LNG FROM COAL-
XINJIANG SYNGAS/LNG PLANT ON STREAM

Shawn D. Hoffart
LNG Technology Manager

Brian C. Price
LNG Advisor

Black & Veatch Corporation
Overland Park, KS, USA
www.bv.com

GASTECH
October 8-11, 2012
London

LNG FROM COAL
XINJIANG SYNGAS/LNG PLANT ON STREAM

Shawn D. Hoffart
LNG Technology Manager

Brian C. Price
LNG Advisor

Black & Veatch Corporation
Overland Park, KS, USA
www.bv.com

ABSTRACT

The LNG market in China is booming with many new plants and increasingly challenging feed stocks. The Xinjiang Guanghui LNG project is one such facility. The liquefaction unit receives feed gas from a large coal gasification plant. The LNG unit handles 405 MMSCFD of feed gas which is about 15% methane. The remainder of the gas is H_2 (59%), CO (25%), and small amounts of nitrogen and ethane. The unit produces LNG with less than 0.5% CO and a H_2/CO syngas product which contains less than 0.5% methane. This separation is achieved by using a modified Single Mixed Refrigeration (SMR) process to perform the syngas separation while producing an LNG product from the bottom of a cryogenic fractionation column. A secondary cold refrigeration loop has been integrated with the base process to provide the extremely low temperatures needed for the separation. The LNG product is trucked from the site and the syngas is used for methanol plant feedstock. This unique plant design is the model for many additional future units.

INTRODUCTION

In May 2007, Xinjiang Guanghui Industry and Commerce Group Co. Ltd. awarded a contract to a consortium of Black & Veatch and Chemtex Intl. to build an LNG production plant in Hami, China. The plant is designed to process the gaseous product from a coal gasification unit. The plant is designed to produce a specification LNG product as well as a CO/H_2 product stream which is to be sent to a methanol plant. This system of utilizing coal gasification to produce LNG and methanol is a unique project for China as well as the first of its kind in the world. Each of the products from this facility will be trucked out to users across China to provide a clean fuel for vehicle and local consumption as well as a valuable chemical commodity.

Construction of the LNG unit was completed in late 2011 and is now ready to receive the syngas feed when the gasification unit start-up has been completed. It is anticipated that the LNG trains will be on stream in the 4th quarter of 2012.

FACILITY DESIGN

The facility is designed to handle 10.86 x 10^6 Nm^3/day (405 MMSCFD) of feed gas from the coal gasification unit. The feed gas has the composition shown in Figure 1. The feed gas is available at 25 bara and 30°C. The liquefaction process is based on application of the PRICO® LNG process developed by Black & Veatch. This process is a single mixed refrigerant (SMR) system which has been modified for the Guanghui project to produce the desired high purity LNG and CO/H_2 products. The PRICO® process is a closed loop refrigeration system using a mixture of nitrogen, methane, ethylene, propane and iso-pentane. The nitrogen and methane makeup components are supplied from internal plant streams, while the remainder of the refrigerant makeup components are supplied from third party sources. The plant was constructed with 2 x 50% production units to provide flexibility for the overall process. The PRICO® process is currently being used in 16 facilities in China, and dozens globally.

Energy for process heating and compressor drivers is provided by steam from the gasification unit. High pressure steam at 89 bara and medium pressure steam at 35 bara are available for these services.

The liquefaction unit is designed to produce LNG with less than 0.5% CO and syngas (CO/H_2) with less than 0.5% C1. The process unit sends the -161°C LNG to a 30,000 m^3 single containment storage tank. Vapors produced in the LNG storage tank are recycled back to the LNG unit for reliquefaction. The LNG will be trucked from the facility to various customers. Approximately 78 truck loads per day are required to transport the LNG product. The syngas is sent out of the unit at a required pressure of 24 bara. This stream feeds a methanol production unit contained within the Guanghui complex.

PROCESS DESCRIPTION

The syngas/LNG process unit consists of the process steps shown in Figure 2. The process unit consists of 1) inlet compression, 2) gas treating 3) liquefaction and 4) refrigerant makeup. The LNG storage and boiloff gas (BOG) handling are provided in OSBL areas. The syngas feed does not contain any heavy hydrocarbons, so separation of NGL's or condensate is not required.

The feed gas is initially compressed from 25 bara to 50 bara. This provides sufficient pressure for an efficient separation process, and is needed to supply the syngas product at 48 bara. The gas is then treated in a molecular sieve bed. The molecular sieve unit dehydrates the feed gas, and also removes methanol - which would freeze in the liquefaction unit. Methanol is used in upstream processing units, and a small amount remains in the liquefaction unit feed gas. Regeneration of the molecular sieve unit is provided by a nitrogen stream heated with HP steam.

After treating, the feed is directed to the PRICO® liquefaction unit. This is a traditional PRICO® SMR process which has been modified to produce the syngas product along with the LNG as shown in Figure 3. The feed gas exits the first pass in the main LNG exchanger and is used for reboiling the cryogenic fractionation column. This stream then goes back to the main exchanger where it is cooled to -151°C. The cold vapor and liquid are separated and are then sent to the main fractionation tower by different paths. The vapor is sent through a turbo expander where it is expanded and sent to the fractionation tower. The liquid is metered to the fractionation tower through a level control valve. The fractionation tower operates at 13 bara with an overhead temperature of -177°C.

Reflux cooling for the fractionation tower is provided by an integrated nitrogen loop. The nitrogen is compressed and then condensed in the main LNG exchanger. The liquid nitrogen expands across a control valve to produce a low temperature stream for condensing tower reflux. The syngas exits the fractionation system at -177°C and is boosted by the compressor linked to the turbo expander. The syngas is then warmed in the main exchanger before being sent to the methanol unit.

The LNG from the bottom of the fractionation tower is subcooled by exchange with the syngas from the tower overhead. This minimizes the flash when the LNG is let down to storage pressure. The vapor from the LNG storage tank is boosted with a reciprocating compressor and recycled back to the liquefaction unit.

The entire refrigeration process and syngas/LNG separation process is driven by a PRICO® refrigeration compressor in a typical SMR configuration as shown in Figure 4. The unit consists of a single compressor driven by a steam turbine with HP steam. The compressor is a single body, two section compressor which is intercooled. The mixed refrigerant compressor for one train of production is shown in Figure 5.

Vapor from the refrigerant exchanger is compressed in the refrigerant compressor and cooled in the interstage cooler. Vapor from the interstage separator is compressed in the second stage of the machine, cooled and condensed in the discharge cooler, and separated in the discharge separator. The interstage liquid is pumped to the discharge stage separator. The discharge separator divides the vapor and liquid phases and feeds them to the main exchanger. The refrigerant is condensed while flowing downward in the main exchanger. After condensing and subcooling, the refrigerant exits the exchanger, is expanded across a JT valve and then reenters the bottom of the exchanger. The cold, low pressure refrigerant provides all the cooling for the liquefaction process as it flows upward and vaporizes in the refrigerant exchanger. The refrigerant exits the top of the exchanger as a vapor and is directed to the compressor suction vessel, completing the refrigeration loop.

UTILITY SYSTEMS

The refrigeration system is supported by a refrigerant makeup system. The makeup components are provided as needed for the mixed refrigerant loop. Nitrogen is supplied from the main gasification plant. The methane is supplied from vaporized LNG product. Ethylene, propane and iso-pentane are stored on site in small tanks. These components are introduced into the system through a sweep gas line. The sweep gas is warm gas from the compressor discharge. The sweep gas with the vaporized makeup components is sent to the compressor suction.

Steam is provided to drive the inlet gas compressor, the mixed refrigerant compressor, and the nitrogen compressor. Steam is also used for various heating loads such as the molecular sieve regeneration heater and steam tracing services. Any streams containing water must be steam traced for freeze protection, due to the low temperatures experienced in the winter months.

A cold flare system is provided for emergency relieving services and maintenance activities. The flare header in the syngas/LNG facilities connects into a plant wide flare system for the entire Xinjiang Guanghui facility.

The Xinjiang Guanghui facility utilizes a state of the art distributed control system (DCS) in a central control room. Operators can control multiple process units from a single location. Similarly, a separate safety instrumented system (SIS) monitors and controls the various initiators and shutdown systems in each train. A fire and gas system is also provided to monitor and protect the process areas.

Waste heat in the treating and liquefaction systems is rejected to cooling water. The cooling water is provided from a plant wide utility network.

DRIVER CONFIGURATION

As noted earlier the compressors in this facility are powered by steam turbines. The inlet gas compressor consumes 26,200 kg/hr of 89 bara HP steam to provide 7.34 MW per train. The refrigerant compressor uses 92,400 kg/hr of HP steam to provide 26.5 MW of compression power in each production train. The nitrogen compressor uses 7,500 kg/hr of 35 bara MP steam per train in a 1.4 MW steam turbine. Each service uses a surface condenser to maximize the turbine efficiency.

MAIN LNG EXCHANGER

The liquefaction process is designed with two 50% trains. Each train has a single refrigeration compressor and single, integrated main exchanger. The main exchanger in this application requires 6 plate fin cores. These are arranged in a parallel configuration with common headers for the streams entering and exiting the cores. Due to shipping restrictions in the nearby mountain range, the six core assemblies had to be fabricated in three two core packages. Each of these two core cold box packages arrived at the site completely assembled from the manufacturer's shop. The individual boxes, shown in Figure 6 are arranged in parallel. The piping is modified to accommodate the multiple box arrangement. No impact on the process occurs due the multiple cold box arrangement. The cores operate in precisely the same manner as if they were contained in a single large box. This is a distinct advantage of core exchangers versus the much less flexible spiral wound units which must be welded in the field with great cost and schedule impact.

OVERALL LAYOUT

The plant layout is shown in Figure 7. Due to the harsh conditions at the site, all the major rotating equipment is located inside enclosures. The three main compressor services are grouped together in a single building per process train. This configuration allows easier operation and maintenance of the machines, as well as the ability to share maintenance facilities such as a single bridge crane. Additional site photos may be found in Figures 8-9.

CONCLUSION

The gasification of coal to produce useful syngas and methane is a key industry development in China. The product from this gasification must be separated in an efficient process unit to produce the desired products. LNG for vehicle and other fuel uses is a key product from this process unit. Equally important is the CO/H_2 which is used for methanol production. The Xinjiang plant is currently undergoing check out, and start up is imminent.

- **Feed**
  - 59.10% H_2
  - 24.76% CO
  - 15.16% C1
  - 0.29% C2
  - 0.39% N_2
  - 0.29% O_2
  - 0.01% MeOH
- **LNG**
  - 97% C1
  - >0.5% CO
  - 1.8% C2
- **Syngas**
  - 69.68% H_2
  - 29.14% CO
  - >0.5% C1
  - 0.5% N_2

FIGURE 1: Feed Gas and Product Compositions

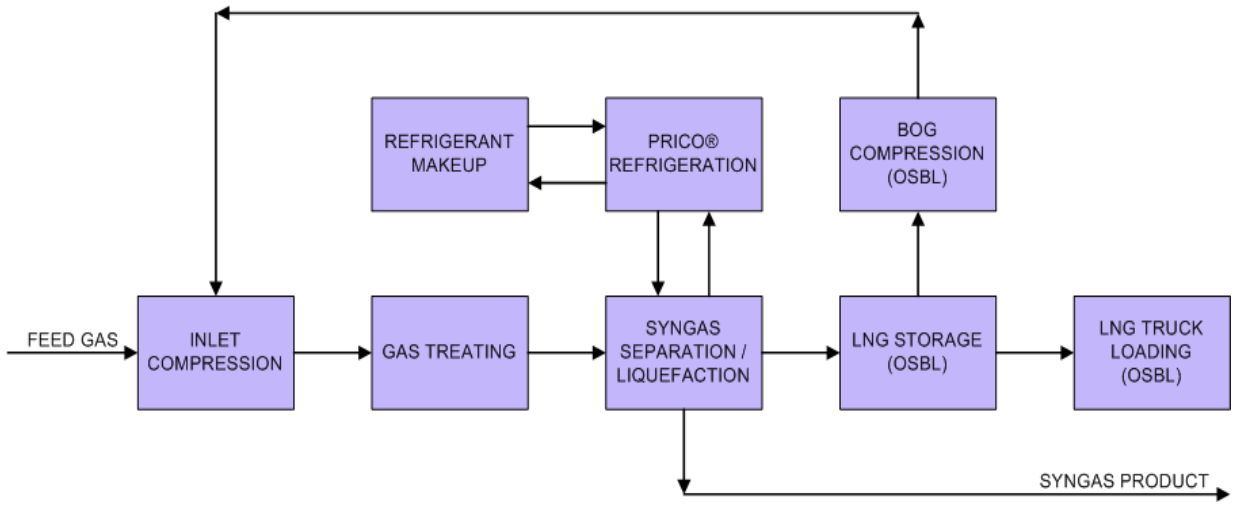

FIGURE 2: Block Flow Diagram

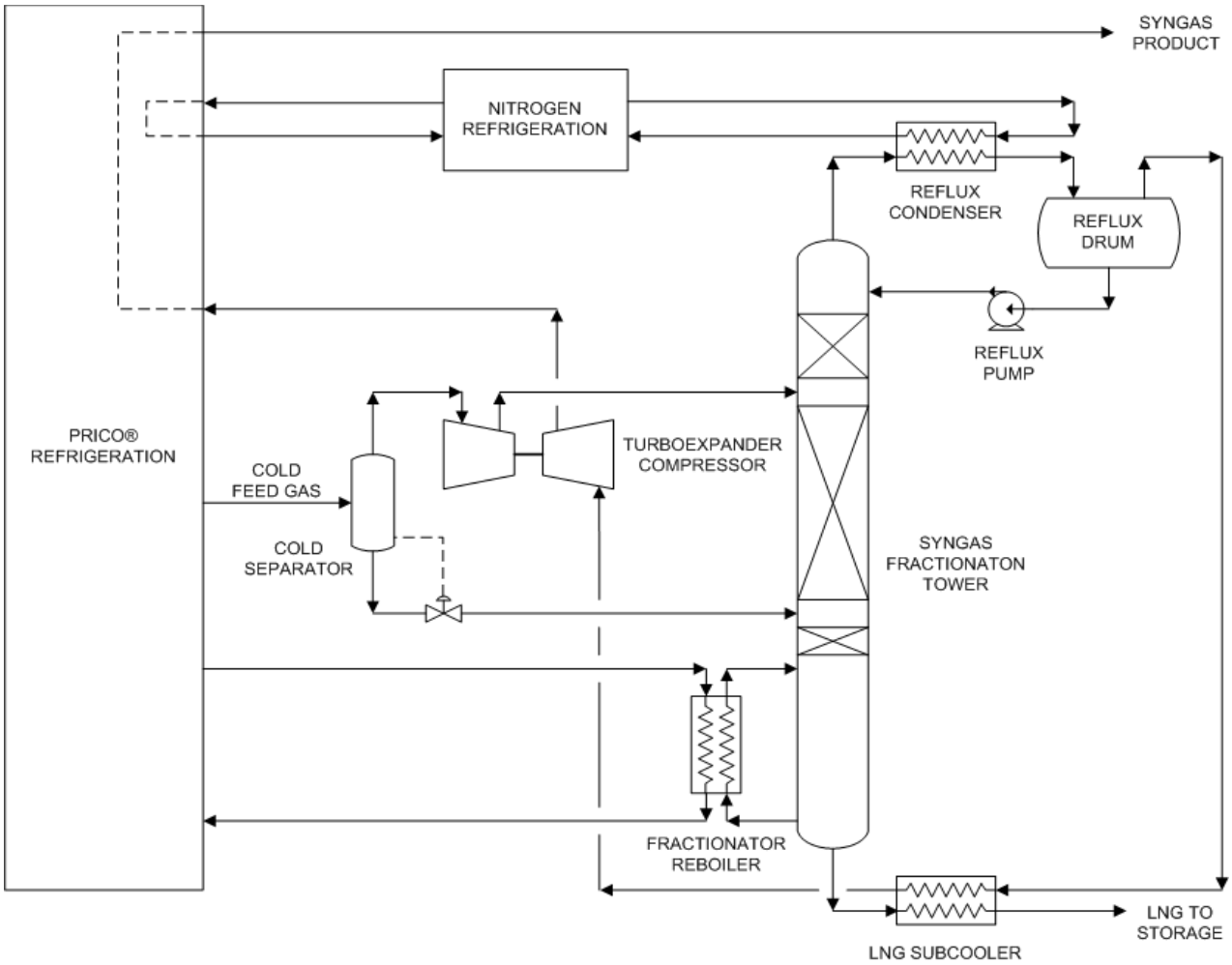

FIGURE 3: Syngas Separation

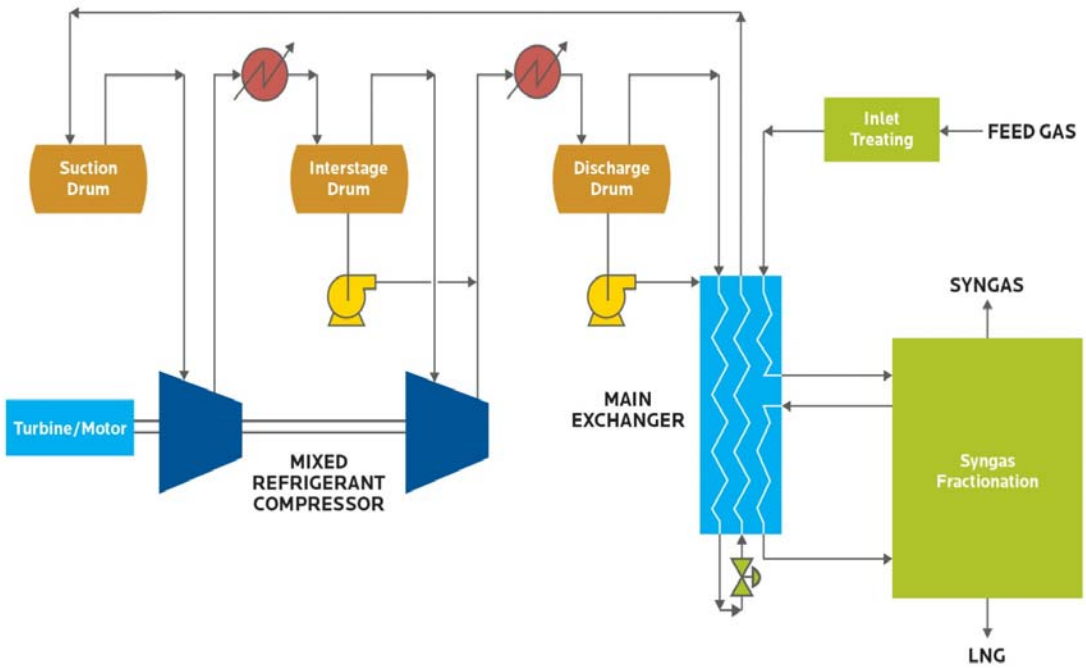

FIGURE 4: PRICO® Refrigeration

FIGURE 5: Mixed Refrigerant Compressor

FIGURE 6: Mixed Refrigerant Exchanger

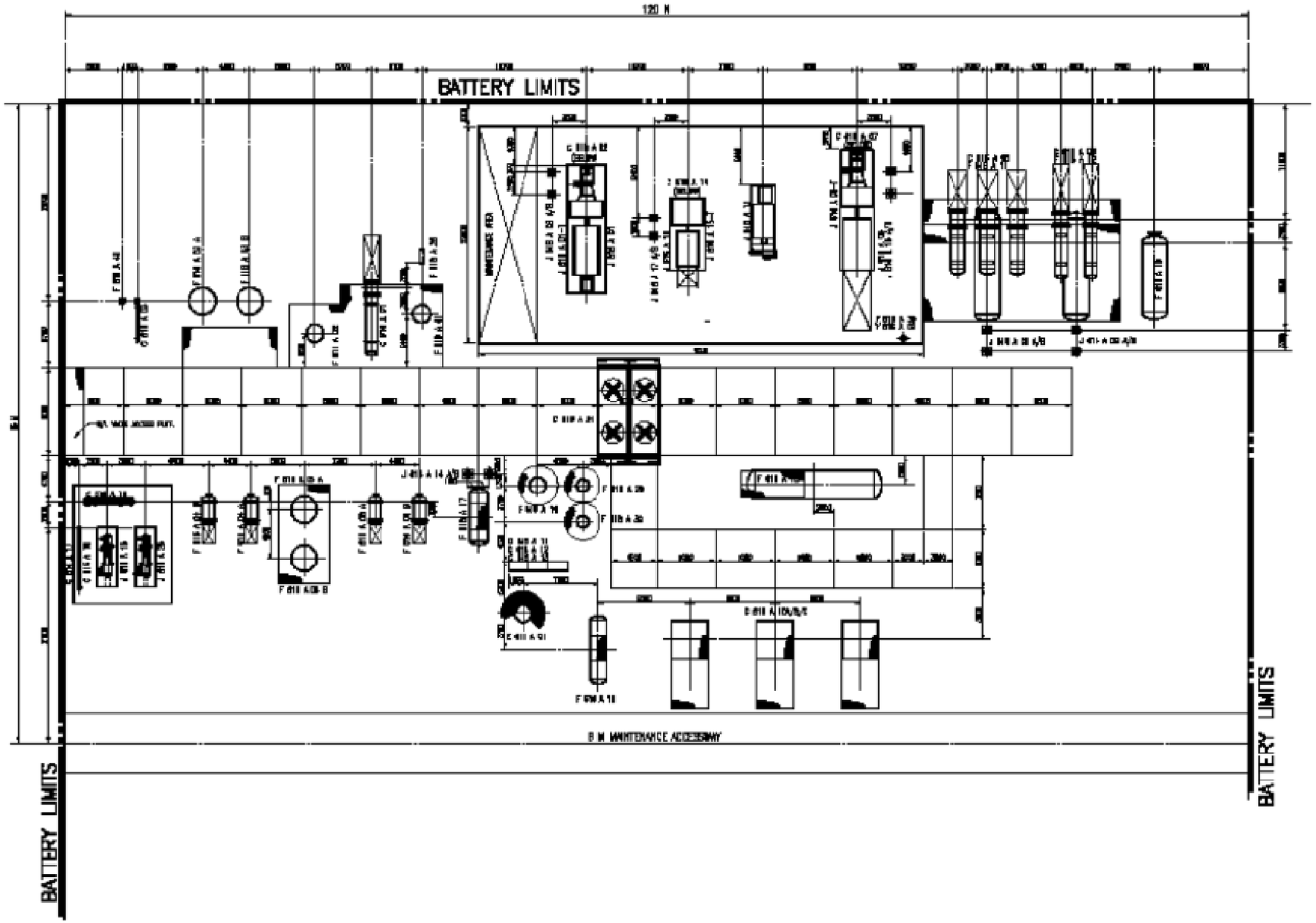

FIGURE 7: Plant Layout

FIGURE 8: Xinjiang Guanghui Liquefaction Trains

FIGURE 9: Syngas Fractionation Tower