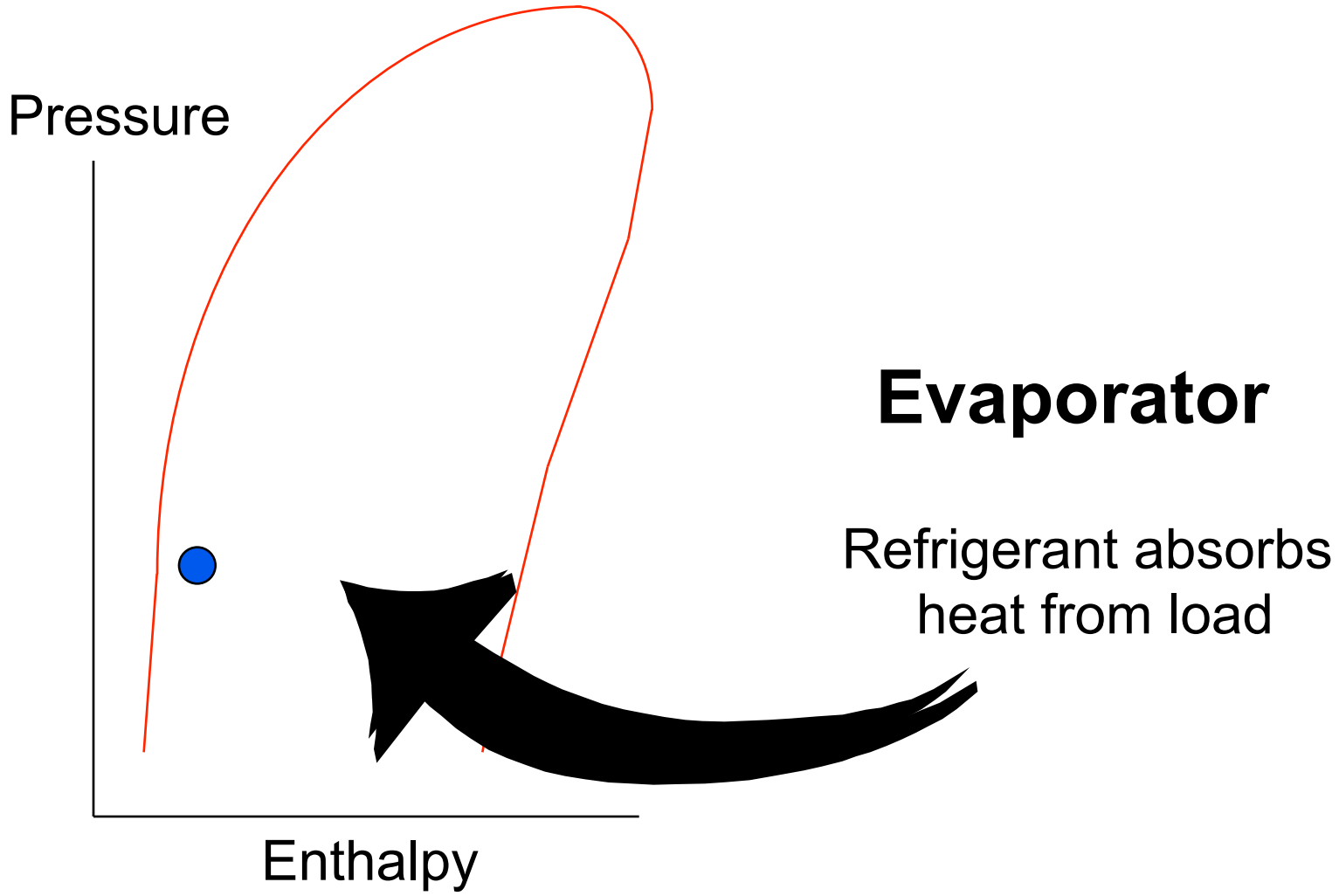
Evaporator

Pressure - Enthalpy Chart

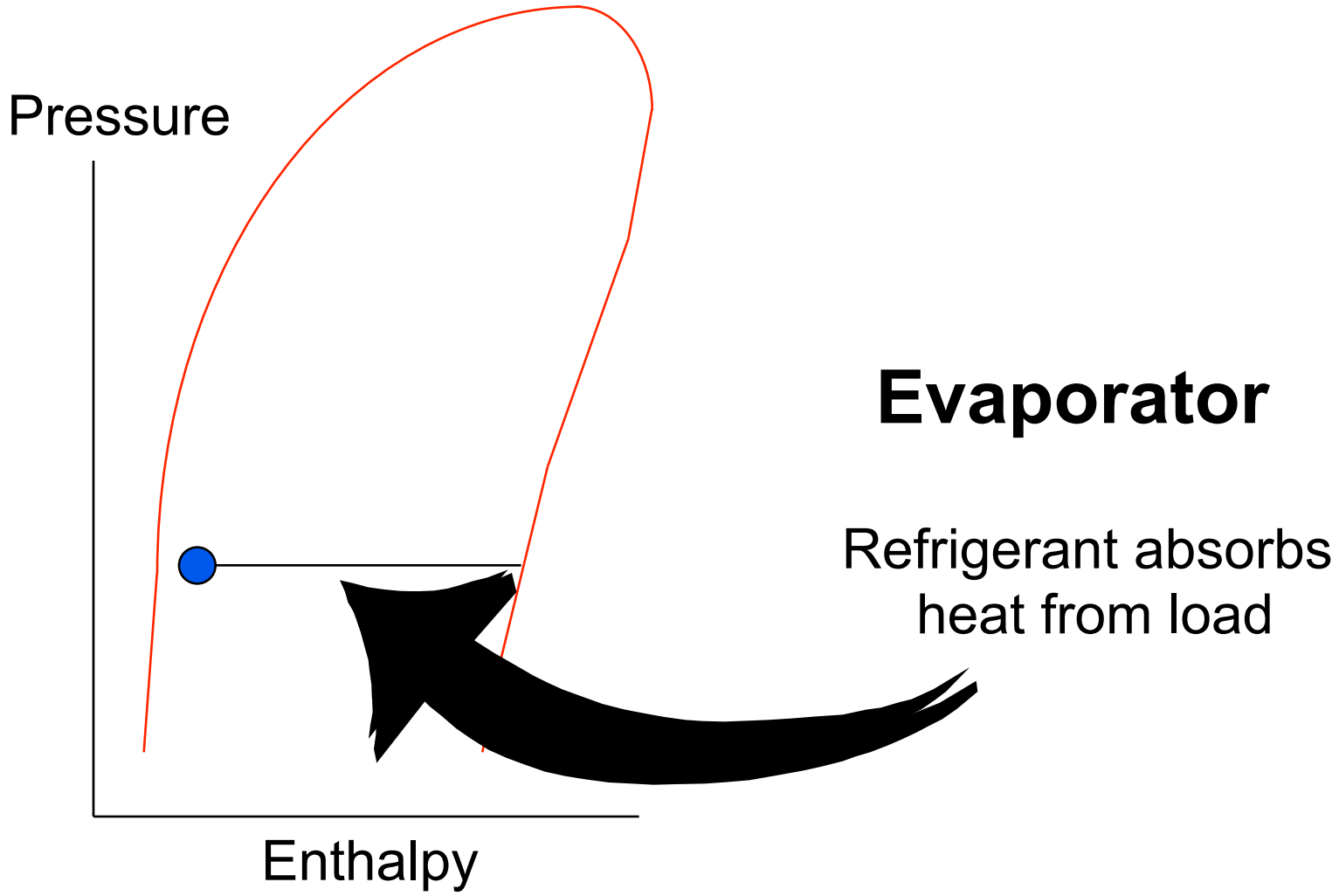


Evaporator

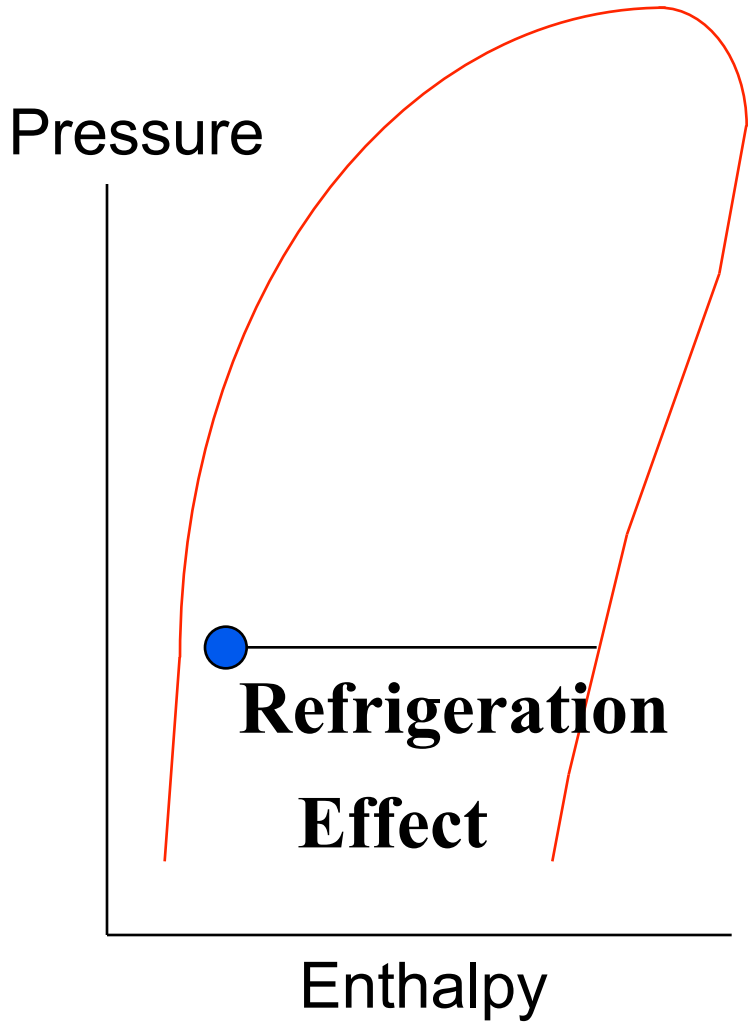
Pressure - Enthalpy Chart



Pressure - Enthalpy Chart

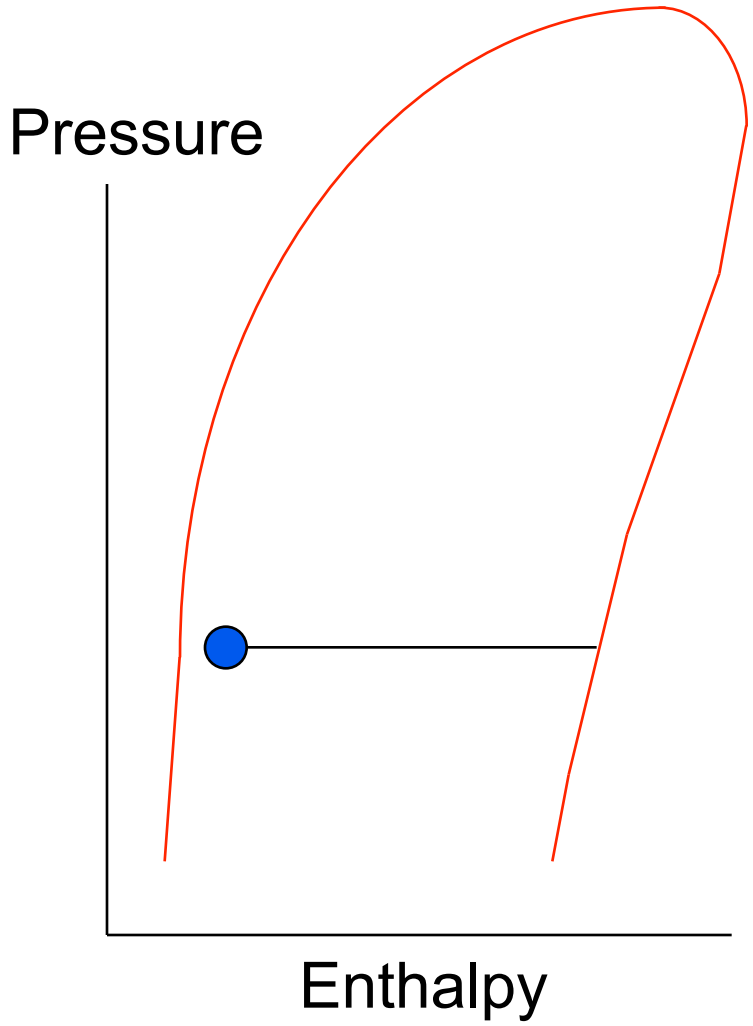


Pressure - Enthalpy Chart



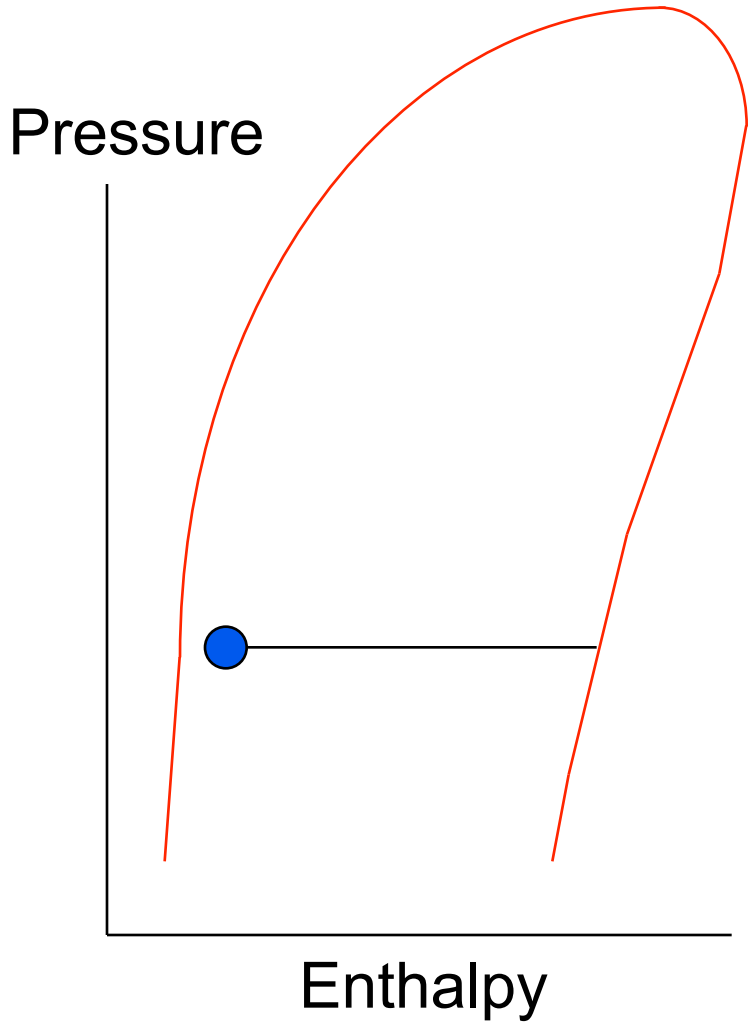
Evaporator

Pressure - Enthalpy Chart



Evaporator

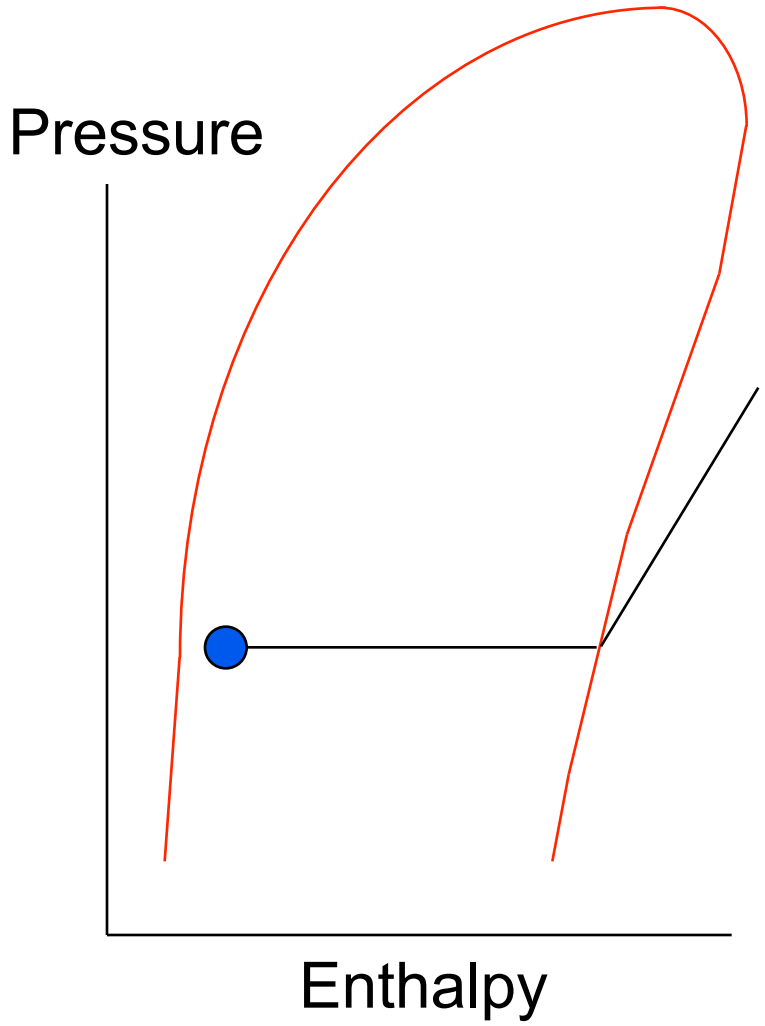
Pressure - Enthalpy Chart



Compressor

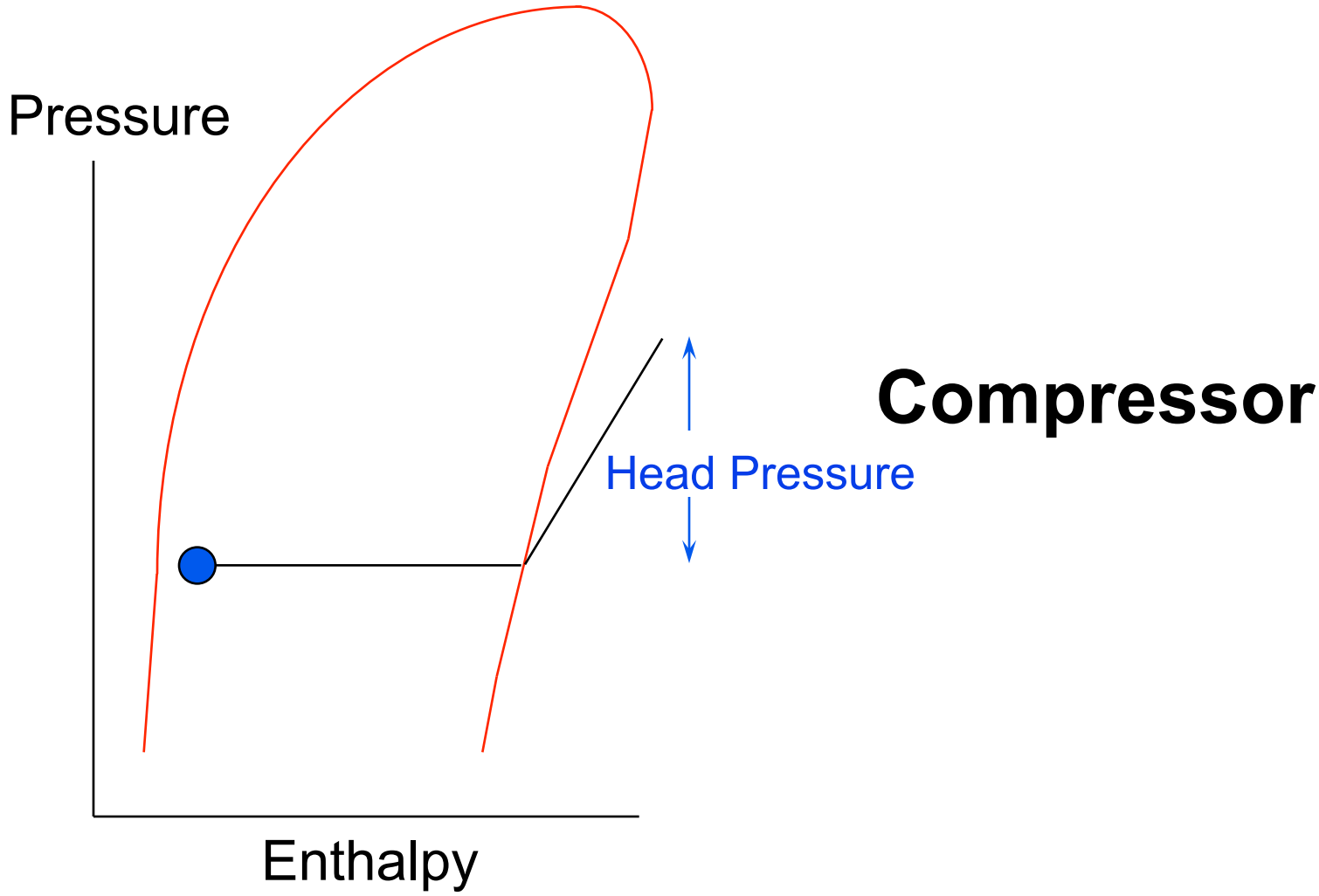
Or Heat Input

Pressure - Enthalpy Chart

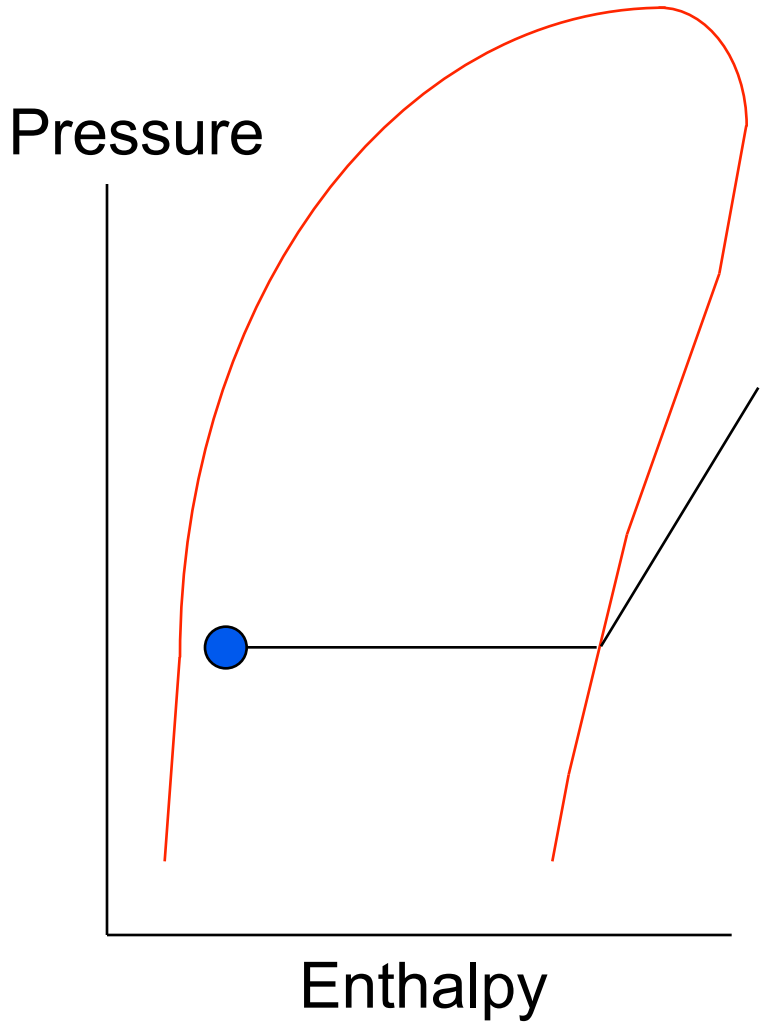


Compressor

Pressure - Enthalpy Chart

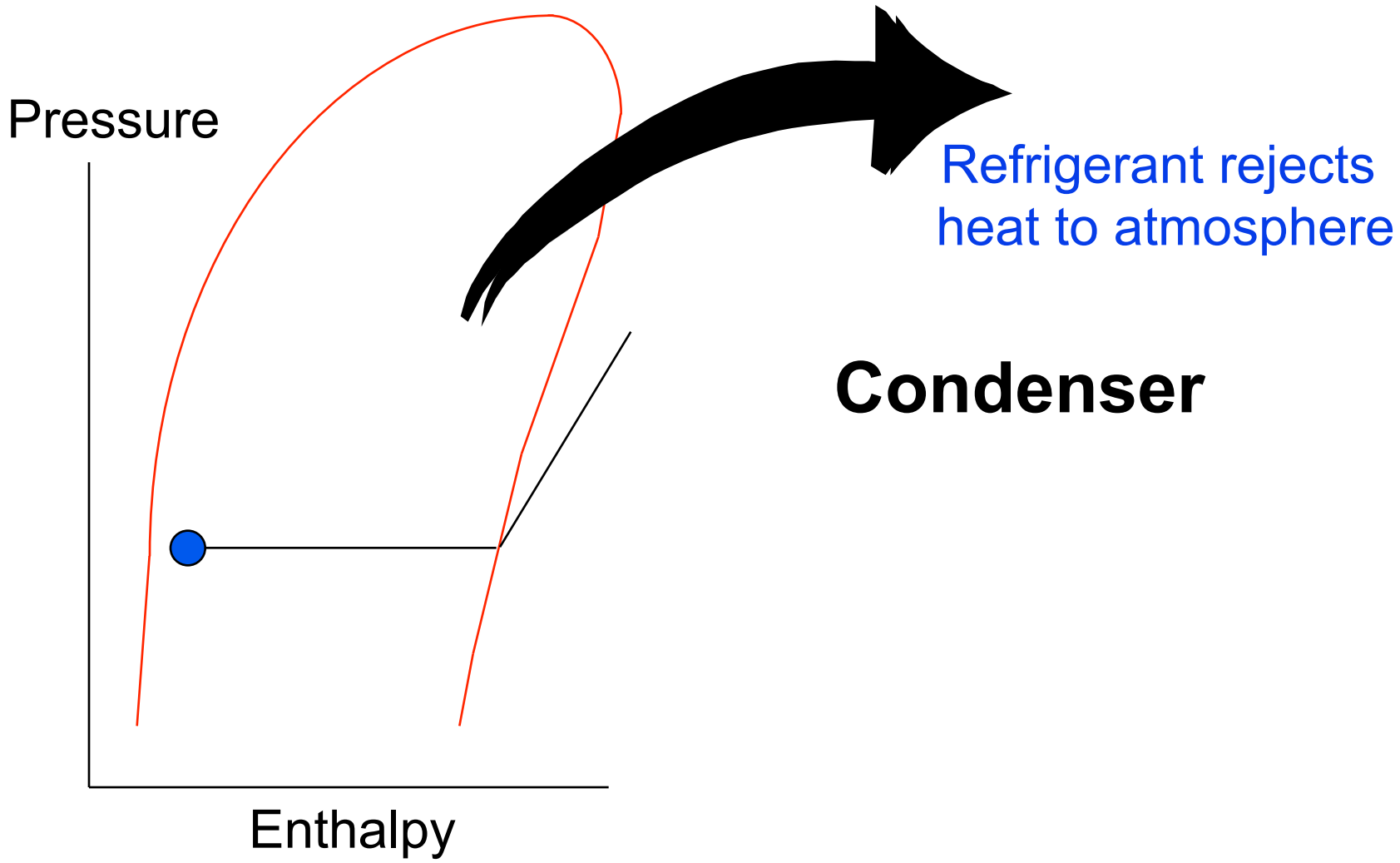


Pressure - Enthalpy Chart

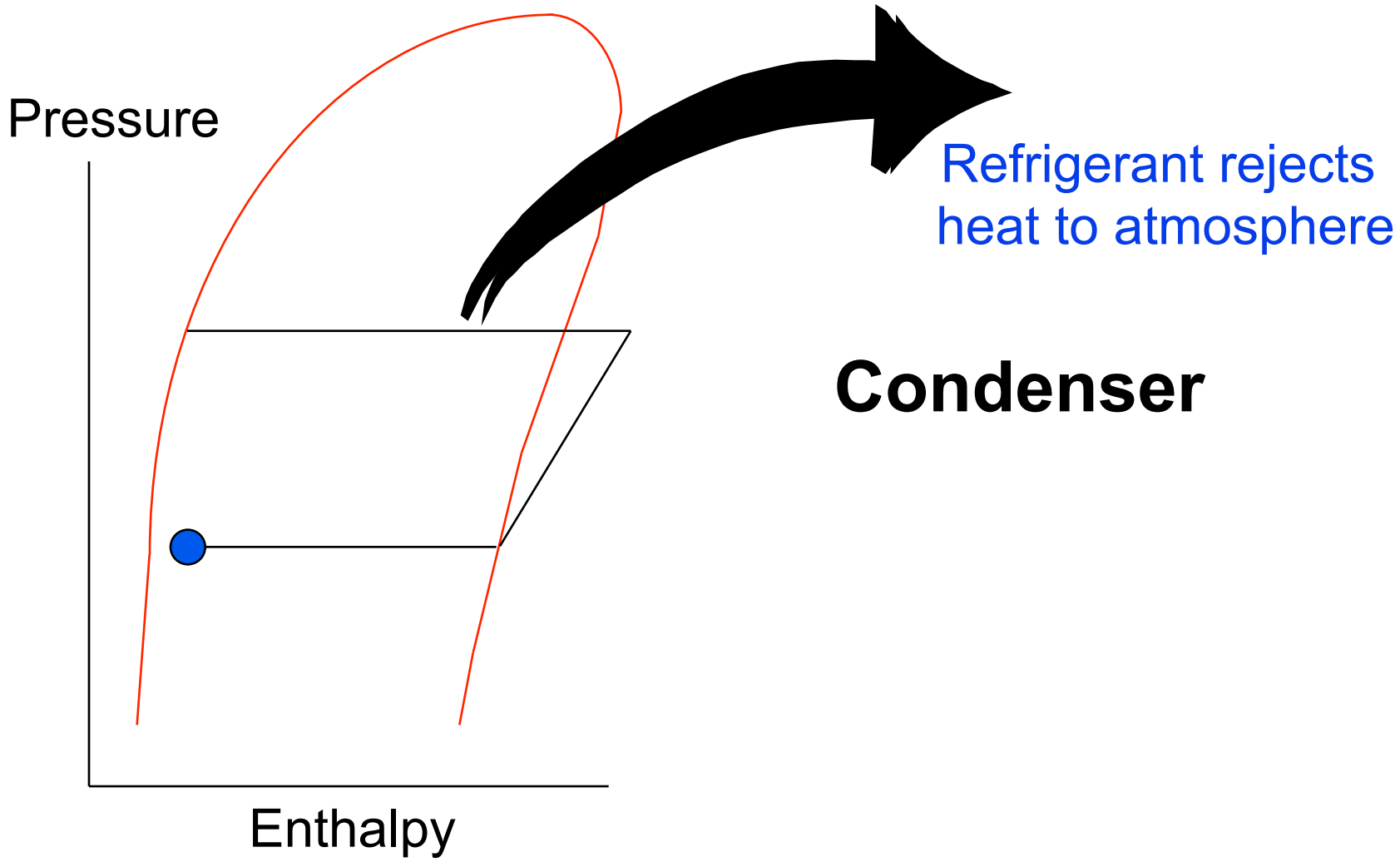


Condenser

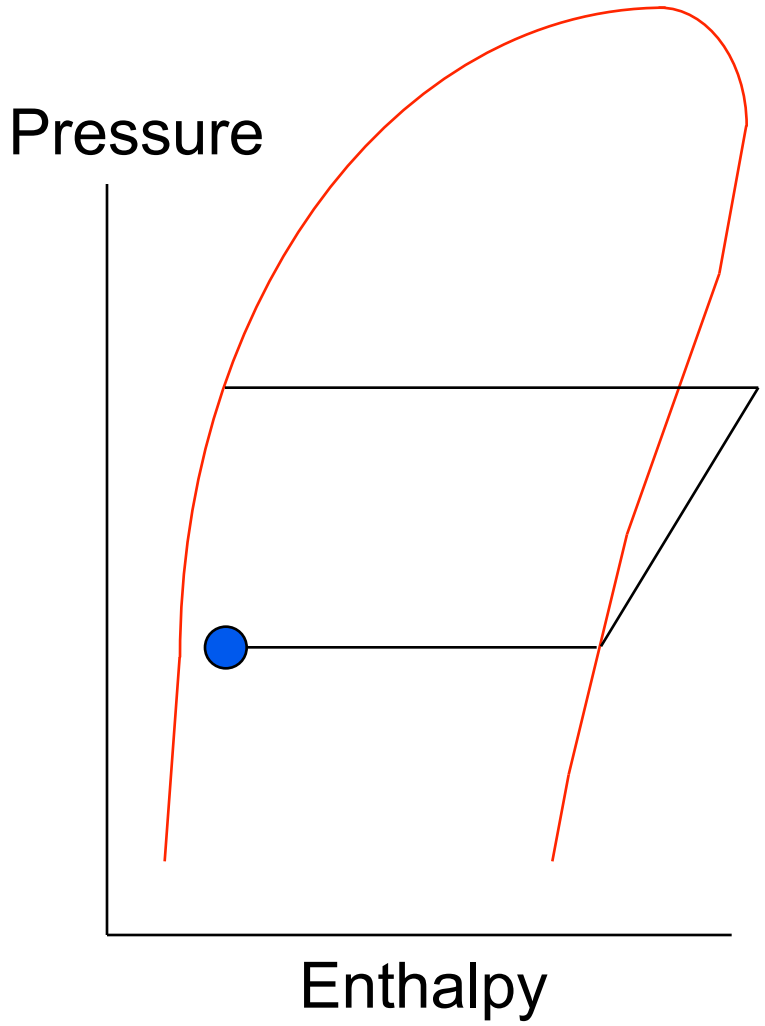
Pressure - Enthalpy Chart



Pressure - Enthalpy Chart

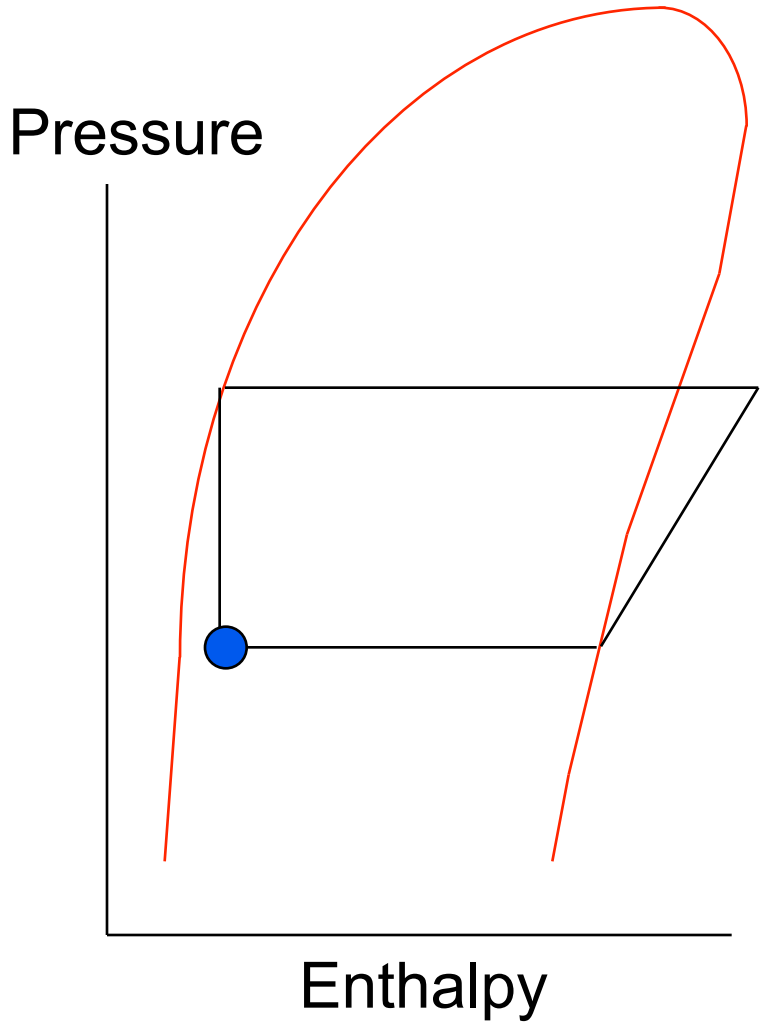


Pressure - Enthalpy Chart



Metering Device

Pressure - Enthalpy Chart



Metering Device

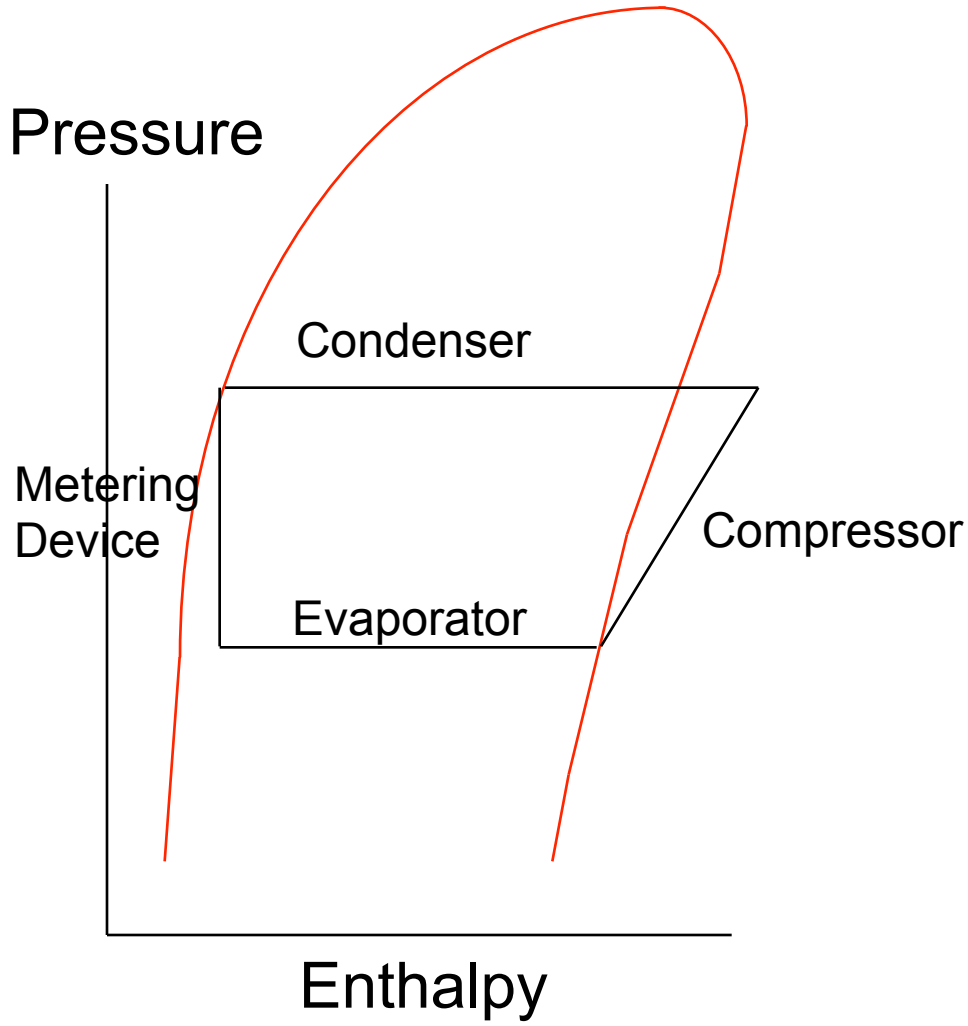
- **Thermal expansion valve**

  In refrigeration gas units

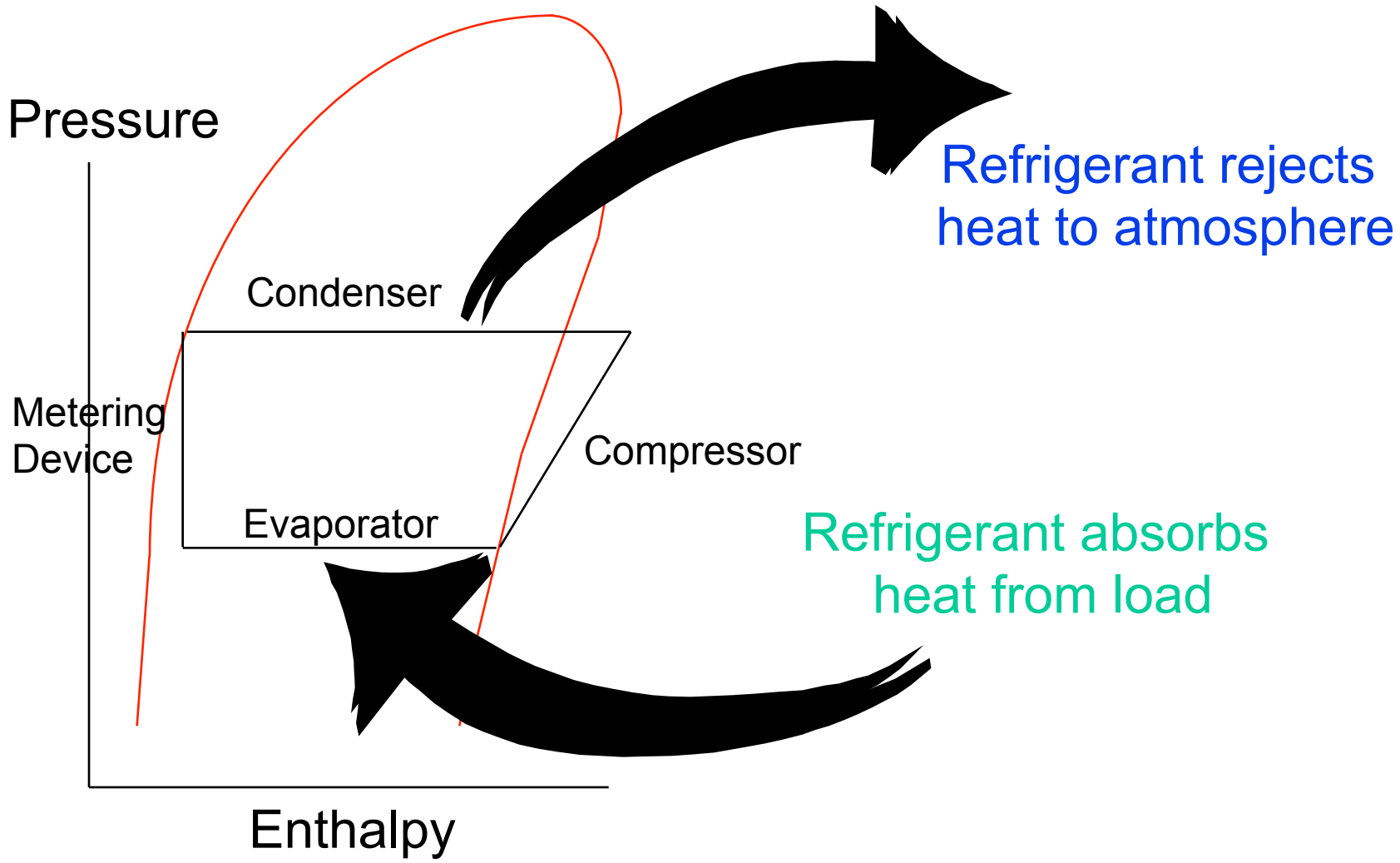
- Orifice Device

  In Absorption Units

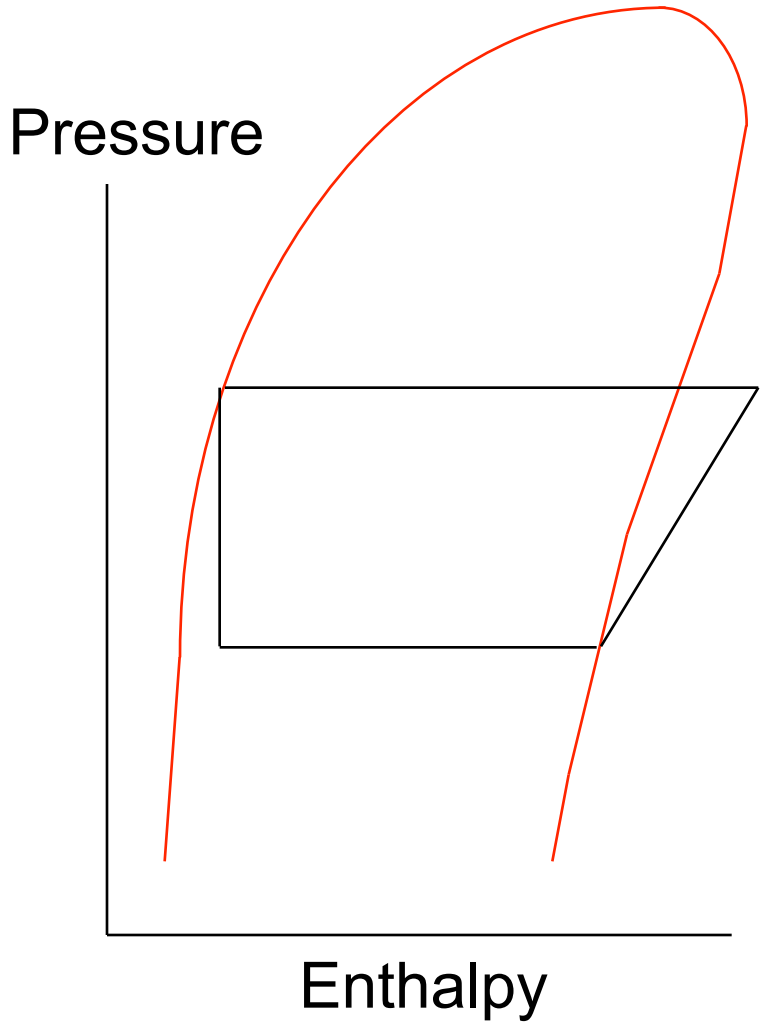
Pressure - Enthalpy Chart



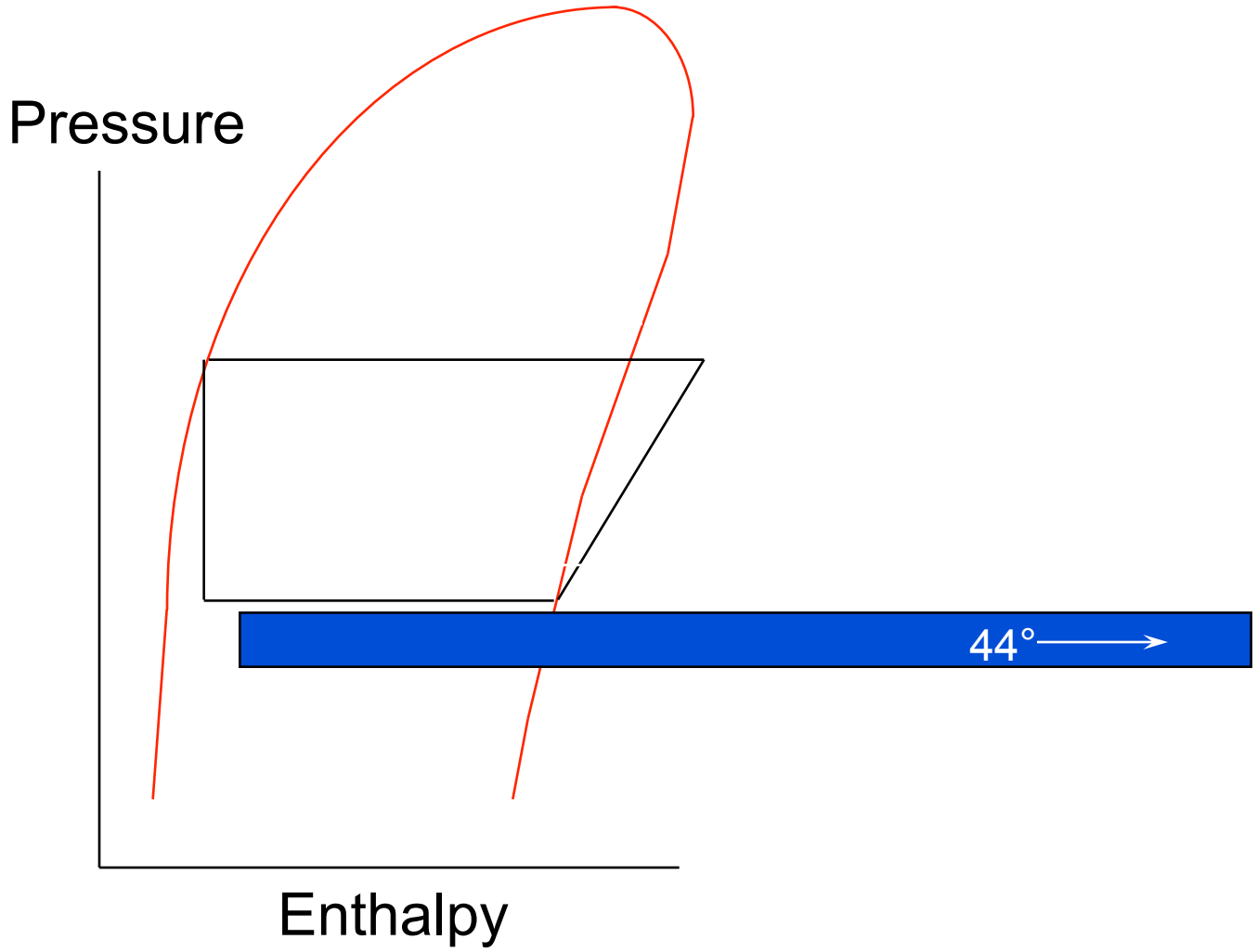
Pressure - Enthalpy Chart



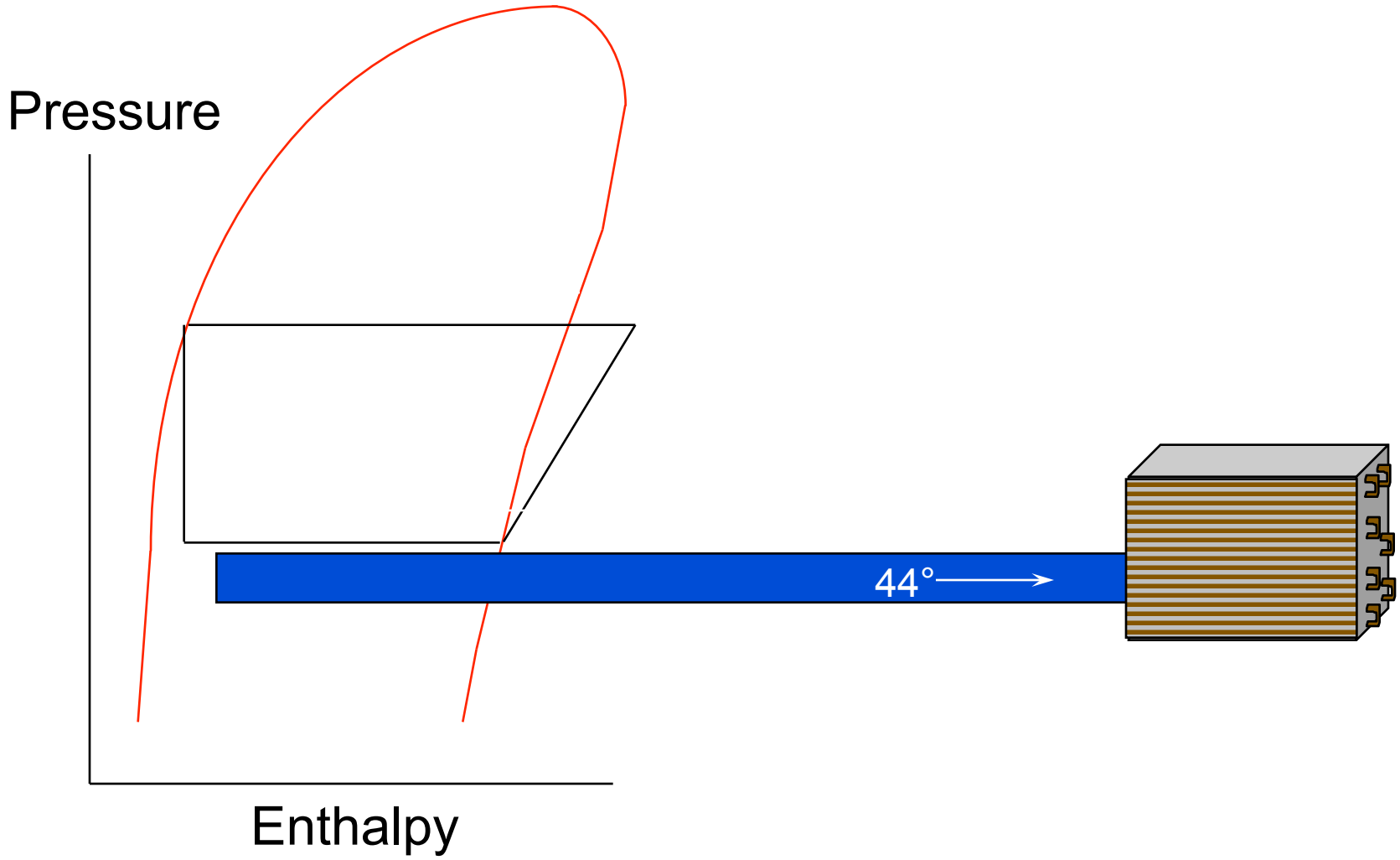
Pressure - Enthalpy Chart



Pressure - Enthalpy Chart



Pressure - Enthalpy Chart



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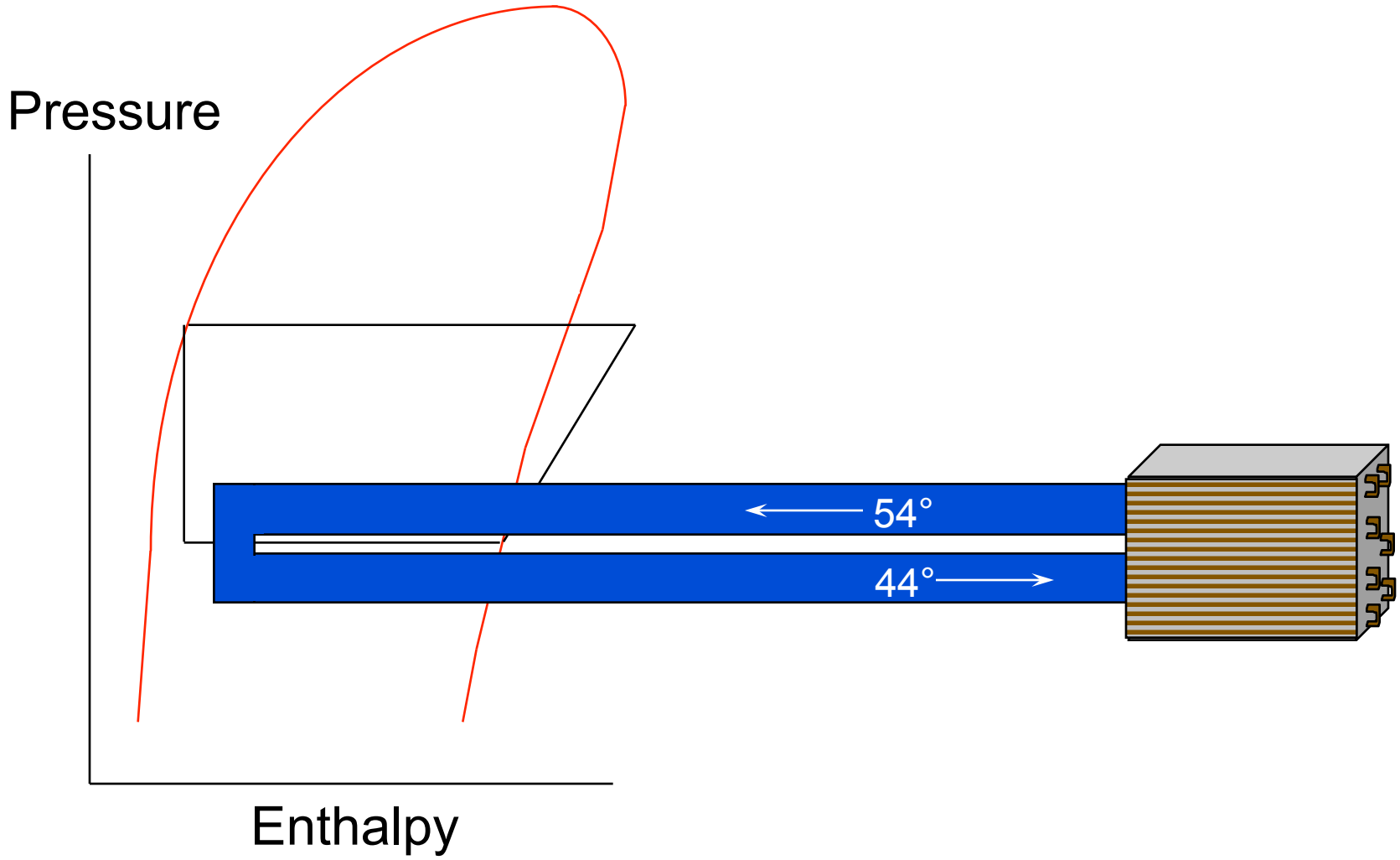
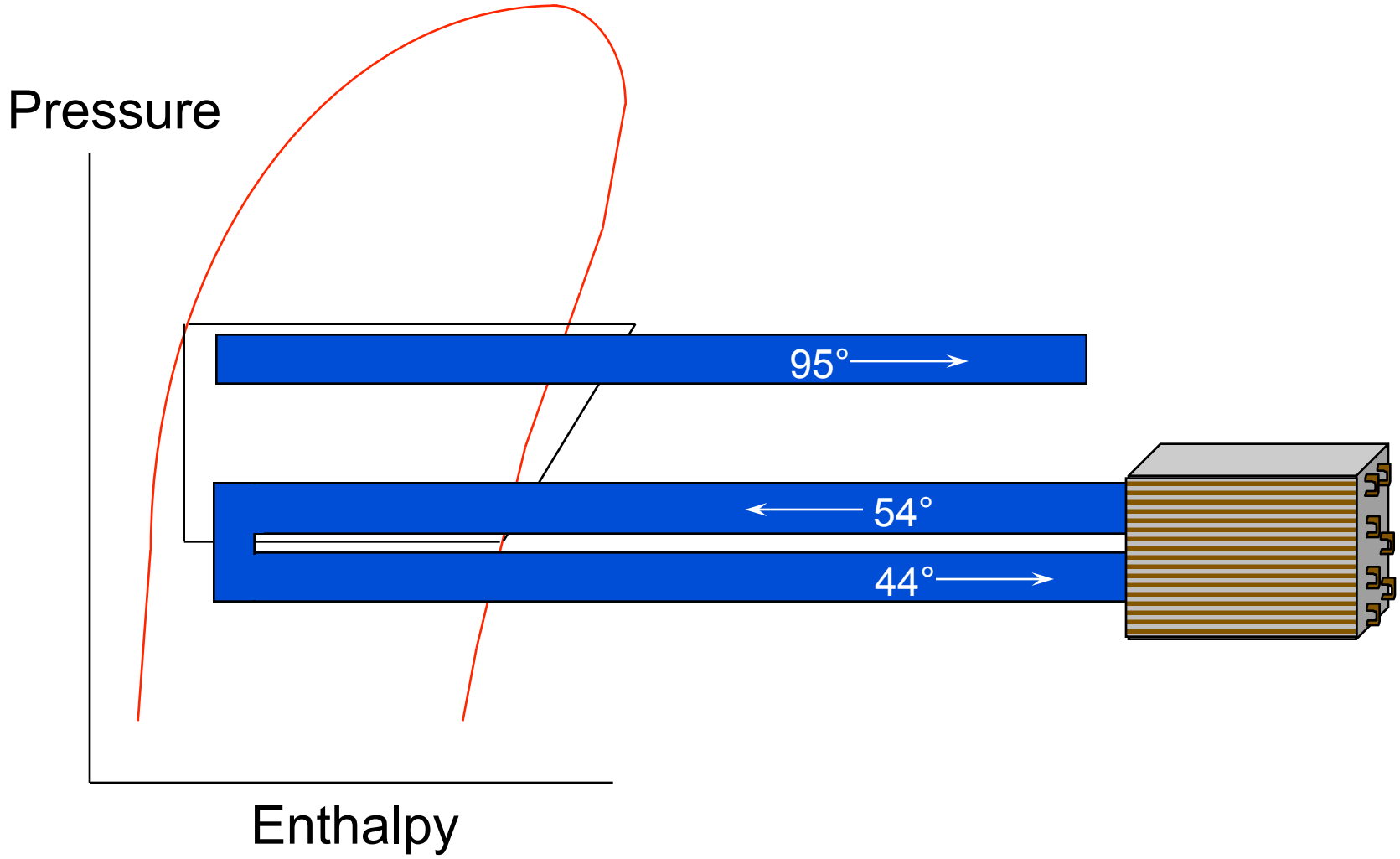


Pressure - Enthalpy Chart



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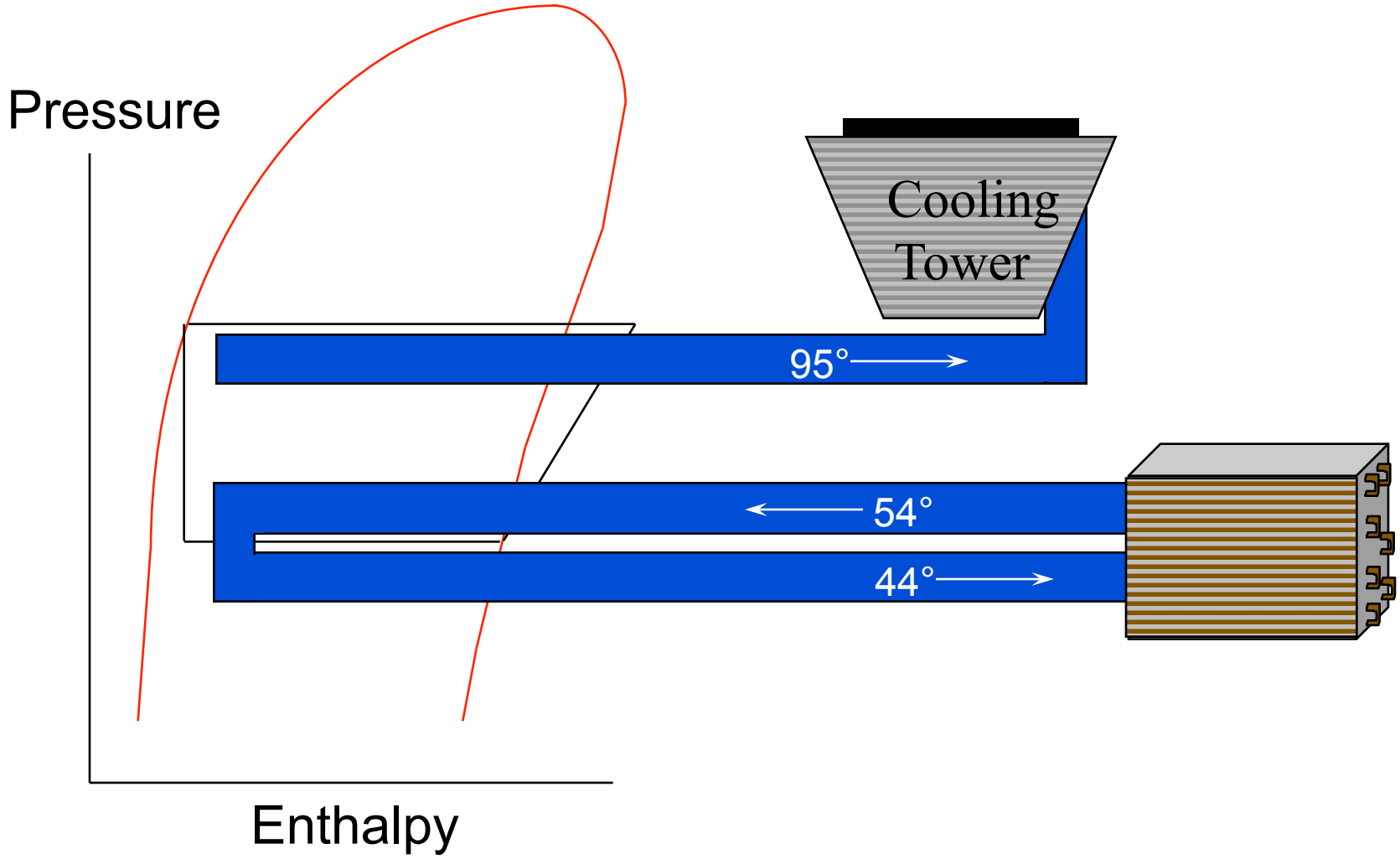
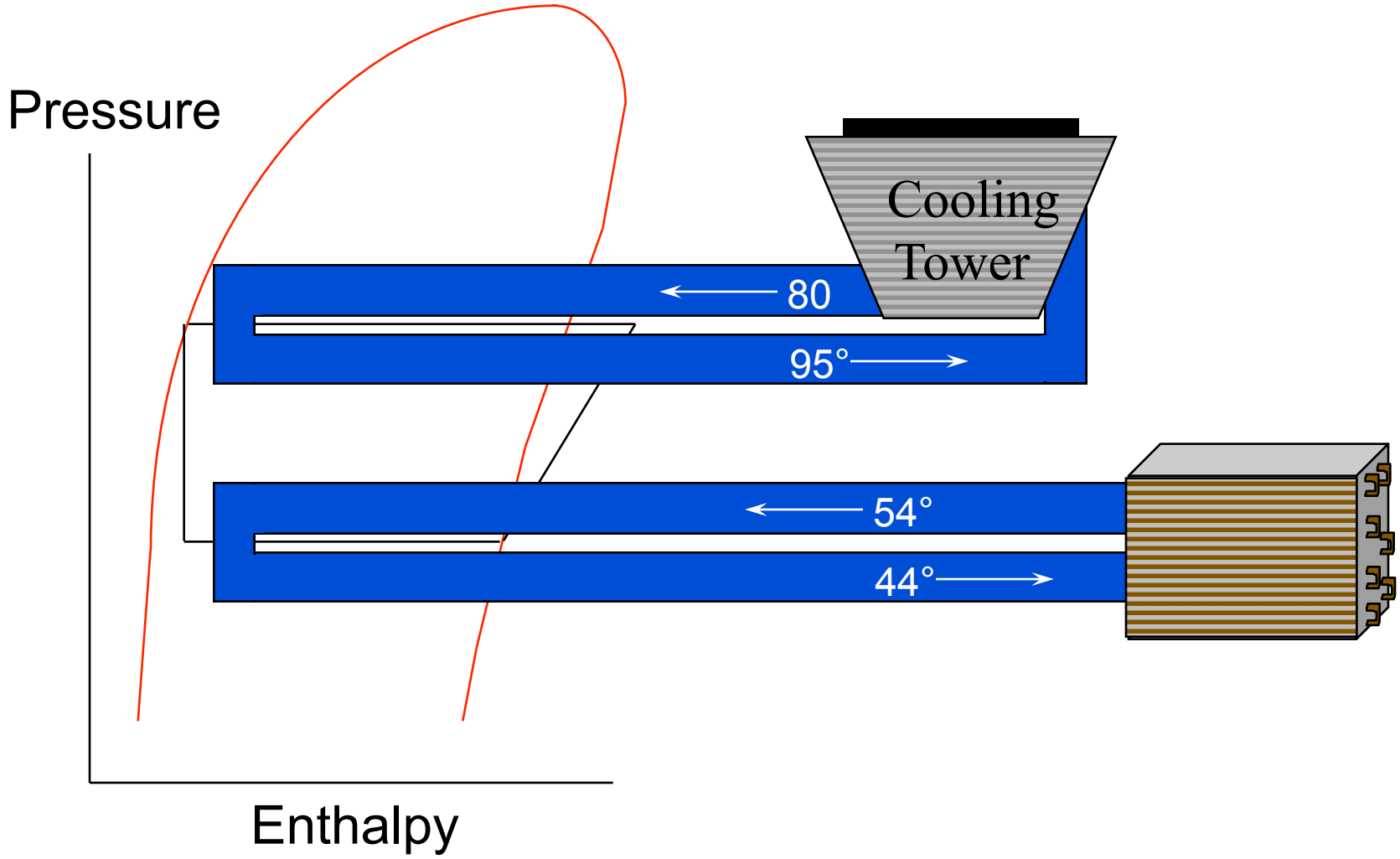
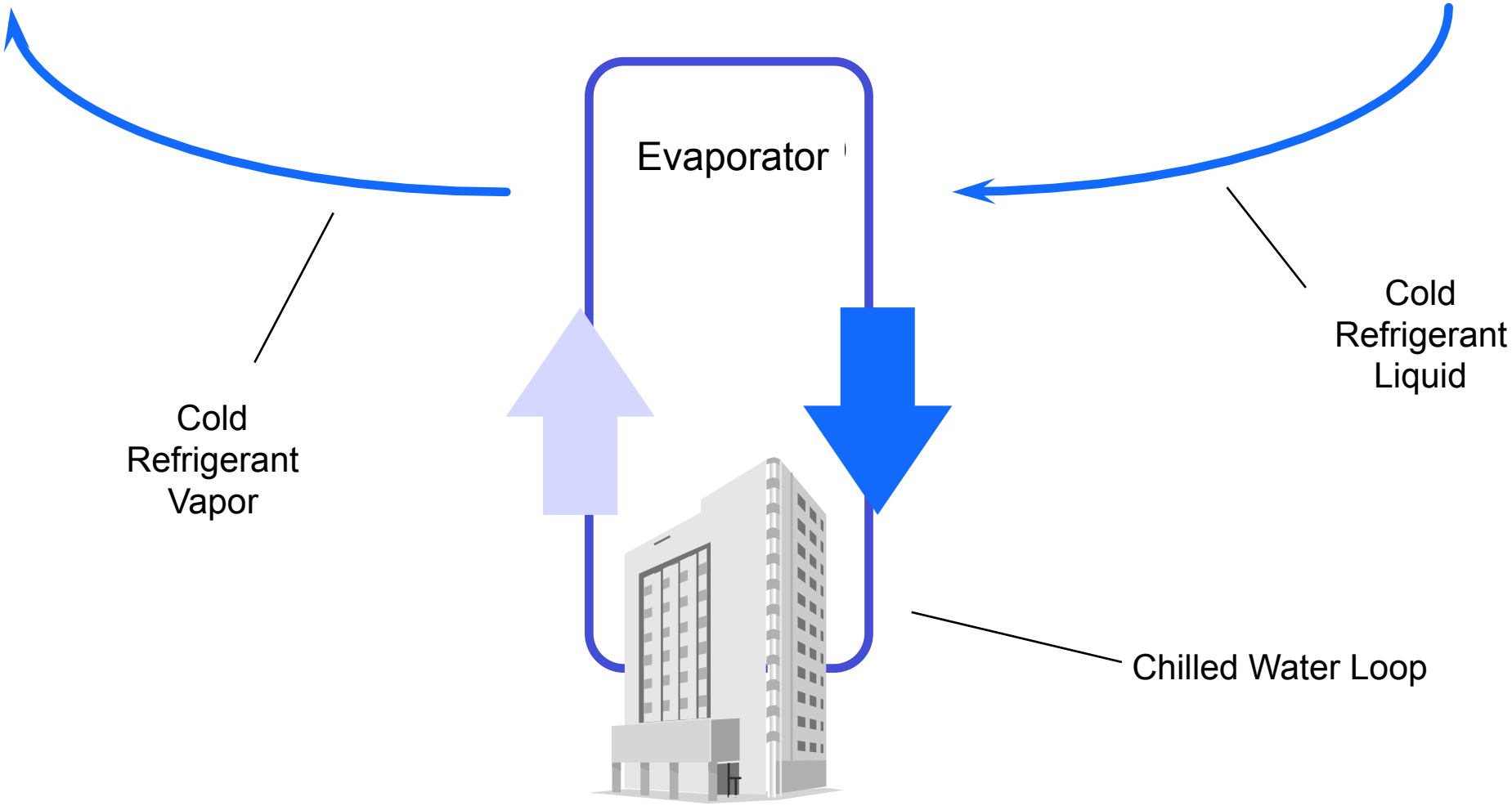


Pressure - Enthalpy Chart

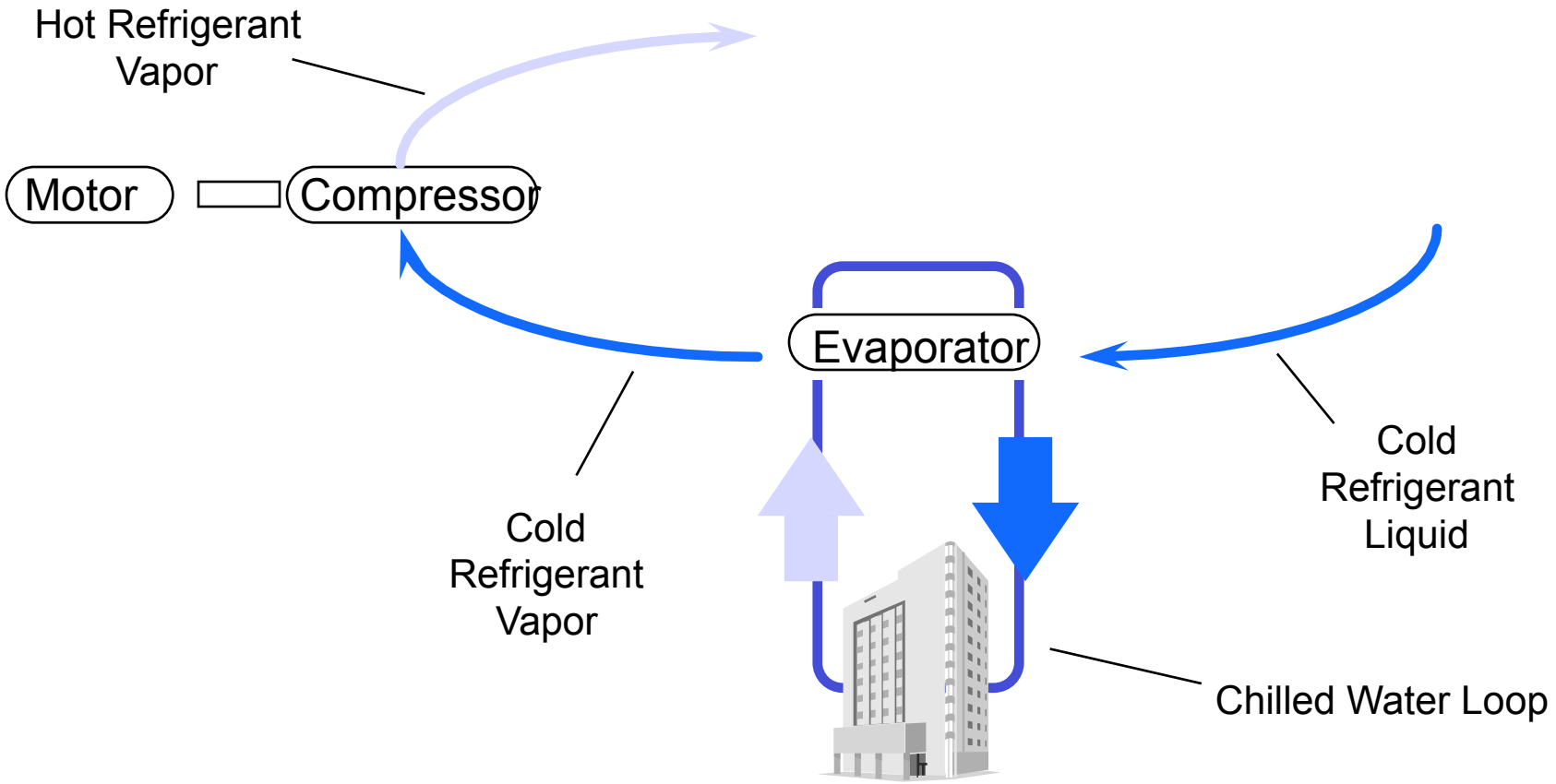



Now for something
completely Different

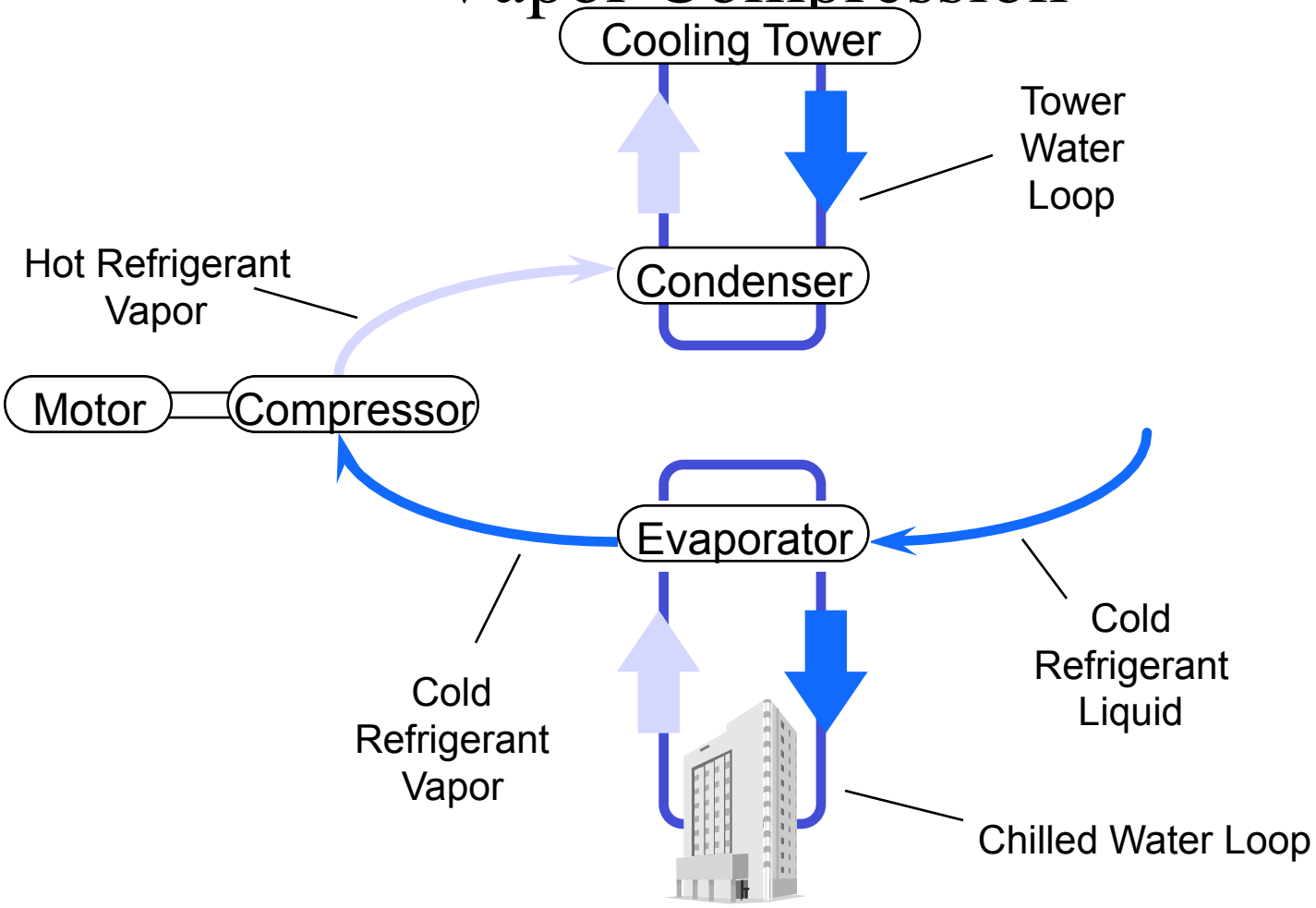
Vapor Compression



Vapor Compression



Vapor Compression



Pressure Conversions

- Absolute Pressure = Gauge Pressure + Atmospheric Pressure

- Gauge Pressure = Absolute Pressure - Atmospheric Pressure

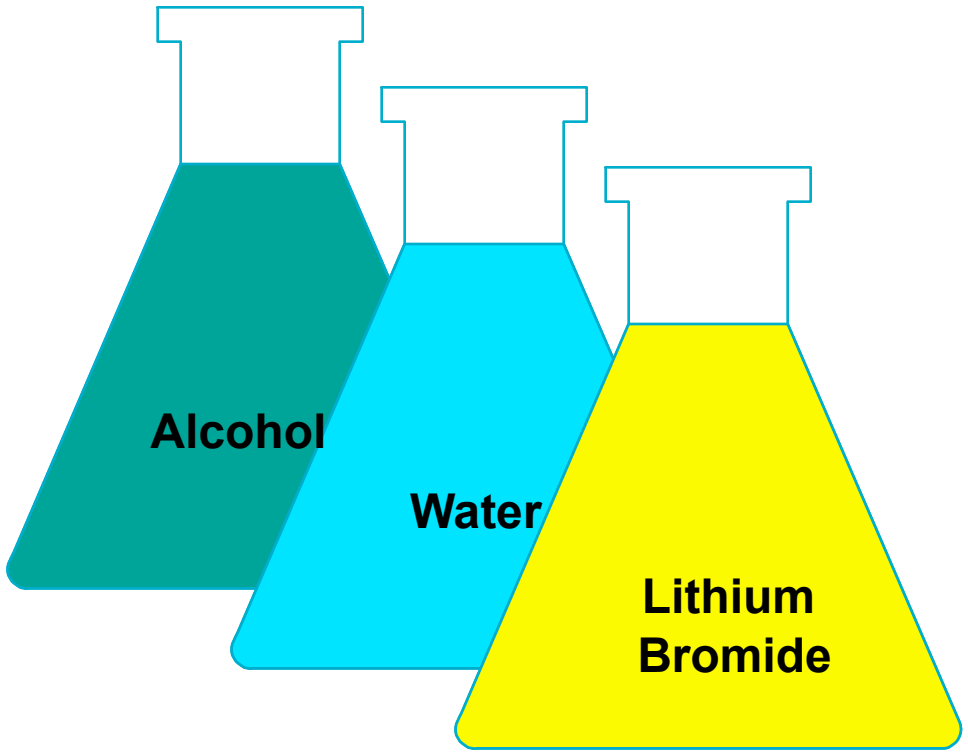
- Example:

Convert 8 PSIG to Absolute Pressure

P Abs = P gauge + P atm

P Abs = 8 PSIG + 14.7 = 22.7 PSIA

Absorption System Fluids



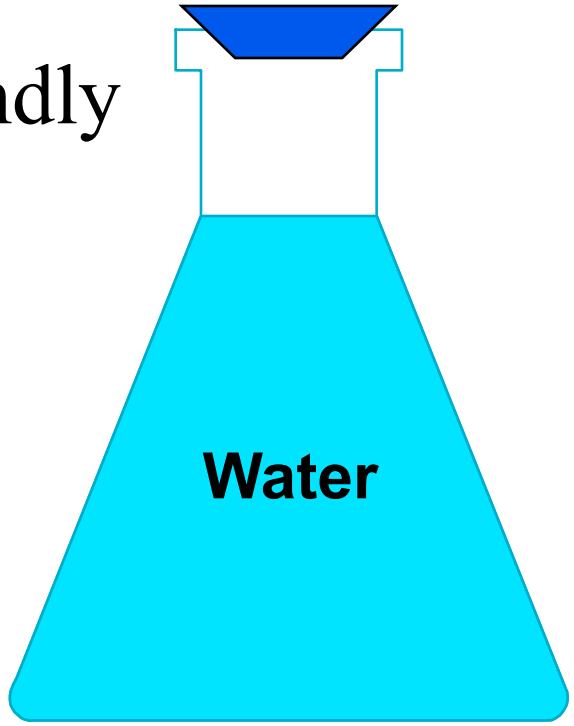
- Alcohol
- Water
- Lithium Bromide

Alcohol

- 2 - Ethyl Hexanol
- Alcohol is only 1% of the total charge in the system, but increases efficiency by 10%-15%
- Each model chiller has an optimum alcohol charge.
- Adding more alcohol will reduce efficiency

Refrigerant is De-Ionized Water

- Stable
- Non-toxic
- Environmentally Friendly
- Low cost

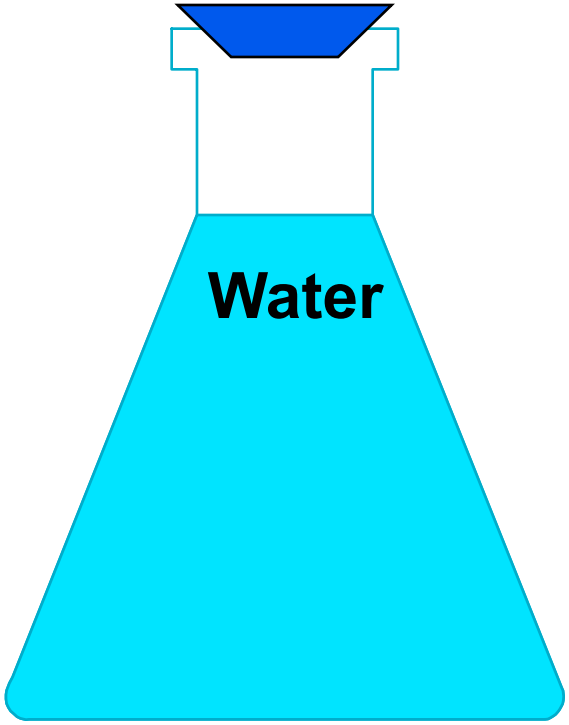


Latent Heat Values (Btu/Lb)

Ammonia	**=**	**536**
R-22	**=**	**86**
R-123	**=**	**77**
Water	**=**	**1070**

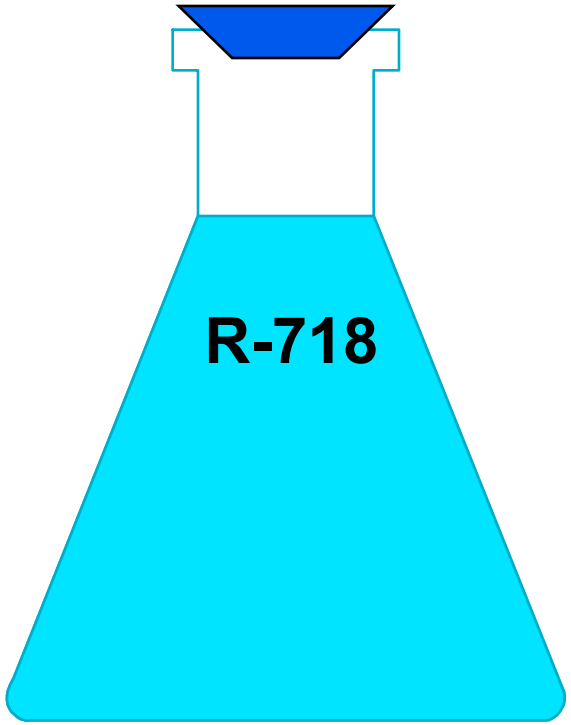
Refrigerant is Water

- The refrigerant number for water is



Refrigerant is Water

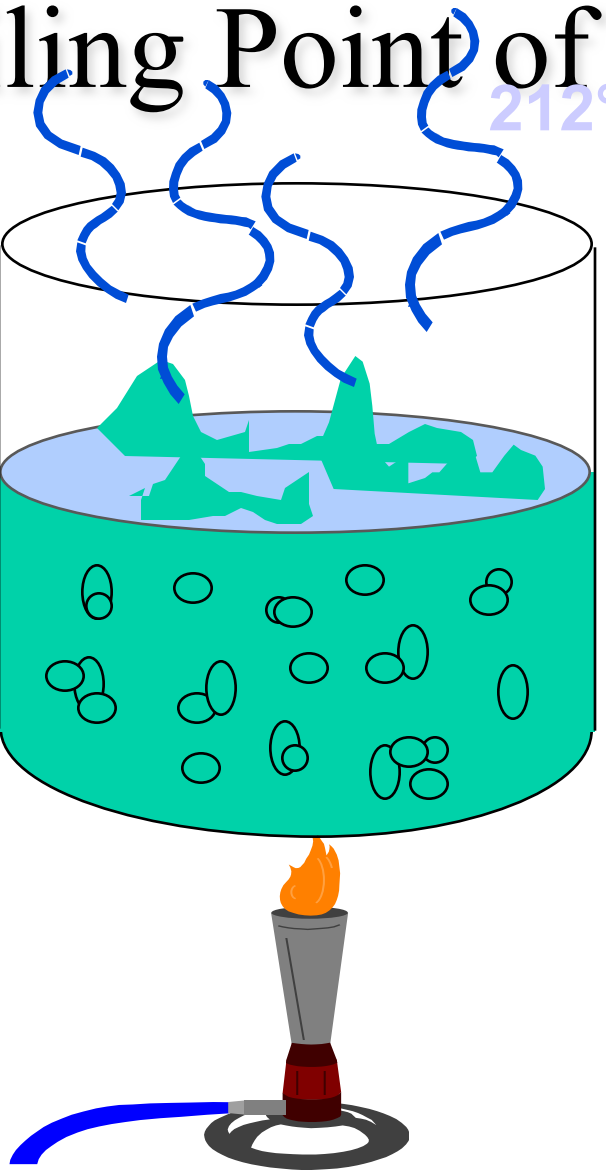
- The refrigerant number for water is R- 718.



Boiling Point of Water

Atmospheric Pressure

(14.696 psia)

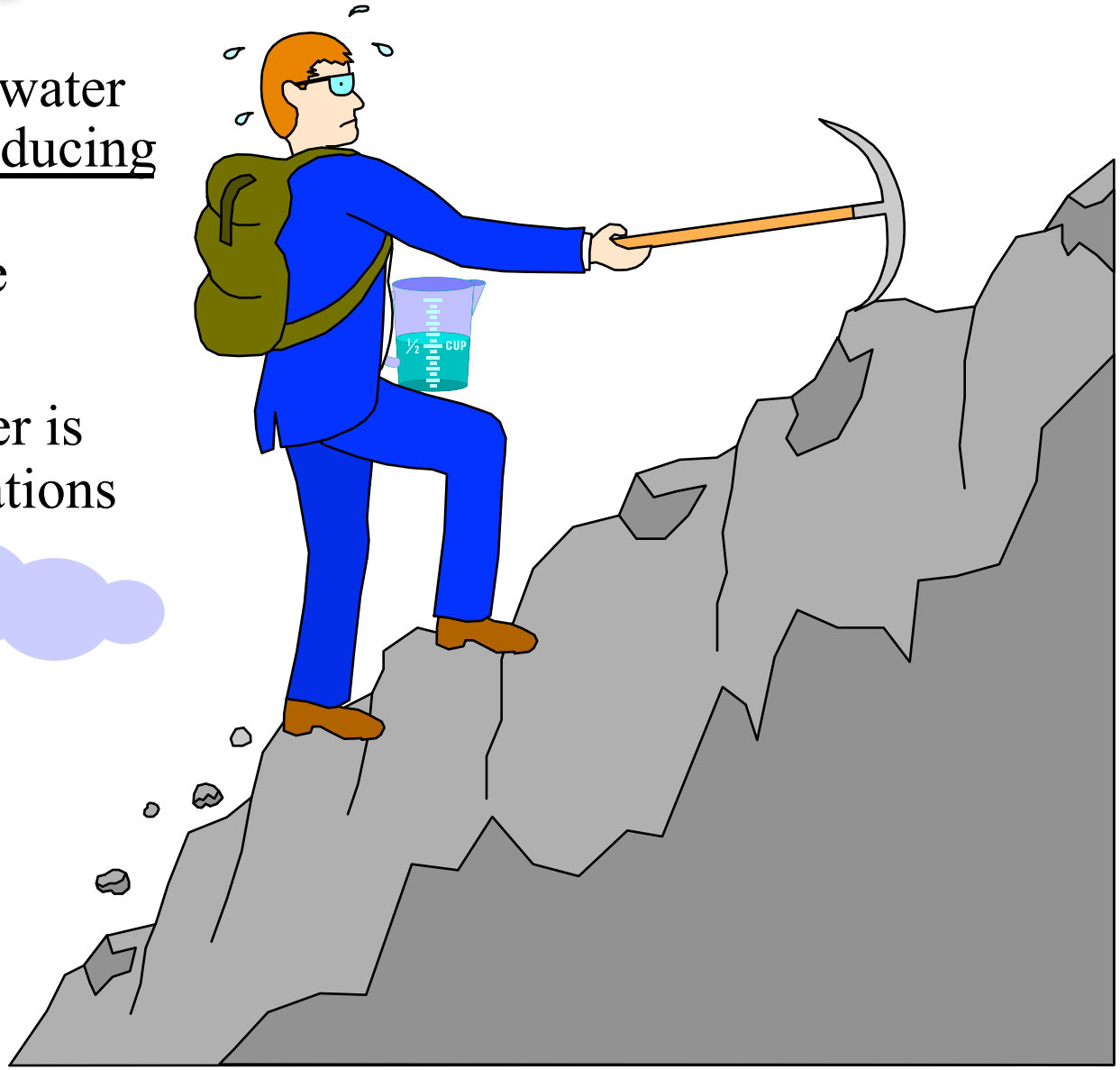


Liquid turns to vapor

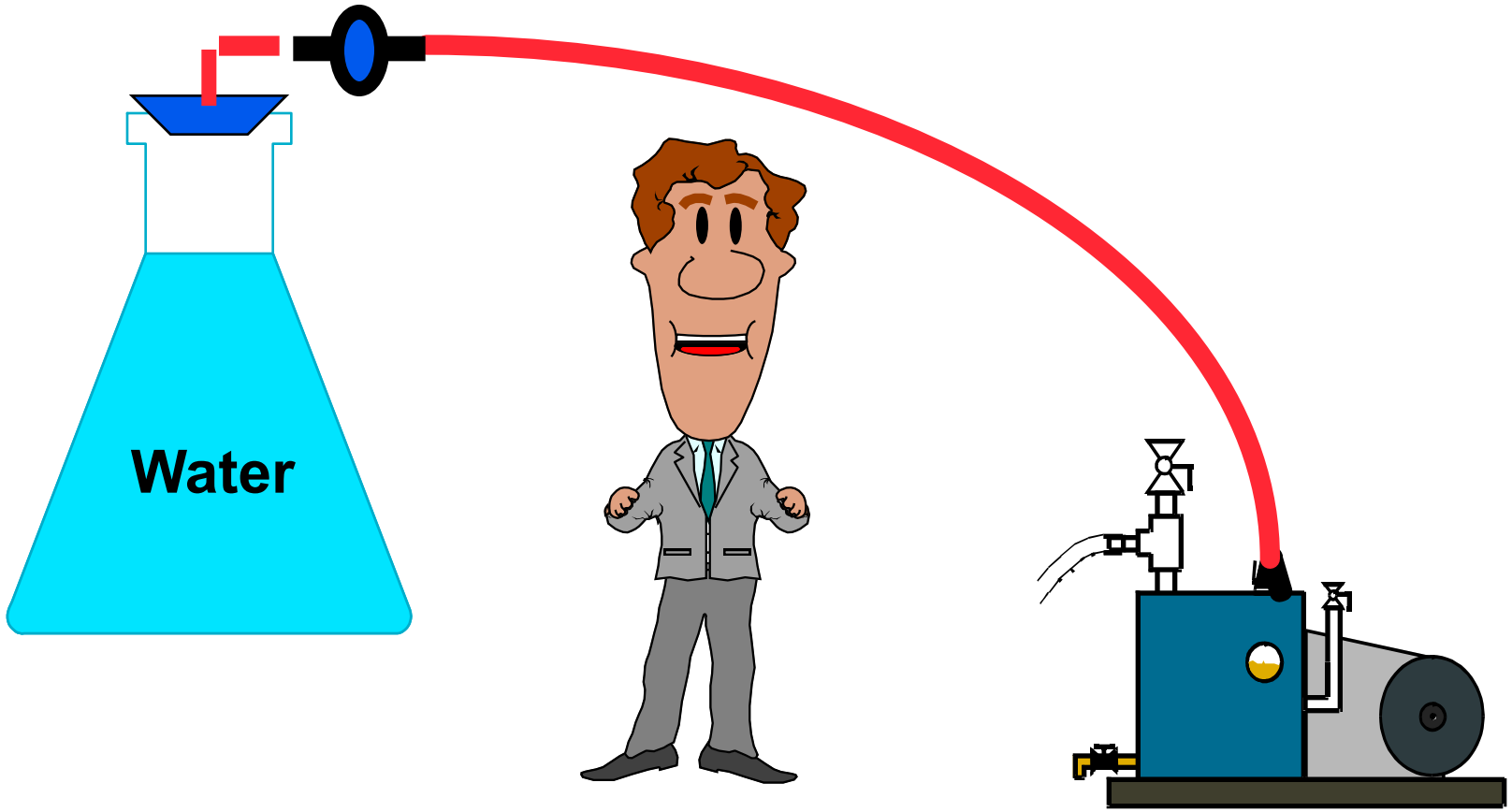
Boiling Point of Water

The boiling point of water can be lowered by reducing the amount of air or atmospheric pressure

Boiling point of water is lower at higher elevations



By removing a portion of the air (atmospheric pressure) a P/T chart can be applied to water which indicates the boiling point of water at various pressures ...

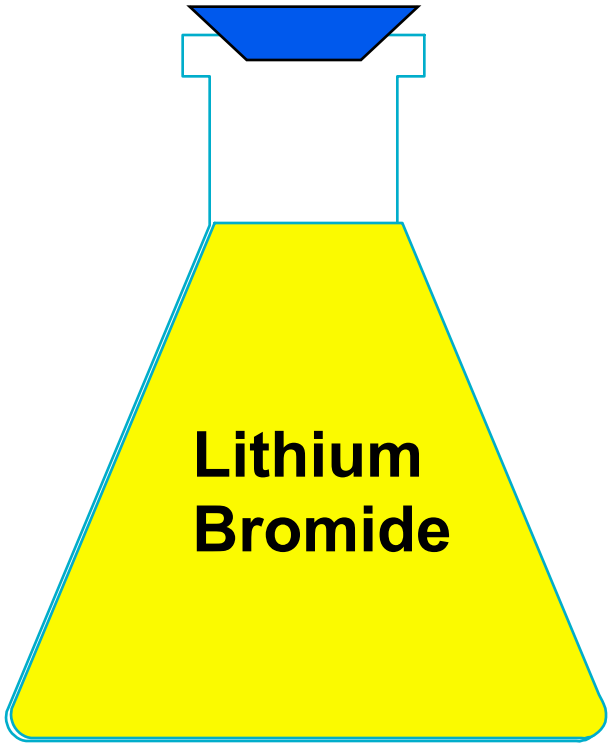


Boiling Temperatures Of Water At Various Pressures

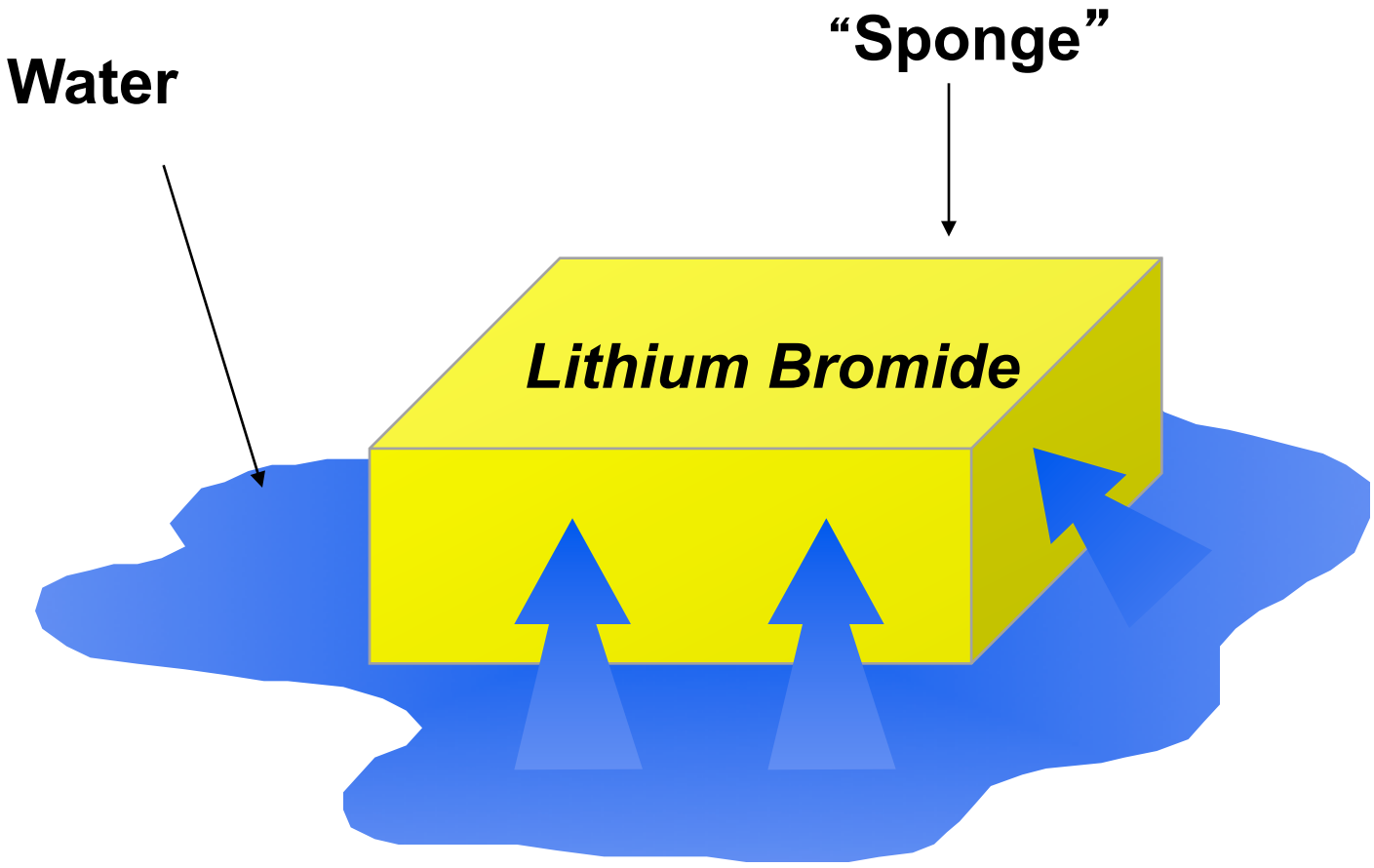
Temps.	*Gauge Pressures*	*Absolute Pressures*		
Deg. F	Pressure (ins. Hg.)	Psia Lb/Sq. In.	Ins. Hg.	Mm. Hg.
212	0	14.696	29.921	759.99
160	20.265	4.742	9.656	245.25
100	27.988	.950	1.933	49.11
80	28.888	.507	1.032	26.22
70	29.182	.363	.739	18.77
60	29.399	.256	.522	13.25
50	29.599	.178	.362	9.20
45	29.621	.147	.300	7.63
40	29.673	.122	.248	6.29
35	29.718	.100	.203	5.17
30	29.757	.081	.165	4.18
20	29.818	.050	.103	2.61

Absorbent is Lithium Bromide

- Water absorbs readily into it
- High boiling point
- Non-toxic
- Relatively low cost

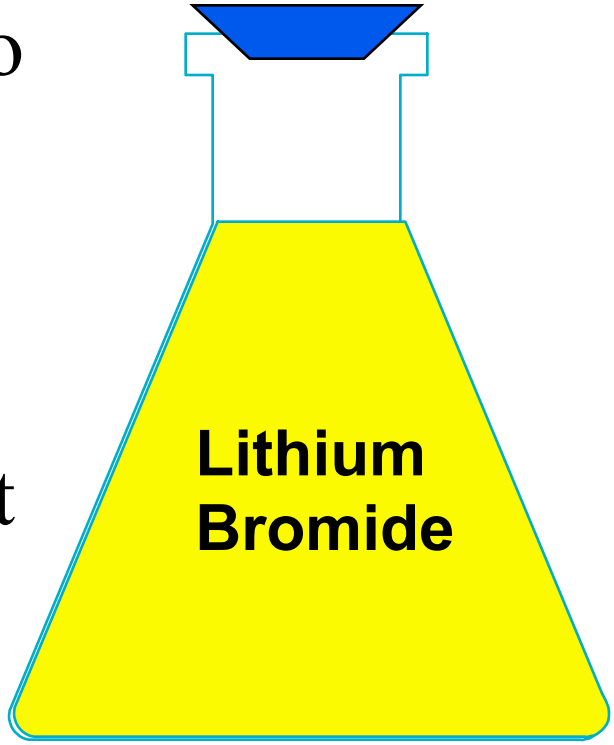


Properties of Lithium Bromide and Water



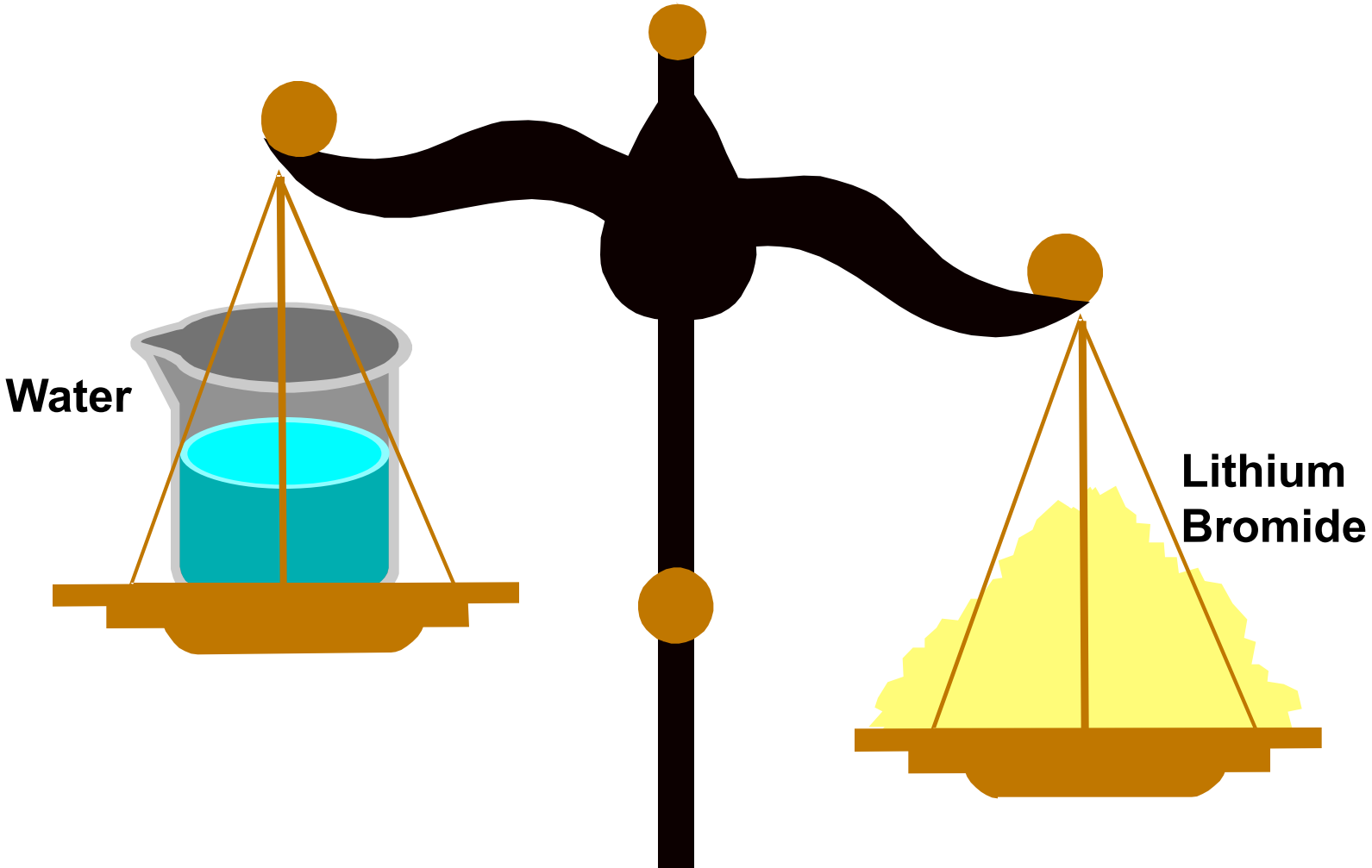
Lithium Bromide

- Lithium Bromide is referred to as “solution”.
- This solution is expressed in “% concentration”.
- Lithium Bromide is shipped at a concentration of 55%.



Concentrations

Solution concentrations are determined by weight ...

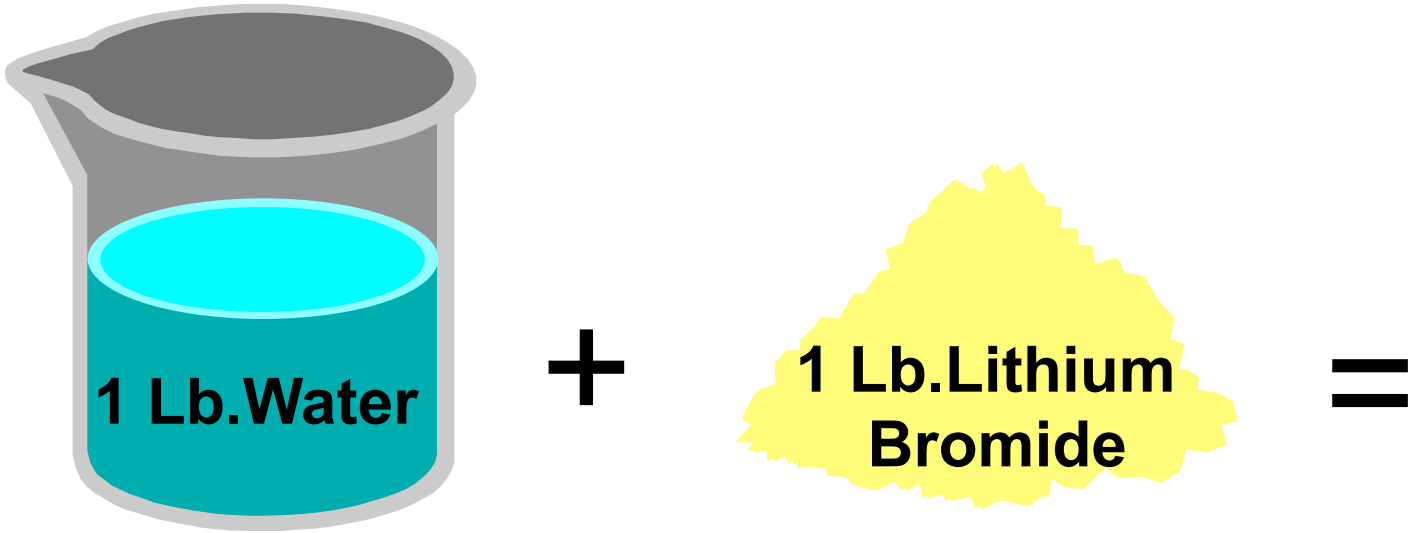


Concentrations

+

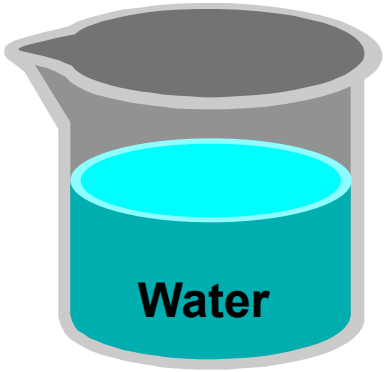
= ???

Concentrations



2Lbs. of Solution @ 50% Concentration

Concentrations

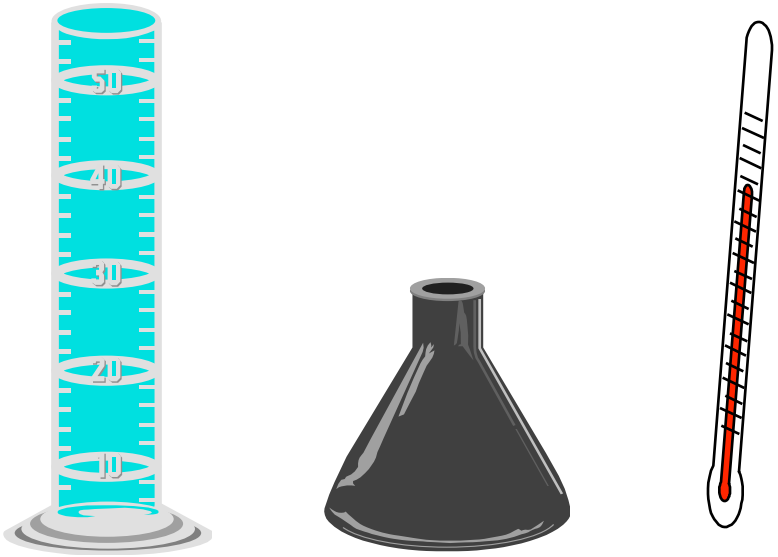


0%
Weak Solution
(Diluted)

100%
Strong Solution
(Concentrated)

Concentrations

Solution concentrations can be determined by using instruments known as hydrometers to determine the specific gravity of the solution and by also measuring the temperature of the solution. This information can then be applied to a chart to determine the concentration of the sample.



Hydrometers

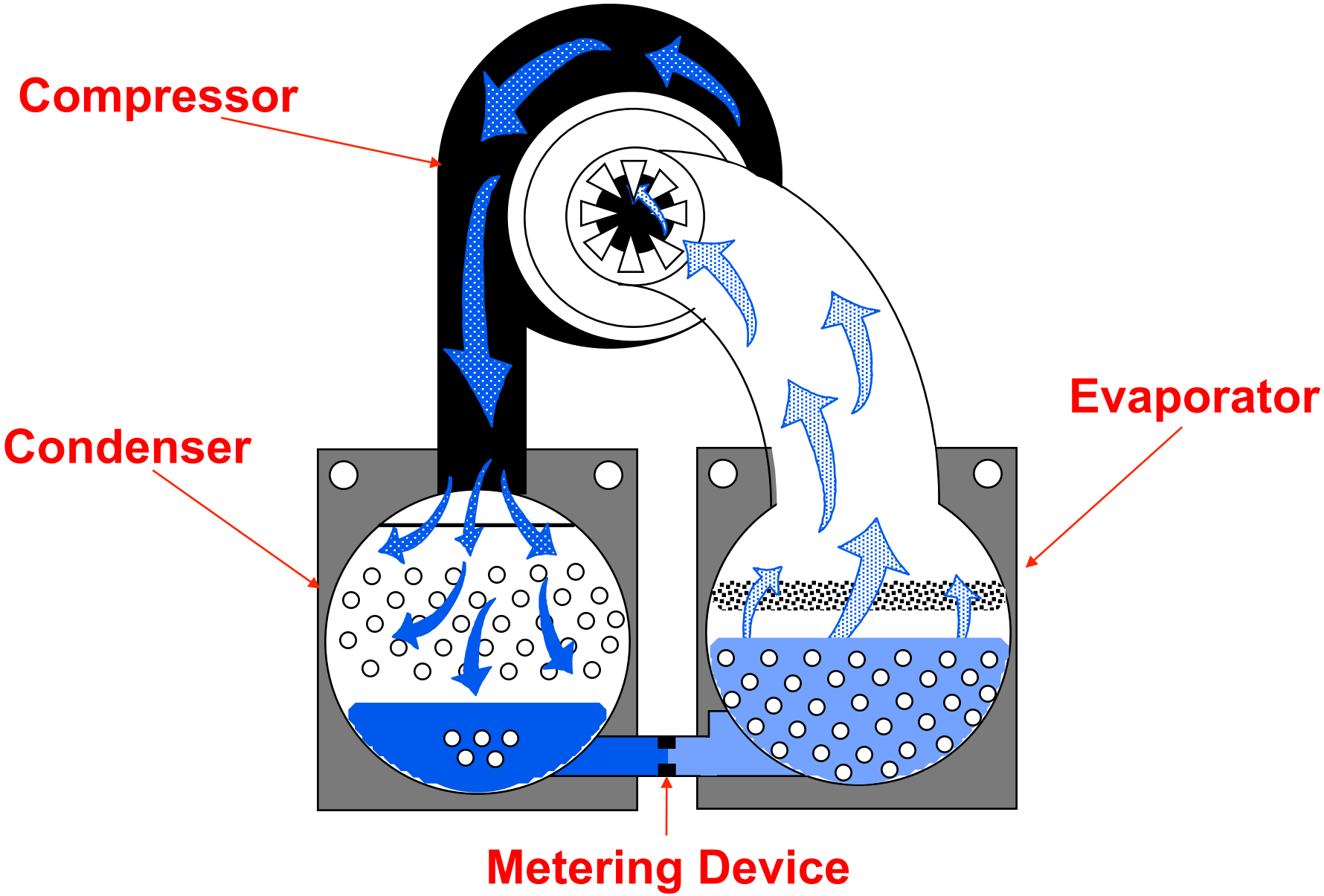
Basic Refrigeration Cycle

What are the four basic components of the vapor compression refrigeration cycle?

Refrigeration Cycle Components

- Evaporator
- Compressor
- Condenser
- Metering Device

Centrifugal Chiller Components



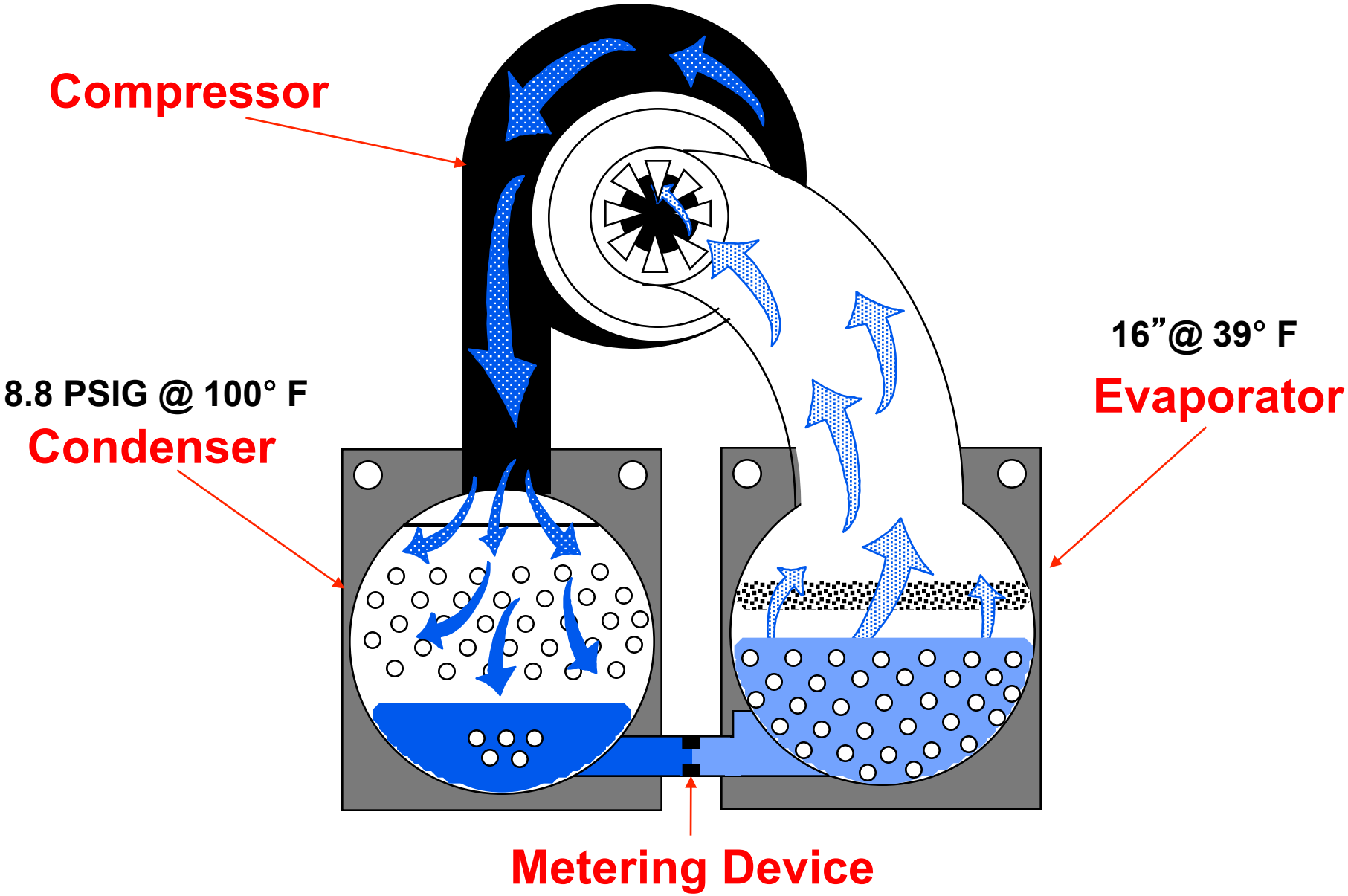
Centrifugal Chiller

- What is the vapor pressure in an idle R-11 chiller if all the refrigerant is at 80° F?
- 1.5 PSIG

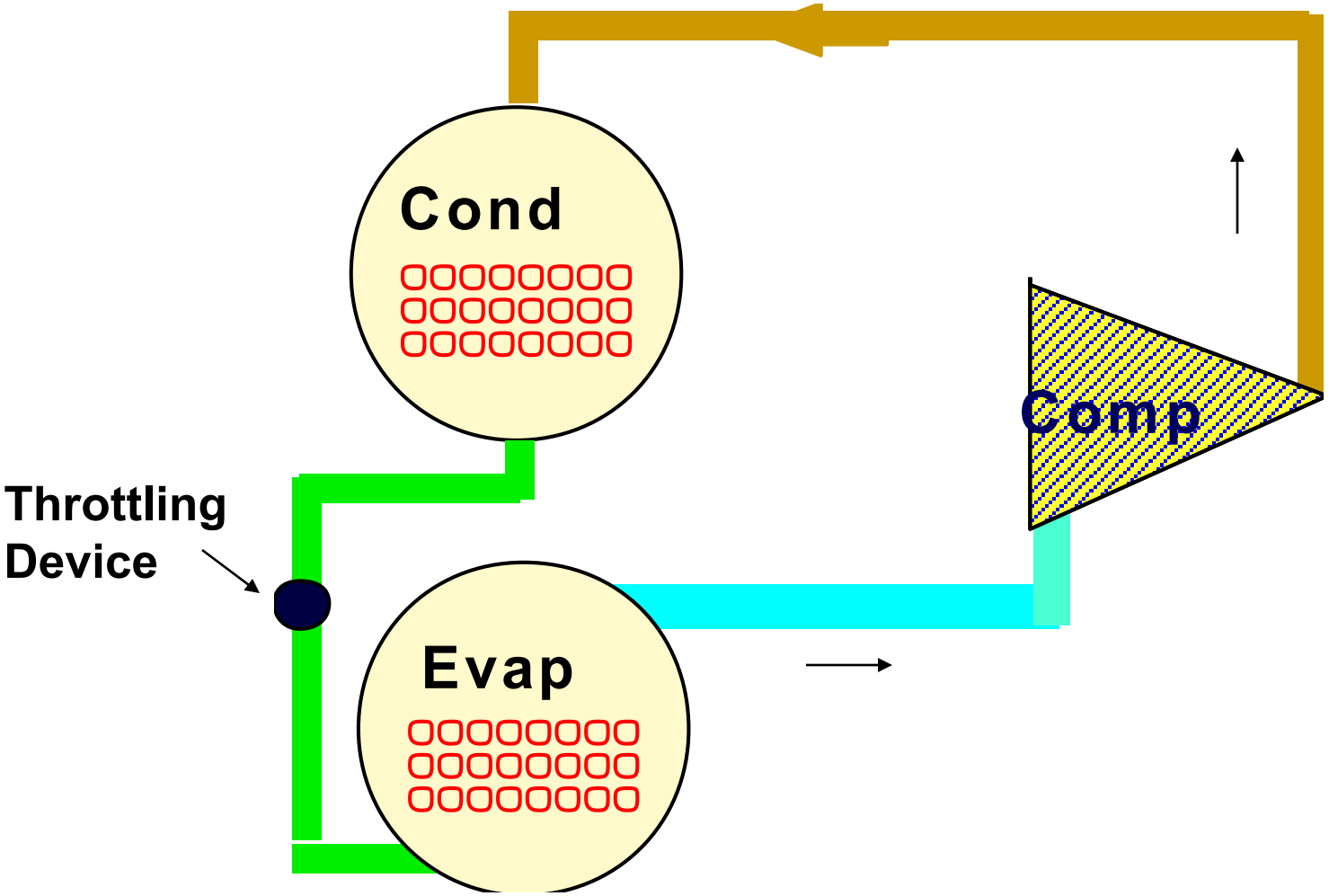
Centrifugal Chiller

- What is the vapor pressure in an idle R-11 chiller if all the refrigerant is at 70° F?
- 2.8 in. Hg.

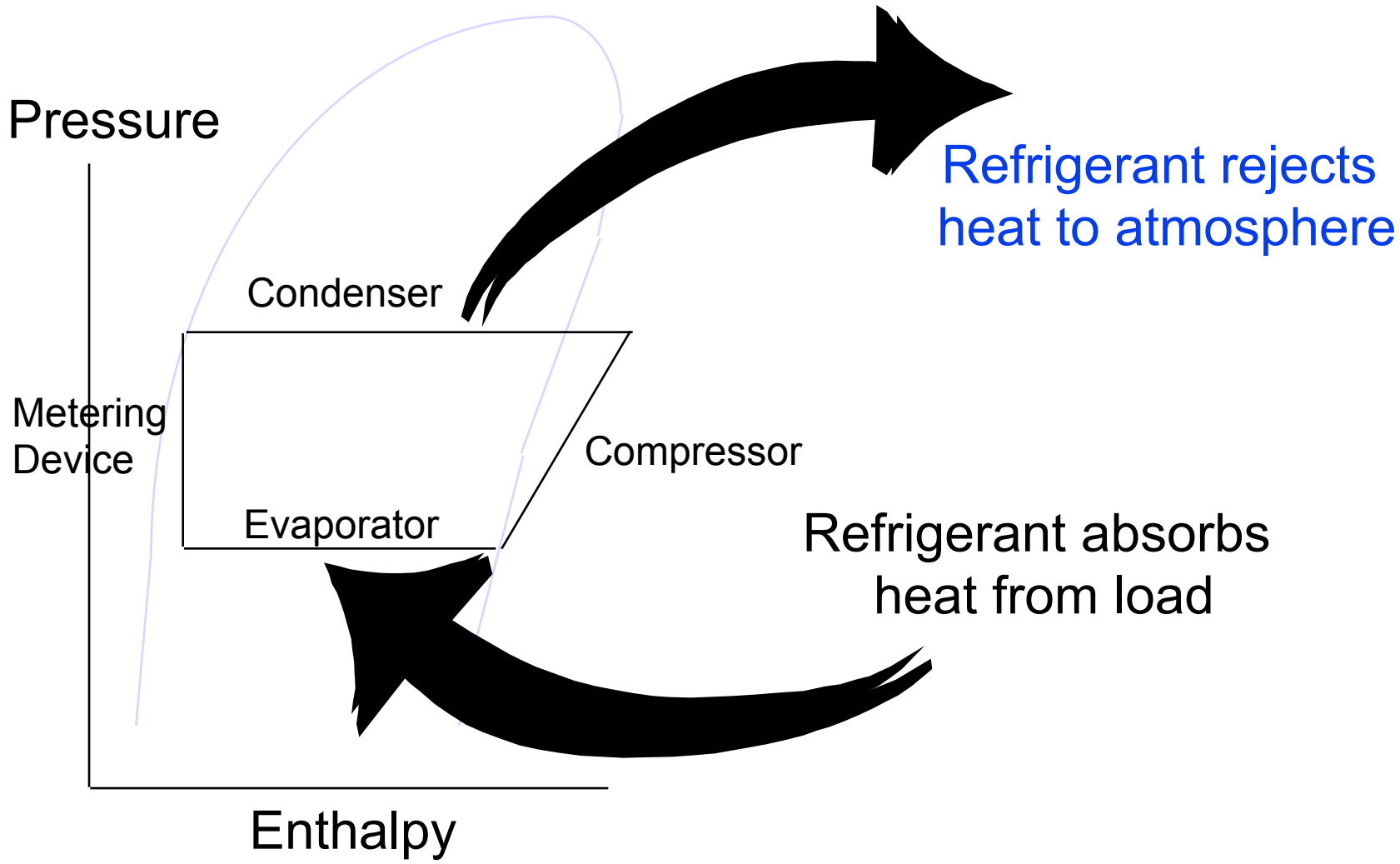
Centrifugal Chiller Cycle



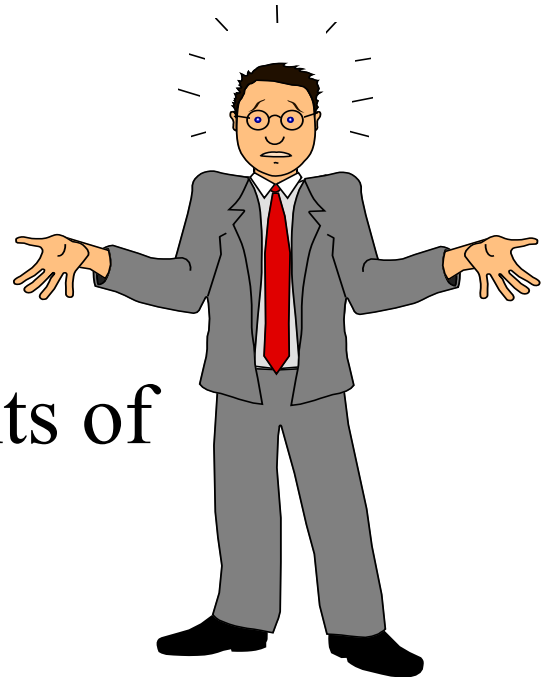
Vapor Compression Cycle



Pressure - Enthalpy Diagram



Basic Absorption Cycle



What are the four main components of the absorption cooling cycle?

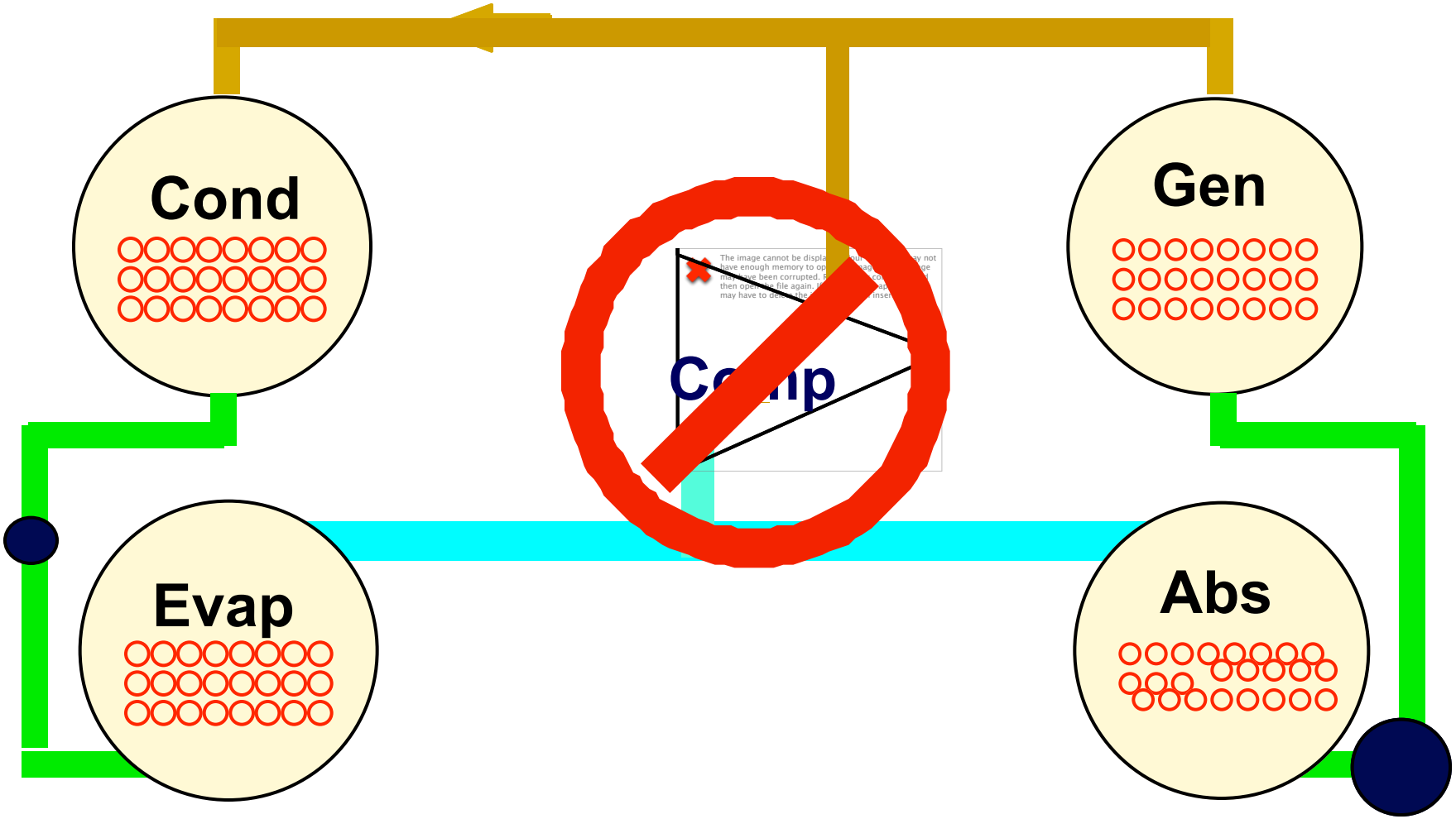
Absorber Components

- Condenser
- Generator
- Evaporator
- Absorber

Absorption Vs. Vapor Compression

Vapor Compression	Absorption
Evaporator……	Evaporator
Condenser……	Condenser
Throttling Device……..	Throttling Device
Compressor ……..	Absorber
	Pump
	Generator

Absorption Unit Conversion



Absorption Vs. Vapor Compression

- Evaporator, condenser and throttling device are present on both technologies
- Compressor is replaced with the absorber and generator sections
- A pump is used to transport the solution from the absorber to the generator

Absorption Vs. Vapor Compression

- Absorber is analogous to the suction stroke of the compressor.

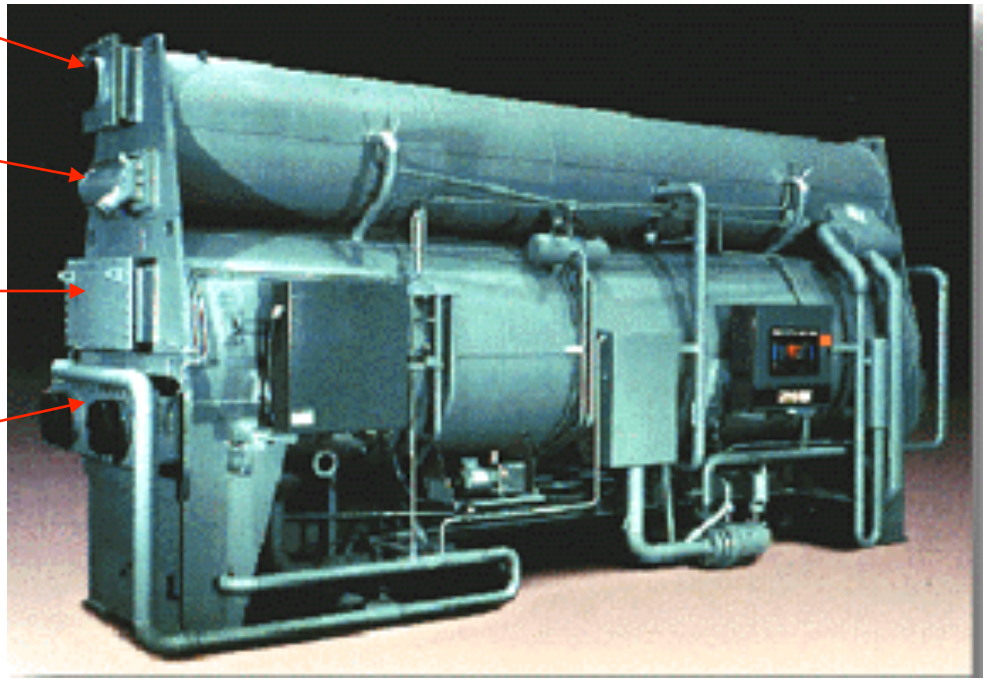
Single Stage Absorber

Condenser

Generator

Evaporator

Absorber



Generator

- Concentrates weak lithium bromide solution by boiling off refrigerant (water).

- Can be fired by either steam or hot water.

Absorber

- Absorbs refrigerant vapor from the evaporator. In the process, the concentration of the solution is decreased (more water). The weight of the solution increases due to mass transfer.
- Three forms of heat must be removed from the absorber section. This heat is removed by the tower water.
  - Sensible Heat - Heat necessary to lower the temperature and vapor pressure of the solution below that of the refrigerant vapor vapor pressure.
  - Latent Heat of Condensation - Heat necessary to change refrigerant from a vapor to liquid.

Absorber (Cont.)

- Heat of Absorption (Dilution) - Heat generated during the absorption process. Heat is given off as the solution is diluted.

  Absorption process will cease if the above heat is not removed.

Absorber (Cont.)

The absorption rate increases with an

- Increase in solution concentration
- Decrease in solution temperature

In both instances, the vapor pressure of the solution is lowered.

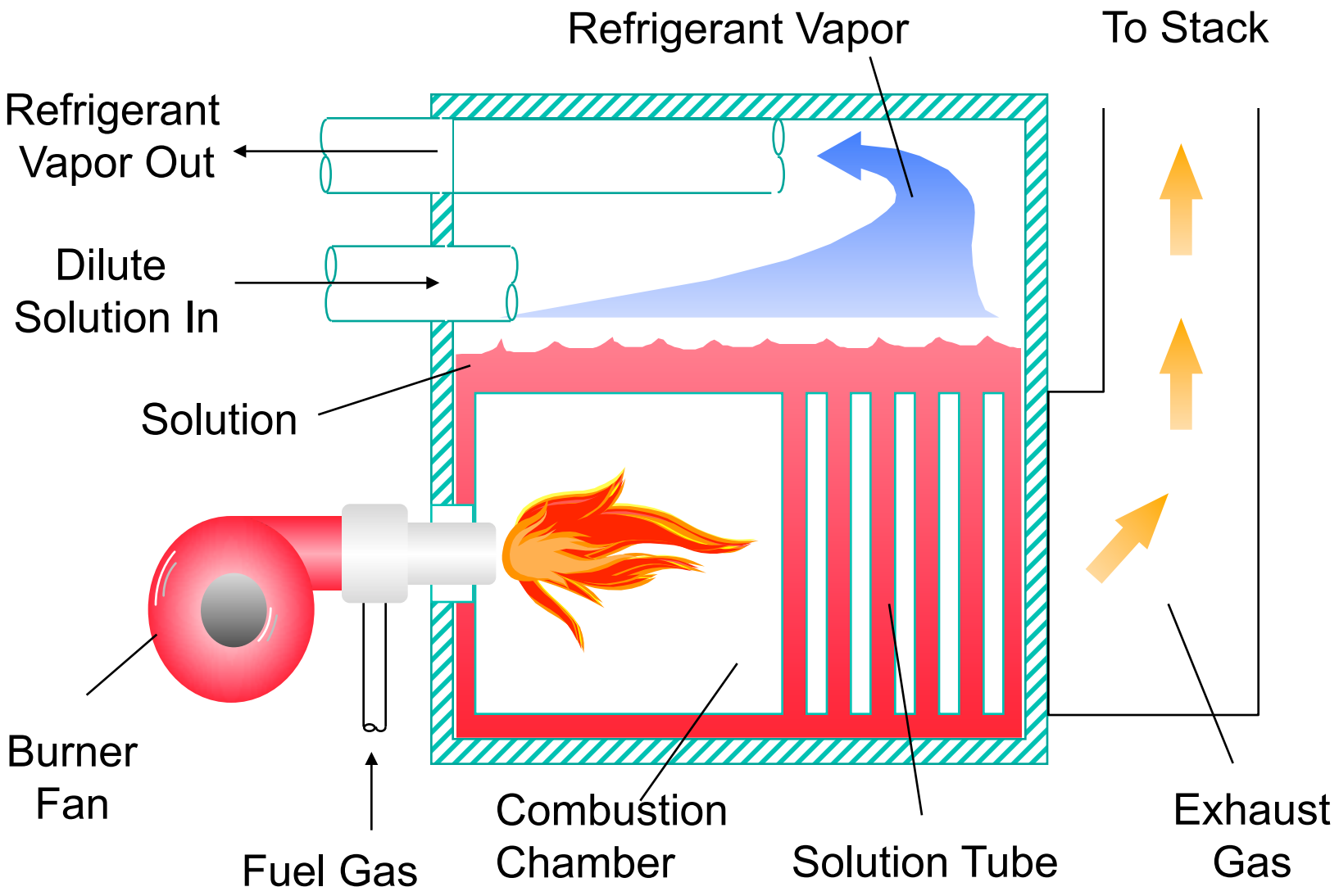
Condenser

- Removes sufficient heat to condense refrigerant vapor coming from the generator.
- Heat is removed by the tower (cooling) water
- Tower water flows in series; 1st through the absorber tube bundle and then through the condenser

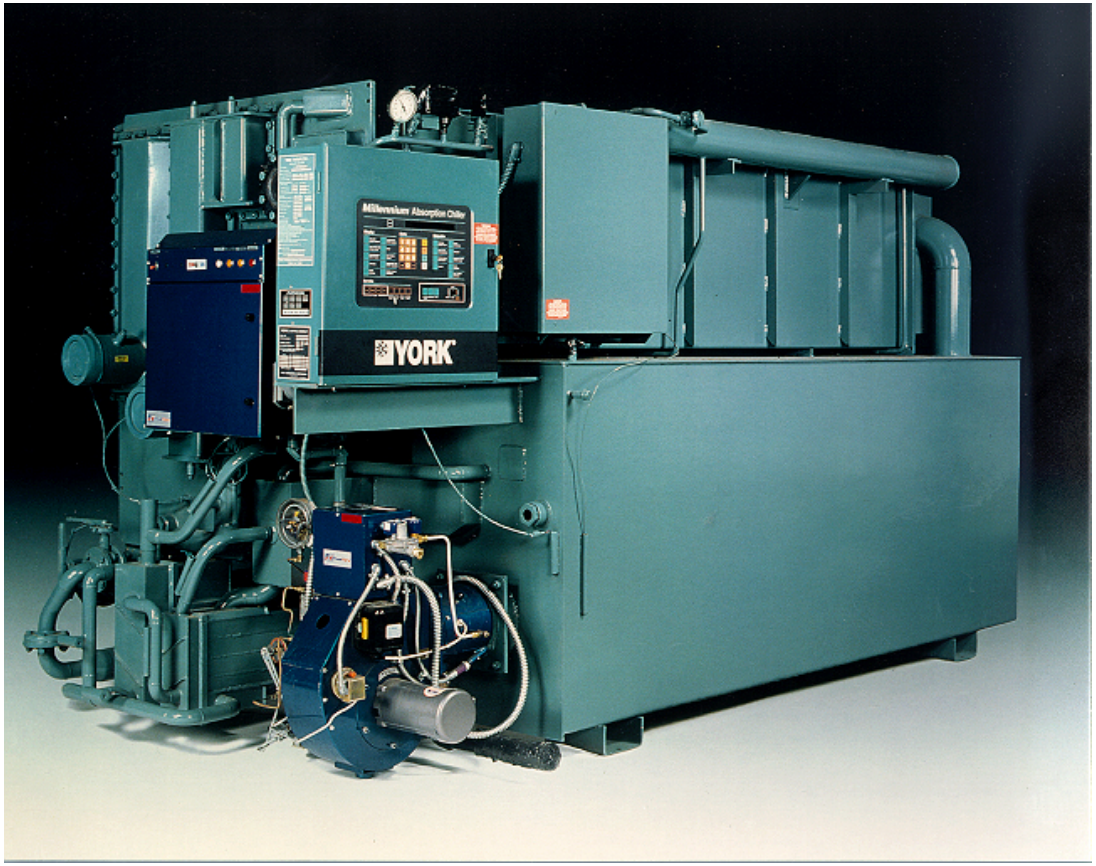
Evaporator

- Absorbs heat from building chilled water loop
- Spray Type Evaporator

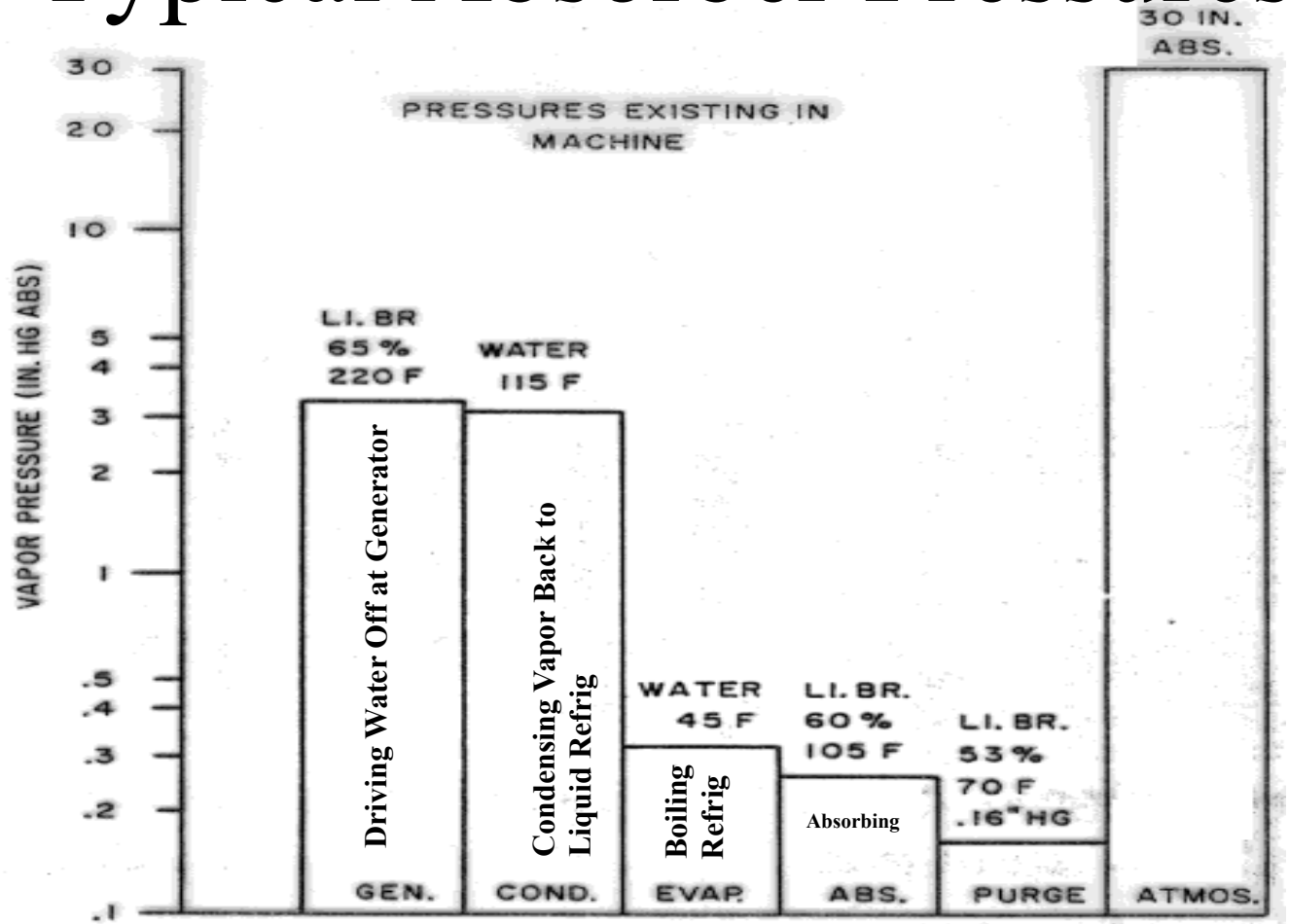
Two-Stage Direct-Fired 1st Stage Generator



Two-Stage Absorber



Typical Absorber Pressures



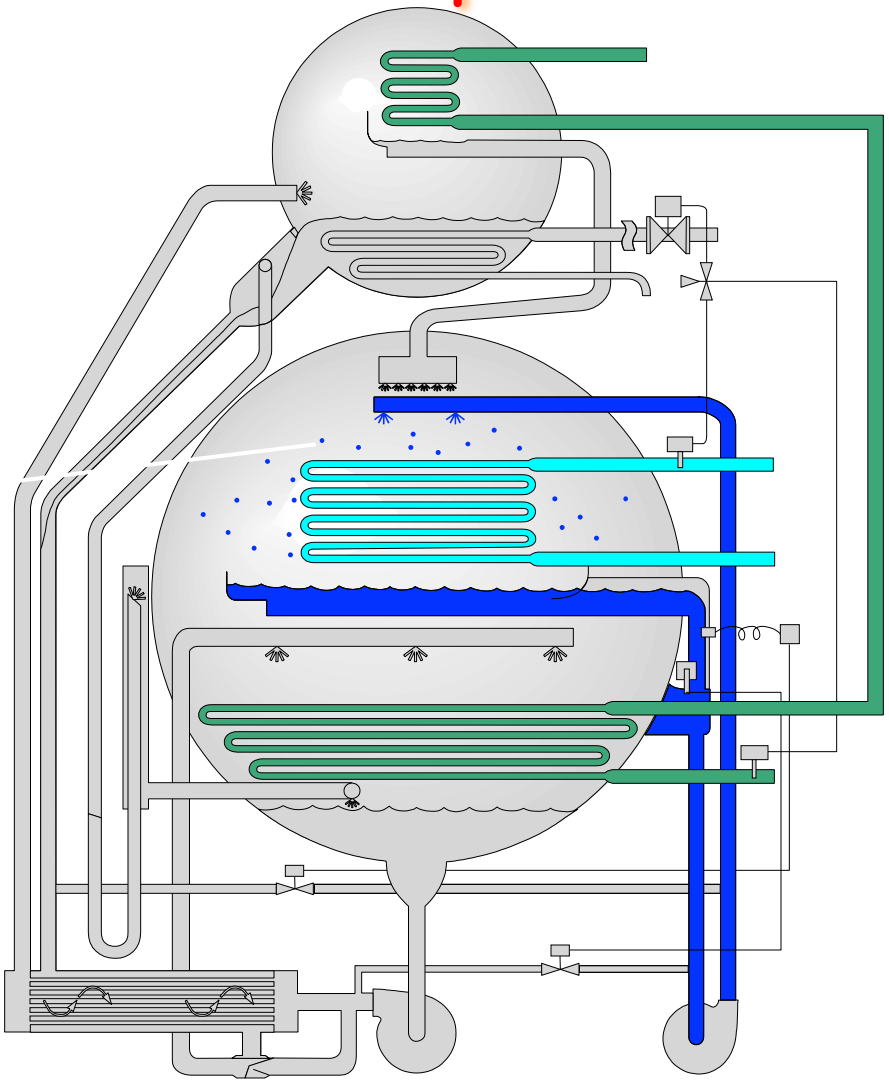
NOTE: Absorption machine at full load, using lithium bromide as absorbent.

— Pressures and Temperatures of a Typical Absorption Machine


Heat Source In
Generator
Evaporator
Out
Chilled Water In
Absorber
Tower Water In

YIA: Evaporator

Evaporator



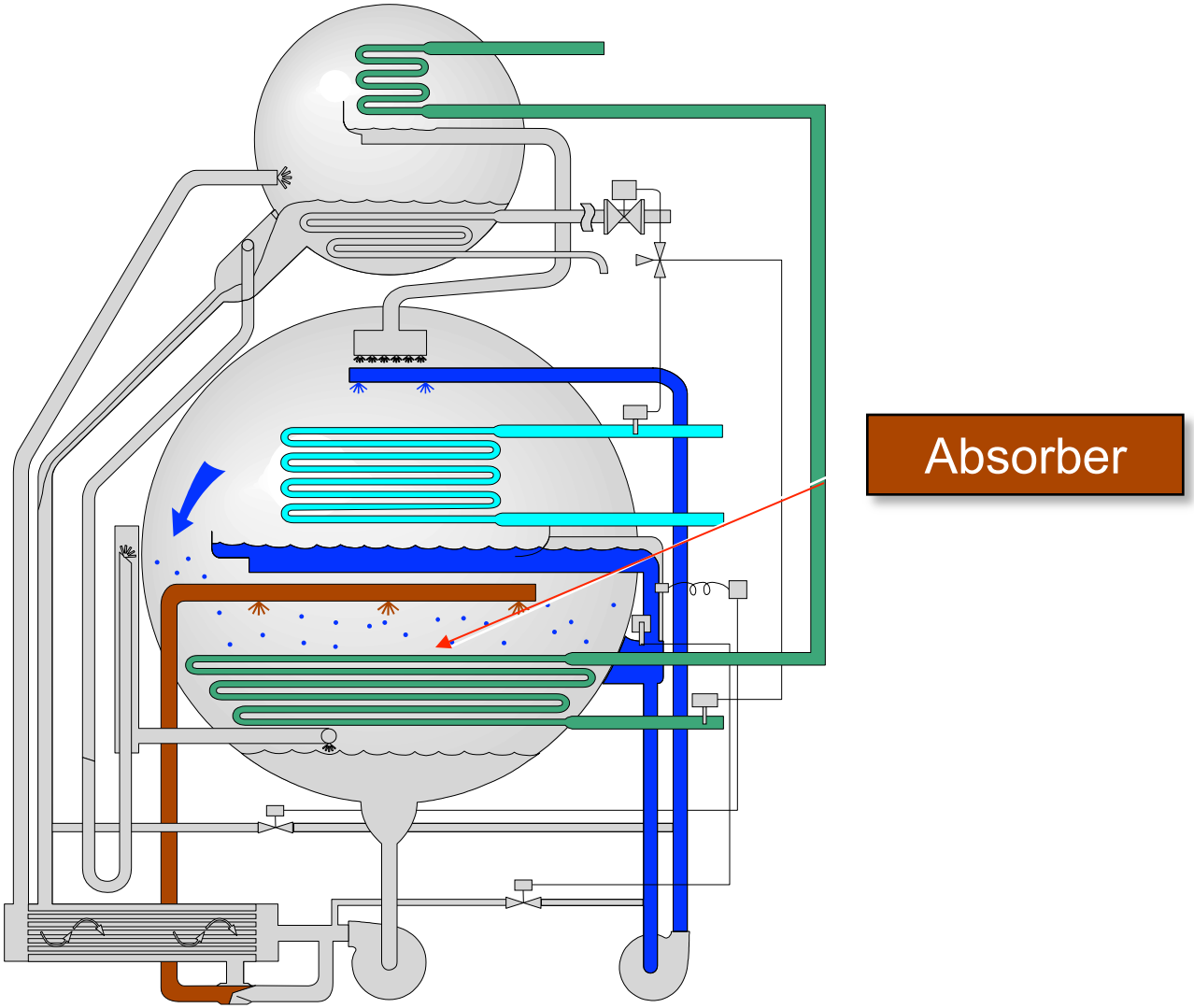

Hole for Spray header
Mist
Eliminators


Spray Header Supports
Evaporator Tray
Refrigerant Outflow Box

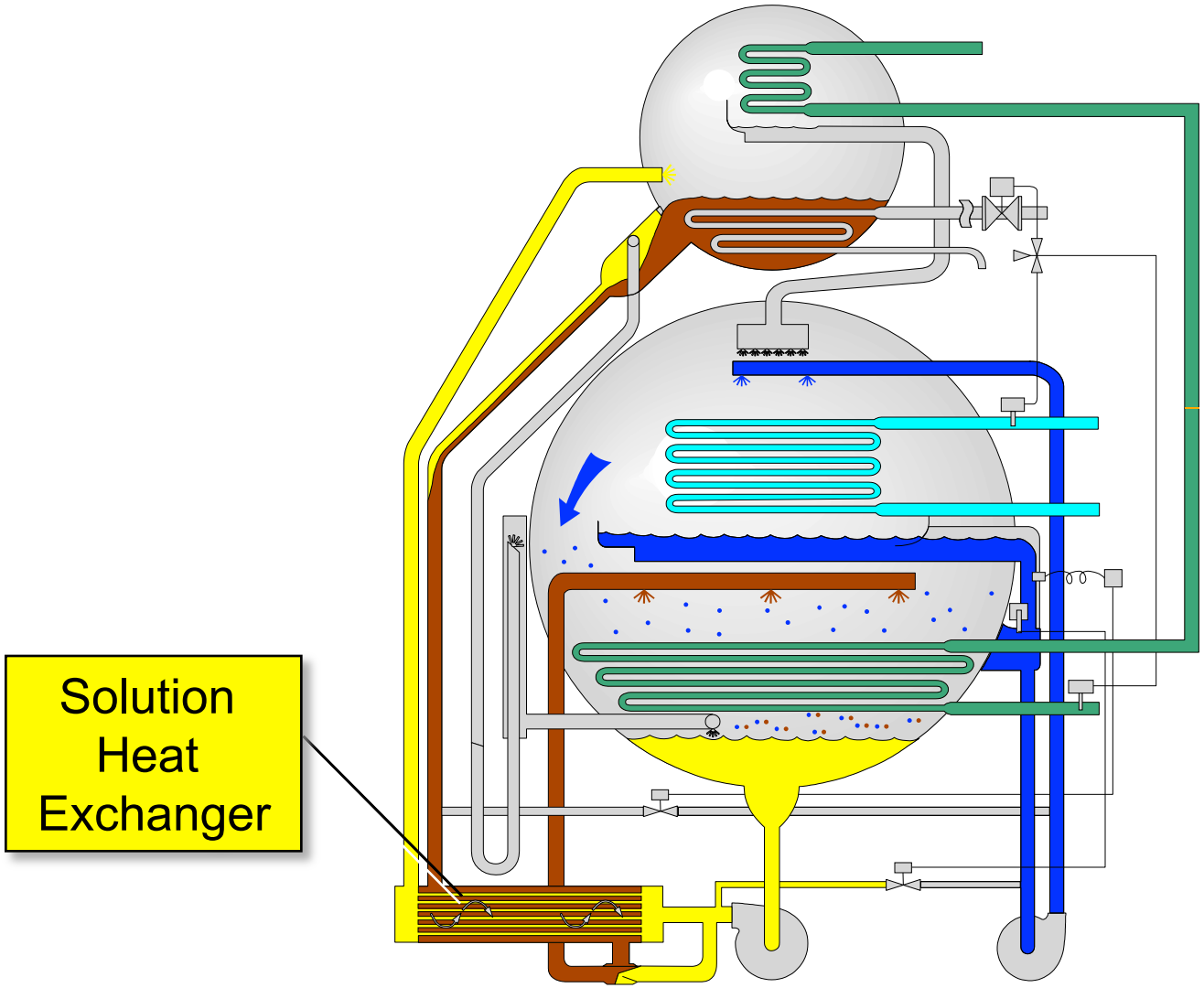

Evaporator Tray showing
outflow

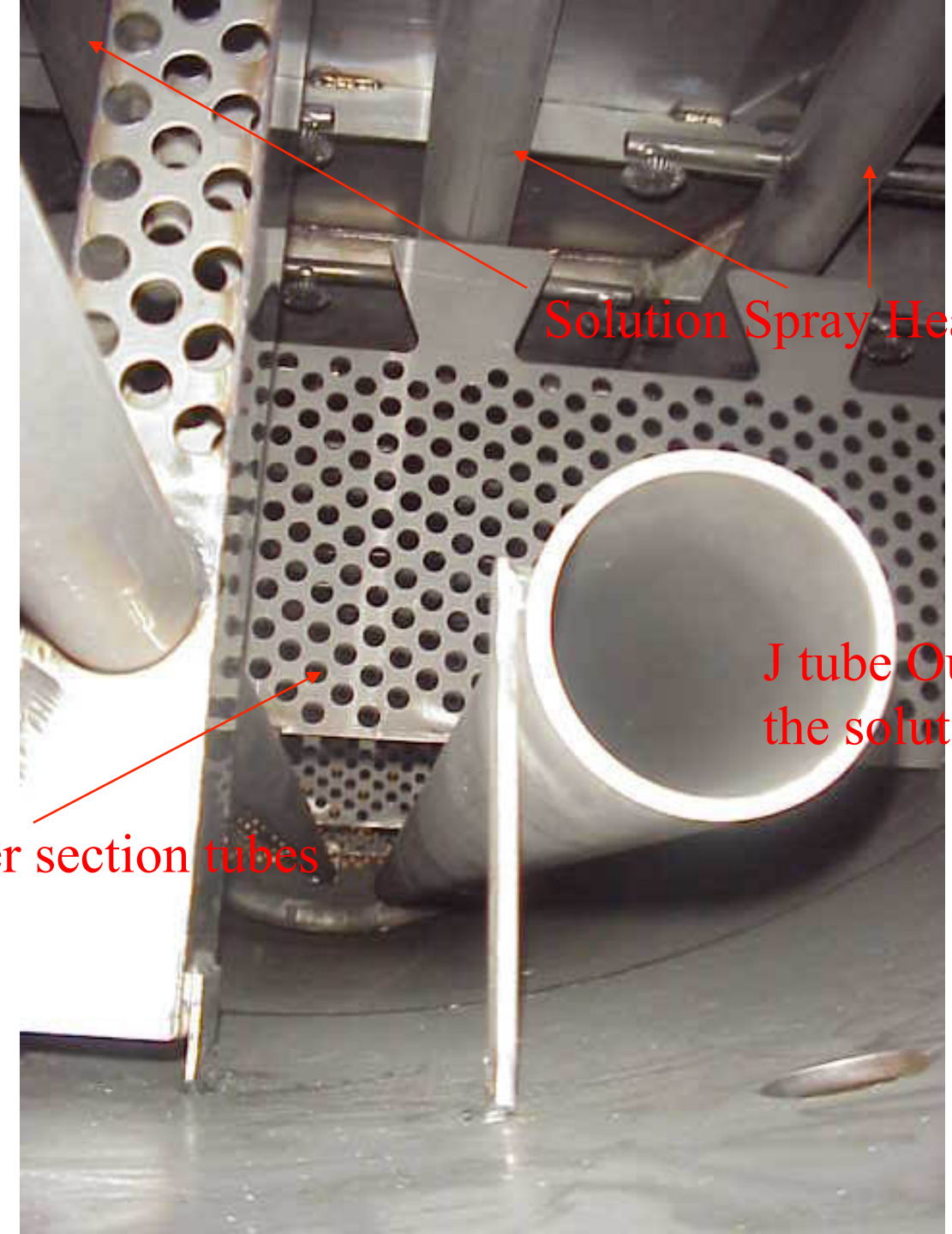

View of Refrigerant Spray Header (Upside Down)
Solution Flow

YIA: Absorber



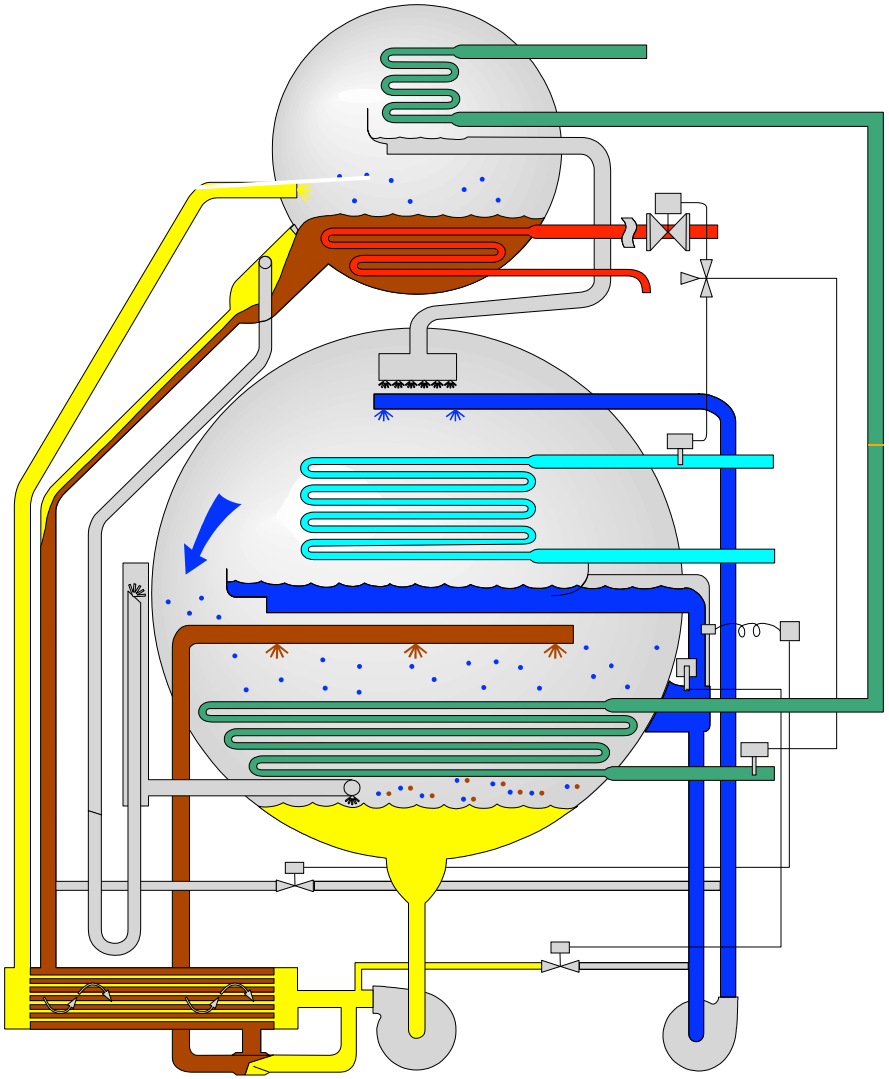
YIA: Solution Heat Exchanger



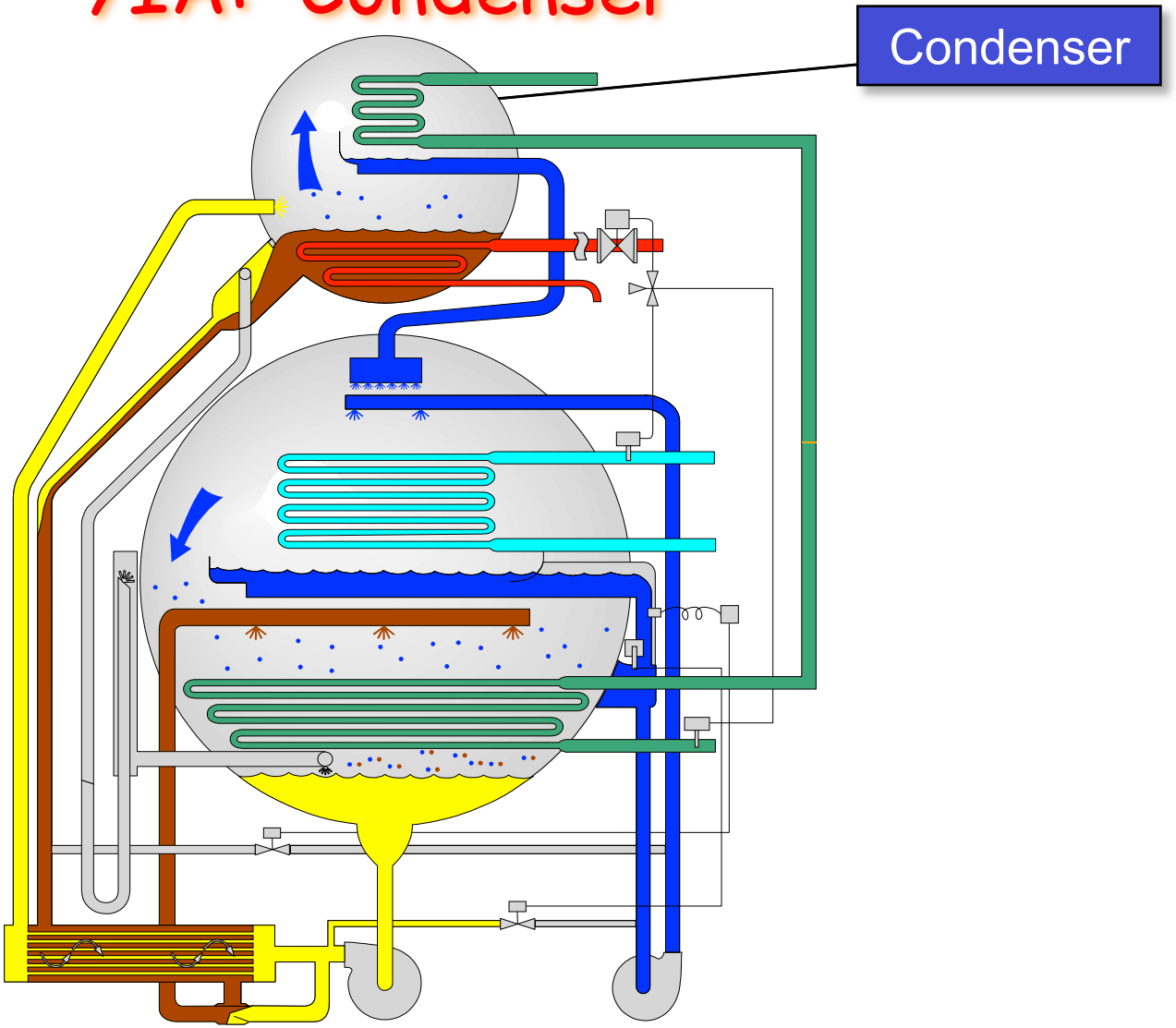

Solution Spray Headers
Purge Suction Header
J tube Out flow into the solution suction
Absorber section tubes

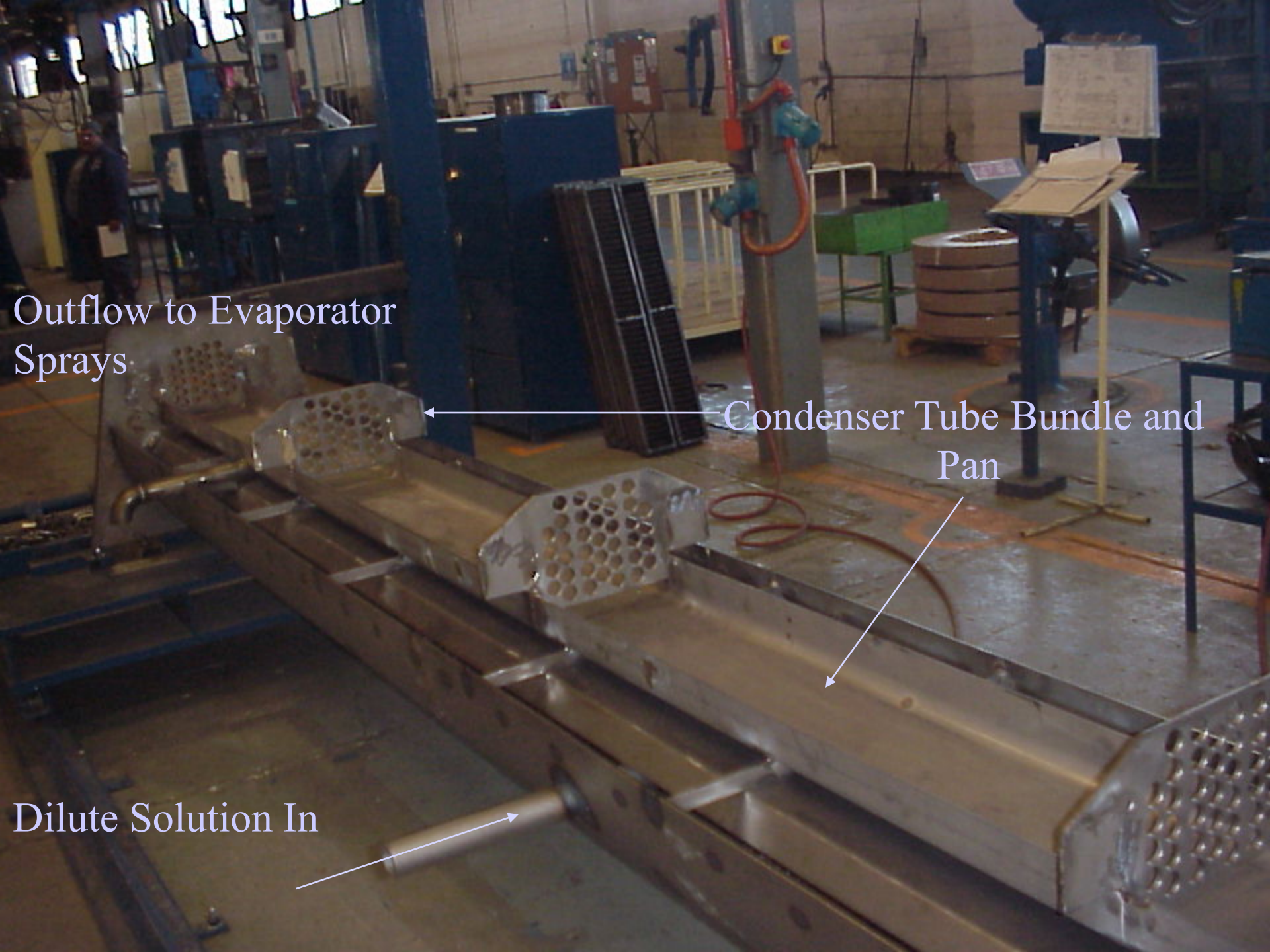
YIA: Generator

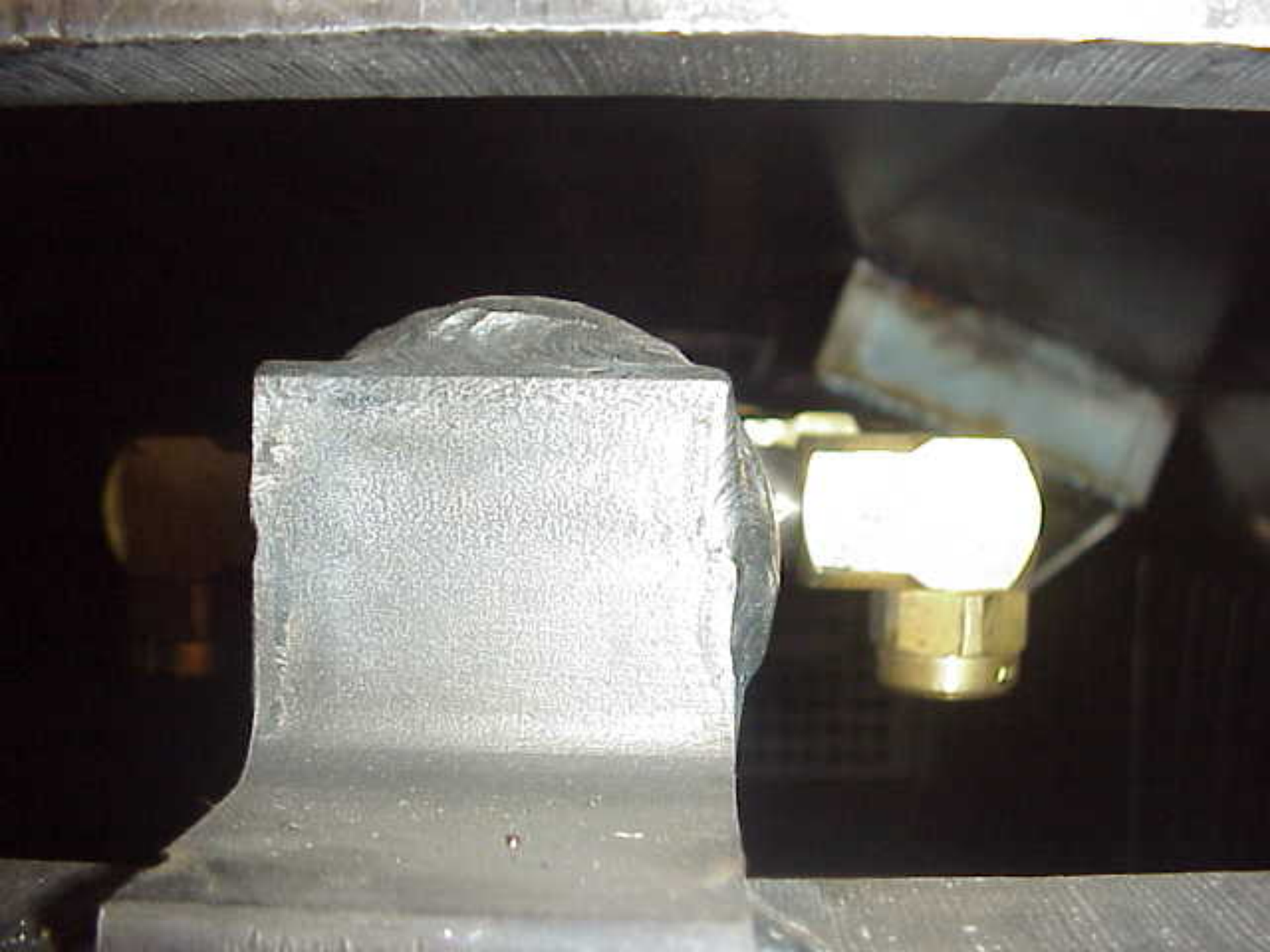
Generator



YIA: Condenser




Outflow to Evaporator Sprays
Condenser Tube Bundle and Pan
Dilute Solution In

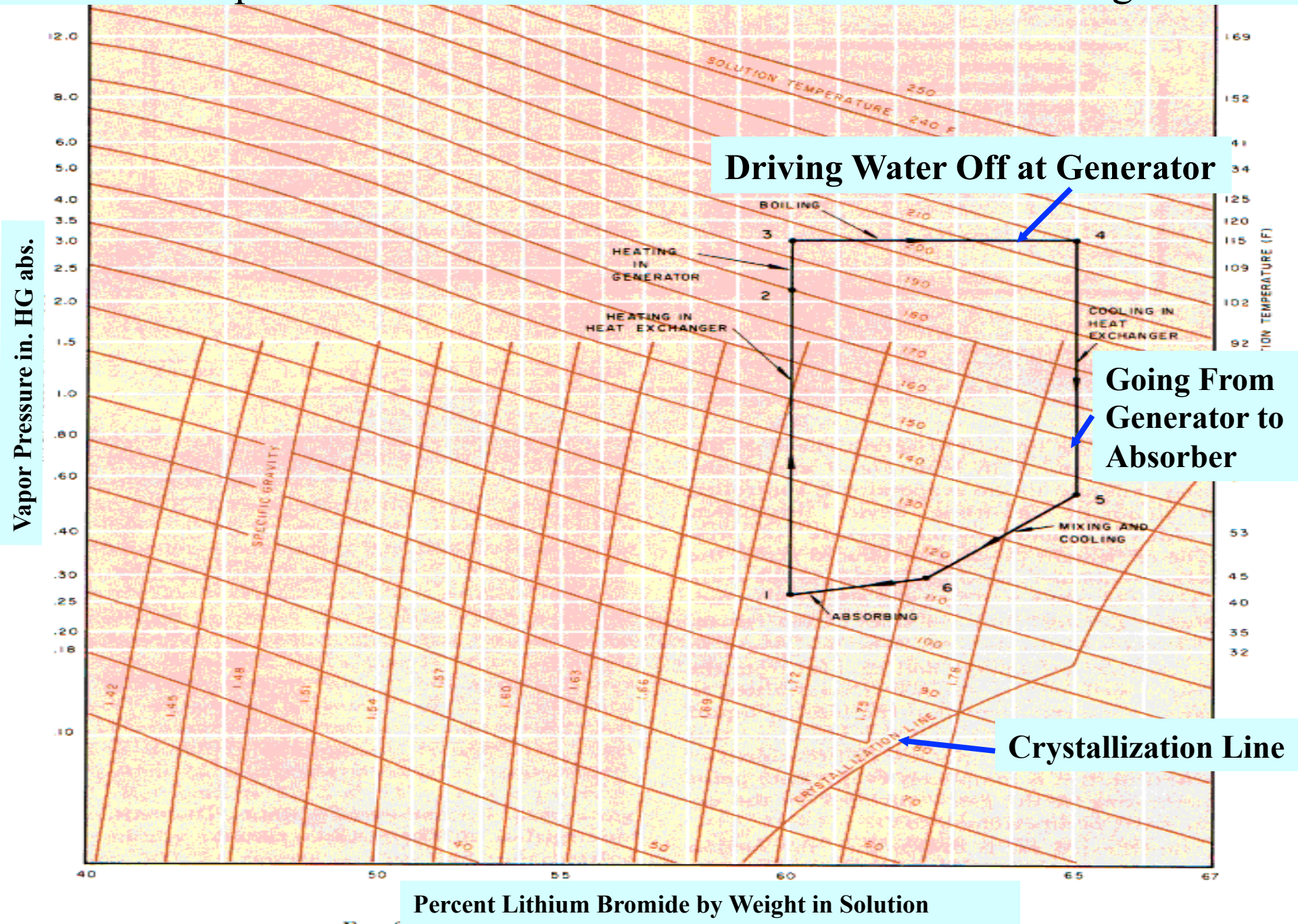



Sections of Condenser

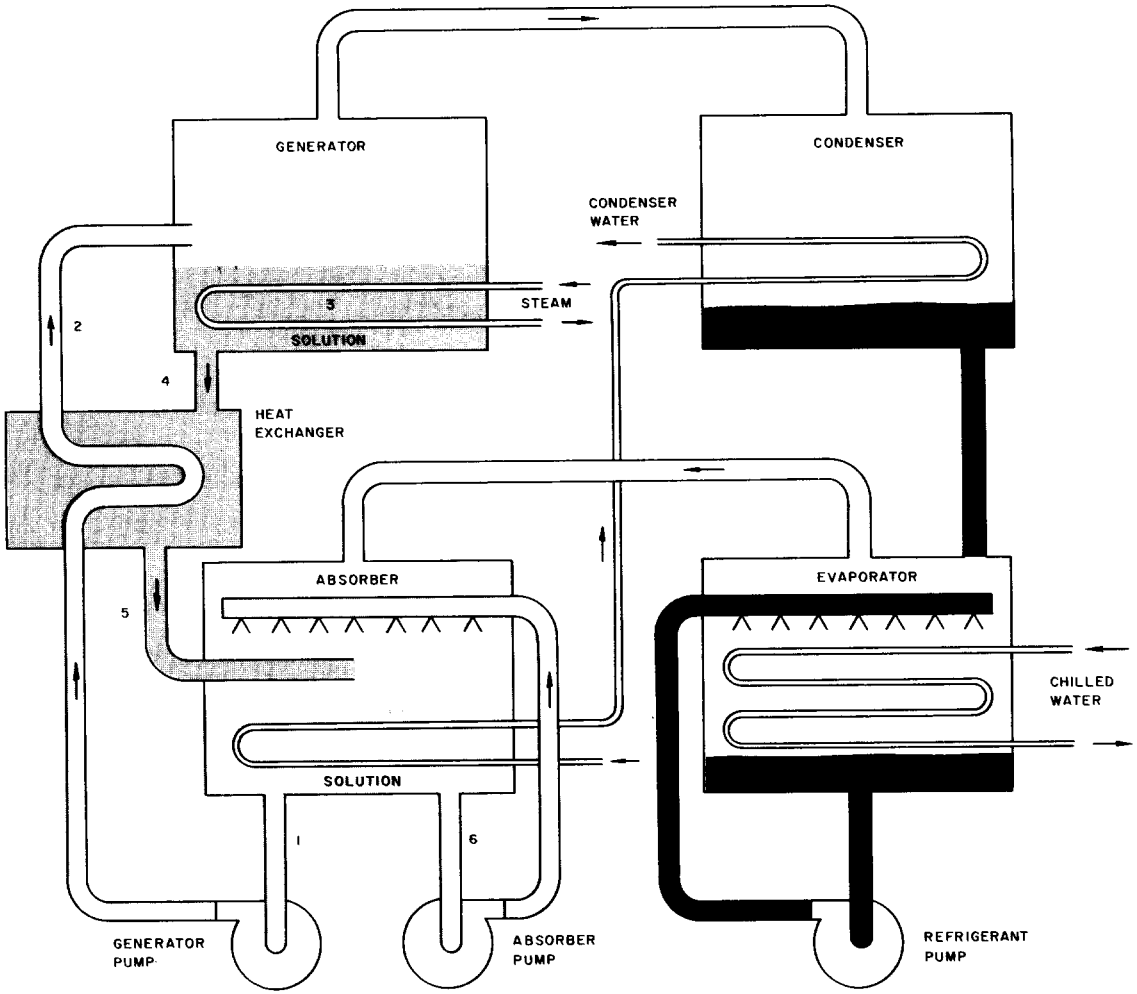
Lithium Bromide

- A brine (salt solution)
- Reactive when combined with oxygen
- Can cause corrosion inside chiller
- Can crystallize when too concentrated

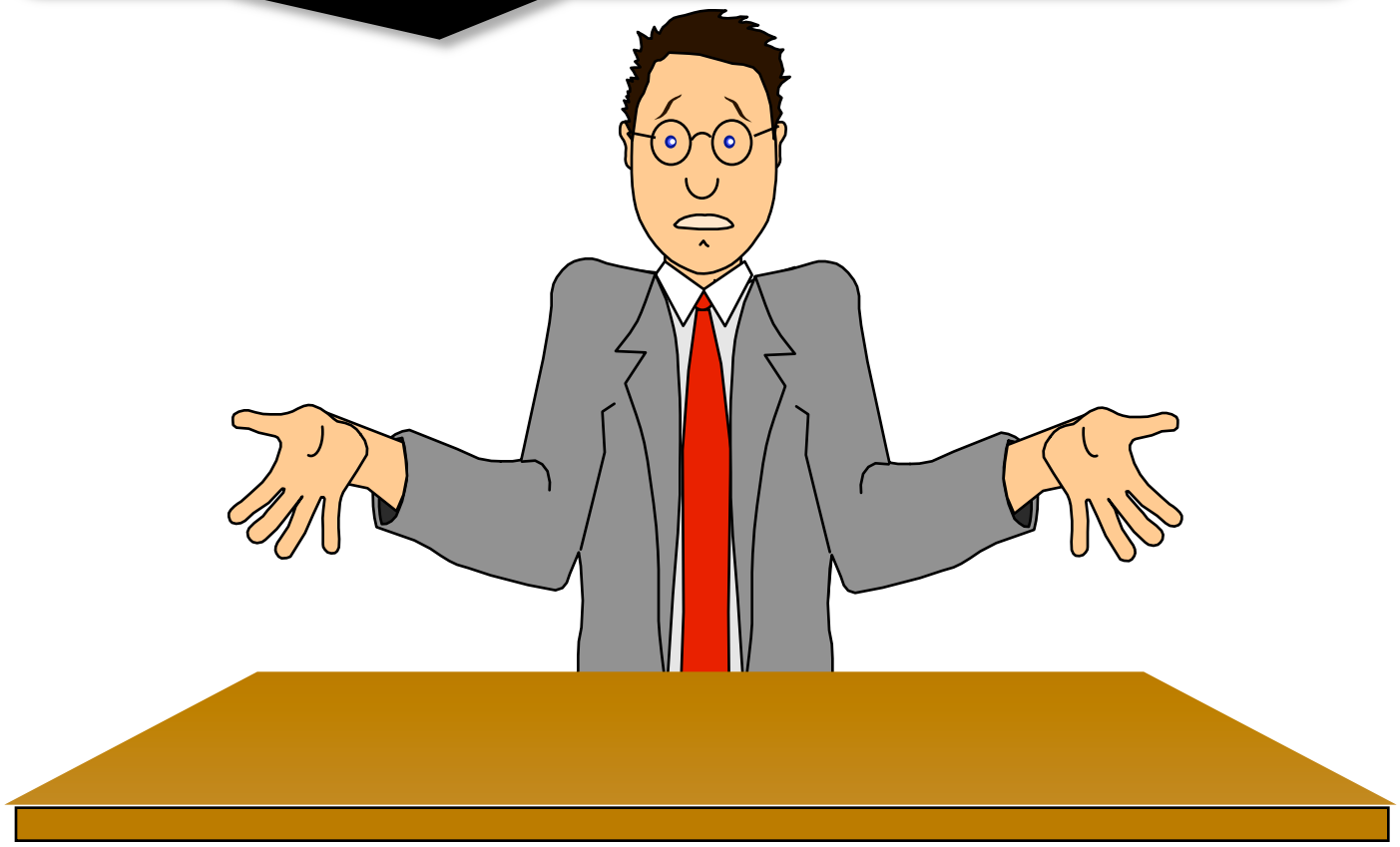
Absorption Process and Lithium Bromide Solution Changes



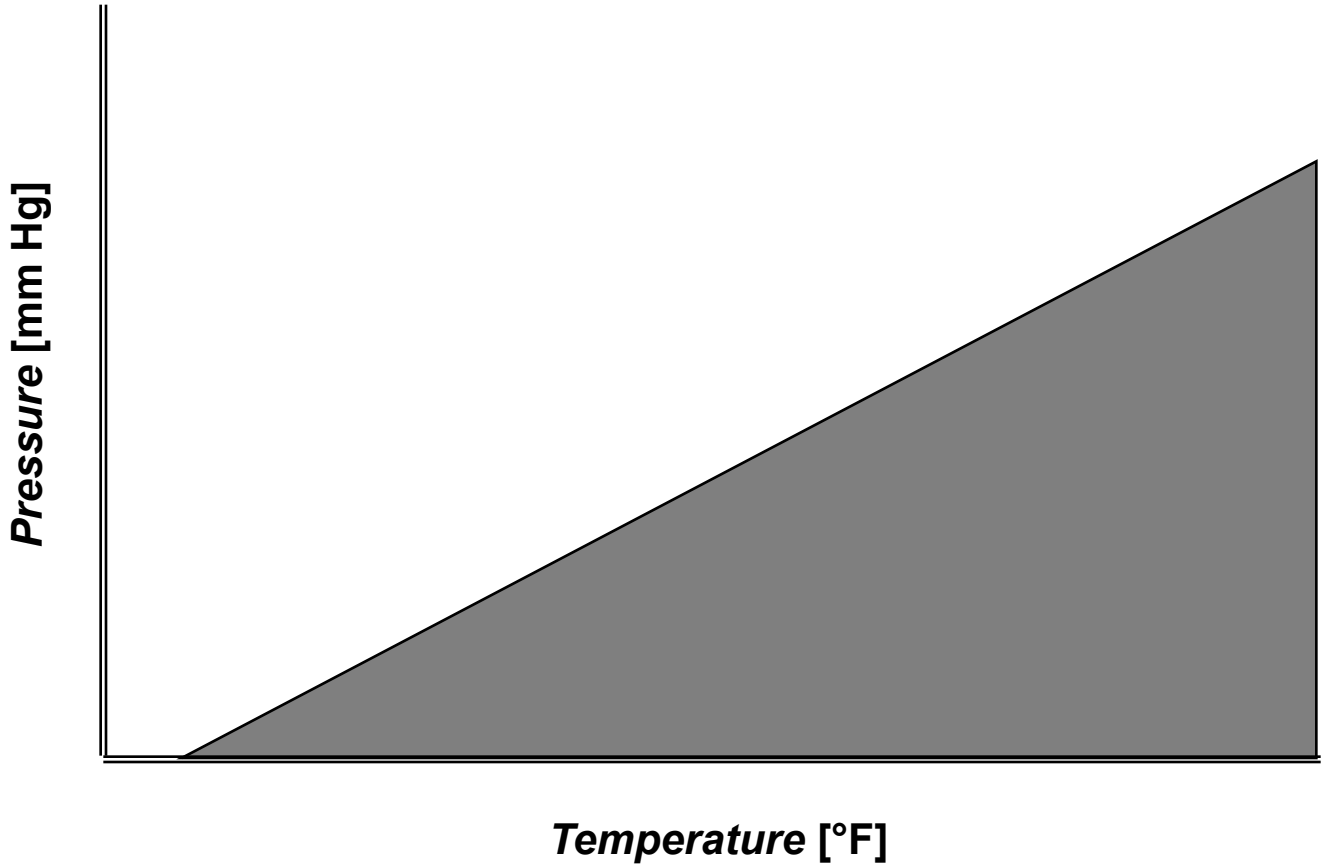
Absorption Cycle



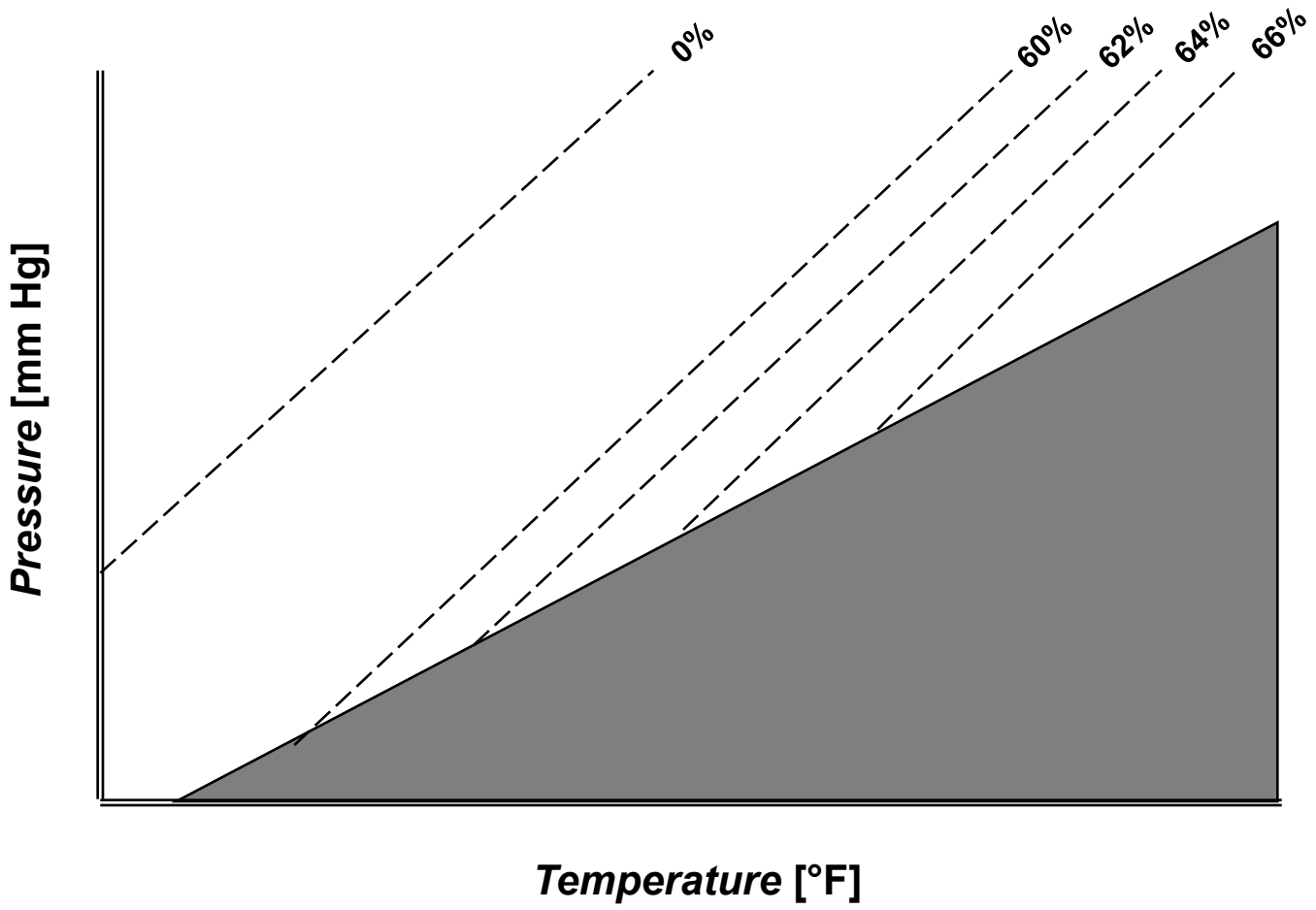
What is crystallization and how does it happen?



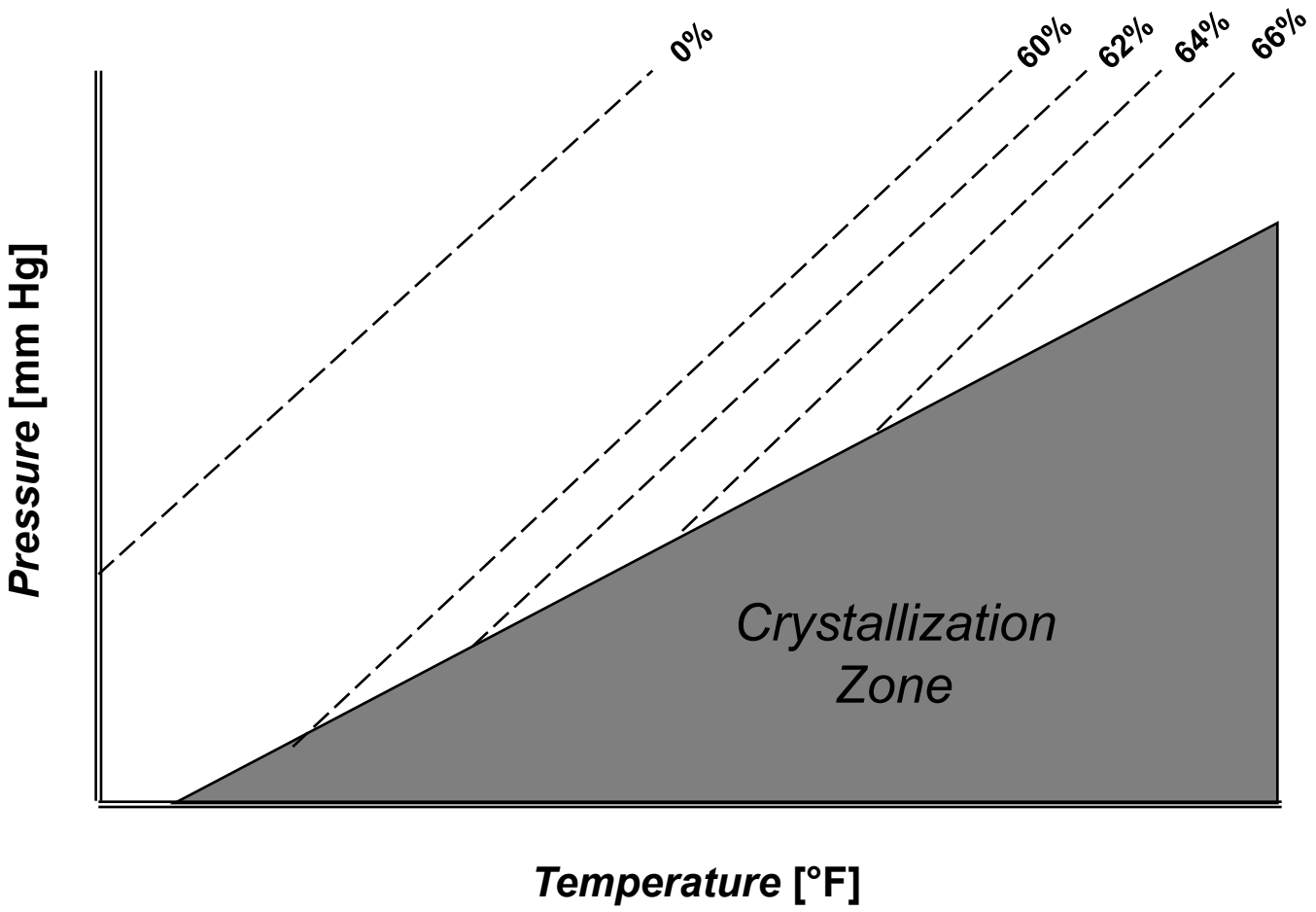
PTX Chart

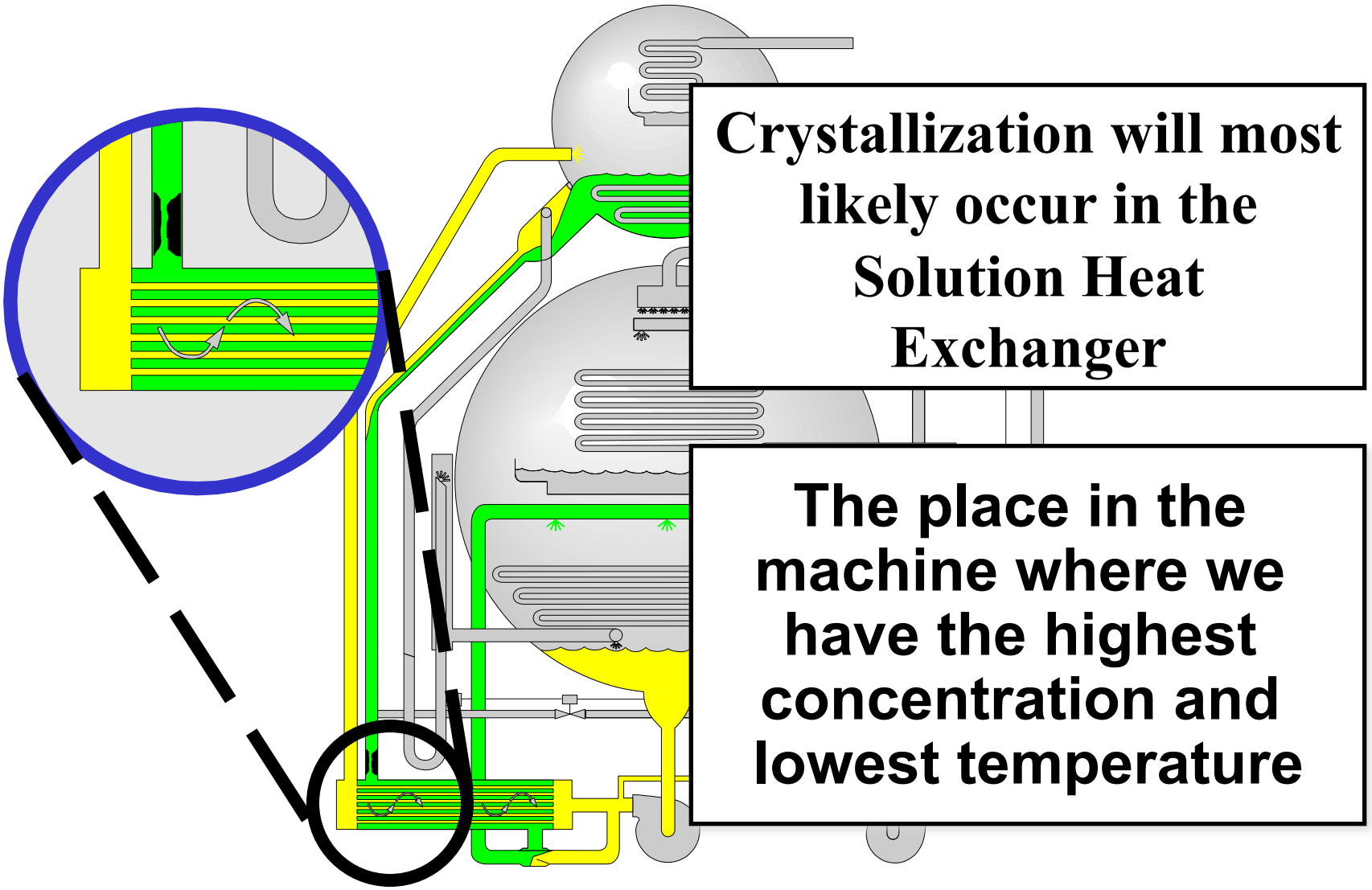


PTX Chart



PTX Chart

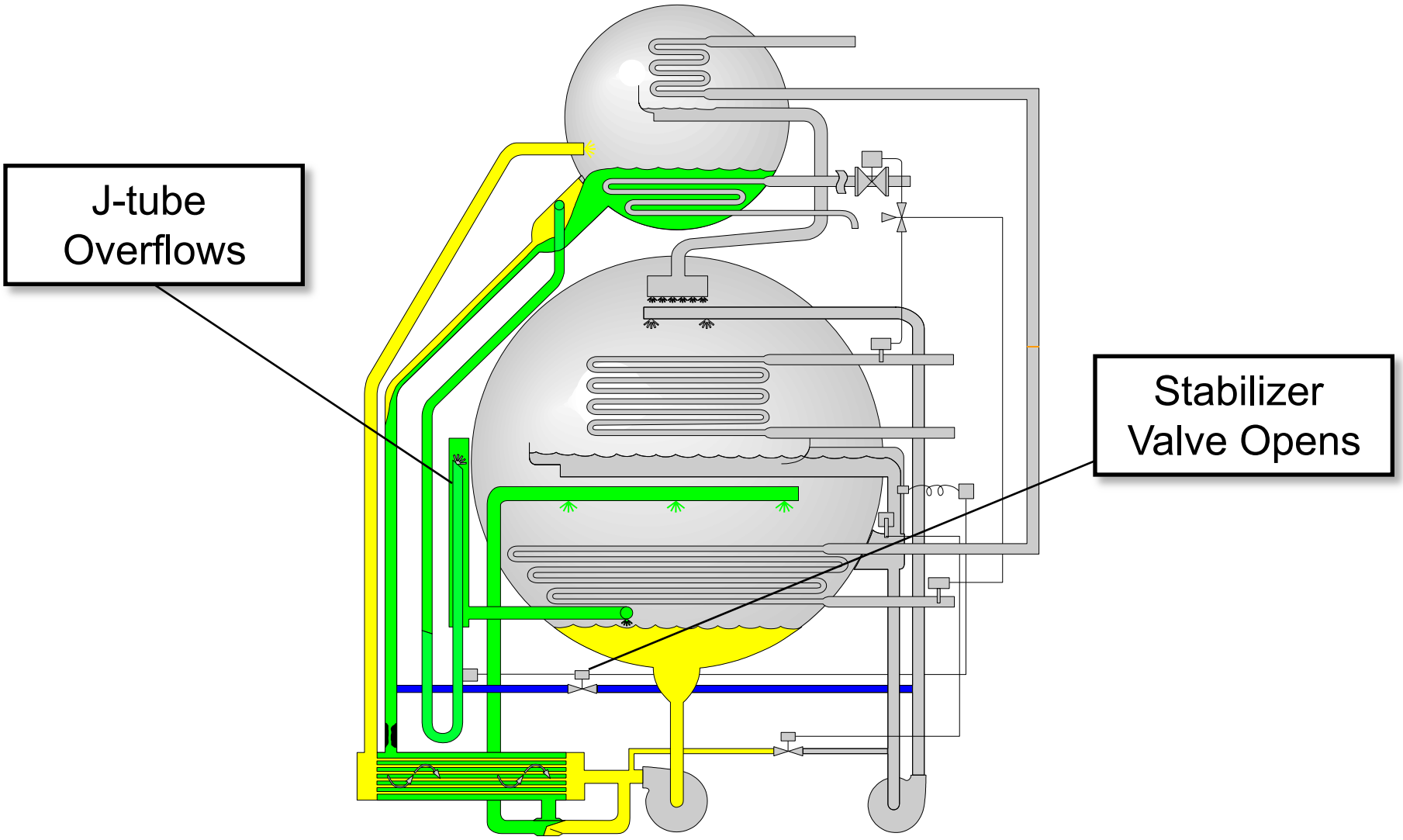

0%
60%
62%
64%
66%
Crystallization Zone
Pressure [mm Hg]
Temperature [°F]



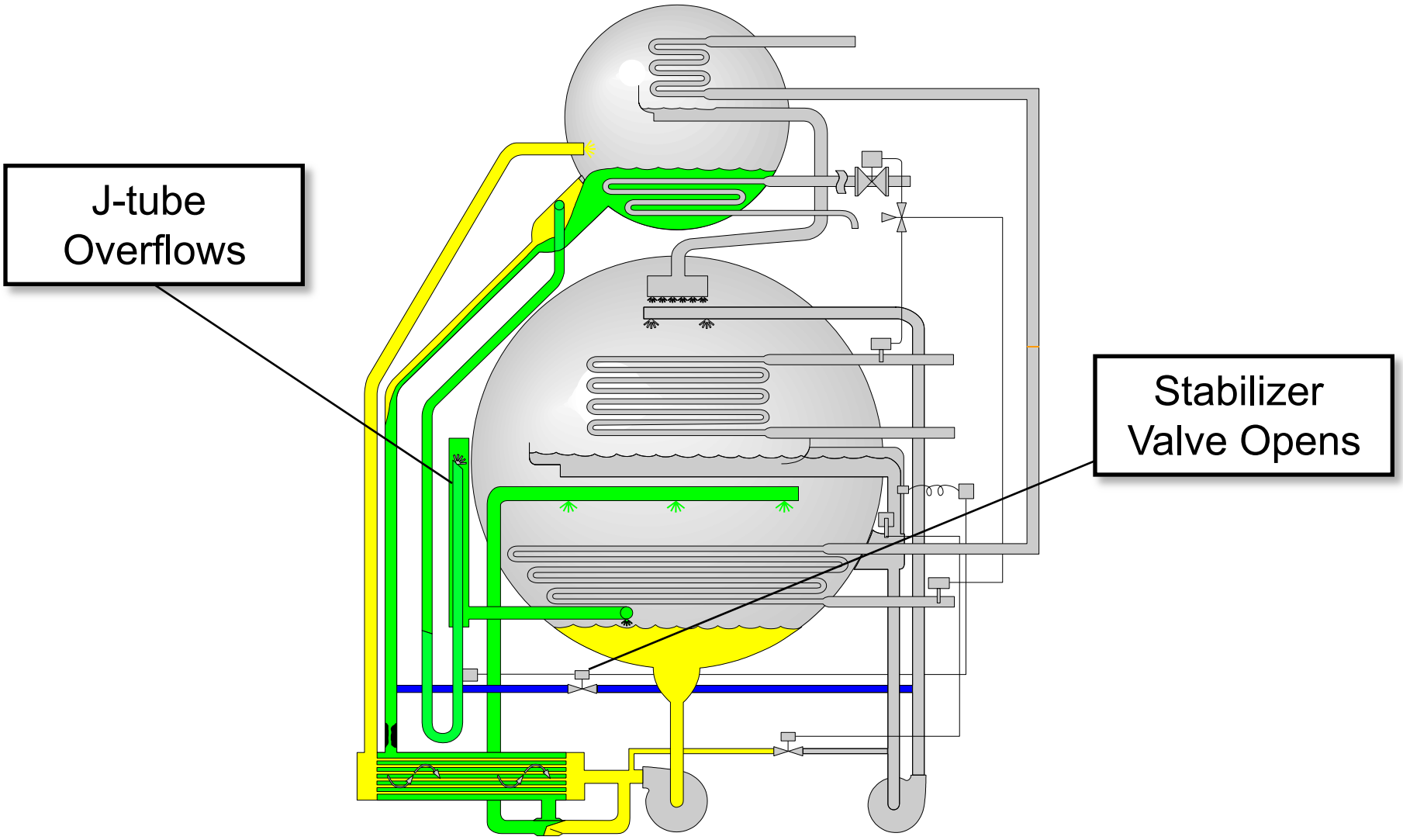
Crystallization will most likely occur in the Solution Heat Exchanger

The place in the machine where we have the highest concentration and lowest temperature

Automatic Decrystallization



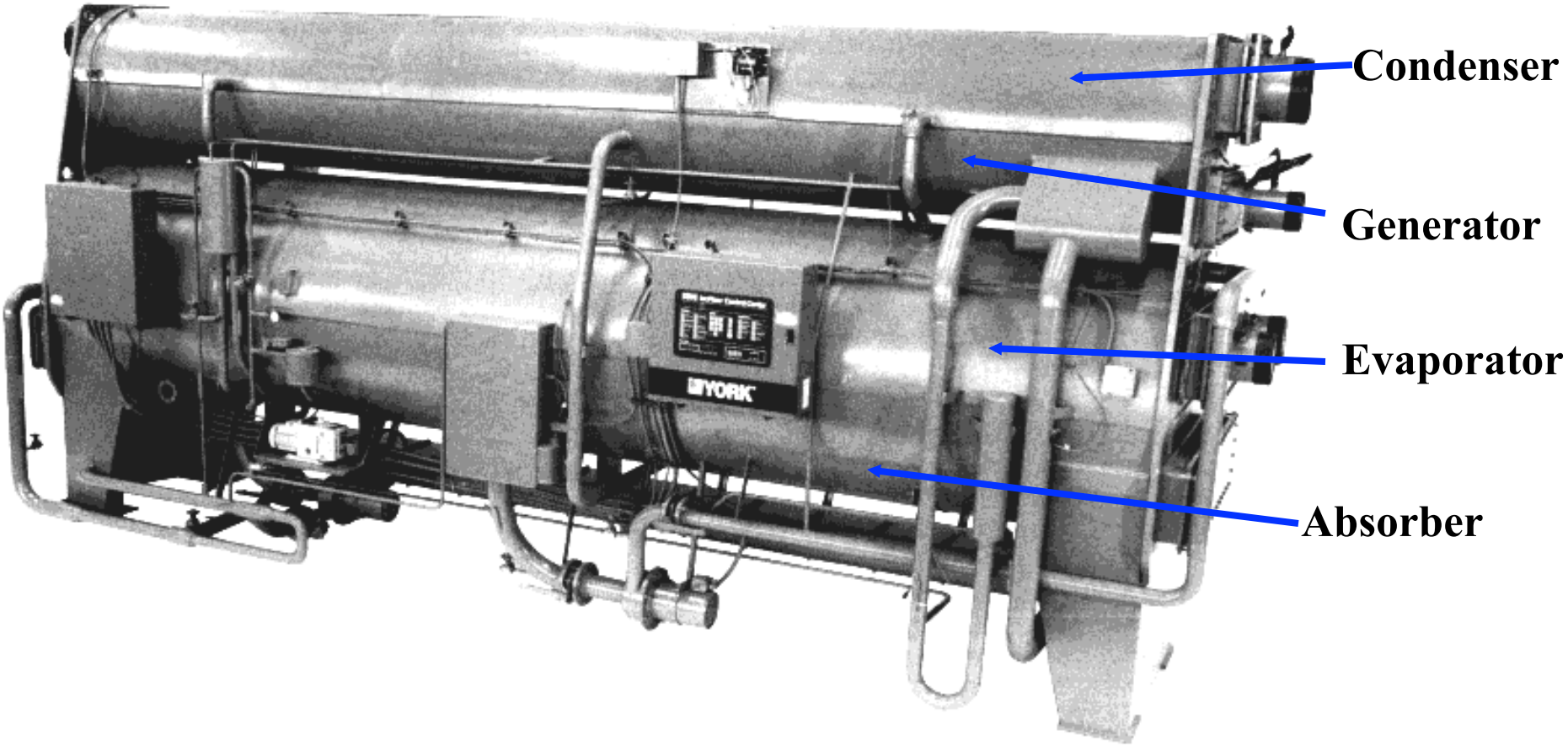
Automatic Decrystallization



Types of Absorption Chillers

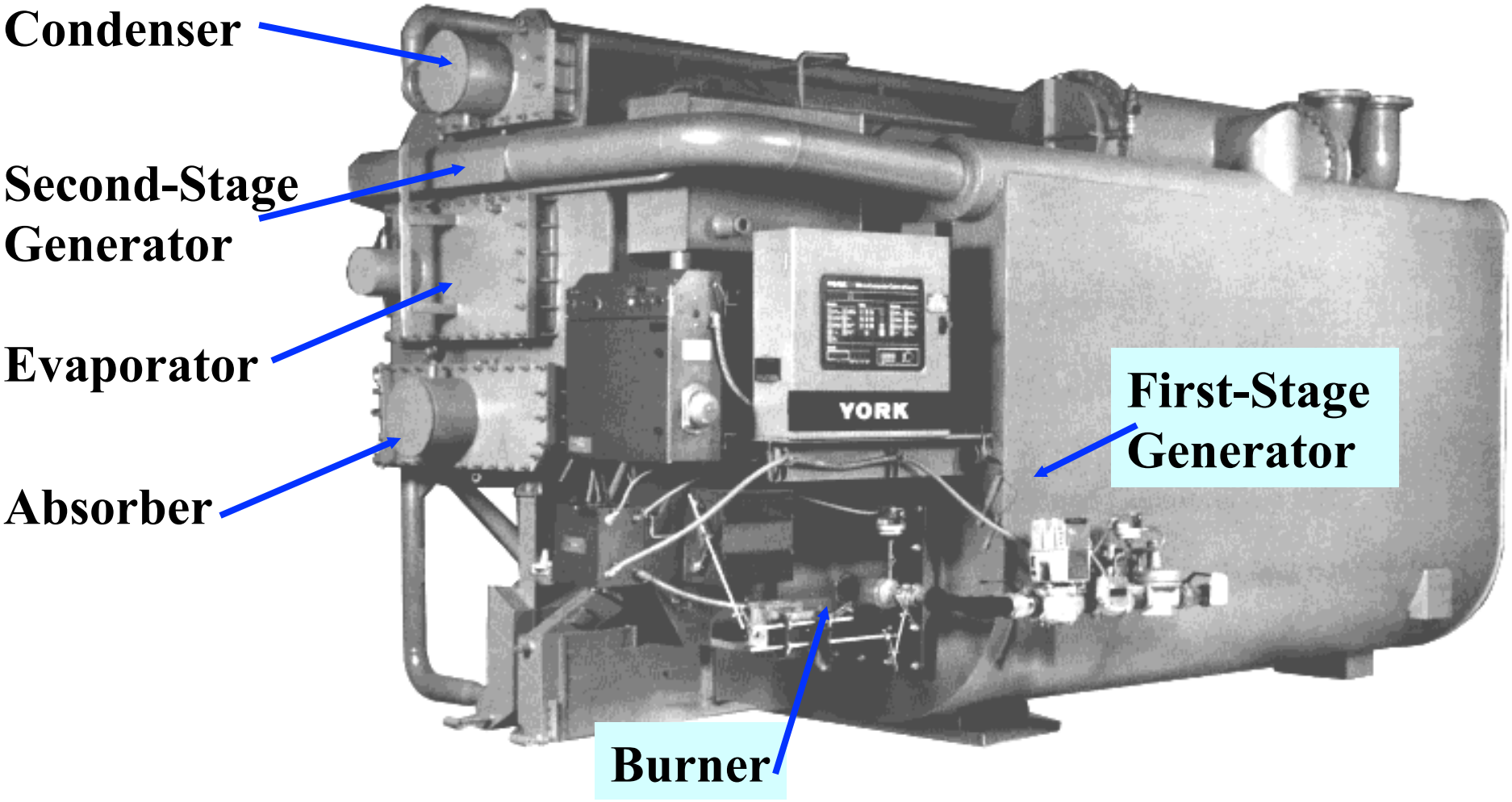
- Single-stage, steam-fired
- Single-stage, hot water-fired
- Two-stage, steam-fired
- Two-stage, natural gas, direct-fired

Single-Stage, Steam-Fired Absorption Chiller (Previously Brand Named "IsoFlow")

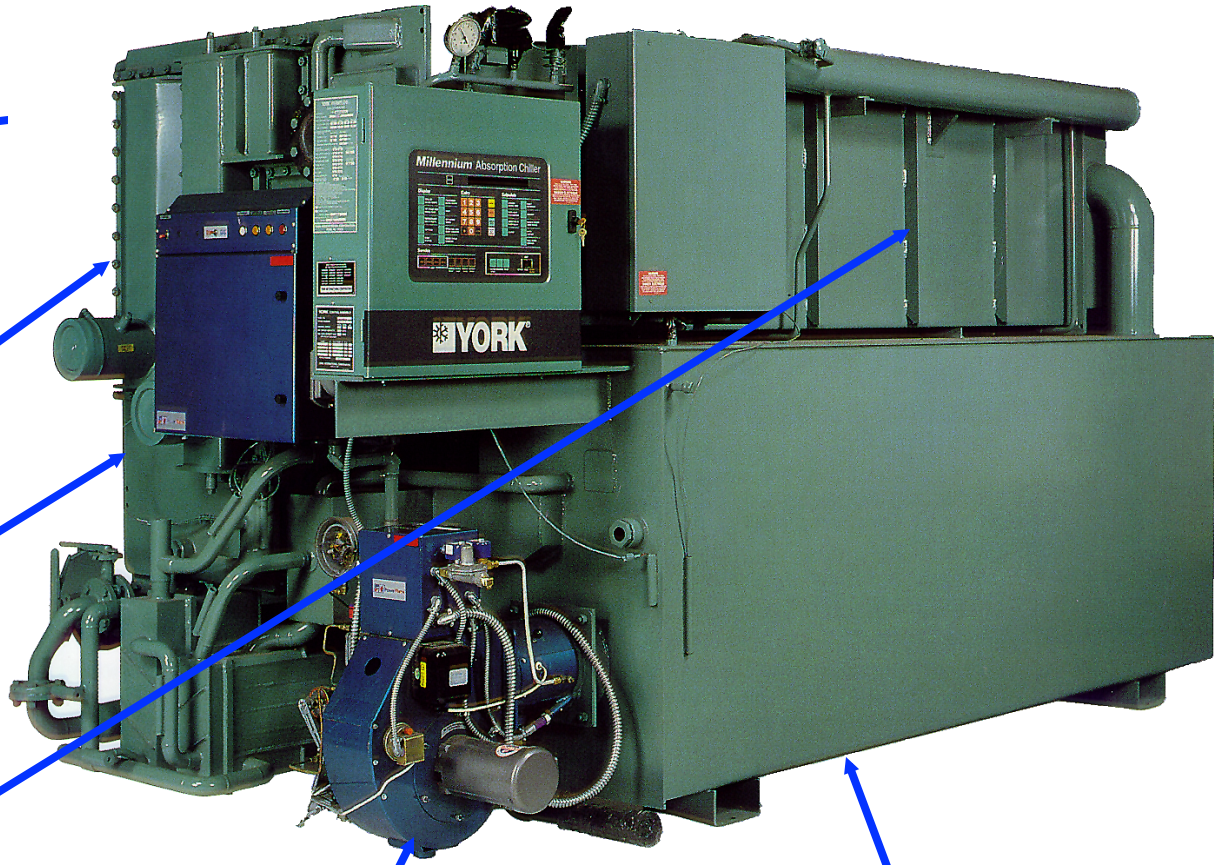


Two-Stage Parallel Flow Absorption Cycle

Two-Stage, Natural Gas, Direct-Fired



Two-Stage, Natural Gas, Direct-Fired (Previously Brand Named "ParaFlow")



Condenser

Evaporator

Absorber

Second-Stage Generator

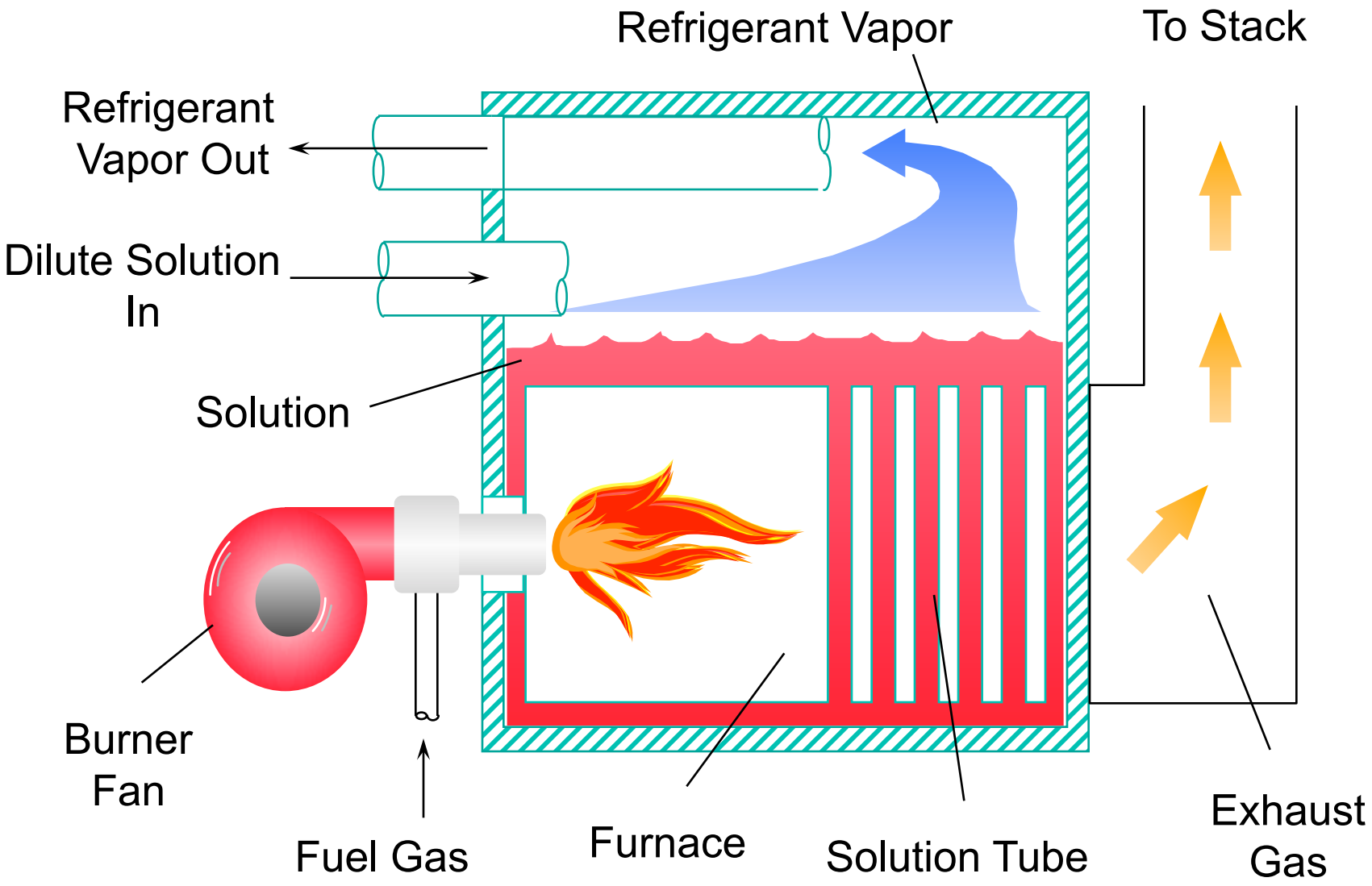
Burner

First-Stage Generator

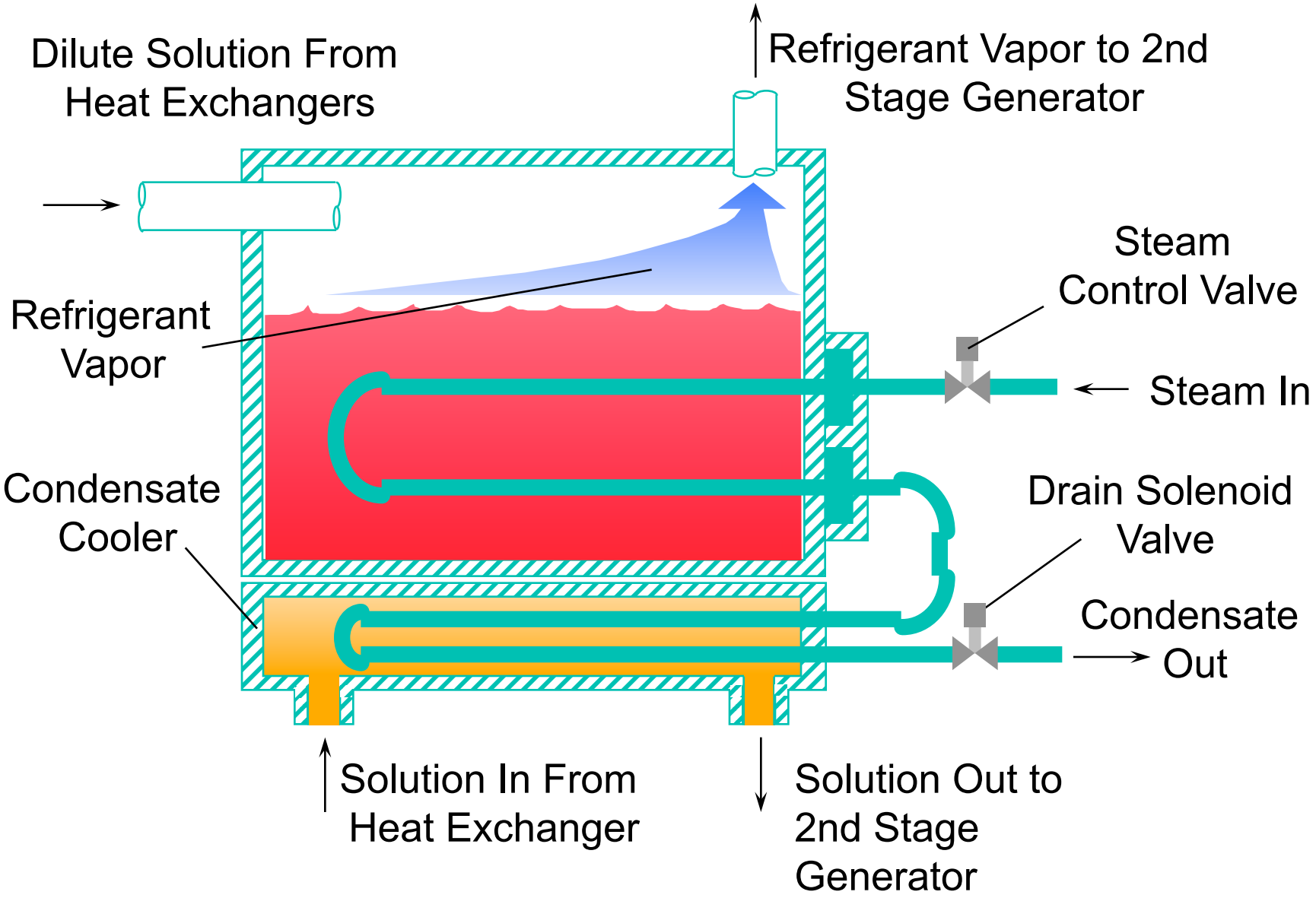

YORK
YORK
USA


P&H

Two Stage Direct Fired 1st Stage Generator



Two Stage Steam Fired 1st Stage Generator



File: CHILLED WATER SYSTEMS EQUIPMENT MANUAL
Absorption Water Cooling Systems Section

Supersedes: Catalog EM-235 revised March 1959
G-12, Form MS40 coded 459

Equip. E & ER(L) - Int.

L FORM MS40
260

FEATURES
DESCRIPTION
SPECIFICATIONS

AIA FILE NO. 30-F-2

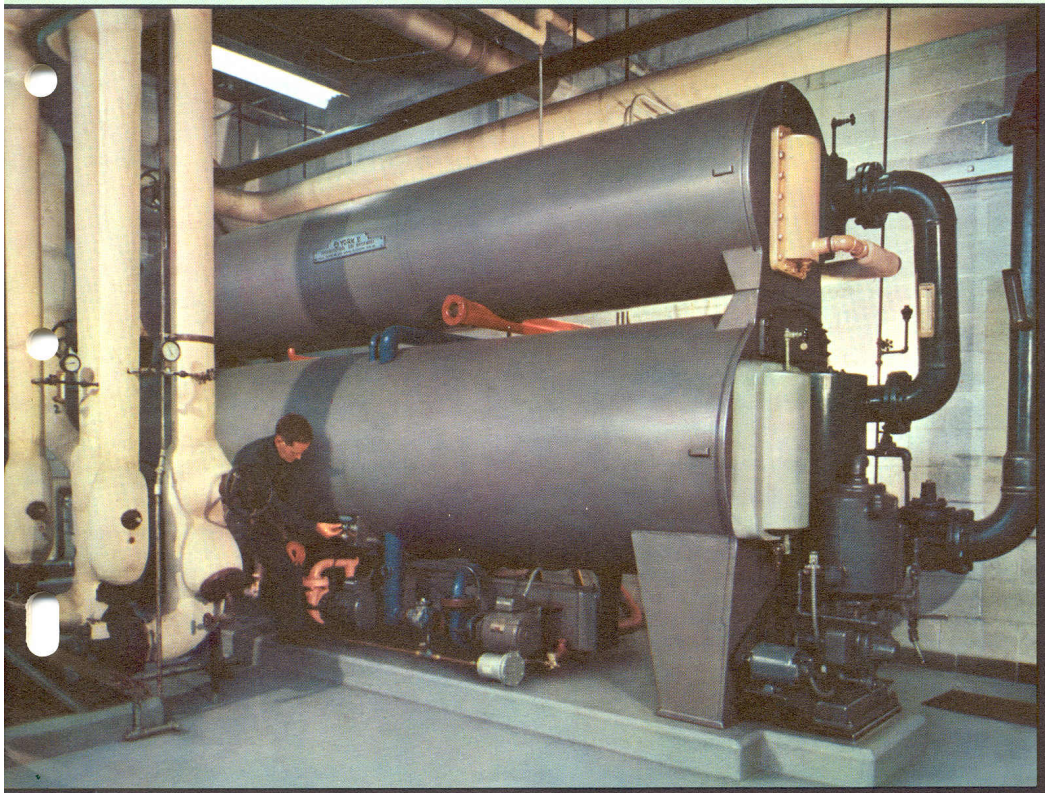
YORK®

ABSORPTION

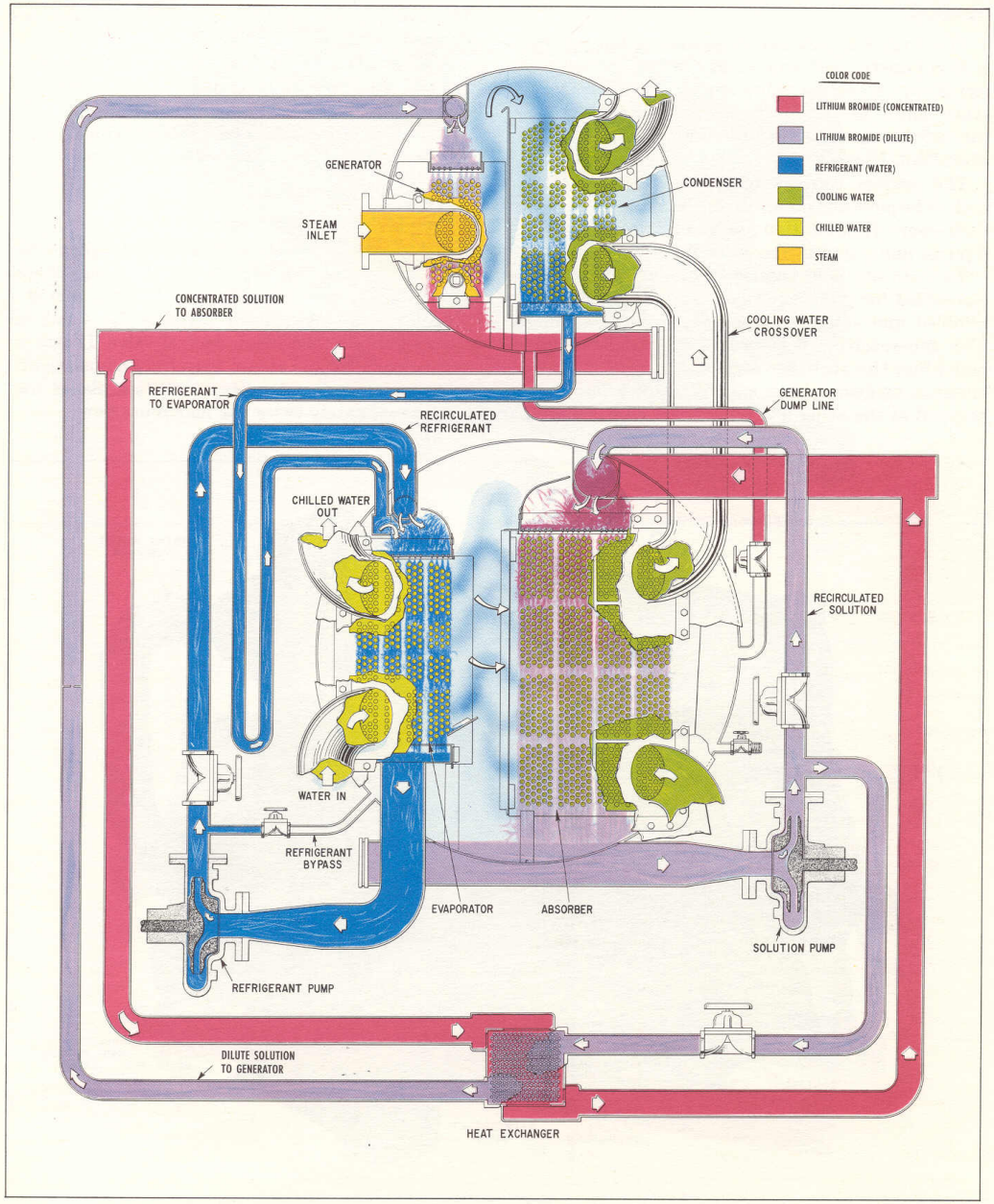
WATER CHILLING SYSTEMS

100 TO 740 TONS CAPACITY

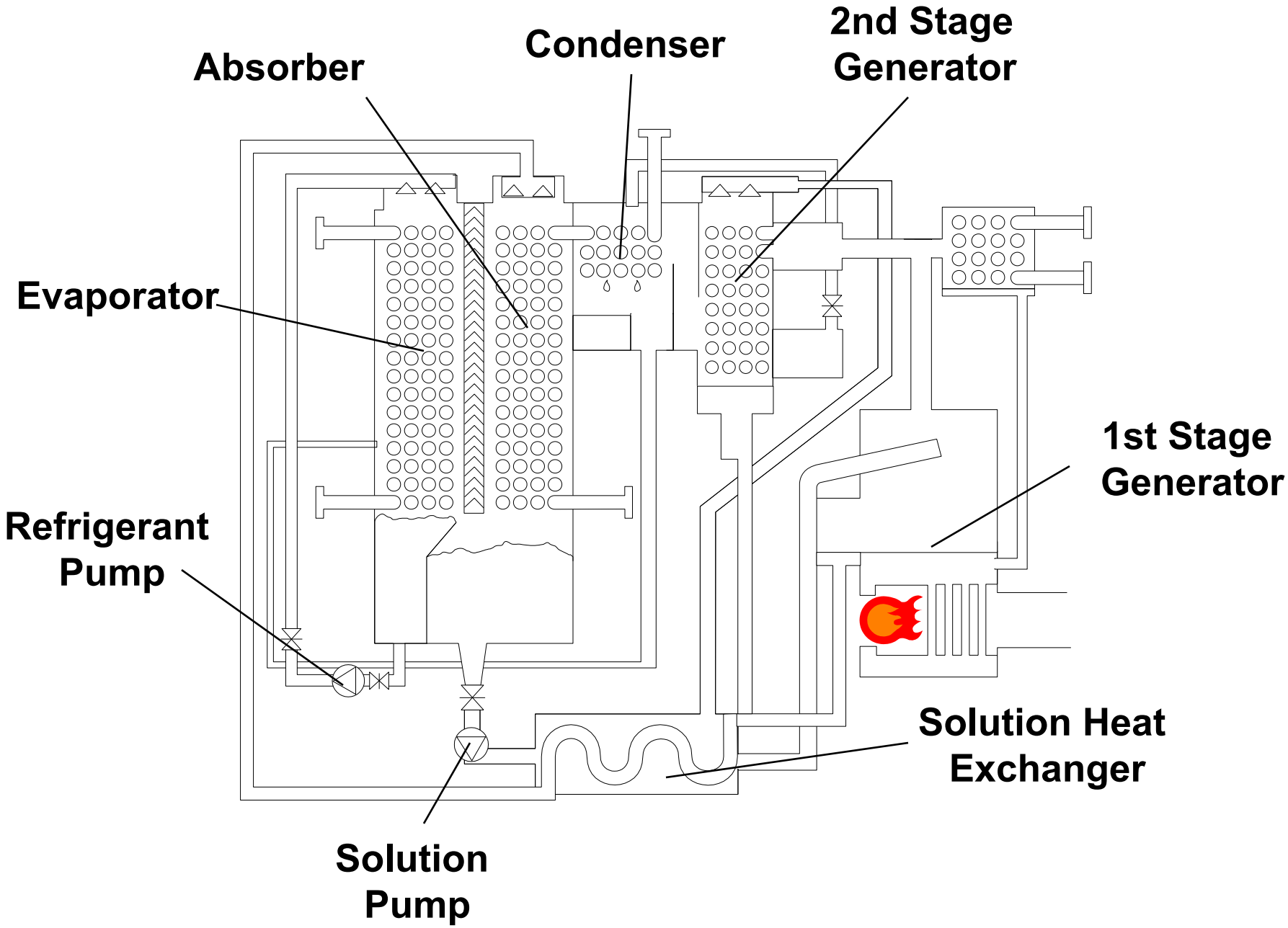
cooling with steam or hot water

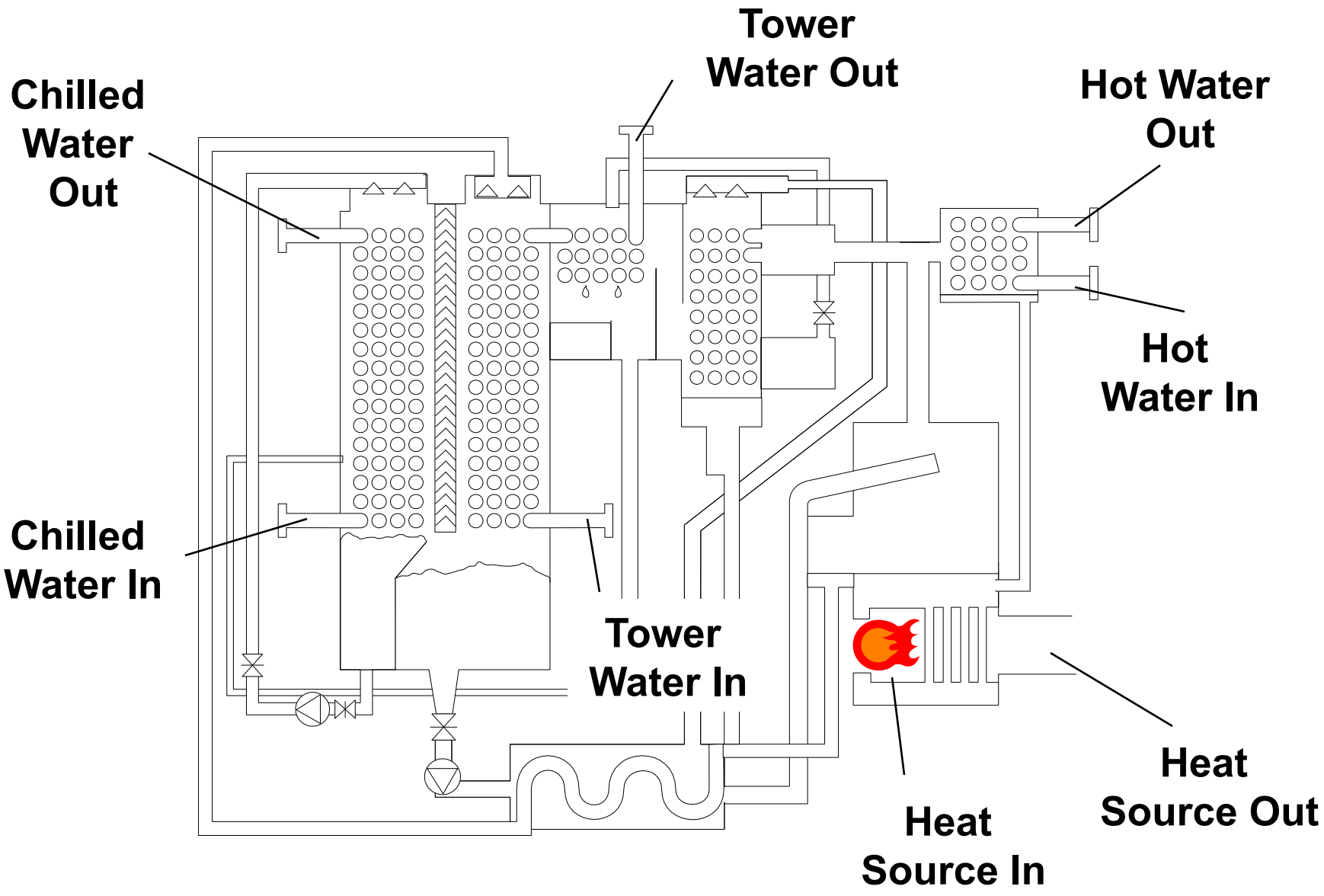


AIA FILE NO. 30-F-2

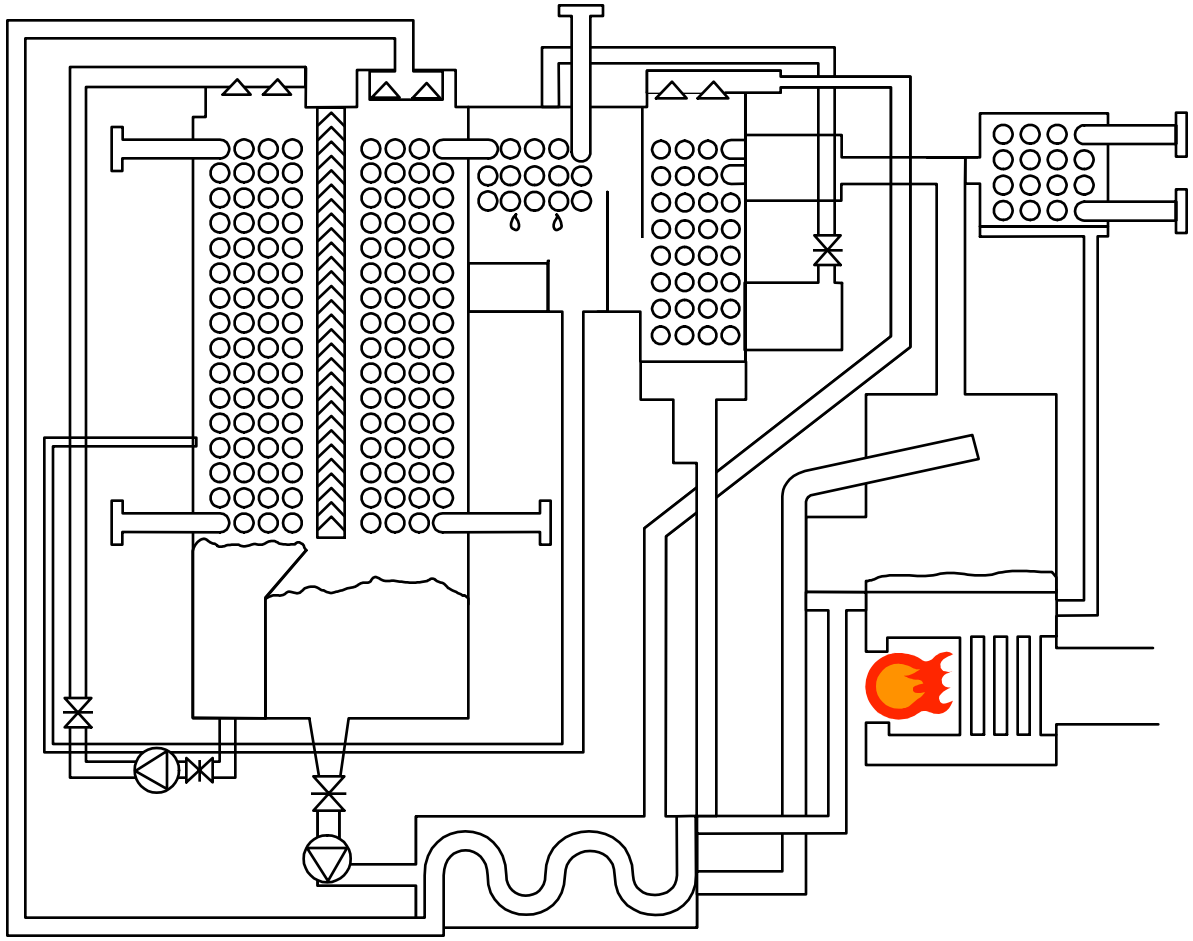


York Absorption System Cycle Diagram

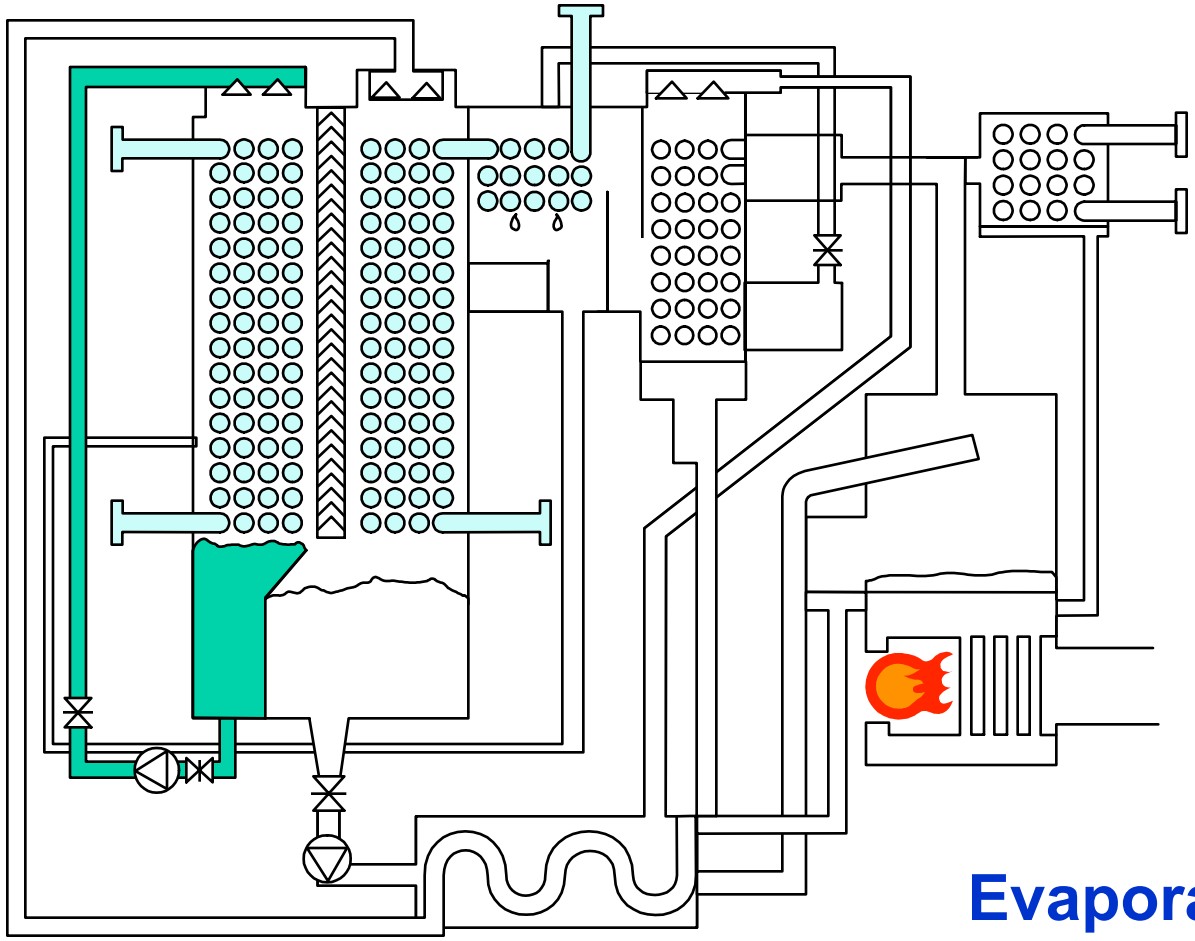

Absorber
Condenser
2nd Stage Generator
Evaporator
1st Stage Generator
Refrigerant Pump
Solution Heat Exchanger
Solution Pump


Tower
Water Out
Chilled
Water
Out
Hot Water
Out
Hot
Water In
Chilled
Water In
Tower
Water In
Heat
Source Out
Heat
Source In

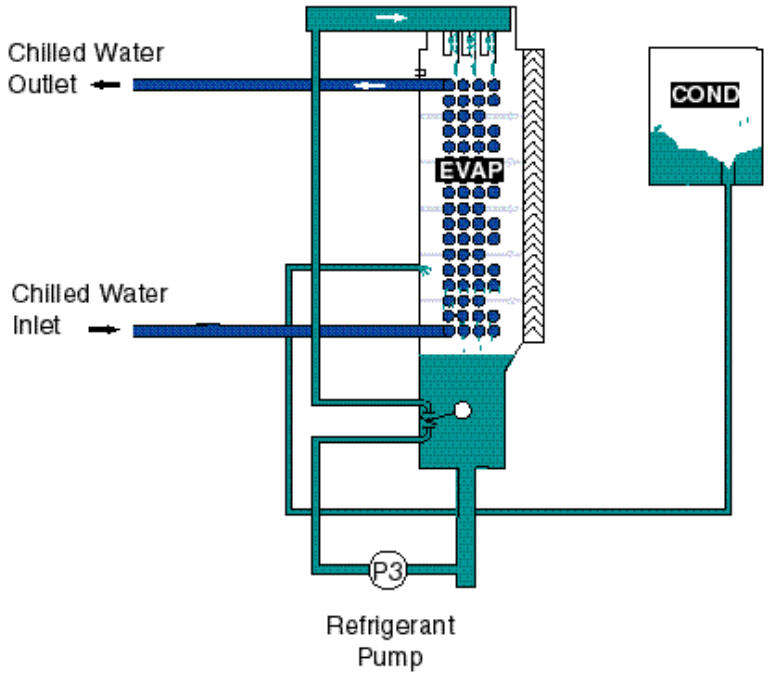
Two-Stage Parallel Flow Absorption Cycle

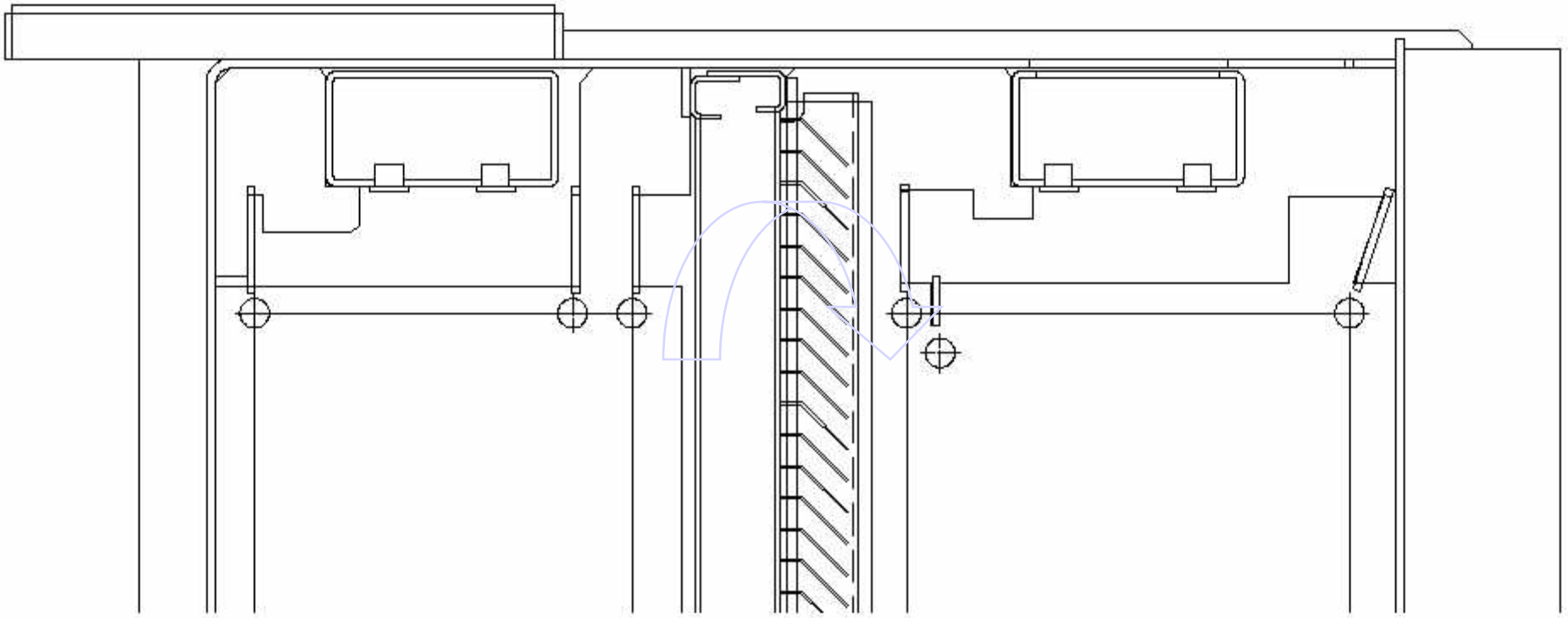


Two-Stage Parallel Flow Absorption Cycle

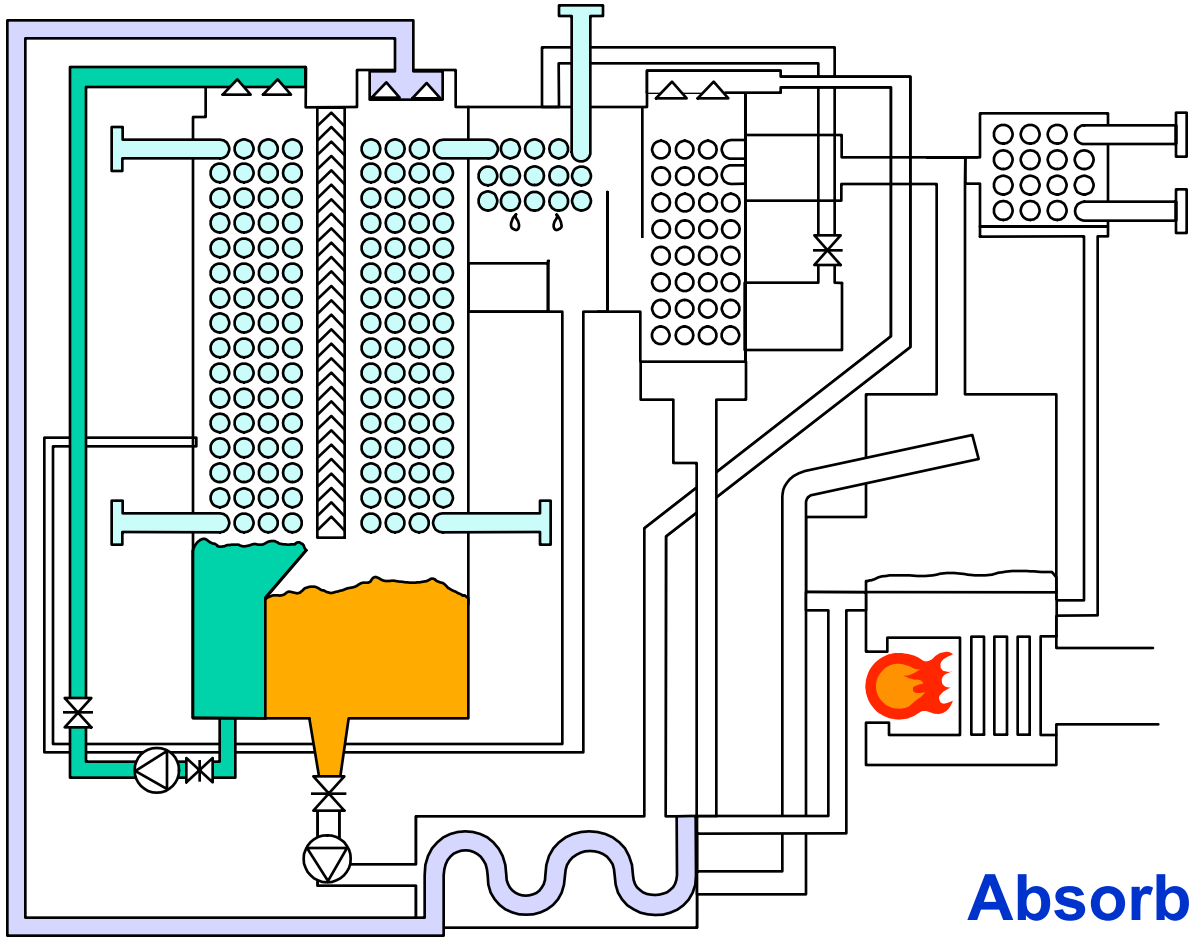


Evaporator and Condenser Sections

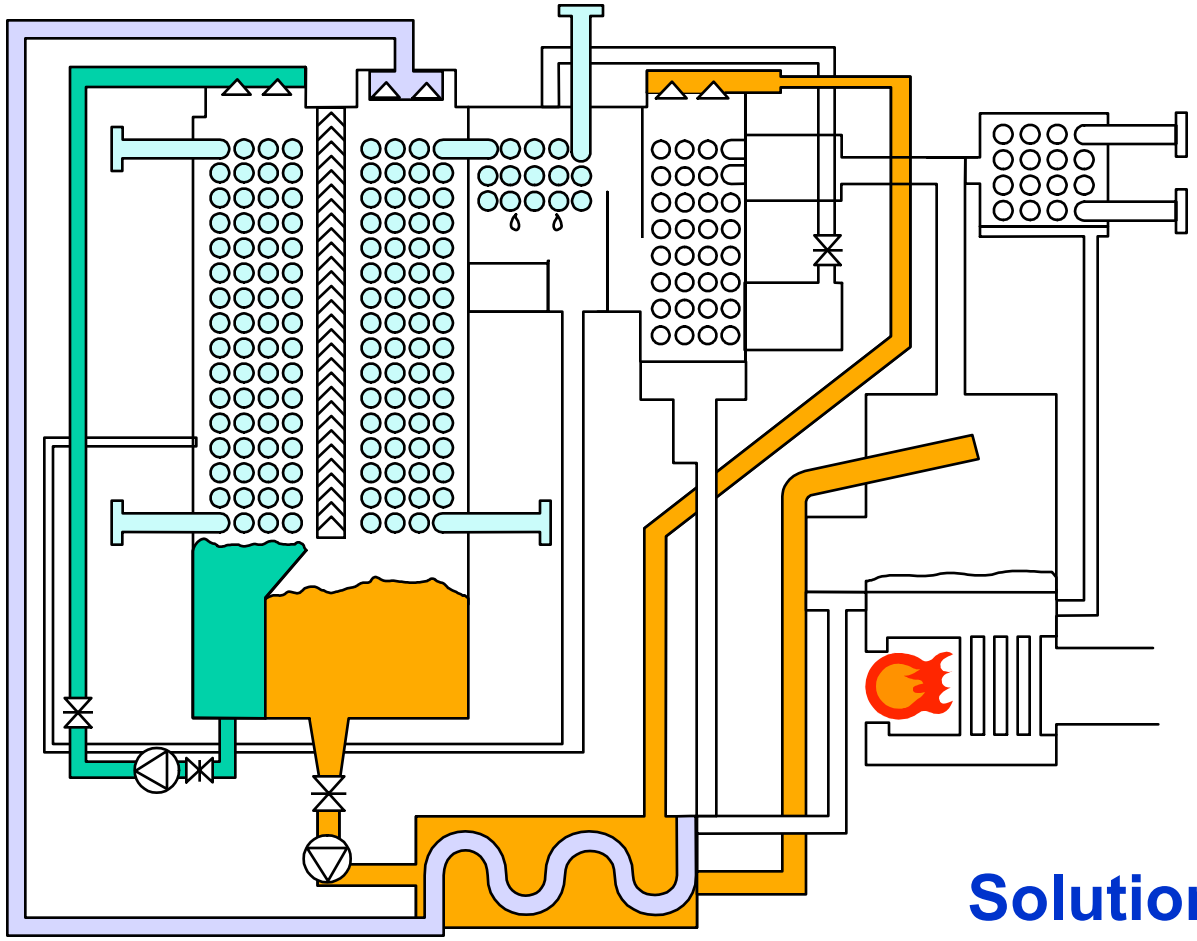




Two-Stage Parallel Flow Absorption Cycle

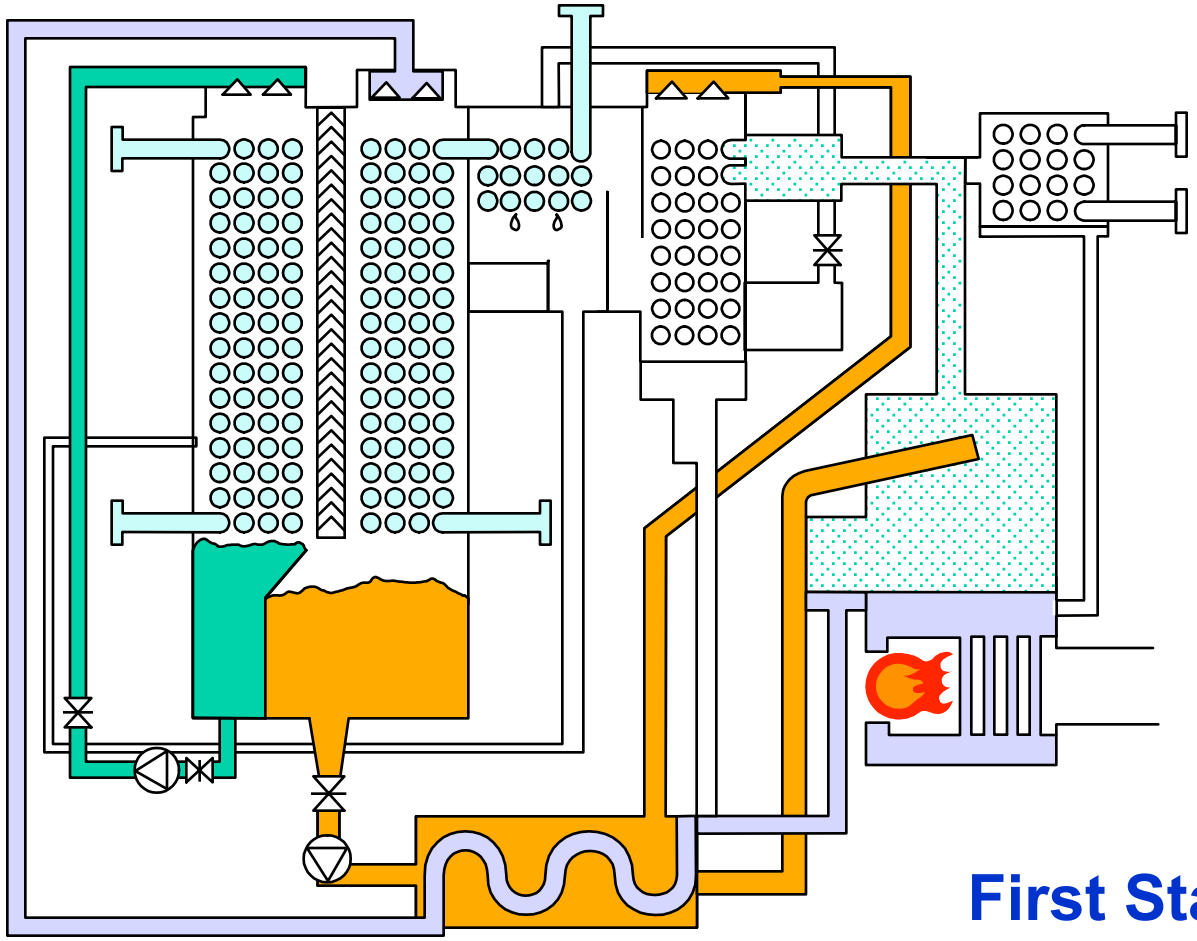


Two-Stage Parallel Flow Absorption Cycle



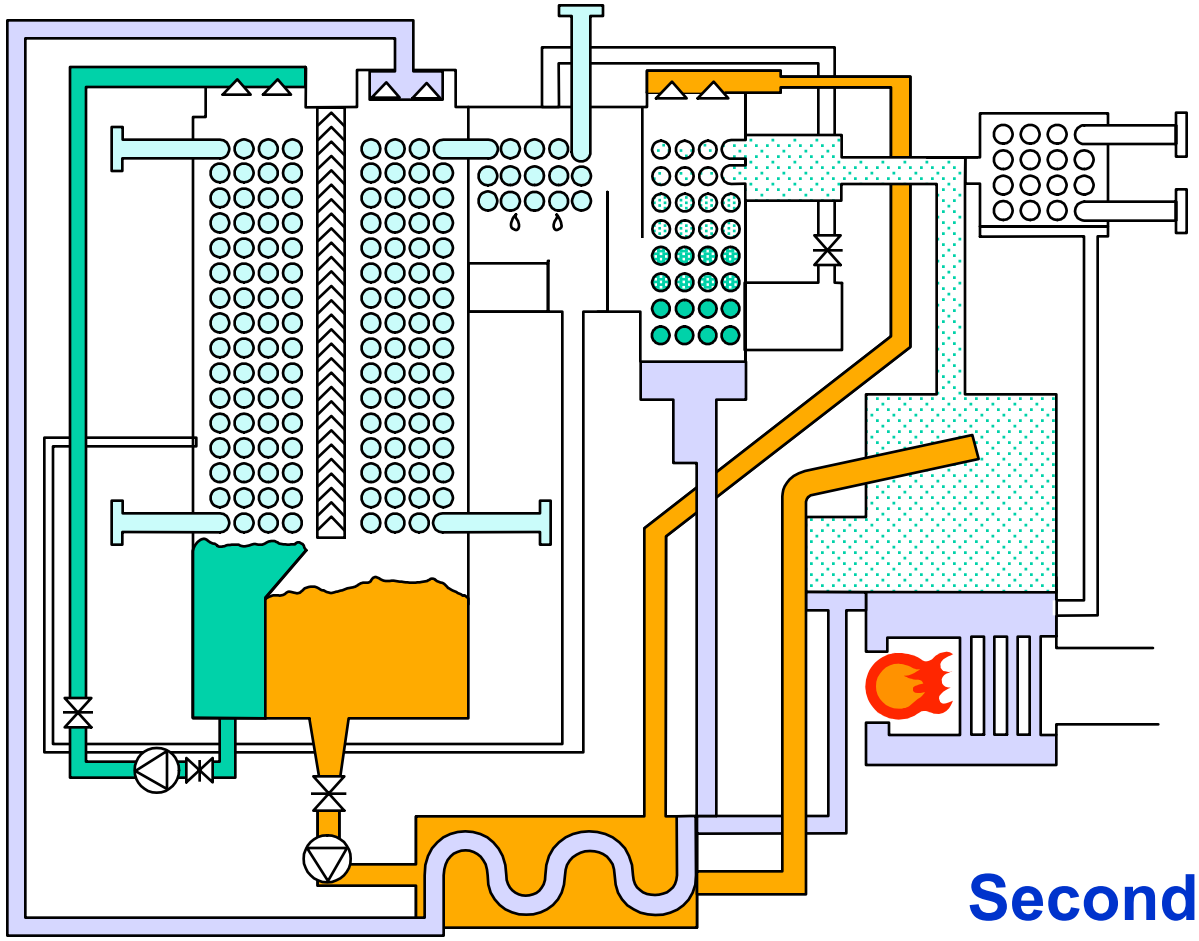
Solution Heat Exchangers

Two-Stage Parallel Flow Absorption Cycle



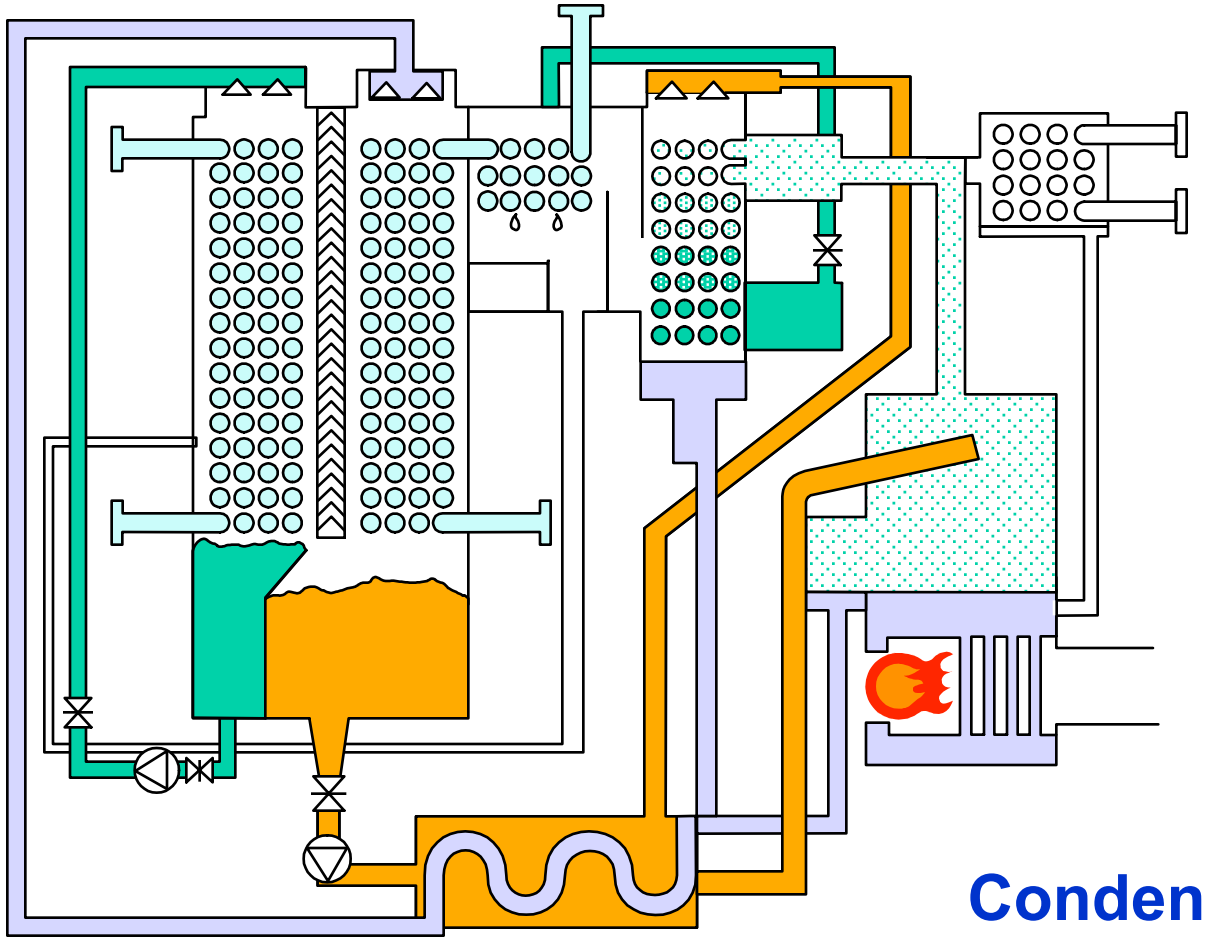
First Stage Generator

Two-Stage Parallel Flow Absorption Cycle

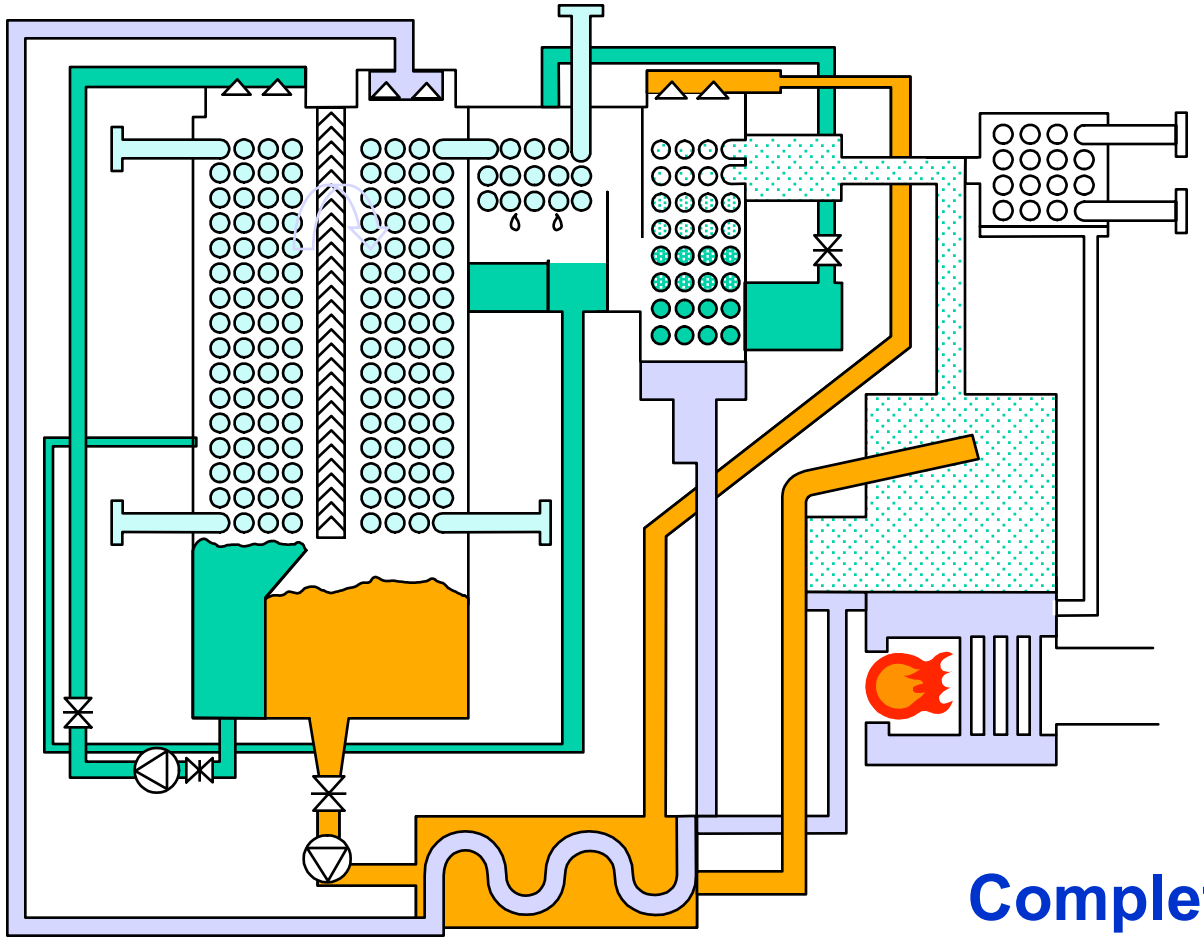


Second Stage Generator

Two-Stage Parallel Flow Absorption Cycle

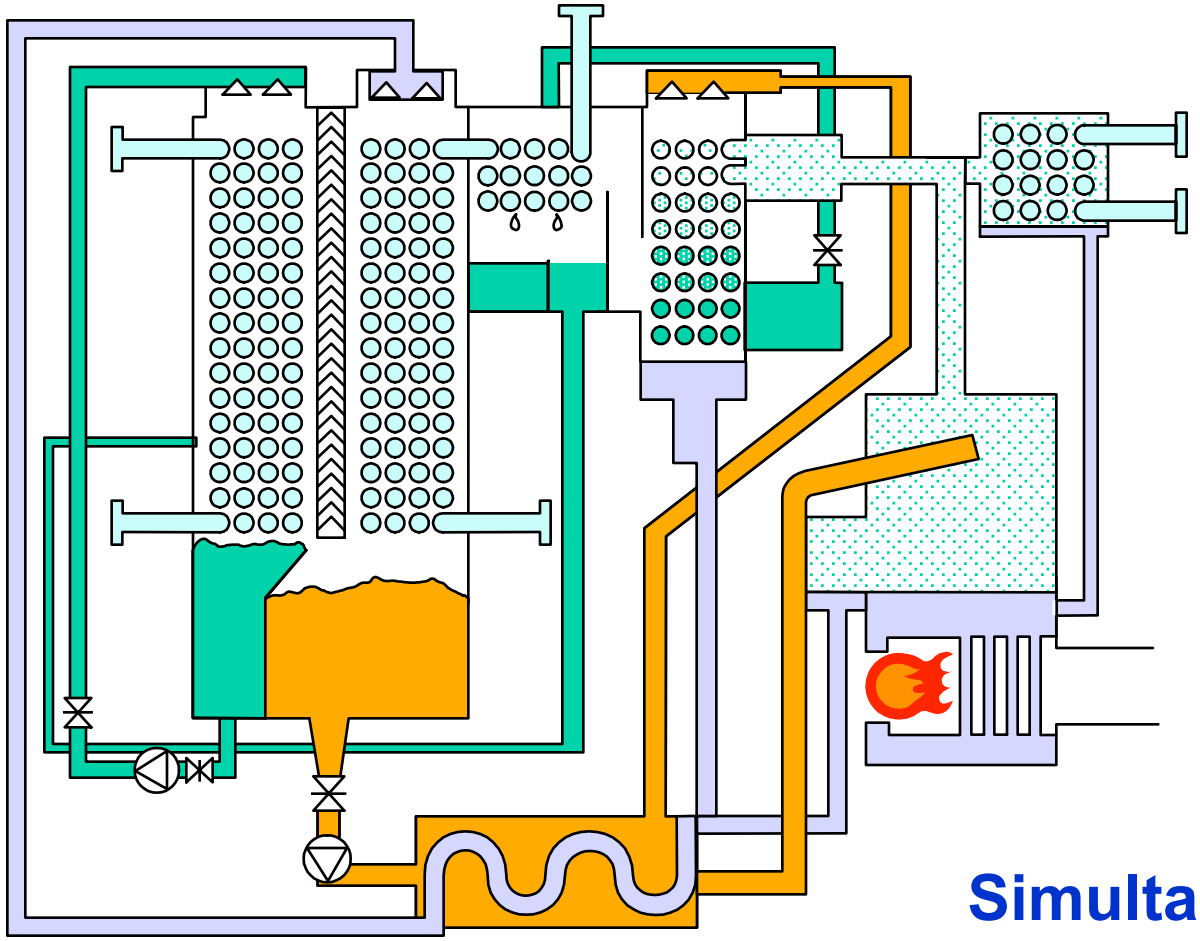


Two-Stage Parallel Flow Absorption Cycle



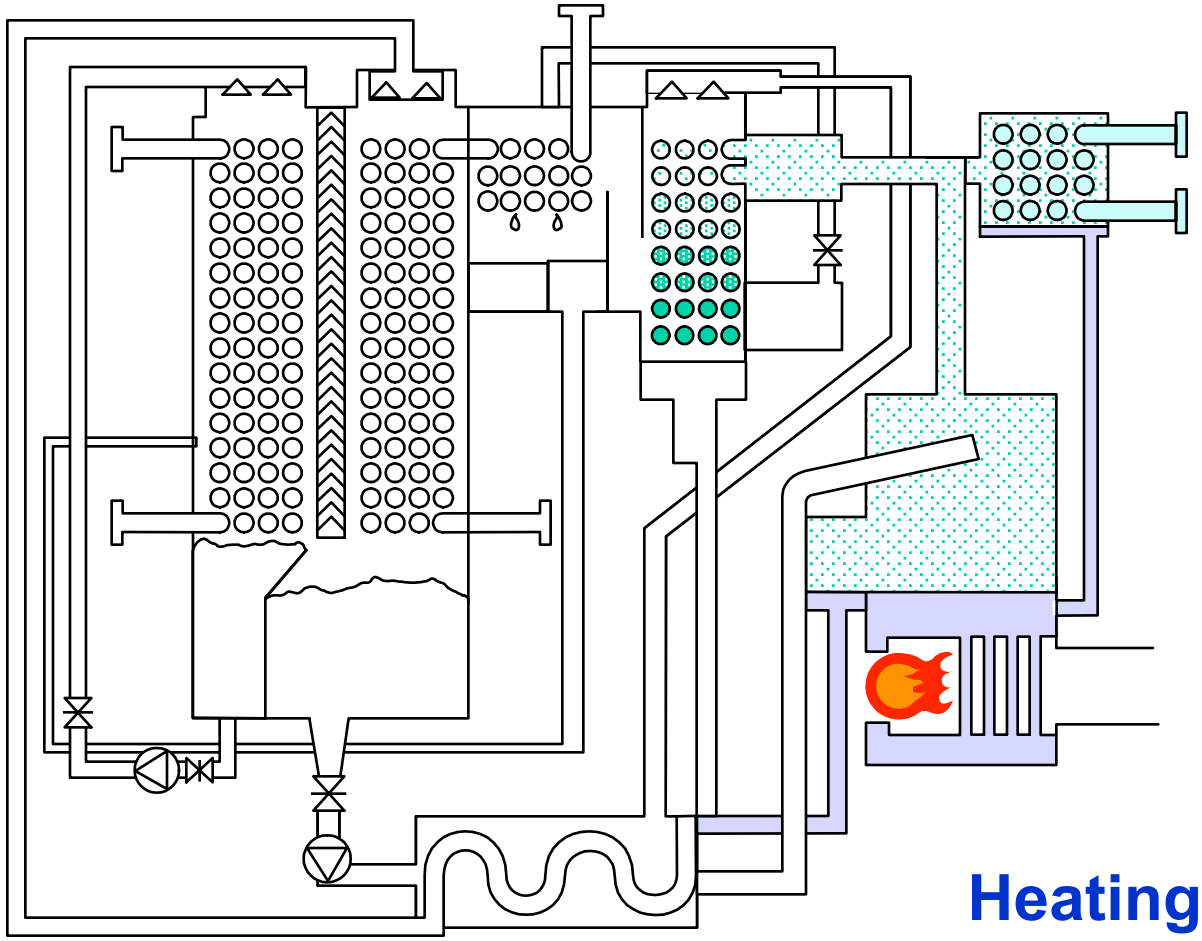
Complete Cooling Cycle

Two-Stage Parallel Flow Absorption Cycle



Simultaneous Heating and Cooling

Two-Stage Parallel Flow Absorption Cycle



Heating Only

Absorption Chiller Cooling Tower Requirements

- **Absorbers are heat-driven chillers**
- **Absorbers have more heat to reject per ton of capacity compared to a mechanical refrigeration chiller**
- **Cooling towers must be larger**
- **Cooling tower capacity control more critical with an absorber (bypass, fan speed control)**

CHILLER TYPE	CENTRIFUGAL	TWO-STAGE ABSORBER	SINGLE-STAGE ABSORBER
Typical Condenser Water Flow	3 cgpm/ton, 85f to 95f	3 cgpm/ton, 85f to 100f or 4.5 cgpm, 85f to 95f	3.6 cgpm/ton, 85f to 101.4f
Relative Quantity of Condenser Water Flow	1.0	1.5	2.0

Avoiding Absorption Chiller Corrosion

- Add inhibitors
- Lithium chromate
- Lithium nitrate . Lithium Molybdate
- Test solution chemistry* every year
- Test chiller for leaks every year
- Automatic purge

***Amount of inhibitors, solution PH, amount of copper in solution, amount of steel in solution**

Inhibitors and Environmental Concerns

- Lithium bromide solution, chromate inhibited
  - Classed as a hazardous waste
  - Must be disposed of according to EPA, city and state regulations*
- Lithium bromide solution, molybdate inhibited
- New Inhibitors are even more effective and are environmentally friendly
  - Not a hazardous waste

***Avoid contact when servicing. Have adequate ventilation or respirator. Wear rubber gloves and goggles. Chromate is a potential carcinogen (not known for sure yet). Follow ASHRAE guidelines on machine room ventilation**

Avoiding Crystallization

- Automatic dilution cycle before shutdown
- Automatic decrystallization control
- Operate chiller with lithium bromide solution as far away from the crystallization line as possible (efficiency tradeoff)

Single-Stage Versus Two-Stage Absorption Chillers

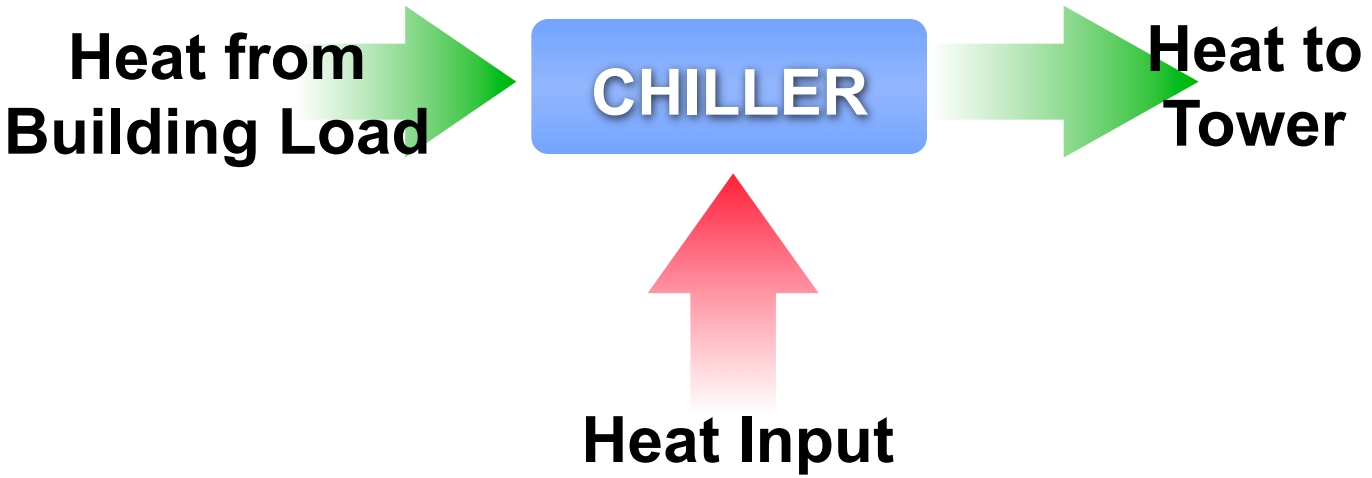
- Two-stage absorber uses refrigerant vapor heat produced in the first stage generator to drive off refrigerant in second stage generator
- As much as 40% more reconcentrated refrigerant is produced by a two stage absorber using the same energy as a single stage absorber

Single-Stage Versus Two-Stage Absorption Chillers

- Types of single-stage absorbers
  - Steam fired
  - Hot water fired
- Types of two-stage absorbers
  - Steam fired
  - Natural gas fired
  - Oil fired
  - Propane fired
- Single-stage COP (coefficient of performance) ≅ 0.65
- Two-stage COP ≅ 0.98

COP Calculation

$$\text{Coefficient of Performance} = \frac{\text{Heat from Building Load}}{\text{Heat Input}}$$



Typical COP's

CHILLER TYPE	COP
Absorption	
Single Stage	**0.68**
Two stage direct fired	**1.00**
Two stage steam fired	**1.19**
Gas engine driven centrifugal	1.90
Electric motor driven centrifugal	6.00

Good Absorption Cooling Applications

- Peak electrical load shaving
- Gas company load balancing
- Simultaneous heating and cooling requirement (two-stage)
- Inadequate electrical service
- Limited machine room space for chillers and boilers (two-stage)
- CFC elimination
- Utility deregulation

Questions


Thank You