Natural Gas Liquids Recovery

CRYO-PLUS™ Technology

NATURAL GAS EXPERIENCE

Linde Process Plants, Inc. (LPP) has constructed NGL Plants since 1969 using traditional processes as well as the more advanced CRYO-PLUS™ technology.

CRYO-PLUS™ Proprietary Technology

Higher Recovery with Less Energy

Designed to be used in natural gas, or shale gas applications, the patented CRYO-PLUS™ process recovers more ethane and heavier components with less energy required than traditional liquid recovery processes.

Higher Flexibility

Enhanced CRYO-PLUS™ is more robust and flexible over a wide range of pressure and feed compositions. This feature is especially important for treatment of wet shale gas, which is known for having large compositional variability over time.

CRYO-PLUS™ provides a high level of ethane recovery in ethane recovery mode, and a high level propane recovery in ethane rejection mode. The process can quickly and easily change between the two modes of operation.

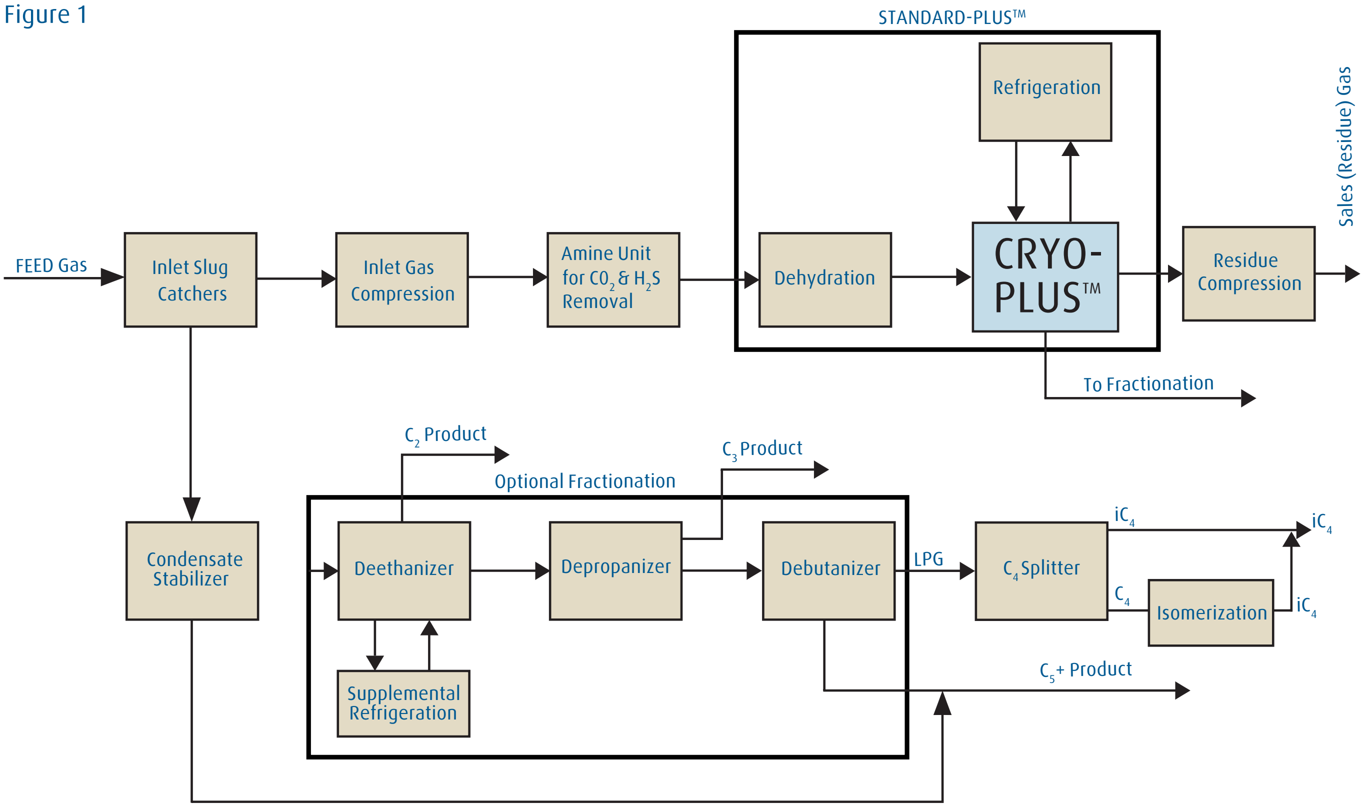
Reduced Feed and Product Compression

The proprietary process has been optimized to operate more efficiently resulting in lower inlet pressure requirements while still providing the same product discharge pressure.

Reduced Fuel Consumption

The CRYO-PLUS™ process requires less power than a typical gas processing plant.

Figure 1



CRYO-PLUS™ in Natural Gas Processing

CRYO-PLUS™

CRYO-PLUS™ improves recovery of C_2+ components, thus allowing gas processors to meet the heating value requirements for the gas while adding profits to the bottom line. The ethane and heavier hydrocarbons recovered become valuable feeds for crackers producing olefins and subsequentially for polyethylene and polypropylene plants.

CRYO-PLUS™

To date, LPP has installed several CRYO-PLUS™ Recovery Systems in Natural Gas Processing Plants. The economic payout of these systems can be as low as one year. All of these systems were designed for recovery or rejection of ethane depending on the required mode of operation

Where is CRYO-PLUS™ Used

CRYO-PLUS™ is used for processing any type of gas containing hydrocarbon liquids. Traditionally, the gas processing industry have been using Dew Point Control or other technology plants to purify the natural gas to meet pipeline requirements, i.e. prevent liquids formation in pipeline and meet a maximum BTU content. Unfortunately, these systems recover less than 80% of the C_2 and some of the C_3+ can slip through into the gas. These C_2+ liquids may provide for a higher sales value than the pipeline gas by itself. Figure 1 shows a block flow diagram for a typical natural gas processing scheme, and indicates where CRYO-PLUS™ is integrated within the operation.

CRYO-PLUS™ Benefits

The optimum C_2 and C_3 recoveries are a function of the relative values of the recovered components, the fuel gas, utilities, fit to available compression, and the required economic payout. CRYO-PLUS™ recovery for C_2 is typically 96%, with essentially 100% recovery of C_3 and heavier components when operated in ethane recovery mode. Corresponding recoveries for ethane rejection mode is 98% or greater for C_3, and 100% of the heavier components. Typical CRYO-PLUS™ feed and product compositions are indicated in Table 1A and Table 1B for the two modes of operation. The material balances are for a nominal 200 MMSCFD feed gas from a shale gas well. For example, assuming a natural gas fuel value of $3.75/MMBTU, this gas as fuel has a value of approximately $1,013,325/Day.

When operating in ethane rejection mode as shown in Table 1A, the CRYO-PLUS™ technology recovers approximately 25,520 BBL/Day of mixed C_2+ liquids. If the average value of the C_2+ liquids is $0.57/gallon, then the combined value of the C_2+ liquids plus the residue gas as fuel is $1,276,317/Day. This differential results in a gross margin between the two operations of over $92,000,000 per year. These simplified calculations assume that the plant can sell the higher BTU natural gas stream without any treatment. This is normally not possible due to pipeline requirements, but it may be possible to do minimum treatment and disposing the liquids. When disposing the liquids or flaring this high BTU gas, these already impressive economics improve dramatically. (Substitute your own product values and see your impact.) The recovered liquid stream's composition is a reflection of the fuel gas streams that comprise the CRYO-PLUS™ feeds. Alternatively, the C_2, C_3 and C_4's can be split by fractionation and each can be fed to a separate process for further upgrading or simply sold as chemical feedstock.

The same economic calculations can be done for operation in ethane recovery mode as is shown in Table 1B. In this case, the CRYO-PLUS™ technology recovers approximately 35,630 BBL/Day of mixed C_2+ liquids. Due to a higher ethane content, the average value of this mix may be lower so if $0.44/gallon is used instead, then the combined value of the C_2+ liquids plus the residue gas as fuel is $1,210,029/Day. The differential this time results in a gross margin between the two operations of over $68,800,000 per year, which is still an attractive return.

A subtle, but very real additional benefit of CRYO-PLUS™ derives from the change in the fuel gas composition after removing the C_3 and C_4 components. The higher heating value of the C_3 and C_4's results in a higher flame temperature within the furnace or boiler; this may result in higher NO_x emissions. Removal of C_3 and C_4 components from the fuel gas therefore achieves a measurable reduction in NO_x emissions. This incremental reduction may be enough to keep the end-user of the gas in compliance and avoid expensive NO_x reduction modifications for the combustion processes.

Table 1-A Typical Propane Recovery (ethane rejection mode)

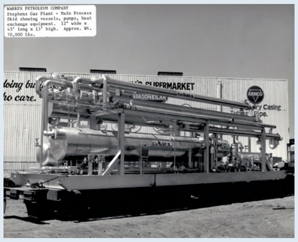
Component	Feed Mol/Hr	Residue Gas Mol/Hr	Liquid Product Mol/Hr	Recovery %
N_2	267	267		
CO_2	11	10	1	
C_1	15,562	15,530	31	
C_2	3,479	2,057	1,421	41*
C_3	1,492	28	1,465	98
iC_4	228		228	100
NC_4	412		412	100
iC_5	112		112	100
NC_5	103		103	100
C_5+	150		150	100
H_2O				
Totals				
Mol/Hr	21,816	17,892	3,923	
Lb/Hr	493,662	320,173	173,488	
MMSCFD	200	163	36	
BBL/day			25,520	
MMBTU/hr	11,259	7,396	3,835	
Avg. MolWt	22.63	17.89	44.22	
BTU/SCF	1,351	1,089	2,576	

*Ethane recovery is governed by the residue gas heating value

Table 1-B Typical Ethane Plus Recovery

Component	Feed Mol/Hr	Residue Gas Mol/Hr	Liquid Product Mol/Hr	Recovery %
N_2	267	267		
CO_2	11	5	6	
C_1	15,562	15,515	47	
C_2	3,479	129	3,349	96
C_3	1,492		1,492	100
iC_4	228		228	100
NC_4	412		412	100
iC_5	112		112	100
NC_5	103		103	100
C_5+	150		150	100
H_2O				
Totals				
Mol/Hr	21,816	15,916	5,899	
Lb/Hr	493,662	260,510	233,155	
MMSCFD	200	145	54	
BBL/day			35,630	
MMBTU/hr	11,259	6,060	5,168	
Avg. MolWt	22.63	16.37	39.52	
BTU/SCF	1,351	1,003	2,309	

Plant modules are workshop prefabricated to maximum extent



20 MMSCFD Cryogenic Natural Gas Plant

120 MMSCFD Cryogenic Natural Gas Plant

120 & 200 MMSCFD Cryogenic Natural Gas Plant

350 MMSCFD Cryogenic Natural Gas Plant

450 MMSCFD Cryogenic Natural Gas Plant

100 MMSCFD CRYO-PLUS™ Natural Gas Plant

Plant is essentially fully modular

1974 | 1988 | 2000 | 2009 | 2012

How CRYO PLUS™ Processes Work

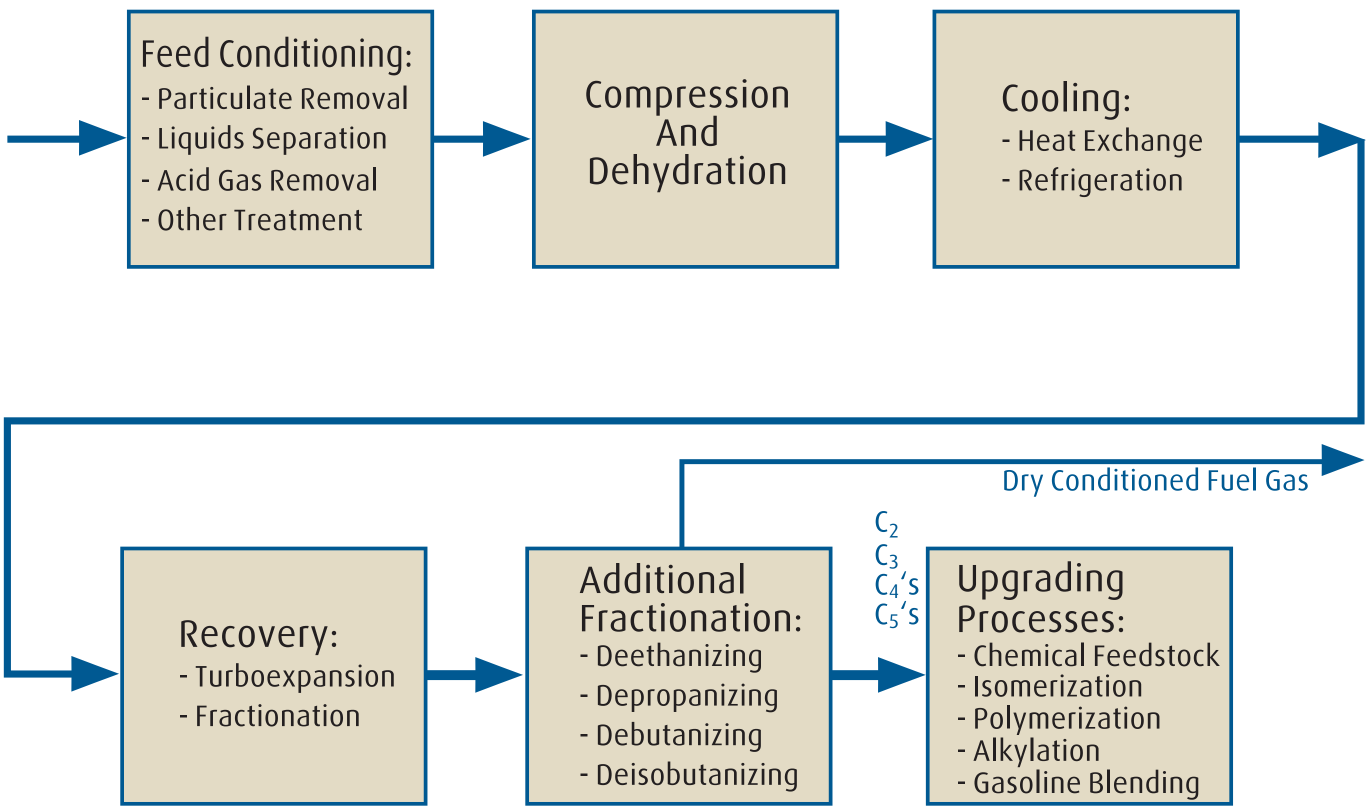
CRYO-PLUS™ is a cryogenic recovery technology which utilizes a turbo-expander to recover energy while cooling the feed gas. CRYO-PLUS™ technology is unique in its ability to process low-pressure gas streams and obtain high recoveries with less compressor and/or refrigeration horsepower than conventional or competing cryogenic processes. A description of the unit operations follows. Figure 2 is a block flow of CRYO-PLUS™ processing.

Feed Conditioning

To protect the unit against upset conditions, feeds may first pass through a coalescing filter/separator designed to remove solid particles and liquid droplets that may carry over from upstream processes.

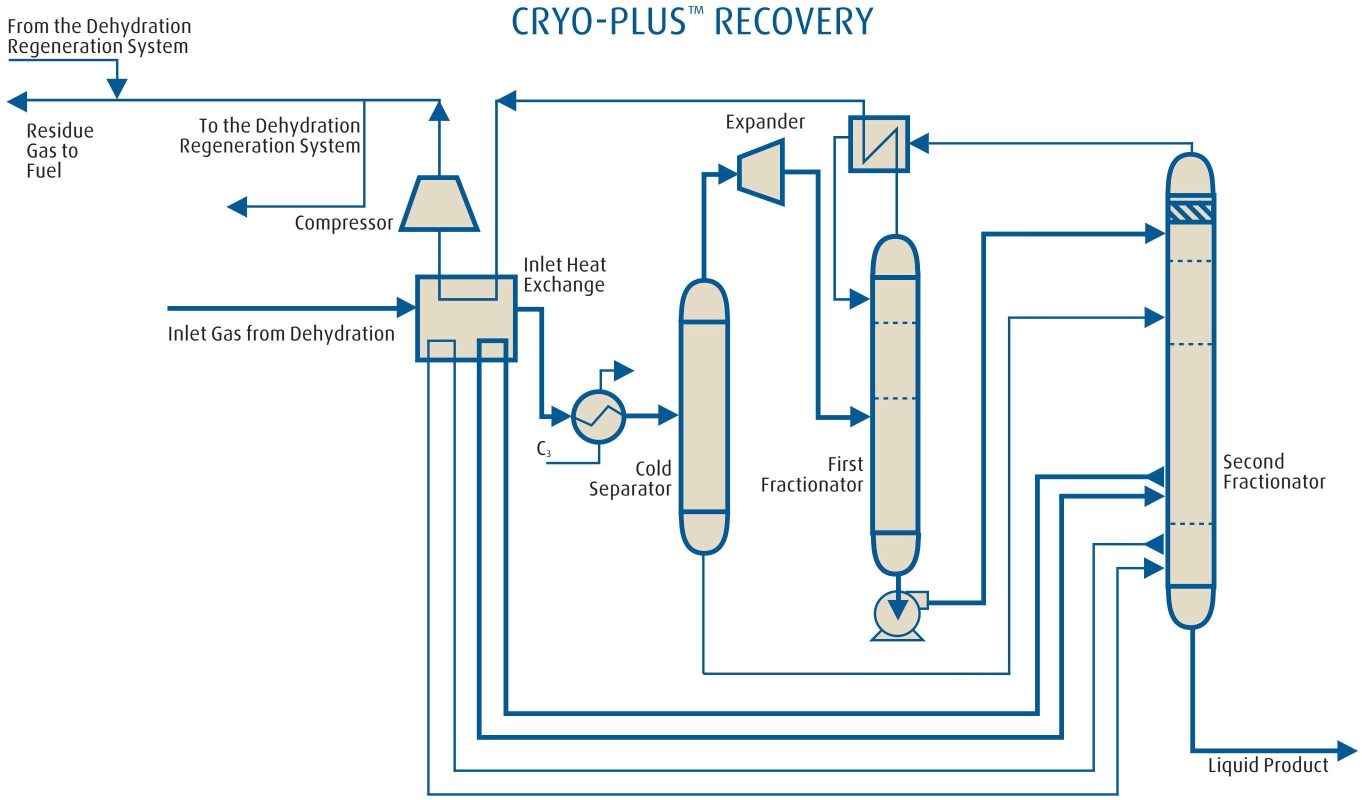
Although CRYO-PLUS™ can tolerate small quantities of H_2S and CO_2 these compounds are not desirable. The use of an amine treating unit for removal of acid gas components removes these compounds in an absorption process as a feed conditioning step

Figure 2



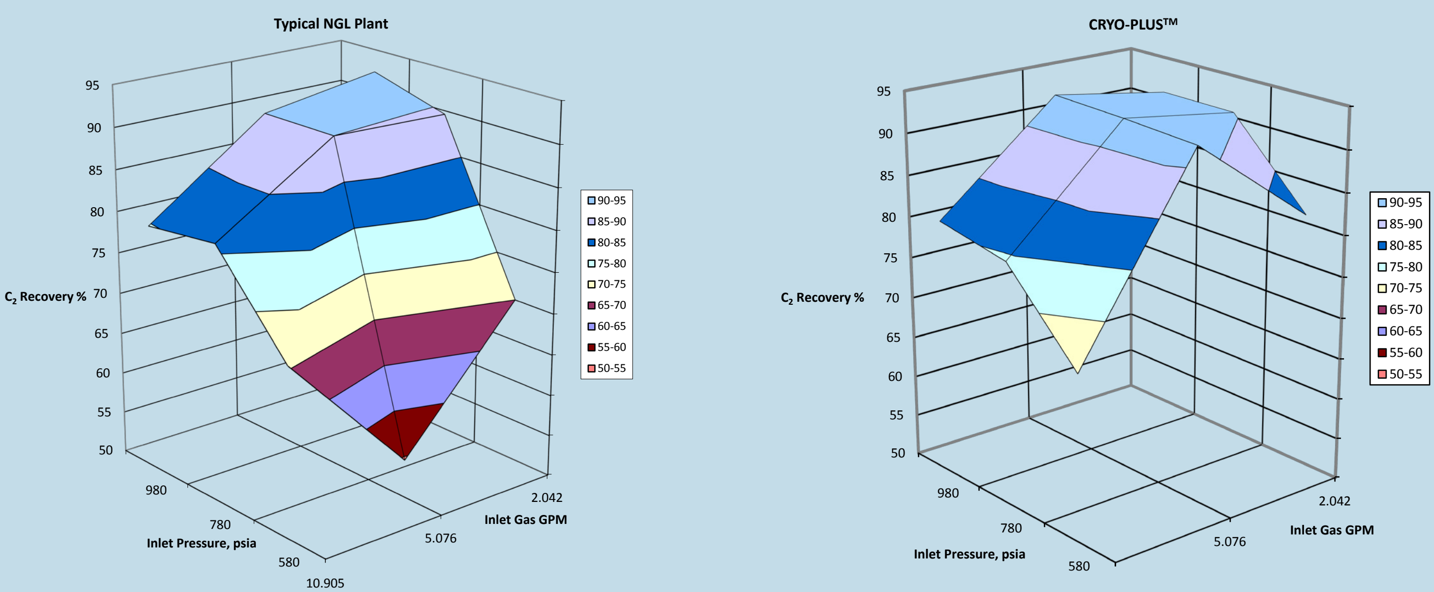
Block Flow Diagram of CRYO-PLUS™ Processing

Figure 3



Schematic of the CRYO-PLUS™ Recovery Process

C_2 Recovery Comparison



- Enhanced CRYO-PLUS™ provides a higher recovery over a wider range of pressure and composition.
- Enhanced CRYO-PLUS™ provides 95% C_2 recovery for 4.0 to 7.7 GPM natural gas.

Feed Compression

The next step is to compress the feed stream unless it is already at elevated pressures. An air cooler or cooling water, cools the gas downstream of the compressor to remove the heat of compression. (Heat of compression can also be used as a heat source for fractionation as permitted by the process heat balance and temperature driving force.)

Dehydration

To avoid ice and hydrate formation in the cryogenic section of the process, the water content of the gas is reduced to an acceptable level through adsorption in molecular sieve desiccant beds. This is a batch process, where multiple (two or more) adsorption beds are used. One or more of the adsorption beds are being regenerated to restore their capacity while the other bed(s) are on-line and drying the feed gas. A recycle portion of the dry gas can be heated and used for regeneration of the beds to drive off the adsorbed water. Cooling of this stream condenses the removed water, before it recycles and combines with the feed gas. A portion of the residue gas may also be used for the regeneration on a once through basis. Downstream of the adsorption beds, the gas passes through a dust filter to remove any particulate carryover before subsequent processing.

Feed Cooling

After dehydration, the feed gas flows into the cold section of the process, where cooling by exchange of heat with the residue gas and cold separator liquids takes place using a brazed aluminum plate-fin heat exchanger. Although not always a requirement, the gas may be further cooled using external refrigeration before it goes to the cryogenic portion of the process.

Cold Separation

Following cooling, the feed gas is partially condensed and delivered to a vapor/liquid separator. The liquid then flows through the inlet exchanger to cool the feed gas before entering the deethanizer for fractionation. The vapor flows to the inlet of the expander/compressor. As the gas expands, it provides the work/energy for the compression. The expansion and removal of energy cools the gas further and causes additional condensation. The expander discharges into the first tower of a two-stage fractionation process. The configuration and the combination of fractionation and heat transfer between these two columns is the proprietary, patented technology that gives CRYO-PLUS™ its advantages (higher recovery at reduced horsepower) over competing technologies.

A residue gas and a deethanized liquid product are produced from this two tower scheme. The residue gas is at or near the fuel system pressure. Following exchange with the feed gas in the inlet cooling step, it arrives at the fuel system as a dry, stable heating value fuel. The liquid product from the fractionation system is the recovered C_2 or C_3 liquid hydrocarbons. The liquid often undergoes additional processing, such as additional fractionation in downstream columns. For C_3 recovery, the liquid stream is normally debutanized. The C_3 and C_4's may then be fed to an alkylation process, or split with the C_3 going to isomerization/polymerization and only the C_4's going to isomerization/alkylation feed. For C_3 recovery, a depropanizer normally precedes the debutanizer.

Customized Design

LPP specifically designs and fabricates unique modules to optimize the site layout and fit the available space. A growing number of gas processing companies have come to recognize the benefits of modular fabrication over traditional field fabricated process systems. Besides the traditional focus on lower initial cost, modular fabrication results in many other operational and maintenance advantages. Modular fabrication results in streamlined project execution, a predictable schedule, low cost, and minimizes the risk of construction within an operating plant.

Modular Construction

The gas processing industry recognizes the challenges of conventional on-site construction. Modularization will minimize the on-site construction time and thereby reduce cost and schedule of the overall project.

Shorter Project Schedule

With field fabrication, workers are at the mercy of the environment. Schedule and quality often suffers under adverse weather conditions. LPP's skilled and stable work force performs their work in the controlled environment of one of the finest fabrication facilities in the US, maintaining schedule regardless of weather conditions with ISO-9001 quality.

Safer to Construct Away from Hazardous Processes

On-site construction alongside operational equipment carrying high-pressure hydrocarbons increases on-site construction risk. LPP performs fabrication in the safety of a controlled environment without the risk of plant upsets or construction worker's errors, and then transports the completed prefabricated and preassembled system to the , where a small crew quickly installs them, thus minimizing risk.

Less Downtime

The cost of downtime associated with construction can add significantly to the overall cost of construction. LPP is minimizing downtime by building units off-site.

About LPP

LPP is a company with over forty years' experience in refining, petrochemicals and natural gas processing. As a subsidiary of The Linde Group, we are a totally integrated technology, engineering, fabrication, and construction company.

Engineering

Engineers are available with all of the disciplines required to provide turnkey plant installations using proprietary technology or the client's design.

Fabrication

LPP is a leader in the field of engineering and fabrication of turnkey process systems. In addition to road and rail transportation, our fabrication facilities have access to the Port of Catoosa on the Arkansas River, which can transport prefabricated modules on ocean-going barges to global markets via the Port of New Orleans.

Technology

Either proprietary LPP or licensed technology is used.

With LPP's Experience and Resources You are Assured Success

Only Linde Process Plants, Inc. has the combination of proprietary technologies, proven experience, specialized skills, impressive record of accomplishment, and certified fabrication facilities to deliver major turnkey process plants to global markets successfully.

Processes Offered by LPP

- CRYO-PLUS™, Recovers C_3+
- CRYO-PLUS C2=™, Recovers C_2+
- Sulfur Recovery
- Natural Gas Processing
- Nitrogen Rejection
- Helium/Hydrogen Liquefiers

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