Liquid Nitrogen Plant #503

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1. Executive Summary

1.1 Plant Capacity

- 10,000 Nm3/hr

1.2 Plant History

- Originally built in 1980.
- Reconditioned and rebuilt in 2004.

1.3 Available Technical Documents

- Compressor Overhaul Summary
- Electrical Drawings
- Equipment Inspection Reports
- Layout Drawings
- P&IDs
- PFDs
- Plant Plot Plan
- Process Description
- Production Report

1.4 Specifications of Nitrogen Product

- CGA Grade L Type II Liquid Nitrogen (purity 99.998%)
- Dew Point (max.) 4 ppm
- Oxygen (max.) 10 ppm

2. Process Description

The air separation unit separates atmospheric air into its primary elements: Nitrogen (78 %), oxygen (21%), and argon with trace amounts of other gases (1%). This process consists of three stages. First is the compression stage where atmospheric air is pre-filtered, compressed and then subsequently cooled. Next is the purification stage in which the process air is then passed through reversing valves which remove water vapor, carbon dioxide and hydrocarbons. The third stage is the distillation stage. Process air enters into a distillation column where it is separated.

1.1.1 Main Air Compressor

The Findlay main air compressor (MAC) is a three-stage centrifugal compressor which draws outside air through a filter housing which removes large airborne particles prior to entering the suction of the compressor. The volume of the air flow entering the compressor, which is metered in Standard Cubic Feet per Hour (SCFH), is controlled by inlet guide veins. The inlet guide veins are a flow-controlled valve. Opening the valve will allow more air to enter the compressor.

The air being introduced into the compressor travels though the three stages of compression. Due to the high volume of flow entering the compressor, three stages of compression are required to supply the plant with enough discharge pressure needed for the high-pressure column, which is where the air separation process takes place.

After each stage of compression is an air cooler. Between each stage is an intercooler and after the last stage of compression is an after cooler. The coolers remove the heat of compression after each stage. The coolers are shell and tube heat exchangers containing a series of tubing running through the coolers. Glycol is circulated through the tubing. The glycol is regulated at a temperature which is lower than the air flow discharging from each stage of compression. As the air enters the coolers, it comes into contact with the glycol filled tubing. This causes a heat exchange which significantly reduces the air temperature.

The coolers are also effective in helping reduce the water content in the air. Condensation occurs on the outside of the glycol tubes and is collected in a condensation trap. The condensate trap works using a float system. When the float gets high the trap will drain into a condensate tank.

1.1.2 Warm/Cold Reversing Heat Exchanger

From the discharge of the MAC, the air flow then travels through the reversing valves and into the warm/cold reversing heat exchanger. The heat exchanger lowers the temperature of the air flow to near its point of condensation before entering the high-pressure column. It also removes water and carbon dioxide impurities from the air by freezing out these impurities.

The impurities freeze on the walls of the exchanger and would soon plug the passage if they were not removed.

The impurities are removed by alternately flowing air and waste gas through the same exchanger passages so that the waste gas can pick up these impurities and carry them out to atmosphere. The alternating flow through the exchanger is controlled by reversing valves.

The reversing valves are set to a timer which switches them every 5 minutes.

Waste gas travels from the top of the low-pressure column, through the liquefier sub-cooler and main heat exchanger, and into the inlet of the expander. The waste gas provides the cross current flow to the main heat exchanger that is necessary to effectively cool the incoming air to the high-pressure column

1.1.3 Expander

The expander is a refrigeration unit that provides cooling for the entire air separation unit. It is an expansion turbine that consists of an expander assembly and a loader assembly. The expander assembly consists of an impeller wheel, inlet nozzle assembly, and a shaft seal. As the gas travels through the impeller, it is expanded (de-compressed) to a lower pressure.

The decrease in pressure creates a decrease in the temperature of the gas and refrigeration is achieved.

The nozzle assembly of the expander has adjustable vanes which directly control the gas flow and along with the loader, is used as a means of controlling expander horsepower and refrigeration. The loader is also adjusted to help maintain a most efficient speed.

The loader consists of three load zones that form an annular space around the circumference of the shaft. Oil supplied these spaces is sheared between the stationary loader and the rotating shaft. Varying the amount of oil supplied to the loaders controls the speed of the turbine. More oil means more load, and therefore a slower speed. The oil flow is controlled by a valve.

From the discharge of the expander, the waste gas travels through Liquefier Sub cooler and through the main heat exchanger, removing the built-up impurities and blowing them out to atmosphere

1.1.4 High Pressure Air Separation Column

From the main heat exchanger, the process air now enters the high-pressure column free of impurities. The air travels up through a series of perforated aluminum trays stacked throughout the height of the column. Each tray connects to the tray beneath by a down-comer pipe which transfers excess liquid to the tray beneath.

The air travels up through the column trays and boils up the liquid in the trays causing the nitrogen in the trays to boil out as a gas. The exchange of latent heat condenses the oxygen out of the air passing up through the trays. Because the boiling point of nitrogen is higher than the boiling point of oxygen, the nitrogen remains as a gas vapor while the oxygen condenses. As boiloff continues up through the column, the vapors increase in nitrogen purity until the gas vapors leaving the top tray of the column are pure nitrogen vapors and all the oxygen has condensed into a liquid.

The condensed oxygen, referred to as crude oxygen, falls towards the bottom of the column into the column sump. By design the height of the column will dictate the purity of the oxygen content within the nitrogen.

To replenish the liquid levels on the trays, a portion of the nitrogen gas is distributed from the high-pressure column up through the reboiler-condenser in the low-pressure column through a reflux valve. The reboiler-condenser is submerged in crude oxygen. The decrease in pressure between the high pressure and low-pressure column as well as the sub-cooling provided by the crude oxygen brings the nitrogen gas to below its boiling point which causes it to condense into a liquid. The majority of the liquid is then routed back onto the trays. A small amount is streamlined through a valve into a separate storage tank.

As the nitrogen reflux gas passes the through the reboiler-condenser, heat transfer occurs with the crude oxygen in the low-pressure column. This heat transfer slightly warms the temperature of the crude oxygen causing it to boil into a gaseous state. The column boil off is referred to as "waste gas" and it is the gas used to blow out the reversing valves.

As the crude oxygen in the low-pressure column boils, the level will decrease. As the level drops below the operator entered set-point, level control valve opens and crude oxygen is subcooled through liquefier-subcooler, sent through the hydrocarbon absorbers, and into the low-pressure column

The liquid level in high pressure column is controlled by the level control valve. When the level increases above the operator entered set-point, the level control valve will open and the crude oxygen will drain to the dump fan.

The nitrogen gas leaving the column passes through the liquefier subcooler where it is used to subcool the crude oxygen stream and then through the main heat exchanger. As it passes through the exchanger, the gas warms to ambient temperature as it cools the air stream entering the high-pressure column.

1.1.5 SP-3 Separator

The nitrogen then passes through the recovery heat exchanger, which cools the nitrogen before it enters the SP-3 separator. The amount of nitrogen entering SP-3 is controlled by pressure control valve. The liquid in SP-3 is controlled by a level control valve. The valve is set to a high set-point to maintain a high liquid level in the separator in order to keep the product at a lower temperature. As the level increases, the valve will open, allowing the product to flow through the heat exchanger, which reduces the temperature even more, and then into the storage tank.

Only a small amount of the flow that enters SP-3 drops out as a liquid. The majority of it passes through SP-2, then through the recovery heat exchanger and into the suction of the recycle. The amount of Findlay flow that is taken from the column, passed through SP-3, and sent to the Recycle compressor is controlled by a flow control valve.

3. Consumptions

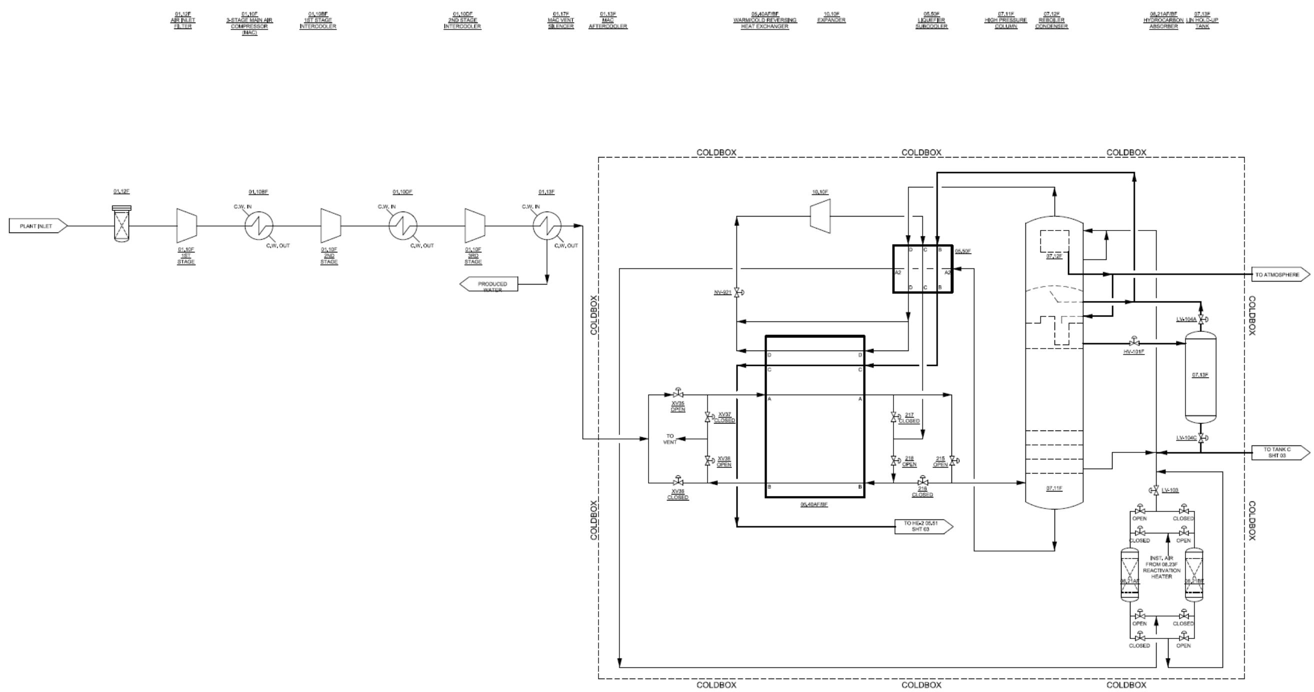
- Average power consumption 0.88 KWH / Nm3

4. Equipment List

01.12	Air Inlet Filters
01.10	1, 2, 3-Stage Main Air Compressors (MAC)
01.10BF	1st Stage Intercooler
01.10DF	2nd Stage Intercooler
01.13	MAC Aftercooler
01.17F	MAC Vent Silencer
01.13F	MAC Aftercooler

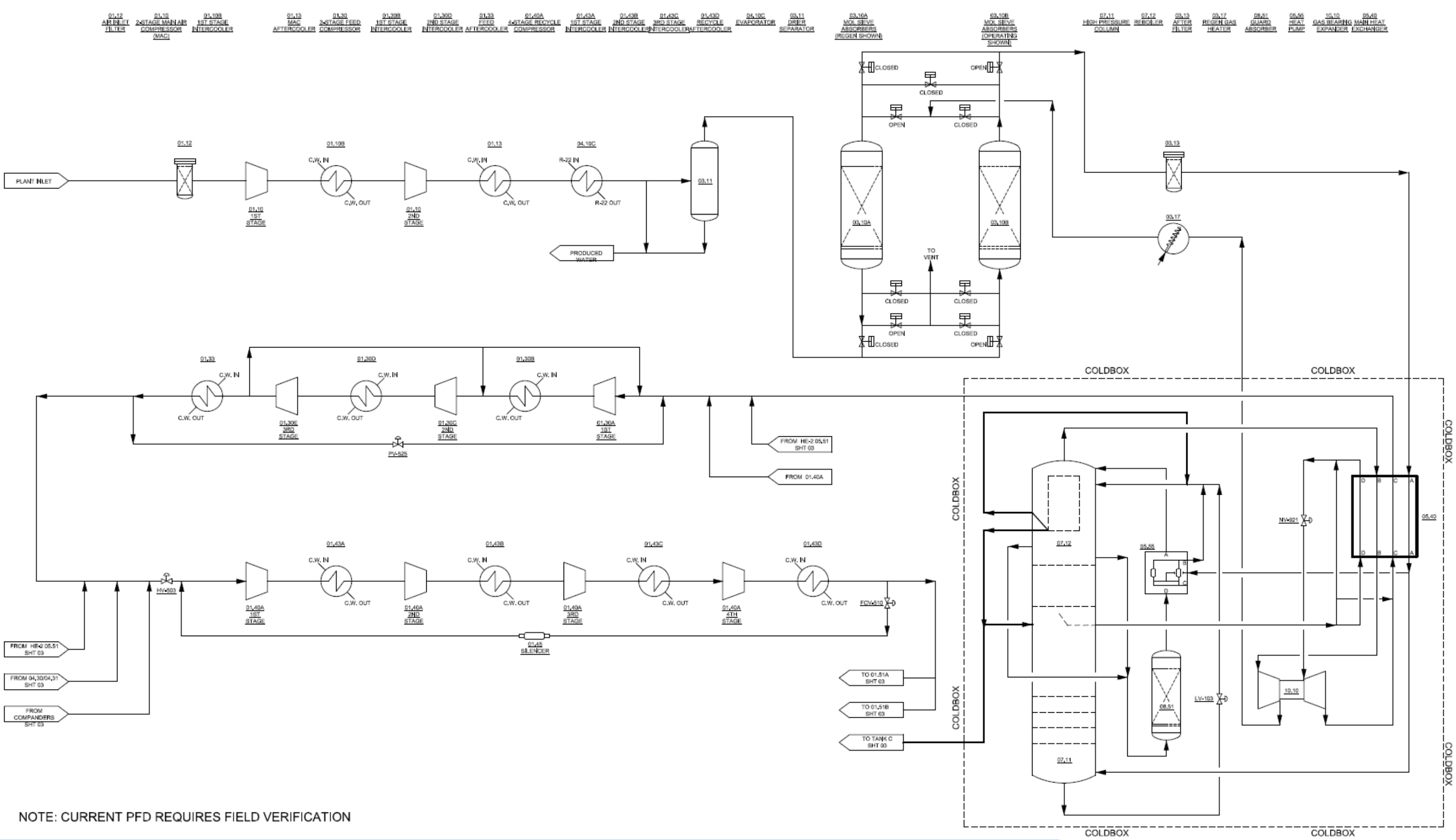
01.30	3-Stage Feed Compressor
01.30B	1st Stage Intercooler
01.30D	2nd Stage Intercooler
01.33	Feed Aftercooler
01.40A	4-Stage Recycle Compressor
01.43A/B/C	1st, 2nd, 3rd Stage Intercooler
01.43D	Recycle Aftercooler
05.40AF/BF	Warm/Cold Reversing Heat Exchanger
10.10F	Expander
05.50F	Liquefier Subcooler
07.11F	High Pressure Column
07.12F	Reboiler Condenser
08.21AF/BF	Hydrocarbon Absorber
07.13F	LIN Hold-Up Tank
04.10C	Evaporator
03.11	Drier Separator
03.10A/B	Mol Sieve Absorbers
07.11	High Pressure Column
07.12	Reboiler
03.13	After Filter
03.17	Regen Gas Heater
08.51	Guard Absorber
05.55	Heat Pump
10.10	Gas Breaking Expander
05.40	Main Heat Exchanger
05.52A/B	Subcoolers
05.51	Precooler
07.83A	Medium Pressure Separator
07.83B	Subcooler Separator
07.83C	Recovery Separator
01.50A	Warm Compressor
10.12	Warm Expander
01.50B	Cold Compressor
10.11	Cold Expander
01.51A	Warm Compressor Aftercooler
01.51B	Cold Compressor Aftercooler
04.30/31	Warm Main Liquefaction Exchangers
04.32	Cold Main Liquefaction Exchangers

5. Process Flow Diagram

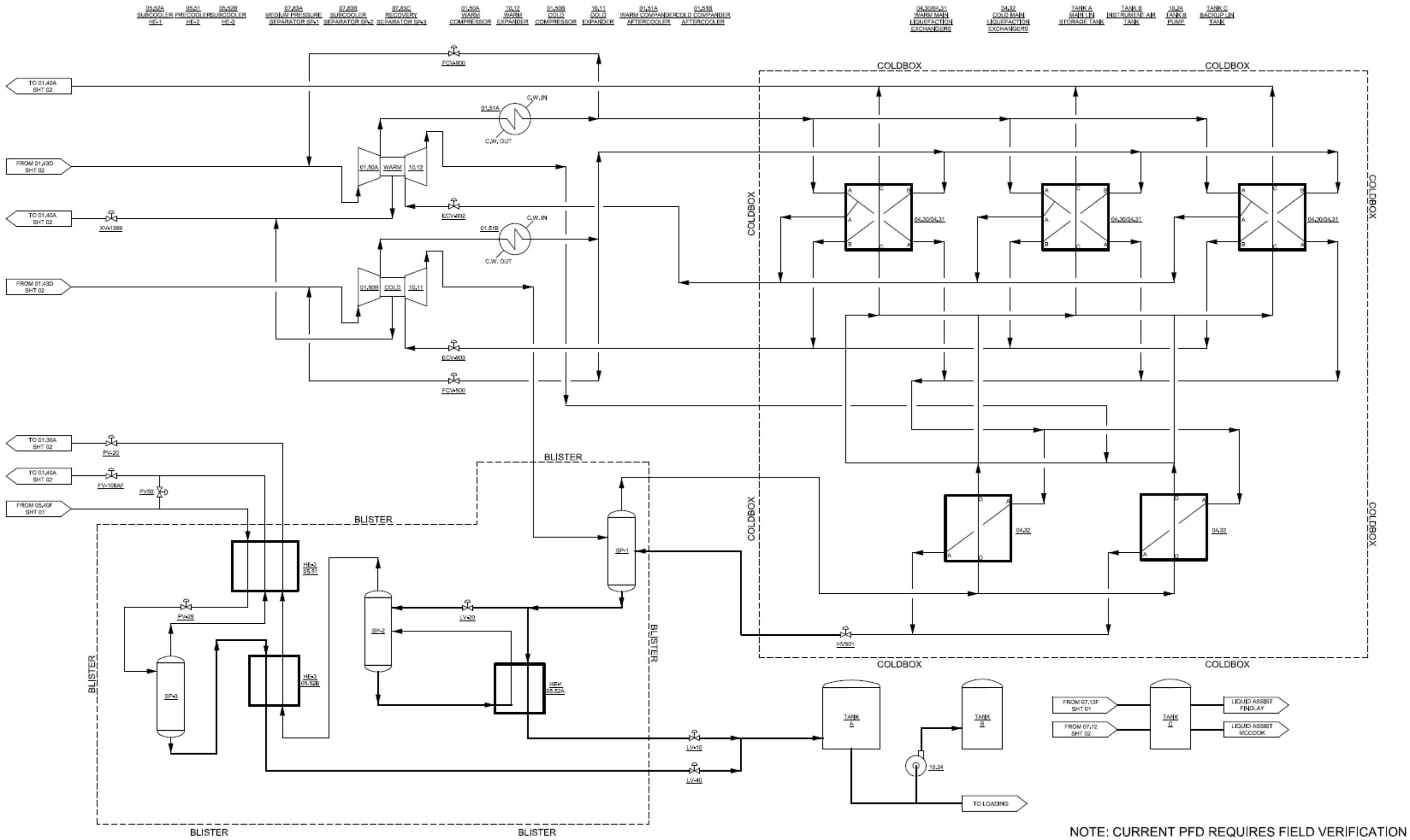


Phoenix

equipment corporation



NOTE: CURRENT PFD REQUIRES FIELD VERIFICATION


05,52A SUBCOOLER HE-1
05,51 PRECOOLER HE-2
05,52B SUBCOOLER HE-3
07,83A MEDIUM PRESSURE SEPARATOR SP-1
07,83B SUBCOOLER SEPARATOR SP-2
07,83C RECOVERY SEPARATOR SP-3
01,50A WARM COMPRESSOR
10,12 WARM EXPANDER
01,50B COLD COMPRESSOR
10,11 COLD EXPANDER
01,51A WARM COMPANDER AFTERCOOLER
01,51B COLD COMPANDER AFTERCOOLER
04,30/04,31 WARM MAIN LIQUEFACTION EXCHANGERS
04,32 COLD MAIN LIQUEFACTION EXCHANGERS
TANK A MAIN LIN STORAGE TANK
TANK B INSTRUMENT AIR TANK
10,24 TANK B PUMP
TANK C BACKUP LIN TANK
FCV-900
COLDBOX
TO 01,40A SHT 02
FROM 01,43D SHT 02
TO 01,40A SHT 02
XV-1369
FROM 01,43D SHT 02
ECV-892
ECV-893
FCV-500
C.W. IN
C.W. OUT
01,51A
01,51B
01,50A
WARM
10,12
01,50B
COLD
10,11
04,30/04,31
04,32
TO 01,30A SHT 02
PV-20
TO 01,40A SHT 02
FV-108AF
PV50
FROM 05,40F SHT 01
BLISTER
HE-2 05,51
PV-26
SP-3
HE-3 05,52B
SP-2
LV-20
HE-1 05,52A
SP-1
HV501
LV-10
LV-40
TANK A
TANK B
10,24
TO LOADING
FROM 07,13F SHT 01
FROM 07,12 SHT 02
TANK C
LIQUID ASSIST FINDLAY
LIQUID ASSIST MCCOOK
NOTE: CURRENT PFD REQUIRES FIELD VERIFICATION