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“Trinidad LNG – The Second Wave”

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Atlantic LNG Trains 2/3 Project in Trinidad

Introduction

Atlantic LNG Company of Trinidad & Tobago has been successfully operating a single-train LNG plant since the facility was turned over from Bechtel International on June 14th, 1999.(1) The facility has been continuously supplying LNG to buyers Tractebel (previously Cabot LNG Corporation) in the United States and Repsol/Enagas in Spain and has sold several spot cargoes. The facility continues the use of minimal expatriate staff and maximum national operations and maintenance staff. The train 1 project is considered a breakthrough in the LNG business. At the outset it was necessary to show competitiveness in cost and in reliability as no availability backup data was available from other similar LNG installations.

On August 7, 2002, Atlantic LNG commenced operations of Train 2, the first of a 2-train expansion project begun in 2000. First LNG was produced at 11.30 am on that day and the First Cargo was shipped to Spain via the Methane Polar on August 12. Train 3 is scheduled to come on stream in the second quarter of 2003.

The member shareholders of Atlantic LNG train 1 are as follows:

Amoco Trinidad (LNG) B.V. (34%)
British Gas Trinidad LNG Limited BG (26%)
Tractebel Trinidad LNG Limited (10%)
NGC Trinidad and Tobago LNG Limited (10%)
Repsol LNG Port Spain B.V. (20%)

The paper gives details of the facility expansion with objective reviews of lessons learned, equipment changes, process design changes incorporating changes made in the liquefaction technology and layout changes. The paper describes how lessons learned from the first train have been incorporated in to the second and third trains. The use or application of different pieces of major equipment in critical areas of the plant is also discussed. The paper presents the project schedule and progress to date with major milestones and accomplishments highlighted. Details of construction and commissioning are also included. The paper closes with a brief update on future expansion plans for the Point Fortin Atlantic LNG facility. Train 2 became operational on August 7, 2002 with production of LNG at 11:30am on that day.

Train 2/3

Introduction

Train 2/3 EPC project was awarded to the Bechtel Corporation in August, 2000. The award was for the construction of two further LNG trains at Point Fortin in Trinidad each with a nominal capacity of 3.3 MTPA. Included in the EPC award was also the construction of a third LNG tank with a storage capacity of 160,000m3. Contractual completion dates for train 2 and 3 were December 15, 2002 and September 1, 2003. The largest part of trains 2 and 3 product (62%) has been committed to Spanish markets. The remaining (38%) is to be sold into the United States market. Whereas the gas supply to train 1 was from the bpTT line only, train 2 is supplied from both bpTT and BG with a 50/50 split of the total amount.

The member shareholders of Atlantic LNG train 2/3 are as follows:

Amoco Trinidad LNG LLC (42.5%)
British Gas Global Investments B.V. (32.5%)
Repsol Overzee Financien B.V. (25.0%)

Process Description

As with train 1[(1)], the basis of design for trains 2 and 3 would be the Phillips Optimized Cascade LNG Process. As has been shown in the operation of train one, there are many benefits in using this process. The process design is simple and extremely reliable. The Kenai plant has been successfully operated since 1969 and the Atlantic LNG plant has shown the same reliable performance in it's first three years of operation. The "two-in-one" design for the refrigeration sections adds to the reliability and also the ease of operation with much quicker start ups and re-starts. This is important to any installation but becomes even more important when considering a single train installation, availability figures of 96% and above are considered achievable without difficulty. The design is also more amenable to a cost effective "gas plant" and "fit-for-purpose" approach with no specialized pieces of equipment such as a spiral wound heat exchanger. This leads to a low cost facility from both capex and opex perspectives.

Inlet Area and Gas Treating

The Feed Gas to Trains 2/3 is from two sources. The BP feed gas enters the facility through the existing train 1 slug catcher where the vapor and liquid streams are separated. The liquid stream is stabilized in train 1 and is exported offsite. The vapor stream is metered for allocation purposes prior to entering the train 1 and train 2 gas sweetening systems where the CO_2 is removed. The BG feed gas enters the facility through a new pig receiver and slug catcher before merging with the BP feed gas to comprise the total feed gas for train 2. The feed gas allocation split for train 2 is 50/50 for BP and BG feed supplies. Diglycolamine (DGA) is the selected solvent for the gas sweetening process due to low CO_2/H_2S concentrations in both feed gas streams and no other sulfur components. The acid gases, CO_2/H_2S and any incidentally removed hydrocarbon components, are safely disposed of by incineration. The BG gas supply has methanol injection into the pipeline and to remove any entrained methanol from the feed gas prior to sending it forward to the dehydration section a methanol stripper has been added to the overhead water tray section of the CO2 system regenerator column that effectively removes the entrained methanol from the feed gas going forward. Treated gas from the amine system is fed to molecular sieve dehydrators where the water vapor is removed down to 0.1 ppm. Dry gas from the dehydrators is further processed through activated carbon beds to remove any mercury that may be in the feed gas.

Refrigeration and Liquefaction

The treated gas is fed to the liquefaction unit where it is cooled and sub-cooled prior to entering the LNG tanks. The liquefaction system utilizes the Phillips Optimized Cascade LNG Process, a modification of the original Phillips LNG plant design at Kenai, Alaska. This process uses two pure refrigerants – propane and ethylene circuits and a methane flash circuit cascaded to provide maximum LNG production by utilizing the horsepower available from 6 Frame 5D gas turbines. Each circuit uses two 50% compressors with common process equipment. The compressor and turbine packages are manufactured by Nuovo Pignone of Florence, Italy. Brazed Aluminum Heat Exchangers and Core-in-Kettle Exchangers are used for the feed gas, propane, ethylene and methane circuits downstream of the mercury removal system. All of these heat exchangers with the exception of the propane chillers are housed in two "Cold Boxes". These boxes are manufactured by Chart-Altec. All compressor inter-cooling, after-cooling and propane refrigerant condensing is provided by fin-fan heat exchangers. The LNG from the last stage flash drum is sent to the LNG tanks by the LNG transfer pumps where it is stored at approximately 70 mbar and $-161\ ^{o}C$.

Fractionation

Fractionation is provided to remove heavy components from the feed gas to prevent freezing in the liquefaction process and to recover 70% of the propane and heavier hydrocarbon components. The NGL stream is exported to a fractionation facility in Trinidad for further fractionation into propane, butane and natural gasoline.

Utilities

The utilities required to support the main process are simple and small in size. The major utilities are:

- Power generation - Solar Mars units are utilized
- Hot Oil system - two 60% indirect forced air heaters per train
- Firewater System
- Instrument Air System - bleed air from power generators with one standby air compressor
- Nitrogen System – one additional membrane N2 generation unit with additional liquid N2 unit
- Demineralization Package - water makeup to Amine system and water for turbine washes
- Refrigerant Storage – additional ethylene storage
- Cooling Water – closed circuit cooling water system for turbine/compressor packages
- Flare systems – additional wet and dry flares for train 3, train 2 tied in to existing flares
- Incinerator – disposal of acid gases from amine regenerator

Figure 1: Gas Sweetening System DGA

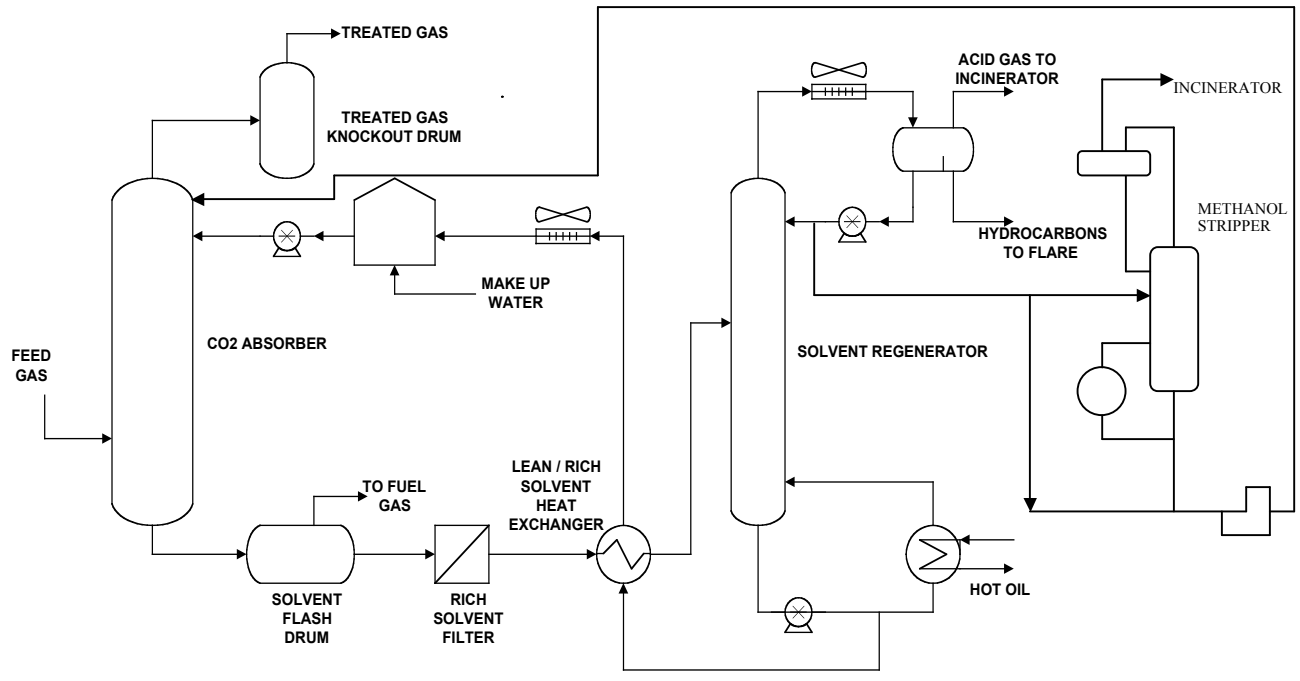
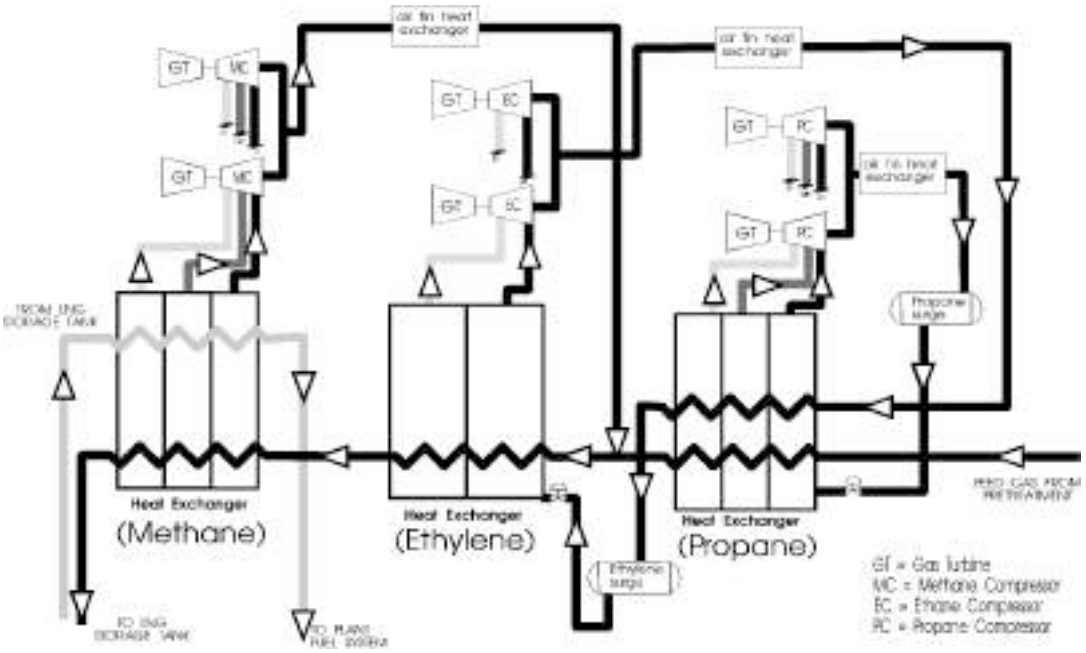


Figure 2: Phillips Optimized Cascade LNG Process [2]



Design/Equipment Changes

The following changes and enhancements were made to the design or equipment of the plant.

- Propane vessel arrangement modified
- Propane piping modified for better hydraulics
- Modified core in kettle exchangers in propane system
- Frame 5D's used as drivers in lieu of frame 5C's
- Heavy Ends Removal System modifications
- Vortex breakers and modified inlet devices in methane flash drums
- Drag valves used on compressor recycle valves and feed gas valves
- Additional filter, porous media, installed on feed gas inlet amine absorber
- Increased size of fin fan motors and installed better, quieter blades
- Improved and strengthened drier support beds
- Installed methanol stripper system (for BG gas supply)
- Improved absorber overheads wash water section

The most significant changes to the design were the changes made to the propane system, the Heavy Ends Removal Column system and to the compressor drivers.
On Train 1 there were operability issues with the overall operation of the propane system that were found to be inherently due to poor hydraulics. These were corrected and implemented for trains 2 and 3 along with increasing the strength of the demister, improving the liquid distributors in the exchangers and improving the vapor outlet systems. The integrated heat exchangers were also re-orientated.
The Heavy Ends Removal Column was modified by increasing the height of the column and raising the feed gas inlet distributor away from the top tray section above the packing section. The integrated heat exchangers were also re-orientated
The change to frame 5D's for compressor drivers gave the additional horsepower required to increase the overall plant capacity from 3.0 MTPA to 3.3 MTPA. The change to the use of drag valves on the

compressor recycle systems improves operating stability as well as reducing noise when the machines are on recycle.
A methanol stripping section was added to the overhead system of the CO2 system regenerator column to remove any entrained methanol from the main feed gas stream before it goes forward to the drying section. This addition is a requirement due to the injection of methanol in to the BG feed gas pipeline.
The remaining changes were all done to improve the performance of the various sections based upon historical operating data from train 1.

Commissioning & Start-up

Operator Training

The seconded plant operations staff was supplied by Atlantic LNG sufficiently early in the project to ensure vendor training could be provided prior to commissioning and start-up activities. The Bechtel supplied operator training requirements for trains 2/3 consisted of a vendor training program only, as Atlantic LNG had performed the basic operator and maintenance training programs in-house prior to their personnel being seconded to Bechtel.

Bechtel was responsible for establishing the vendor training program which consisted of training on critical equipment such as Solar Power Generators, Nuovo Pignone Gas Turbines and Compressors, CCC Controls, Bentley Nevada, Honeywell DCS, General Monitors for Fire & Gas and the Phillips Liquefaction Technology.

The training program was held over a period of 6 weeks and was completed on schedule.

Milestones

Early work on the facility began in March 2000 with the EPC contract being awarded in August, 2000. Most of the utilities were commissioned by May 2002 to allow the introduction of the hydrocarbons into the inlet area up to the pig receiver for supplying fuel gas to the power generators. Initial start of the new power generators used fuel gas from train 1 until train 2 fuel systems were up and running. The new BG pipeline was commissioned in March 2002. The following outlines the major commissioning and startup milestones:

- Power generators started up - March 2002.
- Cooling water system started up – May 2002
- Wet flare system started – June 2002
- HP/LP Fuel gas systems started up - June 2002
- Hot Oil system started up – June 2002
- Perform Solo & Mechanical runs on Turbine/compressor packages – June 2002
- Inlet area pressured up – July 2002
- Amine system commissioned – July 2002
- Startup molecular sieve dryers – July 2002
- Dry out liquefaction process system – July 2002
- Startup refrigeration compressors – August 2002
- Cool down process – August 2002
- Make LNG – August 7, 2002
- Load 1st LNG Tanker – August 14, 2002
- Complete Performance Test – October 3, 2002

Lessons Learned

During commissioning and start-up of the facilities a number of minor problems were encountered. The nature and number of the problems was not inconsistent with those one might expect from a project of this size. Some of these problems are highlighted here.

- Compressor recycle valve positioner problems
- Design problems on one vapor line

Despite these relatively few problems the start-up team was able to find and implement solutions and finish the project ahead of schedule without compromising safety of the start-up or long term plant operations. The value of these experiences will be realized when lessons learned as a result of knowledge gained are applied to design and operations improvements on the future trains and future projects.

AcceptanceTesting

The train 2/3 contract between Bechtel and Atlantic LNG was again 'Turn Key" based upon the same model used for train 1. The principal difference being that for trains 2/3 Bechtel was required to supply only senior operating staff but still all maintenance, safety, technical support and supervisory personnel for the safe start-up and initial operation of the plant until final performance tests had been successfully completed. Members of Atlantic LNG operations experienced staff became a part of the integrated team and continued under Bechtel's direction to be the hands-on-operators during the commissioning and start up of the train. The same philosophy and approach will apply to train 3 also.

There were two types of acceptance tests that made up the plant performance requirements. These were commissioning tests for individual equipment or units and an overall performance test of the operating facility.

Commissioning Tests (process and utility)

Commissioning tests were required for all systems, all package units, various special items such as metering skids, firewater pumps, utility systems and of course, all control systems, alarm systems and shutdown systems. The purpose of the Commissioning tests was to demonstrate that individual systems within the facility performed according to design specifications within the EPC contract. There were 22 individual tests each with a procedure and a report documenting the results and individually signed off by both Bechtel and owner and witnessed by owner. All commissioning tests have to be completed before Performance Tests could begin.

Performance Test

A 72 hour performance test was conducted to prove the plant capacity, fuel efficiency and LPG recovery rate. Additional loading capacity will be tested upon completion of the third LNG tank with train 3. This test is Bechtel's final deliverable required for contract completion and final turnover.
Plant simulations under the exact conditions expected during the test have been done ahead of time to determine the exact effects of site weather and possible variations in feed gas composition.

The 72 hour performance test of train 2 was successfully carried out beginning September 30, 2002 and the following are the results from that test;

Performance Guarantee:	96% of PFD LNG product at ambient 26^{o}C using 93% refrigeration horsepower
Results achieved:	105% of PFD LNG product at a corrected 26^{o}C using 93% refrigeration horsepower

Future Expansion

Atlantic LNG is committed to further expansion of the LNG facility at Point Fortin in Trinidad. Work has already begun on train 4 to further increase the production capacity of the facility. Train 4 will be based upon the Phillips Optimized Cascade LNG Process and will continue with the use of frame 5D's as the primary driver for the refrigeration compressors. The plant capacity will be 4.8 MTPA bringing the overall facility capacity to 14.7 MTPA. (Train 1 capacity is being increased from 3.0 MTPA to 3.3 MTPA with an ongoing upgrade project)

Train 2 Acceleration

Regarding ALNG train 2, early in 2002 Bechtel were approached by Atlantic LNG and asked if there was a possibility of accelerating the schedule to achieve earlier LNG production. The contractual turn over of the facility was December 15, 2002 and at the time of the request the forecast was showing a potential turn over of November 5, 2002. It was agreed that best efforts would be made to try to achieve LNG production in early August 2002 and produce a volume of 87,000m3 of LNG shortly thereafter. All efforts by Bechtel, Phillips and Atlantic LNG were focused on trying to achieve these targets. After an intense period of time beginning March 2002, LNG was produced on August 7, 2002 with an LNG volume of 87,000m3 being produced by August 14, 2002. Once again the only way this was possible was for all parties to be a part of it, as on train 1, one team with no boundaries.

Reference:

(1) "Passing the Baton Cleanly" – Gastech2000 –F.W.Richardson, P.Hunter, T.Diocee, J.Fisher

(2) Phillips Optimized Cascade LNG Process – W.R. Qualls/R. Martinez, ConocoPhillips 2001

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“The Second Wave”

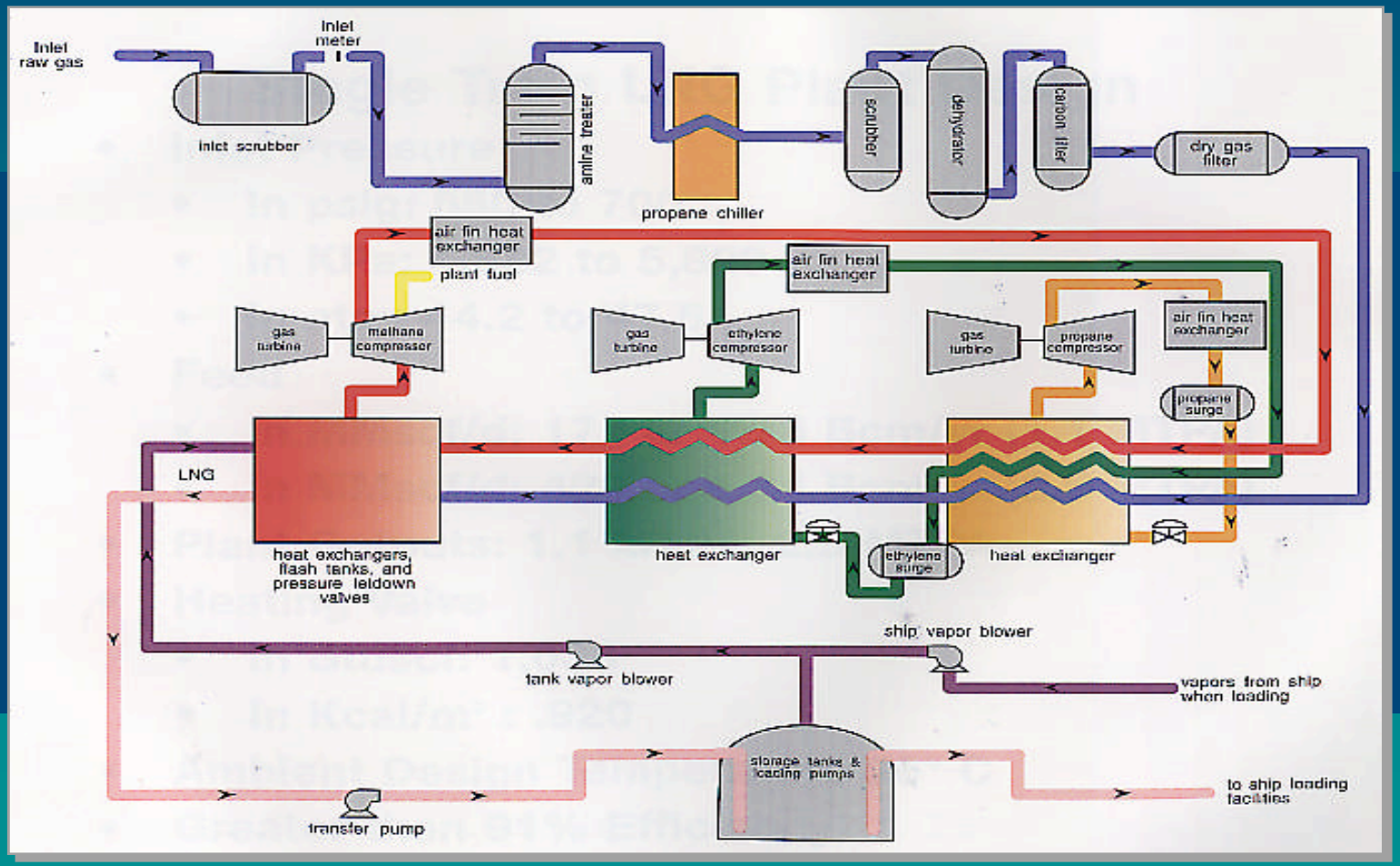
Introduction

- Train 2/3 EPC Award August 2000
- Each Train 3.3 MTPA Capacity
- LNG Storage Tank 160,000 M3

Process Description

- Inlet Area & Gas Treating
- Refrigeration & Liquefaction
- Fractionation
- Utilities

Process Description (cont'd)



Design/Equipment Changes

- Propane suction drums
- Propane piping
- Propane demisters
- Frame 5d's
- Heavy Ends Removal System
- Methane Flash Drums
- Compressor Anti Surge Valves
- Feed Gas Filtration
- Fin Fan Condensers/Coolers
- Drier Bed Supports

Commissioning & Start Up

- Operator Training
- Milestones
- Lessons Learned
- Commissioning Tests
- Performance Test

Train 2 Acceleration

- Original Turn Over
- Accelerated Turn Over

Future Expansion

- Train 4
- Trains 5/6