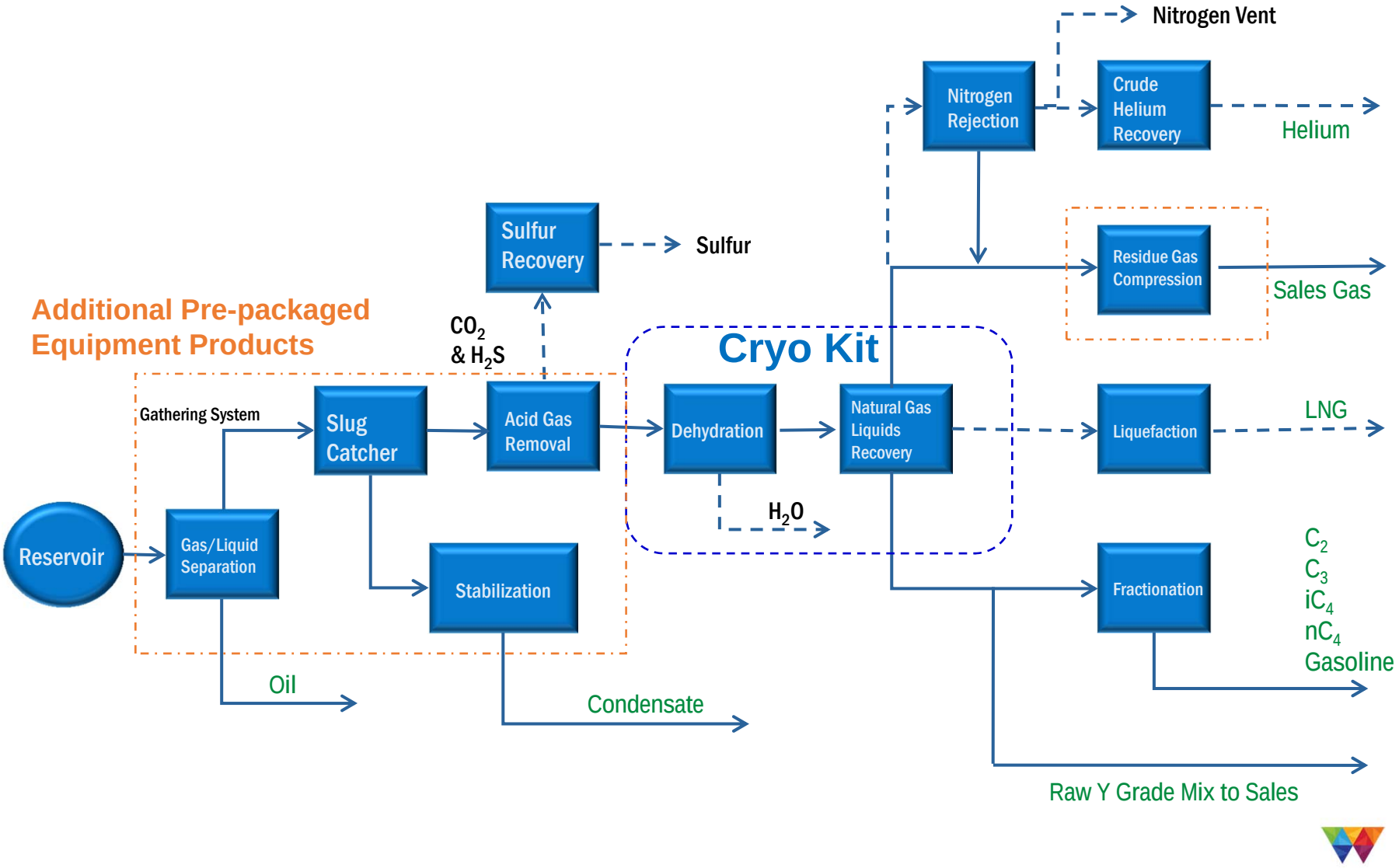
WOOD GROUP MUSTANG

Processing Rich Gas for NGL Recovery

Safety & Assurance | Relationships | Social Responsibility | People | Innovation | Financial Responsibility | Integrity

Schematic Overview of Total Production-Processing System



Cryogenic Gas Plants, Treating, and Fractionation

Gas Plant NGL Processing and Fractionation

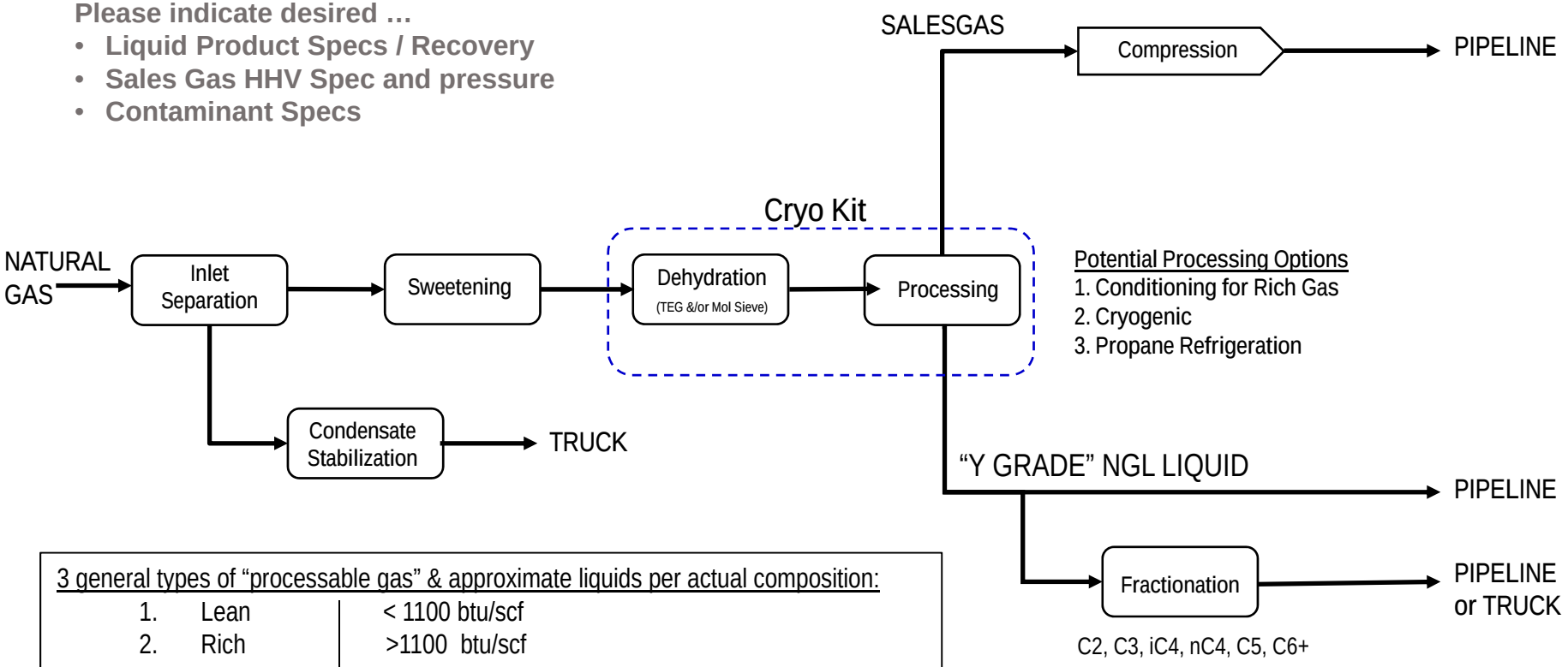
- Rich Gas Considerations
- Contaminant Removal (Hg, H_2S, CO_2, H_2O)
- Conventional or Cryogenic Processing
- Proven Plant Process Cycles
- Project Parameters, and Equipment Product Offerings
  - Typical Plant Equipment Scope
  - Fractionation

Processing Rich Gas for NGL Recovery

Flow Rate? Composition? Pressure? Temperature?

Please indicate desired …

- **Liquid Product Specs / Recovery**
- **Sales Gas HHV Spec and pressure**
- **Contaminant Specs**



3 general types of "processable gas" & approximate liquids per actual composition:

1.	Lean	< 1100 btu/scf
2.	Rich	>1100 btu/scf
3.	Associated	>1200 btu/scf

Note: Some basins include very rich gas -1450 btu/scf to 1600 btu/scf

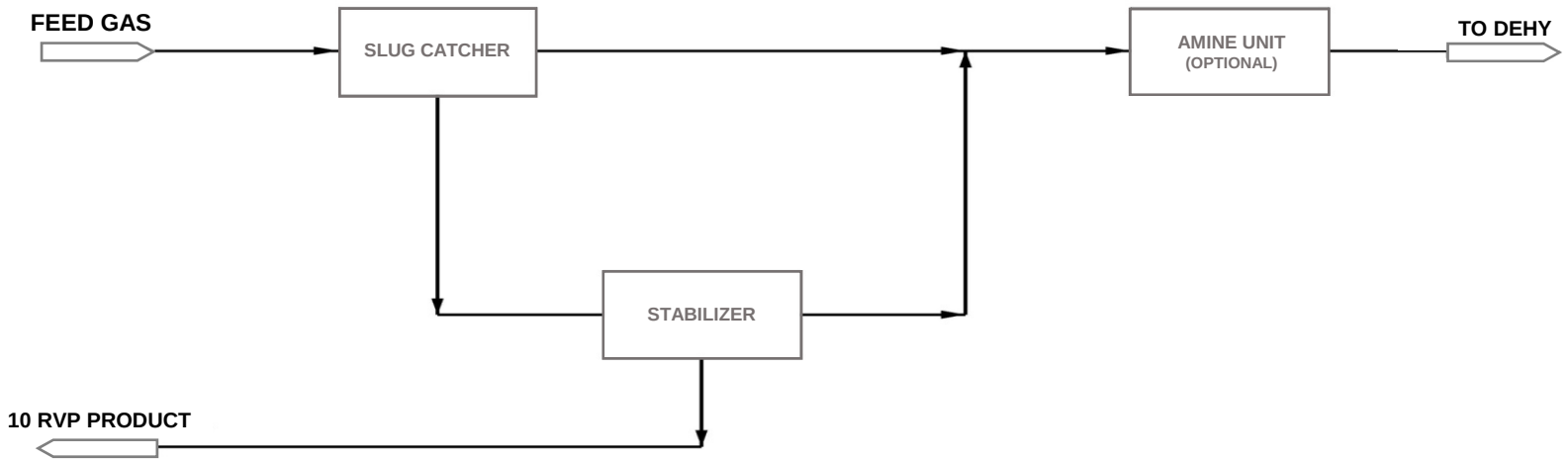
Processing Rich Gas for NGL Recovery

Shale drilling technique advancements have changed gas compositions drastically

- Natural Gases are now similar to Associated Gases in richness
- Hydrocarbon liquids are generated at considerably lower pressure
- This poses unique processing problems not seen before
- The selection of the process has become difficult
- In this presentation, we will consider several processes suitable for the new processing environment.

Processing Rich Gas for NGL Recovery

- **Two types of processing is completed, to produce**
  - Ethane plus product, or
  - Propane plus product
- **First, we will examine the front end handling of gas.**



Glycol Gas Dehydration

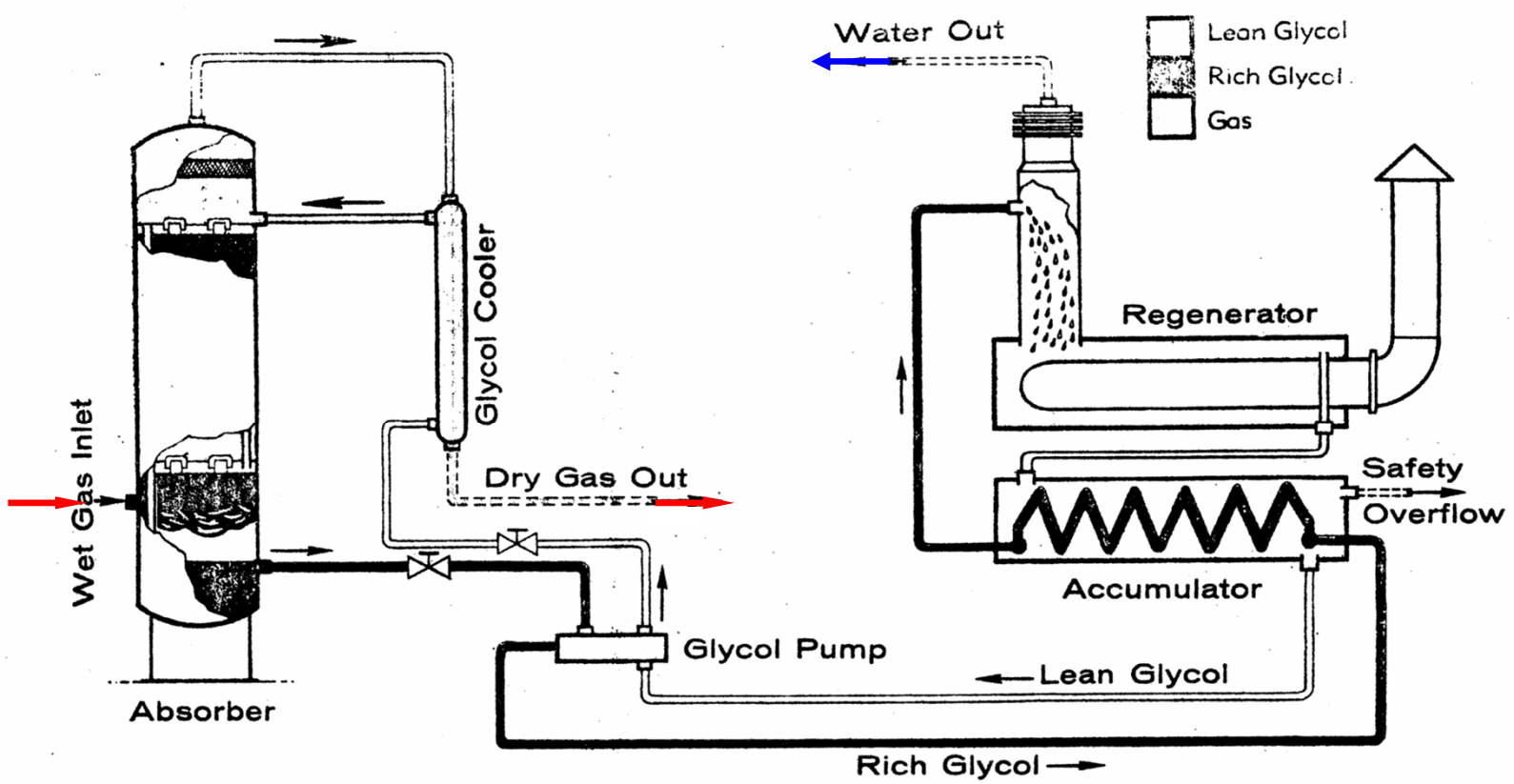
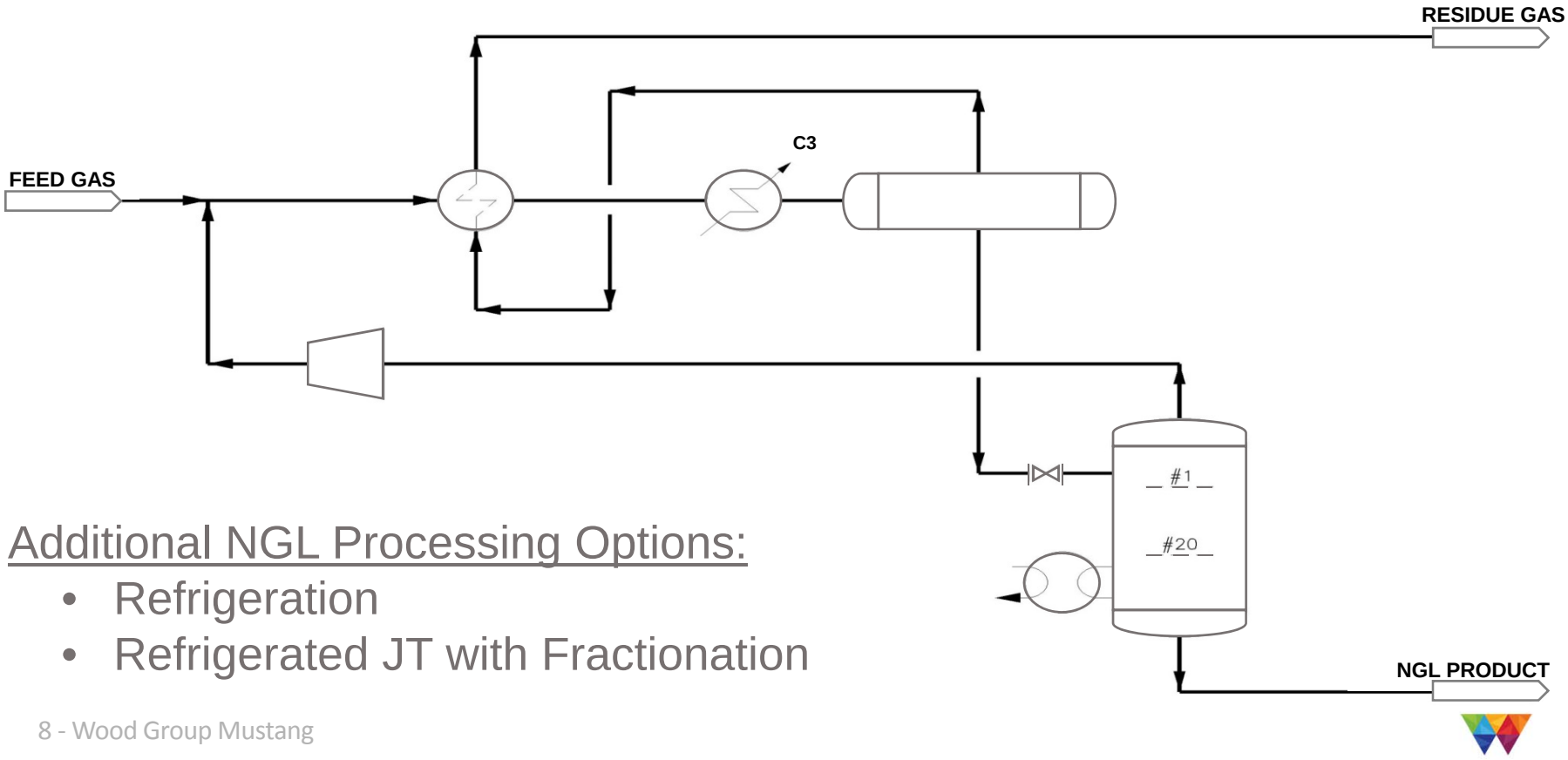


Fig. 2—Typical flow scheme for a glycol plant shows use of gas-glycol pump.

Processing Rich Gas for NGL Recovery

Dew Point Control Unit

- BTU Control
- Condensate Control in the Pipeline
- Bare Minimum Investment



Additional NGL Processing Options:

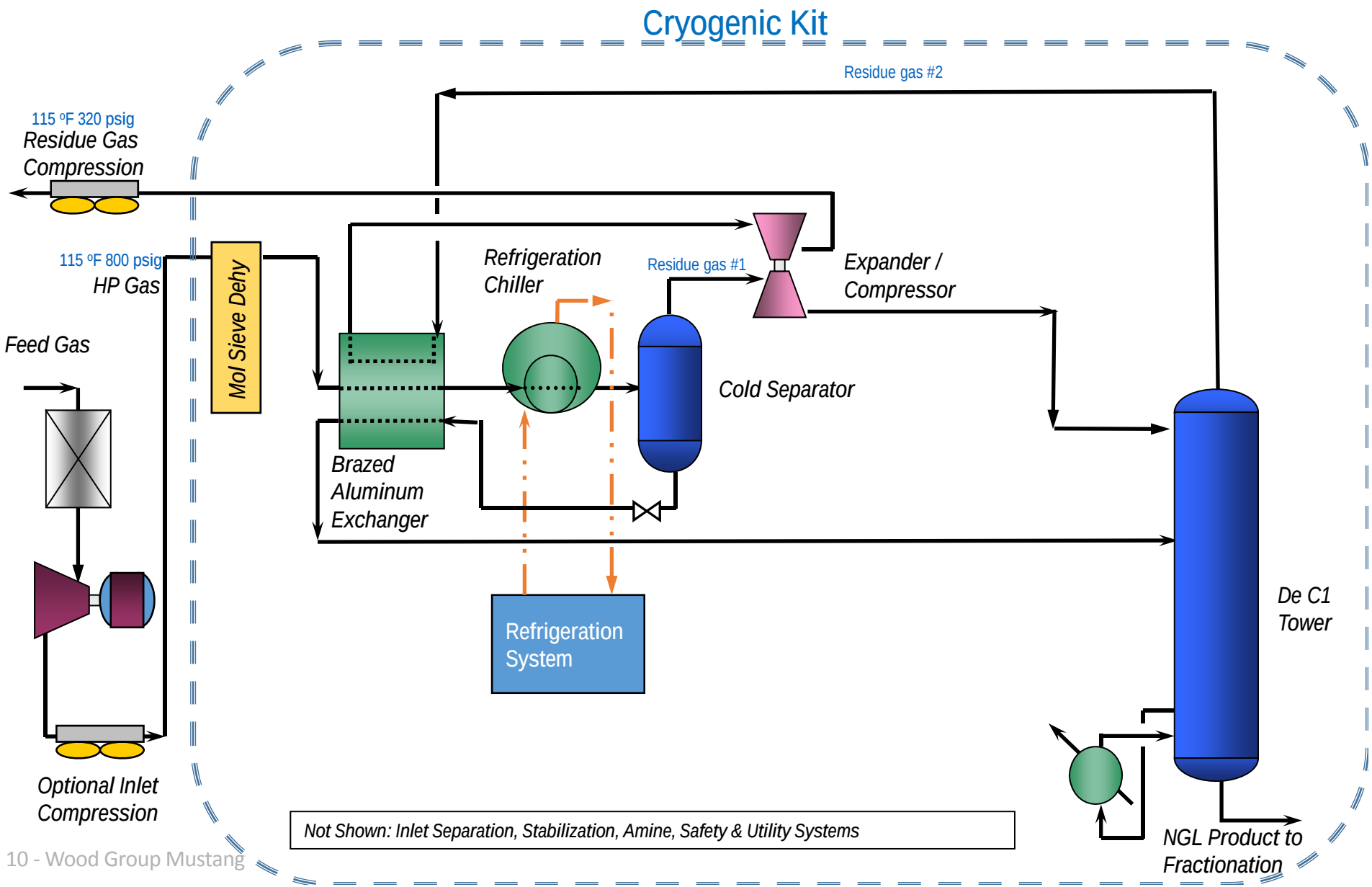
- Refrigeration
- Refrigerated JT with Fractionation

Processing Rich Gas for NGL Recovery

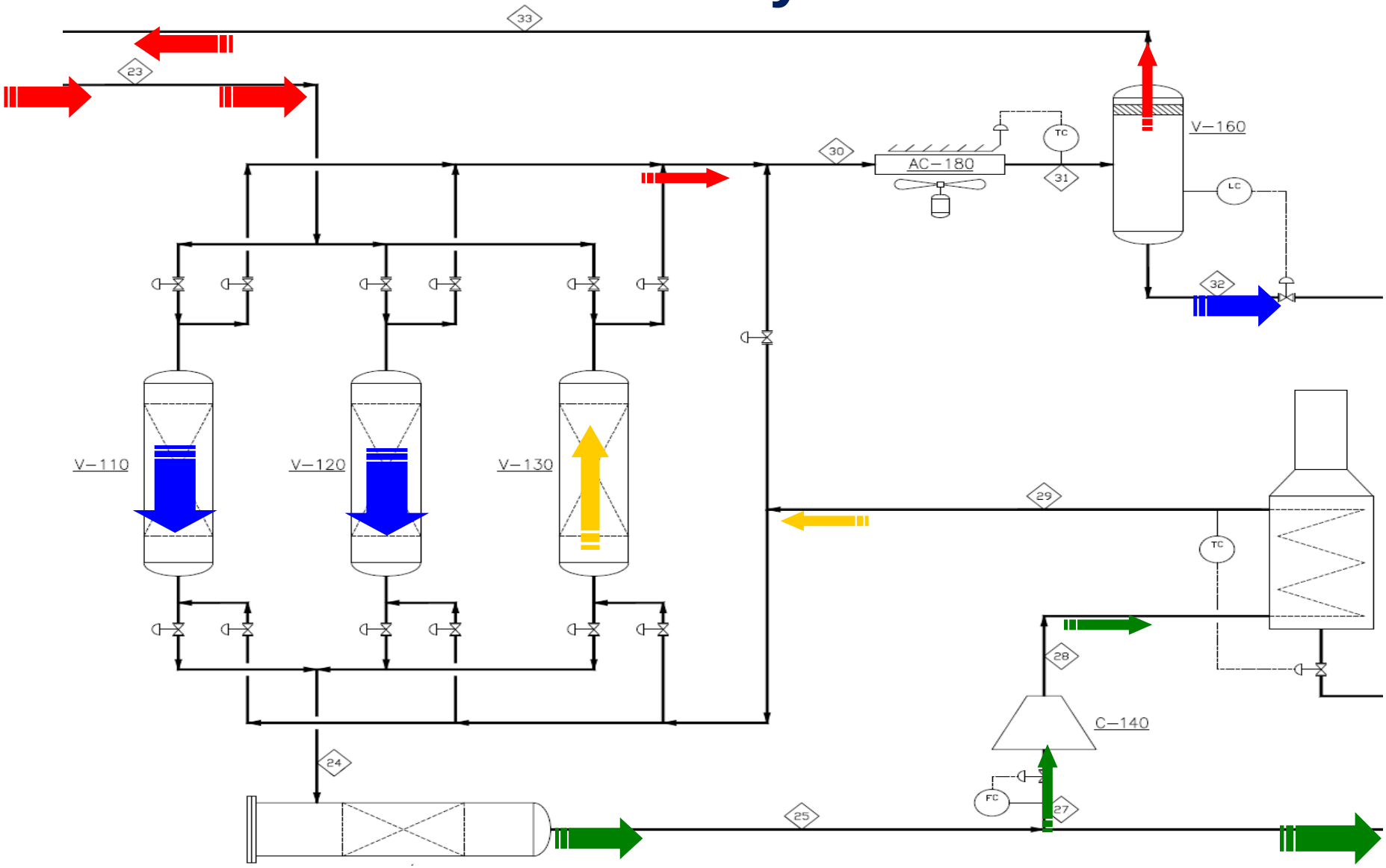
Dew Point Control Unit Advantages and Disadvantages

Advantages	Disadvantages
Open Art. No royalty required	High mechanical refrigeration required
Low capital cost	Recycle compressor is required.
Most widely used	Not suitable for high Ethane Recovery
Very suitable for Propane Recovery of extremely rich gases, 70 to 85% achievable	Turndown is limited to 30% of design flowrate without additional instrumentation and operator attention
No residue gas compression required	
Simple controls, Easy to operate	
Requires mechanical refrigeration	

Cryogenic NGL Recovery Process



Molecular Sieve Gas Dehydration



Molecular Sieve System for Rich Gases

Drying the gas to prevent freeze-up for the selected Cryogenic process

- Requires <1 ppm of moisture
- Some plants utilize Glycol Dehydration with a less robust mol sieve system, i.e. 90ºF water saturated at 850 psig.
- Plants are very successful with stand alone mol sieve systems if designed for 120ºF water saturated at 850 psig and good design practice utilized.
- Careful consideration should be given to the richness of the gas for the design of the molecular sieve system
  - Gases containing more than 1250 BTU/SCF liquid,
    - 3A sieve should be used;
    - otherwise 4A sieve is recommended
  - Hydrocarbon dew point of the gas should be carefully viewed and should be heated to 20ºF above the hydrocarbon dew point so to ensure avoiding condensation in the mol sieve.

Proven Gas Plant Processes

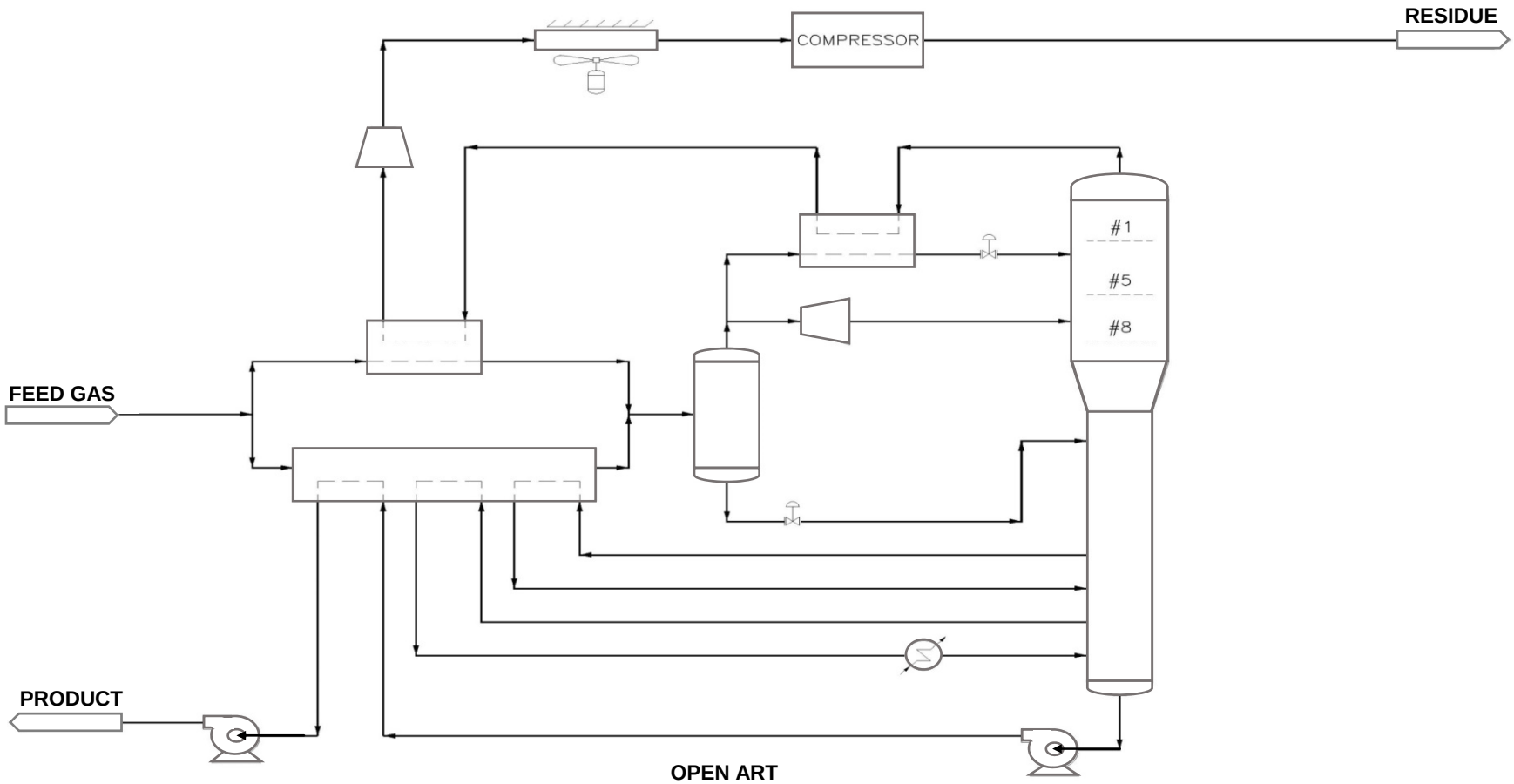
- NGL Gas Subcooled Process (GSP)
- NGL Hi Propane Recovery
- NGL Hi Ethane Recovery
- Propane Refrigeration (closed loop for cryo plant internal refrigeration)
  - Cryo plant duty depends on liquid richness content of feed gas. Above 7,000 BHP refrigeration, stabilization / dew point is used to condition the inlet gas feed to the cryo section

Gas Type	NGL Mol/Hr	Ref. HP
Lean	2,752	0
Lean	3,073	2,000
Rich	3,785	2,500
Richer	5,111	4,500
Associated	6,374	7,044

- LNG - Small or micro scale (Backend of NGL Plant)
- H_2S and CO_2 Treating (Chemical and Physical Absorption) & Recovery
- Sulfur Recovery (if required)
- Nitrogen Rejection / Helium Recovery (if required)

Gas Sub-Cool Process

The most widely used cryogenic process



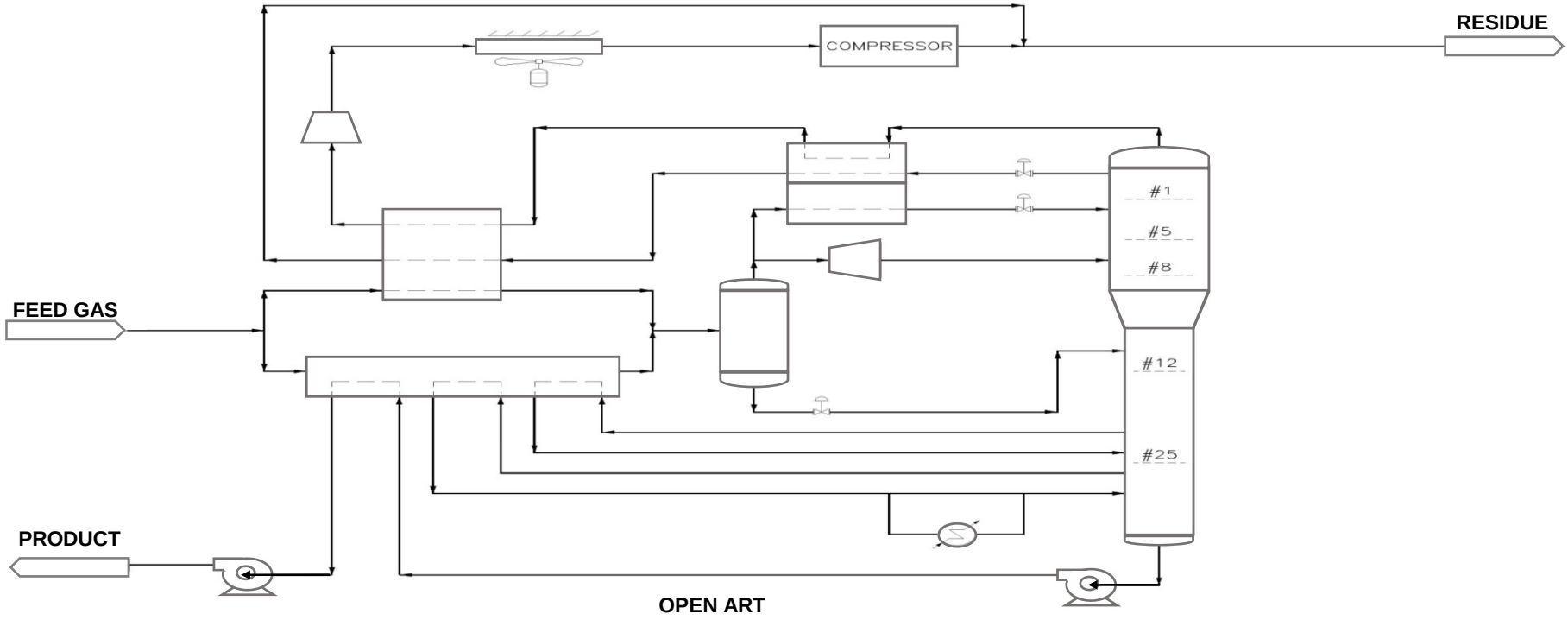
Processing Rich Gas for NGL Recovery

Gas Subcooled Process (GSP) Advantages and Disadvantages

Advantages	Disadvantages
Open Art, No Royalty required	Not efficient in Propane Recovery
Most widely used	Difficult to produce HD-5 Propane without further processing
Very suitable for Ethane Recovery, 90 to 95% achievable	Not suitable for higher than 95% Ethane Recovery
Minimal residue gas compression and fuel required	Turndown is limited to 50% without additional instrumentation and operator attention
Simple controls, Easy to operate	Limited to 0.5 mol% of CO2 to avoid freeze-up
Rich gases require mechanical refrigeration	

Ethane Plus Product Process – RSV

Process Suitable For $C2^+$ & $C3^+$ Recovery



Processing Rich Gas for NGL Recovery

Residue Split Vapor (RSV) Advantages and Disadvantages

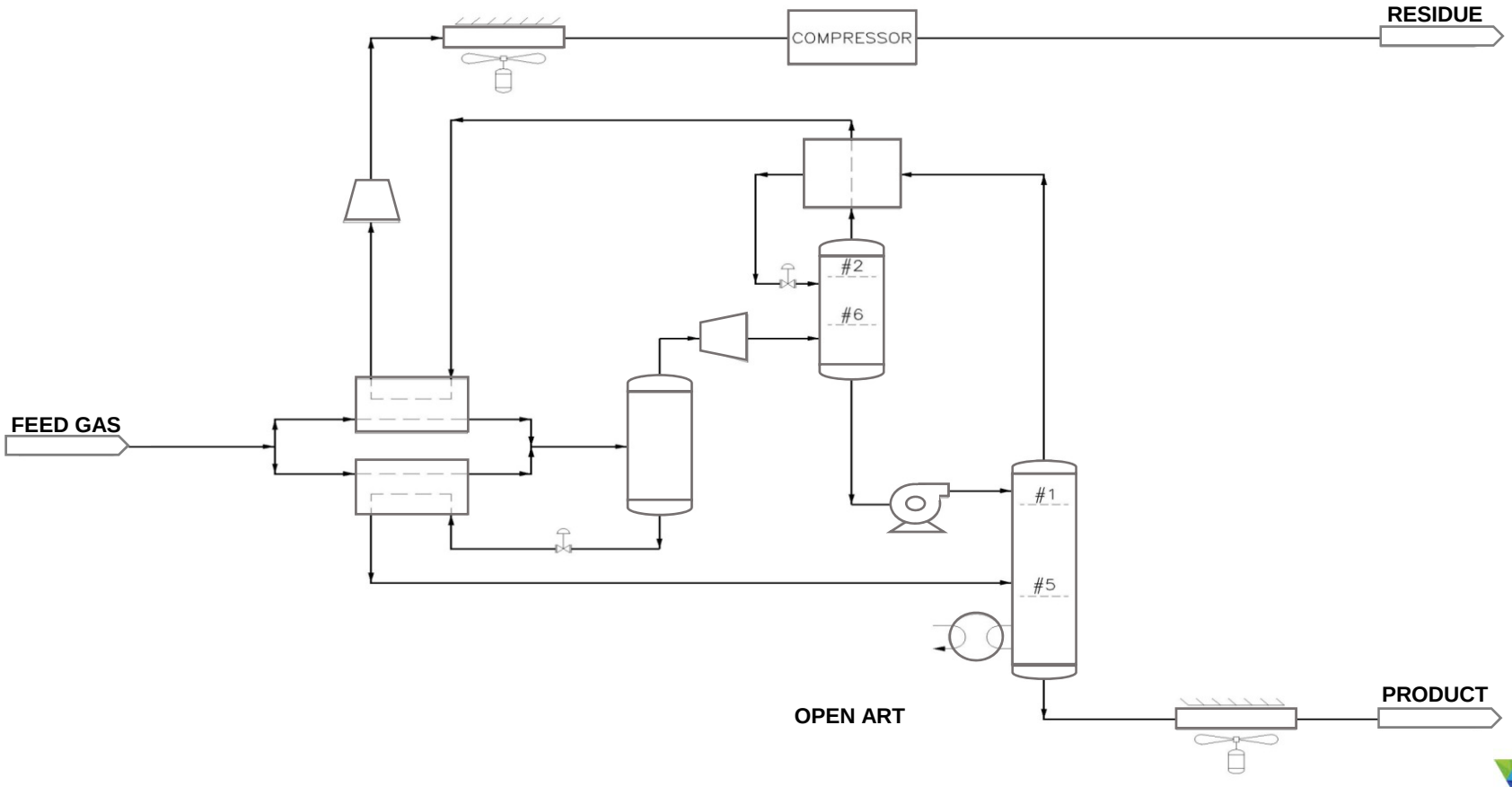
Advantages	Disadvantages
Open Art, No royalty required	Not routinely used in Propane Recovery
Not widely used	7 to 15% gas is recycled resulting in higher compression costs
Suitable for Ethane Recovery, 98 to 99% achievable	High residue fuel requirement
Higher residue gas compression required	Sensitive to CO2 freeze-up
Complex control required	
Rich gases require mechanical refrigeration	

Ethane Plus Product Process – Additional Processes

- There are several competing processes versus the GSP and RSV, which all have slight modifications to these processes.
- Does not provide a distinct advantage or cost savings
- Next, we will discuss the Propane recovery processes

Propane Plus Product Process – Propane Max™

Suitable for high propane recovery



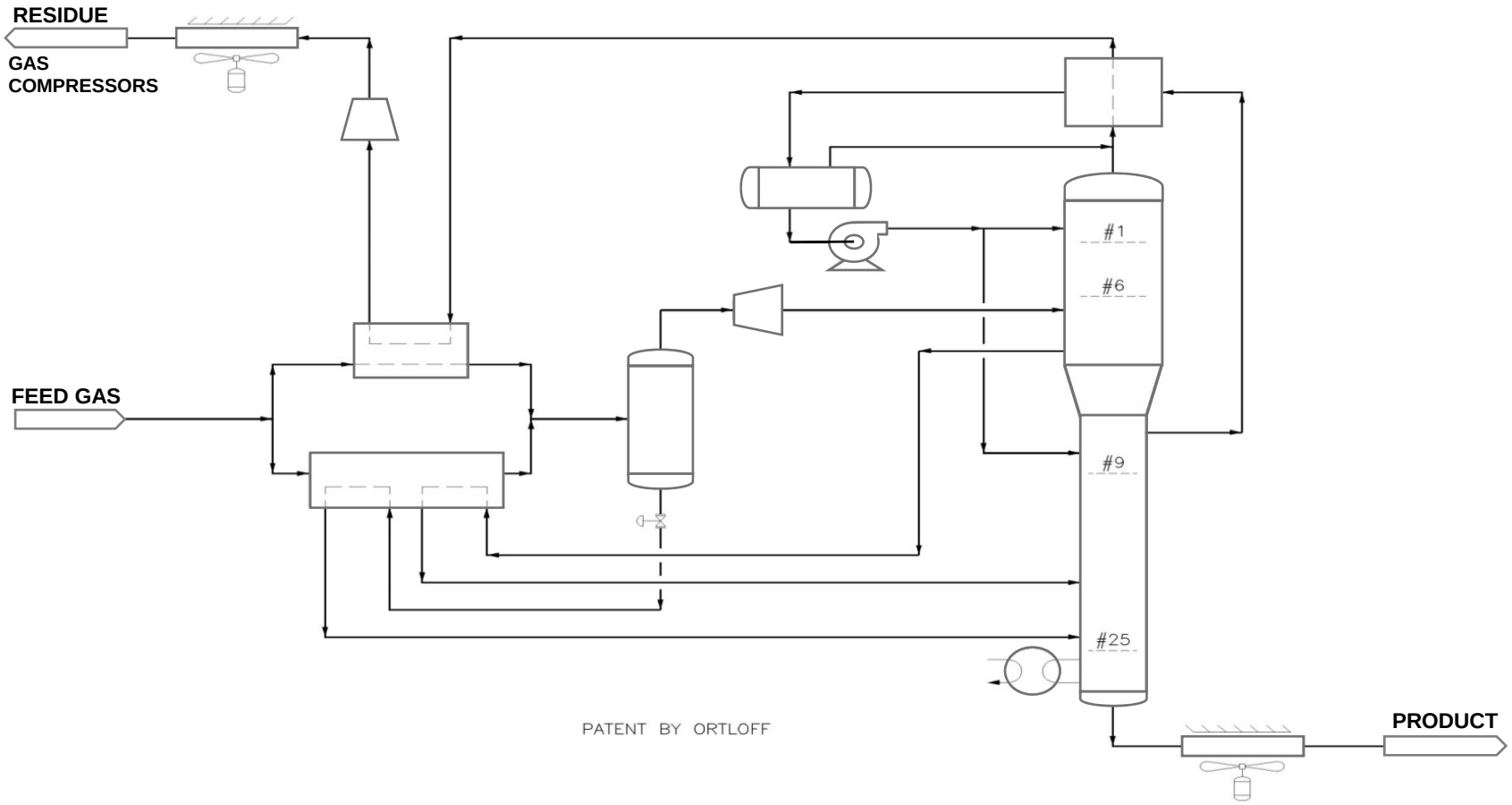
Processing Rich Gas for NGL Recovery

Propane Max Advantages and Disadvantages

Advantages	Disadvantages
Open Art, No royalty required	Cold Pump is required as a recycle pump
Very suitable for low feed gas pressure	Expander operation complex, particularly at initial start-up
Very suitable for 95 to 98% Propane Recovery, and easily modified for 90 to 95% Ethane recovery	Not widely used
For Rich gases may eliminate expander with little impact to recovery	
Less than 2 Vol% Ethane in C3+ product is achievable making a truckable product	
Not sensitive to composition changes	
Simple controls, Easy to operate	
Rich gases require mechanical refrigeration.	
Suitable for Upgrader and Refinery Offgas $C_2/C_3/H_2$ Recovery	

Propane Plus Product Process – SCORE™

Suitable for high Propane recovery and modified version of Propane Max



Processing Rich Gas for NGL Recovery

SCORE Advantages and Disadvantages

Advantages	Disadvantages
Commonly used for Propane Recovery	Patented process, royalty required
Very suitable for 95 to 98% Propane Recovery	Not suitable for Ethane Recovery
Less than 2 Volume % Ethane in C3+ product is achievable	Not suitable for low pressure
Rich gases require mechanical refrigeration	Cold Pump is required as a recycle pump
	Very sensitive to composition changes
	Cold Pump is required as a recycle pump
	Not Suitable for Refinery Offgas $C_2/C_3/H_2$ Recovery

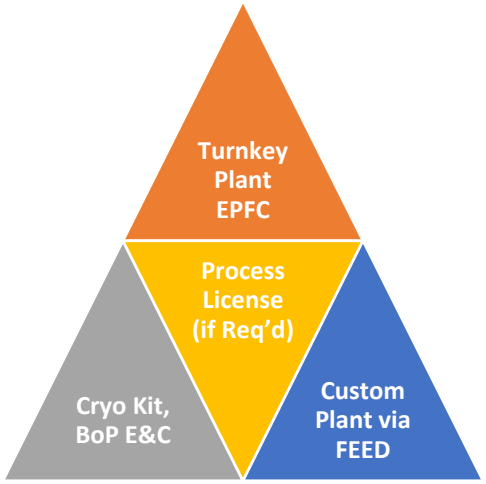
Typical Kits/Available Equipment

Cryogenic Processing • Treating • Stabilization

Equipment	Inventoried / Standard Packages	Critical Path	Notes / Comments
Cryo Kit, MMSCFD	60, 120, 200	Pre-Design &/or Inventoried Long Leads &/or Kits, & Shop Space	P/L Pumps optional
Refrigeration Drive Line, HP	1000, 1500 & Standard Specs	Refrigeration Drive Lines	Larger sizes are custom offerings.
Refrigeration Unit	2 to 3 sizes matching duty	Yes for Gas Plant	Condensers, A/C, Vessels, Skids
Condensate Stabilizer, B/D	1000, 2500	Overhead Compression	5000, 10000, but 25000 and larger are not inventoried
Amine	Yes (< 120 gpm)	Yes for Gas Plant	Plant suppliers have designs up to 1,000gpm
Compression	No	Yes for Gas Plant, 8-12 mo's (typ)	Electric or Gas Drive, Decide if Recip or Turbine / Waste Heat Recovery
Brazed Aluminum Heat Exchangers	No	Yes for Gas Plant	Long Lead Items for Cryo Kits
Expander	Yes	Yes for Gas Plant	Long Lead Items for Cryo Kits
Tight Shut Off Valves	Yes	Yes for Gas Plant	Long Lead Items for Cryo Kits
Demethanizer & Internals	No	Yes for Gas Plant	Long Lead Items for Cryo Kits
BoP Standard Systems	Not Typical	Pre-Designs and Procurement	Drains, Flare, MCC/Control (PLC & / or DCS), Instrument Air, Pipe / Rack Modules, Compression
Product Handling	Occasional		P/L pumps, Metering, Truck Loading

Gas Plant Project Parameters for Cryo Kits & Custom NGL Plants

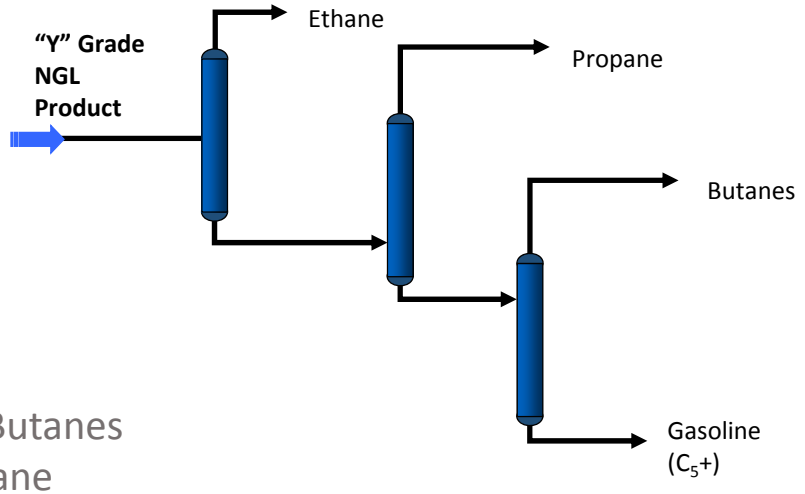
Various Execution Models

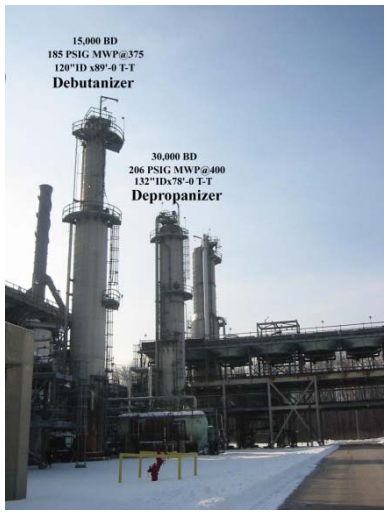


	Generation A Kits	Generation B Kits	Generation C Kits	Custom Plants
Train Sizes (MMSCFD) & GSP, Hi C3, Hi C2	35,60, 120,200 GSP only	35,60, 120, 200 GSP Only	35,60, 120, 200 GSP, $C3^+$, $C2^+$	20 to 450 GSP, or $C2^+$ or $C3^+$
Min. Inlet Feed (psig)	950	950	600, 950	600, 950, 1100
Process License?	No	No, Some Yes	No, Some Yes	No, Some Yes
Gas Richness (Gal/1000scf)	3 to 5	3 to 6.8	3 to 10^+	3 to 10^+
Process Guarantee	No	No, some Yes	Yes	Yes
Nameplate Capacity Limits / Impact with Richer Gas	100% of Design Gal per 1000scf/ **Decreases**	100% of Design Gal per 1000scf/ **Decreases**	115% of Designed Gal per 1000scf/ **Constant**	115% of Designed Gal per 1000scf/ **Constant**
Rich Liquid DewPoint Control Required?	No	Yes	No	No
Typical Turndown (% of Design Capacity)	To 50%	To 50%	Ranges 25 to 60%; Supplier dependent	Ranges 25 to 60%; Supplier dependent
Refrigeration (Combined increments as required)	1000, 1500HP increments	1000, 15000HP Increments	500, 1000, 1500, 2300HP Increments	500, 1000, 1500, 2300HP Increments
Mol Sieve H2O Saturated	90F	90F	120F	90 or 120F
Customization Available?	No	No, Some Yes	Some Yes	Yes
Inventoried	Some	Some	Some	No
Overall Plant Schedule	11 to 18 Months	11 to 18 Months	11 to 18 Months	18 to 24^+ Months

Fractionation

- **Demethanized product from a NGL plant may be routed to a pipeline and fractionated by 3rd parties or fractionated on site.**
- **Potential Products of Fractionation**
  - Ethane
  - Propane
  - Ethane/Propane Mixture (EP Mix)
  - Commercial Propane
  - Propane/Butane Mixture (LPG)
  - Mixed Butanes
  - Iso-Butane
  - n-Butane
  - Butane/Gasoline Mixture
  - Natural Gasoline
- **Industry specifications are available for commercial propane & butane, butane/propane mixtures and HD-5 propane, but client dependent for all others.**
- **If Y Grade NGL and Rich Condensate are mixed, then care must be taken in processing.**





H_2S Processing & Sulfur Recovery

Typical Application Processes:

- Scavenger, Membrane, other
- Claus or Superclaus Sulfur Recovery Units (SRU)
  - Conventional, Subdewpoint and Modified
- Capacities 6-420+ LTPD
- Typically Modularized up to 100 LTPD. Optimize Modular versus Stick-Built Construction
- Amine/Tail Gas Treating Units

Will high H2S become a factor in Rich Shale processing?

Cryo Offgas (from Upgraders and Refiners)

Propane (Propylene) Recovery

Ethane (Ethylene) Recovery

Options

- Polyolefin
- Hydrogen Recovery

Thank you!

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