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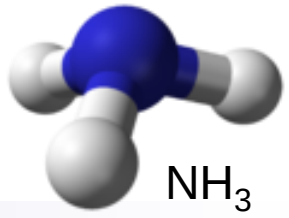
An Introduction to Ammonia Refrigeration Systems

Douglas Reindl, Ph.D., P.E.
ASHRAE Fellow
Director, IRC
Professor, University of Wisconsin-Madison

During this presentation, we will discuss

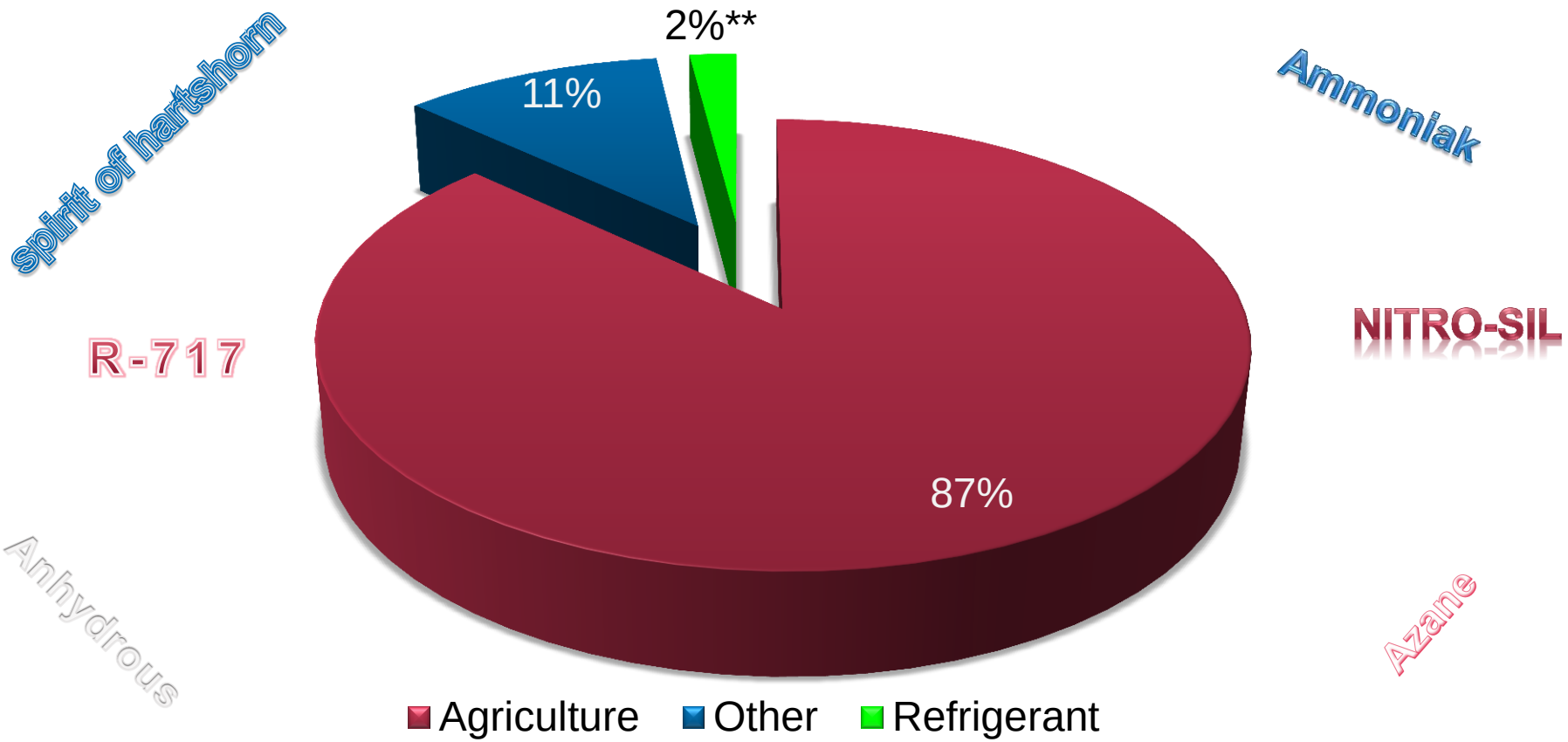
- Brief background on ammonia and its uses
- Ammonia, the refrigerant
- Ammonia refrigeration, the technology
- How is ammonia different compared to other refrigerants?

Where is ammonia used?



Annual ammonia use in U.S.

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



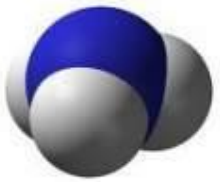
- Source: US Geological Survey (2013).

** Source: ASHRAE Position Document on ammonia (RA 2013)

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. a packaged systems for halocarbons

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**

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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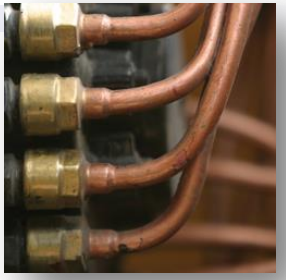
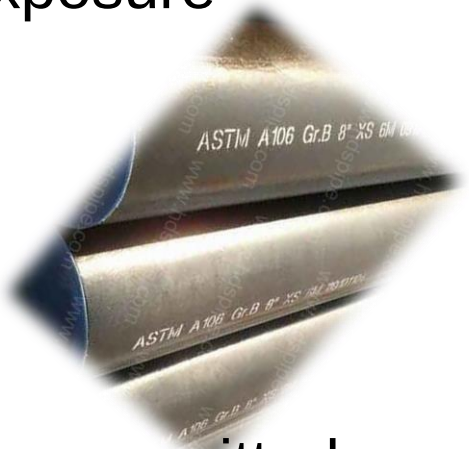
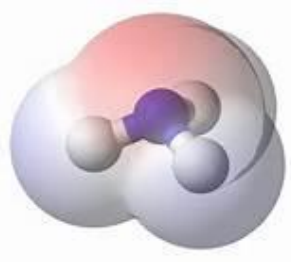
Materials compatibility for ammonia



- **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)



Anhydrous ammonia

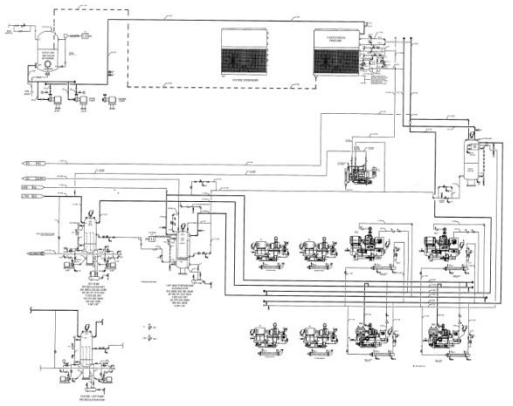


- *Why is ammonia widely used in food processing and storage facilities?*
- Because it is a good refrigerant!
  - High heat transfer coefficients in equipment
  - Efficient compressor operation
  - Low refrigerant cost
  - No ozone depletion & very low/no global warming
  - Sustainable
  - Self-alarming

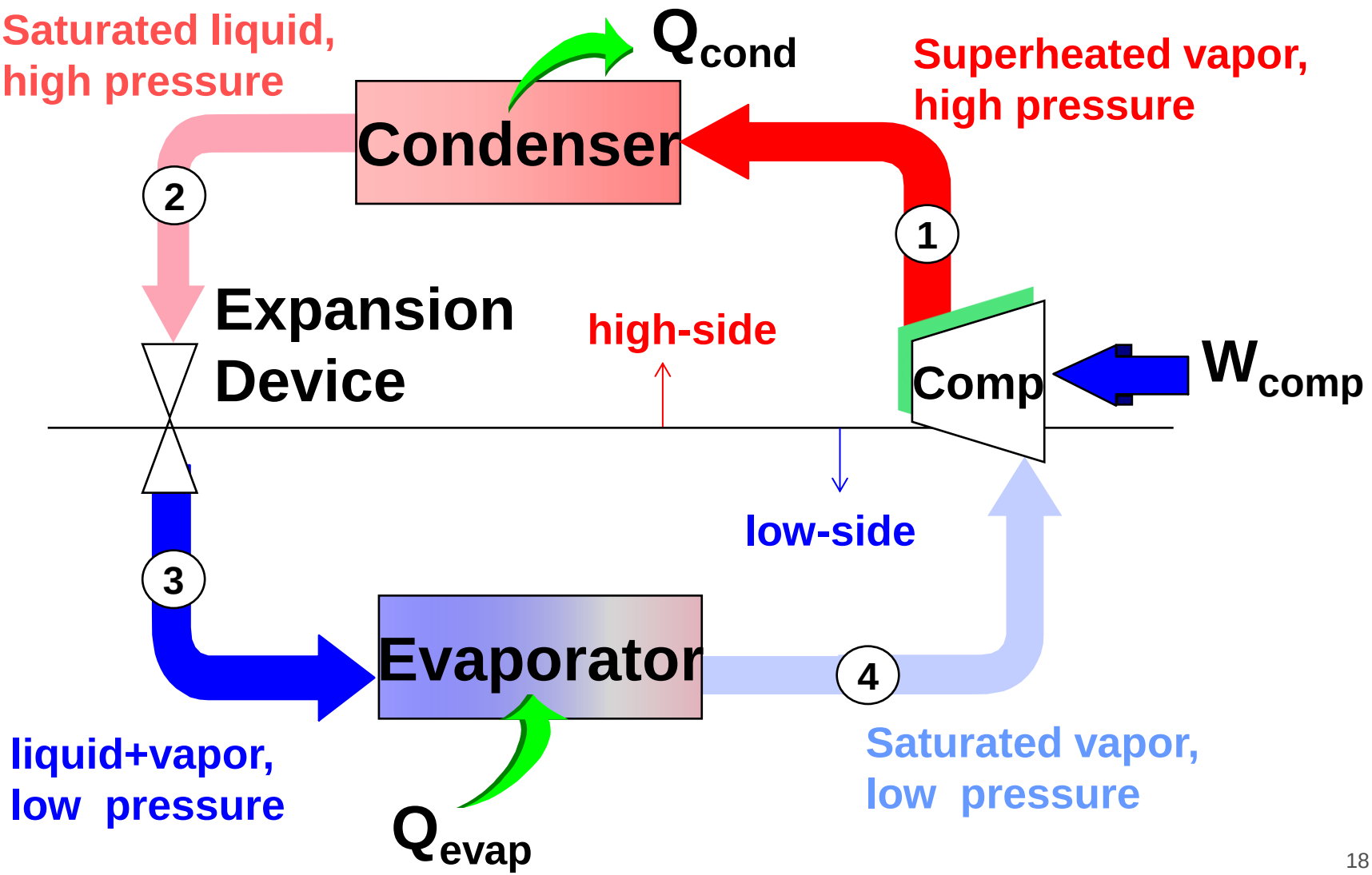
Let’s now look at the technology

Ammonia refrigeration technology

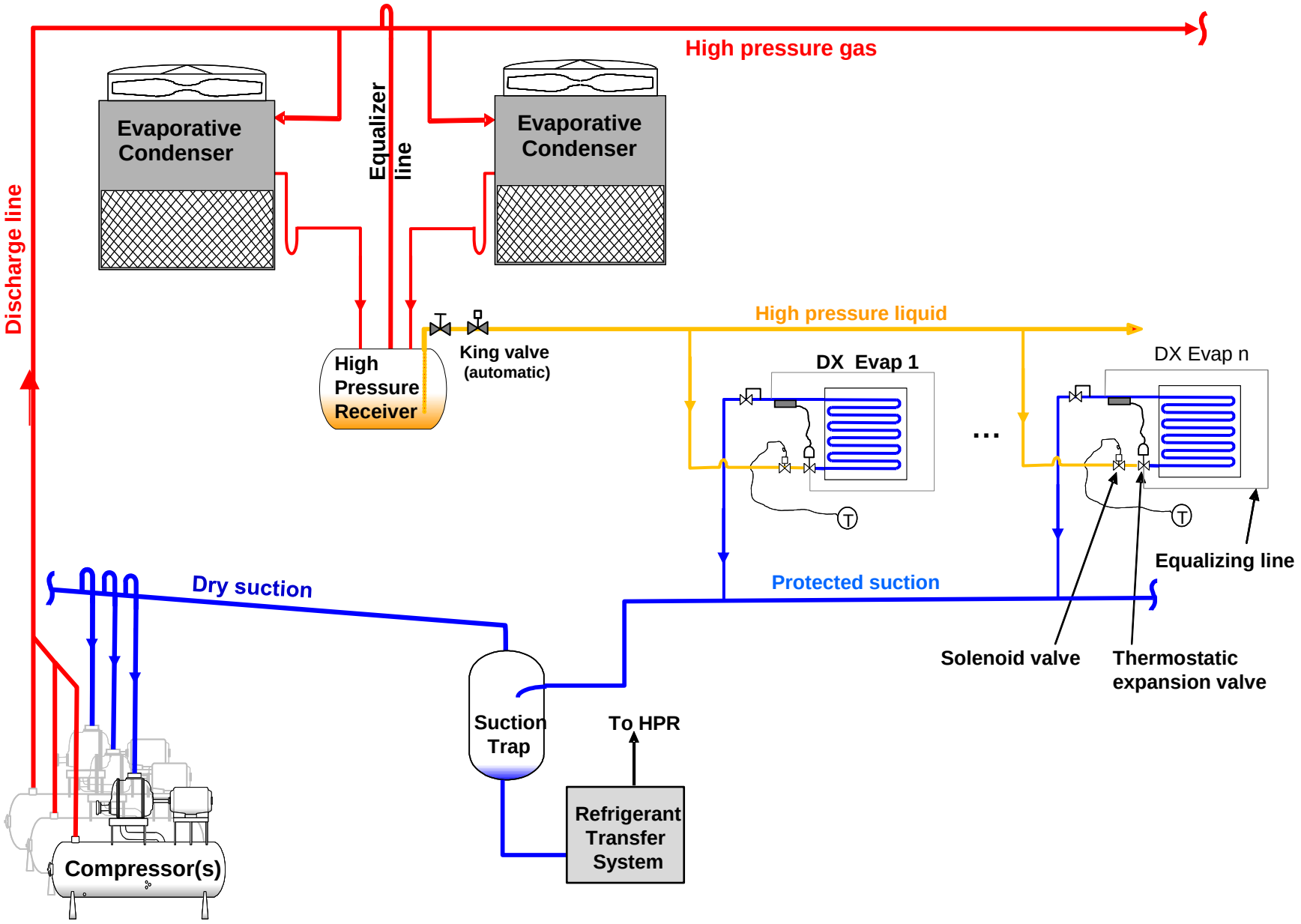
- Single stage compression with evaporators configured as
  - direct-expansion
  - flooded
  - overfeed
- Multi-stage compression systems
- Cascade systems



Simple vapor compression system



Single stage – Direct-eXpansion (DX)



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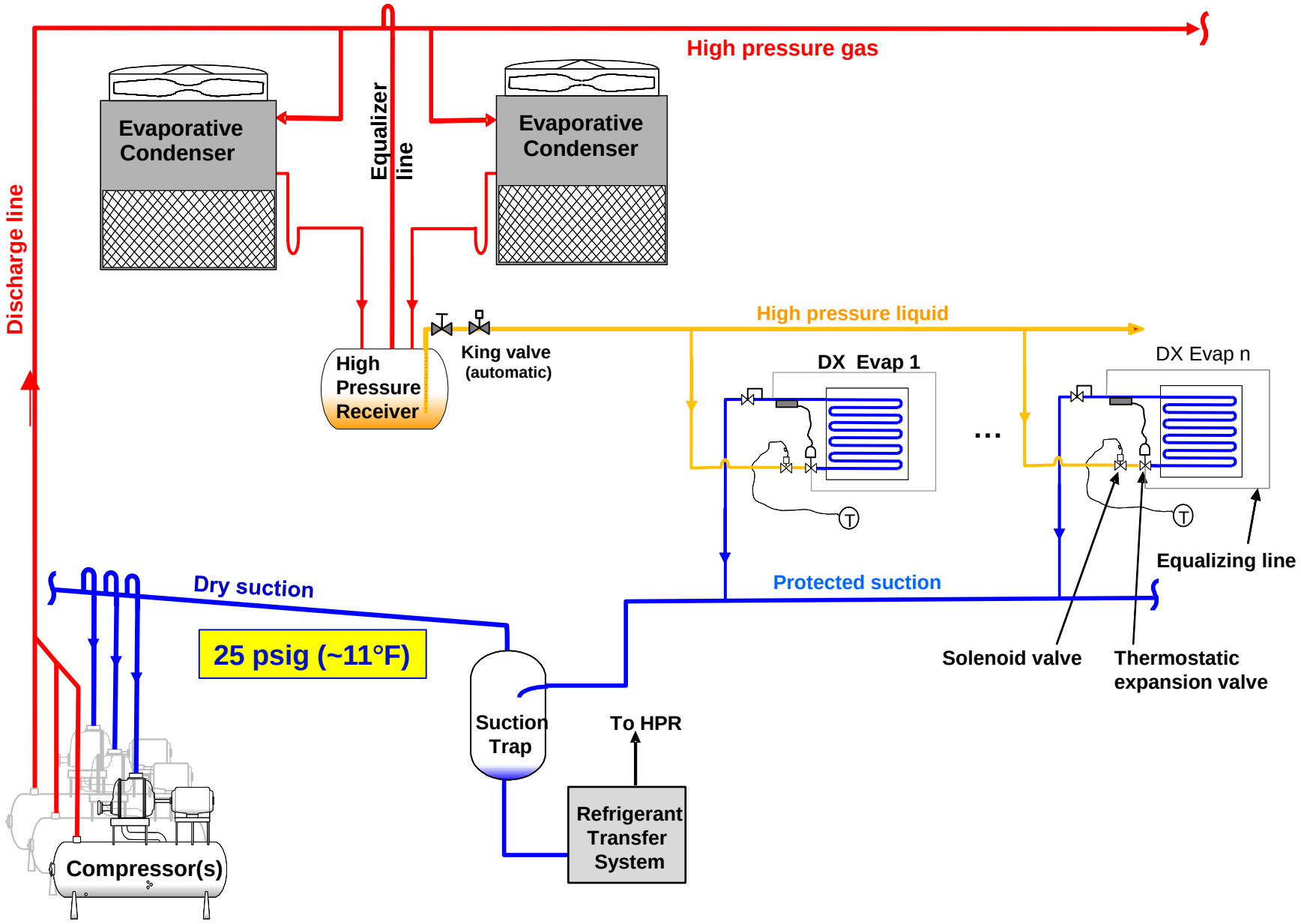

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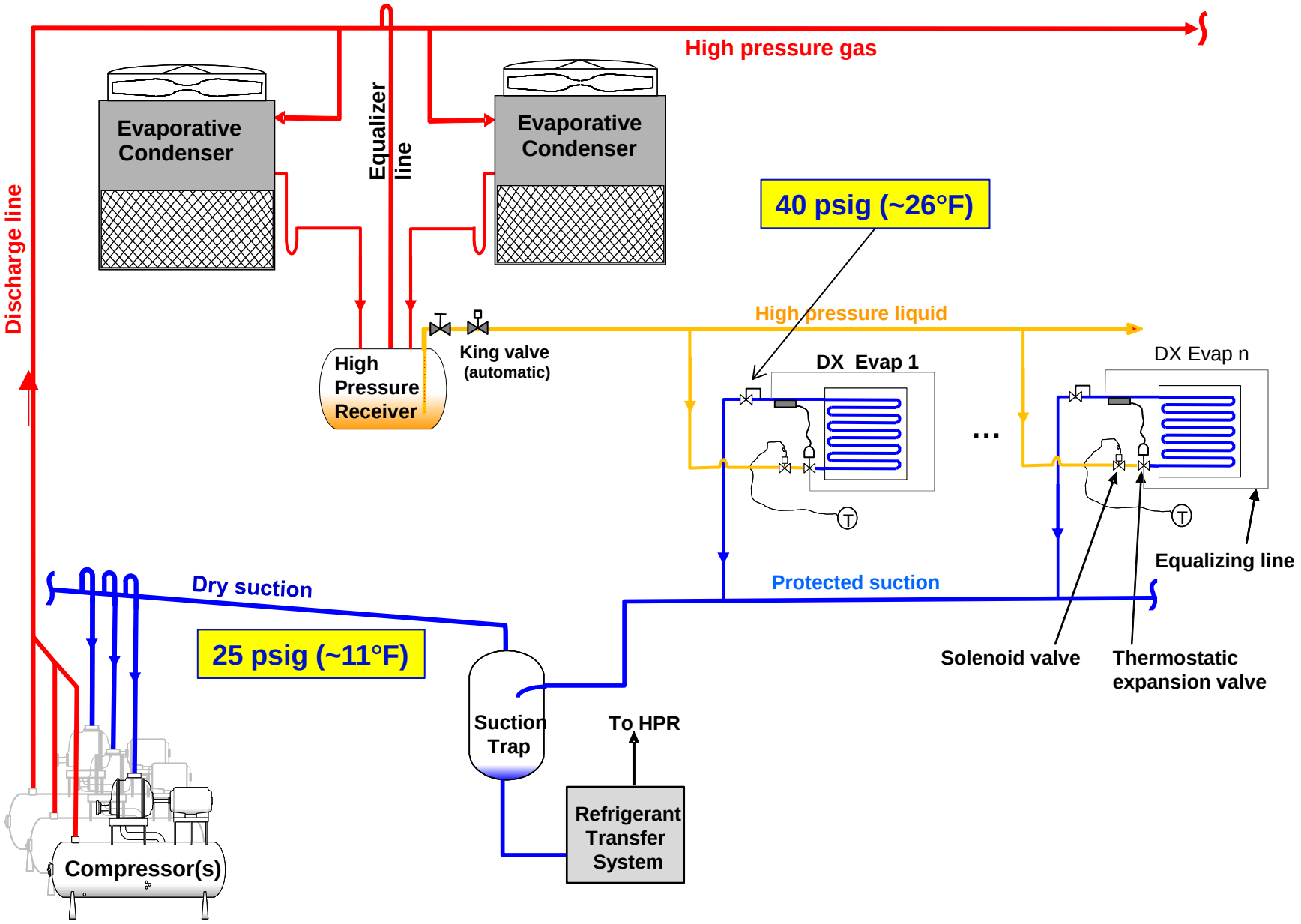

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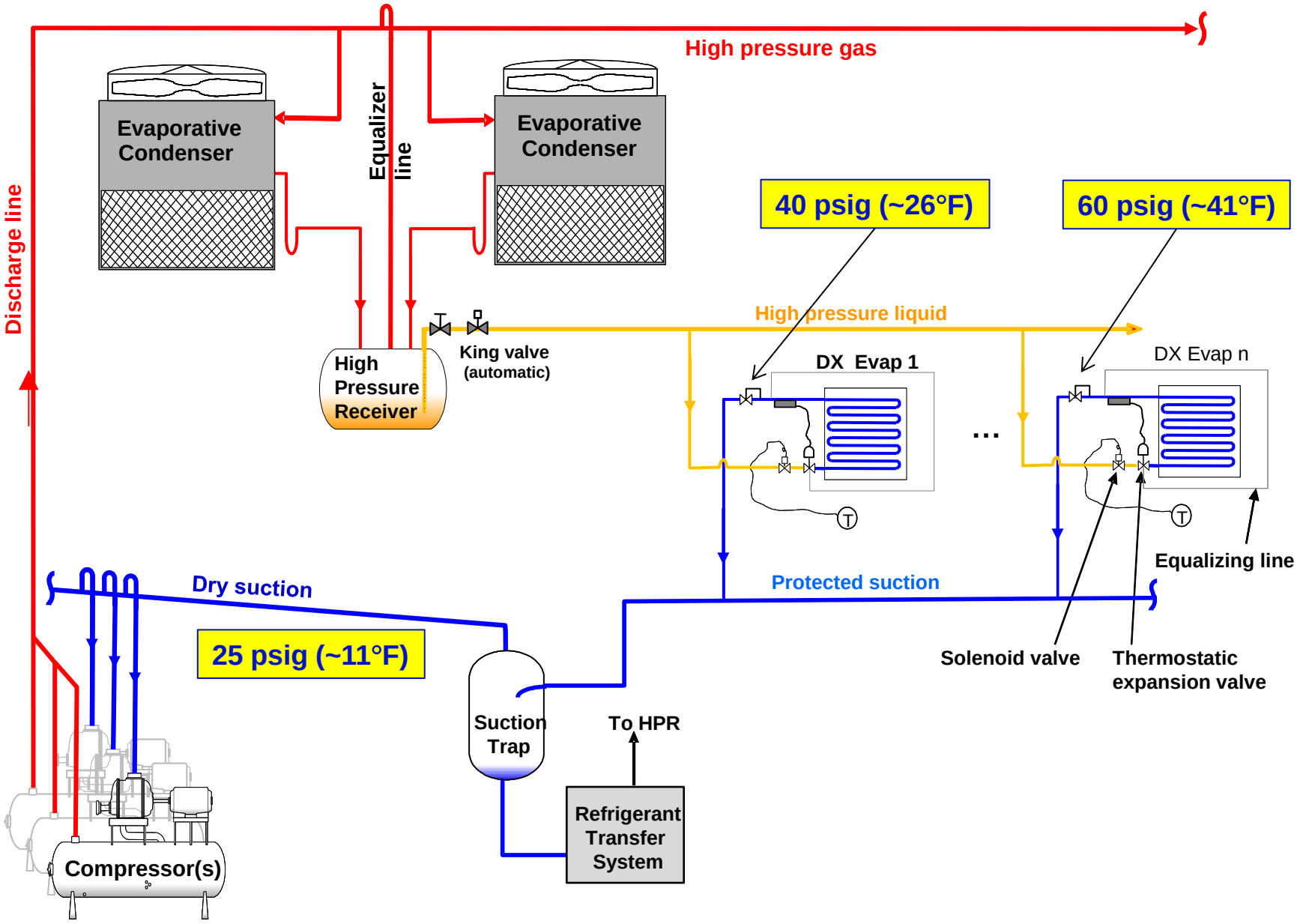

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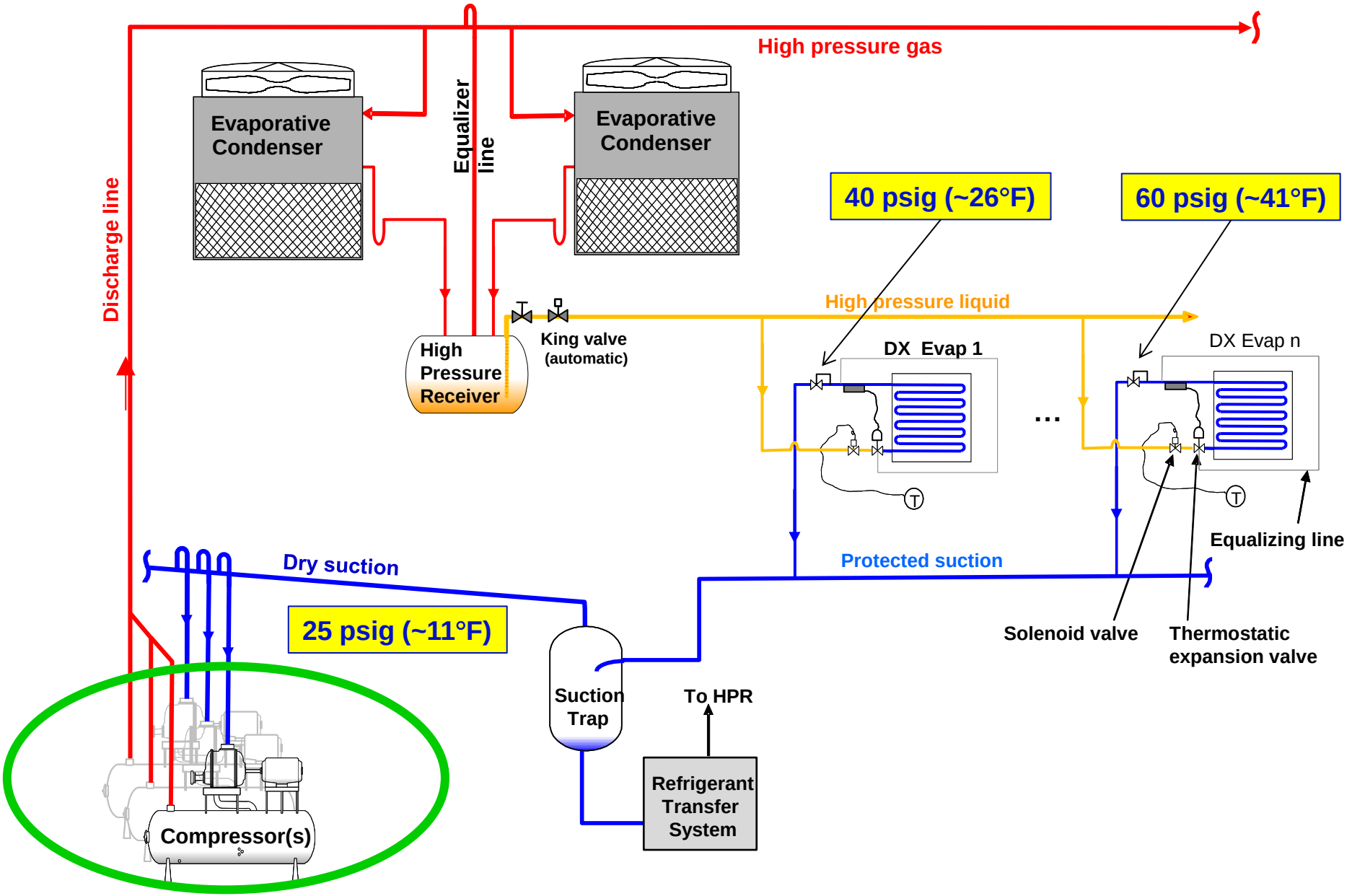
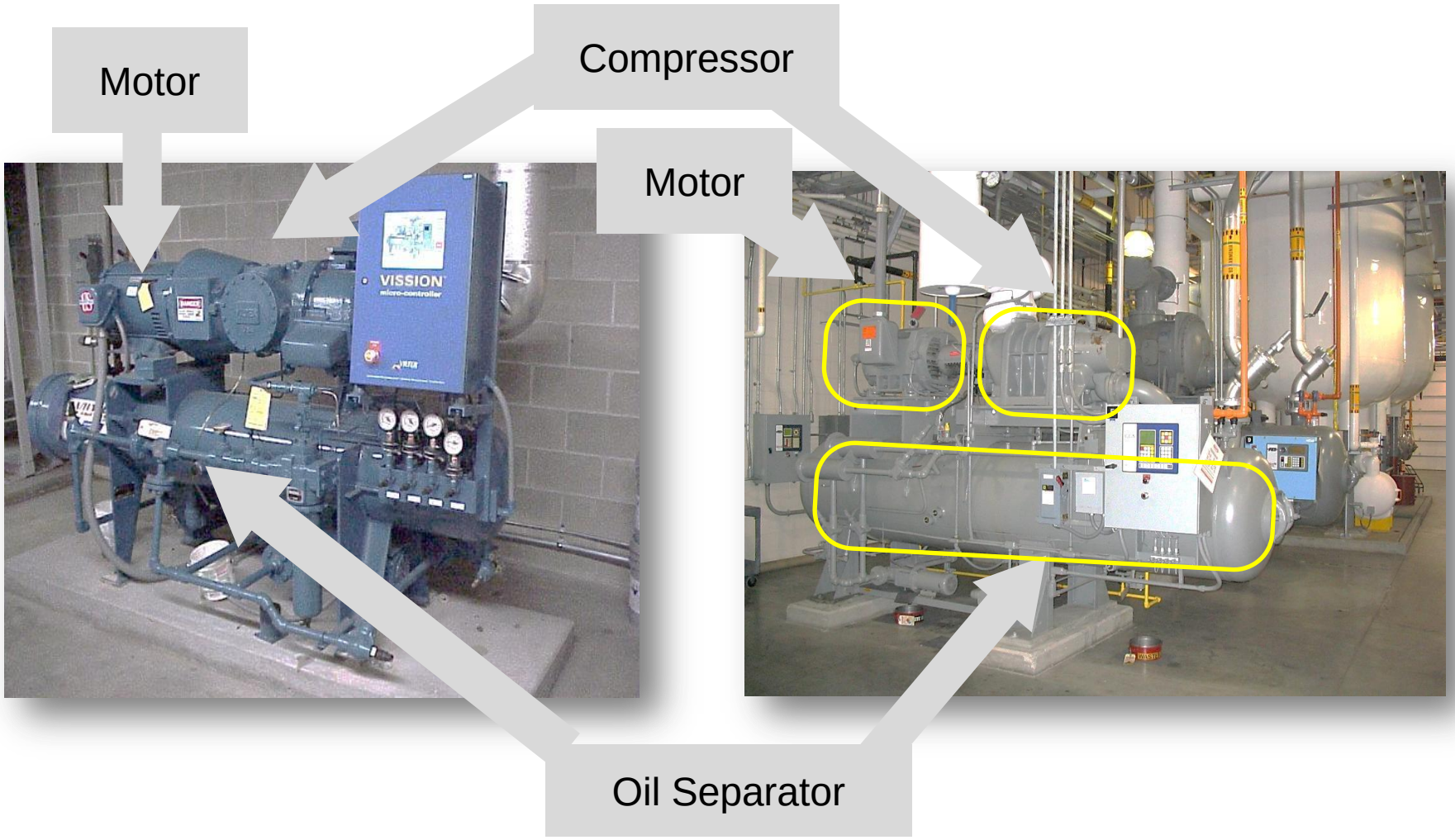
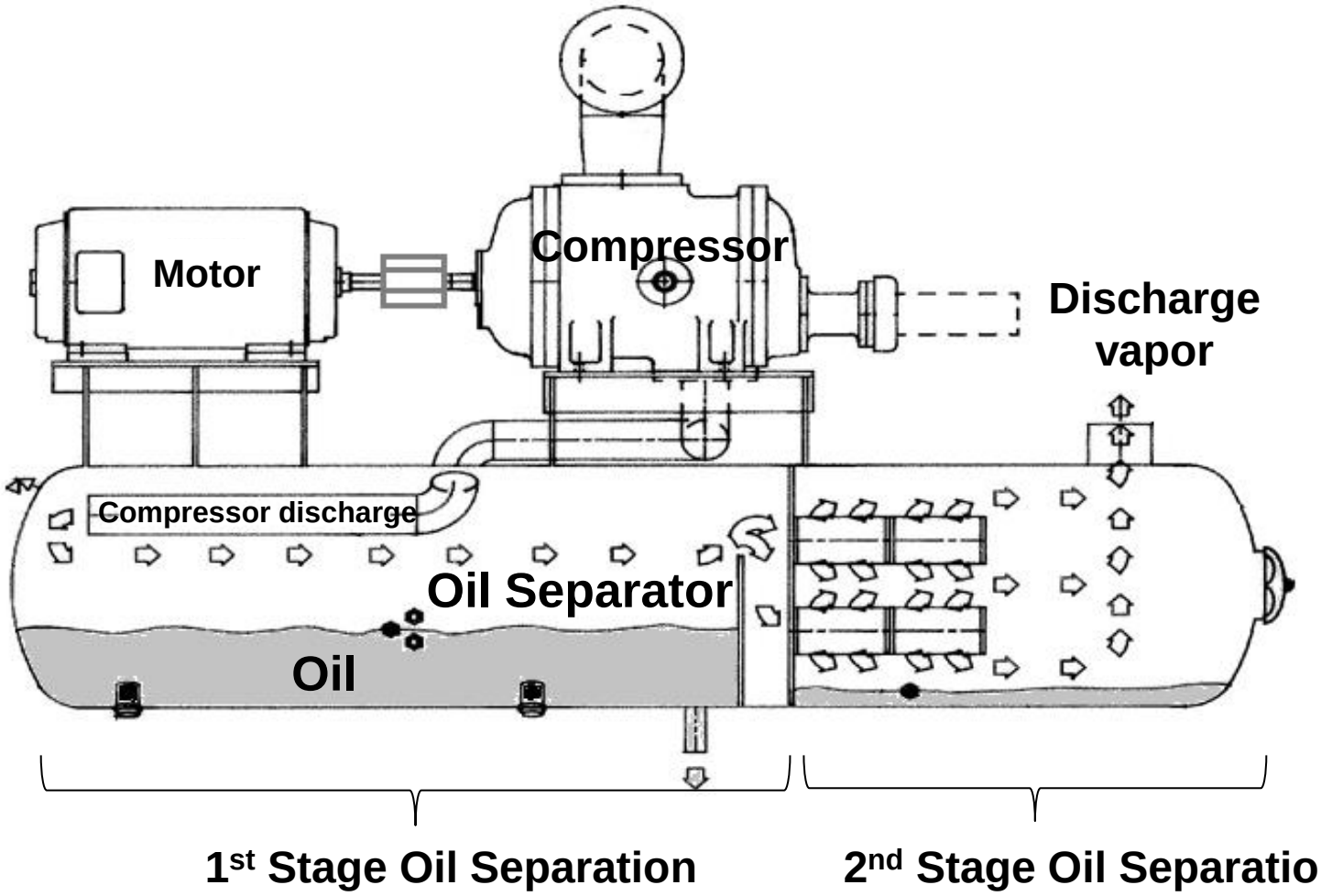


Compressor, rotary screw

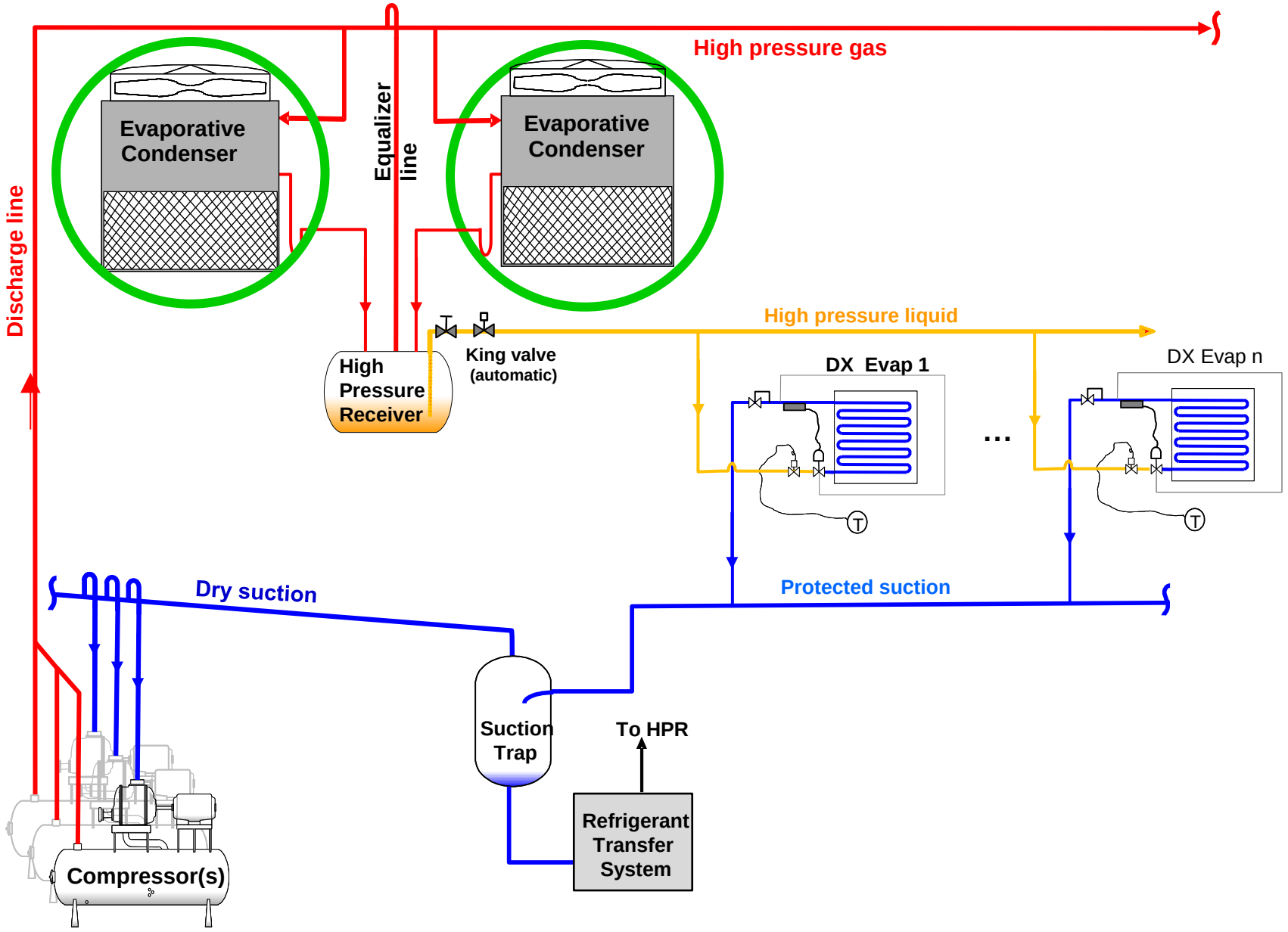


Oil Separator



Compressors, reciprocating

Single stage – Direct-eXpansion (DX)

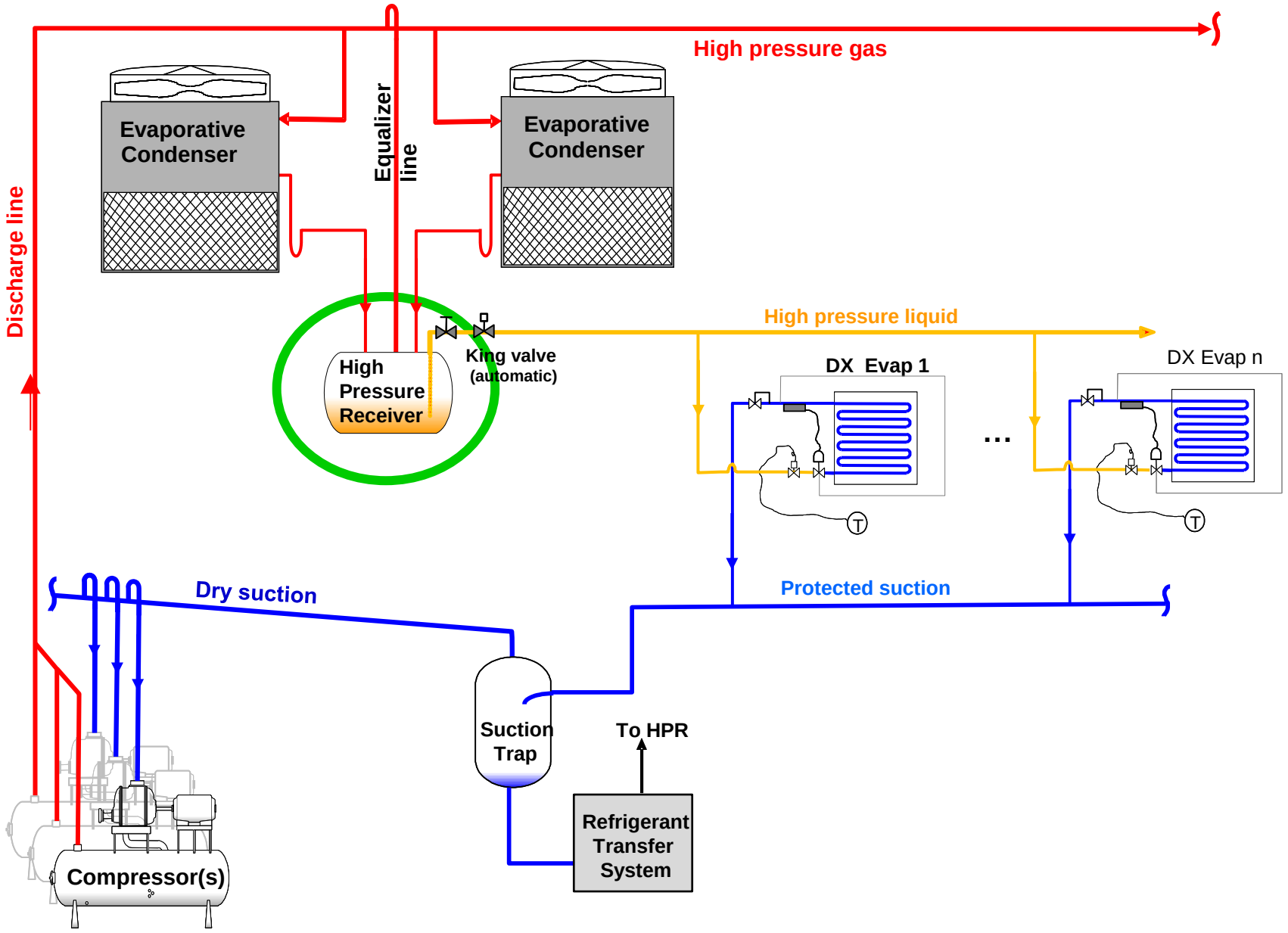


Condensers, evaporative

Condensers, evaporative

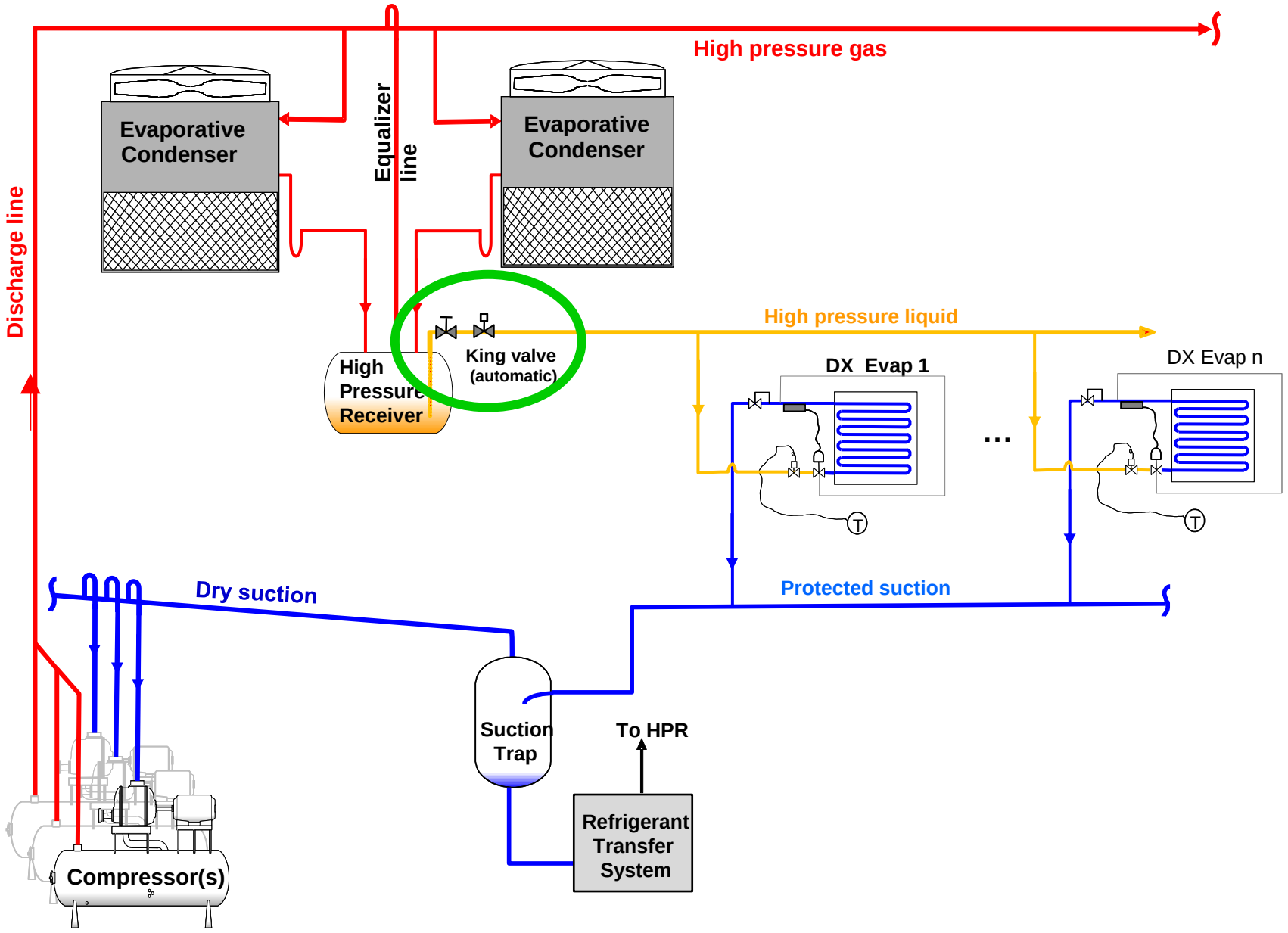
Evaporative condenser coil

Single stage – Direct-eXpansion (DX)



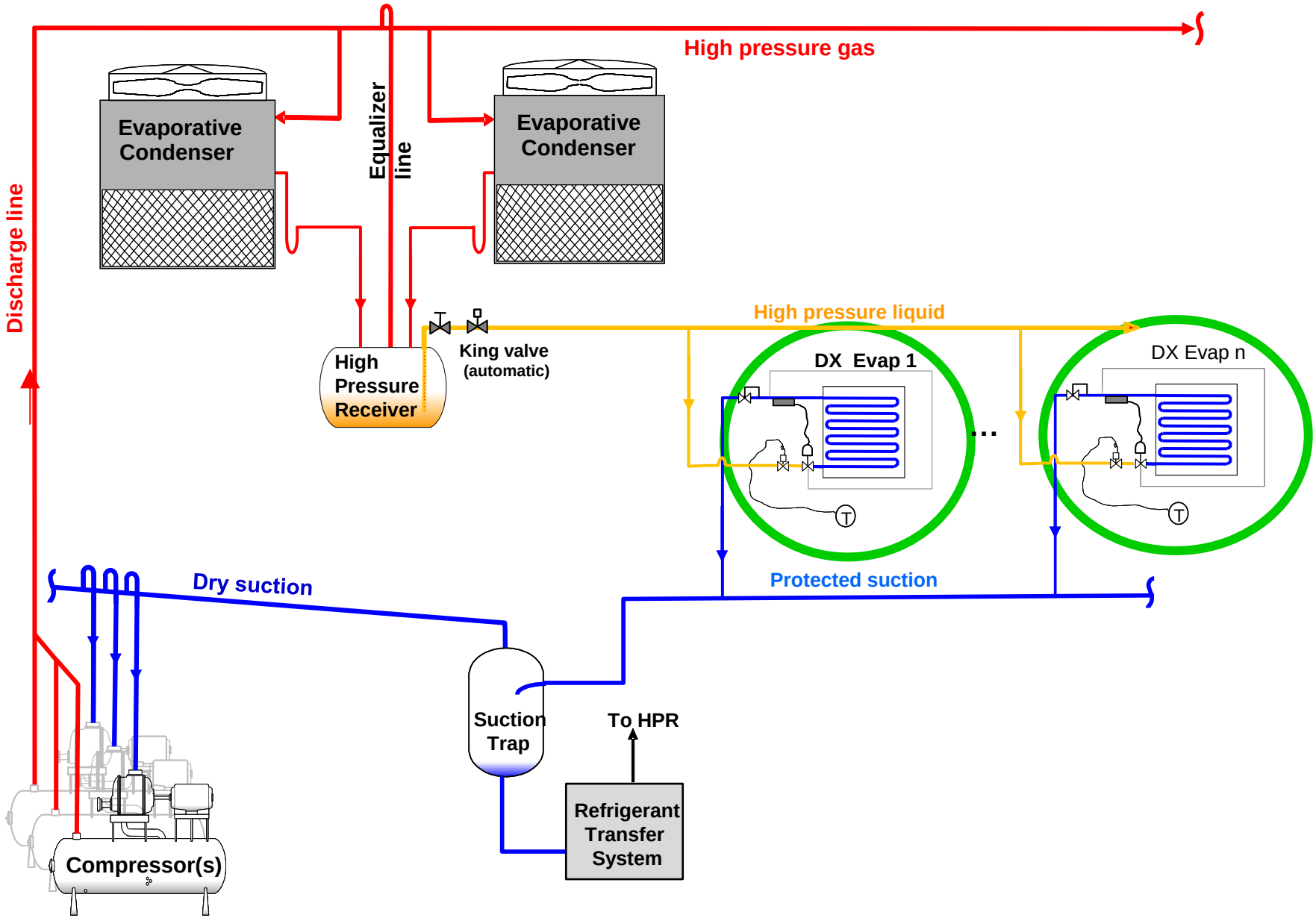
Receivers, high pressure

Single stage – Direct-eXpansion (DX)



King valve

Single stage – Direct-eXpansion (DX)



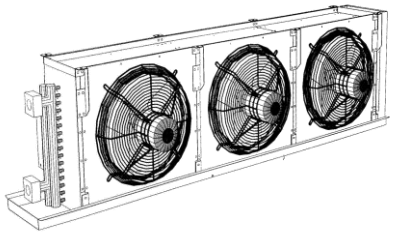
Evaporator, air-cooling

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

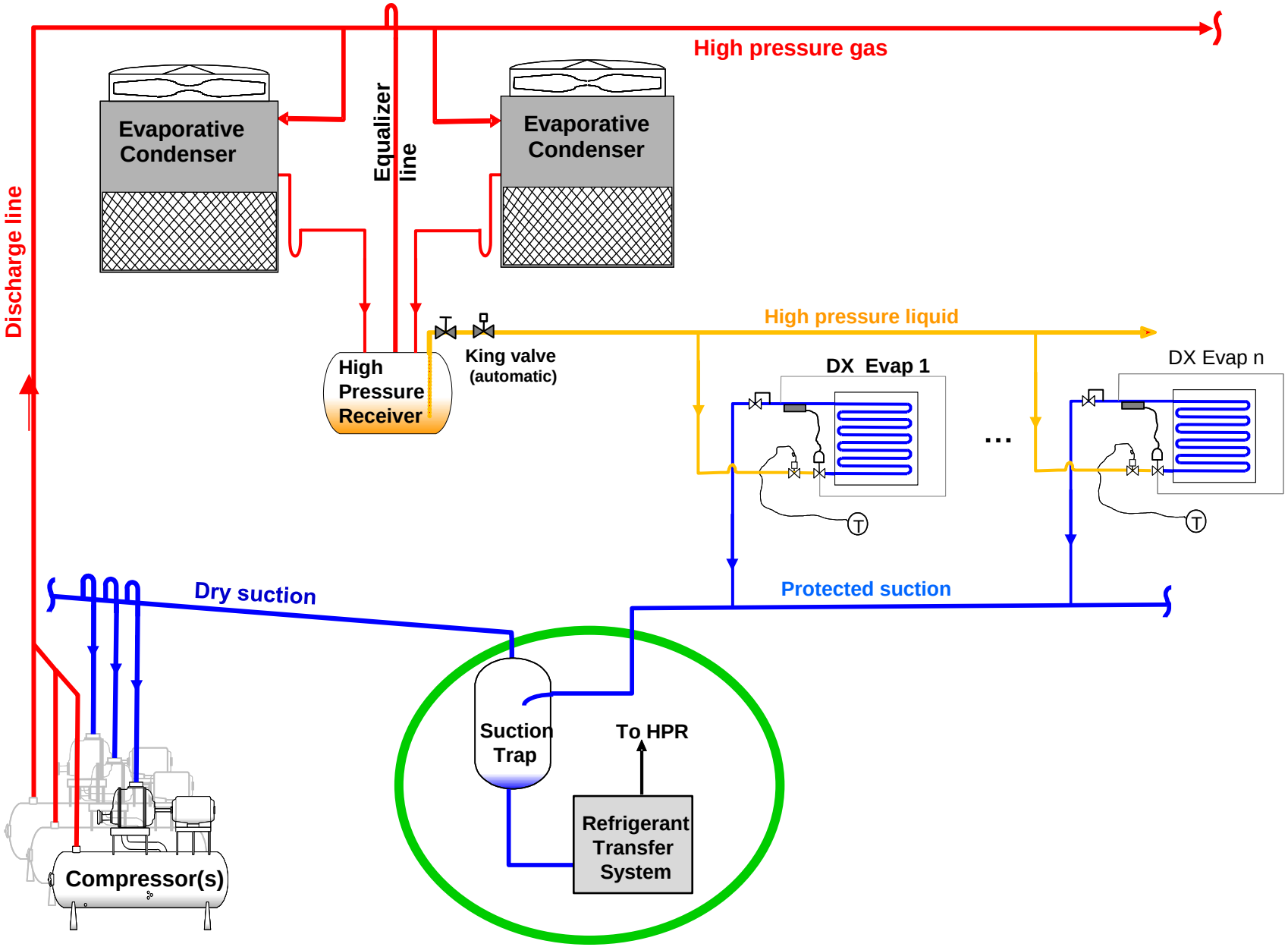


- Liquid-cooling (secondary fluids and products)
  - Shell-and-tube
  - Plate-and-frame
  - Falling film
  - Scraped surface

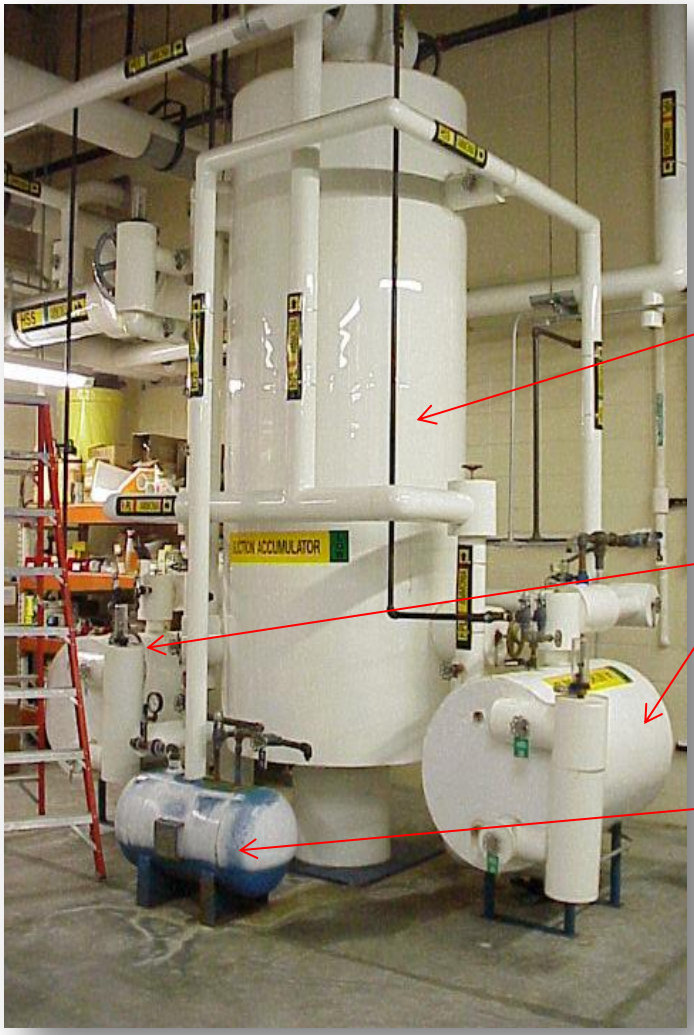
Shell-and-tube liquid chiller

Plate-and-frame liquid chiller

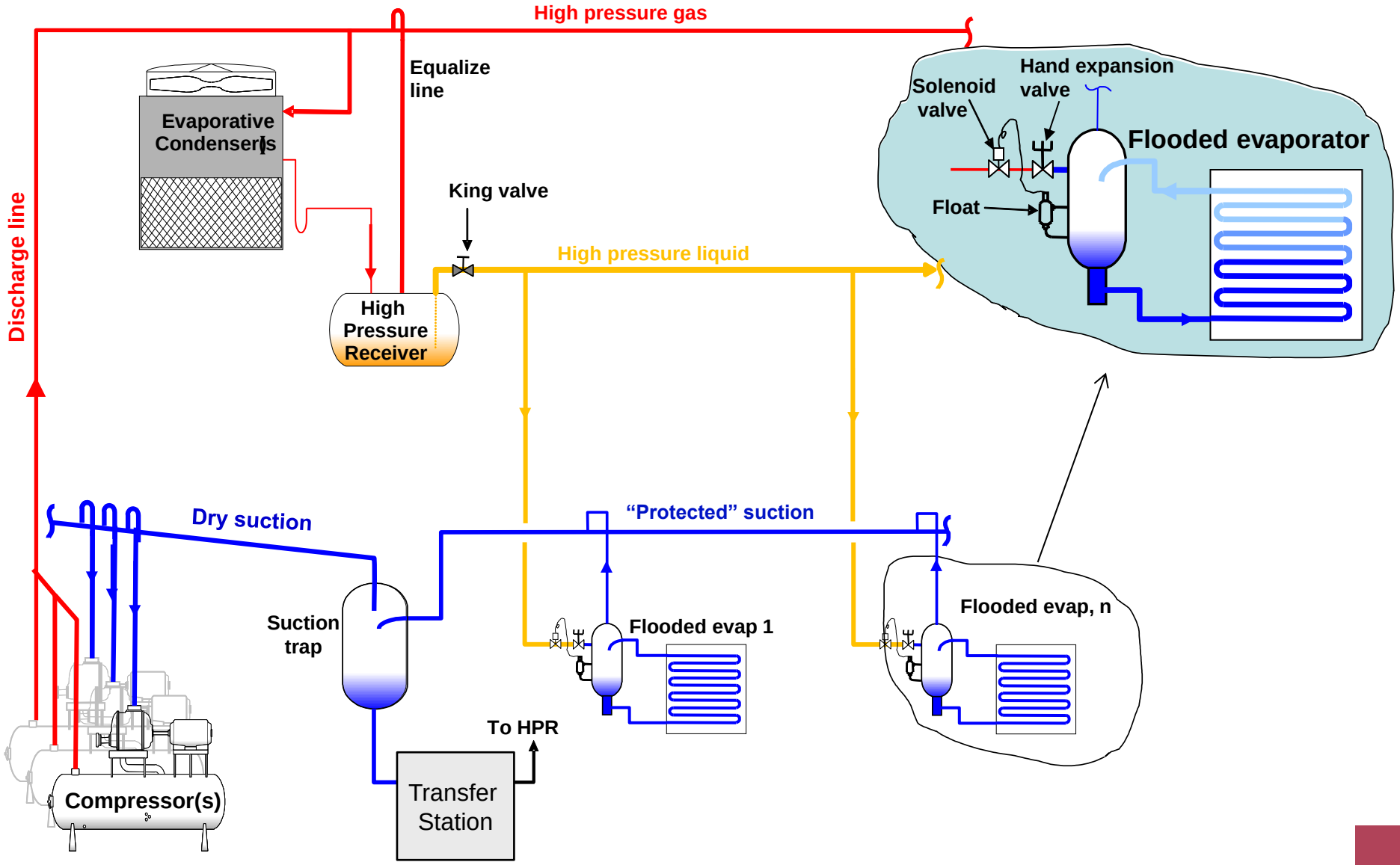
Single stage – Direct-eXpansion (DX)



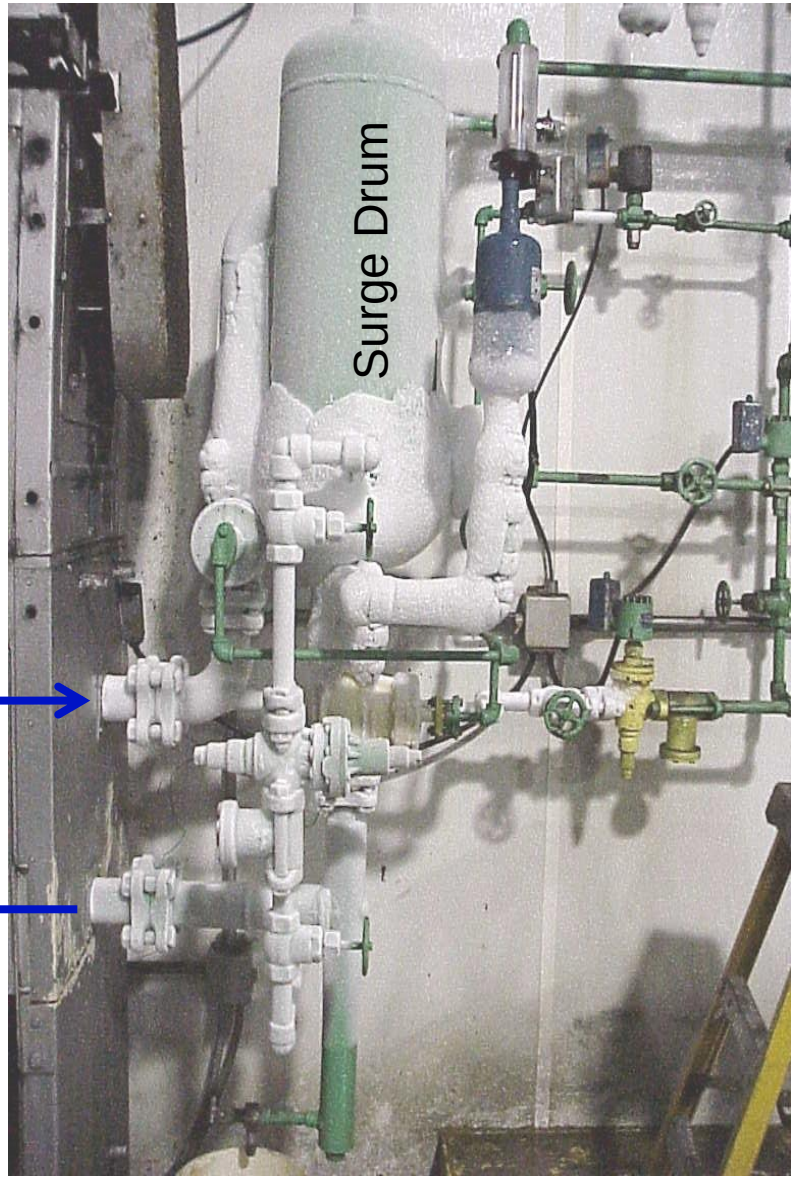
Transfer system



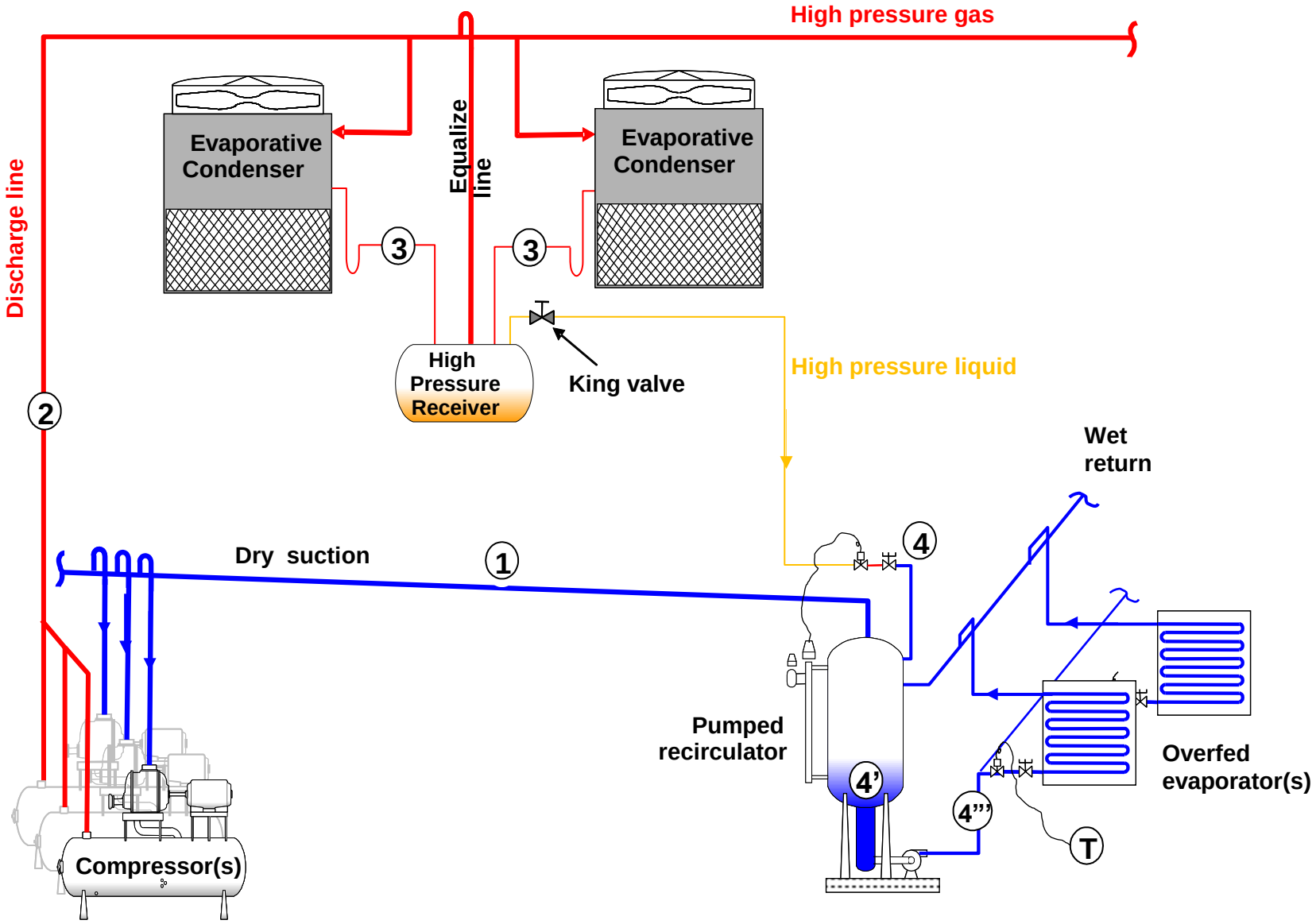
Gravity flooded recirculation system



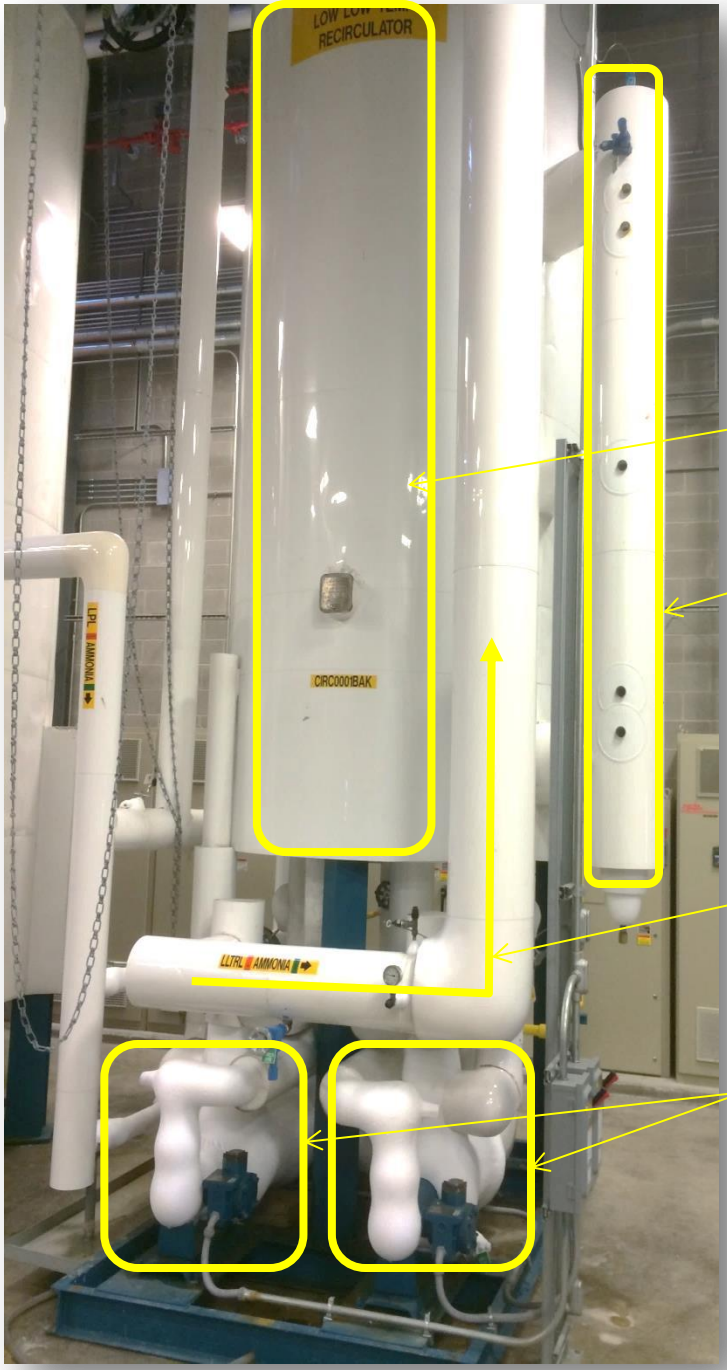
Gravity flooded evaporator



Pumped liquid overfeed



Liquid overfeed system



Recirculator

Float column

Pumped liquid line

Liquid refrigerant pumps

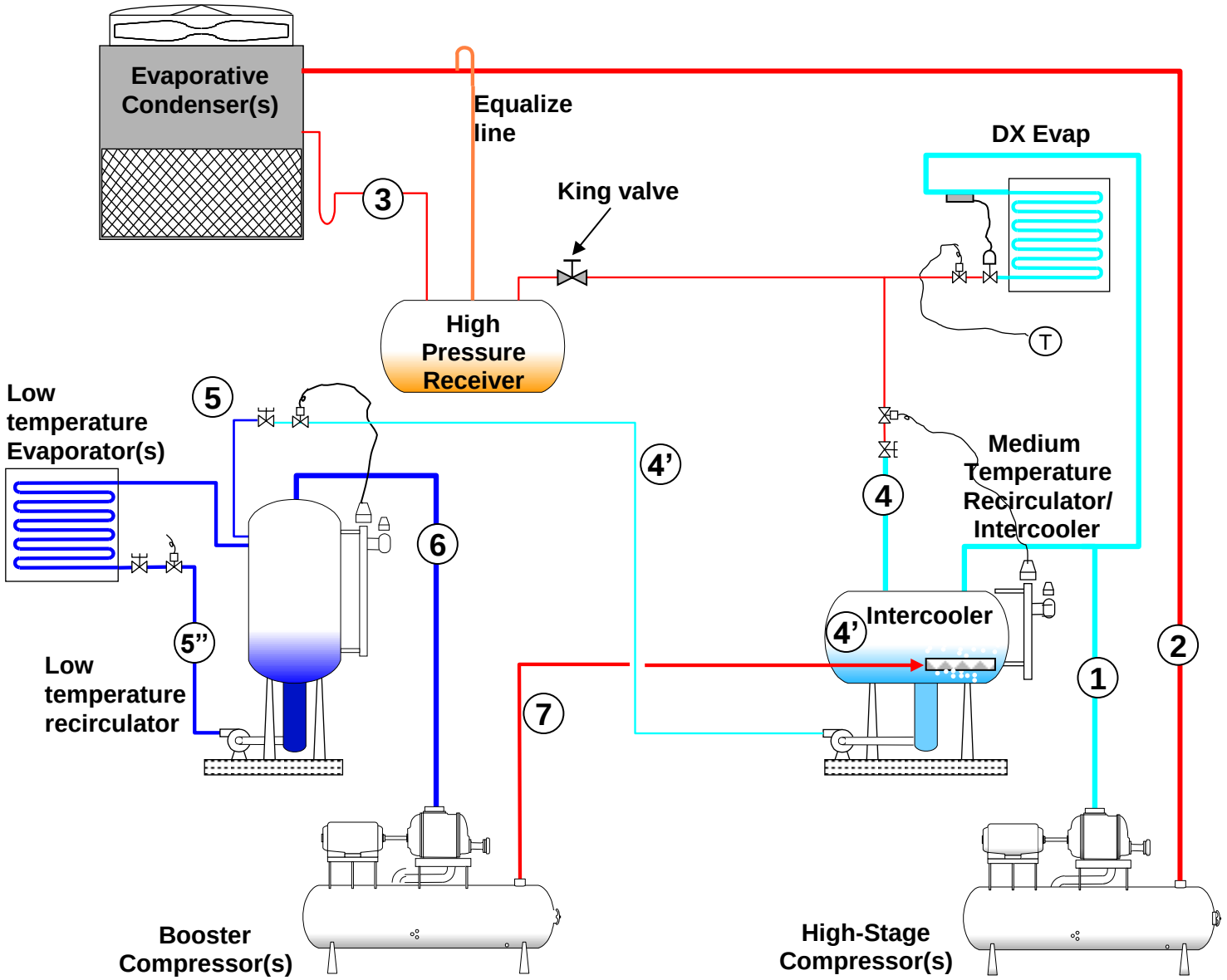
Liquid overfeed system components

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

Two-stage compression

(two temperature level with two stages of liquid expansion)



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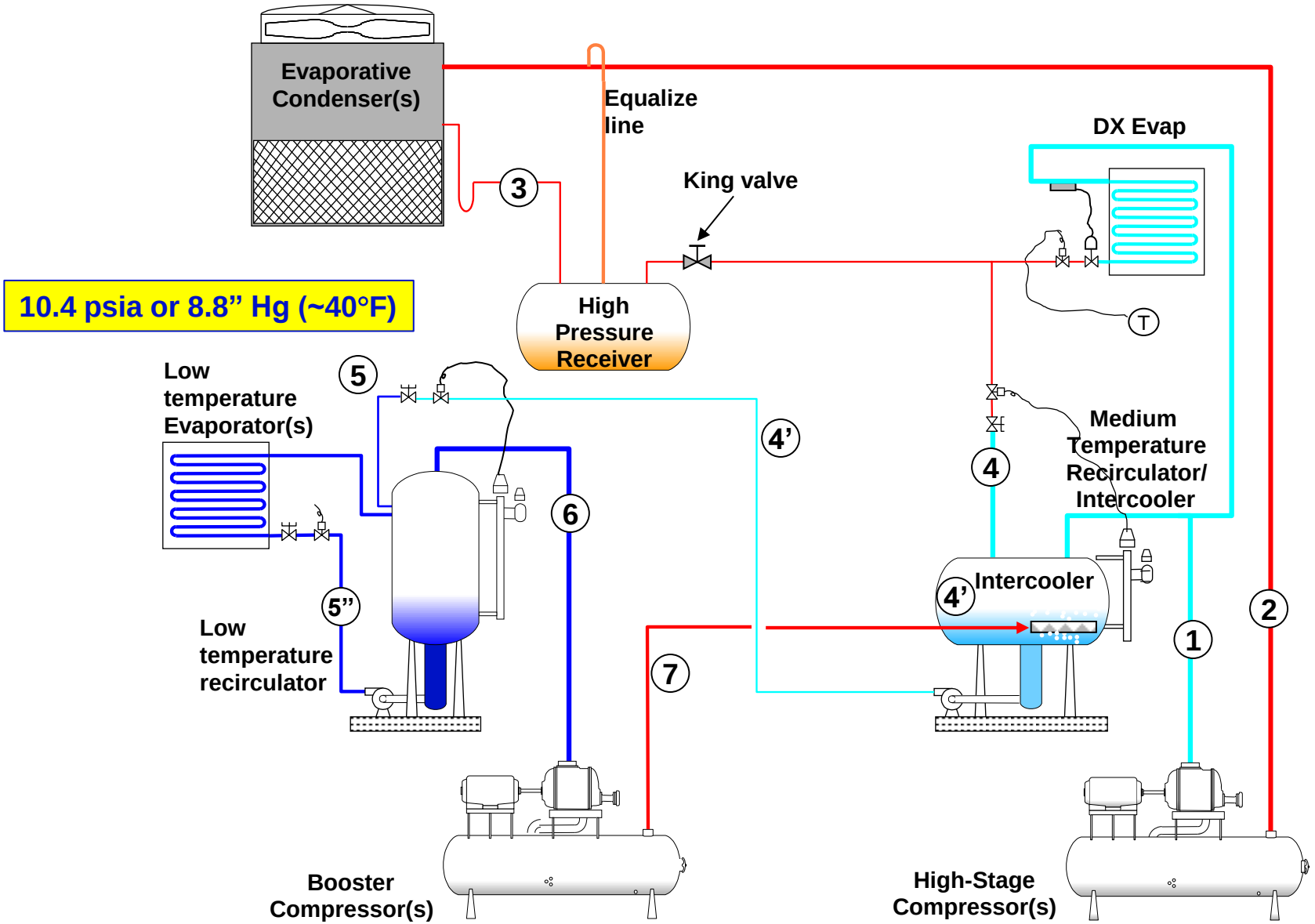

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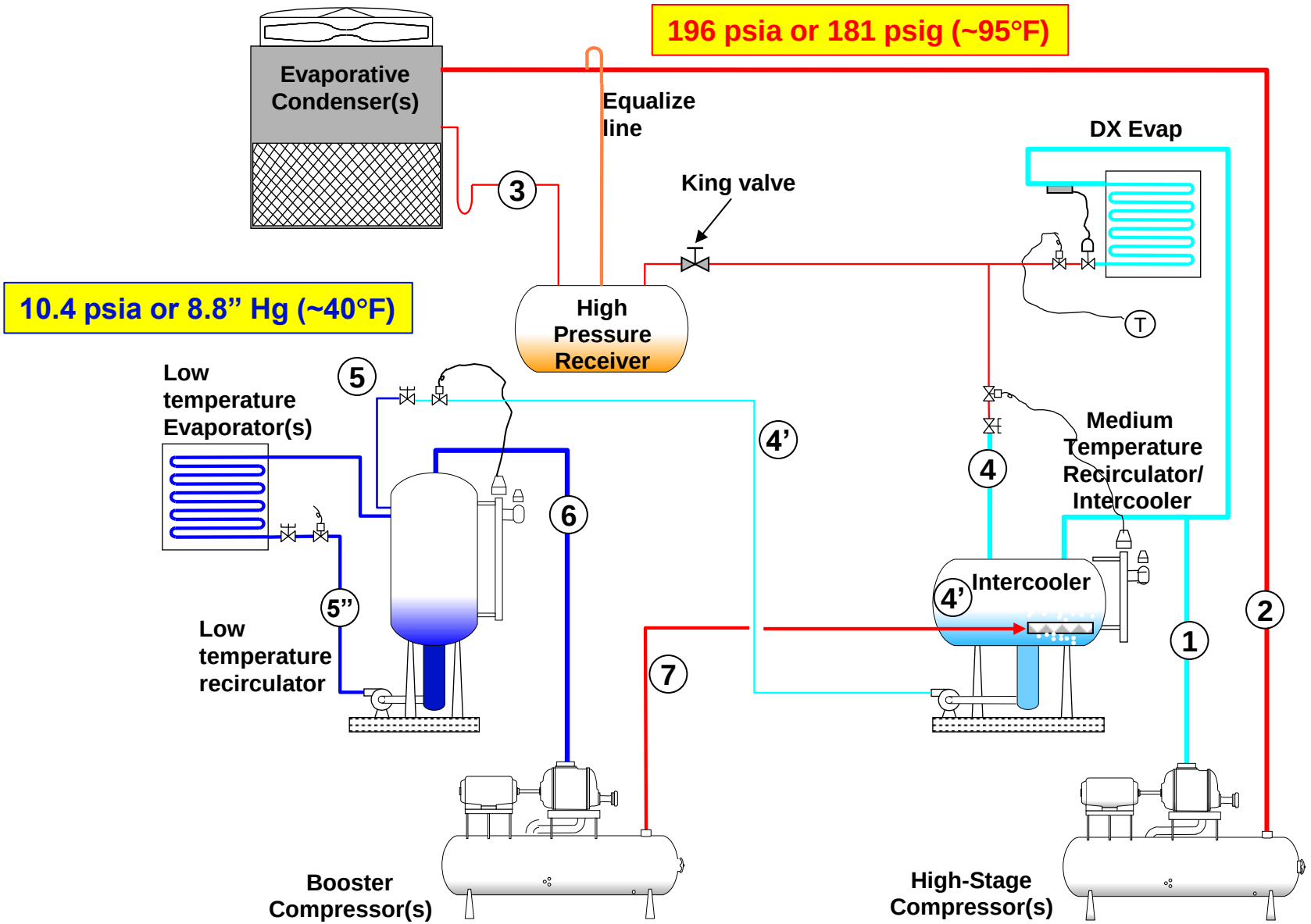

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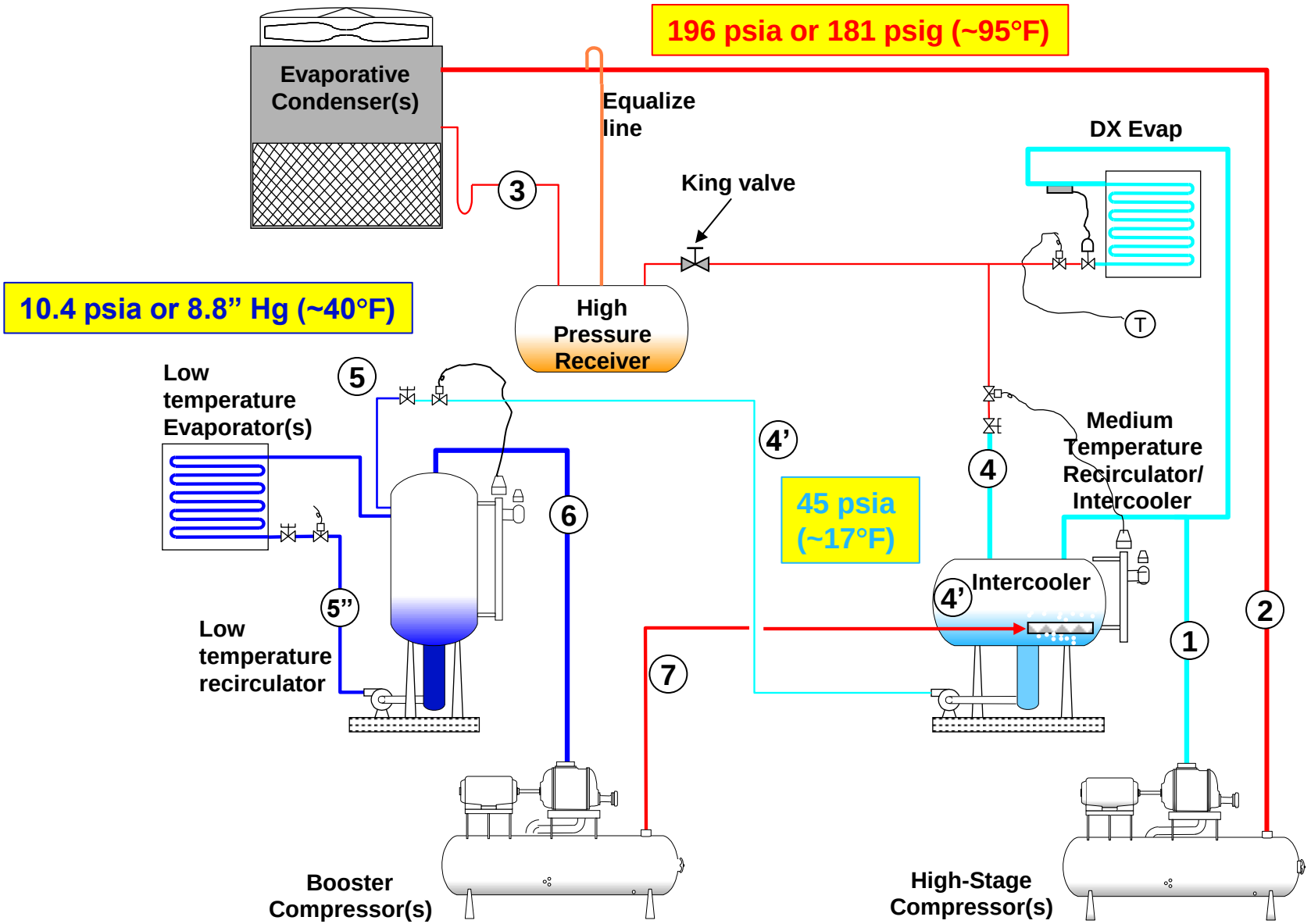

Two-stage compression

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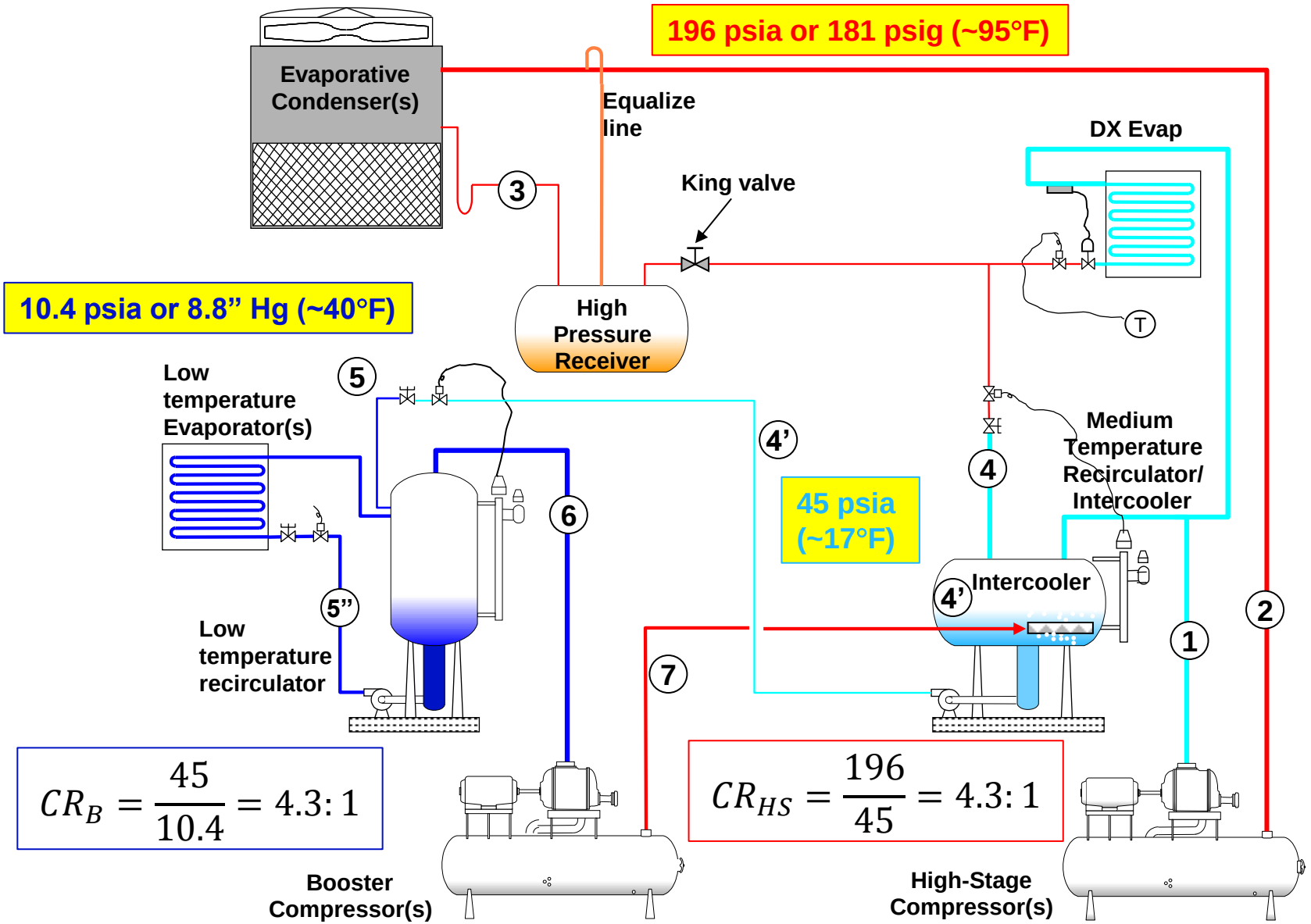
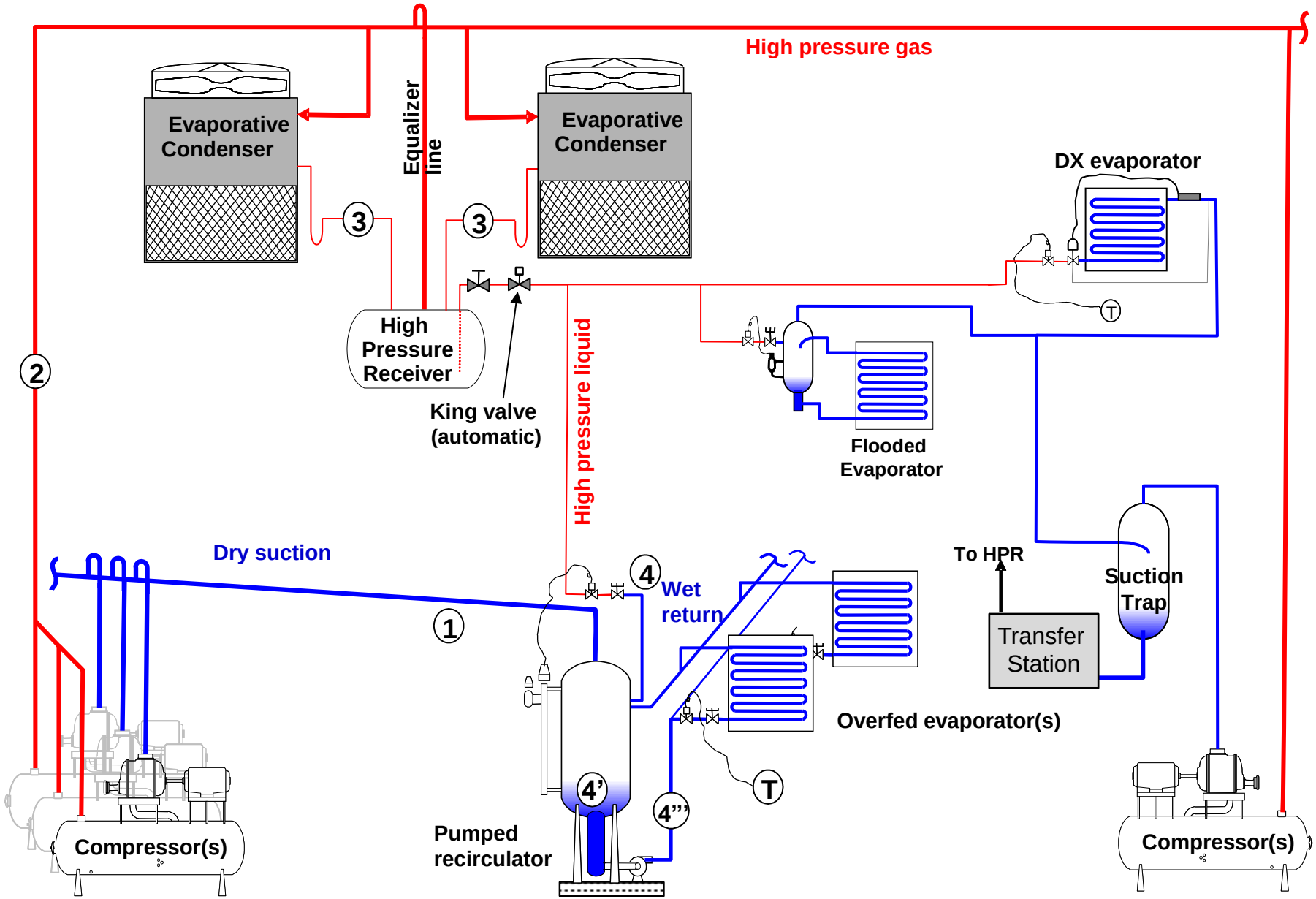


What's a "typical" system?



QUESTIONS?

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?