An Introduction to Ammonia Refrigeration Systems

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Course description

Industrial refrigeration systems have used anhydrous ammonia for more than a sesquicentennial. Although ammonia has a long history of use in the industrial sector, the interest in ammonia as a potential refrigerant for non-industrial applications has grown recently.

This presentation will provide an overview of the ammonia refrigeration systems that have been the mainstay in the industrial sector and emphasize unique characteristics that differentiate ammonia systems from traditional halocarbon refrigeration systems. An emphasis will be placed on safety.

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Learning objectives

1. Identify key safety considerations when using ammonia as a refrigerant
2. Recognize materials used in halocarbon refrigeration systems that are not appropriate for use with ammonia due to material incompatibilities
3. Differentiate direct-expansion, gravity flooded, and liquid overfeed evaporator arrangements
4. Describe the difference between single stage and two stage compression systems

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During this presentation, we will discuss

- Ammonia and its uses
- Ammonia as a refrigerant
- Ammonia refrigeration, the technology
  - Single stage: DX, flooded, overfeed
  - Two-stage
- How is ammonia different compared to other refrigerants?

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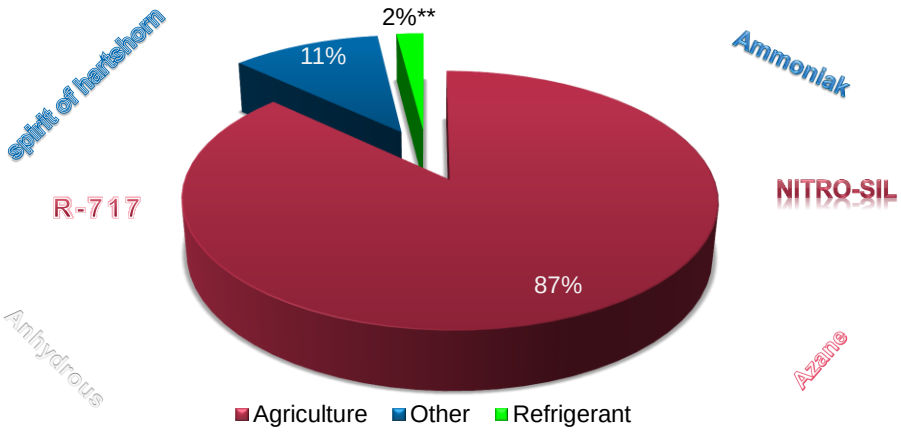
Where is ammonia used?

Annual ammonia use in U.S.

Annual US consumption in 2012 was 14.4 million metric tons*.



* Source: US Geological Survey (2013).
** Source: ASHRAE Position Document on ammonia (RA 2013)

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Anhydrous ammonia as a refrigerant

- *Where is ammonia used as a refrigerant?*
  - Industrial systems: large cold storage and process systems
  - Some HVAC systems (requires a central plant)
  - Where no ODP and low/no GWP is desirable/needed
- Distinct characteristics
  - Usually a custom engineered system vs. packaged systems for halocarbons

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Anhydrous ammonia characteristics

- Refrigerant grade
  - 99.95% Purity
  - 75 PPM H_2O (max)
- Vapor tends to be lighter than air
- Liquid specific gravity ~ 0.65
- Alkaline – pH of 11.6
- Pungent odor makes it self-alarming
- **Highly soluble in water**
- **Very corrosive to human tissue upon exposure!**
- **Toxic at elevated concentrations**

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Flammability characteristics

- ASHRAE 34 flammability classification: 2L
- DOT classified as non-flammable
- Autoignition temperature: 1204°F
- Lower flammability limit (vol.%)[1] 15-16
- Upper flammability limit (vol. %)[1] 25-28
- Combustion products: oxides of nitrogen
- Fire hazard: slight

[1] IIAR Ammonia Data Book, (2009).

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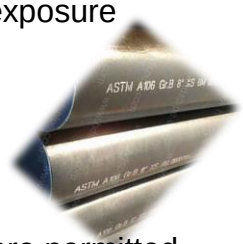
Materials compatibility for ammonia

- **Not permitted**
  - Copper and copper alloys such as brass are prohibited (but allowed for bearing materials)
  - Zinc (in continuous contact with ammonia)
  - Non-metallic materials that degrade upon exposure
- **Permitted**
  - Carbon steel
  - Stainless steel
  - Aluminum
  - Other nonmetallic materials such as PTFE are permitted (if they will not break down)



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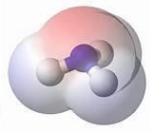
Anhydrous ammonia



- *Why is ammonia widely used in food processing and storage facilities?*
- Because it is a good refrigerant!
  - High heat transfer coefficients in equipment
  - Efficient compressor operation
  - Low refrigerant cost
  - **No ozone depletion & no/low global warming impact**
  - Sustainable
  - Self-alarming

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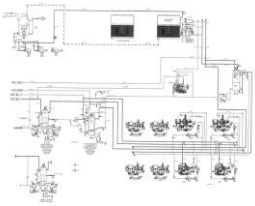
Let's now look at the technology

Ammonia refrigeration technology

- Single stage compression with evaporators configured as
  - direct-expansion
  - flooded
  - overfeed
- Multi-stage compression systems
- Cascade systems



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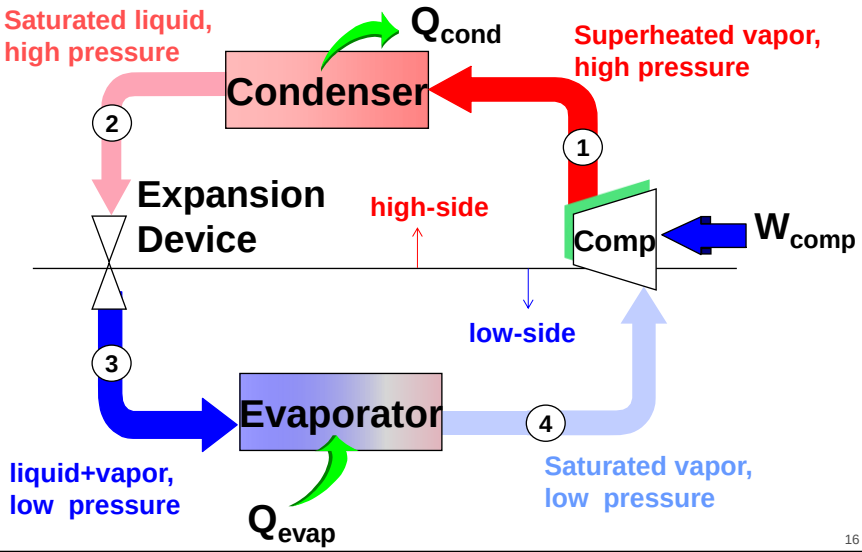
Simple vapor compression system



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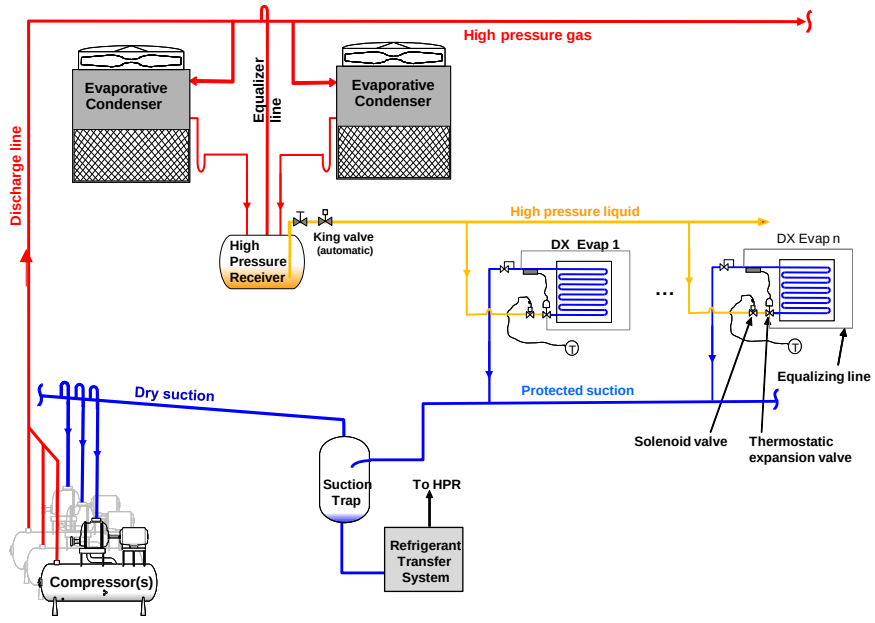
Single stage – Direct-eXpansion (DX)



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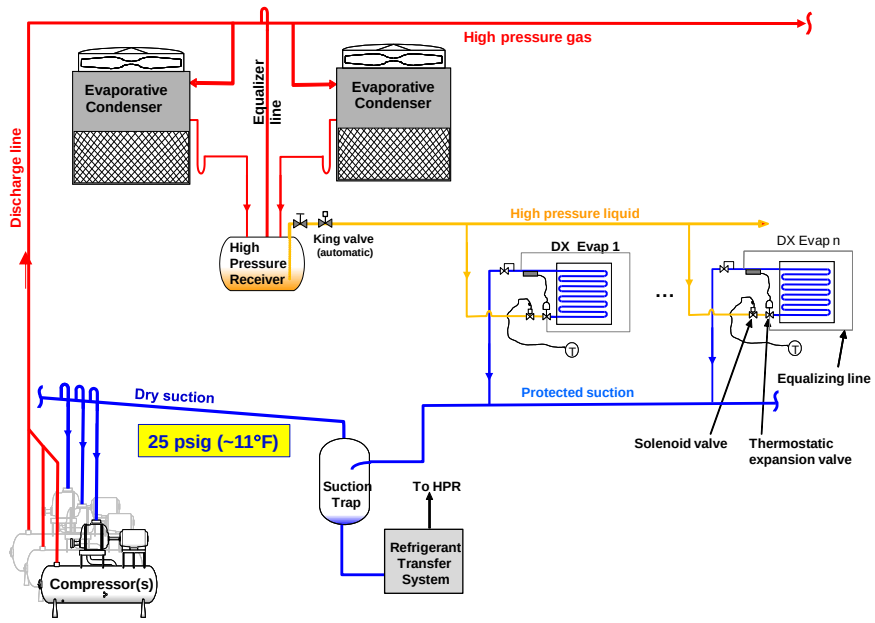

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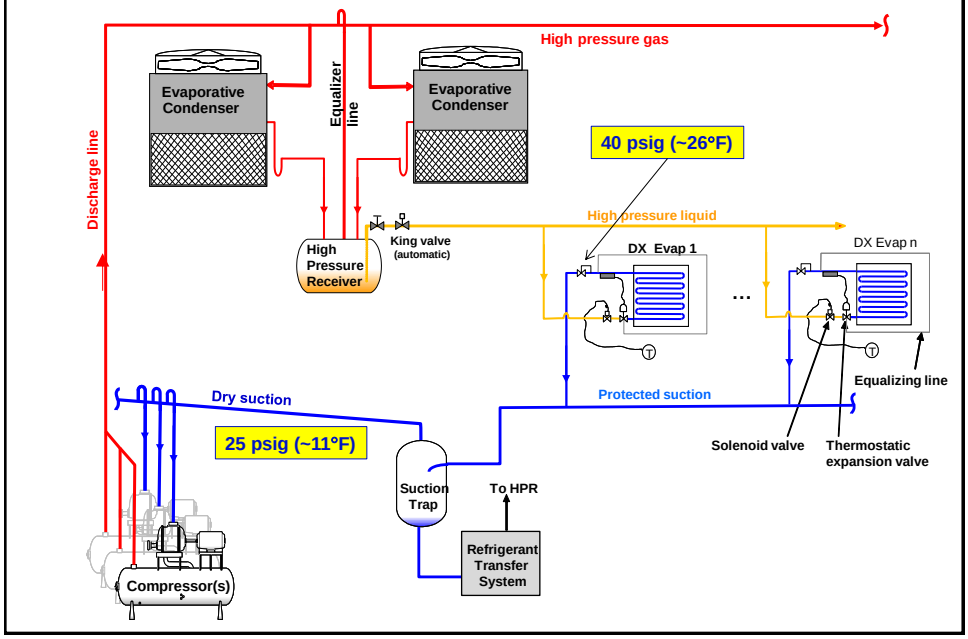

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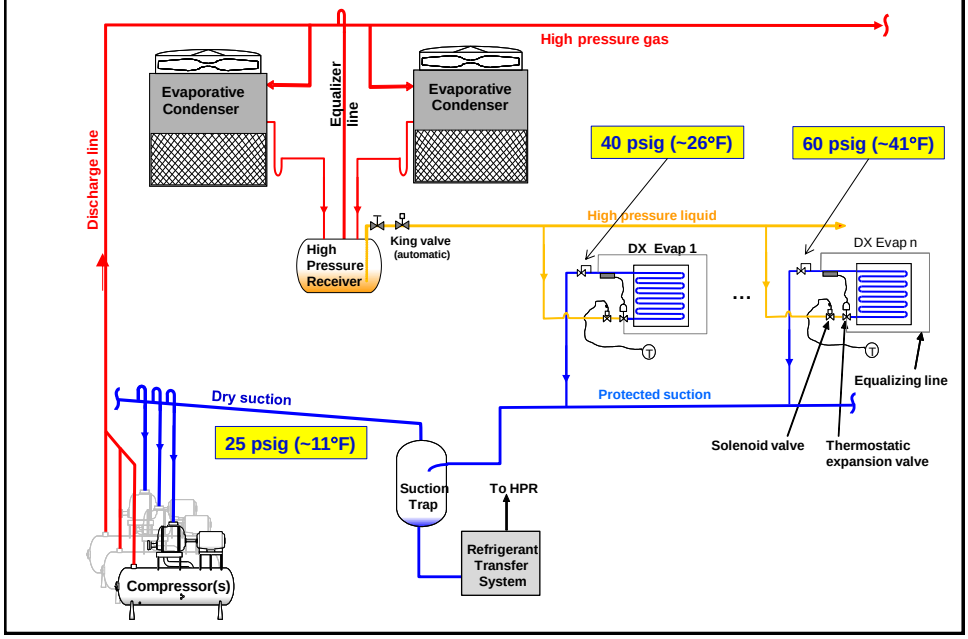

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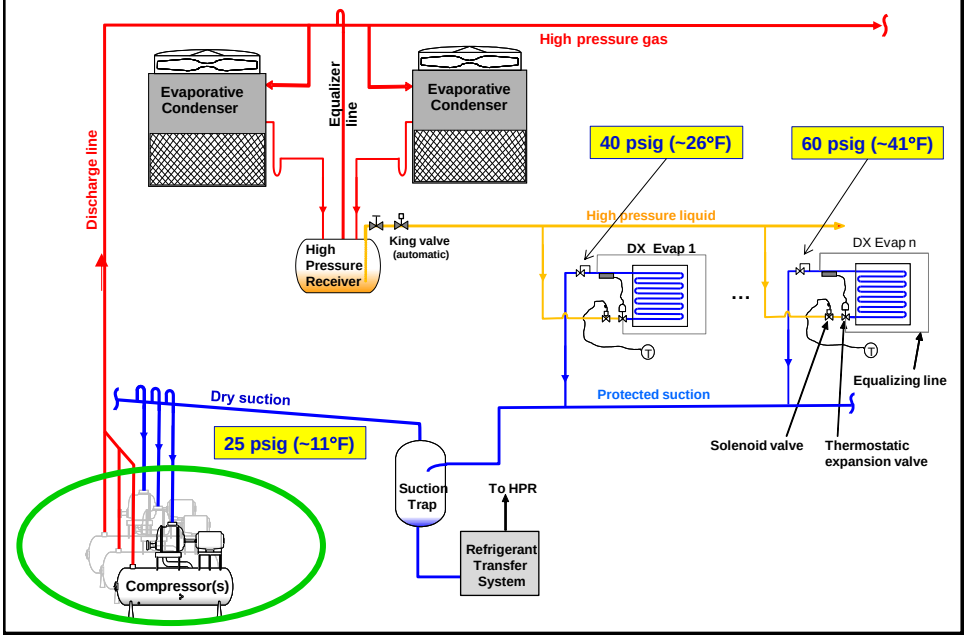
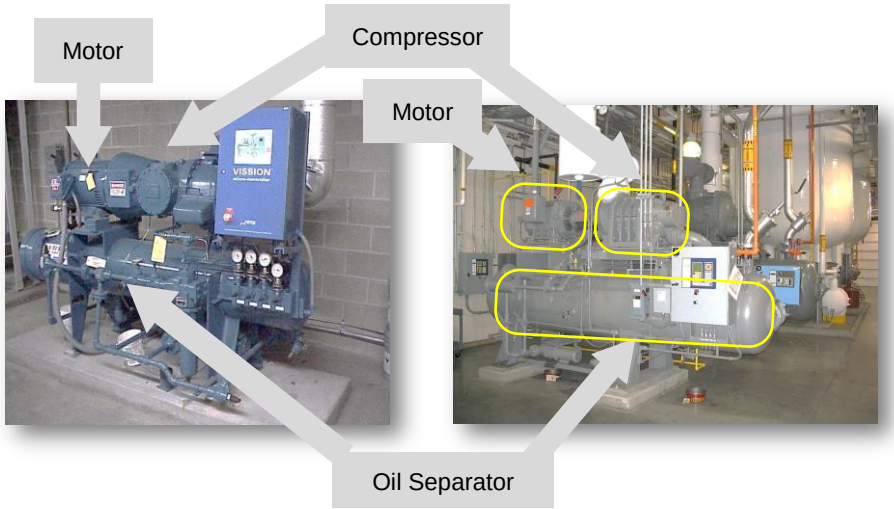


Compressor, rotary screw



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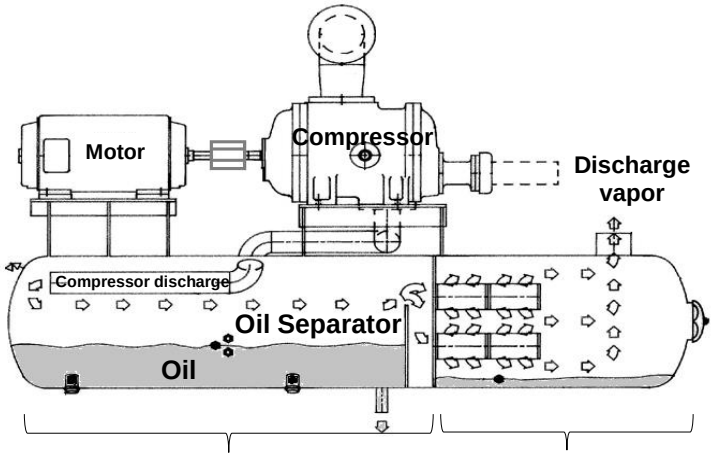
Oil Separator



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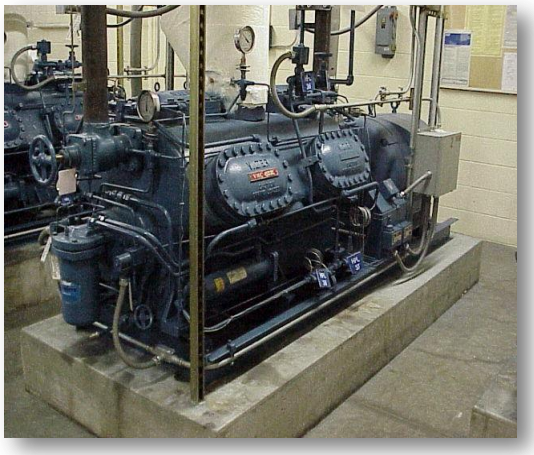
Compressors, reciprocating



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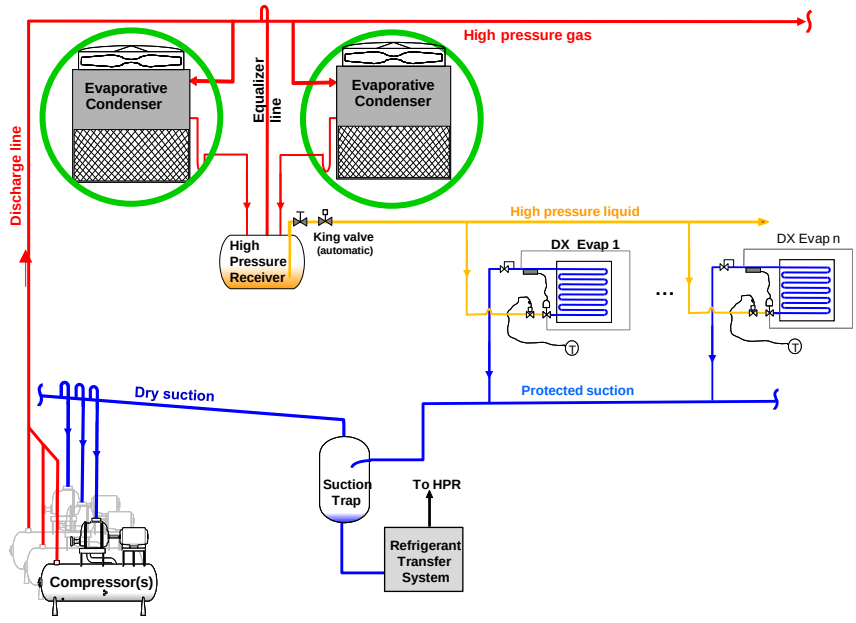
Single stage – Direct-eXpansion (DX)



Condensers, evaporative

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Condensers, evaporative

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Evaporative condenser coil

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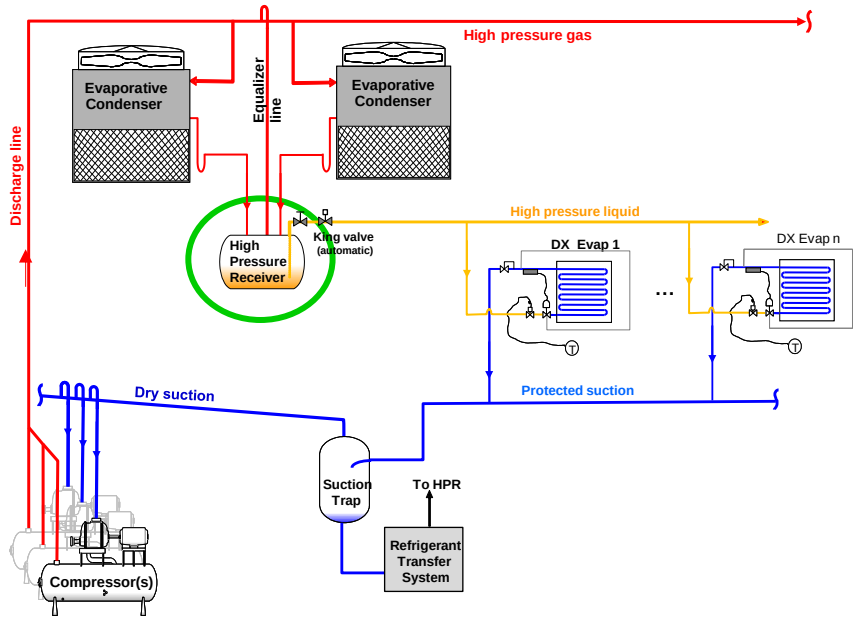
Single stage – Direct-eXpansion (DX)



Receivers, high pressure

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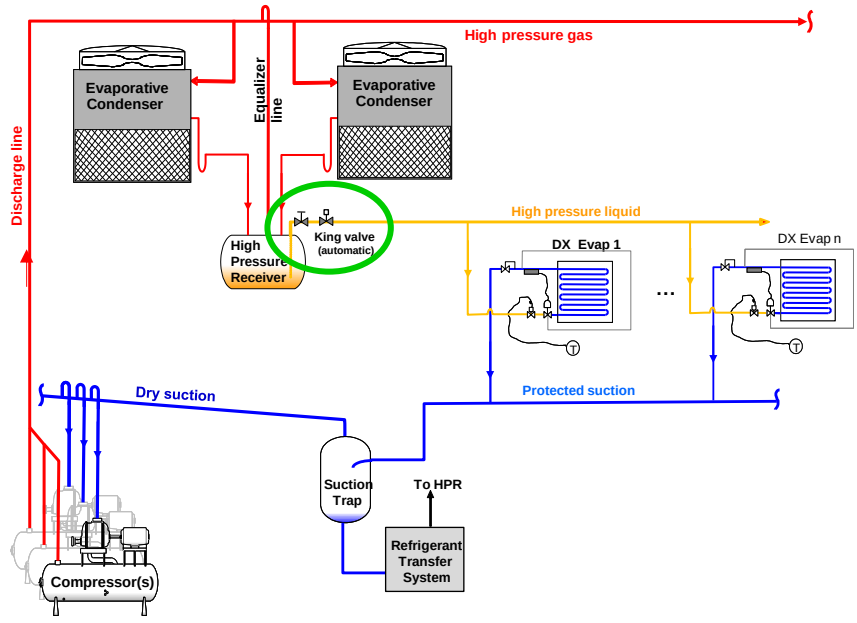
Single stage – Direct-eXpansion (DX)



King valve

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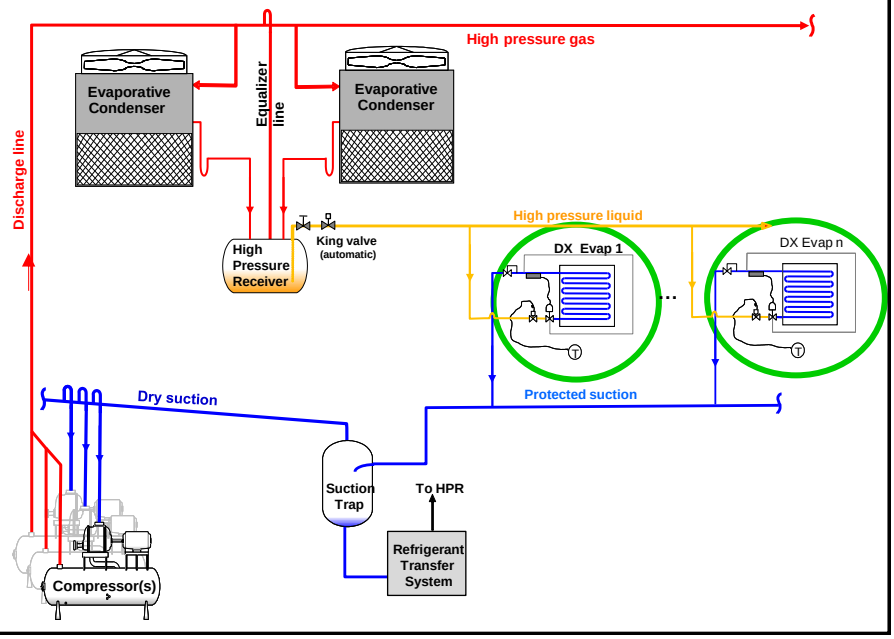
Single stage – Direct-eXpansion (DX)



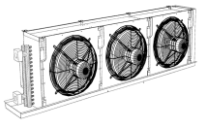
Evaporator, air-cooling

Ceiling-hung evaporator in a dock area

Penthouse evaporator in a freezer

Evaporator technologies

- Air-cooling
  - Very low temperature blast freezing
  - Low temperature holding freezers
  - Higher temperature storage coolers, production areas, air-conditioning



- Liquid-cooling (secondary fluids and products)
  - Shell-and-tube
  - Plate-and-frame
  - Falling film
  - Scraped surface

Shell-and-tube liquid chiller

Plate-and-frame liquid chiller

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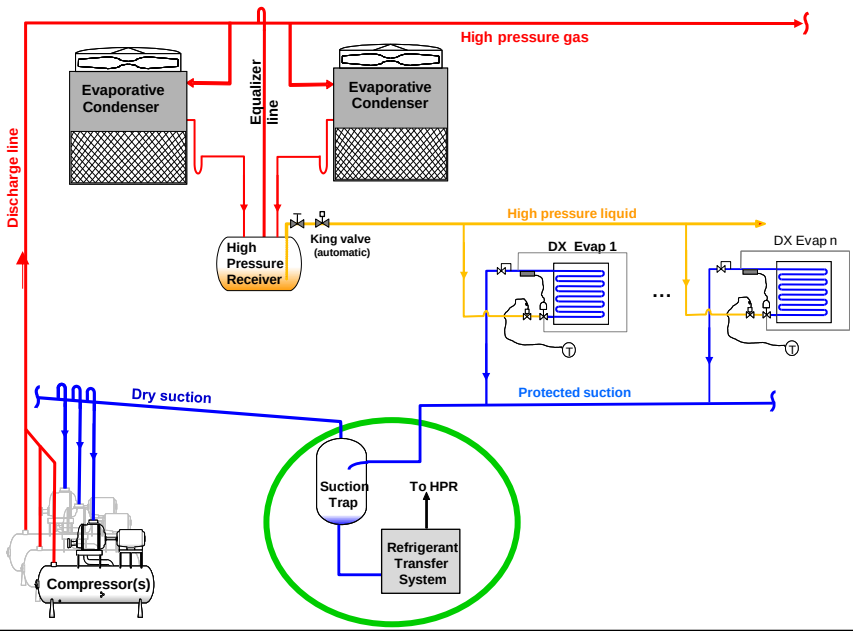
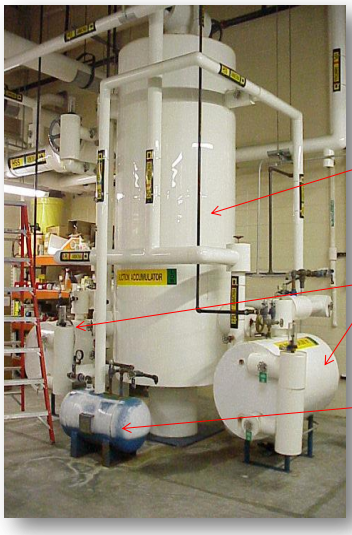
Single stage – Direct-eXpansion (DX)



Transfer system



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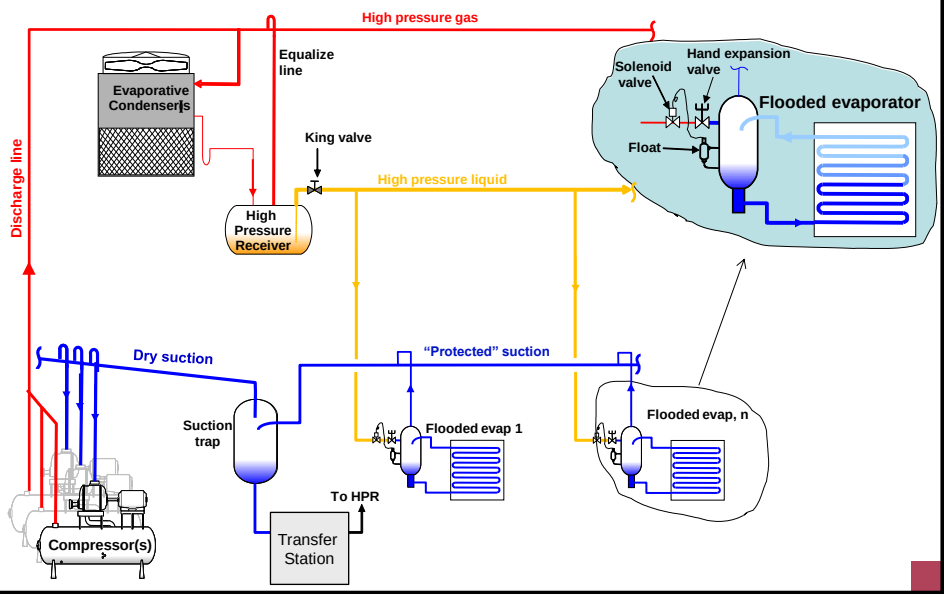
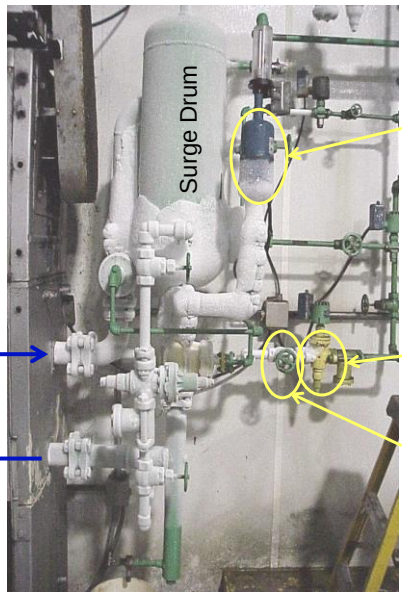
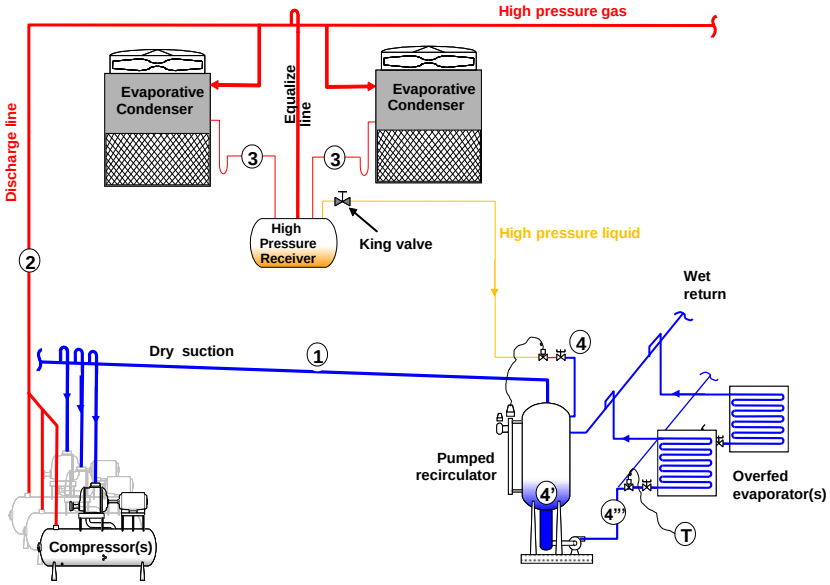
Gravity flooded recirculation system

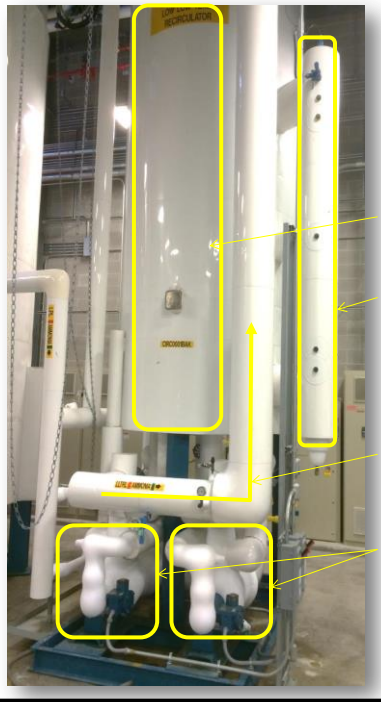


Gravity flooded evaporator

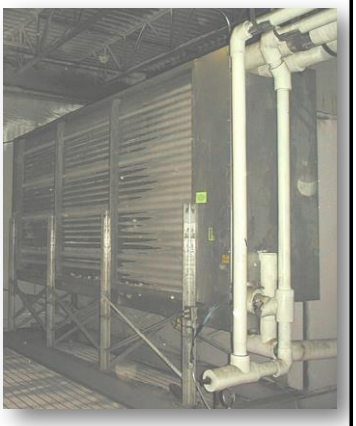


Pumped liquid overfeed





Liquid overfeed system



Liquid overfeed system components

Two-stage compression systems

- Lower evaporator temperatures
  - Requires lower evaporator pressures
  - Leading to increased compressor compression ratios
    - Limitations of specific compression technologies
    - Increased refrigerant discharge superheat

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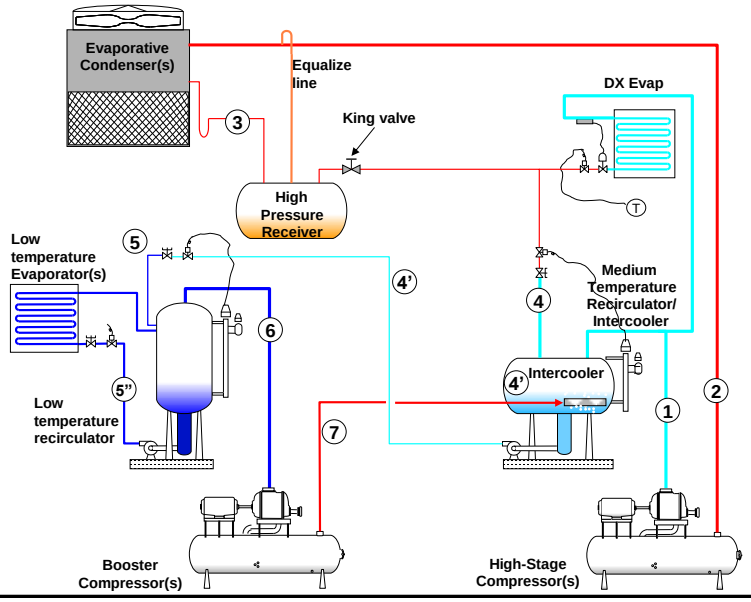
Two-stage compression

(two temperature level with two stages of liquid expansion)



Two-stage compression

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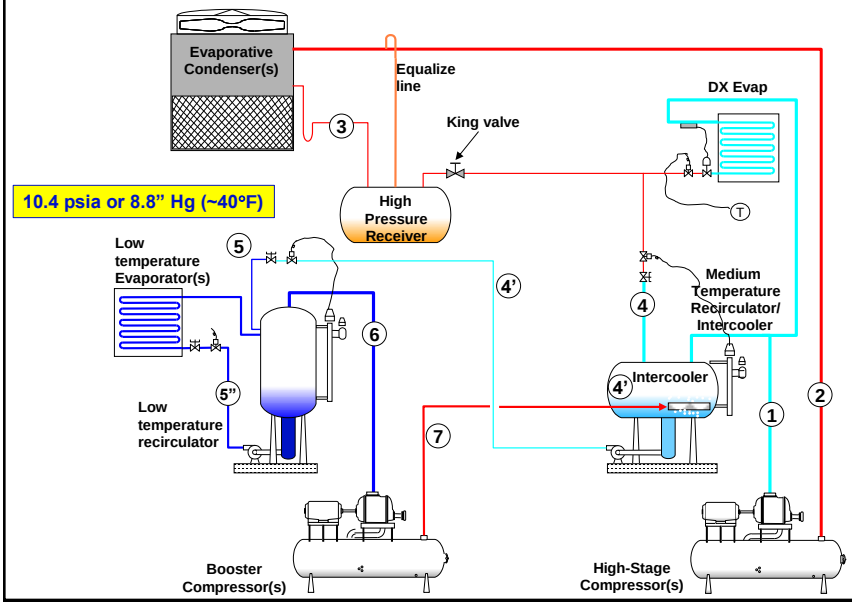

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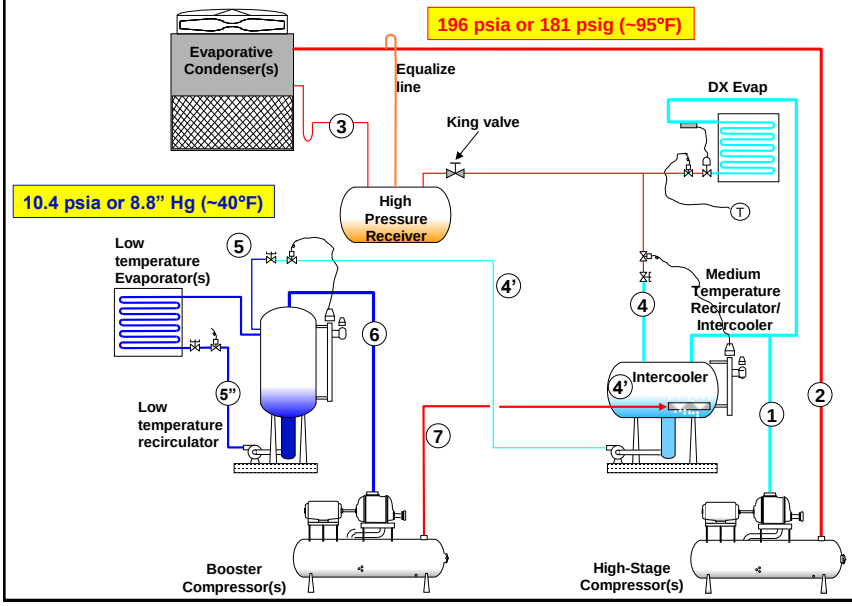

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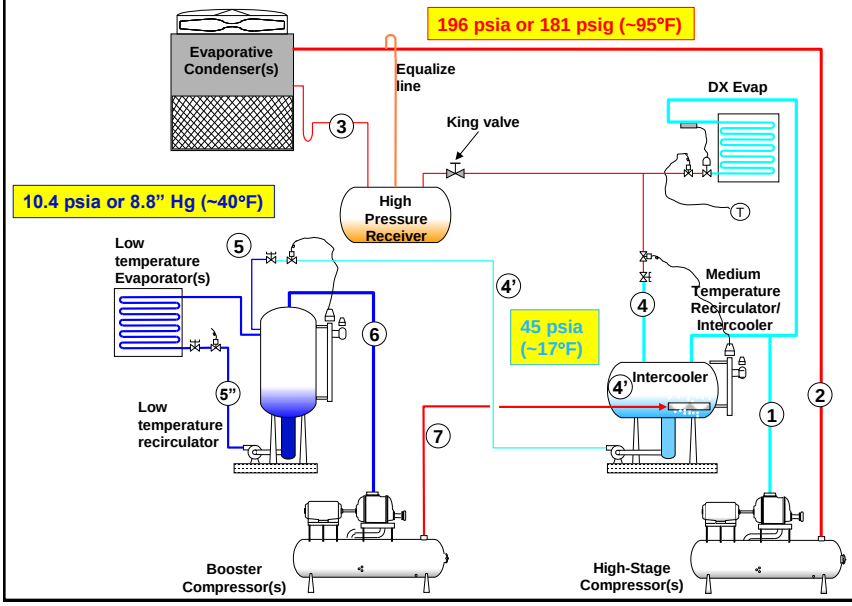

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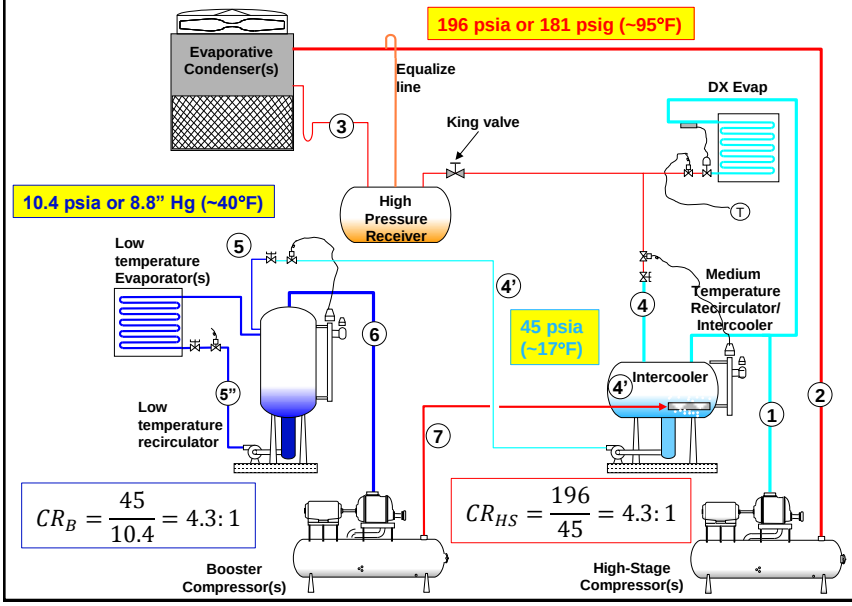
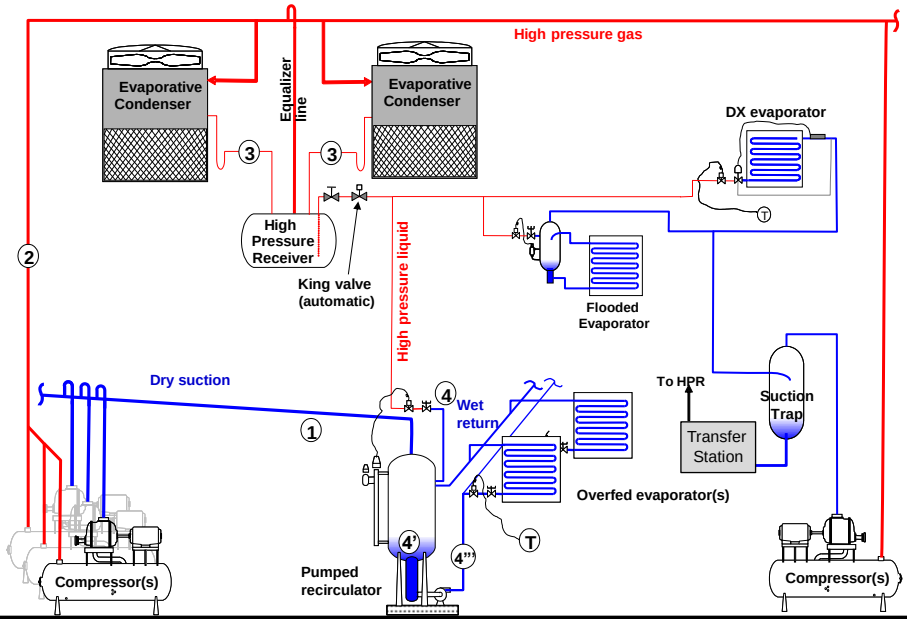


What's a "typical" system?



Conclusions

- Ammonia has been the mainstay refrigerant in the industrial sector
- Must be aware of its safety considerations
- As low GWP refrigerants continue to be pursued, ammonia applications are expanding

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QUESTIONS?

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What did you learn?

1. Where does the vast majority of ammonia originate from?
2. Which of the following materials is not compatible with ammonia: carbon steel, stainless steel, copper, aluminum?
3. Ammonia is considered highly flammable:
   True or False?
4. The “suction trap” is needed to prevent compressors from ingesting liquid refrigerant:
   True or False?
5. Which of the following is not an industrial ammonia system configuration: direct-expansion, liquid underfeed, gravity flooded, two-stage?

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