Intention is that this list will be updated on an opportunity specific basis. The list above is the generic sections that exist and available for use.

When issuing a revised proposal, only change the sections that have been revised, i.e. if only the plot plan has changed the revision on this table of content sheet should reflect the revision on the document and allow customers to see where review changes.

4 PROCESS

## 4.1 PROCESS description

This document provides a generic process description for the ASU offered. The project specific process will be optimized during project execution.

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### 4.1.1 Air Compression and Pre-Treatment

The ASU will have one 100% centrifugal-type main air compressors (“MAC”). Feed air is drawn through the inlet filters to remove dust and particulate matter and passes through the inlet silencers before entering the main air compressor (K111). Inter-stage cooling is provided by cooling water in shell and tube intercoolers. The compressors are driven by an electrical motor (D111).

The air leaving the final stage of the compressor is first cooled against cooling water in the bottom section of the direct contact after cooler (C161). Further cooling is achieved by direct contact with chilled water in the upper section of the direct contact after-cooler. The chilled water for the direct contact after-cooler is produced in the chilled water tower (C171). Cooling water is chilled by direct contact with a portion of the low-pressure waste nitrogen exiting the cold box.

Following cooling, the air is fed to the Temperature Swing Adsorption (“TSA”) air purification system. This consists of two horizontal flow vessels (C182A/B), each containing a bed of adsorbent material to remove water, carbon dioxide and some hydrocarbons from the air, resulting in a clean, dry air stream. The vessels operate on an alternating cycle. One vessel adsorbs impurities from the feed air while the other is regenerated with nitrogen-rich waste gas. During regeneration, the waste nitrogen is heated via an electric heaters (E182) running in parallel. Before regeneration, the bed is depressurized, the gas being vented to atmosphere via a silencer.

Most of the air is sent directly to the main heat exchanger (E201), but a fraction passes through the a centrifugal-type booster air compressors (“BAC”) (K131). The booster air compressor provides higher pressure air streams to condense against the boiling oxygen products in the main heat exchanger (E201). One stream at high pressure and the oter at intermediate pressure. The air used to drive the expander is also taken from the intermediate stage of the booster air compressor. Inter-stage cooling and after-cooling is done with cooling water in shell and tube exchangers.

### 4.1.2 Heat Exchanger and Refrigeration

The dry air sent directly to the main low-pressure heat exchanger (E201) is cooled to near its dew point against product streams and waste nitrogen. This air stream feeds the bottom of the high-pressure column (C211). Air from the discharge of the booster air compressor enters the main heat exchangers (E201). This higher-pressure air is cooled and condensed against boiling liquid oxygen before being let down in pressure and sent to the high-pressure column. The majority of the refrigeration for the process is generated in the compander (K261). Intermediate pressure air from the booster air compressor is cooled to cryogenic temperature in the main heat exchanger (E201) and expanded to the high-pressure column (C211) in expander section of the compander (K261).

### 4.1.3 Air Distillation System

#### 4.1.3.1 High Pressure Column

The gaseous air is fed to the high-pressure column (C211). As it rises through the distillation packing, the air boils the liquid on the packing. The more volatile nitrogen is boiled out of the liquid while the exchange of latent heat condenses oxygen out of the vapor air passing up through the packing. Thus, the vapor increases in nitrogen content as it rises up the column, becoming high purity nitrogen (“GAN”) at the top of the high-pressure column.

The liquid in the sump of the column becomes enriched with oxygen. The high purity nitrogen at the top of the high-pressure column is condensed in the reboiler/condenser (E213), which is located in the bottom of the low-pressure column (C212). Part of this pure liquid nitrogen (“LIN”) is withdrawn and after getting subcooled in the LIN subcooler, part of it is transferred to the liquid nitrogen storage tank as product and the remaining is sent as reflux to the top of LP column (C212). The remainder is used as reflux in the high-pressure column (C211). A part of LIN from top of HP column (E211) is sent to the pure argon column condenser (E462), where it is boiled to provide reflux in the pure argon column (C461); the vapor being sent to the main waste nitrogen stream.

Impure liquid nitrogen is withdrawn from the high-pressure column. After getting subcooled in LIN Subcooler (E222) this Impure liquid nitrogen is fed as reflux to LP Column (C212).

Lower down the high-pressure column, liquid air is withdrawn. This is subcooled in LOX Subcooler (E221) against Waste and injected below the top section of the low-pressure column (C212). Crude liquid oxygen exits at the bottom of the high-pressure column and is fed to the argon column condenser (E401). It is partially boiled against condensing crude argon, with both vapor and liquid crude oxygen being fed to the low-pressure column.

#### 4.1.3.2 Low Pressure Column

The low-pressure column feed streams are distilled into a nitrogen vapor rising to the top of the column and high purity liquid oxygen descending to the bottom of the column through a vapor-liquid contact process similar to that in the high-pressure column. Liquid oxygen (“LOX”) from the low-pressure column is subcooled and transferred to the liquid oxygen storage tank.

A vapor stream is taken from the middle of the low-pressure column and fed into the bottom of the argon column (C401). At the top of the low-pressure column, a nitrogen-rich waste stream is withdrawn. It is warmed in the main heat exchangers (E201) and used to regenerate the temperature swing adsorbers and to provide feed to the chilled water tower. Above this off take an additional section of the low-pressure column purifies the vapor to be warmed in the main heat exchangers (E201) and used as a low pressure nitrogen product.

#### 4.3.1.3 Argon Purification

The argon column (C401) removes any oxygen from the argon product. The vapor feed from the low-pressure column is refluxed by the liquid condensed in the argon column overhead condenser (E401) at the top of the argon column. The oxygen free vapor from the top of the argon column is condensed in the E413 argon product condenser and fed to the pure argon column (C461).

The pure argon column is used for nitrogen rejection. Column boil-up is provided by the pure argon column reboiler (E461) at the bottom of the column by condensing a small amount of GAN drawn from the High-pressure column. Argon vapor vented from the pure liquid argon storage tank is recovered and reprocessed in the pure argon column. Pure liquid argon (“PLAR”) is taken from the bottom of the pure argon column (C461) and transferred to the liquid argon storage tank. Rejected nitrogen is vented from the top of the pure argon column, the argon being mostly re-condensed against boiling liquid nitrogen from the high-pressure column.

### 4.1.4 Product Delivery

#### 4.1.4.1 Gaseous Oxygen (GOX)

Liquid oxygen is pumped from the Low-Pressure Column to the gaseous oxygen delivery pressure by the LOX product pump (G231A/B). A portion of this stream is let down in pressure to the MPGOX delivery bressure. Both LOX streams are boiled in the main heat exchangers (E201) against the condensing high pressure air and intermediate pressure air from the booster air compressor, before being delivered as gaseous products.

#### 4.1.4.2 Gaseous Nitrogen (GAN)

GAN from the low-Pressure column (C212) is compressed in the GAN Compressors (K701) to an intermediate pressure then joined with GAN from the HP column before compression to the final product pressures in K702. K702 has an intermediate take-off to supply the 0.6 MPa GAN. When additional HP GAN is required the Auxilliary GAN compressor is used to supplement K702. All compressor are driven by electric motors.

#### 4.1.4.4 Liquid Products

The ASU produces liquid oxygen, liquid nitrogen and liquid argon which are transferred to storage tanks.