1. Process description

1.1. General

All information and data in this manual is to be taken as confidential. Any figures are preliminary and subject to confirmation during plant commissioning.

The air separation plant is designed to run the following cases at guarantee conditions (ambient temperature 12 °C, relative humidity 65 %, cooling water temperature 16 °C):

Operating cases			Normal	Max LOX	Max LIN	Max GOX	Min GOX
AIR	flow	Nm^3/h	97.000	97.000	97.500	98.500	73.000
HP GOX	flow	Nm^3/h	20.000	17.000	20.000	25.000	11.000
	pressure	bara	28	28	28	28	28
	purity	% O_2	99,5	99,5	99,5	99,5	99,5
HP GAN	flow	Nm^3/h	3.500	3.500	3.500	3.500	3.500
	pressure	bara	21	21	21	21	21
	purity	ppm O_2	10	10	10	10	10
MP GAN	flow	Nm^3/h	29.500	29.500	29.500	29.500	29.500
	pressure	bara	7	7	7	7	7
	purity	ppm O_2	10	10	10	10	10
GAR	flow	Nm^3/h	240	240	240	240	240
	pressure	bara	21	21	21	21	21
	purity	ppm O_2	2	2	2	2	2
	purity	ppm N_2	5	5	5	5	5
LOX	flow	Nm^3/h	0	3.000	0	-5.000	4.000
	purity	% O_2	99,5	99,5	99,5	99,5	99,5
LIN	flow	Nm^3/h	0	0	3.000	4.200	-700
	purity	ppm O_2	10	10	10	10	10
LAR	flow	Nm^3/h	430	450	360	360	210
	purity	ppm O_2	2	2	2	2	2
	purity	ppm N_2	5	5	5	5	5

Note: In this manual Nm^3 is defined at 0 °C and 1.013 bar. If not mentioned explicitly pressures are given as absolute pressure.

The ASU is designed to be operated permanently manned by shift personnel. A minimum supervision and operation, mainly from the control room, is necessary. During extraordinary operational modes such as drying, thawing, cool down or in case of a malfunction in the plant the operator will make adjustments using the DCS or directly operate the instrumentation in the field. It should be noted that all adjustments in the field or via the DCS as well as all maintenance work on the plant must only be carried out by specially trained personnel. Thus it is assumed that all adjustments - including adjustments to seldom operated valves etc. - will be carried out using appropriate tools and in agreement with the relevant health and safety regulations.

If plant parameters are not according to design, products are led to dump or in case of dangerous plant states single units or even the whole plant will shut down automatically to a safe position.

For process control, process visualisation and alarm management a DCS is installed. The plant has to be operated by on-site personnel all the time.

The air separation unit consists mainly of the following components:

- Air compression
- Air cooling and purification
- Air separation and liquefaction
- Gaseous product handling
- Storage tanks and back-up
- Utilities

1.2. Air compression and purification

The process air is cleaned from dust and other particles in an air filter system F10001 and then compressed to the required process pressure by a multi-stage, intercooled turbo compressor MAC (main air compressor), V11000.

After the last compressor stage the process air is cooled down in a direct contact aftercooler (DCAC, W13001). This cooler is fed by cooling water and chilled water from the chill tower W14001 and the refrigeration unit KA12001.

The air purification system comprises two cyclic operating adsorber vessels A15001/2 filled with activated alumina and molecular sieve adsorbent. To remove water, CO2 and potentially hazardous hydrocarbons the process air passes through one of the vessels. Simultaneously, the other adsorber vessel is regenerated by waste nitrogen leaving the cold box. The regeneration cycle is divided into two main steps. In the first step, the regeneration gas is heated in a steam driven heater (W15001) prior to entering the adsorber unit to improve the desorption process. In a second step, the heater is bypassed to cool down the adsorbent and the vessel to ambient temperature. After the completion of the regeneration sequence, the adsorber is pressurised before being switched over to the adsorption cycle.

One part of the air stream leaving the molecular sieve station is fed directly to the main heat exchanger W20000. A small part of the dry and clean air is withdrawn as instrument air. The remainder is compressed by the booster air compressor (BAC, V16000) and also fed to the main heat exchanger.

1.3. Air separation and liquefaction

The compressed air leaving the BAC enters the main heat exchanger and is cooled to an intermediate temperature. At this point a side stream is withdrawn and directed to the expansion turbines ET24101 and ET24201. To produce partially liquefied air, the remaining high pressure air is cooled further in the main heat exchanger before being expanded in the Joule-Thomson valve. The air from the molecular sieve unit is also cooled in the main heat exchanger. It is mixed with the exhaust of the turbines and the vapour fraction of the air downstream of the air separator B21001 and then directed to the high pressure column (HPC) K21001.

The liquid air stream from the air separator is divided with one part entering the high pressure column. The other part of the liquid air is cooled further in subcooler W23001 before being flashed into the low pressure column (LPC) K22001.

In the high pressure column the air is pre-separated into pure nitrogen, withdrawn from the top, and an oxygen enriched liquid at the bottom. The pure nitrogen, GAN, is condensed against boiling oxygen in the main condenser W21001 and fed as a liquid to the LIN-separator B21002. Most of the LIN is recycled to serve as reflux for the high pressure column. A portion however is withdrawn and either fed via the subcooler to the liquid nitrogen storage tank B72001 or as reflux to the low pressure column. Another part is sent to the LIN IC pump P71100/200 and vaporised in the main heat exchanger to serve as gaseous nitrogen product (HP GAN).

The oxygen enriched liquid from the bottom of the high pressure column is cooled in the subcooler and flashed into the crude argon condenser B40001/W40001. In this condenser, the liquid is vaporised to provide reflux for the crude argon column K40001/2 and passed on to the low pressure column as gaseous crude oxygen feed. The remaining liquid is withdrawn from the crude argon condenser and directed to the low pressure column. This provides a purge stream which helps to avoid hazardous hydrocarbon concentrations in the bath of the crude argon condenser.

In the low pressure column the remaining air separation takes place. A pure nitrogen gas is obtained from the top. This stream passes the subcooler and the main heat exchanger to be fed as LP GAN to the nitrogen product compressors providing MP GAN product. Further down the column waste nitrogen is withdrawn, brought to ambient temperature in the subcooler and main heat exchanger and used as regeneration or cooling gas for the molecular sieve unit and the chill tower.

The pure oxygen product from the bottom of the low pressure column is compressed by LOX IC pump P61100/200 and vaporised in the main heat exchanger to provide the gaseous oxygen product (HP GOX). A portion of the liquid that is withdrawn from the sump of the low pressure column is fed to the liquid oxygen storage tank B62001.

1.4. Argon Recovery and production

In the lower part of the low pressure column a zone of argon enriched oxygen gas exists. This gas is used as feed stream for the crude argon column K40001/.2. In this column the oxygen is removed by cryogenic rectification. The crude argon product withdrawn at the top has the required product purity in terms of oxygen.

Reflux for the crude argon column is provided by condensing the gaseous crude argon top product (poor in oxygen) in heat exchange against rich liquid from the high pressure column in the crude argon column condenser. Liquid is withdrawn from the sump and transferred to the low pressure column by argon pump P40100.

A small fraction of the crude argon (poor in oxygen) is withdrawn as a liquid from the crude argon condenser and is fed to the pure argon column K43001. In the pure argon column nitrogen and non-condensable components are removed. The top gas from the pure argon column is liquefied in the pure argon condenser W43002 and provides reflux for the rectification. In order to purge nitrogen from the column, part of the top gas is vented to atmosphere. Liquid argon in the sump of the pure argon column is vaporised against air in the reboiler W43001 and serves as vapour flow for the column. Pure liquid argon is withdrawn from the sump of the pure argon column and passes on to the storage tank B44101 and B44201.

1.5. Gaseous product handling

The HP GOX flow from the main heat exchanger controls the pressure in the customer supply pipe. Additional oxygen will be supplied from the back-up if the line pressure to the customer is too low.

A similar arrangement has been provided for the gaseous nitrogen to the customer.

The HP GAN flow from the main heat exchanger controls the pressure in the customer supply pipe. Additional nitrogen will be supplied from the back-up if the line pressure to the customer is too low.

The LP GAN flow from the main heat exchanger is sent to the nitrogen product compressors. After compression it serves as MP GAN product Additional MP GAN will be supplied from the back-up if the line pressure to the customer is too low.

1.6. Storage tanks and back-up

1.6.1. Argon

Liquid argon is stored in the low pressure tanks B44101 and B44201. From there it is transferred via the back-up pump P48100 to the HP argon tank B48001. The high pressure argon is vaporised in the ambient air vaporisers W48101 and W48201 and send to the customer. The vaporised argon serves as product supply to the customer.

Pump P44001 is used for road tanker filling from the low pressure tanks.

1.7. Utilities

1.7.1. Cooling water system

The cooling water system is there to remove heat from the machines and the process. Cooling water is supplied by the customer.

1.7.2. Instrument Gas

A clean and dry medium free of oil and grease is required for operating various instruments. For this purpose air is withdrawn after the molecular sieve unit. Back-up instrument gas is supplied by the customer.

1.7.3. Seal gas and cold box purge

The cold box has to be purged continuously with dry nitrogen gas to avoid moisture ingress and local air liquefaction. The nitrogen gas is supplied either from the ASU or the nitrogen gas header.

1.7.4. Steam

Steam is supplied by the customer as a source of heat to vaporise liquid products for back-up purposes and to heat gas for the molecular sieve regeneration. Steam is also used in the liquid dump vaporiser.

1.7.5. Liquid dump vaporiser

The plant is equipped with a steam driven vaporiser to dispose of cryogenic liquids like the liquid inventory from the cold box.