

TECHNICAL SPECIFICATION

StirLAIR-4 Liquid Air Plant



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1. INTRODUCTION

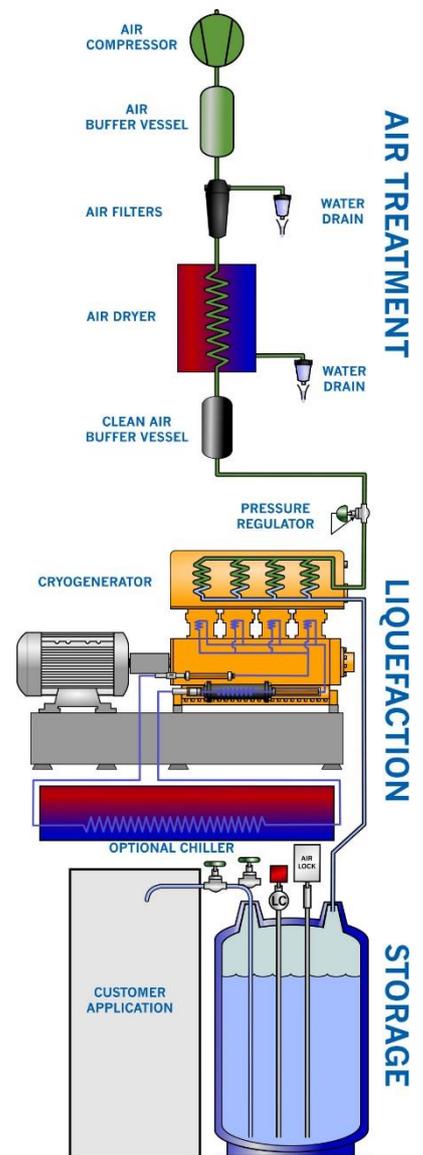
Please find enclosed our technical specification for the StirLAIR-4. This liquid air plant is developed for stand-alone, fully automatic and unattended operation, which almost eliminates the care of a plant technician during its operation and start/stop procedures.

These plants are characterized by a quick start up, low energy consumption and reliable operation. We trust this plant will be a valuable asset in meeting your liquid air demand.

Thank you for your interest in our company and our products, we look forward to your soonest response

2. PLANT PROCESS DESCRIPTION

1. Ambient air is taken in by a compressor and fed to a buffer vessel.
2. The air then passes a number of filters for cleaning and removes moisture and particles.
3. An air dryer removes the remaining moisture.
4. The clean air flows, via a buffer vessel, to an adjustable pressure regulator. This is set to the pressure at which the customer requires the liquid air to be stored in the vessel.
5. The clean air is liquefied by the cryogenerator after which the liquid air flows via an insulated pipeline by gravity into the storage vessel.
6. Water cooling required for the cryogenerator can either be tap water, or by a dedicated water chiller available from Stirling.
7. The AirLock system will prevent O₂ enrichment in the liquid air vessel.
8. The PLC will stop the StirLAIR when the vessel is full, and automatically re-starts when the level drops to 80% due to liquid withdrawal.
9. Liquid air can be withdrawn from the vessel via a flexible delivery line by opening a manually operated valve. In this way small dewars can be filled. For applications with an auto-fill system, a direct connection line can be made between the Stirling vessel and the application.
10. Liquid air withdrawal is independent from the plant's operation mode. There is no requirement for a mechanical transfer pump.



3. TYPICAL StirLAIR FEATURES

This chapter introduces the functionality and specifications of the StirLAIR range and the advantages that on-site liquid air production will provide to your organization.

- **Ease of installation**
With the plant room and utilities prepared before arrival of the plant, the StirLAIR will be producing liquid air within a few days after opening of the crate.
During the visit of one of our engineers the StirLAIR will be installed and commissioned. Your personnel will be trained how to optimally operate the plant.
- **Fully automatic operation by PLC**
All StirLAIR plants are monitored, controlled and safeguarded by a Programmable Logical Controller (PLC). Through the display, the operator is continuously informed about the operational status of the plant such as liquid air level in the storage vessel. For efficient troubleshooting, messages of the safety devices are indicated as error codes that refer to the operator manual for further action.

The PLC will automatically stop and start the StirLAIR depending the level of liquid in the vessel. In case of power or water supply failure, the PLC automatically re-starts the StirLAIR when the supply is restored.

- **Easy liquid air dispense**
The storage vessel is equipped with a manual valve and a flexible delivery line. Dispensing of liquid air can be done in several ways, depending the type of dewar to be filled:
 - Open dewars are filled by placing them beside the StirLAIR vessel and dispensing the liquid through the flexible line into the dewar opening.
 - Closed dewars can be filled by connecting the flexible line to their fill connection and opening valves according instructions of their manufacturer.
 - For applications with an auto-fill system, an optional direct connection line can be made between the StirLAIR vessel and the application.
- **Adjustable liquid air pressure**
The StirLAIR is equipped with a pressure regulator to adjust the pressure at which the liquid air is kept in the storage vessel. This allows the customer to choose the pressure that best suits his application. This also prevents high losses by flashing due to unnecessary over pressure in the storage vessel.
- **Efficient production**
The StirLAIR's are designed around the highly efficient Stirling cycle. Economical use of electrical energy results in low electricity consumption per liter of LAIR produced.
- **Low noise level**
The noise level of the StirLAIR is only 70 – 74 dBA depending on the type of StirLAIR. This allows a normal conversation in the plant room in direct vicinity of the system.

- Built for stringent climatic conditions, adaptable to extremes
Functional specifications of StirLAIR plants are defined at the nominal conditions of 250 m altitude and 25°C air temperature. Their working range is however much larger. At altitudes up to 2.000 m or temperatures up to 45°C ambient temperature a standard StirLAIR will still perform. For more extreme circumstances a StirLAIR can be adapted to your specific climatic conditions such as high altitude or hot deserts.
- The StirLAIR range is available for all common, worldwide used, 3-phase power supplies, i.e. 110V to 500V and 50 Hz or 60 Hz.

4. EXCELLENT SERVICE SUPPORT

StirLAIR plants are made for the future, not just to meet the sheer functional specifications; they are designed to ensure minimal service effort.

This is supported by our Service philosophy and organization.

- **Low operator attention**
The operators' activities are limited to a daily routine check, regular cleaning/replacement of filters and simple compressor oil changes.
- **Low maintenance**
Maintenance on the StirLAIR shall be done only every 6.000 hours of operation and will take approximately one day.
- **On-site maintenance**
Maintenance on all components of the StirLAIR plants including the Stirling cryogenerator can be done on-site. There is no requirement of shipping components back to the factory for maintenance or repair, meaning less down-time and transport costs.
- **10 Years supply of spare parts**
Stirling Cryogenics guarantees the supply of spare parts for any given StirLAIR component for a period of 10 years after shipment of a system.
- **World-wide Service Network**
Certified Service Engineers are available from Stirling or its Certified Service Representatives to assure service support anywhere in the world.
- **Availability of Cryogenerator spare parts**
Stirling Cryogenics fulfills 90 percent of requests for Cryogenerator spare parts within 48 hours in Europe, and within 5 working days in the rest of the world.
- **Free of charge help-desk**
For the lifetime of the StirLAIR plant, Stirling Cryogenics will support customers with a free of charge help-desk.

5. StirLAIR Operational Safety

The StirLAIR system is equipped with a number of safety devices. Furthermore the system has all necessary pressure safeties. Below, the AirLock system and other safety measures are described.

The AirLock System, preventing O₂ enrichment in liquid air vessels

The AirLock System name, idea and concept are the sole proprietary of DH Industries BV

For many applications in the entertainment industry liquid nitrogen is used as a cold fluid to produce effects like fog and snow. The purpose of the liquid is not the nitrogen but it's cold. In fact the nitrogen is a problem in itself since measures and precautions have to be taken to avoid oxygen depletion in the space where the liquid nitrogen is evaporated.

Therefore another option should be considered: liquid air produced with an on-site plant. This will give the same effects as liquid nitrogen as it carries the same cold, but does not have the negative side-effect of oxygen depletion. Since the liquid that is evaporated has the same consistency as air, no alteration to the environment is possible. Liquid air thus is a safer liquid to use.

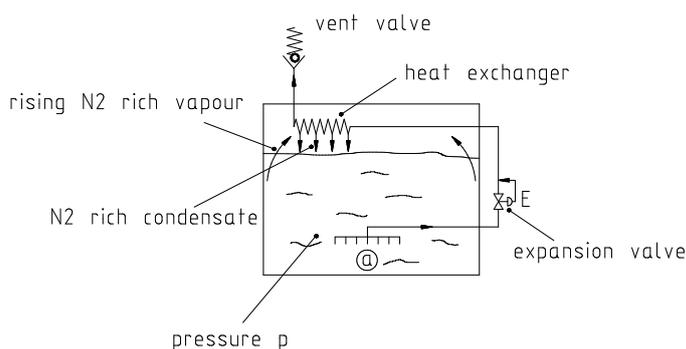
However, sometimes it is thought that liquid air has the threat of turning into liquid oxygen, something which is obviously not considered to be acceptable.

As a first note, we would like to point out that the issue of enrichment can only occur when the liquid air production plant is in stand-by. When running, the boil-off gas is simply re-liquefied and no enrichment is possible.

For a plant in an environment where liquid is used every day, the situation of stand-by will not occur often, reason of which the separation issue is limited any way.

The AirLock System

With the AirLock System, oxygen enrichment of liquid Air inside the storage tank becomes impossible. These arrangements and there functioning are explained below.



In this arrangement pressure build up is not released by blowing off gas, but by taking out a liquid volume at point a. This flow then continues via an expansion valve E and a heat exchanger to the vent valve.

Due to the throttling at E, the temperature of the liquid drops and part of the liquid is evaporated (flashing). This mixture of liquid and gas is then led through the heat exchanger, which acts as a

condensing surface for the N₂ rich vapour in the vessel. By condensing, the pressure in the vessel is reduced again which was the goal of venting.

In this set-up not the gas at the top, but liquid from the bottom at point a is taken out to prevent over-pressure. No separation has taken place since the evaporated gas in the top of the vessel is re-liquefied again. Therefore the consistency of the liquid in the tank remains what it was: liquid air.

Additional safety system

In order to add additional safety for the StirLAIR is equipped with the following safety feature:

A small part of the liquid flow going to the effect is continuously monitored for its O₂ content. Due to the AirLock system no segregation of Oxygen and Nitrogen should have taken place hence the composition of the liquid air should be identical as normal air (21% Oxygen and 79% Nitrogen). By continuously monitoring the Oxygen content of the liquid air going to the effect this can be safeguarded. A small flow of the liquid air is first fed into a small heat-exchanger (not shown) where it is vaporized and then fed to an Oxygen analyser, which measures the percentage of Oxygen. In case the Oxygen content deviates too much from the setpoint (19% > setpoint < 23%) the automatic valve is closed, closing the liquid air flow to the effect and hence preventing people being exposed to high Oxygen or Nitrogen quantities.

In case of automatic shut down the storage tank will have to be drained (as it will contain segregated air). This has to be done manually by opening the valve to the vent and can be done at any given / appropriate time. The system (+ AirLock) has to be checked for malfunction before the unit is restarted.

6. StirLAIR INSTALLATION AND MAINTENANCE

Installation, commissioning and maintenance of the plant must be done by a Stirling service engineer or by our certified representative to qualify for the warranty. The plant room will be prepared by the customer according to Stirling's Site Preparation Instructions and must comply with local legislation. Local, qualified technicians, made available by and on account of the customer, will carry out electrical and plumbing work, as well as construction/civil work prior and during installation. The Stirling engineer will supervise the work.

After installation and the performance of a test run, the customer is invited to conduct an acceptance test. The results are listed in an acceptance test report. Both parties sign an acceptance certificate and the plant is handed over. During the test run, an operator is trained on operating the plant, routine maintenance (replacing filter cartridges, adjusting pressure setting and first line fault reporting) and on simple diagnostics. This 'on the job' training takes approximately one working day.

Stirling also offers training courses at our facilities in Son, The Netherlands, to improve the knowledge of plant operators and technicians.

During the warranty period, maintenance must be performed by a technician trained by Stirling at Son or by a Stirling engineer. If non-qualified personnel carry out maintenance or repair, the warranty will be null and void.

We recommend to include in your order a set of consumable parts and tools to cover the initial requirements.

7. TECHNICAL SPECIFICATION StirLAIR-4

The StirLAIR-4 liquid air plant has the following specifications.

Liquid air production capacity at nominal conditions¹

LAIR produced at	[barg]	1	3	5
Production capacity	[l/h]	48	64	75
Expanded to atmospheric pressure (usable liters) ²	[l/h]	44	49	53

Nominal operating conditions: Plant room temperature 25°C, altitude 250m, relative humidity 95%, cooling water temperature 15°C, power supply: voltage $\pm 5\%$, frequency $\pm 2\%$.

Working range; plant room temperature 5-45°C, altitude 0-2.000 m, relative humidity 20-95%.

When the ambient conditions differ from nominal, the specifications might differ.

- ² When high-pressure liquid air is transferred and expanded to a lower pressure, up to 30 percent of the liquid quantity can be lost through evaporation flashing. That is why Stirling presents its production also as the amount of liquid air available when used at normal atmospheric pressure, besides the amount produced in a liquid vessel at higher pressure. This is what we call usable liters of liquid air.

Additional specifications

		StirLAIR-4	Optional water chiller
Plant size	lxwxh; m	4,90 x 3,65 x 1,80	2,70 x 1,10 x 1,60
Advised plant room	lxwxh; m	6,50 x 4,80 x 3,00	3,70 x 2,10 x 2,60
Weight	kg	4.000	1.350
Power supply	V / Hz	adapted for local power supply	
Power consumption	kW	62	25
Noise level	dBA	72	60
Liquid nitrogen storage capacity	Litres	2.000	N/A
Maintenance interval (apart from oil and filter changes)	Running hours	6.000	N/A

StirLAIR plants meet the European CE and PED safety standards, as well as the IP54 and IEC 60204. For other national standards that may be applicable in your country, please contact Stirling to discuss the consequences.

Lay-out

Refer to the attached drawing, which gives the main sizes of the plant components and the different elements required in the room. The room set-up is an example to give an idea of required size. When an existing plant room is chosen, a new specific drawing can be made.

Remarks:

- Sizes are in mm.
- Actual plant room lay-out will be determined with the customer during the order stage based on actual plant room availability.
- Plant room shall be equipped with oxygen monitoring system as per local legislation for safety of personnel.
- Ventilation is required for proper functioning of the plant and safety of personnel. Ducts are recommended for areas with ambient temperatures above 25°C.
- Ventilation and air ducts to be installed by customer. Actual placement depends on position of outside walls.
- Doors are not shown because their position depends on building lay-out. Doors must be placed near the dewar fill area. Minimum door size is 1.700 x 2.300 mm.
- Provided ambient outside temperature does not drop below -10°C, the water chiller can be placed outside under a simple roof for protection against direct sun and rain. Maximum distance is 8 m from the StirLAIR.

8. StirLAIR-4 SCOPE OF SUPPLY

The Scope of Supply of the StirLAIR-4 consists not only of the actual system but also includes all additional materials to ensure a proper installation and functioning of the plant.

Main system:

- Clean air production skid including:
 - One air compressor
 - One air buffer vessel
 - One air dryer
 - One set of air filters
 - One clean air buffer vessel
 - One control box with monitor display using PLC technology

- Liquid air production skid including:
 - One 4-cylinder Stirling cryogenerator
 - One 2.000 liters storage vessel, including a level sensor to measure the liquid level, flexible hose with a manual valve to dispense liquid, O₂ level detector and AirLock system.

Additional materials:

- Set of Installation materials
- Helium gas cylinder
- Pressure regulator for helium gas cylinder
- Oil for cryogenerator and compressor

Documentation (in English):

- Pre-installation manual including lay-out details
- Operating and maintenance instructions
- CE declaration of conformity

The StirLAIR-4 will be tested at the factory for its performance according out standard test procedure. Customer can witness the final 2 days of Factory Acceptance Test at its own cost. Additional factory acceptance test/requirements need to be discussed and might be subject to additional charges.