

Hydrocarbon Recovery

Chapter 12

Based on presentation by Prof. Art Kidnay



COLORADOSCHOOLOF**MINES**

Reasons for Hydrocarbon Recovery

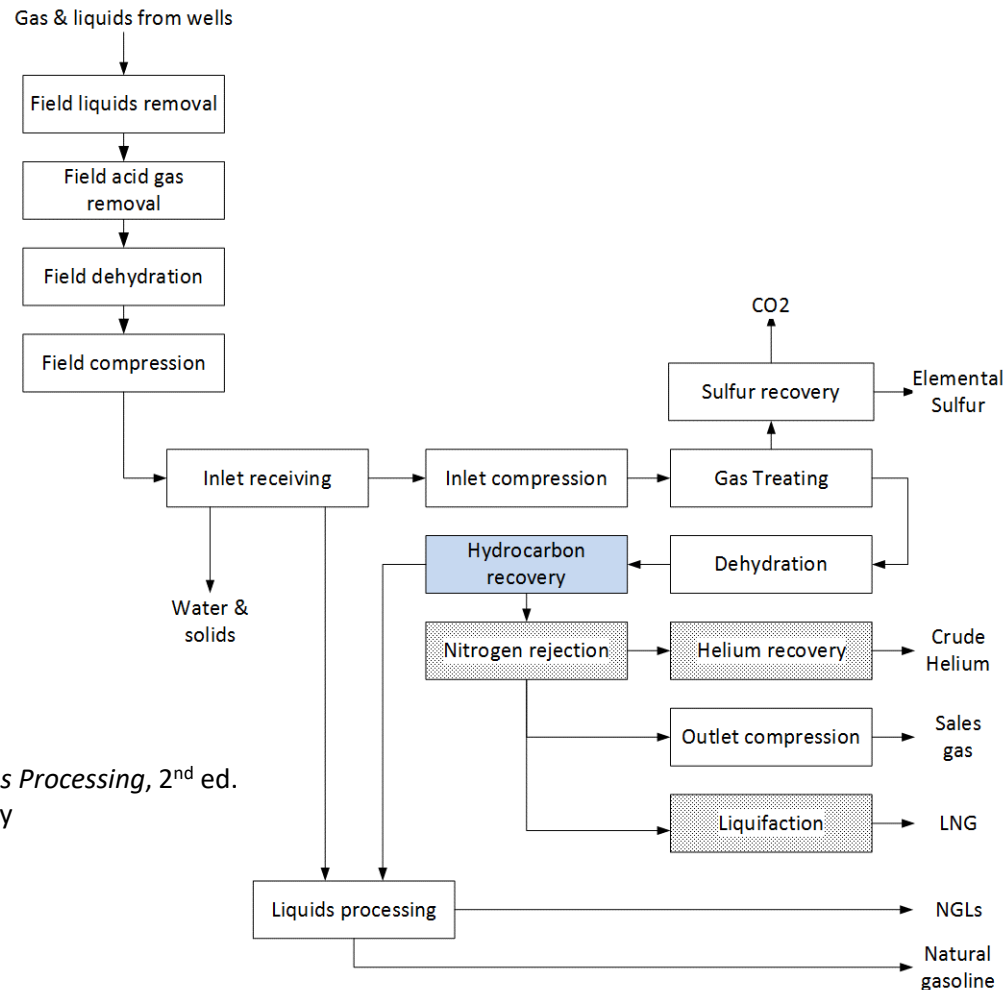
Field Operations

- Reduce liquid content of high GPM gases in gathering systems
- Eliminate or reduce potential for condensation (dew-pointing)
- Reduce Btu content of gas for use in engines (fuel conditioning)

Plant Operations

- Reduce Sales gas Btu content to spec (950 to 1150 Btu/scf)
- Eliminate possible condensation
- Recover valuable C_2^+ liquids

Plant Block Schematic



Adapted from Figure 7.1,
Fundamentals of Natural Gas Processing, 2nd ed.
Kidnay, Parrish, & McCartney

Topics

Fundamentals

- Retrograde Condensation

Process Components

- Refrigeration System
- Turboexpansion
- Heat exchange
- Gas-Liquid Separators
- Fractionation

Recovery Processes

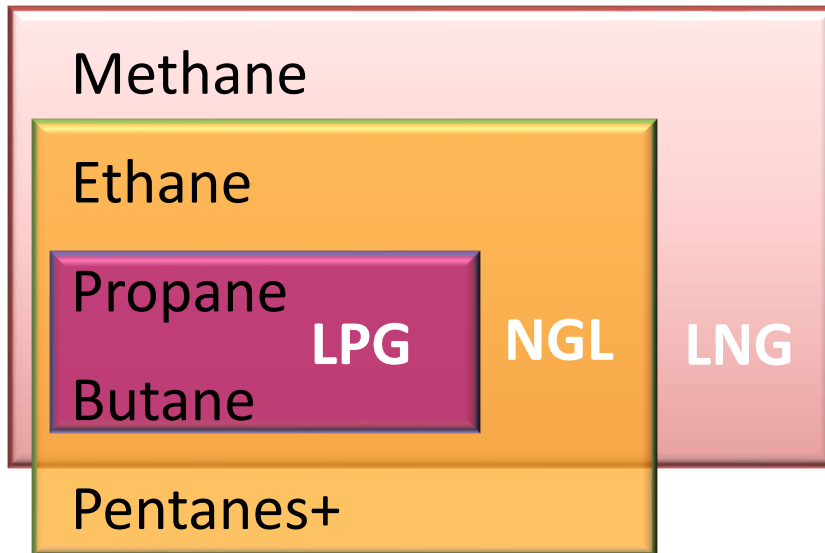
- Dew Point Control and Fuel Conditioning
- Low C2+ Recovery
- High C2+ recovery

Fundamentals



Reminder – Liquids Composition

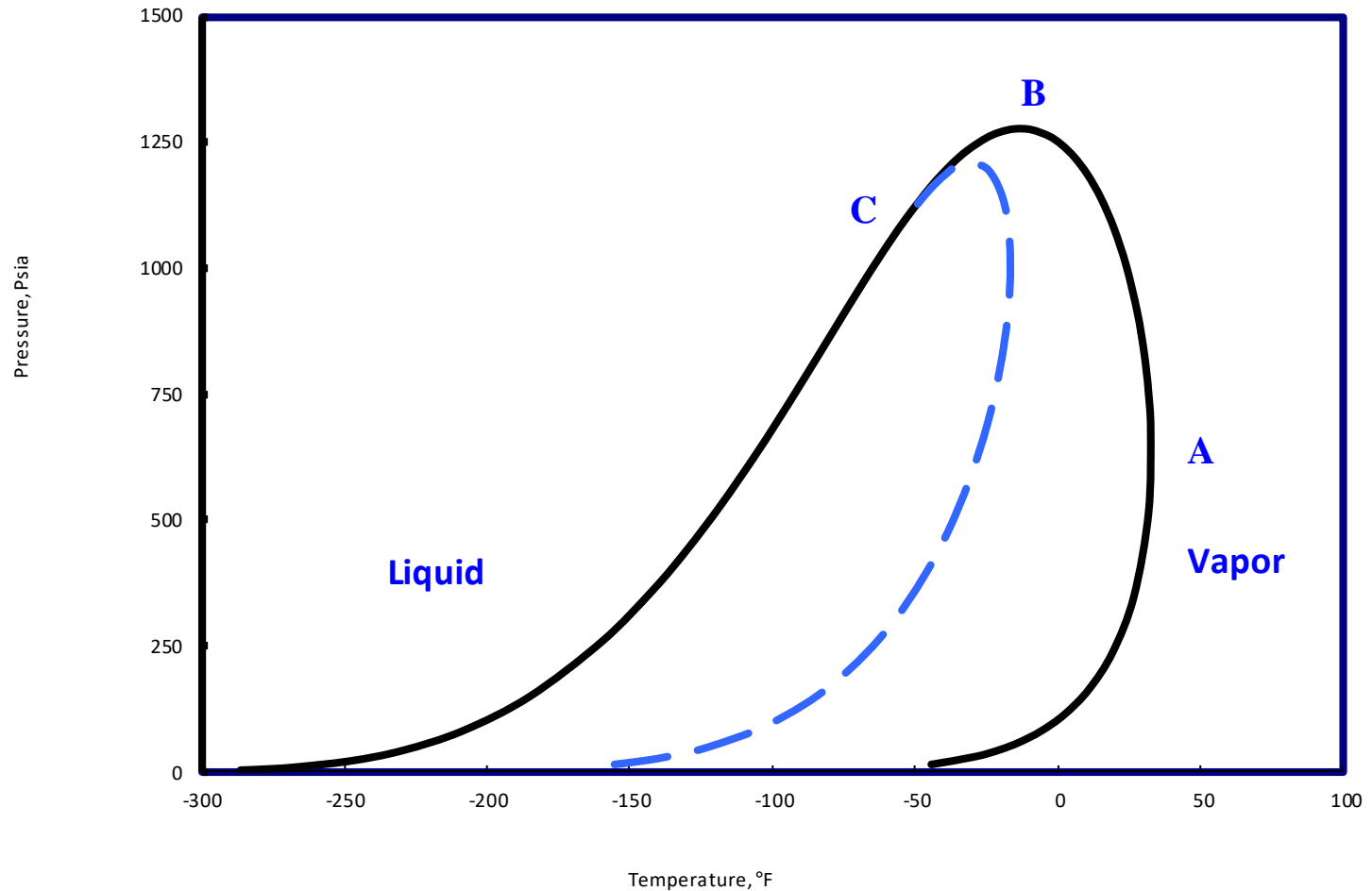
What are Natural Gas Liquids (NGL vs LPG vs LNG)?



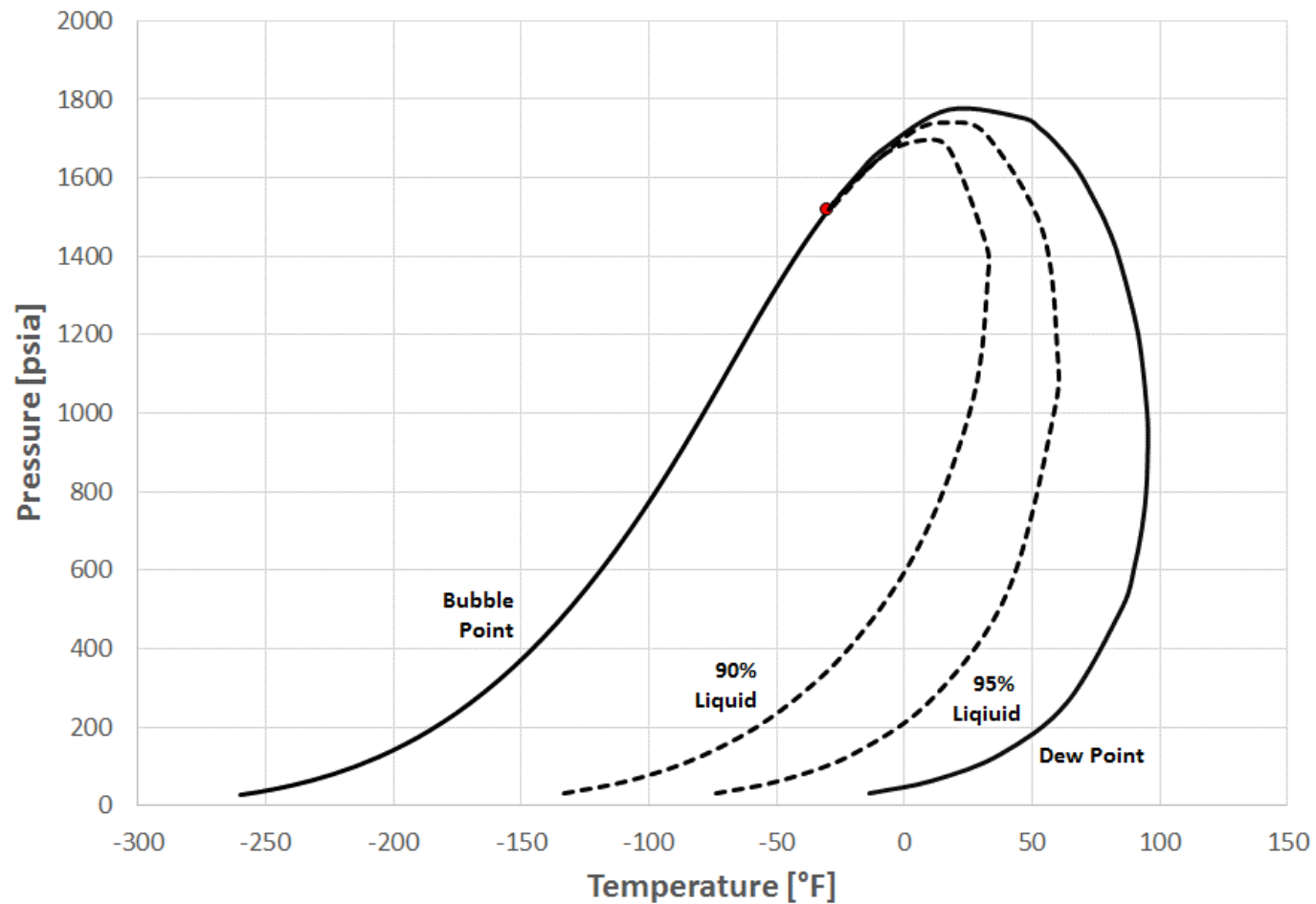
What is the GPM of a gas?

- Gallons of NGL components per 1000 scf (Mscf) of gas
- Either C2+ GPM or C3+ GPM

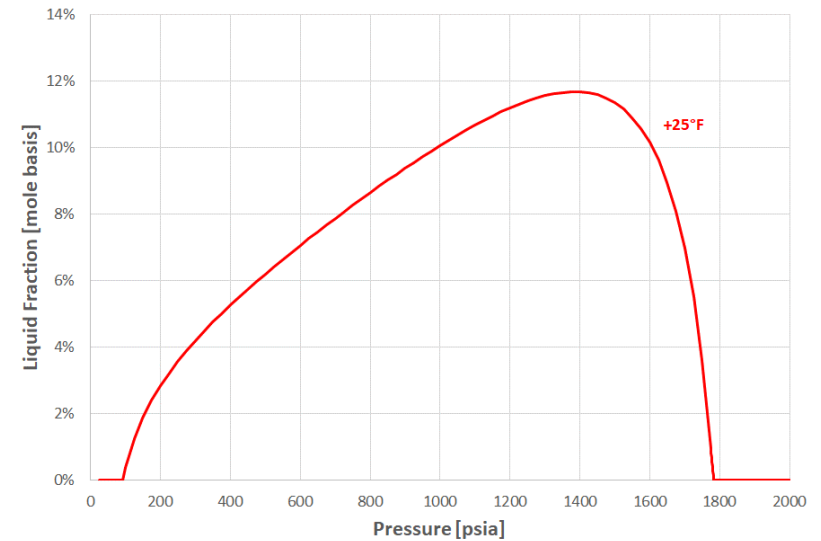
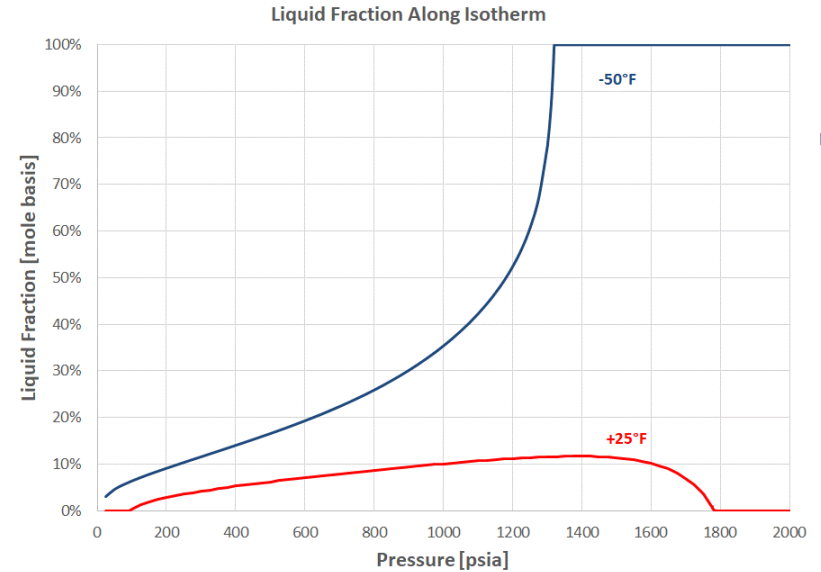
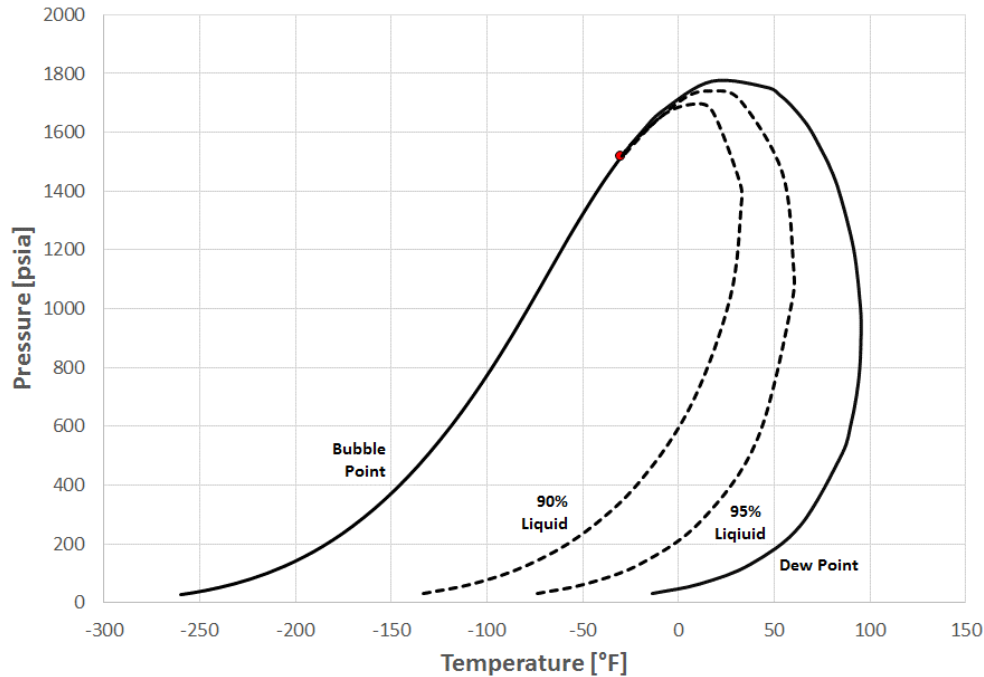
Retrograde Condensation



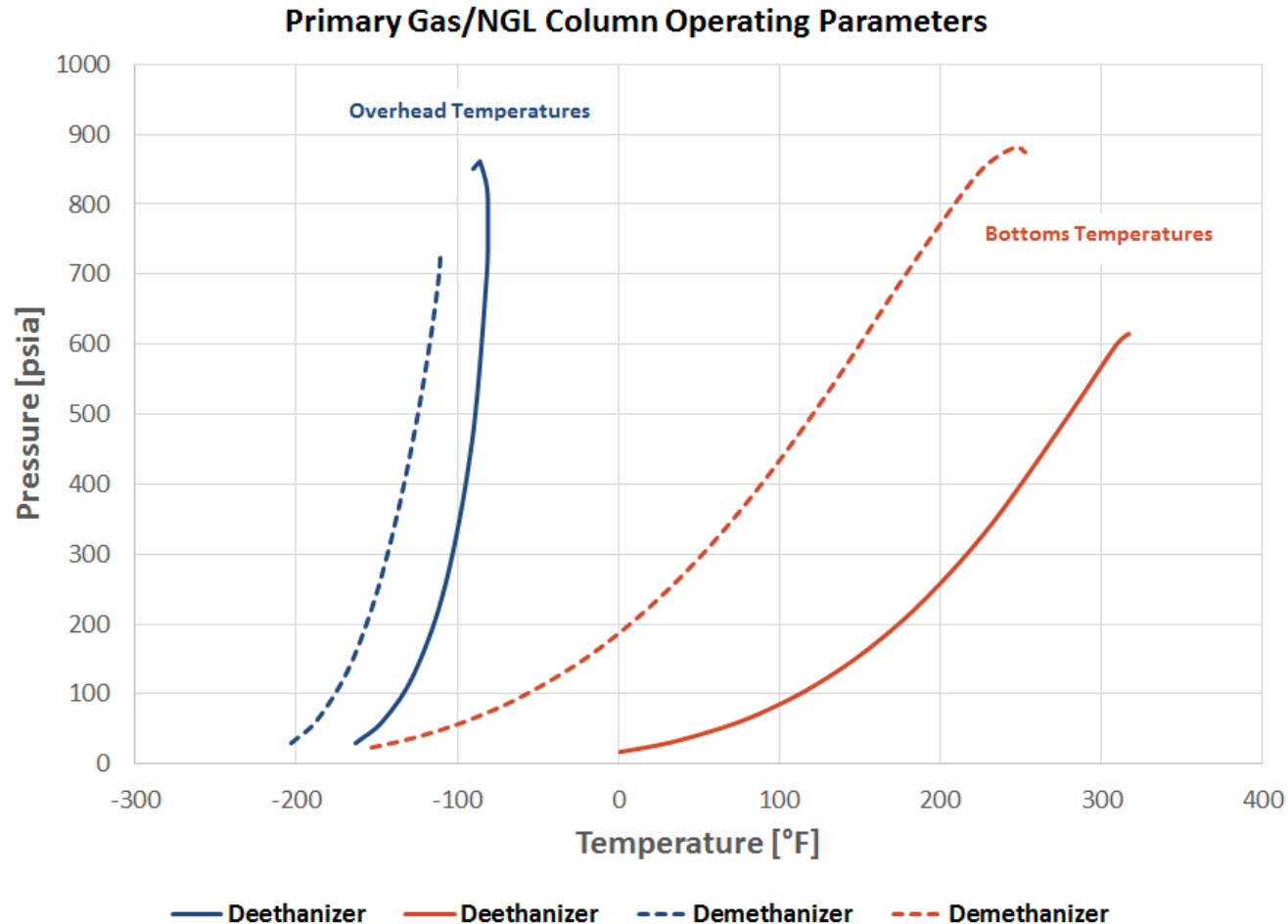
Rich Gas Phase Diagram



Rich Gas Phase Diagram



Operating Conditions Depend on Type of NGL Recovery



Process Components



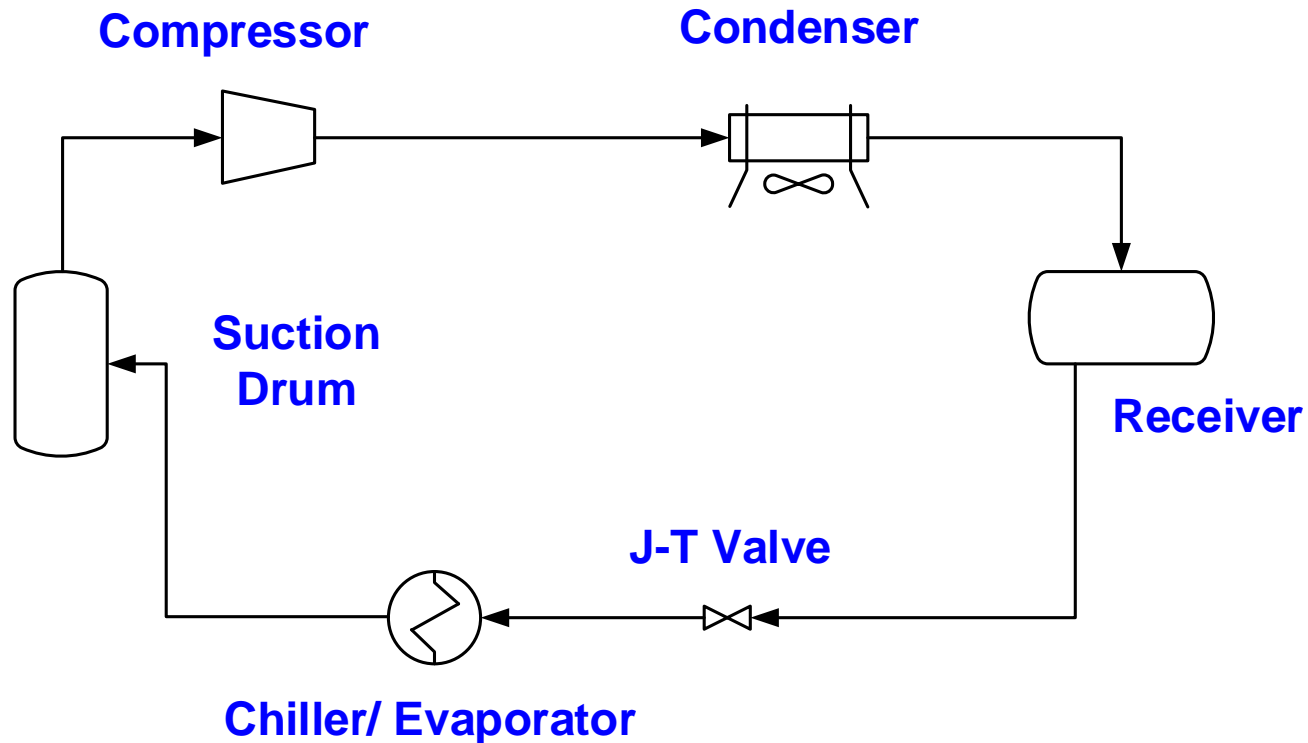
External Refrigeration

When inlet pressures to Hydrocarbon Recovery are too low to provide required cooling by expansion we can obtain additional refrigeration by:

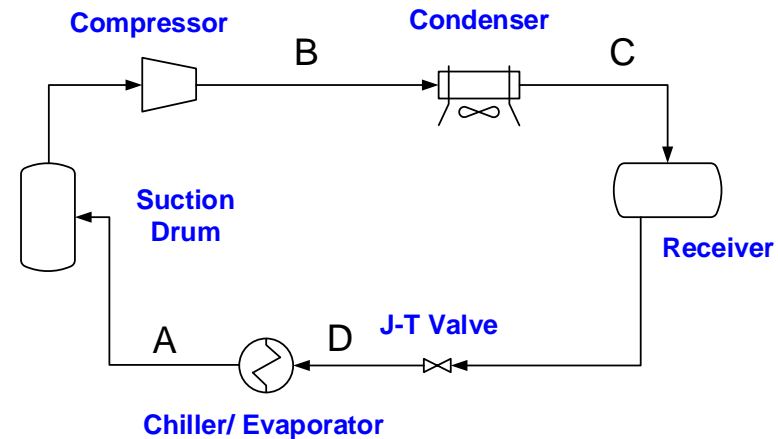
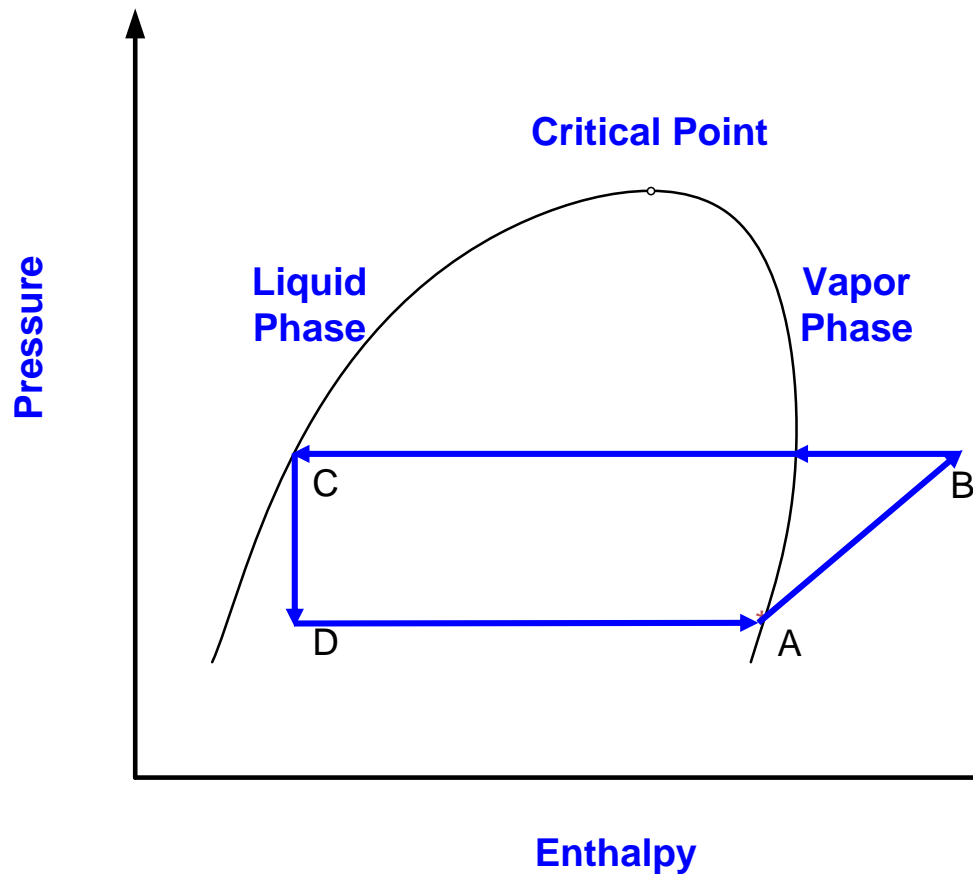
- Compressing inlet gas to higher pressure
- Compressing propane in refrigeration cycle

Compressing propane is usually the best choice

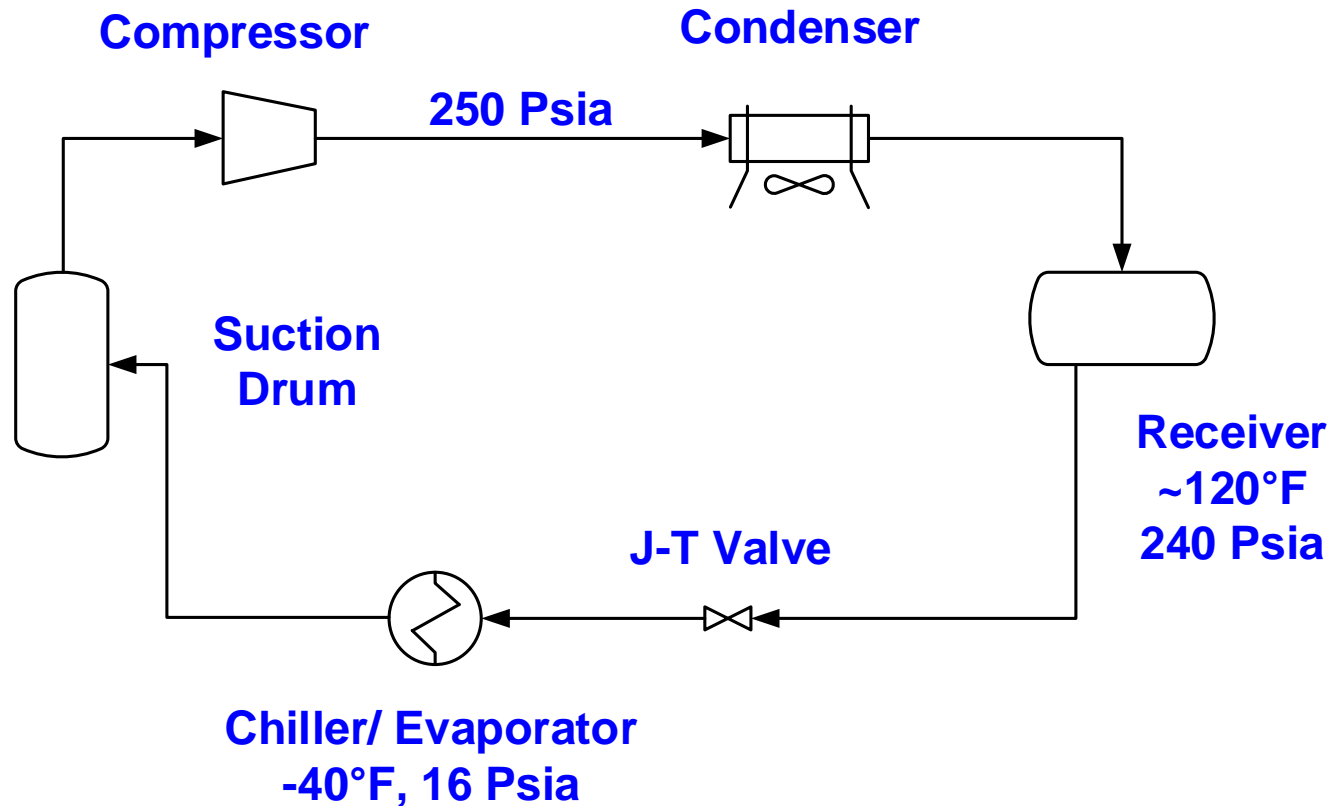
Basic Single-Stage Refrigeration System



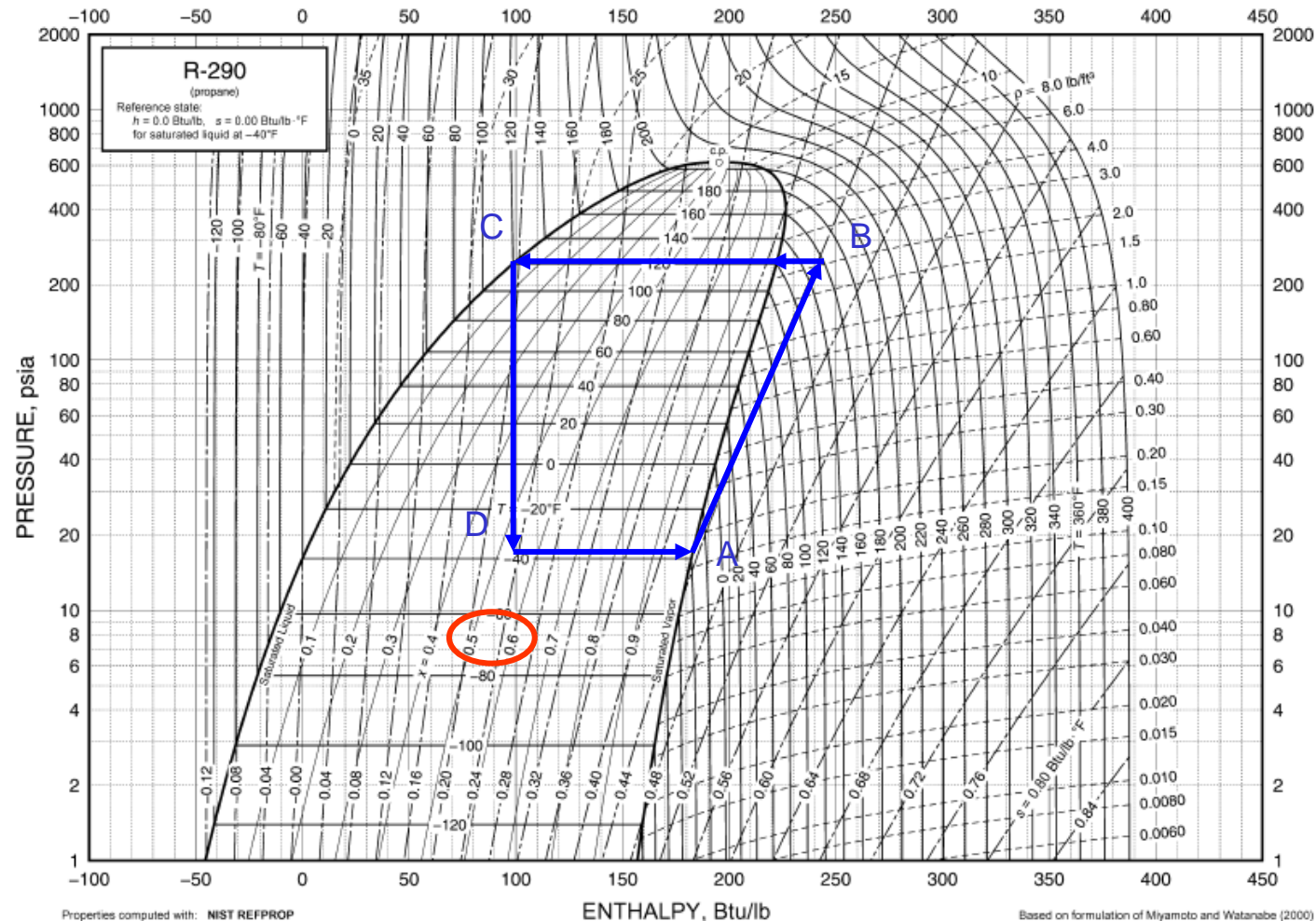
Single-Stage Refrigeration cycle



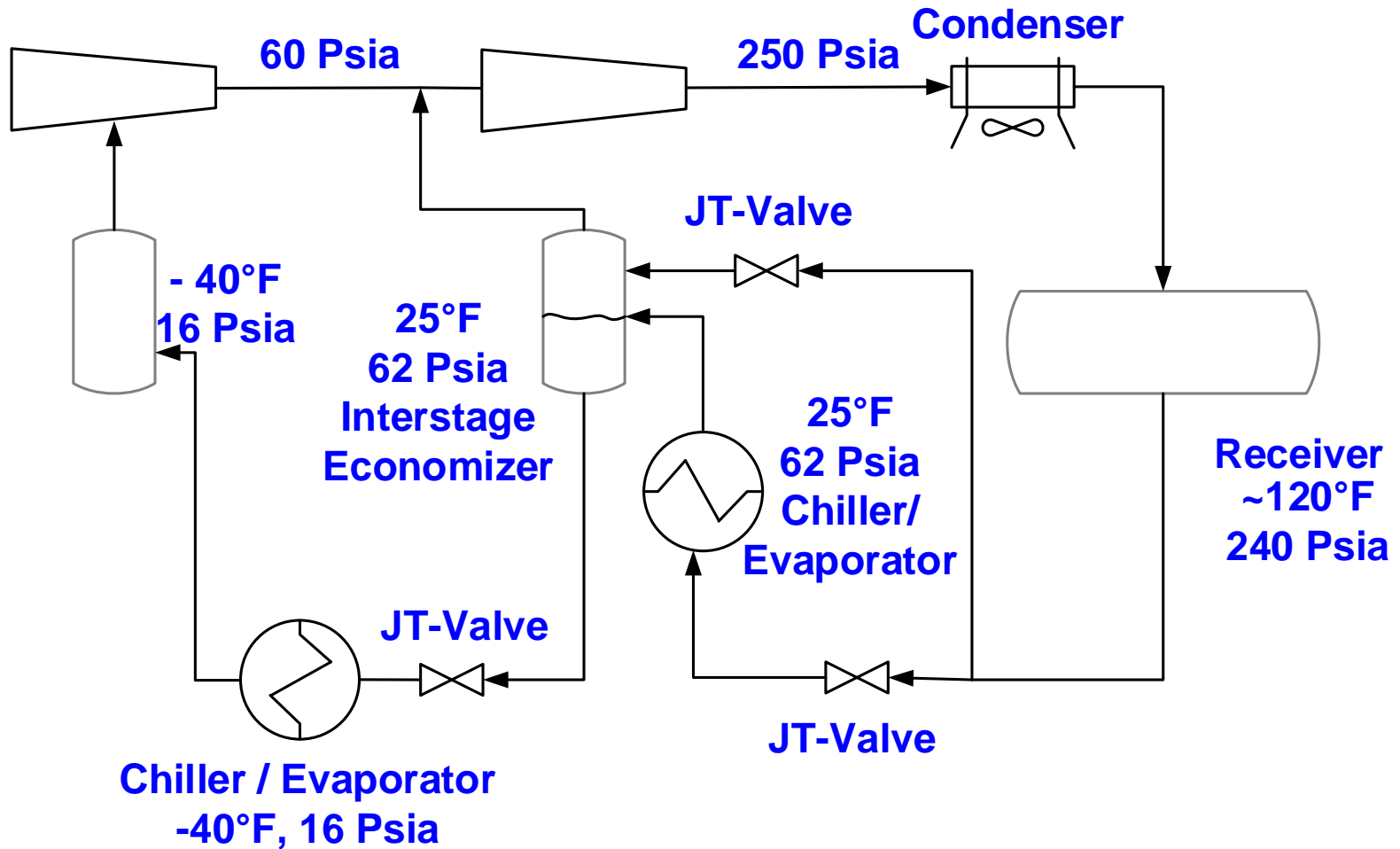
1-Stage Propane Refrigeration System



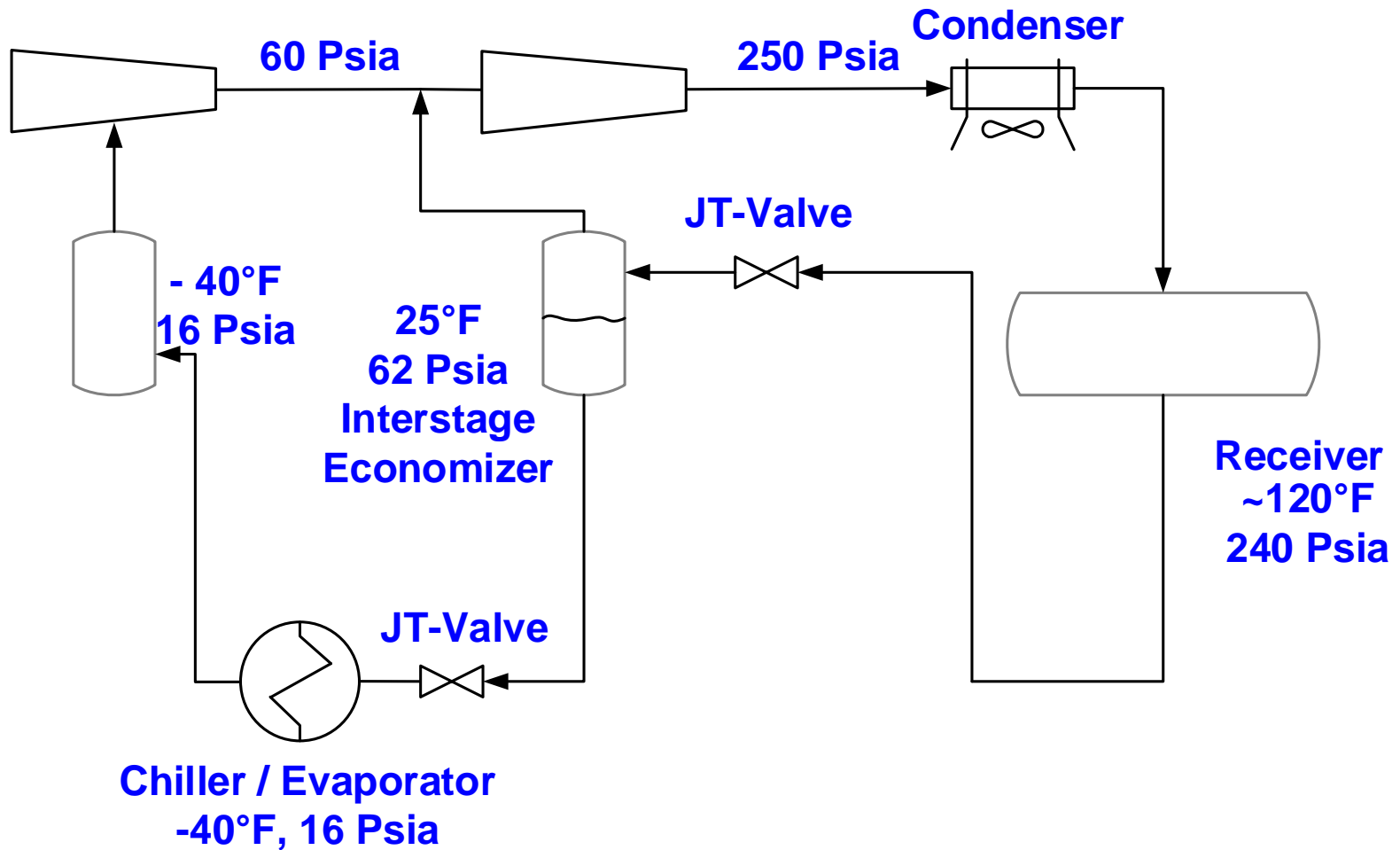
Refrigeration cycle



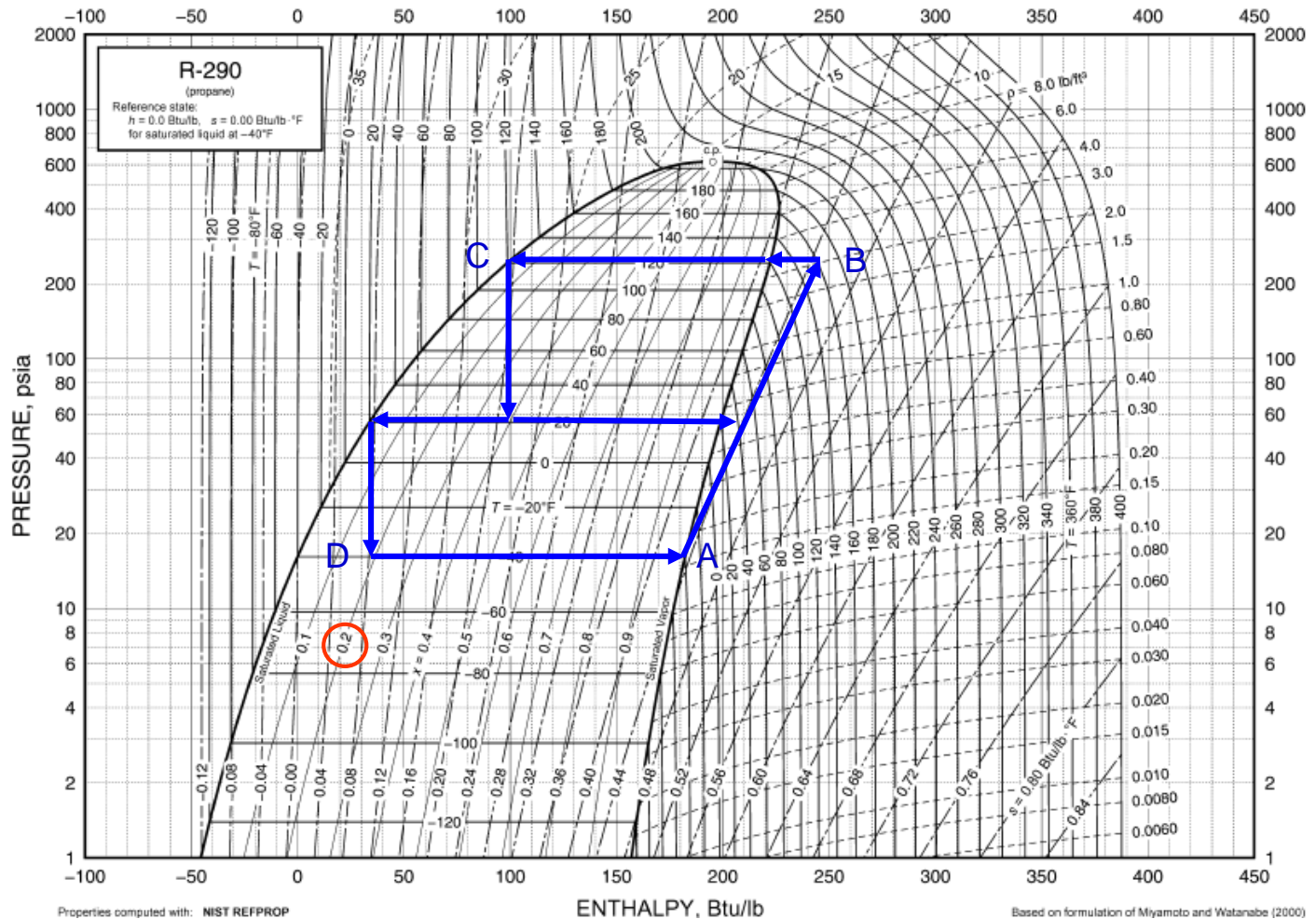
2 Stage C₃ Refrigeration System



2 Stage C₃ Refrigeration System



Refrigeration cycle



Benefits of Staging

Number of Stages	1	2	3
Reduction in Compression Power	0	19%	23%
Reduction in Condenser Duty	0	8%	10%

Condenser Temp = 100°F Chiller Temp = -40°F

Turboexpanders

Provide

- Maximum possible cooling
- Work which can drive compressors

Operate

- Over wide temperature range
- At high speeds, $> 15,000$ rpm

Require clean gas

Can handle up to 50 wt % liquid formation provided droplet size less than $20\text{ }\mu\text{m}$

Methane Expansion – Isentropic vs. Isenthalpic

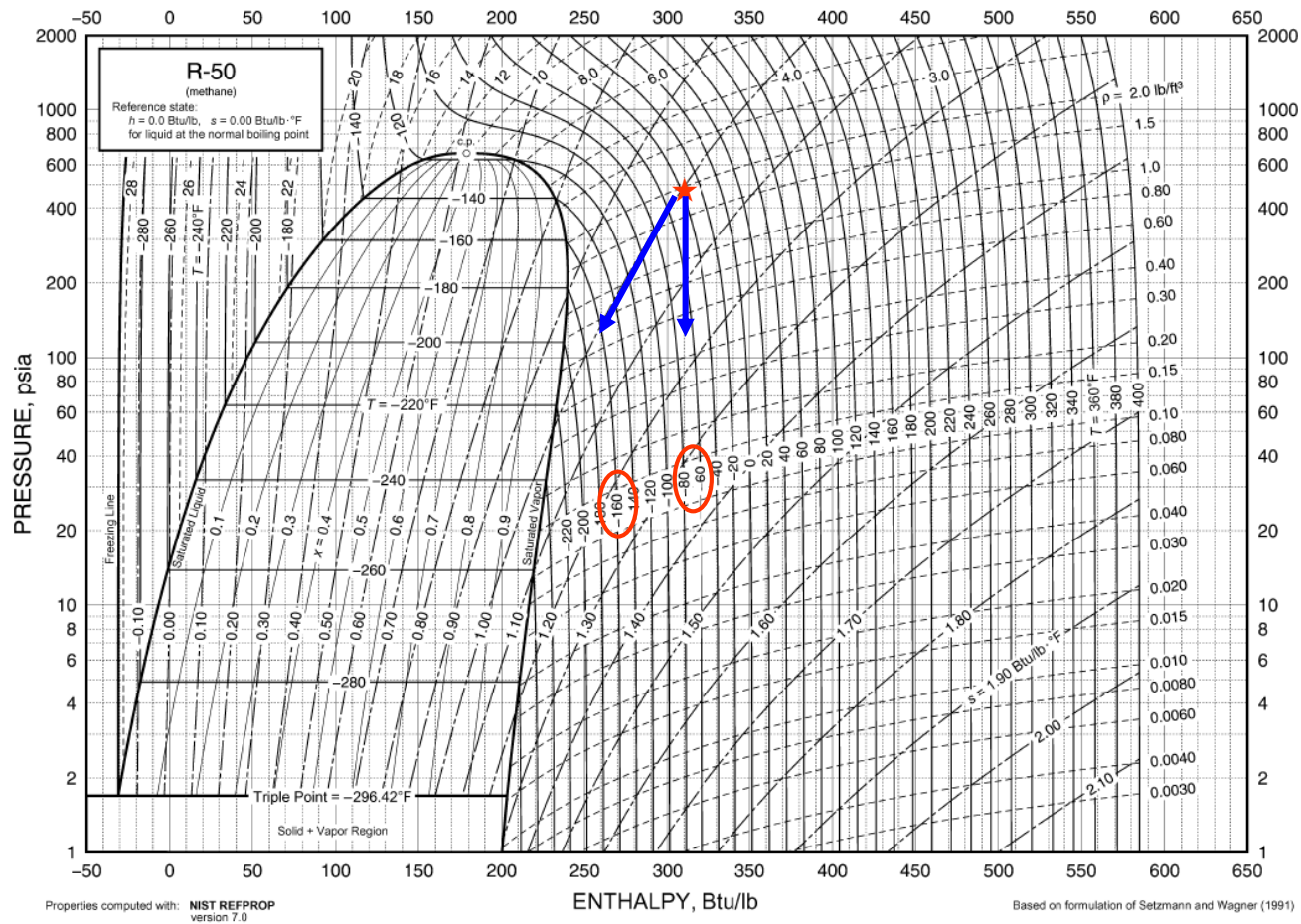


Fig. 19 Pressure-Enthalpy Diagram for Refrigerant 50 (Methane)

Recovery Processes



Recovery Processes

Dew Point Control and Fuel Conditioning

- High recovery not needed
- Operating temperatures $\sim 0^{\circ}\text{F}$ for fractionation

Low C_2^+ Recovery

- $< 60\%$ C_2^+ recovery needed
- Operating temperatures $\sim -35^{\circ}\text{F}$ for fractionation

High C_2^+ recovery

- $\sim 90\%$ C_2^+ recovery needed
- Operating temperatures $\sim -165^{\circ}\text{F}$ for fractionation

Dew Point Control and Fuel Conditioning

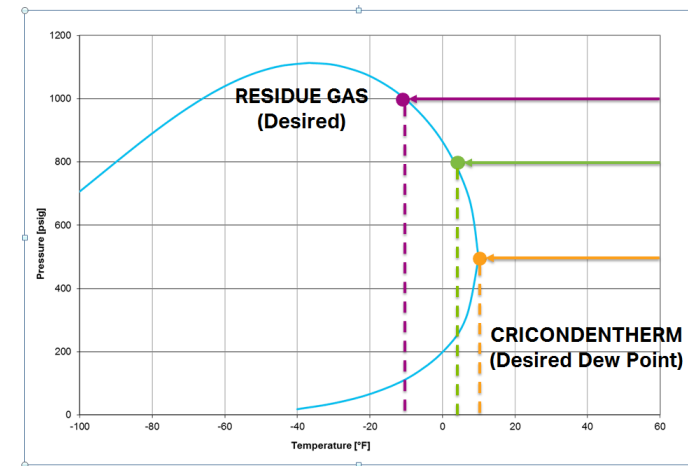
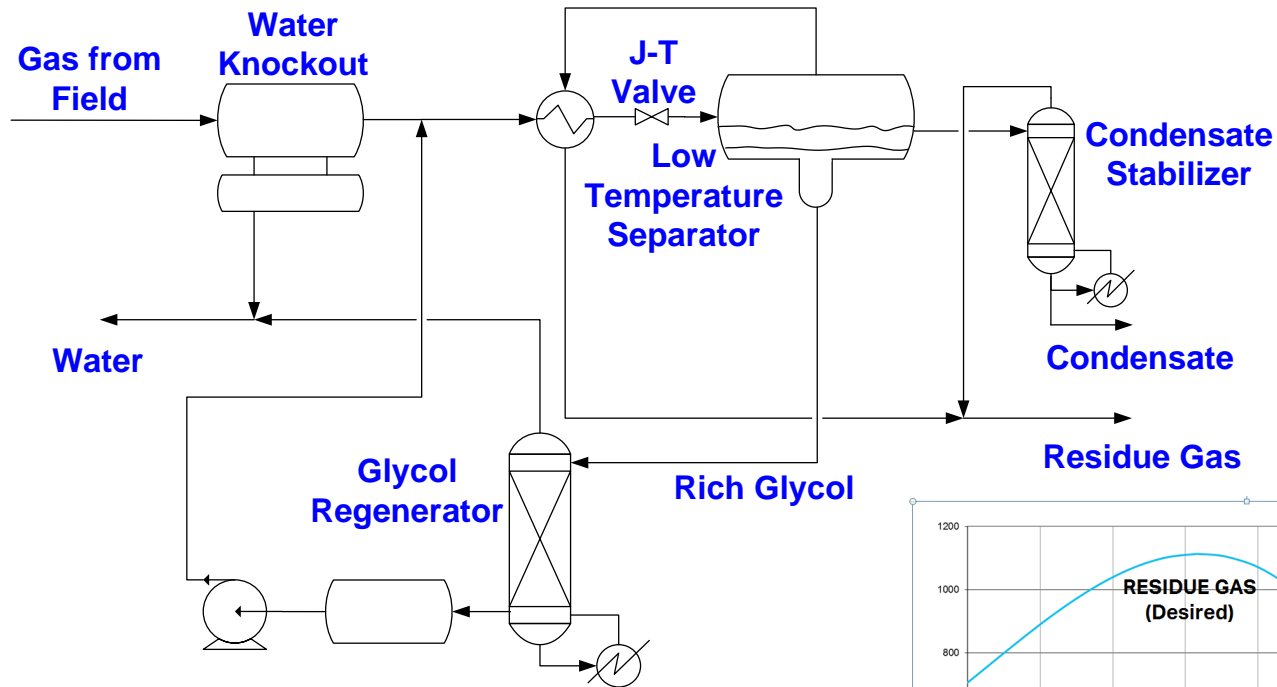
Traditional technology

- Low Temperature Separators (LTS or LTX)
 - Standard technology (>60 years old)

Newer technologies

- Membrane System
 - Newer technology (~10 years old)
- Twister
 - Newest technology (~5 years old)

Dew Point Control (No External Refrigeration)



Dew Point Control (With External Refrigeration)

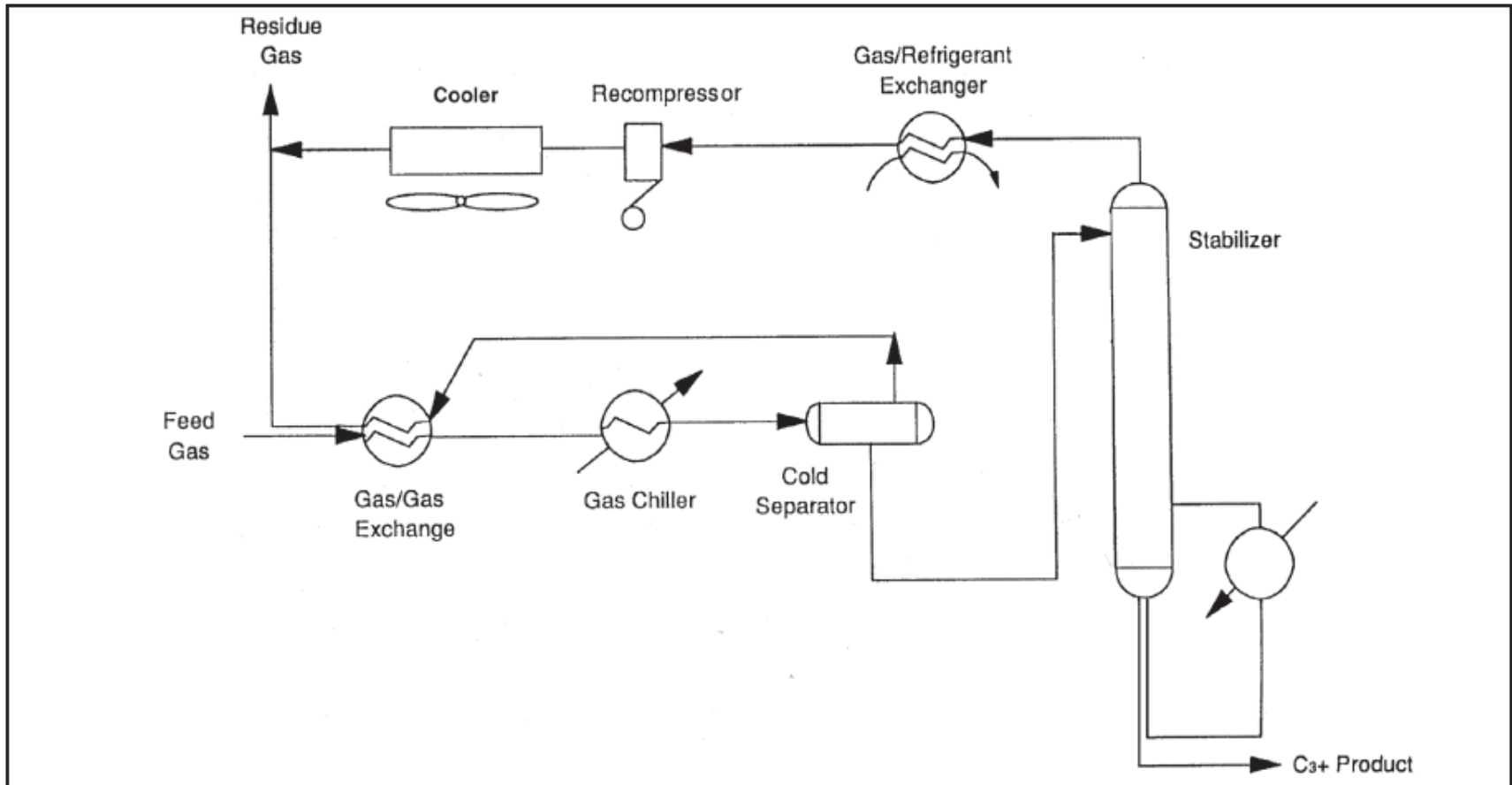
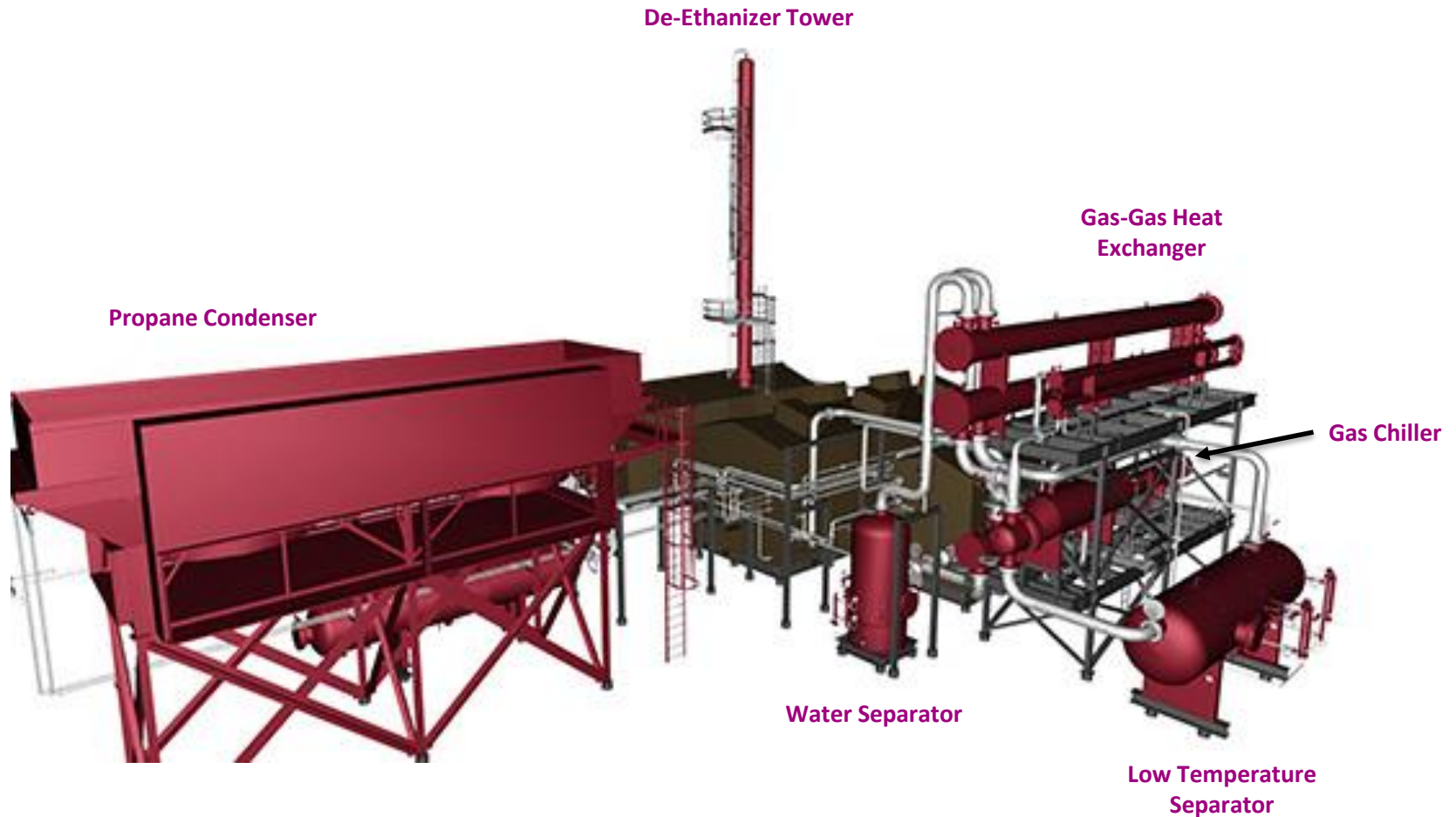


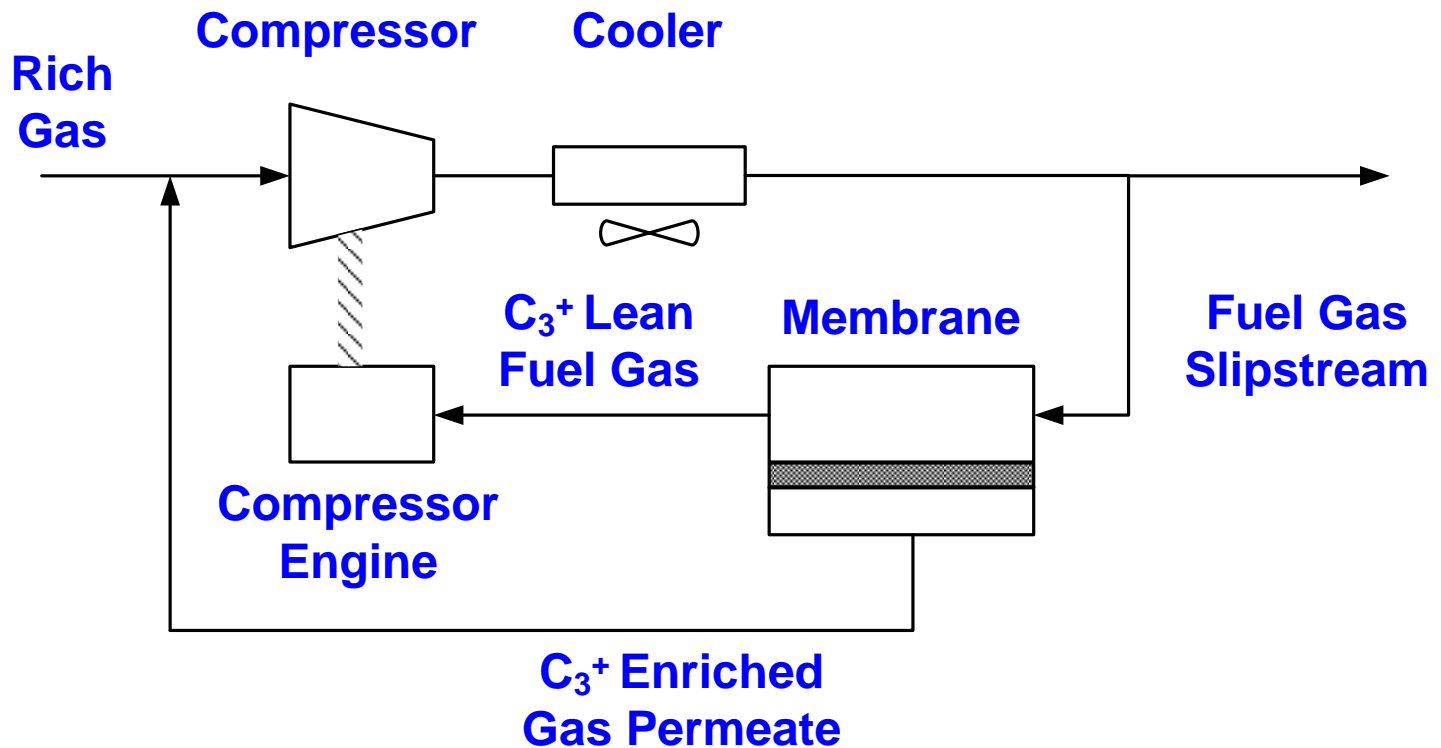
Fig. 16-5, *GPSA Engineering Data Book*, 14th ed.

Example Dew Point Control Package



<http://www.enerflex.com/Oil-and-Gas-Solutions/Gas-Processing/Dew-Point-Control/index.php>

Membrane for Fuel Conditioning



Twister

Modular, flow dependent

Depends upon pressure ratio, $\Delta P \sim 20$ to 30%

Slip gas is 10 to 15%

Used for dehydration and liquids removal

Is being tested in subsea application

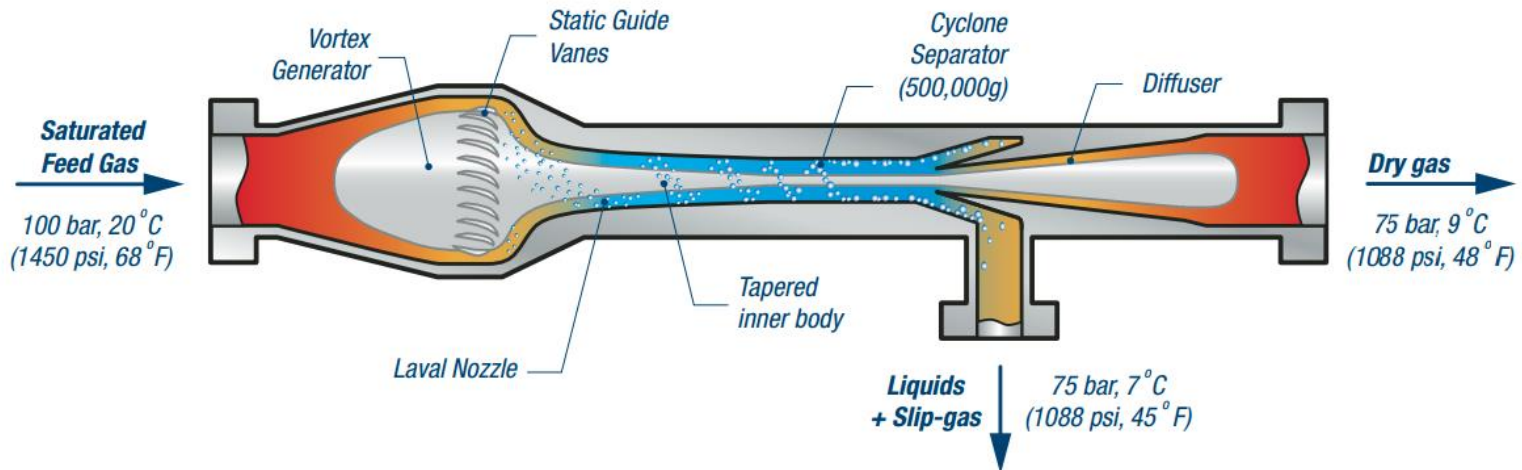


Figure 1 shows a cross-section of a Twister tube with typical process conditions

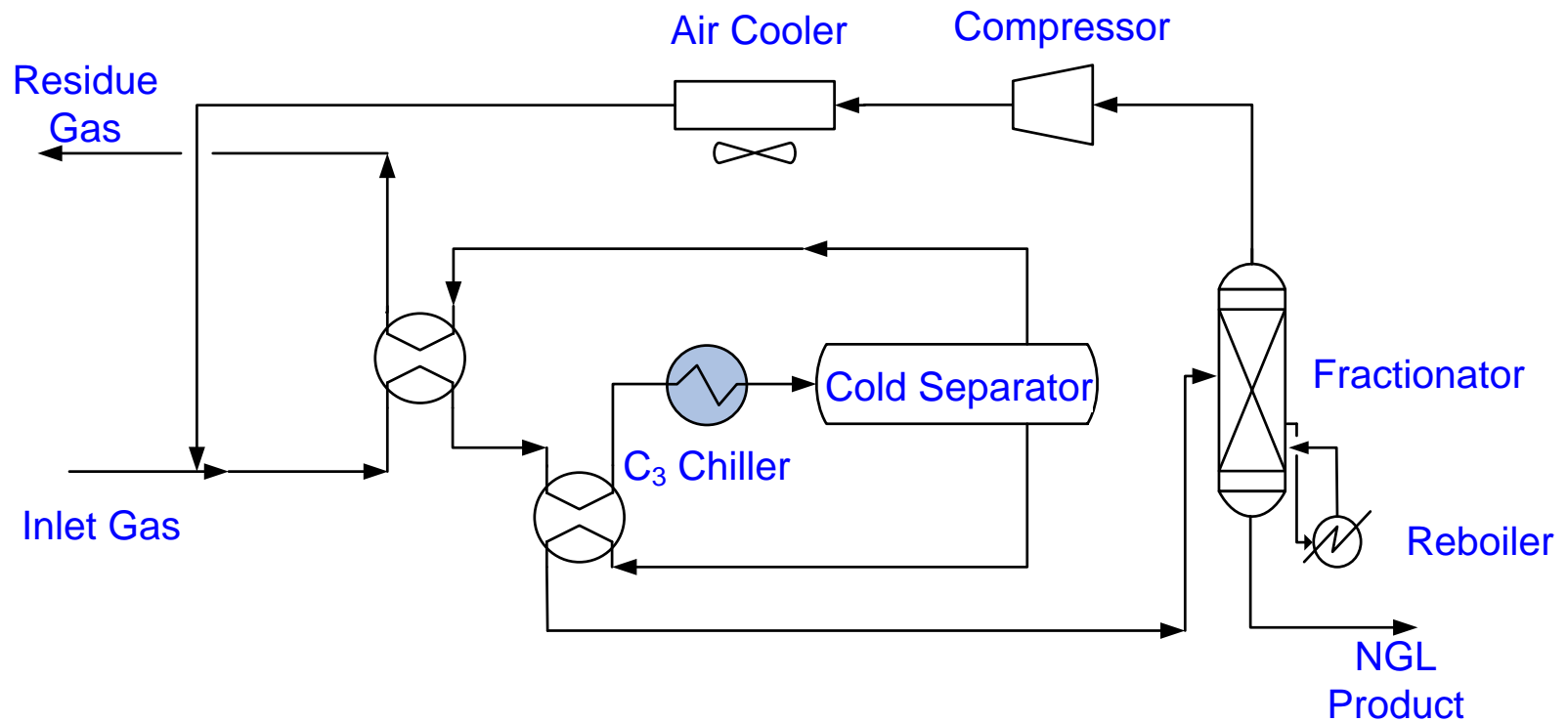
[http://twisterbv.com/PDF/resources/Twister - How Does It Work.pdf](http://twisterbv.com/PDF/resources/Twister%20-%20How%20Does%20It%20Work.pdf)

Low C_2^+ Recovery

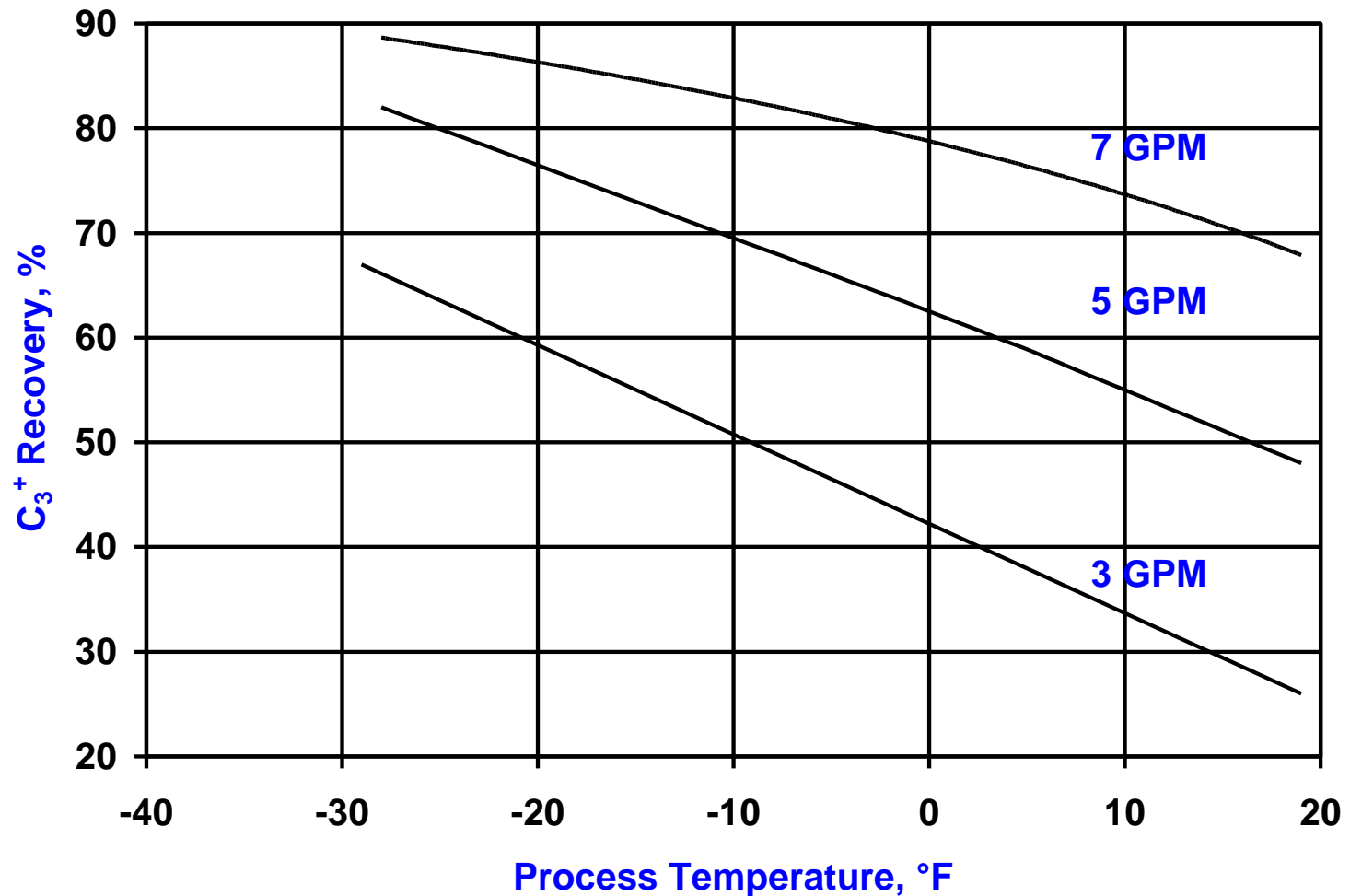
Two major processes

- Refrigerated Lean Oil
 - Lean Oil Absorption first process for liquids recovery
 - Existing plants now use refrigerated system
- Refrigerated Process
 - Simpler than Lean Oil process
 - Lower recoveries

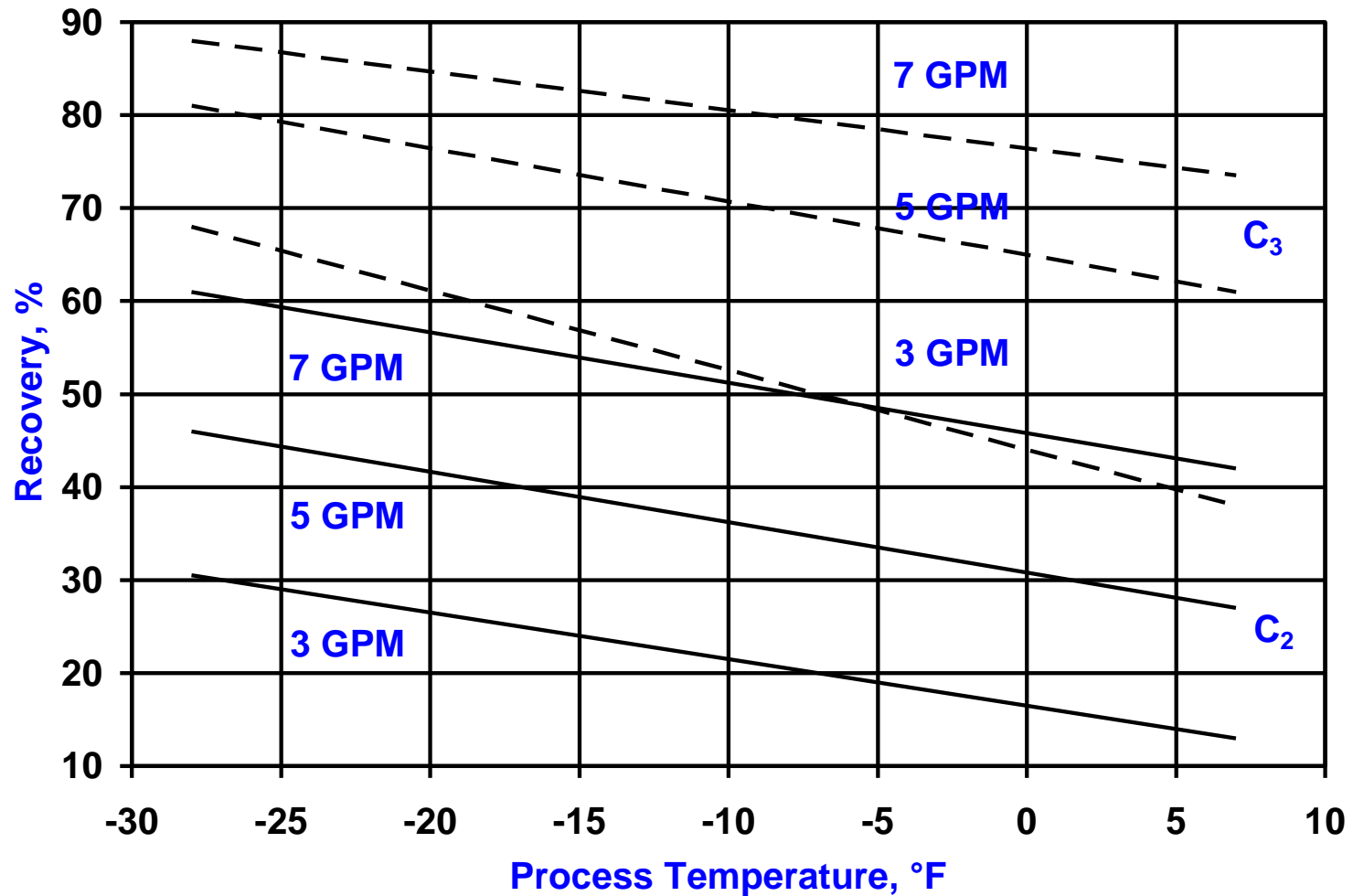
Refrigerated Process



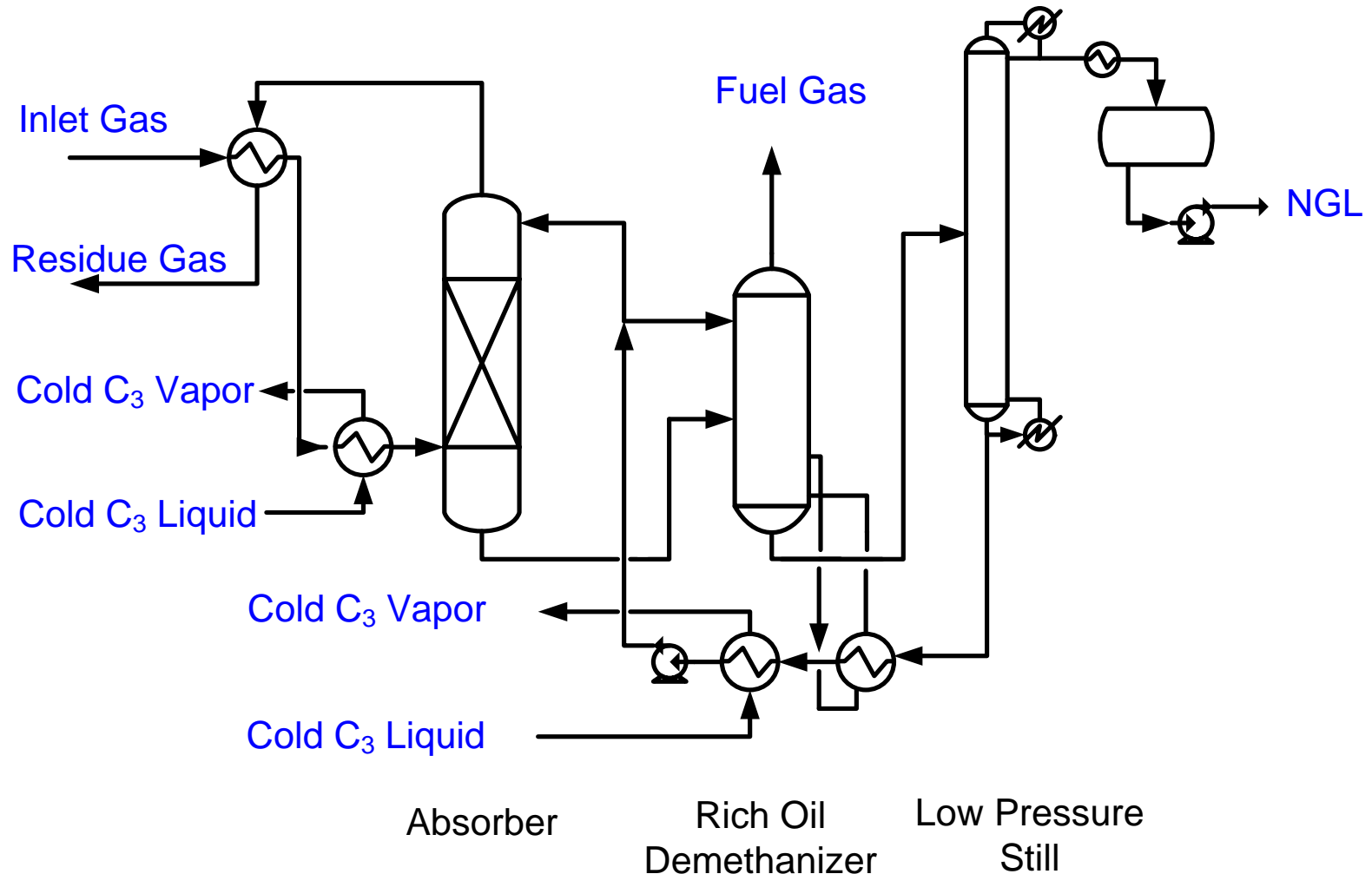
Effect of Composition on C_3^+ Recovery



Recovery Efficiency of C_2 and C_3



Refrigerated Lean Oil



High C₂⁺ Recovery

Requires cryogenic separation

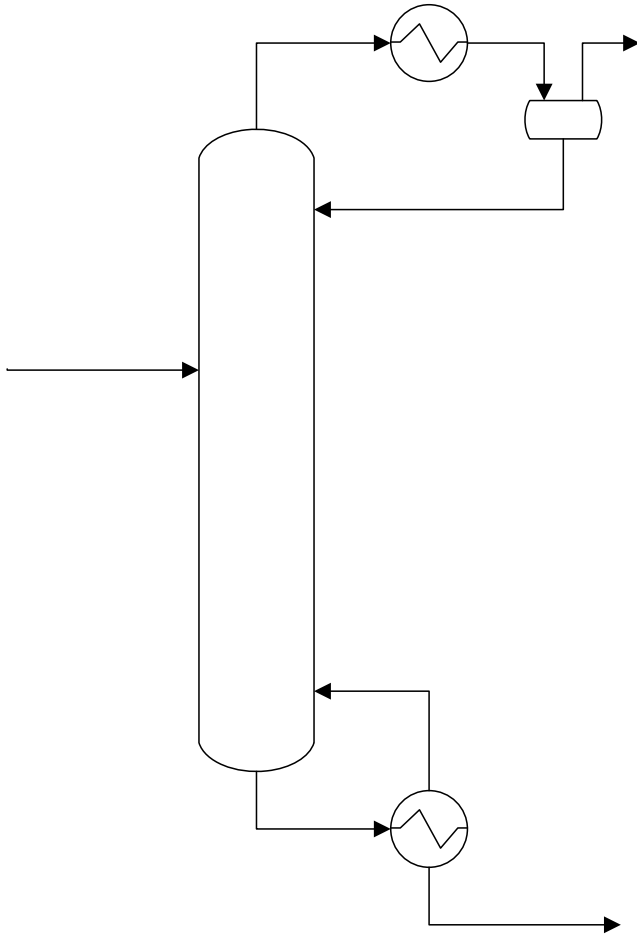
Processes involve:

- Propane refrigeration (unless high inlet gas pressure)
- Multipass heat exchangers (gas-gas)
- Expansion, turbo and JT
- Demethanizer column

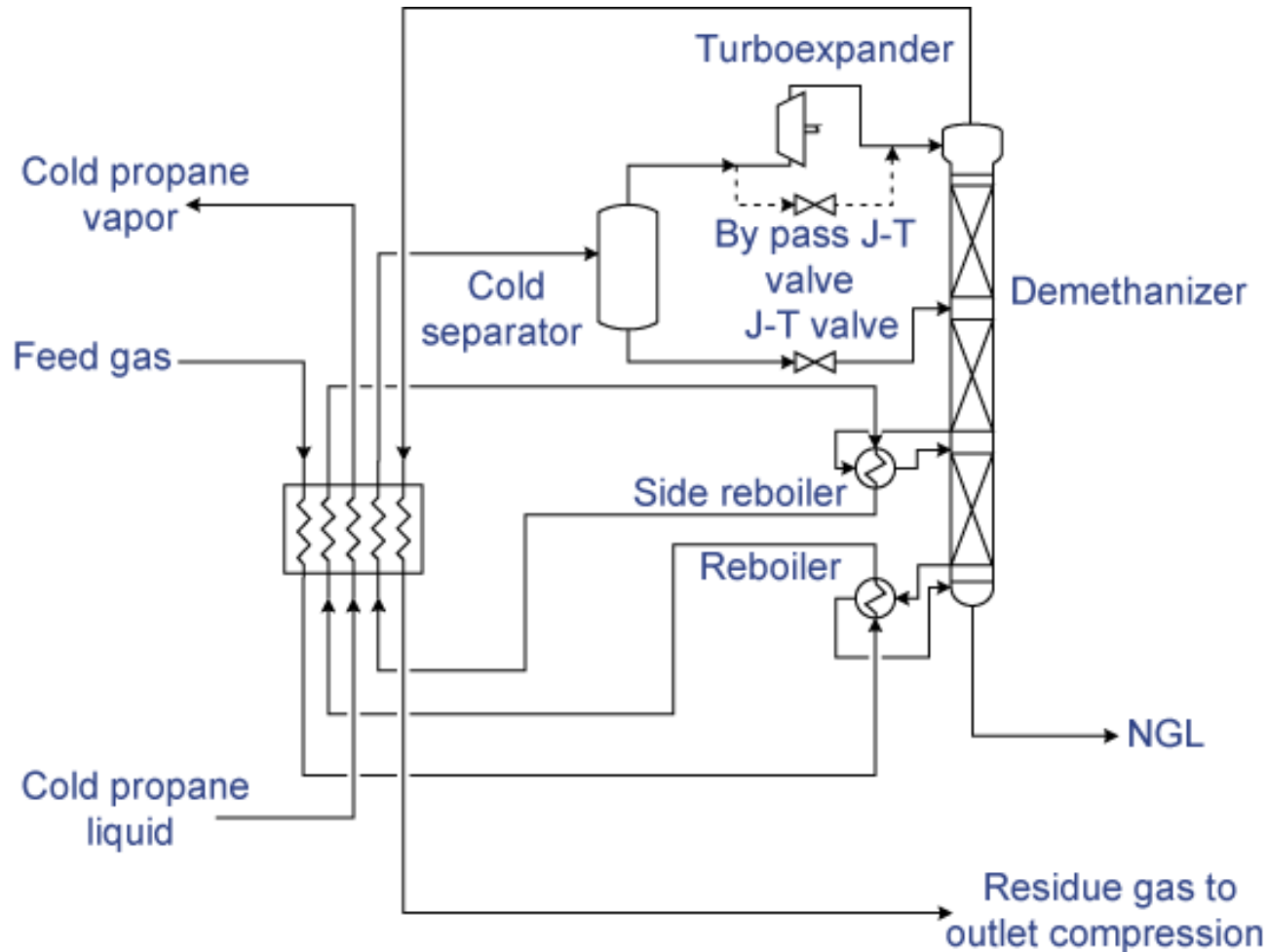
Two processes:

- “1st Generation” – simplest
- Gas Subcooled Process (GSP) – more efficient, higher recoveries and commonly used

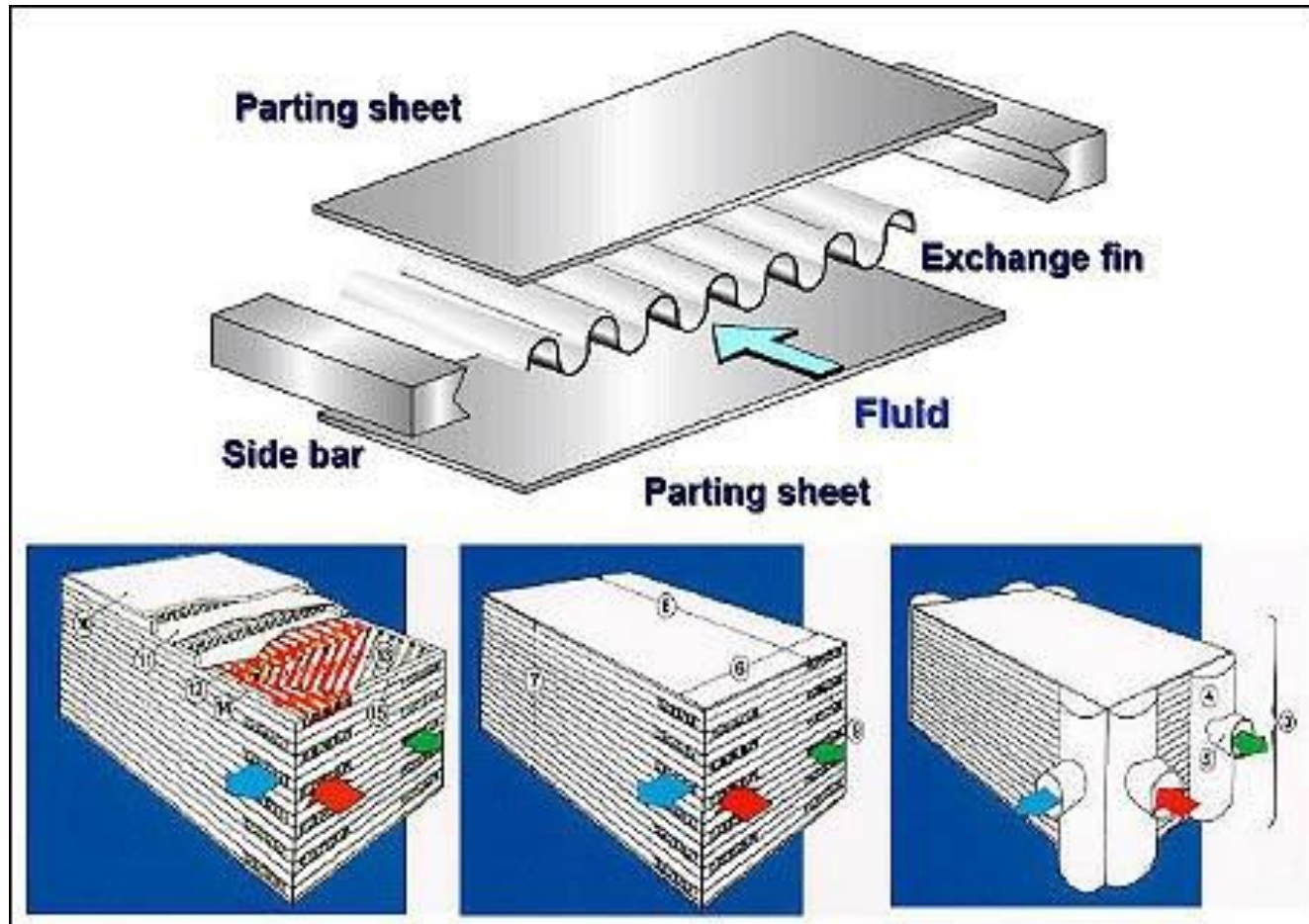
Considerations for Cryogenic Distillation



1st Generation Cryo Process

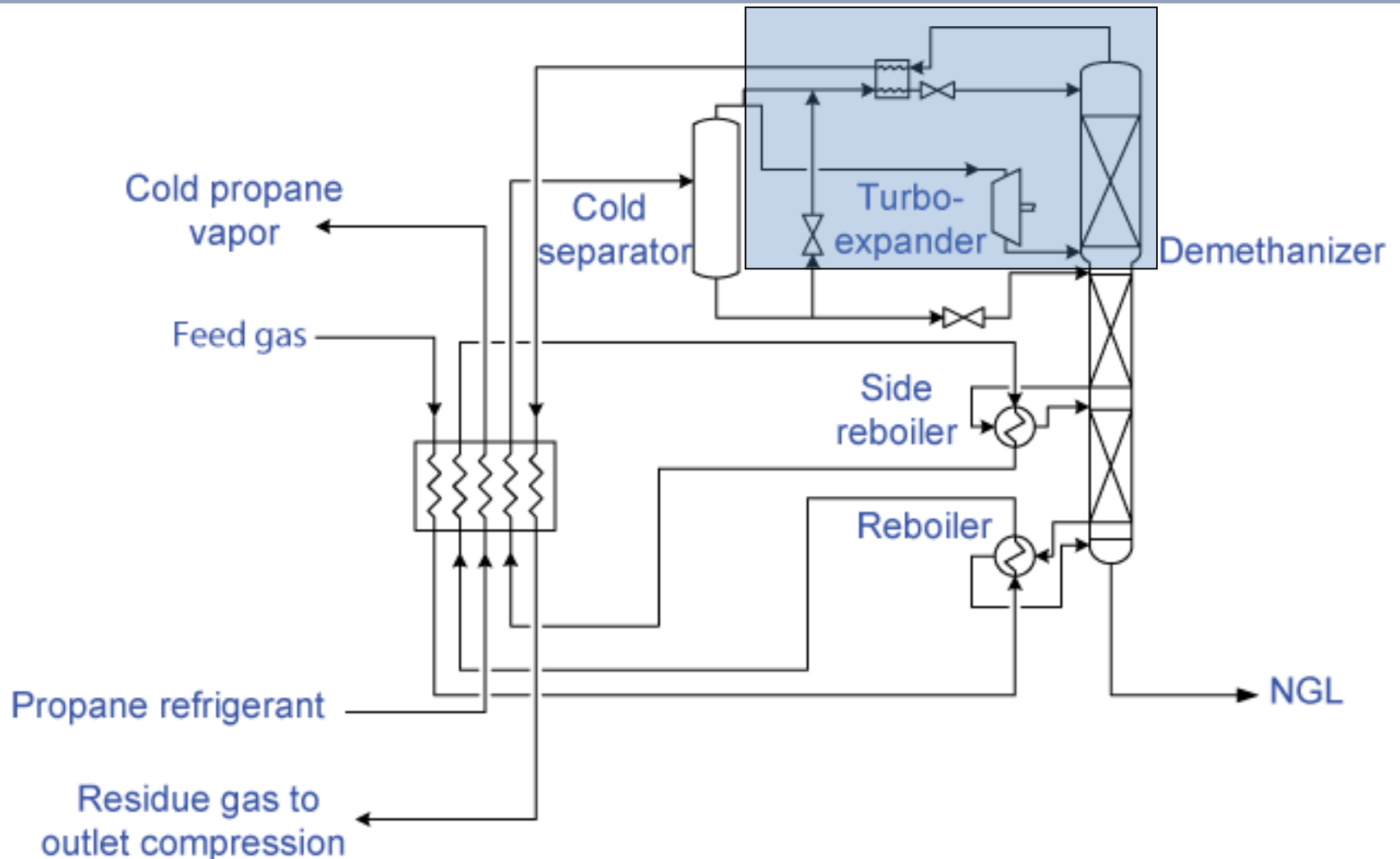


Brazed Aluminum Heat Exchanger – “Cold Box”

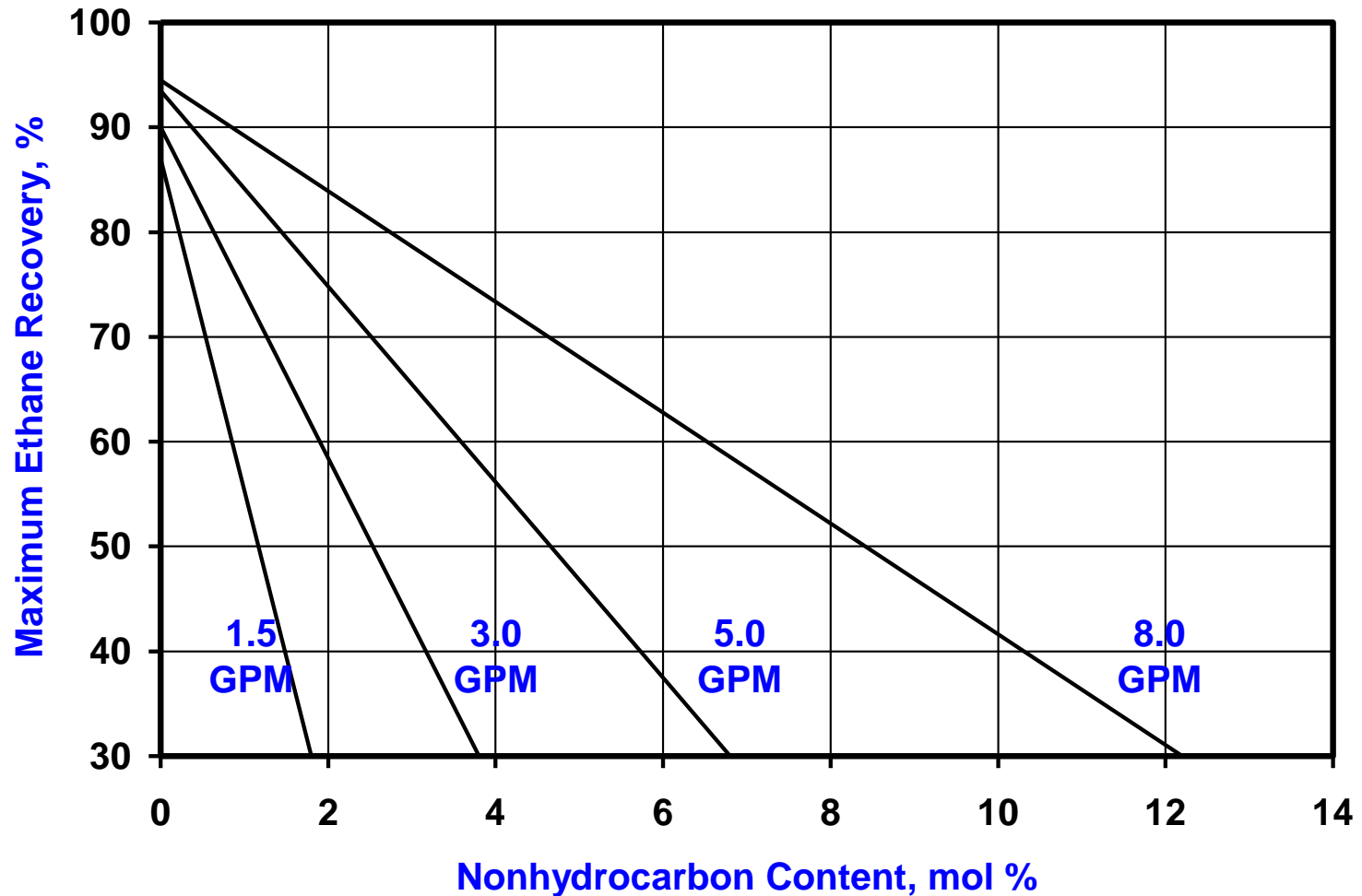


<http://hub.globalccsinstitute.com/publications/co2-liquid-logistics-shipping-concept-llsc-overall-supply-chain-optimization/53-co2>

GSP Schematic



Effect of Inerts on Max C₂ Recovery



Propane Recovery Processes

FIG. 16-17
Simple Turboexpander Process for Propane Recovery

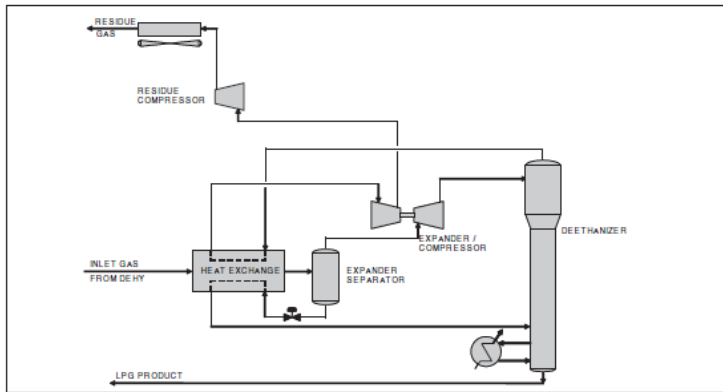


FIG. 16-18
GSP Process for Propane Recovery

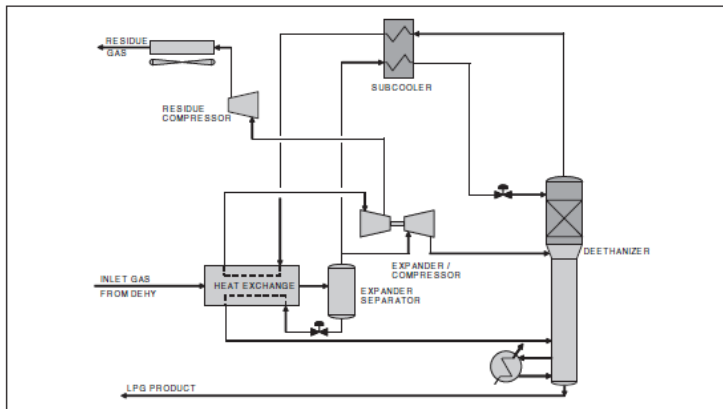


FIG. 16-21
IOR Propane Recovery Process

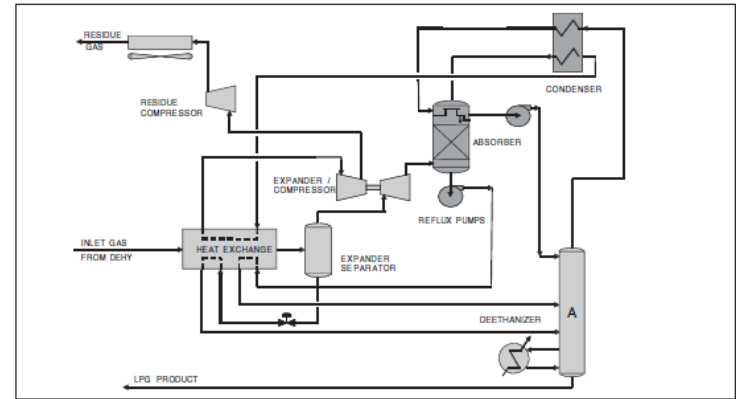
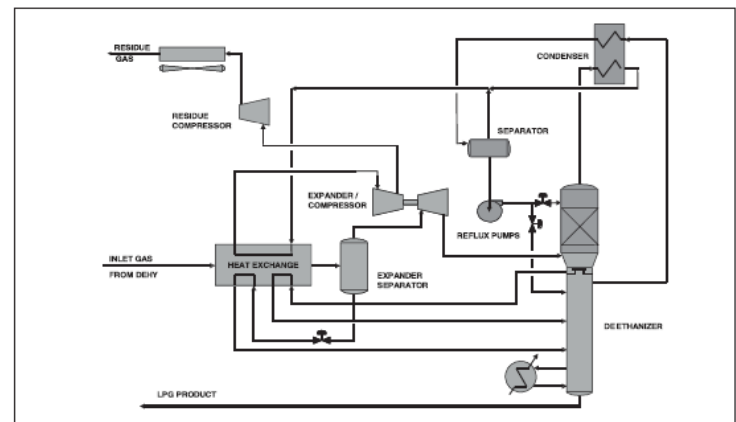


FIG. 16-22
SCORE Propane Recovery Process



GPSA Engineering Data Book, 14th ed.

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The diagram illustrates a nitrogen liquefaction process. It begins with 'INLET GAS' entering a 'HEAT EXCHANGER'. The gas is then compressed by a 'RESIDUE COMPRESSOR' and enters a 'DEMETHANIZER' column. The top product is 'RESIDUE GAS'. The bottom product is 'NGL PRODUCT'. The gas is then expanded through an 'EXPANDER / COMPRESSOR' and an 'EXPANDER SEPARATOR' before returning to the 'HEAT EXCHANGER'.

The diagram illustrates a cryogenic demethanizer process. Inlet gas from a dehydrator enters a heat exchanger. The gas is then compressed by a residue compressor and cooled in a subcooler before entering the demethanizer column. The demethanizer separates the gas into a top product stream (NGL product) and a bottom residue stream. The residue stream is compressed and cooled in the subcooler before being recycled back to the heat exchanger. The top product stream is also cooled in the heat exchanger before being collected.

The diagram illustrates a typical NGL extraction process. It begins with 'INLET GAS' entering a 'HEAT EXCHANGER'. The gas then flows to a 'RESIDUE COMPRESSOR' and then to a 'SUB COOLER / GAS-GAS EXCHANGER'. From there, it enters a 'DEMETHANIZER' column. The top product is 'RESIDUE GAS'. The bottom product is 'NGL PRODUCT'. The gas from the bottom of the column goes through an 'EXPANDER / COMPRESSOR' and a 'COLD SEPARATOR'. The gas from the cold separator goes back to the 'HEAT EXCHANGER' and the 'SUB COOLER / GAS-GAS EXCHANGER'. The liquid from the cold separator goes back to the 'DEMETHANIZER'.

The diagram illustrates a nitrogen liquefaction and demethanization process. The cycle includes the following components and flow paths:

- INLET GAS**: Enters the system from the bottom left.
- INLET EXCHANGER**: A heat exchanger where the inlet gas is pre-cooled by the returning liquid nitrogen stream.
- RESIDUE COMPRESSOR**: Compresses the gas from the inlet exchanger.
- BOOSTER COMPRESSOR**: Further compresses the gas to high pressure.
- REFLUX EXCHANGER**: A heat exchanger where the high-pressure gas is cooled by the reflux stream.
- SUBCOOLER**: Further cools the high-pressure gas.
- REFLUX SEPARATOR**: Separates the liquid reflux from the gas stream.
- EXPANDER**: Expands the gas to reduce its temperature.
- COLD SEPARATOR**: Separates the liquid nitrogen from the gas stream.
- DEMETHANIZER**: A distillation column where the liquid nitrogen is separated from the methane-rich gas.
- REBOILERS**: Three reboilers at the bottom of the demethanizer column, heated by a **NO₂** source.
- RESIDUE AFTER-COOLER**: Cools the residue gas before it is vented.

The process flow is as follows: Inlet gas is compressed and cooled in the inlet exchanger, then compressed further and cooled in the reflux exchanger and subcooler. The resulting liquid is separated in the reflux separator and expanded. The expanded gas is cooled in the cold separator and then in the reflux exchanger. The liquid is separated in the cold separator and then in the demethanizer. The demethanizer separates the liquid nitrogen from the methane-rich gas. The liquid nitrogen is collected in the cold separator and then in the demethanizer. The methane-rich gas is vented after being cooled in the residue after-cooler.

Summary



Summary

Primary liquids' production from cold separation

- Produced gas at dew point condition at last conditions in contact with hydrocarbon liquid

Lower liquid content of produced gas has a lower dew point requiring lower temperatures

Propane refrigeration loop

- Typical low temperatures to -40°F
- Intermediate pressures reduce compression power & can make chilling temperatures about 10°F