4. Start-up

4.1. General

It is important to notice that the start-up procedure differs depending on the plant state. One condition is the start-up from warm which applies for the initial start-up during commissioning, after plant thawing, repair works or similar actions. The other one is the cold condition after a short plant stop with liquids being kept inside the cold box. This procedure is detailed in the following lists.

The following sequences are not final. They may be changed when better procedures are found during operation of the plant. These changes should be noted in this manual. Always check and follow vendor operating manuals in addition to the listed procedures.

Nomenclature:

Y	output of controller (e.g. valve position)
W	set-point of controller
X	actual value of controller (normally measurement)
auto	automatic mode of controller
man	manual mode of controller (output can be changed)

4.2. Preparations

Before starting the plant the following conditions have to be fulfilled:

- The plant is mechanically complete.
- Any temporary installation, construction, support etc. has been removed.
- The electricity supply is available.
- All measurements have been checked.
- All control system loop checks have been performed.
- All valves have been checked.
- A leak test of the entire plant has been done.
- A complete P&ID check has been carried out.
- Calibration gases for the analysers are available.
- Compressors, pumps and the cooling water system have been prepared.
- Instrument gas is available.

A list of controller positions (set-points and limits) eases the definition of a start setting. Before using any controller it has to be made sure that it is configured properly (parameters, etc.)

It is useful to record changes made and positions used during the start-up including the time. A form with plant measurements and settings should be prepared to record the start-up behaviour.

4.3. Cold Box Purge

To avoid air ingress into the cold boxes a constant positive nitrogen pressure is required inside the cold boxes. Attention must be paid not to increase the pressure too close to the pressure relief device setting.

Step	Activity	Name	Item	Value
1	Adjust pressure controller:			
	PCV87011	P87012	X	100 mbar
2	Adjust purge flow			
	Set purge flows through:			
	V87020	F87020	X	5 Nm^3/h
	V87021	F87021	X	5 Nm^3/h
	V87060	F87060	X	5 Nm^3/h
	V87061	F87061	X	5 Nm^3/h
	V87062	F87062	X	5 Nm^3/h
	V87063	F87063	X	5 Nm^3/h
	V87064	F87064		5 Nm^3/h
	The start-up of the box purge lines cannot be done simultaneously. Because they affect each other all pressures and flows must be checked regularly during start-up.			

Remarks:

1. The given flows are estimates only and have to be adjusted to provide a positive pressure inside the cold boxes which is below the pressure relief device settings (approximately 1 mbar) and should not be high to prevent valves icing because of N2 blowing through leaks.
2. For the cold box purge only dry nitrogen with an oxygen content of less than 3% must be used to make sure that no oxygen will condense at the cold parts of the plant i.e. at the subcooler or the upper part of the low pressure column. The perlite, which is used as isolation material for the cold box has a capacity to store liquid – and liquid oxygen inside the perlite room constitutes a hazard for the operation of the cold box. Thus the box atmosphere must be checked on a regular basis.

4.4. Instrument Air, Seal and Purge Gas

Step	Activity	Name	Item	Value
1	Adjust N2 purge and seal gas back-up supply on PC81041	PC81041	W	4 barg
2	Adjust N2 purge and seal gas supply on PC81040	PC81040	W	4.5 barg
3	Adjust instrument air back-up supply on PC82020	PC82020	W	3.5 barg
4	Adjust oxygen seal gas supply on PC81020	PC81020	W	5 barg
5	Adjust nitrogen seal gas supply on PC7180	PC71180	W	8 barg

Remarks:

4.5. Cooling Water System

Step	Activity	Name	Item	Value
1	Cooling water total flow to ASU9	F80001		1700 Nm^3/h

Remarks:

Cooling water is supplied from the existing cooling water system. Sufficient flow to each consumer has to be ensured.

4.6. Main Air Compressor

Step	Activity	Name	Item	Value
1	Reset trip			
	main air compressor	HS11000		reset
	DCAC	HS13000		reset
2	Check oil system			
	oil pressure	P11854	X	> 1.2 bar
	oil temperature	T11854	X	30 - 50 °C
3	Check cooling water is running			
4	Make sure that the inlet valves of the molecular sieve are closed			
	UK15011 closed	G15011		closed
	UK15021 closed	G15021		closed
	UK15018 closed			
	UK15028 closed			
5	Establish "ready to start" conditions (see "Start conditions" screen).			
6	Switch on air compressor	HS11001		ON
7	After running in steady conditions			
	open inlet guide vane slowly to	F15035	Y	35 %
	close manual controller of blow-off	H11074	Y	0%
	close blow-off slowly until outlet pressure is reached	H11074	Y	decrease
	adjust pressure controller set-point	P11041	W	4.8 barg
	and switch to automatic mode			AUTO
8	Check oil pump and heater have been switched off automatically Check oil and bearing temperatures Check vibrations Check cooling water outlet temperatures			

Remarks:

Check vendor operating manual for start-up preparations and procedures.

4.7. DCAC

Step	Activity	Name	Item	Value
1	Reset trip DCAC	HS13000		reset
	Make sure the MAC is running on pressure control and delivering enough pressure	P11041	X	>4 barg
2	Check inlet manual valve of the pump which will be started is open.			
	Check that the outlet valve is closed (in order not to have air coming from the DCAC tower (which is at >4 barg) to the pump.			
	Make sure there is no air in the pump by opening the drains and vents valves of the pump.			
3	Close FK13007	F13007	Y	0%
4	Set level controller	L13003	W	30%
		L13003		AUTO
5	Switch on water pump	HS13100 or		
	When pump is started and building pressure, open quickly outlet manual valve.	HS13200		ON
6	Open FK13007	F13007	Y	adjust
	until required flow is met	F13007	X	180 m^3/h
	and set to automatic	F13007		AUTO
		F13007	W	210 m^3/h

Remarks:

Monitor the water level for proper controller function during level build-up.

Switch DCAC pumps regularly.

4.8. Chill Tower

Step	Activity	Name	Item	Value
1	Reset trip	HS14000		reset
2	Check inlet and outlet manual valves of the pump which will be started are open. Make sure there is no air in the pump by opening the drains and vents valves of the pump.			
3	Close FK13006 Close FV12005	F13006 F12005	Y Y	0% 0%
4	Set level controller	L14003 L14003	W	50% AUTO
5	Switch on water pump	HS14100 or HS14200		ON
6	Open FK13005 until required flow is met and set to automatic	F13005 F13005 F13005 F13005	Y X W	adjust 45 m^3/h AUTO 45 m^3/h
7	Open FK13006 until required flow is met and set to automatic	F13006 F13006 F13006 F13006	Y X W	adjust 33 m^3/h AUTO 33 m^3/h

Remarks:

Monitor the water level for proper controller function during level build-up.

Switch chill tower pumps regularly.

4.9. Refrigeration Unit

Step	Activity	Name	Item	Value
1	Chilled water pumps are running at design conditions	P14100/200		ON
	Chilled water is flowing in recycle to chill tower and	F12005	X	45 m^3/h
	to DCAC	F13006	X	33 m^3/h
2	Cooling water to the unit is available			
	Chilled water bypass is closed			
3	Reset trip refrigeration unit	HS12001Re s		reset
4	Switch on refrigeration unit	HS12001		ACTIVE
	Make sure the chilled water temperature is high enough	T13026	X	> 5°C
	by either changing the flow to the DCAC	F13006	W	increase
	or by injecting warm water into the chill tower	T12003	W	increase

Remarks:

Check vendor operating manual for start-up preparations and procedures.

4.10. Molecular Sieve Adsorber (MSA)

Step	Activity		Name	Item	Value
1	Reset MSA trip: the molecular sieve will automatically start to pressurise the bed which is going on-stream (adsorption)		HS15000		reset
2	Wait till the pressurisation is finished and check that the valves are in correct position.				
	When pressurisation is complete, switch ON the sequence		HS15001		ON
	then put P15037 in auto		P15037	W	200 mbarg
3	Then switch ON Air Regeneration to get regeneration gas flow.		HS15006		ON
4	Make sure steam for the heater is available. Make sure that manual valve **K15042 is close**. It is mandatory to close this valve to avoid to withdraw cold gas at the waste warm end of main exchanger.				
	Adjust :				
	regeneration gas flow	AUTO	F15041	W	19,000 Nm^3/h for heating and 20,000 Nm3/h for cooling.
	regeneration gas temperature	AUTO	T15043	W	200°C
5	Later, when air flow is established through main exchanger of cold box and P15041 is in AUTO at operation value, manual valve K15042 must be reopened . Temperature of the warm end of exchanger must be checked closely during this operation.				

Remarks:

1. The large butterfly valves in the molecular sieve skid are of the three lever valve type. This means they are only closing tight in one direction (indicated by the P →) and that they cannot open against that direction if the pressure difference between in- and outlet of the valve is greater than about 0.3 bar.

4.11. Booster Air Compressor

Step	Activity	Name	Item	Value
1	Reset the trip BAC Make sure the molecular sieve is running	HS16000		reset
2	Check oil system			
	oil pressure	P16855	X	> 2 bar
	oil temperature	T16854	X	45 - 50°C
3	Check cooling water is running			
3 bis	Close cooling water on the oil cooler			
4	Check seal gas pressure is sufficient	P16751	X	70 mbarg
5	Close BAC discharge valves	HK16073		close
		HV16071	Y	0%
	and cold box valves	UK20026		close
		UK20027	Y	0%
6	Pressurise BAC slowly and open PK16007 at 100% when pressure is equal to the pressure in the mole sieve	PK16007	Y	open
7	Establish "ready to start" conditions			
8	Switch on booster air compressor	HS16001		ON
9	After running in steady conditions			
	Open cooling water on oil cooler			
	open inlet guide vane slowly to	U16010	Y	15 %
	close H16074 controller	H16074	Y	0%
	close recycle valve slowly until required pressure is reached	U16074	Y	decrease
	adjust pressure controller set-point	P16045_1	W	56 barg
	and switch to automatic mode	P16045_1		AUTO
10	Check oil pump and heater have been switched off automatically Check oil and bearing temperatures Check vibrations Check cooling water outlet temperatures Check suction valve is fully open	PK16007	Y	100%
11	Set pressure protection controller set point and turn it to automatic mode	P16045_2	W	58 barg AUTO

Remarks:

Check vendor operating manual for start-up preparations and procedures.

4.12. Cold Box Pressurisation and Set-up

Before pressurising the cold box all drain, vent, defrost, product and control valves in and around the cold box must be closed.

Step	Activity	Name	Item	Value
1	Check all front end equipment is running properly and reset cold box trip. Make sure that the turbines have seal and purge gas and their oil pumps and demister fans are running.	US2000		reset
2	Check all process and product valves beyond MSA and BAC are closed. In particular make sure that the turbine and pump inlets are shut.	UK24101 UK24201 HV61110 HV61210 HV71110 HV71210 HV40110		closed closed closed closed closed closed closed
	Make sure that all automatic valves between HP and LP system are closed to isolate the HP-column. Open all manual valves of turbines. Open all manual valves of pumps except production valves. Open side arm gas valve to CrAr column Adjust crude argon pressure controller and switch to automatic.	PK40003 P40003 P40003	 Y W	100% 500 mbarg AUTO
3	Adjust LP column pressure controller and switch to automatic	P15041 P15041	W	500 mbarg AUTO
4	Open cold box pressurisation valve stepwise and monitor HP and LP column pressure After pressure equalisation open cold box inlet valve	UK20027 UK20026	Y	100% open
5	Increase flow to LP system by slowly opening LIN reflux valve LAIR reflux valve CLOX to CrAr condenser valve CLOX to LP column valve gradually to a maximum of 70% open gas lifts 2 turns Observe LP column pressure is kept at approx.	 F22013 L21060 L21003 L40007 V21017 V22015 V40010 P22001	 Y Y Y Y X	 increase increase increase increase 500 mbarg
6	Slowly pressurise pure argon column and put pressure controller into automatic	F40014 P43022 P43022	Y W	increase 400 mbarg AUTO
7	Slowly pressurise pure argon column condenser and put pressure controller into automatic	PD43021 P43028 P43028	Y W	increase 1.5 barg AUTO
8	Slowly pressurise the high pressure air system. The JT valve is closed during pressurisation. After pressure equalisation open BAC discharge and gradually establish flow through the JT-valve	HK16073 T20008 HK16073 T20008	Y Y Y Y	increase 0% 100% 50%

Step	Activity	Name	Item	Value
9	Slowly pressurise LOX pump via recycle line	P61170/270	Y	100%
	and start flow through the main exchanger.	F20012	Y	increase
	The product valve is closed.	F20011	Y	0%
10	Slowly pressurise LIN pump via recycle line	P71170/270	Y	100%
	and start flow through the main exchanger.	F20002	Y	increase
	The product valve is closed.	F20001	Y	0%
11	Slowly start LP GAN flow through the main exchanger.	F20006	Y	increase
	The product valve is closed.	F20005	Y	0%
12	Slowly pressurise LAR pump via recycle line	P40170	Y	100%

Remarks:

This procedure covers pressurisation when the plant is warm. The pressure in the LP-column is kept at the indicated high level to facilitate being able to put a significant amount of gas through the GOX - passages of the main heat exchanger.

4.13. Blow through

Purpose of the cold box blow through is to remove particles from the air separation unit which have been accumulated during fabrication and assembly of the equipment and piping. The following points give guidance for performing the blow through. Locations which cannot be blown through must be cleaned by other methods like sweeping, flashing, wiping etc.

- After a period of 15 – 20 minutes steady blow through at high velocity (30 - 40 m/s) sufficient cleaning of the respective circuit can be assumed.
- The blow through should be conducted with dry and clean air from the MSA.
- In general the blow through should be performed in such a manner that particles are not blown into equipment like heat exchangers, columns or machines.
- Special care has to be taken at the cold box inlets. These pipes are normally made of carbon steel and therefore prone to corrosion. The cold box inlet flange is spread and some sort of barrier such as a wooden board is placed over the cold box inlet to prevent particles from entering the cold box pipe.
- Bursting disks are used to conduct a blow through when a valve is not available. A piece of cardboard or plastic is used to cover the open section of the piping to be blown. A blind flange with a centre circle cut out covers the cardboard or plastic. The piping is pressurised until the bursting disk ruptures. Sometimes the cardboard has to be slightly scored to help it burst. Depressurise the piping before scoring the disk. Clamps can be put on the flange to help prevent leaks around the disk. The procedure is repeated until the line is clear of debris. If this cannot be determined visually a target made of cardboard or gasket material can be used.
- The turbine and all pumps have to be protected against uncontrolled spinning by suitable valve opening sequences, by disconnecting attached piping or spin protection devices.
- Flexible hoses at pump flanges should be disconnected and used for venting.
- Instrument piping must only be blown through and dried after all other equipment has been cleaned.
- The pressure in each circuit has to be controlled such that lifting of safety valves is avoided.
- All filters and strainers must be cleaned after the blow through is completed.

- To conduct the blow through in a systematic manner mark up the P&ID showing the flow circuits and the valve positions.
- After liquid levels have been build for the first time all liquid have to be drained from the plant to remove collected particles. Subsequently all filters must be cleaned.

4.14. Cold Box Drying

Drying of the equipment is required to remove traces of moisture and CO_2 from all cold box equipment, i.e. heat exchangers, columns, piping and other vessels, before it is cooled down to cryogenic temperatures. The following general points should be noted.

- Drying should be conducted with dry and clean air from the MSA.
- Drying is completed when the moisture content of all vented streams is below 3 vppm, equivalent to -70°C dew point temperature. This can be measured by a mobile moisture analyser, a Dräger moisture test tube or equivalent.
- The pressure in each circuit has to be controlled such that lifting of safety valves is avoided.
- The plant has to be dried in sequential steps. It must be made sure that already dried circuits are not subsequently exposed to wet air.
- Under any circumstances it must be avoided to feed wet air into the regeneration piping to the MSA. Hence the manual valve in this line is to be closed until the cold box is dry.
- In case of an interruption of the drying process all connections to ambient must be closed.
- Where no dry air flow can be forced through equipment, e.g. condensers, the surrounding vessel should be repeatedly pressurised and depressurised to purge the passages concerned.

To conduct the drying in a systematic manner mark up the P&ID showing the flow circuits and the valve positions.

4.15. Gas Expansion Turbines

The start-up is described for a single turbine. The second identical unit is to be handled accordingly.

Step	Activity	Name	Item	Value
1	Make sure that the starting conditions are fulfilled and trip reset Check that generator switch is engaged	HS24100		reset
2	Close inlet nozzles Make sure that the oil pump is running, seal gas is available, manual isolation valves are open and defrost, purge and drain lines are closed.	F24101 H24105 K24110 K24102	Y Y	0 % 0 % open open
3	Open quick shut-off valve	HS24101		on
4	Open FV24101 to 20% in on shot (MIN selector) Then slowly open inlet nozzles to speed up the turbine Minimum speed 500 rpm must be achieved within the defined time (30 seconds). The generator will automatically switch on at operating speed Increase load until generator power is positive (trip if < 5 kW for 30s).	F24101 S24124	Y X	increase 36,000 rpm
5	Adjust turbine flow to the required cold production	F24101	Y	adjust
6	Make sure that the turbine is not operated at too low inlet temperature to keep away from liquid creating at the discharge. To avoid liquid formation adjust the JT-valve to increase the inlet temperature. If an increase in inlet temperature is followed by an increase in discharge temperature there is no liquid at the turbine outlet.			

Remarks:

Check vendor operating manual for start-up preparations and procedures.

4.16. Cool Down

Before cooling the plant down to cryogenic temperatures moisture and CO_2 must be removed from the equipment. Otherwise some passages in heat exchangers, columns or piping can get blocked by solid H_2O or CO_2.

Make sure that as much air as possible is guided through the cold box. To achieve this set up the main valves to the LP column to manual with a maximum opening of 70%. The pressure in the LP column should be kept at about 0.5 barg to encourage flow through the IC GOX passages. Make sure that the outlet and recycle valves of the LOX and LIN process pumps are fully open and that the pressure controller is able to maintain the desired pressure in the LP column. The turbine air flow must be manually controlled to avoid cooling down the plant too quickly. The ASU must not be cooled down any quicker than 30 K per hour. Adjust the JT-valve to control the inlet temperature to the turbine. In the beginning only a limited air flow can be fed to the plant. The flow can be increased as the plant is cooled down.

During the cool down temperature differences within equipment have to be kept to a minimum. For plate fin heat exchangers a limit of 30 °C applies within a cross section. Another limit is the cool down rate which must not exceed 30 °C/h. Particular care must be taken where no flow can be forced through equipment, e.g. condensers. In order to slow down the cooling process either take back turbine flow or open a vent in the vicinity of the part of the plant that is cooling down too quickly.

While cooling down adjust the various reflux, bypass and drain lines suitably to ensure that the equipment cools down as uniformly as possible. Continuously monitor the heat exchanger and column temperature indicators to check the progress. As the plant cools down it will be necessary to load the main air compressor further in order to maintain the pressures.

Monitor the temperature and pressure at the turbine inlet. From there outlet conditions can be calculated. The formation of liquid at the turbine outlet must be avoided under any circumstances.

The cooling speed is essentially controlled by the temperature gradient of the HP LOX passage, since this has the smallest cross section. For accelerating the cooling procedure the dump valves behind the LOX IC pumps and the LOX product to dump can be opened. This is to increase the flow rate through the low pressure column. Keeping the pressure in low pressure column high also supports the cool down speed. The control GOX should be fully open to encourage flow towards the sump of the low pressure column.

Cool down is completed after the dew point temperature has been achieved at the cold end of the main heat exchanger and liquid levels begin to build up.

At the end of the cool down all piping opened only for cooling the equipment down to cryogenic temperatures, e.g. all vents, must be closed.

4.17. Establish Liquid Levels

Once the first liquid levels appear start to decrease the pressure in the LP and CAR column to eventually reach the normal set-point. When liquid temperatures are reached level will start to build in the HP column. This is directly transferred to the LP column sump. Build up the level in the main condenser until it is fully submerged. Keep the HP column reflux valve HV21006 closed during the liquid build-up.

Once level is established at the main condenser, start building up liquid in the HP column by slightly opening the HPC reflux valve HV21006 (5%) and closing in on the CLOX valve LV21003. The increasing pressure drop in the HP column indicates the build-up of liquid inventory on the trays. Once the pressure drop has stabilised the HPC HV21006 reflux valve can be opened further. This procedure is repeated until the reflux valve is fully open. Make sure that the level in the main condenser does not drop below 90% while filling the high pressure column. Once the normal level is reached in the HP column sump, set the level controller to AUTO and start to build up level in the condenser of the crude argon column. While increasing the level in the crude argon condenser throttle LV40007 and keep the reflux to the CAR column FV40011 closed.

The levels in the main condenser and in the crude argon condenser should be build up as quickly as possible to avoid dry boiling in the heat exchangers.

The level in the air separator is established by reducing the liquid air flow to the HP column (HV21014) to approximately 30% and setting the level controller LV21060 to automatic mode.

Open the vents at the condensers for a few minutes to release the non - condensable gases.

Monitor the pressure levels during the entire process and try to keep the conditions constant. Also keep an eye on the main air compressor and booster air compressor to avoid operating at the surge limit. During the cool down the air flow to the cold box will increase continuously. The MAC inlet guide vanes have to be adjusted accordingly. For an even distribution in the main heat exchanger adjust the GAN flow to keep the GAN/WN flow ratio constant. The air flow should be limited to about 70% of the design air flow.

To assist the process LIN can be injected from the tank. LIN inject must only be used after liquid level has been build in the main condenser. Otherwise high temperature differences may lead to excessive tensions in the equipment. After cooling down the LIN assist piping liquid nitrogen is fed to the top of the HP column.

4.18. Cold Box Operation

Step	Activity	Name	Item	Value
1	After building the liquid inventory, the levels in the HP column, main condenser, air separator and crude argon condenser are brought to normal operating values	L21003 L22001 L21060 L40007	X X X X	30% 102% 60% 102%
	Afterwards set all level controllers to AUTO The HP column reflux valve is open			
2	Gradually reduce WN pressure controller and start MSA regeneration with WN	P15041 HS15006 K15042	W	140 mbar OFF open
	Set MAC flow and switch to automatic mode	F11070 F11070	W	75,000 Nm^3/h AUTO
3	HP column Open liquid air to HP column Adjust LIN reflux to achieve HP column purity	HV21014 F22013 Q21002	Y W X	30% adjust < 10 ppm
	and set to automatic mode	F22013		AUTO
4	Set Joule-Thomson valve	T20008 T20008 T20008	X W	adjust -168°C AUTO

Remarks:

4.19. HP GOX production

The start-up is described for a single pump. The second identical unit is to be handled accordingly.

Step	Activity	Name	Item	Value
1	GOX vent valve is closed.	FV20012	Y	0%
	GOX product valve is closed.	FV20011	Y	0%
	Manual production valves at LOX IC pumps are closed.	V61152		Closed
	Manual recycle valves at LOX IC pumps are open.	V61171		Open
	Drain and defrost valves are closed.			
	BAC is operating at design pressure.			
	Establish start conditions.			
2	Cool down LOX pump.	HS61101		ON
	Make sure the outlet temperature falls below maximum value for a period of time before attempting to start the pump.	T61130	X	< -150°C
3	Adjust pump discharge pressure.	P61170	Y	28,3 barg
	Start pump after permission is given.	HS61101_S		ON
	!!! Do not run pump against a closed valve as a minimum throughput is required!!!			
4	Check JT valve is in automatic mode.	T20008		AUTO
5	Slowly open manual production valve of the pump to pressurize GOX pipe.	V61152		open
	Open GOX vent valve slowly.	F20012	Y	increase
	Check JT valve controls works properly.			
	Check conditions around gas turbines are to design.			
6	Increase GOX flow to	F20012	X	14,000
	and when steady switch JT-valve and	T20008	W	Nm^3/h
	GOX flow to automatic mode.	F20012		-168°C
				AUTO
7	Start supply to customer once purity is steady.	F20011	Y	increase
	After reaching steady conditions switch controller to	F20011	W	14,000
	automatic mode.	F20011		Nm^3/h
		F20012	W	AUTO
		F20012		< F20011
				AUTO

Remarks:

Check vendor operating manual for start-up preparations and procedures.

For details about the split range controller please refer to the attachment.

4.20. HP GAN production

The start-up is described for a single pump. The second identical unit is to be handled accordingly.

Step	Activity	Name	Item	Value
1	HPGAN vent valve is closed. HPGAN product valve is closed. Manual production valves at LIN IC pumps are closed. Manual recycle valves at LIN IC pumps are open. Drain and defrost valves are closed. BAC is operating at design pressure. Establish start conditions.	FV20002 FV20001 V71152 V71171	Y Y	0% 0% Closed Open
2	Cool down LIN pump Make sure the outlet temperature falls below maximum value for a period of time before attempting to start the pump.	HS71101 T71130	 X	ON < -160°C
3	Adjust pump discharge pressure. Start pump after permission is given. !!! Do not run pump against a closed valve as a minimum throughput is required!!!	 HS71101_S	W 	21 barg ON
4	Check JT valve is in automatic mode.	T20008		AUTO
5	Open slowly manual production valve to pressurize HP GAN pipe. Open HP GAN vent valve slowly. Check conditions around JT-valve and gas turbines are to design and HP column purity is to specification.	V71152 F20002	 Y	open increase
6	Increase HP GAN flow to and when steady switch GAN flow to automatic mode.	F20002 F20002	X W	2,500 Nm^3/h AUTO
7	Start supply to customer once purity is steady After reaching steady conditions switch controller to automatic mode.	F20001 F20001 F20001 F20002 F20002	Y W W 	increase 2,500 Nm^3/h AUTO < F20001 AUTO

Remarks:

Check vendor operating manual for start-up preparations and procedures.

For details about the split range controller please refer to the attachment.

4.21. MP GAN production

The start-up is described for a single compressor. The second identical unit is to be handled accordingly.

Step	Activity	Name	Item	Value
1	LP GAN product valve is closed	FK20005	Y	0%
	Increase LP GAN flow by opening vent valve	FK20006	Y	increase
	and set to automatic control	F20006	W	20,000
		F20006		Nm^3/h
				AUTO
2	Open GAN product valve slowly,	FK20005	Y	100%
	adjust set point	F20005	W	20,000
	and switch to automatic mode	F20005		Nm^3/h
		F20006	W	AUTO
		F20006		< F20001
				AUTO
3	Reset trip GAN compressor	HS70000		reset
4	Check oil system			
	oil pressure	P70854	X	> ... bar
	oil temperature	T70854	X	... - ... °C
5	Check cooling water is running			
6	Open suction valve	HK70001	Y	open
	Close discharge valve	HK70036	Y	close
	and vent valve	HV70035	Y	close
7	Establish "ready to start" conditions			
8	Switch on compressor	HS70001		ON
9	After running in steady conditions			
	adjust setpoint of P70007	P70007	W	0,95 bara
	and switch it to automatic	P70007		AUTO
	open inlet guide vane slowly to	U70010	Y	... %
	close recycle valve slowly until outlet pressure is reached	U70074	Y	decrease
	adjust pressure controller set-point	P70035	W	6 barg
	and switch to automatic mode	P70035		AUTO
10	Check oil pump and heater have been switched off automatically Check oil and bearing temperatures Check vibrations Check cooling water outlet temperatures			
11	Open vent valve until purity is to specification	HV70035	Y	increase
		Q70035	X	< 10 ppm O_2
12	Start supply to customer by opening discharge valve	HK70036	Y	increase
	and product valve	HK77041	Y	increase

Remarks:

Check vendor operating manual for start-up preparations and procedures.

4.22. LOX production

Applicable when plant is running producing LOX.

Step	Activity	Name	Item	Value
1	Product valve is closed	L22001	Y	0%
	LP Tank inlet valve is closed	HV62051	Y	0%
	LOX LGCC valves are closed	LV22030	Y	0%
		HV63034		closed
	LP tank is ready for operation			
	LOX IC pump is running			
	Plant is producing LOX to dump			
2	Once purity has been achieved open product valves and	L22001	Y	10%
		HV62052		open
		HV62051	Y	open
	adjust dump valve to provide enough purge flow	L23076		decrease
4	When line to tank is cooled down, slowly open tank inlet	L22001	Y	increase
	and stop flow to dump vaporiser	L23076	Y	0%
5	When product flow and LP column are steady switch on level	L22001	W	100%
	controller	L22001		AUTO

Remarks:

4.23. LIN production

Applicable when plant is running producing LIN.

Step	Activity	Name	Item	Value
1	Product valve is closed	F23013	Y	0%
	LP Tank inlet valve is closed	HV72051	Y	0%
	LIN LGCC valves are closed	LV73001	Y	0%
		HV72053		closed
	LP tank is ready for operation			
2	Once purity has been achieved open product valve and	F23013	Y	10%
		HV72051	Y	open
	adjust dump valve to provide enough purge flow	F23073	Y	decrease
4	When line is cooled down, slowly increase production valve	F23013		
	and stop flow to dump vaporiser	F23073	Y	0%
5	When product flow is steady choose set point and switch on	F23013	W	... Nm^3/h
	flow controller	F23013		AUTO

Remarks:

4.24. LOX LGCC

Step	Activity	Name	Item	Value
1	Product valve is closed	L22001	Y	0%
	Manual isolation valve is open	V22002		open
	LP Tank inlet valves are closed	H62051&52	Y	closed
	LOX LGCC pump discharge valve is closed	HV63034		closed
	LGCC valve to LP column is closed	L22002	Y	closed
2	Cool down LOX LGCC pump	HS63001		ON
	Make sure the outlet temperature falls below maximum value for a period of time before attempting to start the pump.	T63001	X	< -150°C
3	Start pump after permission is given	HS63001_S		ON
	Adjust pump discharge pressure	P63033	X	increase
	and switch to automatic pressure control	P63033	W	4 barg AUTO
	!!! Do not run pump against a closed valve as a minimum throughput is required!!!			
4	Open LOX LGCC pump discharge (be carefull with the pump discharge pressure !)	HV63034		open
	carefully cool down and purge product pipe	V61108		increase
5	After sufficient purging close manual purge valve	V61108		close
	and slowly open LOX LGCC ASU inlet and adjust to stabilise main condenser level	L22002	Y	increase
6	When system is steady switch on level controller	L22002	W	100%
		L22002		AUTO

Remarks:

A sufficient amount of liquid storage has to be available before commencing the LGCC operation.

To satisfy the oxygen balance the GOX product flow has to be adjusted in proportion to the amount of LOX LGCC and air flow to the cold box. At the same time the additional refrigeration introduced by LOX LGCC has to be balanced with the turbine power and the LIN product flow.

4.25. LIN LGCC

Step	Activity	Name	Item	Value
1	Product valve is closed	F23013	Y	0%
	Isolation valve is open	V23014		open
	LP Tank inlet valve is closed	HV72051	Y	0%
	LIN LGCC valve is closed	HV73001	Y	0%
4	Open LIN LGCC isolation valves	V73011		open
		HV72053	Y	open
	carefully cool down and purge product pipe	V73081		increase
5	After sufficient purging close manual purge valve	V73081		close
	and slowly open LIN LGCC ASU inlet	HV73001	Y	increase

Remarks:

A sufficient amount of liquid storage has to be available before commencing the LGCC operation.

The additional refrigeration introduced by LIN LGCC has to be balanced with the turbine power and the LOX product flow. Simultaneously the oxygen balance has to be satisfied by adjusting the HP GOX product flow, the LOX product flow and the air flow to the cold box.

4.26. LAR production

Step	Activity	Name	Item	Value
1	HP column and LP column are operating steady with sidearm gas purity at about	Q40011	X	≈ 95% O_2
	Vent, product, reflux valves are closed	HK40012	Y	0%
		HV40005	Y	0%
		F40014	Y	0%
		F40011	Y	0%
	Feed throttle valve is open	P40003	Y	100%
2	Crude argon condenser is filled operating in automatic mode	L40007	W	102%
		L40007		AUTO
3	Start vapour flow to crude argon column	F40011	Y	increase
	Partially open vent to release non-condensable gases	HK40012	Y	10%
	Adjust GOX production to control sidearm gas purity As the condenser starts working the vapour flow and the differential pressure across the crude argon column increases. If the effect is too strong (flow > 5,000 Nm^3/h) close the reflux valve completely. After the system has settled start again.			
4	When level builds up in the crude argon column			
	Open LAR pump manual recycle valve	V40171		
	Close manual outlet valve	V40151		
	Cool down reflux pump	HS40101	X	ON
	Make sure the outlet temperature falls below maximum value for a period of time before attempting to start the pump.	T40130		< -120°C
5	Start pump after permission is given	HS40101_S		ON
	Cool-down line 100-OL-40101 to LP column by opening carefully manual outlet valve	V40151		
	Adjust recycle valve to control sump level	HS40100		adjust
	and switch to automatic level control	L40053	W	55%
		L40053		AUTO
	!!! Do not run pump against a closed valve as a minimum throughput is required!!!			
6	Increase sidearm gas flow and	F40011	X	adjust
	reduce sidearm gas purity gradually to design conditions	Q40011	X	adjust
	Activate side arm gas flow controller and	F40011	W	20,000 Nm^3/h
		F40011		AUTO
	top pressure controller and	P40003	W	160 mbarg
		P40003		AUTO
	sidearm gas purity controller on GOX production	Q40011_2	W	90%
		Q40011_2		AUTO
7	Dump vaporiser is ready for operation			
	After the crude argon column is on oxygen purity start the pure argon column	L43023	Y	0%
	Product and dump valves are closed	L43033	Y	0%
8	Fill condenser and	L43027	Y	open
	open vapour outlet to control pressure and	P43028	Y	open
	set pressure controller to automatic mode	P43028	W	1.5 barg
		P43028		AUTO
	Activate column pressure controller	P43022	W	0.5 barg
		P43022		AUTO
9	Open liquid feed to pure argon column and	F40014	Y	open
	start reboiler operation once the condenser is working and column pressure is dropping	PD43021	Y	open
10	Purge pure argon column to dump to control the level	L43033	Y	open
	and set to automatic	L43033	W	80%

Step	*Activity*	*Name*	*Item*	*Value*
		L43033		AUTO
11	Once column system is running stable put controllers in automatic mode	F40014		AUTO
		L43027	W	90%
		L43027		AUTO
		PD43021	W	15 mbar
		PD43021		AUTO
		Q21004	W	1,9%-2,0%
		Q21004		AUTO
12	Argon tank is ready for operation			
	After product is on purity open product valve and	L43023	Y	increase
	close dump valve and	L43033	Y	decrease
	set both to automatic mode	L43023	W	80%
	Cool down and purge product line carefully before sending argon into the tank	L43023		AUTO
		L43033	W	90%
		L43033		AUTO

Remarks:

If the level in the crude argon column sump is above 65% the pump may be started before sending gas to the column. The sump level must be kept below 78% to avoid mechanical damage to the column.

Should the pure argon condenser start working during the filling process thus reducing the column pressure it is advised to start the reboiler operation at the same time.

For details about the split range controller please refer to the attachment.

4.27. Start up from Cold Conditions

When starting up from cold conditions the operator has to pass through different stages each of which requires attention to different areas of the plant. Cold condition means that the plant has been stopped for a short period of time and liquid inventory has been kept. Steps not explained in detail are described in above chapters.

- In order to avoid freezing of the waste nitrogen line going to the molesieve unit, **it is compulsory to close the valve HK15042 before starting molesieve sequence.** This valve must be re-opened as soon as a steady flow of air is established through the main exchangers W20010/20/30/40. **As soon as the cold box is cold, operators must monitor closely the temperature at warm ends of this exchanger during transitional phase.**
- To begin with, the process pumps for LOX, LIN and LAR need to be cooled down so that at least one unit is ready to be started when needed later on.
- Pressurisation

  P40003 should be in automatic mode acting on HK40012. Adjust P40003 so that the pressure P22001 in the LP column reaches a level above its normal operating value.

  Furthermore decrease the level in the sump of the pure argon column to values below 0% to ensure that no gas is drawn from the HP column during pressurisation.

  The air compressor should be in automatic mode with a suitable guide vane position and a discharge pressure set-point of 4.8 barg;

  The molecular sieve adsorber sequence should not be switched on during pressurisation;

  The booster air compressor should be running at about 56 barg discharge pressure; HK16073 should be fully open and the quick shut-off valves before the turbines and the Joule Thompson valve (JT-valve) should be closed.

  All connections between high pressure column and the low pressure circuit should be closed.

  When all these settings are stable open the valve UK20027; monitor the pressures in the cold box; one should aim to keep the time required for pressure built up to a minimum – if the pressure in the high pressure column does not rise any more open the JT-valve to let more air into the HP-column; make sure that there are no leaks on the warm side of the exchanger: air must flow into but no product should leave the main exchanger during pressurisation.

  Once the pressure in the high pressure column is established, UK20026 can be opened.
- Open P15041 in manual mode to bring the pressure of the low pressure column down to its normal operating level and set to automatic mode; open F20002, F20006 and F20012 slightly to allow flow through the oxygen and nitrogen passages of the main exchanger; monitor the cold end temperature difference: one cannot avoid increasing the cold end temperature difference when pressurising the HP column – but one should only allow small flow rates through the exchanger as long as the temperature differences are still high.

- Once pressure built up is finished stable flow conditions through the plant must be established and the liquid levels built up again. Start with establishing flow from the high pressure column to the low pressure circuit and open:
    - V21006, reflux to the high pressure column
    - F22013, LIN to LP column
    - L21003, CLOX to crude argon condenser
    - L40007, CLOX ex crude argon condenser
    - V21060, LAIR to the LP column;

    Bring the pressure controller P15041 down to its normal operating pressure; adjust the set point of P40012 accordingly; activate the molecular sieve adsorber sequence and manually increase the regeneration gas flow to the molecular sieve adsorber when the steps heating or cooling are active;
- Start the turbine/s when the plant is running stable at an air flow of more than 30,000 Nm^3/h. Activate JT-valve to control the cold end temperature at the main heat exchanger.

  Start the oxygen pump (product and vent valves are initially closed) as soon as a normal level is reached in the main condenser and adjust the flow to vent at F20012.

  Start the nitrogen pump (product and vent valves are initially closed) and adjust flow at F20001.

  Adjust the LP GAN flow to design.
- Built up liquid levels to design conditions; priorities are:
    - First adjust the main condenser level L22001 to 100%; to do this one might have to lower the level in the sump of the high pressure column L21003; make sure that the crude argon system is not drawing gas i.e. by closing the reflux valve F40011 and by lowering the level in the crude argon condenser.
    - Then fill up the crude argon condenser and start to draw gas into the crude argon column.
- Built up purities in the columns

4.28. Plant Preparation after Cold Box Trip

Step	Activity		Name	Item	Value
1	Check dump vaporiser availability		HV90013	X	open
			HV90014	X	open
			HV90015	X	open
2	Liquid levels	DCAC	L13003	X	20 - 95%
		chill tower	L14003	X	15 - 75%
		HP column	L21003	X	< 80%
		LP column	L22001	X	< 160%
		Crude argon column	L40053	X	< 78%
		Pure argon column	L43023	X	< 131%
3	To avoid cooling down the main heat exchanger at the warm end during shutdown all vapour generated must be vented on the cold side of the main heat exchanger.				
	LP system	crude argon vent on pressure control	P40003	W	300 mbarg
		WN to chill tower on pressure control	P15041	W	500 mbarg
	Check crude argon vent has sufficient capacity to control the pressure; if necessary open additional cold vents				
	HP system	normally not required			
4	Ensure all product outlets at the warm end of the main heat exchanger are closed, e.g. product valves, vents. This is to prevent flow through the main heat exchanger which would lead to severe damages of the unit		PK15041	Y	0%
			UK15044	Y	0%
			UK15045	Y	0%
			FV20001	Y	0%
			FV20002	Y	0%
			FK20005	Y	0%
			FK20006	Y	0%
			FV20011	Y	0%
			FV20012	Y	0%
5	Close gas lifts		V22015	X	close
			V21017	X	close
			V40010	X	close

Remarks:

If necessary liquid inventory must be disposed (refer to section 3).

4.29. Argon Storage and Back-up

4.29.1. LP Argon Tanks

- The tanks are filled via valve V44101 and V44201 respectively.
- The level is shown locally at L44107 and L44207. Level switches protect the vessels against too high and too low levels.
- The operation pressure of the inner vessel is about 500 mbarg. This pressure is monitored at P44105/P44205. The maximum pressure is controlled by vent valve P44105/P44205, the minimum pressure by pressure build up controller P44106/P44206.

4.29.2. Argon Back-up Pump

- Make sure that sufficient purge gas is available before operating the pump.
- It is mandatory to cool down cryogenic centrifugal pumps to their working temperature. A pump which is not cooled down sufficiently will not convey any fluid. This may have severe influence on the lifetime of the pump.
    - The cooling down starts with opening the tank withdrawal lines V44136 and V44236, which should be kept open at all times. Afterwards pump suction valve HV48010 is opened. Recycle valve HV48070 is set to approximately 50% and increased in small steps up to 100%.
    - The temperature of the pump is monitored by T48050. If the pump has reached its working temperature it is ready for operation . Close recycle valve down to 50% and start by switching on HS48001. Discharge pressure is controlled by recycling to the LP tanks.

4.29.3. HP Argon Tank

- The tank is filled by opening HV48050. Manual valves V48038, V48028 and V48010 at the tank should be always open. PV48027 regulates the tank pressure by distributing the feed between the bottom and top of the vessel.
- The level is shown locally at L48020. A level switch protects the vessel against too high and too low levels.
- The operation pressure of the inner vessel is ca. 21 barg. This pressure is monitored at P48005. The maximum pressure is controlled by vent valve P48005, the minimum pressure by pressure build up controller P48006.

4.29.4. Argon Vaporiser

- The product is sent to the ambient air heated vaporisers by opening V48011. The vaporisers possess 100% of the required capacity each. Open inlet and outlet valves, e.g. V48101 and V48102 of the operational unit, whereas the inlet to the standby unit is kept closed (outlet open).
- The vaporisers are designed to be in operation for approximately eight hours. The actual maximum online duration depends on the present ambient conditions and the product demand. If the outlet temperature from the vaporiser falls too low the units have to be switched by opening the inlet to the standby vaporiser and closing the inlet to the other one.
- The vaporiser flow is determined by the product valve PV4020, controlling the pressure on the customer side. To protect the equipment the pressure controller is disabled if the temperature falls too low or the tank level is insufficient.

4.29.5. Road Tanker Filling

- Make sure that sufficient purge gas is available before operating the pump.

It is mandatory to cool down cryogenic centrifugal pumps to their working temperature. The cooling down starts with opening the feed in the suction line HV44210, opening the recycle valve V44004 approximately 50% and increasing opening in small steps up to 100%. After approximately 30 min, we can consider that the pump is cool-down (as there is no temperature probe for checking).

When the pump is properly cool-down, follow the here under procedure to start the pump :

1. In Control Room, switch HS44013 to have it from BLOCKED to ENABLE status.
2. On field, press START FILLING button.
3. In Control Room, when START FILLING button is pressed on field, the pump gets READY in DCS.
4. On field, press the DEAD MAN HANDLE and keep it pressed to run the pump.
5. On site, every 30 seconds, a horn and a flash will show up : stop pressing the DEAD MAN HANDLE for 1 second and after keep it pressed to carry on with the pump running.
6. To stop the pump, leave the DEAD MAN HANDLE : after 10 seconds, the pump will stop.