

DEW POINT TURBOEXPANDER PROCESS A SOLUTION FOR HIGH PRESSURE FIELDS

Author: Jorge H. Foglietta
Director of Technology Development and Process Engineering
Lummus Process Technology – Randall Gas Technologies, A Division of ABB Lummus Global Inc.
Houston, Texas, U.S.A.

1-713-821-4313
email: jorge.h.foglietta@us.abb.com

ABSTRACT

Classical dew point control units are typically featured with propane refrigeration to achieve the gas specification and desired gas dew points. It is the most used technology, especially for gas fields where the operating pressure of the plant is below the critical point of the gas mixture.

However, when the gas to be processed is available at conditions above the critical point, the processor cannot adjust the dew point of the gas, for lack of condensation, unless the pressure is reduced to a point where the gas could be managed adequately. In this case, a turboexpander dew point process is more adequate as it generates refrigeration and benefits from the expansion to generate work.

The turboexpander technology is also justified when it is necessary to save space and weight. Offshore or remote site applications are typical examples. Randall Gas Technologies has a solid record in designing turboexpander units which have been used very efficiently to dew point gases for the conditions indicated above. The most known applications are offshore (North Sea, South East Asia, etc) and in remote locations in South America.

This paper discusses design considerations, equipment design options, and different process flowschemes, learnt from the experience in the application of the turboexpander for dew point applications.

Introduction

Dew point control is one of the most important operations at the beginning of the gas processing chain. Its main purpose is to ensure that liquids (either hydrocarbons or water) are not formed in the pipelines to allow a safe and reliable transportation of the gas to markets.

The by-product liquids recovered could be used as fuel, or alternatively stabilized and marketed as condensate. Occasionally, regional markets allow the extraction of LPG from these liquids.

Flow Assurance - Pipeline gas dew point adjustment needs

Flow assurance is the analysis developed with the concurrence of thermodynamic, pipeline hydraulic, site survey profile, and chemistry science to ensure that the pipeline operation is reliable and free of operational issues (plugging, sediments, slugs, hydrates, etc.) that would jeopardize its performance with the consequent loss of business revenues.

It is well known that retrograde condensation (occurrence of two dew point at constant pressure or constant temperature) is formed at reservoir conditions. This phenomenon also occurs in pipelines, and consideration must be given to avoid the formation of liquids in pipelines. Liquids accumulating in low points of pipelines represent an operational issue with the consequential formation of two-phase flow, liquid slugs, and problems in metering stations.

The requirements for dew point control are usually set once the pipeline gas composition and operating and environmental conditions are known. Normally, these conditions are set by the lowest pressure existing in the pipeline system, usually at the inlet of the compression stations. However, other non-operational conditions should be considered, such as flow transients, depressurizations, etc. A thorough analysis of the phase envelope curves is required to determine the pipeline dew point requirements (See figure 1).

Dew point control methods

We include a brief review of the methods used to reduce hydrocarbon dew point in gas streams. As these processes are well known, for the sake of brevity we will not include their descriptions, which are well covered in the literature (see References 1, 2).

1) Low Temperature Separation (LTS)

If the raw gas is at high pressure, the removal of hydrocarbons can be accomplished by refrigeration obtained through the expansion of gas by means of a Joule-Thomson valve. Injection of glycol is required to prevent the formation of hydrates. (See Figure 2)

2) Turboexpander Dew Point

This process is a variation of the LTS process in which the energy pressure hold in the gas is used to move an expander turbine, which in the isentropic expansion generates refrigeration and exports mechanical work. This work is used to drive a compressor to partially restore the gas pressure. This method will be the focus of our discussion. (See Figure 3)

3) Refrigeration

The most common method used for gas dew point control is mechanical refrigeration. This technology is suited especially when pressure is not available to be used to self refrigerate the gas (See Figure 4). Two variations exist of this process: one that recycles the stabilizer overhead to the front end of the plant, used to maximize the recovery of certain components, and a second that re-injects the stabilizer overhead in the residue gas stream.

4) Adsorption

This method uses adsorbents like silica gel that have the capability to adsorb heavy hydrocarbons. The system is set up in multiple beds cycling in short operating cycles of adsorption, desorption, of approximately 20 minutes. This method was well used in the 60s and early 70s and was gradually abandoned. Recently, new adsorption materials are making this method economically attractive for certain project applications (See Figure 5)

5) New Technologies

There are new processes technologies that have recently being introduced to the market:

a) Static expansion devices: the Vortex-Tube Device (see Figure 6) and the Supersonic Tube technology (see Figure 7).

b) Membranes: Silicon rubber membranes, for example, have the ability to permeate heavy hydrocarbons rather than light. This makes them a potential candidate for dew point control (see figure 8).

Most of the dew point facilities worldwide use the mechanical refrigeration process, which can be considered as the “workhorse” solution for this purpose. There have been many units built using the turboexpander process, especially in offshore environments, where weight and space limitations benefit this process.

In the following sections of this work we will focus in the turboexpander dew point control process, different process configurations, operational “sweet spot” and other technical features.

High pressure fields- Effects on dew point conditioning

The table below (Table 1) shows a variety of compositions of different gas sources that are available at high pressure. Figure 9 shows the different pressure-temperature phase envelope curves.

Table I

<u>Composition, mol %</u>	NorthSea	SE Asia	S.Am. 1	S.Am. 2	India
Nitrogen	0.35	0.08	0.045	2.07	0.42
Carbon Dioxide	0.26	0.71	0.537	0.05	0.71
Methane	92.3	86.84	93.79	86.5	93.42
Ethane	3.4	6.92	0.891	6.26	2.88
Propane	1.28	3.87	1.292	2.67	0.73
i-Butane	0.24	0.4	0.298	0.39	0.25
n-Butane	0.34	0.67	0.675	0.84	0.25
i-Pentane	0.14	0.14	0.788	0.3	0.15
n-Pentane	0.15	0.11	0.905	0.31	0.10
n-Hexane	0.21	0.26	0.559	0.42	0.19
Heptanes+	1.33	0.00	0.220	0.19	0.90
Pressure, bar	90	138	5.2	83	144
Temperature, ° C	20	24	41	32	50
Sales Gas Pressure (bar)	215	90	72	75	90
HC Dew Point _{req'd} Cricon. (° C @ bar)	-10 @50	0 @ 80	-2 Cricon.	7 @44	0

As can be observed, the SE Asia , and the India gases have operating conditions above the phase envelope in the “dense phase” region, and the remaining gases have operating conditions above the pseudo-critical points. Expert judgment is required when designing above these conditions. This could make the dew point control operation difficult with mechanical refrigeration because of poor separation and difficult condensation due to non-favorable equilibrium conditions.

One issue that has a negative impact when using mechanical refrigeration at high pressures is the co-absorption of light end products (methane, ethane) when chilling the gas. Using a turboexpander, the reduction in pressure of the gas and consequent production of refrigeration reduces the impact of the co-absorption of light ends because of the equilibrium at lower pressures. This has as a direct consequence an increase in the energy used in stabilization of liquids, as well as in the recompression of the stabilizer overhead gases.

For example, for the South American gas 1 and the conditions of dew point required, the mechanical refrigeration process will produce liquids that will generate 31% more gases, and 27% less volume of liquids produced in the stabilization unit, compared with the turboexpander.

There is an incentive, not only operational but economical also, to evaluate the dew point control with use of turboexpansion as an alternative process.

Recently, Randall Gas Technologies completed the design of a turboexpander dew point control unit for an associated gas project for a major operating company in South America. The turboexpander process was selected because of the remote and difficult to access plant site, process simplicity and ease of operation, logistics of supply of propane refrigerant, and energy efficiency.

Dew point control using turboexpanders - Process Description

What follows is a description of the basic turboexpander dew point control unit (see figure 10) (*note: inlet dehydration and stabilization sections not shown, for simplification*) according to recent designs in projects worldwide.

The process is as follows: the inlet gas, after having been received, separated, filtrated (optionally dehydrated) is sent to a **gas/gas exchanger** to recover refrigeration from the process. To prevent formation of hydrates in the exchanger, a solution of MEG (mono-ethylene-glycol) in water is injected on to exchanger tube sheet via a spray nozzle assembly, as in the standard refrigeration units. Provision is also made to inject methanol in the case of freezing. The pre-chilled gas is then sent to a **turboexpander suction scrubber** where condensed hydrocarbon and aqueous glycol are separated from the gas in the scrubber and are sent to the stabilization unit. The gas stream continues to the **turboexpander** where the gas is expanded to a lower pressure to achieve the dew point requirements. In the expansion process that follows an isentropic pattern, the temperature is lowered by the effect of the pressure descent, while there is a simultaneous extraction of work from the process. This work is then reused to drive a booster compressor to partially recover the gas pressure. To prevent hydrate formation during the expansion, a solution of MEG in water is sprayed into the turboexpander inlet, and/or turboexpander body. It is important to note here that there are practically no chances of solid formation in the body of the expander (wheel). In fact, the rate at which the expansion occurs is so fast, that there is not enough residence time for the crystals and hydrates to form. However, those conditions need to be verified downstream of the turboexpander.

The turboexpander discharge is directed to the **low temperature separator** where the gas and liquids formed during the expansion are separated in gas and hydrocarbon and glycol/water liquid streams. The gas stream is directed to the gas/gas exchanger to chill the inlet gas, while the liquids are sent to stabilization for safe storage and transportation, and regeneration of MEG respectively. After leaving the gas/gas exchanger, the residue gas is directed to the **turboexpander/booster compressor** where the gas is compressed. This gas is then ready to be sent to pipeline or to a final sales compression train for delivery to pipeline.

As described, when compared with a traditional mechanical refrigeration unit, this process offers fewer pieces of equipment. It can be seen from this description that the elimination of the refrigeration system, associated condenser, and refrigeration storage and surge tank,

contribute to the simplification of this process, providing an advantage for projects that, like those mentioned, will benefit from operational simplicity and ease of access to remote locations.

Design considerations

We will focus in the turboexpander section.

When designing a turboexpander dew point control unit, the most important step is the analysis of the gas phase envelope and the determination of the expander operating point.

This is of extreme importance especially in cases where the inlet pressure to the expander is not at high pressure or requires compression prior to expansion as occurs with associated gas scenarios.

There are two type of designs (see Figure 11):

- a) Design to a dew point temperature at certain pressure, or
- b) Design to a cricondenthem temperature.

In searching for the operating conditions, the designer needs to conduct trial runs using the target temperature and pressure, separately, to determine phase envelopes at those conditions and most important, the phase envelope of the resulting sales gas phase. For the cricondenthem design case, the recommendations are similar, although the design starts by setting the exhaust turboexpander temperature close to the cricondenthem and verifying the phase envelope of the resulting gas phase to ensure that the dew point is achieved at all pressures. The maximum discharge pressure of the turboexpander should be within a margin not exceeding 10-15% of the cricondenbar pressure. The final design dew point temperature should have a 2.5° to 5° C design margin to allow for condensate entrainment.

The fluid properties at the expander exhaust need to be verified to ensure that a good separation is possible. At high operating pressures and low temperatures, approach to critical conditions, densities and transport properties should be verified. If separation conditions are difficult, there is the risk of re-entraining the formed liquid during the expansion, and being out of specification on the required dew point. In general the ratio of the vapor density to the liquid density should not exceed 0.3.

The hydrate/ice formation conditions need to be analyzed to determine whether inhibition or dehydration steps are required. In general a good design margin of 2.5° to 5° C is suggested to stay away from freezing conditions.

Most facilities installed use a gas/gas exchanger to recover refrigeration justified on the basis of increasing the discharge pressure of the expander, and saving some recompression energy. If used, an approach of 5° to 10° C is suggested. The type of exchanger recommended is the shell and tube type, because it is more tolerant to dirt and the usual scaling, drilling fluids and fouling that are present in this type of plant. Unless the inlet gas cannot be delivered in a well cleaned and filtered condition, the use of other types of exchangers, like plate fins, is not recommended.

The warmer the gas, the more energy is recovered from the expander for the same pressure drop. However, the pressure will have to be lowered to achieve the same dew point as before. The key issue in this situation is to consult with the turboexpander manufacturer to verify that the booster can perform the required head. If the design is acceptable, the cost of the gas/gas exchanger and the suction scrubber can be saved. This design is acceptable for high temperature dew points.

In general, turboexpander dew point units can recover about 70% to 75% of the initial pressure conditions. In rich gas scenarios, the pressure recovery could be even higher. When gas has to be compressed before conditioning, it is worth it to study different pressure levels, including the use of the booster in mode “pre-boost” to save compression cost. Pressure ratios need to be analyzed to determine where the highest impact is.

Should the expander be out of service, the gas from the scrubber can be routed to a “Joule-Thomson” valve to bypass or maintain the suction pressure of the turboexpander, therefore enabling liquids recovery to continue.

The design of the low temperature separator could be vertical or horizontal, depending on the liquid load and the presence of a glycol/water phase, that could require longer time to settle and separate. An internal coil should be considered to maintain liquids at a temperature to prevent hydrates or ice to form. The fluid from the expander exhaust is a fine mist rather than a stratified flow. Proper time to coalesce and settle needs to be allocated in the separator design. The piping between the expander exhaust and the separator should have enough length to allow a well-defined separation of phases to occur. Optionally, the final water/hydrocarbon separation could be done in a secondary separator.

Process Configurations

There are alternative schemes to design a turboexpander dew point control unit:

- a) Gas/gas exchanger recovery scheme, described previously (see Figure 10).
- b) Gas/gas exchanger, gas/liquid exchanger recovery scheme (see Figure 12).

In this scheme, an additional exchanger is added to configuration a), to recover refrigeration from the liquids of the turboexpander suction scrubber and the low temperature separator, prior to being sent to the stabilizer column.

- c) Minimum configuration, no heat recovery (see Figure 13).

In this scheme, the gas coming from the inlet gas facilities is adequately filtered and sent to the turboexpander. The exhaust of the turboexpander is then sent to the low temperature separator. From the low temperature separator the gas is sent to the booster compressor. The gas from the booster compressor is then sent to pipeline or to final sales gas compression.

Safety Aspects

From the safety in design point of view when compared with the mechanical refrigeration technology, the turboexpander is an inherently safer technology, since no refrigerant is used and surge and storage tanks are not required for propane therefore eliminating

hydrocarbon inventories and the risk associated with it. All the risks associated with refrigeration systems, like jet fire, pool fire, cloud fire, explosions and the like are eliminated.

Associated with the refrigeration system is also the management of inventory relief in the case of fire, or lack of refrigerant condensation, that usually becomes the limiting factor when designing flare and relief systems. This scenario is not required with turboexpander technology.

Comparison between refrigeration and turboexpander Unit

To demonstrate the benefits of the turboexpander dew point technology a case study is presented using the gas "S. American 1". This gas has a flow of 3.35 MMNcmd of gas associated to oil production. The dew point requirement is -2°C , cricondenthem, that is, at all pressures. The pipeline sales gas operating pressure is 72 barg. We will compare the mechanical refrigeration with the turboexpander dew point process.

Mechanical refrigeration

Looking at the phase envelope curve (see Figure 14), we read a pseudo-critical pressure at 48 bar. The inlet gas is at 5.2 barg, and needs to be compressed to a pressure where we could condense liquid without problems. A 55 barg pressure is selected. A typical gas/gas and chiller scheme is used. Examination of the phase envelope, and residue gas, indicates that a process temperature of -6.5°C (refrigeration @ -9.5°C) is adequate to obtain the -2°C of cricondenthem dew point required. After separation in the low temperature separator ($p_v/p_l = 0.07 < 0.3$ is adequate) and recovery of refrigeration in the gas/gas exchanger, the residue gas is compressed to the final operating pressure of 72 barg.

The energy requirements for this process are:

Inlet compression, from 5.2 barg to 55 barg (80% ad. Eff):	21,500 bhp
Propane refrigeration, 1.42 Mmkcal/hr @ -9.5°C , (75% ad. Eff):	845 "
Residue gas compression, 3.23 MMNcmd, from 54 barg to 72 barg:	2,120 "

Total 24,465 bhp

Turboexpander dew point

We design the system such that the booster discharge pressure "floats" on the pipeline pressure. The inlet gas is at 5.2 barg, and needs to be compressed to a pressure where after the drop in the expander it could reconstitute the pressure to pipeline requirement. A 90 barg pressure is selected. After compression, the gas follows scheme 'a' described above. Examination of the phase envelope and residue gas indicates that an expander discharge pressure of 62 barg is enough to generate a process temperature of -9.5°C adequate to obtain the -2°C of dew point required. After separation in the low temperature separator ($p_v/p_l = 0.09 < 0.3$ is adequate) and recovery of refrigeration in the gas/gas exchanger, the residue gas is compressed to the final operating pressure of 72 barg by the booster compressor.

The energy requirements for this process are:

Inlet compression, from 5.2 barg to 90 barg (80% ad. Eff): 25,120 bhp

Total 25,120 bhp

A capital cost estimate with focus in the “delta” equipment is shown below for the two units:

Mechanical Refrigeration:

Inlet Compression	\$ 9,700,000
Refrigeration Compr.	\$ 850,000
Residue Gas Compr.	\$ 1,900,000
Gas Chiller	\$ 250,000
Cold Separator	\$ 250,000
Propane Cond.	\$ 185,000
Propane Surge	\$ 85,000
Propane Storage	\$ 150,000
Total	\$ 13,370,000

Turboexpander Unit

Inlet Compression	\$ 11,300,000
Expander	\$ 1,000,000
Exp. Inlet Sep	\$ 75,000
Total	\$ 12,375,000

Delta Capital Cost	\$ 995,000
Installation factor	x 3
Total Installed Cost	\$ 2,985,000

At a value of 4 \$/Mmbtu the difference of 655 bhp, in favor of the mechanical refrigeration represents a yearly expense of \$ 202,000.

As it can be seen the savings in operating costs, will not offset the additional capital expenses of the residue gas compressor and the propane refrigeration system. The additional benefits in space requirements, unit safety (no propane inventory), less flare system requirements (refrigeration systems normally design the flare loads), make evident by inspection that the turboexpander dew point unit represents the most attractive option.

Gas available at sales pipeline pressure

Let’s consider now a case in which the gas to be conditioned is available at 72 barg. When using mechanical refrigeration, the gas needs to be chilled to -15°C in order to be able to achieve a cricondenbar of -2°C . Two expander cases could be evaluated: one with residue gas compression, and a second with inlet gas compression, and the booster discharging at pipeline pressure. The results are presented below:

Mechanical refrigeration (2.28 Mmkcal @ -18° C),	1,635 bhp
Turboexpander (residue gas compressor, 59 barg to 72 barg),	1,480 bhp
Turboexpander (inlet gas compressor, 72 barg to 90 barg),	1,290 bhp

In this case, the turboexpander process has lower operating cost than the mechanical refrigeration. The capital costs will again make favorable the selection of the turboexpander process.

Summary and Conclusions

We have discussed the use of the turboexpander dew point as a viable and economically advantageous technology for gas conditioning. It is the option of choice for high pressure fields, benefiting with the production of refrigeration and compression work.

Its use in the offshore environments has helped to prove that is adequately fit for the purpose of gas conditioning. Although the cases analyzed were favorable to its use, sound economical analysis is recommended on a case-by-case basis to prove its adequacy to specific scenarios.

The turboexpander is a mature technology that is based on sound and robust experience, and it brings operational reliability and a safe operation -all factors that enhance the lifecycle operational results.

References:

1. GPSA- Engineering Data Handbook
2. Gas Conditioning - Campbell

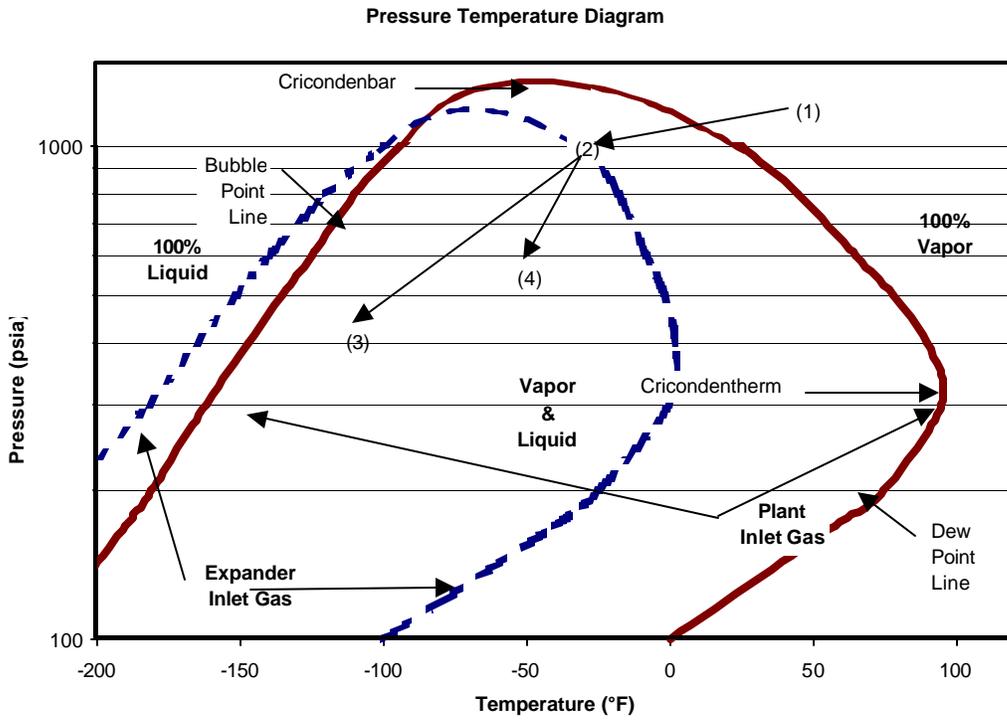


Figure 1
Phase Envelope

Figure 2
LTS Scheme

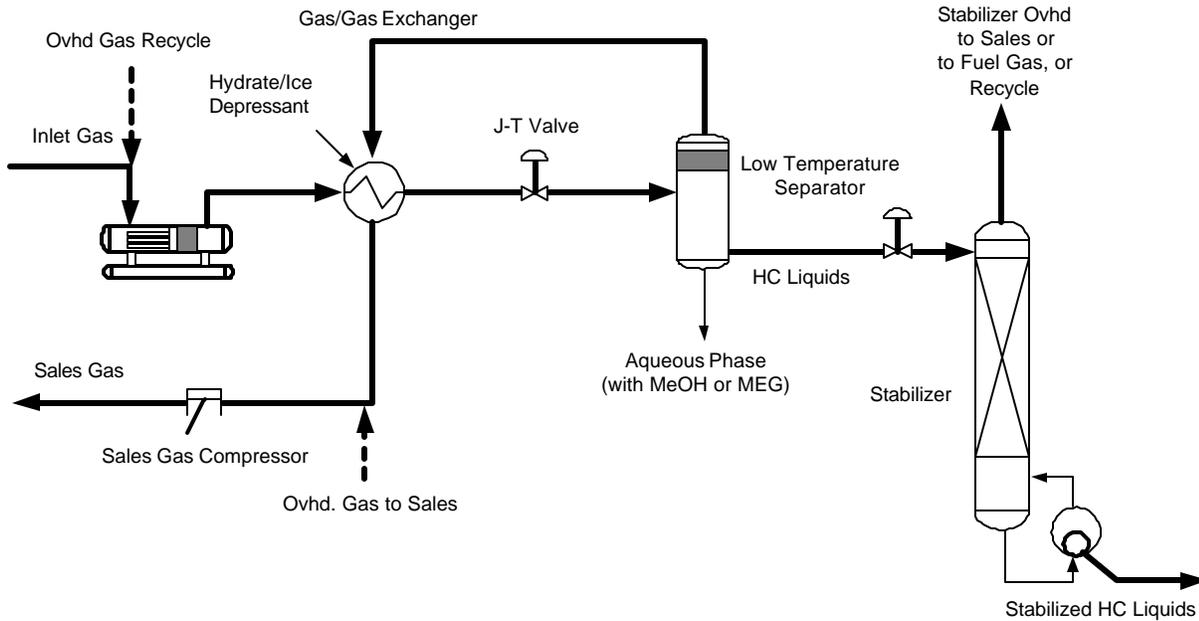


Figure 3
TEX Scheme

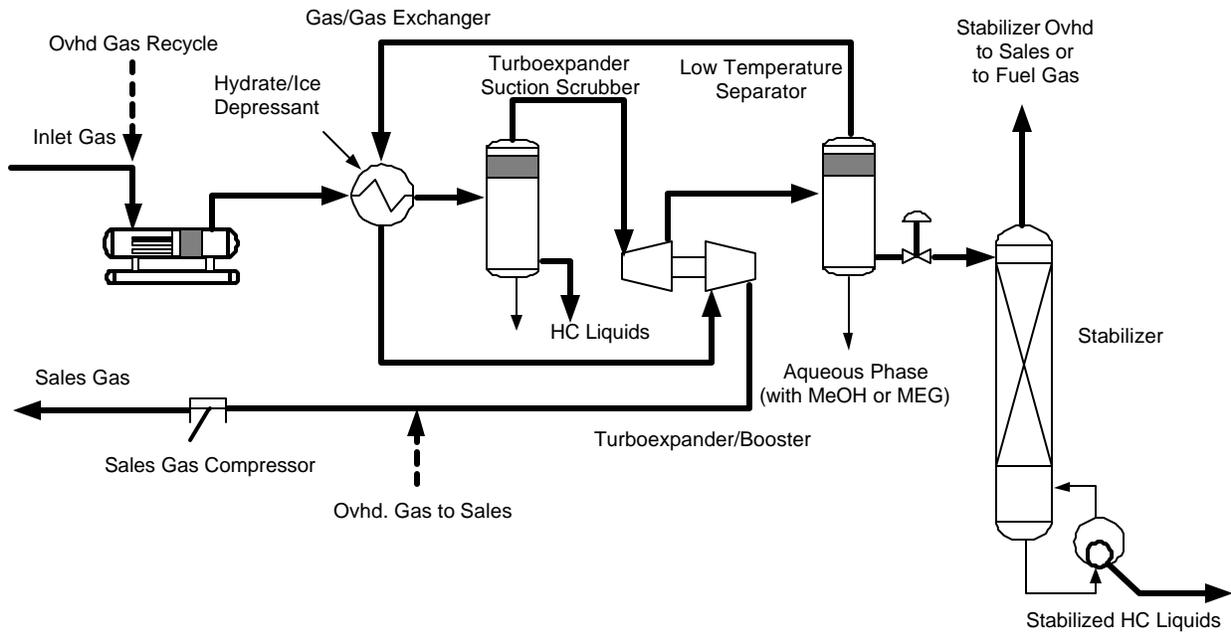
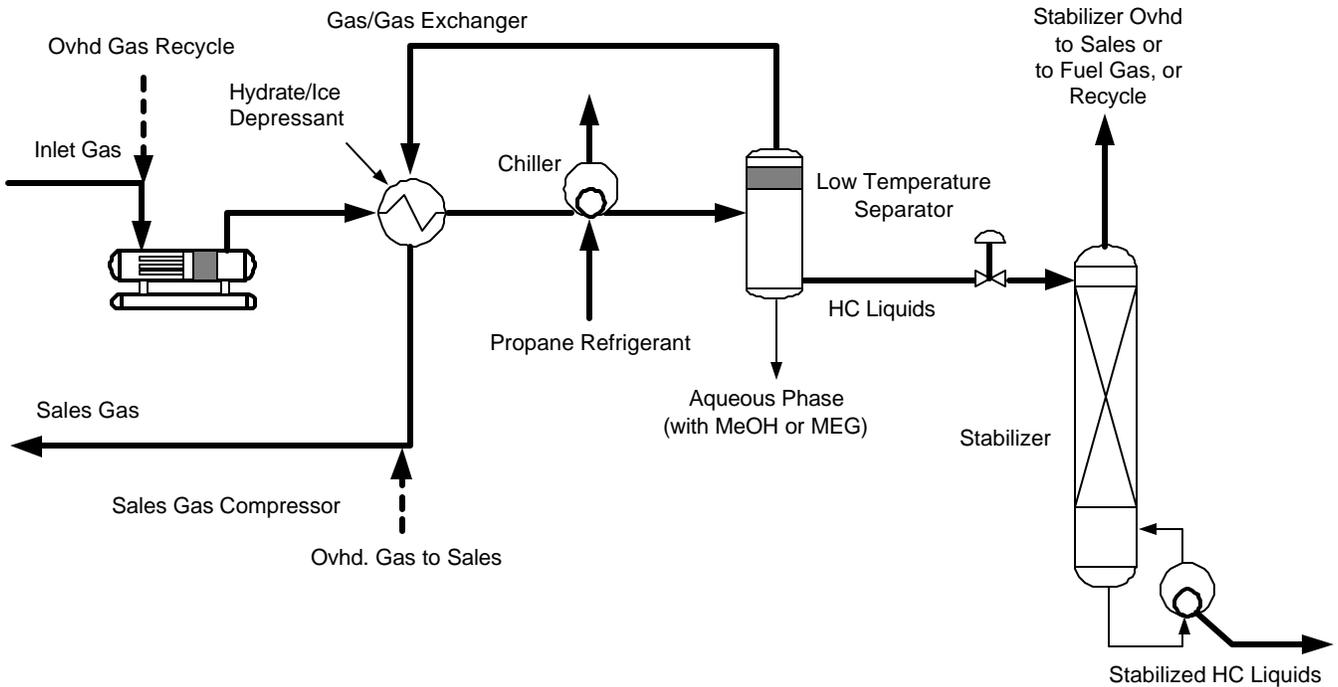


Figure 4
Mechanical Refrigeration



Adsorption Scheme

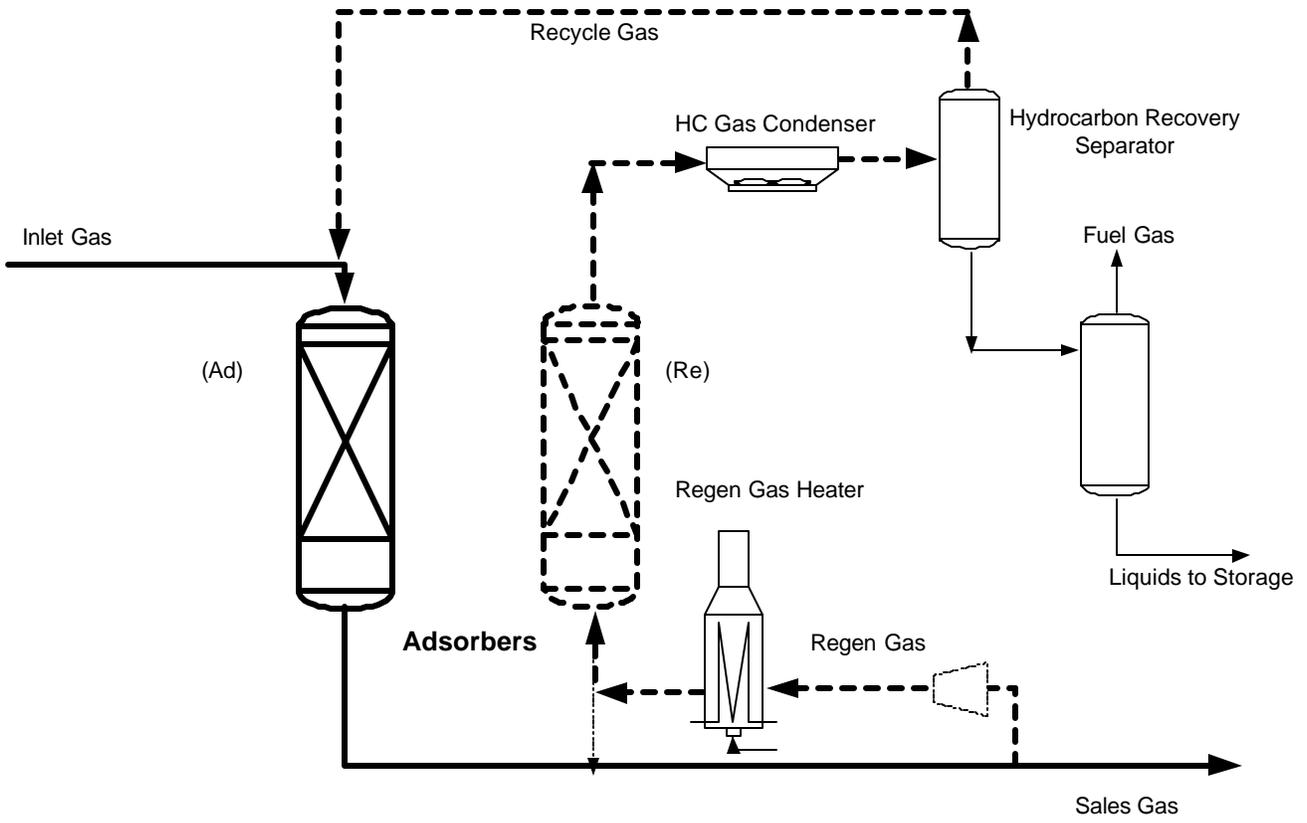


Figure 6

Vortex Tube Scheme

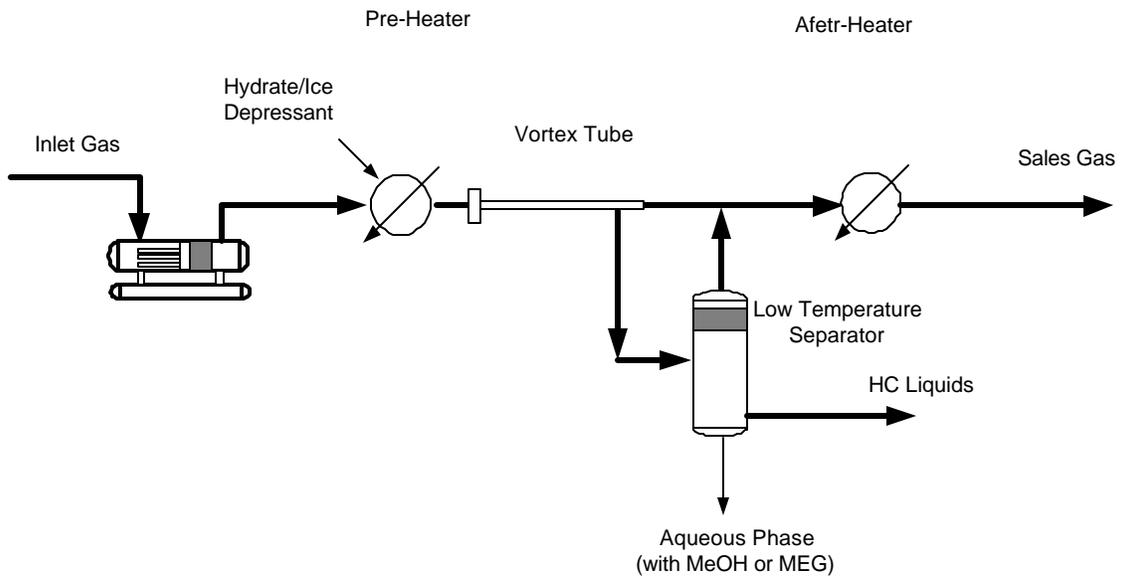


Figure 7
Supersonic Tube

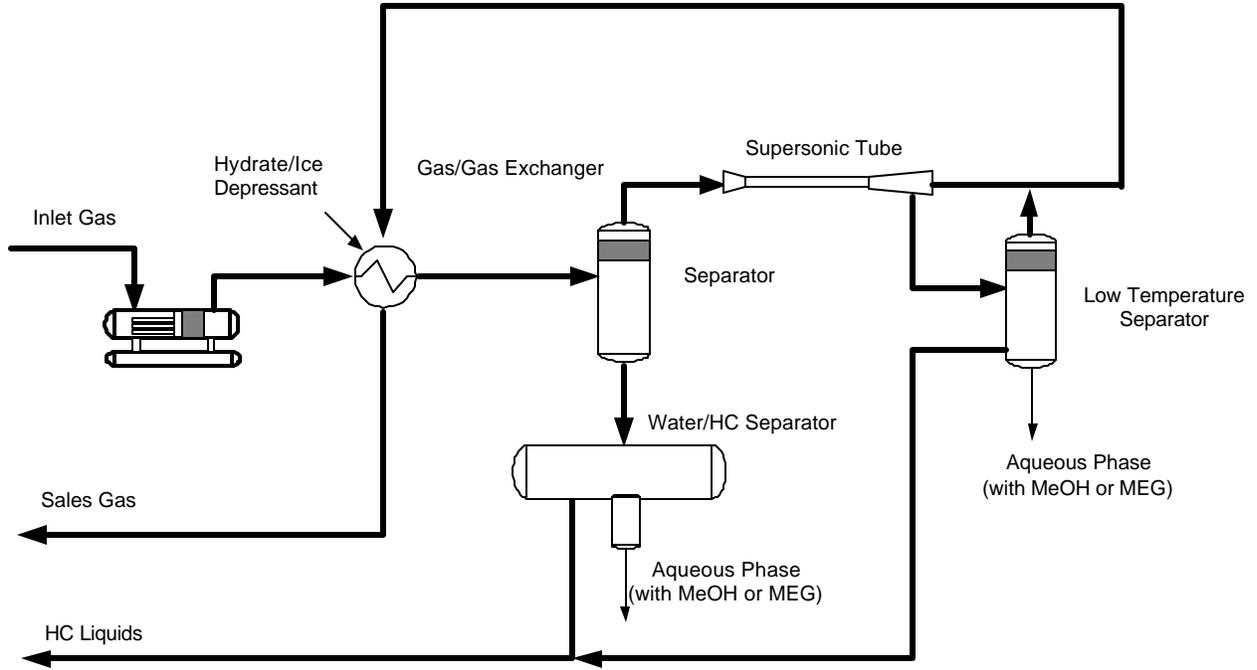
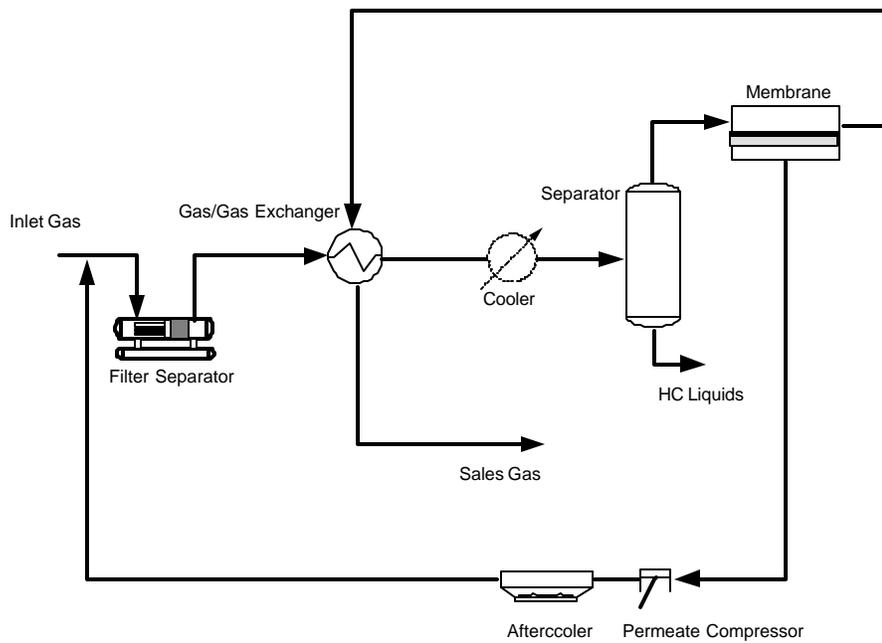
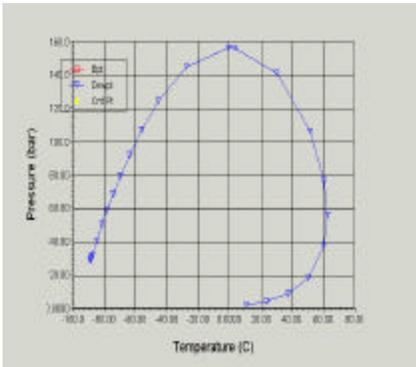
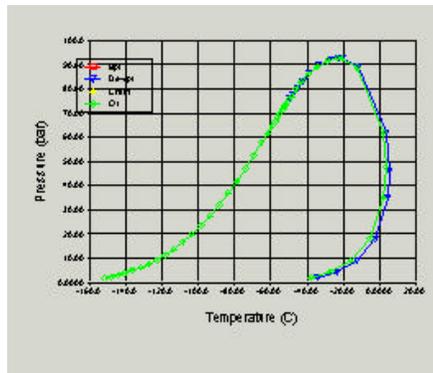


Figure 8
Membrane Dew Point

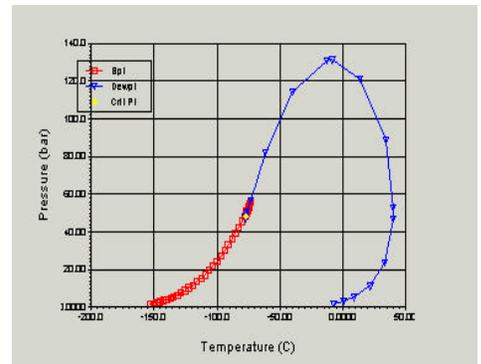




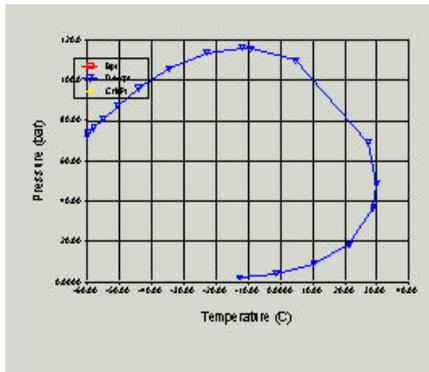
North Sea



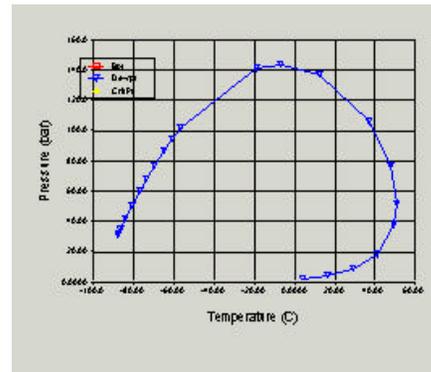
South East Asia



South America



South America



India/Pakistan

Figure 8
Phase Envelopes

Figure 10

TEX Scheme (a)

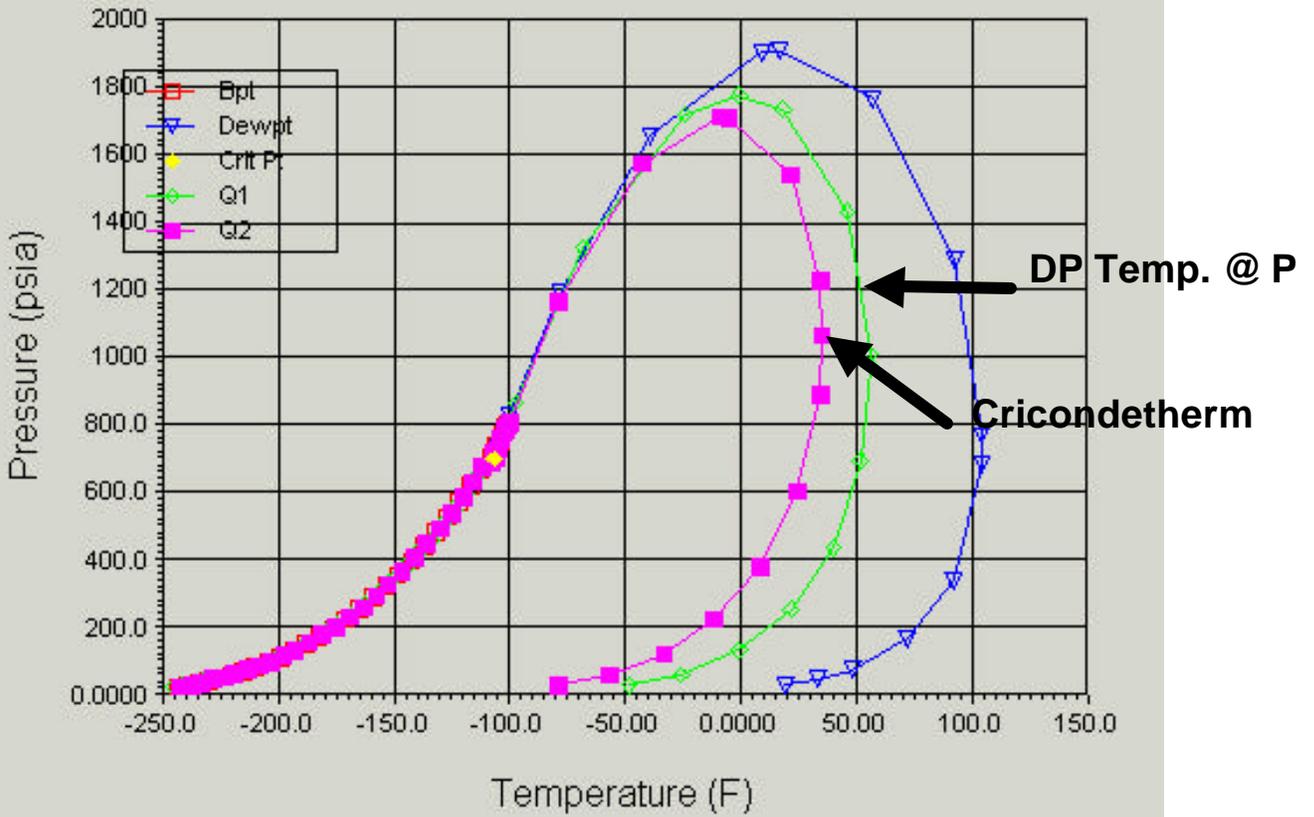
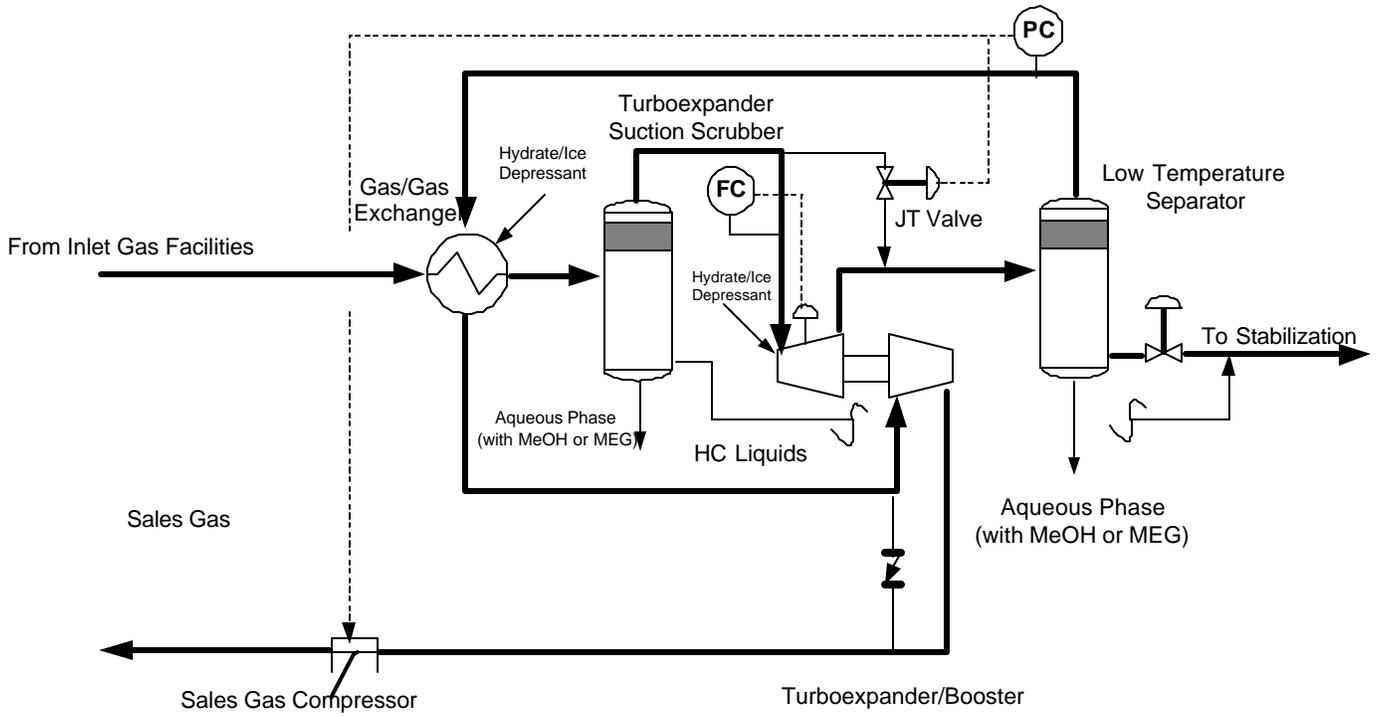


Figure 11

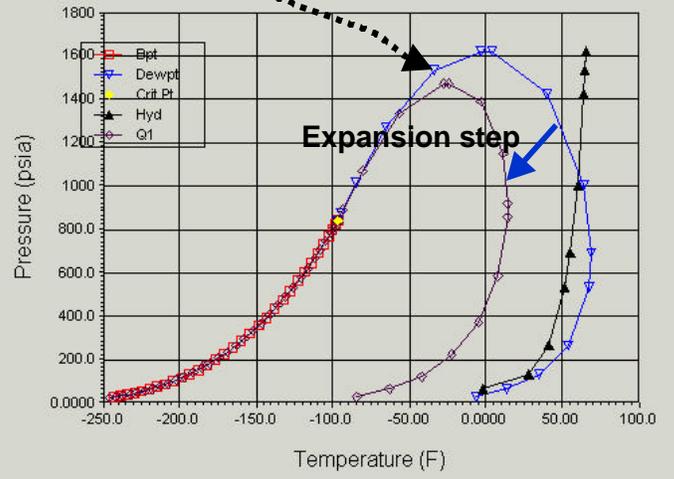
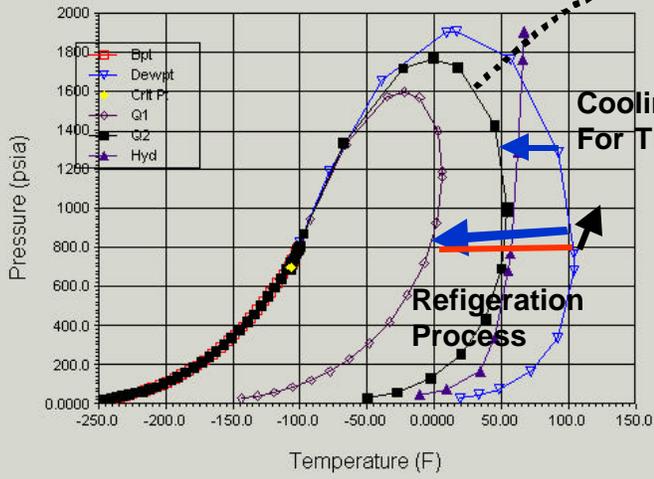


Figure 14