RETA Book 2 Chapter 9 – Two Stage Systems

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CIRO Exam Content

Fundamentals and Introductory Concepts	30 Questions
Safety Standards & Procedures	12 Questions
Electricity	12 Questions
Valves and Controls	12 Questions
Two-Stage Refrigeration System Operations	10 Questions
Other Refrigeration System Operations	13 Questions
Heat Flow of Refrigeration Systems	15 Questions
Troubleshooting	6 Questions
Measuring System Performance	14 Questions

Objectives of This Chapter

1. Discuss two stage systems
2. Understand the way intercoolers work
3. Understand why it costs less in energy to produce refrigeration with two stages of compression instead of one

Low Evaporator Temperatures

- Lower evaporator temperature leads to lower evaporator pressure
- Greater distance between the suction and discharge pressure leads to increased compression ratio
- Higher compression ratio leads to increased work (heat) that the compressor must put into a pound of gas in order to compress it to the required discharge pressure

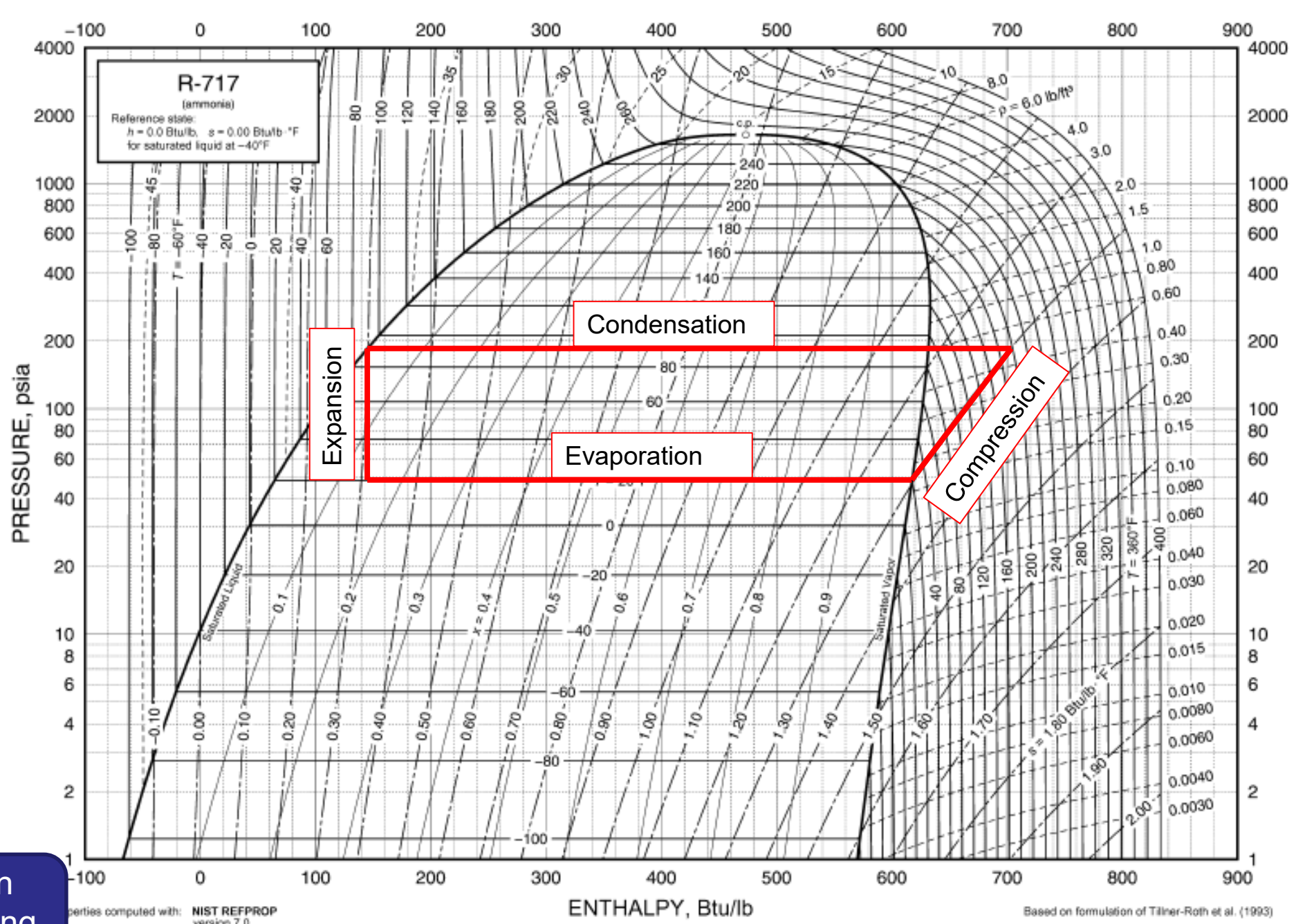

Fig. 19 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)

+20ºF Suction
90ºF Condensing
Single Stage

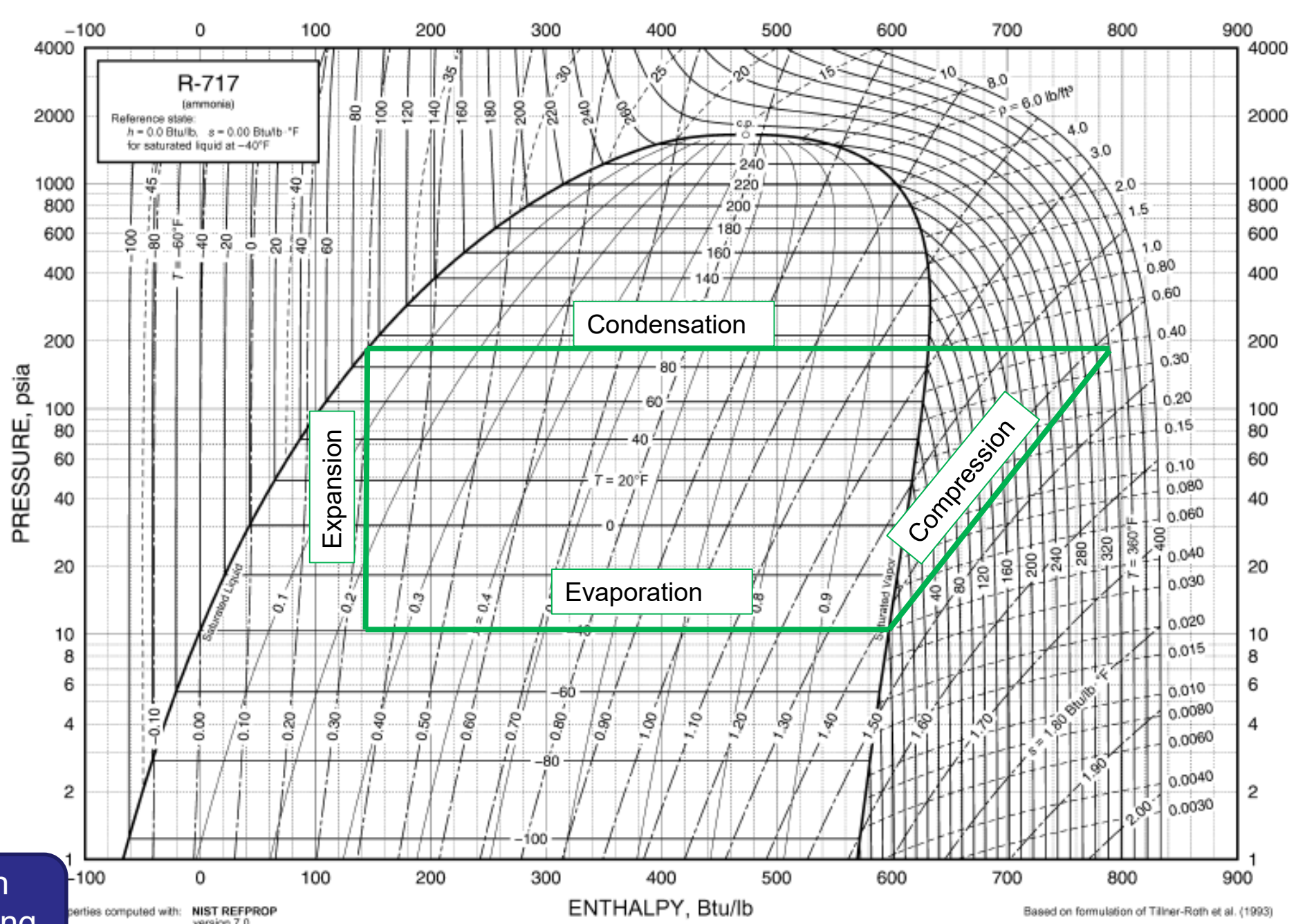

Fig. 19 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)

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90ºF Condensing
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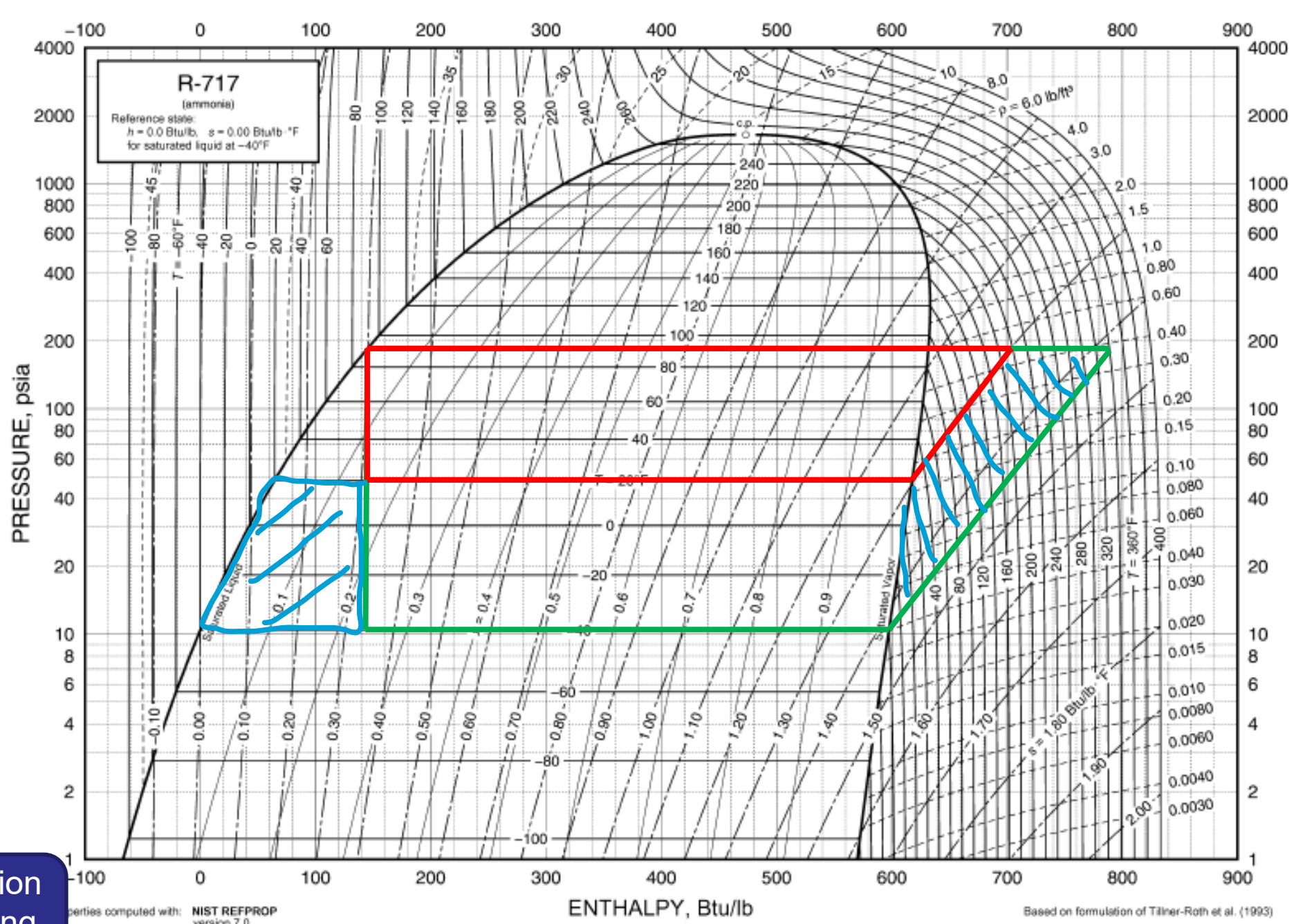

Fig. 19 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)

+20/-40ºF Suction
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Single Stage

Intro to Two Stage Compression

- Greater compression ratio = Higher discharge temperature

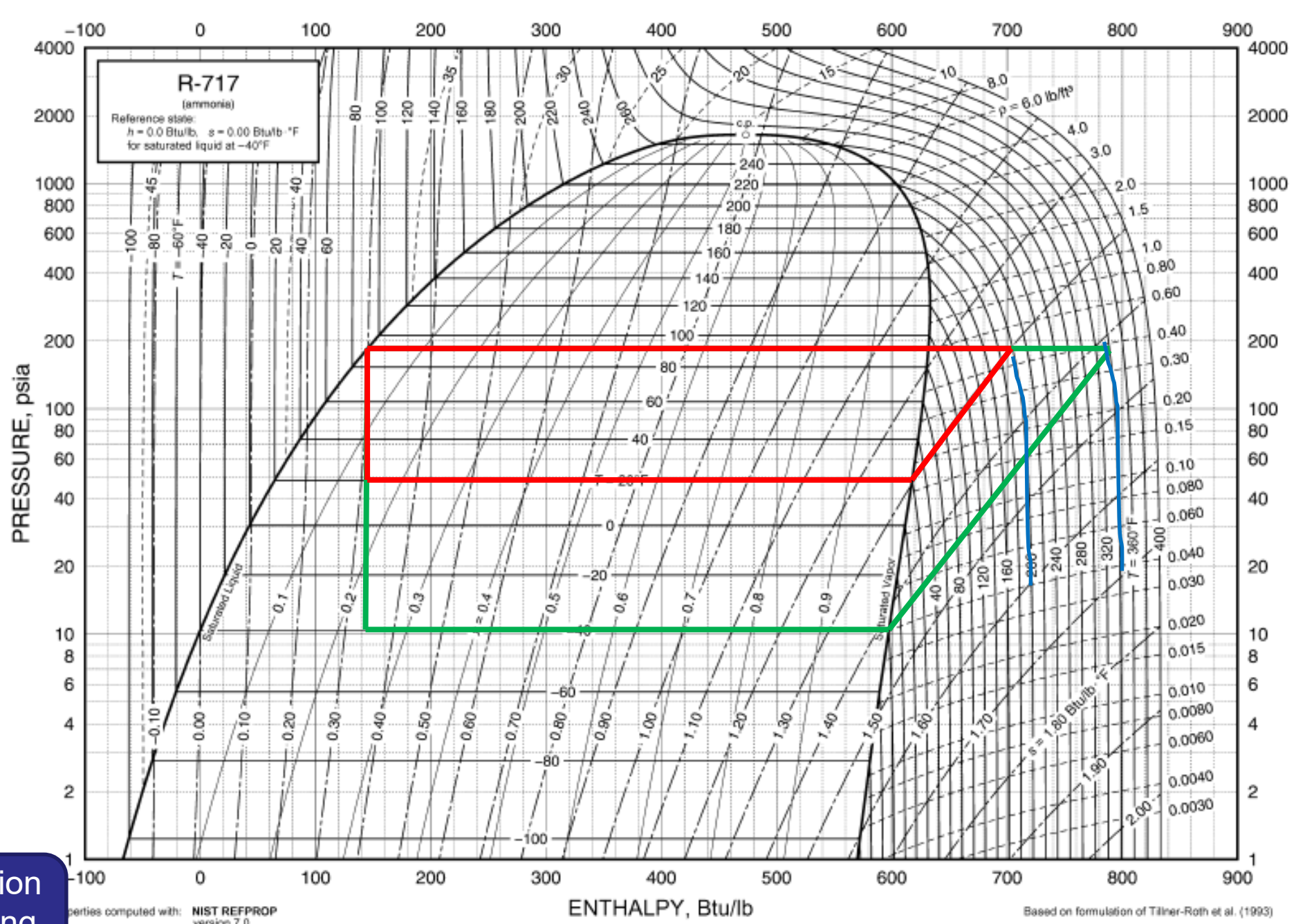


Fig. 19 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)

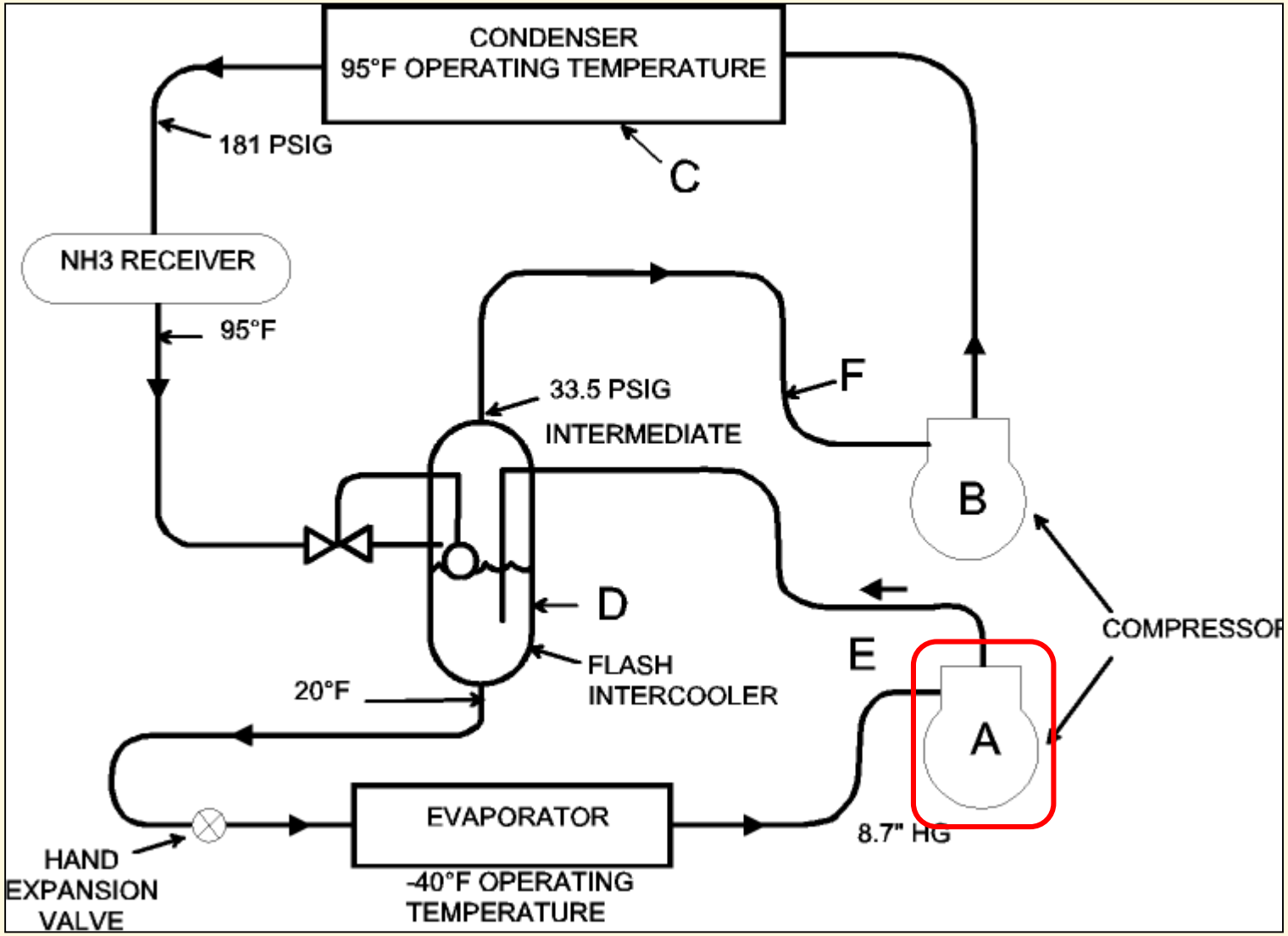
+20/-40ºF Suction
90ºF Condensing
Single Stage

Intro to Two Stage Compression

- Greater compression ratio = Higher discharge temperature
- Cannot cool to extremely low temperatures in a single stage because we would break down the oil

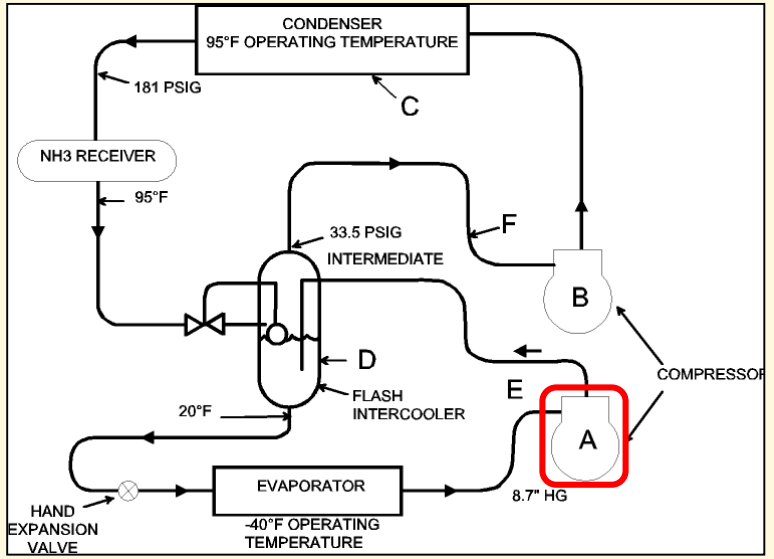
Intro to Two Stage Compression

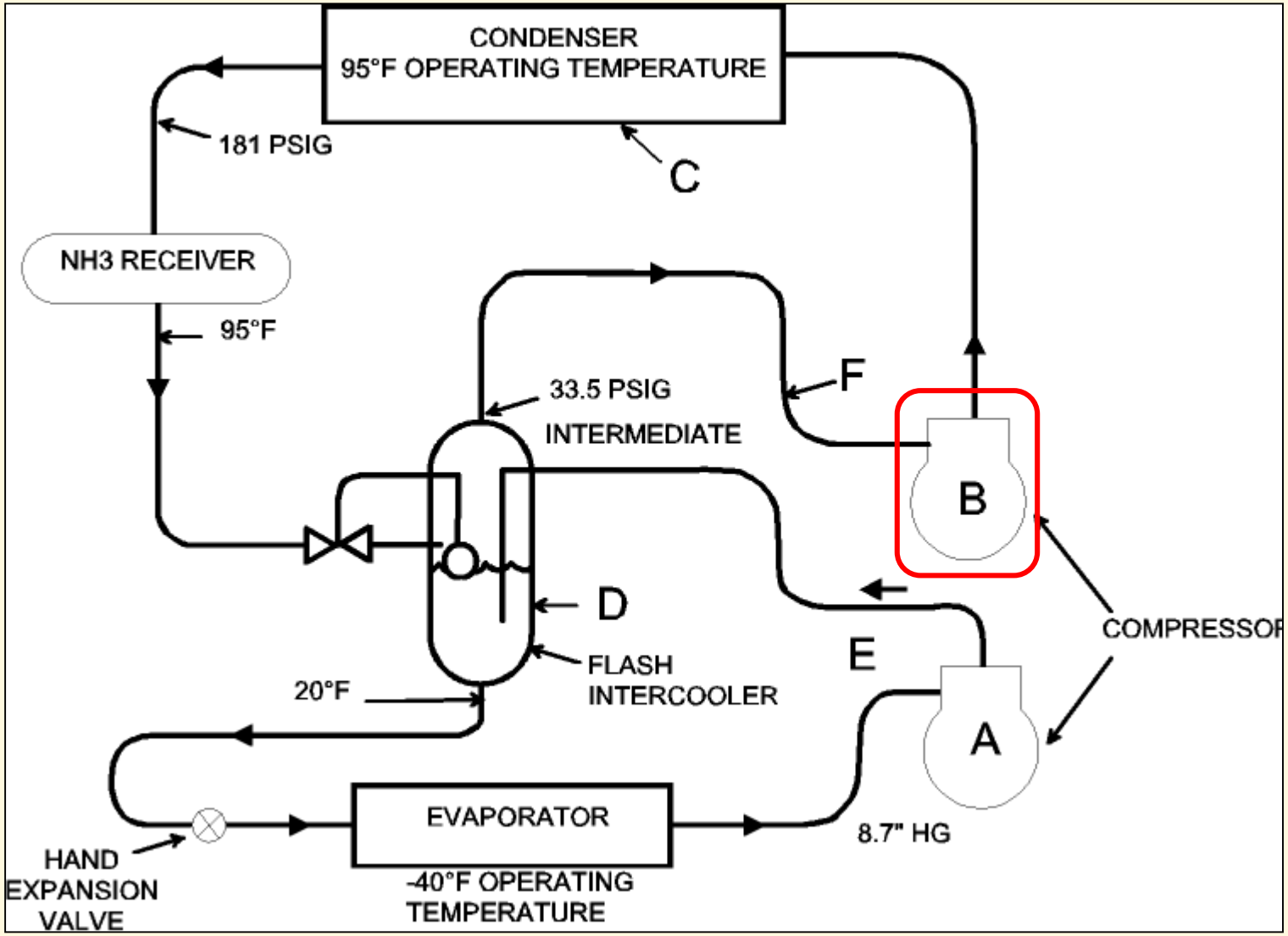
- Assume -40°F evaporator temperature, 95°F condensing
  - Single stage → 20:1 Compression Ratio
  - Huge economic penalties for single stage
  - Large compression ratio → higher heat of compression
- White Board Comparison


CONDENSER
95°F OPERATING TEMPERATURE
181 PSIG
C
NH3 RECEIVER
95°F
33.5 PSIG
INTERMEDIATE
F
B
D
FLASH
INTERCOOLER
E
COMPRESSOR
20°F
A
EVAPORATOR
8.7" HG
HAND
EXPANSION
VALVE
-40°F OPERATING
TEMPERATURE

Booster vs High Stage Compressors

- **Booster Compressor**
  - The first stage of a multi-stage system compressor is a booster compressor.
  - Receives vapor from the evaporator.
  - Discharge from this compressor goes to the intermediate pressure.
  - Characterized as a high volume, low compression ratio machine.

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EXPANSION
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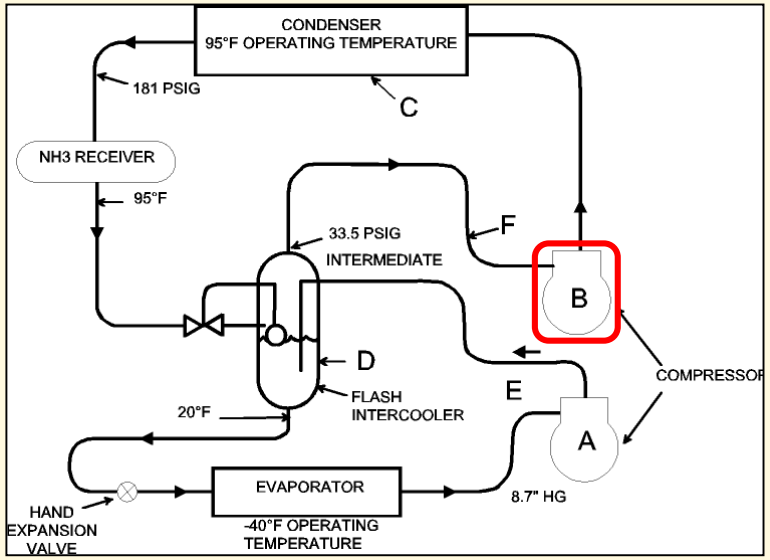
-40°F OPERATING
TEMPERATURE

Booster vs High Stage Compressors

- **High Stage Compressor**
  - The second stage of a multi-stage system.
  - Receives vapor that has been compressed by the booster compressor.
  - Discharge from this compressor goes to the condenser.
  - The rotary vane compressor cannot be used as a high stage compressor, only booster.



Physical Characteristics of Low Temp Operation

- As evaporator temperature is lowered
  - Discharge temperature increases
  - Oil degrades faster
  - Efficiency decreases
  - Power consumption increases
  - Oil return from evaporators becomes difficult
  - Compression ratio increases

Evaporator Psig/Temp °F	Suction Psia	Discharge Psia	Compression Ratio	Theoretical Discharge Temperature	Suction Gas Cubic Feet per Ton	Hp / Ton (est.)
45 / 30°F	59.74	195.8	3.28	190°F	2.04	0.96
33 / 20°F	48.21	195.8	4.06	204°F	2.52	1.16
24 / 10°F	38.51	195.8	5.08	228°F	3.14	1.37
16 / 0°F	30.42	195.8	6.44	251°F	3.95	1.75
9 / -10°F	23.74	195.8	8.25	275°F	5.01	1.89
4 / -20°F	18.30	195.8	10.70	295°F	6.47	2.38
2” hg / -30°F	13.90	195.8	14.09	325°F	8.44	2.84
9” hg / -40°F	10.35	195.8	18.92	355°F	11.13	3.43

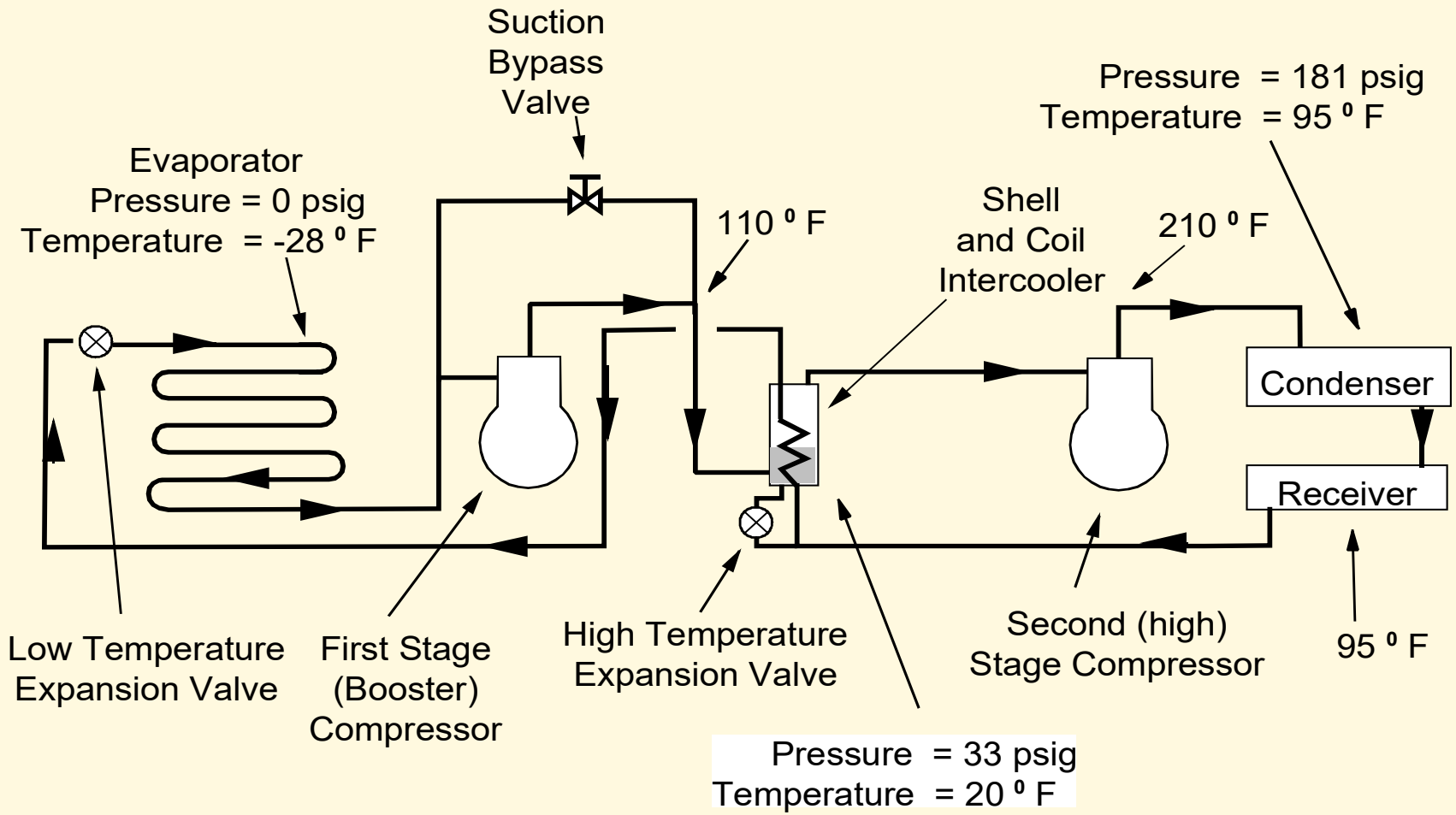
Physical Characteristics of Low Temp Operation

- Screw compressor can operate up to 20:1 compression ratio because of oil cooling
  - 3.1 Bhp/Tr at -40°F/95°F, Single Stage
  - 2.1 Bhp/Tr at -40°F/95°F, Two Stage

Compare Single-Stage and Two-Stage

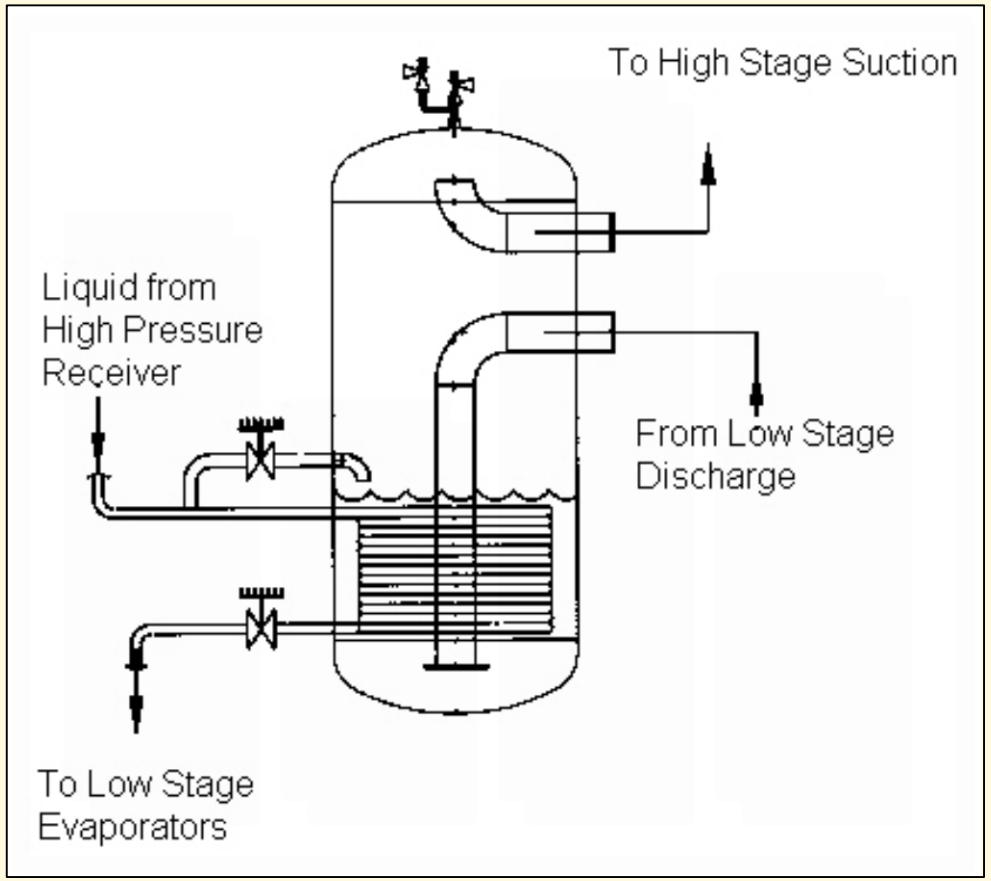
- Given:
  - Low stage evaporating temperature is -28°F with no superheat
  - Condensing temperature is 95°F and there is no liquid subcooling at the condenser
  - Interstage pressure is 33 psig
- Single Stage: 284 Bhp
- 2-Stage: 97 Bhp & 130 Bhp = 227 Bhp

Two-Stage Compression Systems



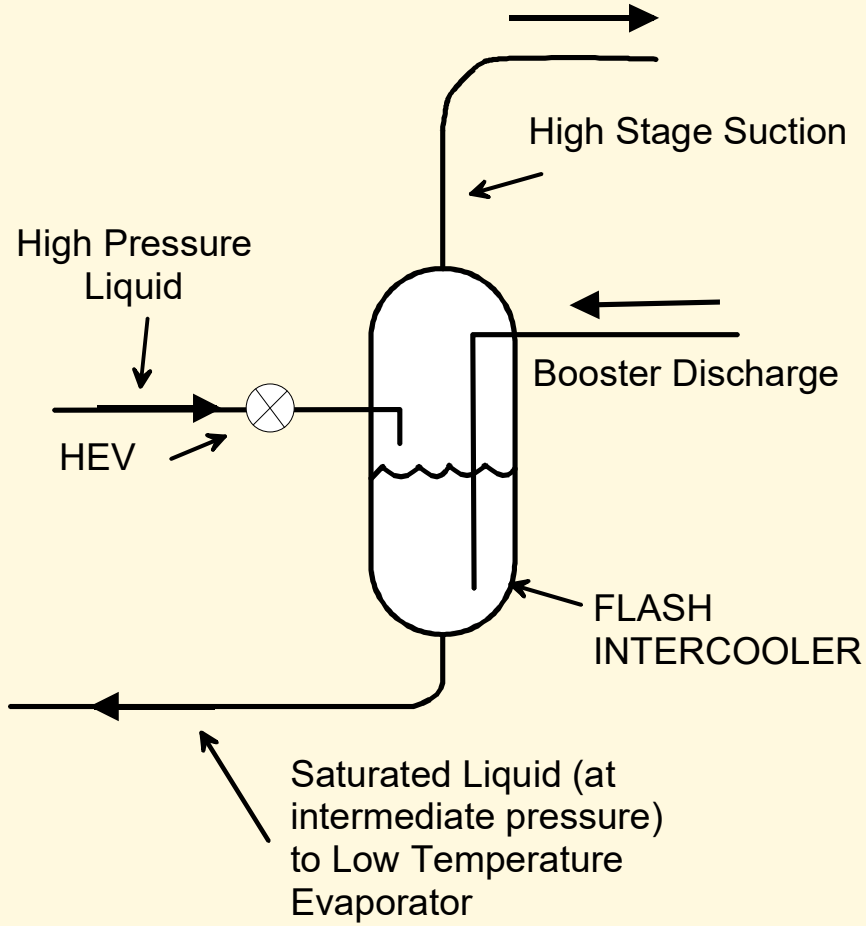
Two Type of Intercoolers

1. Shell & Coil



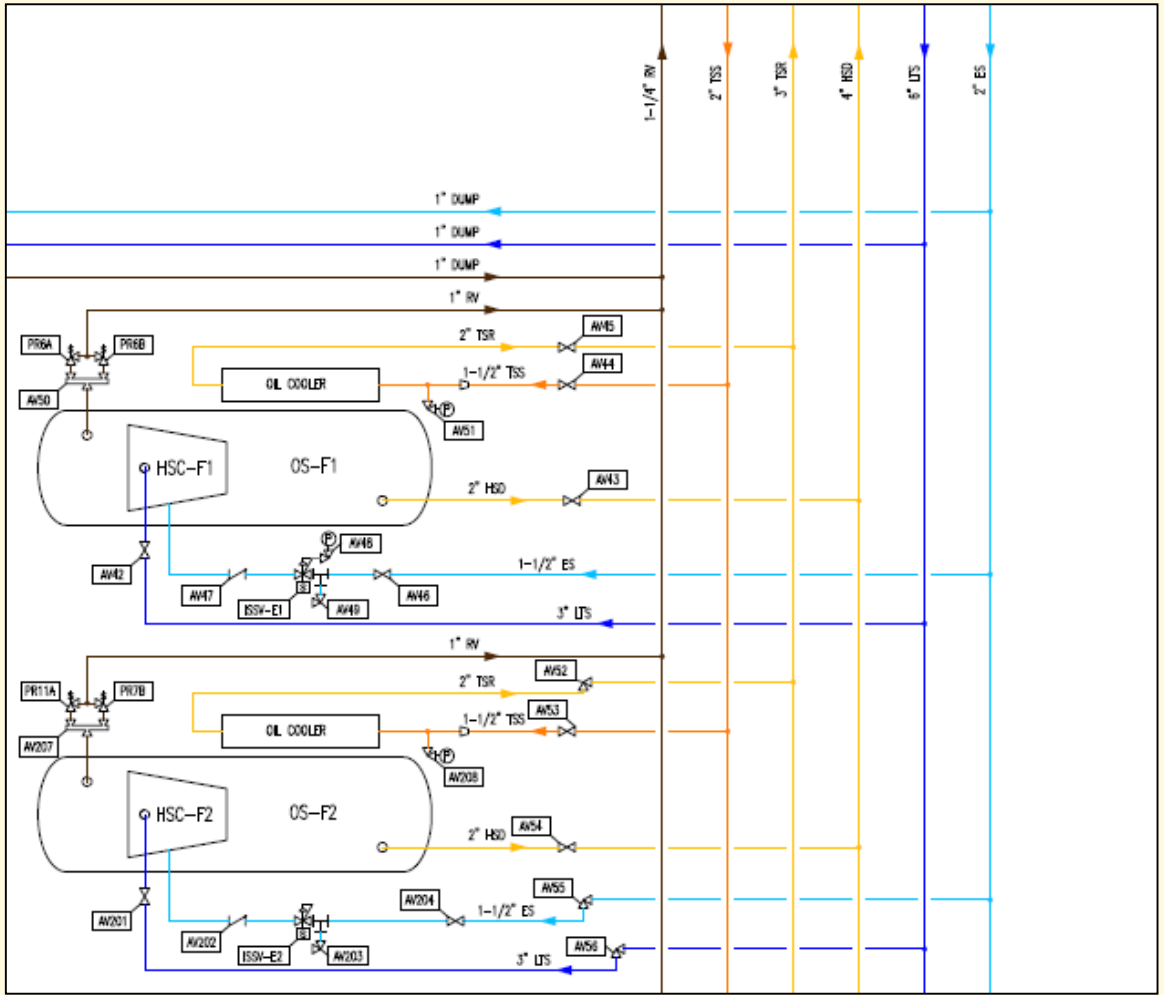
Two Type of Intercoolers

2. Flash Type



Internally Compounded Compressors

- One compressor capable of doing both stages of compression



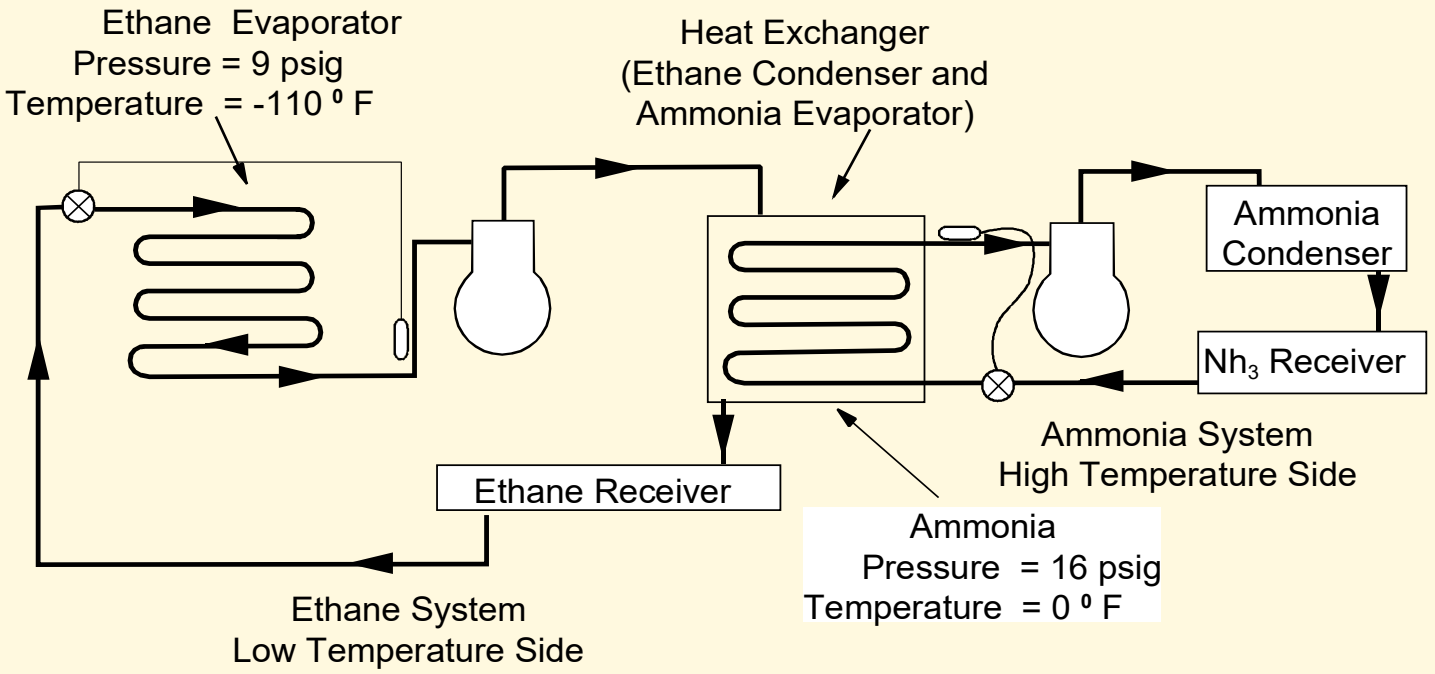
Two Stage Systems and Non-Condensables

- Low stage almost always operates in a vacuum
- Leakage at joints, valve stems, and shaft seals is very common and hard to detect
- Air accumulates in the condenser
- Water accumulates in the evaporator
- Solution…
  - Seal cap valves
  - Auto-purger

Cascade Systems

- Systems below -100°F
- Two different refrigerants
- Why cascade systems?
  - -100°F means 27.4” Hg vacuum for ammonia
  - Lubricants are stiff at -100°F
  - -100°F/95°F would be a 159:1 compression ratio for single stage

Cascade Systems



Cascade Systems

- One refrigerant will be at a higher pressure than commonly used refrigerants (no vacuum)
- Low temp receiver typically requires a storage pressure of 650 psig (ethane)

Summary

- Two stage systems require less Bhp/Tr than single stage systems
- Low temp systems require large overall compression ratios
- By using two stages of compression the function of de-superheating and the function of medium temperature cooling units can be combined as suction to the second stage of compression

Summary

- The overall compression ratio is not the sum of the two individual ratios, but rather the product of the two ratios
- Discharge temp from each stage of compression must be suitable for the oil used in the compressors
- Low stage compressors are high volume, low HP
- High stage compressors have lower volume, high HP

Summary

- The intercooler is used to desuperheat the discharge gas from the first stage of compression
- More than one type of intercooler is available
- Purger is very important in low temp application
- A cascade system is not a 2-stage system. It is two single stage systems.

Questions?

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