Elekta Neuromag® TRIUX Internal Helium Recycler

Instructions for Use

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ELEKTA

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Referenced documents

Elekta does not supply all the documents that we refer to in this document with the equipment. Elekta reserves the right to make the decision on which of the documents we supply with the equipment.

Contact information

Elekta Oy
Siltasaarenkatu 18-20 A
FI-00530 Helsinki
Finland

Tel +358 9 756 2400
Fax +358 9 756 24011
www.elekta.com
meg-support@elekta.com

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CE 0537

Elekta Neuromag® TRIUX with internal helium recycler complies with the requirements of the Medical Device Directive 93/42/EEC.

1. Safety and regulations

1.1. Use of the equipment

The internal helium recycler is a closed-loop helium reliquefaction system designed to be integrated into and used with an Elekta Neuromag® TRIUX MEG system. The internal helium recycler is not a medical device itself, but it becomes a part of a medical electrical system when connected to Elekta Neuromag® TRIUX. The internal helium recycler does not affect the intended use or indications for use, performance, or specification (except of helium and power consumption) of Elekta Neuromag® TRIUX.

1.2. Incorrect use

Installation and use of this equipment is subject to the applicable legislation. Users shall only set up and use the equipment in such ways that do not conflict with applicable laws or regulations which have the force of law.

Use of the equipment for purposes other than those intended and expressly stated by the manufacturer, as well as incorrect use or operation, may relieve the manufacturer or his agent from all or some of the responsibility for resultant non-compliance, damage or injury.

1.3. Compliance with international standards

Elekta Neuromag® TRIUX with internal helium recycler complies with the requirements of the Medical Device Directive 93/42/EEC. The product is CE marked.

1.3.1. Standard compliance

The internal helium recycler (helium gas storage part) complies with the requirements of the Pressure Equipment Directive (PED) and the following safety standards:

- IEC 61010-1:2010 Safety requirements for electrical equipment for measurement, control, and laboratory use
    - National deviations for USA
    - National deviations for Canada
    - National deviations for Japan
- IEC 61326-1:2012 Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements

Elekta Neuromag® TRIUX with internal helium recycler complies with the following safety standards:

- IEC 60601-1:2007 Medical electrical equipment – Part 1: General requirements for Basic Safety and Essential Performance
    - National deviations for USA
    - National deviations for Canada
    - National deviations for Japan
- IEC 60601-1-2:2007 Medical eletrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral standard: Electromagnetic compatibility – Requirements and tests

1.3.2. IEC classification

Elekta Neuromag® TRIUX with internal helium recycler is classified according to IEC 60601-1 as follows:

- Installation and use: Fixed equipment
- Device type: System
- Mode of operation: Continuous
- Supply connection: Permanently installed

1.4. Training requirements

Users of the equipment shall have received adequate training on its safe and effective use before attempting to work with it.

Country-specific regulations on training may apply. The user shall ensure that training is received in accordance with applicable local laws or regulations. Information on training is available from Elekta or the local Elekta representative.

1.5. Safety symbols

1.5.1. Warning, caution and note symbols

The following are samples of how warnings, cautions and notes appear throughout this document. The text within the samples explains their meaning.

WARNING 1.1

Warnings are directions which, if ignored, can constitute a health hazard, cause fatal or serious injury, or lead to erroneous clinical diagnosis and, possibly, to clinical mistreatment.

CAUTION 1.1

Cautions are directions which you must obey to ensure safe and efficient operation and to avoid damage to the system.

Note: *Notes give you advice and recommendations for safe and efficient use of the product as well as highlight unusual points.*

1.5.2. Symbols on the equipment

The following symbols are used on the equipment. Familiarize yourself with each symbol and its meaning before you operate the equipment.

Table 1.1 List of symbols on the equipment

Label	Meaning
	Caution. Parts of the system are marked with this label when it is necessary for the user to draw attention to avoiding a potential hazard or to ensure safe, correct or improved operation and to avoid damage.
	Refer to the instruction manual. Parts of the system are marked with this symbol when it is *mandatory* for the user to refer to instructions given in the manuals accompanying the system to ensure safe operation. In the manuals, it also calls attention to these instructions.
	Consult instructions for use. Parts of the system are marked with this symbol when it is necessary for the user to refer to instructions given in the manuals accompanying the system. In the manuals, it also calls attention to these instructions. They intend to ensure correct of improved operation and/or increased safety and to avoid damage.
	Type BF (body floating) equipment symbol. The applied parts (parts in direct contact with the person being investigated with the system) and the type plate are marked with this symbol to indicate that they fulfill the leakage current requirements of the safety standard IEC 60601-1.
	Alternating current (power line) symbol.
	Protective ground (earth) terminal symbol. Used to identify terminals which are intended for connection to an external protective conductor for protection against electrical shock in case of a fault, or to the terminal of a protective ground (earth) electrode.
	Static electricity symbol. The parts of the system marked with this symbol indicate the presence of components susceptible to static electricity and require the use of special static-electricity preventing techniques.
	Non-ionizing radiation, RF transmitter. Marking on equipment or equipment parts that include RF transmitters or that intentionally apply RF electromagnetic energy.
	Disposal instruction symbol. Separate collection of waste electrical and electronics equipment (WEEE) necessary (European Union directive 2012/19/EU on WEEE).
	Date of manufacture: year (four digits) followed by month and day (if applicable).

1.6. Safety precautions

Elekta products are designed to meet stringent safety standards. Every reasonable precaution has been taken during manufacture to safeguard the health and safety of patients and persons who will operate this equipment.

All medical electrical equipment requires proper installation, operation and maintenance, particularly with regard to safety.

It is vital that the user read, understand, and where applicable strictly obey, all safety directions, warnings, cautions, notes, and safety markings within this document and on the equipment.

WARNING 1.2

This section contains important information concerning the safe use of the product and maintaining reliable operation. Read the safety instructions entirely before you use the product.

In addition, read and obey the complete safety instructions for Elekta Neuromag® TRIUX in *Elekta Neuromag® TRIUX User's Manual*. The manual contains important safety instructions not included in this manual.

Changes to the product

Any changes to the equipment provided by Elekta may only be performed by persons expressly authorized to do so by Elekta. Such changes must comply with best engineering practices and effective laws and regulations.

CAUTION 1.2

Changes, additions, or maintenance to the equipment performed by persons without appropriate knowledge, qualifications, and training may cause risks of serious injury and/or damage to the equipment. Furthermore, such alterations may void the warranty. No modification of this equipment is allowed without authorization from Elekta.

Third party devices and other auxiliary user-supplied equipment

Elekta assumes responsibility only for third-party equipment or components that are expressly recognized as compatible by Elekta. Elekta assumes no responsibility for the compatibility, fitness for use, or safety of third-party equipment not expressly recognized as compatible by Elekta.

1.6.1. Safe handling of helium

The Dewar is a vacuum-insulated vessel containing liquid helium at a cryogenic temperature. Since the cold liquid is potentially dangerous, certain precautions must be made in order to assure completely safe operation of the device.

WARNING 1.3

Wear protective gloves to avoid skin contact with liquid helium or exhaust gas or any objects that have recently been in direct contact with liquid or evaporated gas. During helium transfer, monitor pressure gauges and do not let pressure to rise above the predefined limits.

WARNING 1.4

Beware of the extremely cold, non-life-supporting helium gas.

1.6.1.1. Properties of helium

- Helium liquid or gas is nonflammable and nontoxic
- Helium is one of the noble gases (He, Ne, Ar, Kr, Ra)
- Helium gas is odorless and colorless
- Helium gas is seven times lighter than air

- Helium gas is not life-supporting: it may replace air thus reducing the relative oxygen content in closed rooms if evaporated rapidly in large quantities, resulting in a risk of suffocation. Breathing helium gas does not bring about any physiological unpleasant symptoms before dizziness. The pitch of the voice of the person characteristically raises when a large fraction of air is replaced with helium gas.
- Boiling point 4.2 K (—269°C or -452°F)
- Density of liquid 0.125 kg/liter
- The liquid evaporates very easily (latent heat of evaporation 20.9 kJ/kg= 2.6 kJ/liter).
- One liter liquid corresponds to approx. 750 liters of gas (+20°C, 101,3 kPa).
- Skin contact with liquid or cold gas or cooled objects may cause severe frostbite
- Flow of cold helium gas makes a very good thermal contact with any surface it passes by; unprotected skin cools below freezing point in seconds
- Dangerous pressures may arise as a result of rapid vaporization inside closed vessels. If the liquid gets in contact with objects at temperatures higher than 4 K it will immediately evaporate and expand. This means that a potential for dangerous pressure rise always exists if this cryogenic liquid is handled carelessly or left to warm up in a completely closed volume.
- Liquid helium can cryopump other gases such as nitrogen, oxygen, water vapor, which at liquid helium temperature solidify. This may lead to blocking of the vents and consequently buildup of dangerous pressures in cryogenic vessels.

1.6.1.2. Structural safety

- The Dewar has a good thermal insulation to minimize helium boil-off.
- The insulating vacuum is properly sealed and all parts are fabricated leak-tight.
- Because of the thermal insulation, all parts of the Dewar that may come into contact with the user remain at room temperature at all times during normal operation.
- The cooling capacity of the evaporating cold helium gas is employed to partly minimize the unavoidable heat leak from room temperature to the cryogenic temperature. Therefore, under normal operating conditions the outflowing exhaust gas is warmed up to essentially room temperature before leaving the Dewar. However, during increased outflow occurring normally only during liquid helium refills, the gas exiting from Dewar may be extremely cold. Skin contact with the helium line should then be avoided.
- The helium space of the Dewar is connected to the helium gas storage system or vented outside to prevent buildup of pressure.
- The outflowing gas is directed via the helium line to the gas storage system (normal operation) or to open air (during possible refill).
- The helium storage system keeps a slight overpressure to prevent cryopumping of other gases from the atmosphere.
- The top flange of the Dewar is equipped with pressure relief valve and a rupturing membrane which will let gas out, should the pressure inside the Dewar rise for some reason. Also, a pressure gauge is attached on the top flange.
- The safety pressure relief which is based on rupturing membrane vents via a separate safety exhaust duct to outside of the building.
- The gantry is designed to keep the Dewar in proper position.
- Hard shocks to the Dewar must be avoided.

WARNING 1.5

Do not cause damage to the structural integrity of the Dewar in any way. Absolutely no holes may be drilled to the Dewar.

WARNING 1.6

Do not open the Dewar vacuum to atmospheric pressure under any circumstances.

- The Dewar is equipped with a vacuum lock valve and is sealed by means of a blind flange to prevent accidental opening and leakage through the vacuum lock. The vacuum lock is operated with a separate vacuum-valve adapter.
- The magnetically shielded room must be properly ventilated. For details, see *Elekta Neuromag® TRIUX Site Planning Guide*.

CAUTION 1.3

The refill bypass valve must be open, and the input valve of the helium gas storage system must be closed during helium refill.

WARNING 1.7

Do not tilt or tip the storage Dewar.

- The overpressure inside the Dewar (with respect to atmospheric pressure) should be kept below 100 mbar (10 kPa) even during refill. Should the pressure rise, the relief valve in the gas storage system input will open at 100 mbar (10 kPa), and the relief valve on the top of the MEG Dewar will open at 140 mbar (14 kPa). If for some reason the pressure rises even further, a rupture disc will break approximately at 500 mbar (50 kPa), letting gaseous helium to escape via the safety exhaust duct to the outside of the building.
- The fixed L-siphon used in the helium refills and located on top of the Dewar is normally sealed with a plug that has an additional relief valve which effectively vents the cold helium space directly into the atmosphere through the siphon in the unlikely case all other exhaust routes get blocked.
- When you transfer liquid helium, obey the helium transfer instructions.
- Transfer of liquid helium can be carried out by a single person. For safety reasons it is, however, highly recommended that another person is present to assist or call for help in possible abnormal conditions. This is especially important if the transfer is carried out off-hours.

WARNING 1.8

Do not leave anybody alone inside a closed magnetically shielded room without the presence of another person outside the room.

1.6.1.3. Cryopumping

At liquid helium temperature all common materials are solid. This means that the vapor pressure of for example the atmospheric gases (nitrogen, oxygen, water) is practically zero in any volume containing liquid helium. This leads to so-called cryopumping of these gases: any helium vessel left open to atmosphere will very effectively suck in large amounts of these gases. Water freezes and may block the helium vessel or the transfer siphon. Oxygen in the probe unit Dewar might cause large irregular low frequency drifts of MEG signals because the magnetic susceptibility of the paramagnetic oxygen in its solid form is very high.

- All helium vessels must be sealed from the atmosphere and properly vented, via a back flow valve or a sufficiently long and narrow exhaust line.

- Do not leave the fixed L-siphon at the top of the Dewar open. Block the opening with the dedicated plug when not transferring helium.
- Do not leave the helium line vent directly into the room. The boil-off gas is guided via a helium line either to the gas storage (normal operation) or outside (helium refills).
- Do not remove the fixed siphon or the boil-off tube from the top plate. The openings must be plugged with rubber bungs (provided in the Cryogenic Accessory Kit) if the fixed siphon or the boil-off tube are ever removed even for a short while.
- If the safety exhaust rupture disc accidentally breaks, the opening must be plugged with a large rubber bung and the disc replaced (authorized service only).

WARNING 1.9

Do not open the Dewar helium space to atmosphere during normal operation.

1.6.2. Safe operation of the equipment

WARNING 1.10

Do not change the measurement position while a patient is under the probe unit.

WARNING 1.11

Do not put a patient under the probe unit except when the green OK light on the position indicator display is continuously lit. A blinking green OK light means that the probe unit is in the liquefaction position. The liquefaction position is not intended to be used for patient measurements.

CAUTION 1.4

Do not do MEG measurements when the cryocooler is in operation. The cryocooler cold head causes severe magnetic interference in MEG signals and audible acoustic noise when in operation.

CAUTION 1.5

Mechanical vibrations of the cryocooler cold head parts inside the probe unit can cause magnetic interference in MEG signals even when the cryocooler cold head is inactive. Monitor the signal quality during MEG measurements and use appropriate noise reduction techniques, such as SSP and MaxFilter. For more information, see *Elekta Neuromag® TRIUX Data Acquisition User's Manual* and *MaxFilter User's Manual*.

Note: *You are not recommended to leave the sensor tuner in a suspended state. The suspended state prevents the cryocooler from operating. This can cause decreased measurement time budget or loss of helium.*

1.6.3. Pressure safety

The owner of the internal helium recycler is responsible for the safe use and maintenance of the pressure equipment assembly according to the instructions given by Elekta. The owner shall appoint a pressure equipment supervisor, who is responsible for:

- Making sure that the pressure equipment assembly complies with the local pressure safety regulations
- Monitoring the use and condition of the pressure equipment assembly
- Making sure that the users of the internal helium recycler are familiar with the principle of operation, instructions, safety precautions and safety devices of the pressure equipment assembly

- Maintenance of the pressure equipment assembly.

If the owner has a service contract with Elekta, Elekta performs maintenance tasks of the pressure equipment assembly. The maintenance tasks include:

- Doing a safety relief valve test
- Examining the helium gas storage tanks.

The pressure equipment assembly type plate is located on the side wall of the helium recycler cabinet above the cable feedthrough.

Figure 1.1 Pressure equipment assembly type plate

WARNING 1.12

Do not open the helium gas line connections or the service hatch of the helium gas storage tanks.

1.6.3.1. Doing a safety relief valve test

Check interval
12 months

Before you start

- Make sure that the storage tank pressure is between 8.8-9.0 bar during the test. This means that the tanks must be full.

Note: *The test must be short and done just once.*

To do a safety relief valve test:

1. Open the valve manually by loosening the opening nut.
    - The valve must open clearly and release an abundant amount of gas.
2. Close the valve.
    - The valve must close fully when you tighten the nut.
3. If the safety relief valve does not work as expected or is damaged based on visual inspection, contact Elekta service.

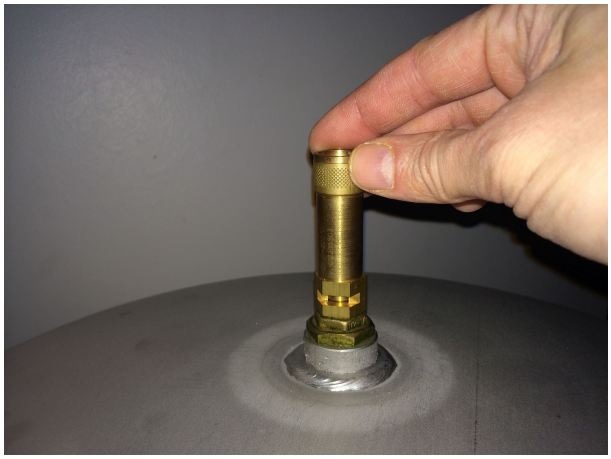


Figure 1.2 The opening nut of the safety relief valve

1.6.3.2. Examining the helium gas storage tanks

Check interval
12 months

1. On each helium gas storage tank, examine the label that states the commissioning date ('Taken into use') and the replacement date ('Replace latest').
    - If replacement is due within the next 12 months for any of the tanks, contact Elekta service for tank replacement.
2. Examine the external condition of the helium gas storage tanks and their accessories (pressure meter and pipe fittings) by visual inspection.
    - If you notice signs of deformation, corrosion or other visible damage, contact Elekta service and inform the owner of the internal helium recycler and the pressure equipment supervisor.

If you notice signs of deformation, corrosion or other visible damage at any time between the check intervals, contact Elekta service.

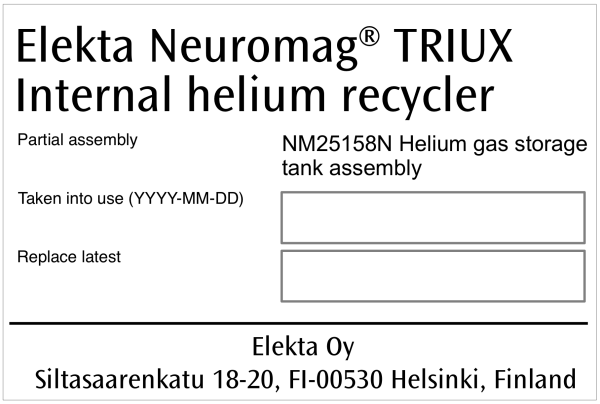


Figure 1.3 Helium gas storage tank assembly label

1.6.4. Electrical safety

CAUTION 1.6

The isolation transformers provide step-up or step-down voltage conversion to other mains voltage than 230 V~. Inside the helium recycler cabinet, the voltage is always 230 V~.

CAUTION 1.7

Do not do any maintenance work on the parts inside the helium recycler cabinet. There are no operator serviceable parts inside the helium recycler cabinet.

1.6.5. Final disposal

The term final disposal means disposal of the equipment, or any part of the equipment, in such a way that the equipment or part can no longer be used for its intended purpose(s).

Never dispose of Elekta products in the domestic waste stream. Disposal must always be executed in an environmentally sensitive manner that complies with all local and international regulations and laws. Materials hazardous to human health and the environment must be separately removed and disposed of through competent, licensed facilities. The remaining material may be recycled where facilities and local regulations permit.

Prior to disposal, always contact Elekta for advice.

WARNING 1.13

Incorrect handling during disassembly of device components related to liquid or gaseous helium may cause death, serious injury and environmental damage.

1.7. Emergency situations

1.7.1. Helium leakage

WARNING 1.14

Beware of the extremely cold, non-life-supporting helium gas.

The helium gas storage system can contain up to 5-20 m^3 NTP (normal temperature and pressure) helium gas, depending on the number of the helium gas storage tanks in the system. If a sudden significant leakage occurs, this amount of gas can cause a risk of losing consciousness or even suffocation, if let in a small room within a short time without proper ventilation. Because helium is lighter than air, helium concentration is higher in the upper parts of the room.

If you detect a significant helium leakage:

1. Immediately evacuate the room and instruct others not to enter it.
2. Arrange proper ventilation with doors and, if possible, windows open.

1.7.2. Disconnecting the mains

In an emergency situation such as fire in a cabinet or electric shock, you must disconnect the internal helium recycler from the mains completely.

1. Turn off the power of the helium recycler cabinet from the mains disconnection switch mounted on a wall near the cabinet.
    - The switch also disconnects the output of the built-in uninterruptile power unit (UPS).
2. Turn off the power of the cryocooler by turning the main power switch of the compressor to **Off**.
    - The main power switch is located on the front panel of the cryocooler compressor.

2. Introduction

2.1. Function of this manual

This manual applies to:

- Factory-installed Elekta Neuromag® TRIUX with internal helium recycler (NM25000N)
- Retrofitted internal helium recycler (NM25135N) to Elekta Neuromag® TRIUX (NM23900N).

This manual is intended to instruct users in the safe and effective operation and maintenance of the equipment described. The user includes the responsible organization with authority over the equipment and those persons who actually handle the equipment.

Before attempting to work with this equipment, the user must:

- Thoroughly read and completely understand this manual
- Keep this manual with the equipment for easy access.

In addition, the user must have *Elekta Neuromag® TRIUX User's Manual* available, as it contains important information not included in this manual.

2.2. Intended audience

This manual is written for trained users of an Elekta Neuromag® TRIUX MEG system with internal helium recycler. The user groups are defined below.

Table 2.2 User definitions

User	Definition
MEG user	A person trained to use the MEG system who operates the system for MEG measurements. Plans the daily measurement schedules, taking into account the operation times of the internal helium recycler.
MEG key user	A person trained to use the MEG system who is technically responsible for the day-to-day operations of the system. Trained to monitor the operation of the internal helium recycler and to resolve minor temporary problems that arise from local circumstances. Assesses whether problem escalation to Elekta service is needed.

Note: *An Elekta Neuromag® TRIUX MEG system with internal helium recycler must always have a MEG key user. The MEG key user must be appointed by the administrator responsible for the MEG facility.*

2.3. Accompanying documentation

The accompanying documentation is a list of other documents related to the product. Contact your Elekta representative for more information.

Table 2.3 Accompanying documentation

Manual	Neuromag p/n
User Manuals	
Elekta Neuromag® TRIUX User's Manual	NM24131A-*
Elekta Neuromag® TRIUX Data Acquisition Software Release 6.0 User's Manual	NM23732A-*
Elekta Neuromag® TRIUX MaxFilter™ 2.2 User's Guide	NM24057A-*
Other Manuals	
Elekta Neuromag® TRIUX Site Planning Guide	NM21643A-*
Elekta Neuromag® TRIUX Technical Manual	NM24132A-*

2.4. Disclaimer

- Elekta assumes no liability for use of this document if any unauthorized changes to the content or format have been made.
- Every care has been taken to ensure the accuracy of the information in this document. However, Elekta assumes no responsibility or liability for errors, inaccuracies, or omissions that may appear in this document.
- Elekta reserves the right to change the product without further notice to improve reliability, function or design.
- This document is provided without warranty of any kind, either implied or expressed, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose.
- Elekta assumes no liability for loss of helium or downtime of the system, either directly or indirectly caused by a mains supply power failure exceeding the capacity of the built-in uninterruptible power supply or loss of cooling of the cryocooler compressor.

2.5. Glossary of terms

The following terms have this specific signification throughout this document.

For the terms related to the MEG system in general, see *Elekta Neuromag® TRIUX User's Manual*.

Table 2.4 Terms

Term	Definition
Ball valve	Quarter-turn valve which uses a hollow, perforated and pivoting ball to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is pivoted 90° by the valve handle.
Check valve	Valve that allows flow only in one direction. Prevents backflow.
Control PC	Industrial embedded PC in the helium recycler cabinet. A part of the control unit.
Control unit	Unit in the helium recycler cabinet that controls and monitors the operation of the internal helium recycler
Cryocooler	Cooling system that consists of a cryocooler cold head, cryocooler compressor, and cryocooler gas lines
Cryocooler cold head	Part of the cryocooler that liquefies helium gas from the helium gas storage tanks back into the Dewar
Cryocooler compressor	Part of the cryocooler that supplies working gas and electrical power to the cryocooler cold head

Term	Definition
Cryocooler gas lines	Part of the cryocooler that transmits working gas from the cryocooler compressor to the cryocooler cold head
Default measurement schedule	Repetitive daily interval at which measurement windows have been configured to occur, unless changed via the service GUI by the MEG key user
Gas collection	Process during which helium gas accumulates into the helium gas storage tanks
Helium gas storage system	System that pumps and compresses boiling helium gas from the Dewar into the helium gas storage tanks, and lets the gas back to the Dewar for liquefaction. The helium gas storage system consists of: • Pressure regulator unit, buffer tanks, and control unit in the helium recycler cabinet • Helium gas storage tanks • Piping.
Helium gas storage tank	Part of the helium gas storage system that stores the helium gas boiling off the MEG system during MEG measurements
Helium leakage	Situation where helium gas escapes through unintentional small holes, slits or defects
Helium loss	Situation where helium gas escapes through pressure limiting devices because the helium gas storage tanks are full or because the internal helium recycler has been in the fail-safe mode or shut-down mode for too long
Helium recycler cabinet	Part of the helium gas storage system that contains the pressure regulator unit, buffer tanks, control unit and service interface of the internal helium recycler
Helium recycler module	Part of the internal helium recycler
Helium recycler scheduler	Software application for making changes to the measurement schedule. Accessible via the graphical user interface of the internal helium recycler.
Hose reel	Mechanism that reels up the cryocooler gas lines when the MEG user changes the position of the probe unit. The hose reel is located in a cabinet of its own next to the probe unit in the MSR.
Liquefaction	Process during which the cryocooler cold head reliquefies helium gas from the helium storage tanks back into the Dewar
Measurement time budget	Time limits to the daily operation of the internal helium recycler which the user is recommended to consider before making changes to the measurement schedule
Measurement window	Daily time slots reserved for making MEG measurements
MEG service engineer	Qualified person from Elekta who installs, assembles, maintains and repairs the MEG system. A MEG service engineer is capable of performing any required installation, monitoring, maintenance and repair of the internal helium recycler and the MEG system.
Notification	Message to users that includes important information on the operating conditions of the internal helium recycler. Some of the notifications are targeted at MEG user (notice), some to MEG key user and MEG service engineers (alert message). The delivery mechanisms depend on the target group.
Owner of the internal helium recycler	Person responsible for the safe use and maintenance of the pressure equipment assembly. Appoints a pressure equipment supervisor for the site.

Term	Definition
Pressure equipment supervisor	Representative of the owner of the internal helium recycler responsible for: • Monitoring the use and condition of the pressure equipment assembly • Making sure that the users of the internal helium recycler are familiar with the principle of operation, instructions, safety precautions and safety devices of the pressure equipment assembly • Maintenance of the pressure equipment assembly.
Pressure regulator unit	Unit that controls the helium gas pressure and flow in the MEG system both during gas collection and liquefaction. The pressure regulator unit consists of the pressure regulator panel and related pipeline components inside the helium recycler cabinet.
Refill bypass valve	Valve in the helium gas line outside the MSR that is opened only during liquid helium refill to vent boiling helium rapidly out of the line
Relief valve	Valve that limits the pressure by allowing the flow of pressurized fluid (gas or liquid) out of the pressurized assembly
Service GUI	Graphical software interface inside the helium recycler cabinet. A part of the service interface.
Service interface	All controls, including hardware and software, inside the helium recycler cabinet

2.6. Abbreviations

The following abbreviations may be found in this document.

Table 2.5 Abbreviations

Abbreviation	Term
CPU	Central Processing Unit
DACQ	Data Acquisition
GUI	Graphical User Interface
IAS	Internal Active Shielding
MEG	Magnetoencephalography
MSR	Magnetically Shielded Room
NTP	Normal temperature and pressure 100 kPa = 1 bar, 273.15 K = 0 °C
QA	Quality Assurance
SQUID	Superconducting Quantum Interference Device
SSH	Secure Shell
SSP	Signal Space Projection
SSS	Signal Space Separation
UPS	Uninterruptible Power Supply

3. Product description

3.1. Product overview

The internal helium recycler is a closed-loop helium reliquefaction system designed to be integrated into and used with an Elekta Neuromag® TRIUX MEG system. The internal helium recycler collects the helium gas that boils off from the MEG system and automatically liquefies it back into the MEG system. To prevent interference to the MEG system during MEG measurements, the internal helium recycler liquefies helium only when MEG measurements are not made, that is, primarily by night.

In a MEG system without the internal helium recycler, the liquid helium evaporates slowly and escapes outside the building via a helium gas line. Thus, the liquid helium must be refilled regularly, typically once a week. With the internal helium recycler, the helium consumption of the MEG system becomes nearly zero, and the liquid helium refill interval changes to, roughly, once a year. As a result, the weekly downtime of the MEG system caused by the refill procedures decreases.

The internal helium recycler is available both as factory-installed and retrofitted to Elekta Neuromag® TRIUX. The internal helium recycler adds modules to the MEG system, but for the most part, the MEG system stays unchanged.

3.2. Operating principle

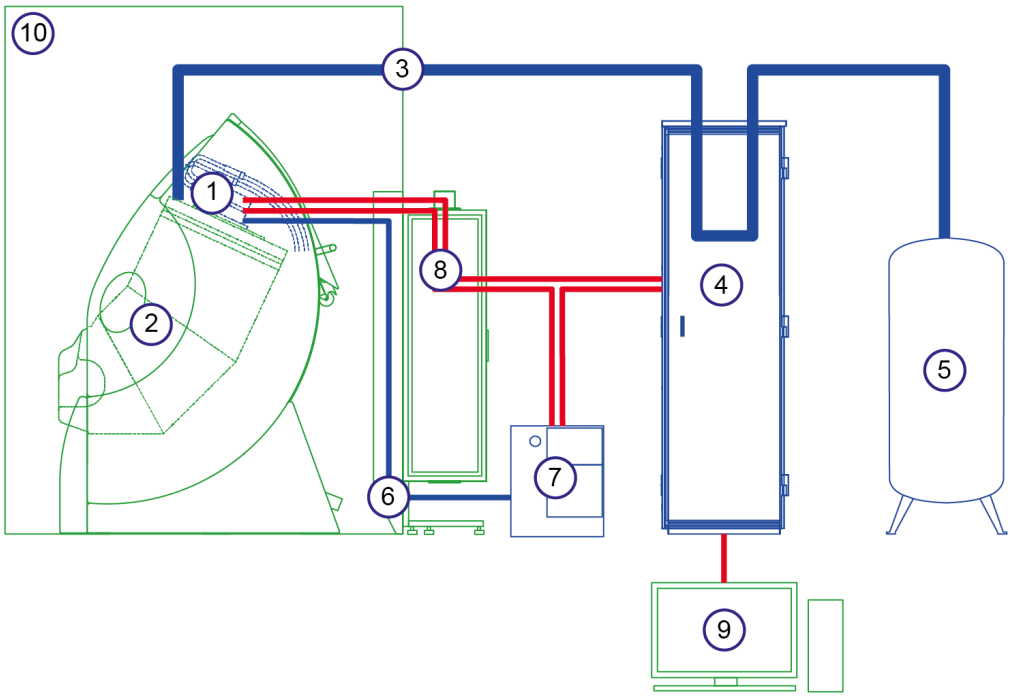


Figure 3.4 Operating principle of the internal helium recycler

(1) Cryocooler cold head
(2) Probe unit
(3) Helium gas lines
(4) Helium recycler cabinet
(5) Helium gas storage tank
(6) Cryocooler gas lines
(7) Cryocooler compressor
(8) Cryocooler control and power cables (through the filter cabinet)
(9) DACQ (Data Acquisition) workstation
(10) Magnetically shielded room (MSR)

The operation of the internal helium recycler is based on a commercially available cryocooler that cools and reliquefies the helium gas inside the probe unit (2).

The cryocooler consists of:

- A cold head (1) to supply the cooling and reliquefaction effect
- A compressor (7) running the cold head
- Cryocooler gas lines (6) between the cold head and the compressor.

The cooling and reliquefaction effect is caused by expansion of pressurized working gas inside the cryocooler cold head, which takes up heat. A moving displacer inside the cold head and an external compressor accomplish this. The displacer moves back and forth about once every second, generating the characteristic sound that is heard when the cold head operates.

Because of the mechanical movement and the electromagnetic components of the cold head, magnetic interference, acoustic noise, and vibration are unavoidable during operation. Therefore, the cryocooler cannot operate during MEG measurements. Instead, during MEG measurements, the internal helium recycler performs gas collection.

Gas collection phase

During gas collection, that is, when MEG measurements are made, the boiling helium gas is directed via a helium gas line (3) to a helium recycler cabinet (4) for compression, and from there for storage in pressurized helium gas storage tanks (5).

The tanks can take up all the helium gas that evaporates during a day's MEG operation. If the tanks become full, built-in overpressure protection releases the extra gas to the atmosphere.

Liquefaction phase

During liquefaction, that is, when MEG measurements are not made, the compressed helium gas from the helium gas storage tanks (5) flows back to the helium recycler cabinet (4). The cabinet regulates the gas pressure down to near atmospheric pressure and lets the helium gas flow back via the helium gas line (3) to the probe unit (2). The cryocooler cold head (1) condenses the helium gas back to liquid. Liquefaction reduces the helium pressure inside the Dewar slightly, causing more helium gas to flow to the Dewar.

The liquefaction rate depends on the position of the Dewar in the probe unit. The liquefaction rate is at the maximum when the upper part of the Dewar with the cryocooler cold head is oriented vertically. Therefore, a new vertical liquefaction position has been added for the probe unit. For optimum results, the probe unit must be set to the liquefaction position overnight and during weekends when the MEG system is not in use.

Note: *The liquefaction position is not intended for MEG measurements. In this position, patient comfort is degraded, SSP noise reduction is not optimized, and Internal Active Shielding (IAS) does not work.*

MEG measurements

With the internal helium recycler, the daily MEG measurements take place during the gas collection phase.

The daily time slots available for the measurements are called measurement windows. By default, the measurement windows automatically alternate with the liquefaction phase as defined in the default measurement schedule.

If needed, the user can change the default measurement schedule via a graphical user interface on the DACQ (Data Acquisition) workstation (9).

3.3. Main components

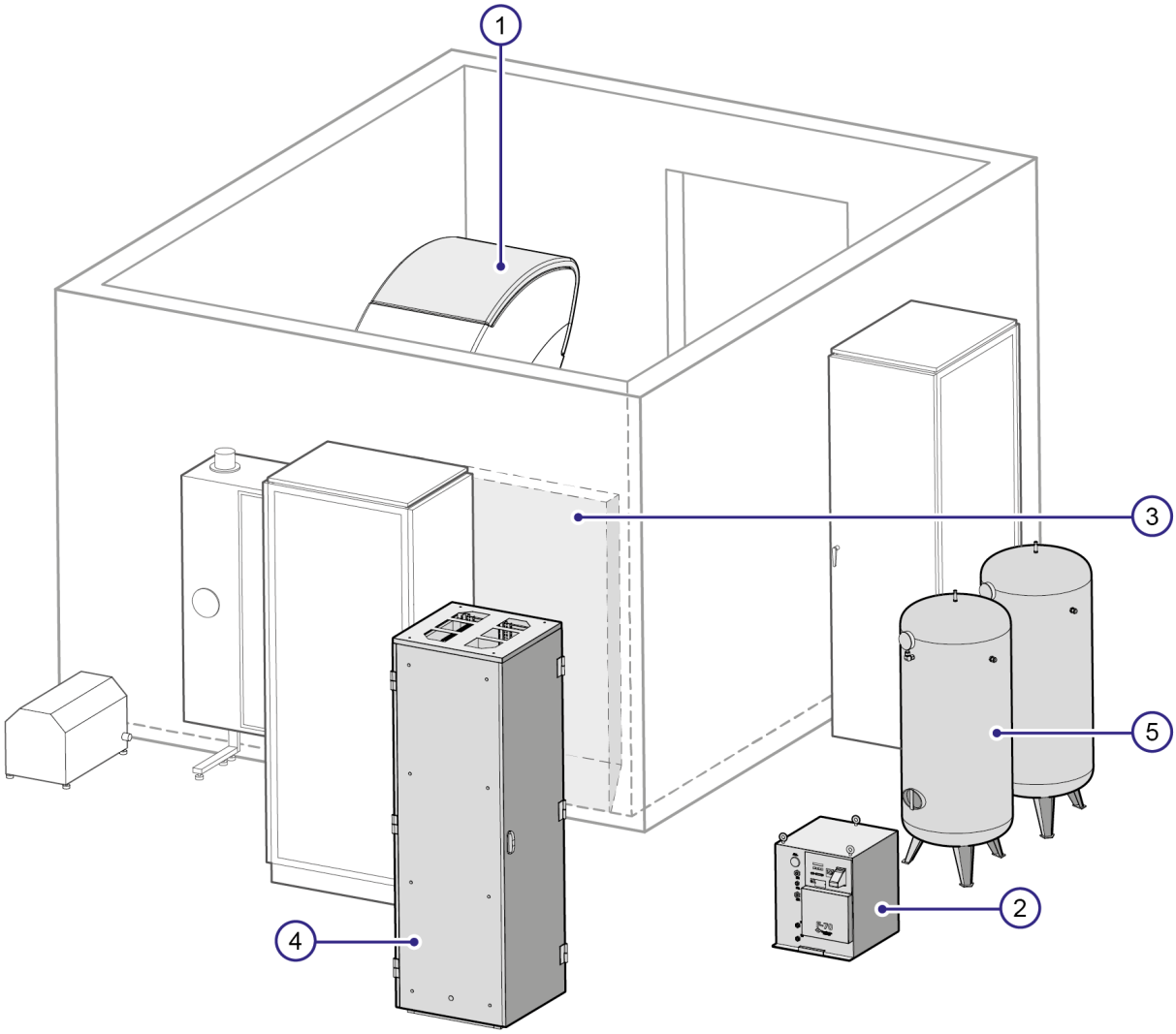


Figure 3.5 Helium recycler modules as a part of the MEG system

(1) Cryocooler cold head (inside the probe unit)
(2) Cryocooler compressor
(3) Hose reel (inside the MSR)
(4) Helium recycler cabinet
(5) Helium gas storage tanks

3.3.1. Cryocooler

The cryocooler of the internal helium recycler is a stand-alone cooler that can produce cryogenic temperature.

The cryocooler consists of a cold head, a compressor, and gas lines between the cold head and the compressor.

A hose reel next to the probe unit reels up the cryocooler gas lines when the MEG user changes the position of the probe unit.

3.3.1.1. Cryocooler cold head

The cryocooler cold head is located in the neck portion of the Dewar inside the probe unit.

The cold head contains a displacer, valves to control the flow of the working gas, and an electric motor to drive the displacer. The gas expansion caused by the working gas flow and the displacer movement takes up heat that cools and liquefies the helium gas inside the Dewar.

3.3.1.2. Cryocooler compressor

The cryocooler compressor supplies working gas and power to the cryocooler cold head.

Because gas is heated when it is compressed, the resulting extra heat must be dissipated in cooling water. Interruption in the cooling stops the operation of the cryocooler compressor.

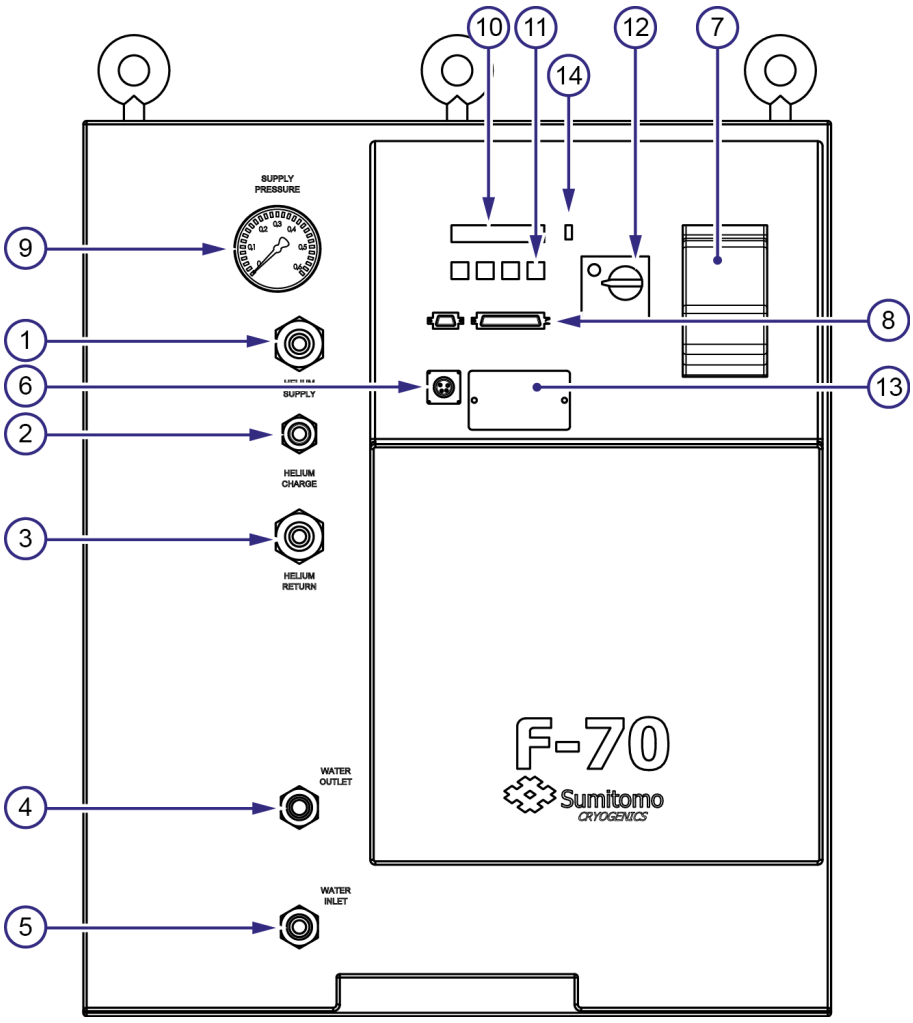


Figure 3.6 Layout of the cryocooler compressor

Front panel connections

(1) Cryocooler gas line connection, supply line
(2) Helium fill port
(3) Cryocooler gas line connection, return line
(4) Cooling water connection, outlet
(5) Cooling water connection, inlet
(6) Connector for cold head power cable
(7) Connector for compressor power cable
(8) Diagnostic interface connector for compressor control cable

Front panel mounted items

(9) Supply pressure gauge
(10) LCD display
(11) ON and OFF buttons, and two display buttons to scroll the LCD display
(12) Main power switch
(13) Voltage selection access panel
(14) Configuration mode selector switch

3.3.2. Helium gas storage system

The helium gas storage system of the internal helium recycler consists of:

- Pressure regulator unit, buffer tanks, and control unit in the helium recycler cabinet
- Helium gas storage tanks
- Piping.

During gas collection, the helium gas boiling off from the Dewar is routed to the helium recycler cabinet. A storage pump collects the gas and stores it in the buffer tanks in the cabinet. The pressure inside the buffer tanks is always less than 500 mbar above the ambient pressure. When a pre-set buffer tank pressure limit is reached, a storage compressor starts and transfers the gas to the helium gas storage tanks at a maximum pressure of 10 bar.

During liquefaction, the pressure regulator unit inside the helium recycler cabinet lets the gas back from the helium gas storage tanks to the Dewar. As a result, a slight, stable overpressure of about 50 mbar is kept in the Dewar. The overpressure prevents the helium gas from being contaminated by impurities. When the cryocooler cold head operates, liquefaction decreases the helium pressure inside the Dewar slightly. This is compensated for by the pressure regulator unit.

In special operating conditions, for example, maintenance, start-up and shutdown operations, the valve settings of the pressure regulator unit can be adjusted manually via a panel in the helium recycler cabinet. In normal operation, gas flow is automatically controlled without a need to change the settings.

3.3.2.1. Helium recycler cabinet

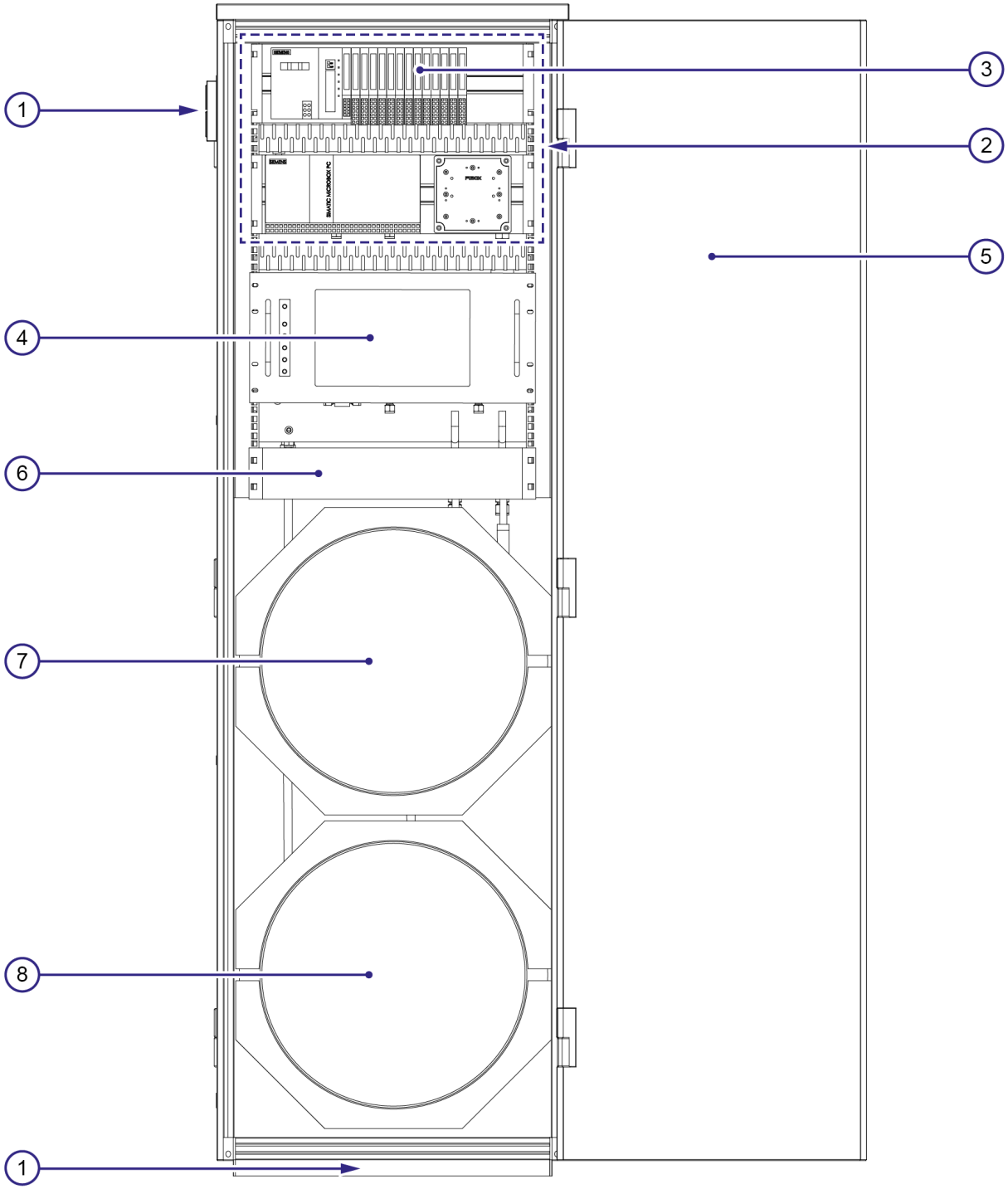


Figure 3.7 Layout of the helium recycler cabinet, front view

(1) Cable feedthrough
(2) Control unit
(3) I/O modules
(4) Service GUI
(5) LEDs on the backside of the cabinet door, visible to outside
(6) Uninterruptible power supply (UPS)
(7) Buffer tank for storage pump
(8) Buffer tank for storage compressor

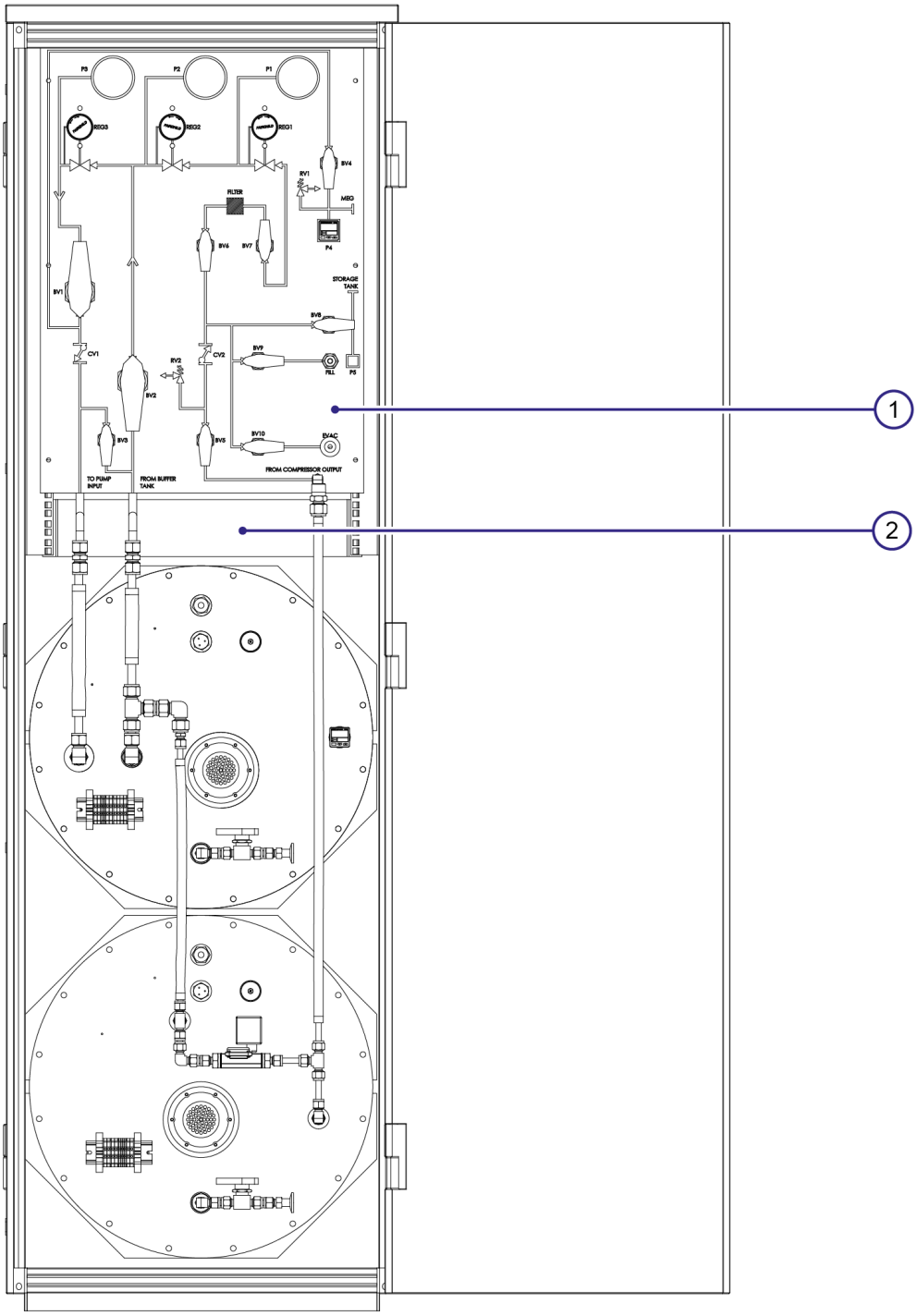


Figure 3.8 Layout of the helium recycler cabinet, rear view

(1) Pressure regulator panel

(2) Uninterruptible power supply (UPS)

3.3.2.2. Control unit

The control unit inside the helium recycler cabinet controls the cryocooler compressor as well as the storage compressor in the lower buffer tank, and monitors the temperature and pressure of the key system components.

The control unit also reacts to any changes made to the default measurement schedule to make sure that the helium level in the helium gas storage tanks is as low as possible when the next scheduled measurement window is due.

The control unit consists of a cryocooler control interface unit (5), a control PC (4), and I/O modules (3) with interfaces to, for example, temperature and pressure transducers inside the helium recycler cabinet. The operation of the control unit is controlled and monitored by the control software running on the control PC.

The MEG key user and MEG service engineer can log on to the control PC from within the helium recycler cabinet, where a desktop login is available on a service console. The control PC is also connected to the laboratory Ethernet network and can be accessed remotely with an SSH connection from the same network. In addition, it is possible to access the control PC remotely using the TeamViewer remote access software.

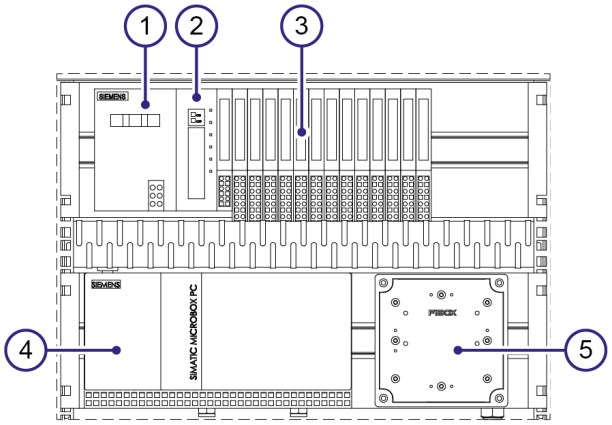


Figure 3.9 Layout of the control unit

(1) Power module of the basic I/O modules

(2) CPU module of the basic I/O modules

(3) Basic I/O modules connected to, e.g., temperature and pressure transducers

(4) Control PC

(5) Cryocooler control interface unit

3.3.2.3. Helium gas storage tanks

Depending on the system configuration, there are 2-8 helium gas storage tanks in the system. The tank layout can vary depending on the market area.

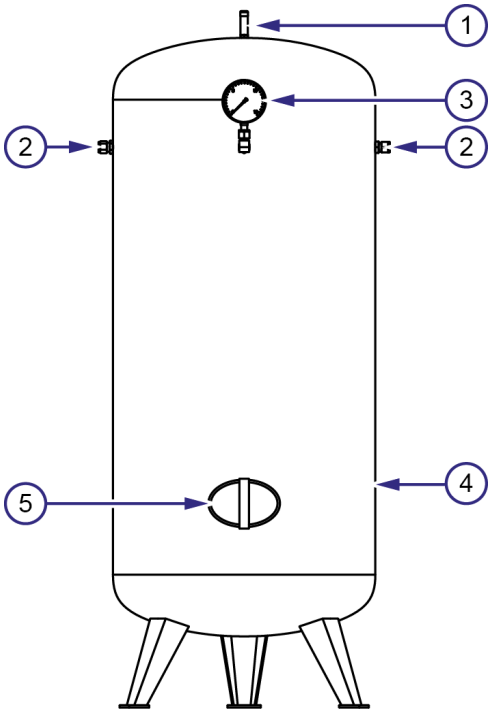


Figure 3.10 Example layout of a helium gas storage tank

(1) Safety relief valve
(2) Helium gas line connections
(3) Pressure gauge
(4) Type plate (on the reverse side)
(5) Service hatch

3.4. Operating modes

The internal helium recycler operates in four operating modes:

- Normal mode
- Cool-down mode
- Fail-safe mode
- Maintenance mode.

The active operating mode is indicated by two LED indicators on the door of the helium recycler cabinet.

Normal mode

The normal mode is the default operating mode of the internal helium recycler. In the normal mode, gas collection and liquefaction periods alternate as defined in the daily measurement schedule.

Note: *If you reboot the internal helium recycler in the normal mode, the normal mode resumes automatically. If you reboot when the internal helium recycler is in the maintenance mode or shut down, the normal mode will not resume automatically. To resume normal operations, you need to reactivate the normal mode via the service GUI.*

Cool-down mode

The cool-down mode is activated via the service GUI. The cool-down mode can be used for maintenance operations and for recovering from situations where the helium gas storage tanks have become full.

In the cool-down mode, the cryocooler compressor is switched on immediately, and liquefaction continues until all the helium gas in the helium gas storage tanks has been liquefied. Then, the internal helium recycler automatically resumes the normal mode.

Note: *No MEG measurements are allowed during the cool-down mode.*

The following operating conditions must be present for the cool-down mode to stay active:

- The Dewar pressure must stay above the lower limit.
- The cryocooler compressor must not show any errors.
- The storage tank pressure must stay above the lower limit.

Fail-safe mode

If the internal helium recycler encounters conditions in which it is impossible to continue normal operations, it automatically goes into the fail-safe mode and sends an alert.

In the fail-safe mode, the internal helium recycler is not in operation. This means that the MEG system operates as if without the internal helium recycler. The MEG system starts to lose helium first via a relief valve on the pressure regulator panel (100 mbar) and, if necessary, via the Dewar relief valve (150 mbar). Thus, whenever the fail-safe mode is activated, the MEG key user is recommended to examine and correct the situation without delay.

Maintenance mode

The maintenance mode is activated via the service GUI. The maintenance mode is used for maintenance operations, and only by MEG service engineers.

In the maintenance mode, the internal helium recycler is temporarily out of operation. The cryocooler compressor and pressure regulator unit are off. The control unit keeps on collecting data for history plots.

Shutdown

The MEG service engineer can shut down the internal helium recycler via the service GUI.

When shut down, the internal helium recycler is not in operation, and the MEG system starts to warm up. In addition:

- The cryocooler compressor and pressure regulator unit are off, but the control PC stays on.
- The control unit does not collect data for history plots.
- The amount of helium accumulated in the helium gas storage tanks so far stays in the tanks.

4. Getting started

4.1. Measurement schedule

After the installation, the internal helium recycler is fully operational and automatic: it liquefies helium according to the default measurement schedule, with optimal liquefaction performance.

The default measurement schedule is configured during the MEG system installation. The simplest schedule consists of one daily measurement window, for example, from 9:00 to 16:00. This time is available for MEG measurements, while the rest of the day is reserved for liquefaction.

As long as the default measurement schedule is sufficient for your daily operations, no further actions are required from you as a MEG user. However, if you want to adapt the default measurement schedule to your needs, changes to the schedule are possible. You can either:

- Agree on the changes with the MEG key user. The MEG key user can then modify the default measurement schedule via the service GUI.
- Make temporary changes to the schedule yourself using the graphical user interface.

Whenever you plan to make changes to the measurement schedule, you are recommended to think about how the changes affect the measurement time budget.

4.1.1. Measurement time budget

The internal helium recycler collects the boiling helium gas during the day, stores it temporarily into the helium gas storage tanks, and, during the night, liquefies the gas back into the Dewar. To have the capacity to liquefy all the collected gas during the night, the internal helium recycler has certain time limits to its daily operation. These time limits, that is, the duration of the gas collection phase/MEG measurements in relation to the liquefaction phase, form the measurement time budget.

The daily measurement time with the internal helium recycler is at least 7 hours. The actual available daily measurement time can be a few hours longer. It depends, for example, on these factors:

- The position of the probe unit during liquefaction
- The number of position changes during the day
- The time since the last preventive maintenance operation.

Example: Measurement time budget of 7 hours/17 hours

When the measurement time budget is 7 hours/17 hours, it means that 7 hours of gas collection/MEG measurements requires 17 hours of liquefaction. The 7-hour period can consist of one measurement window, or it can be divided into two windows separated by a break of 1-3 hours. The cryocooler operates during the break, which makes it possible to shift the beginning and end of the second measurement window.

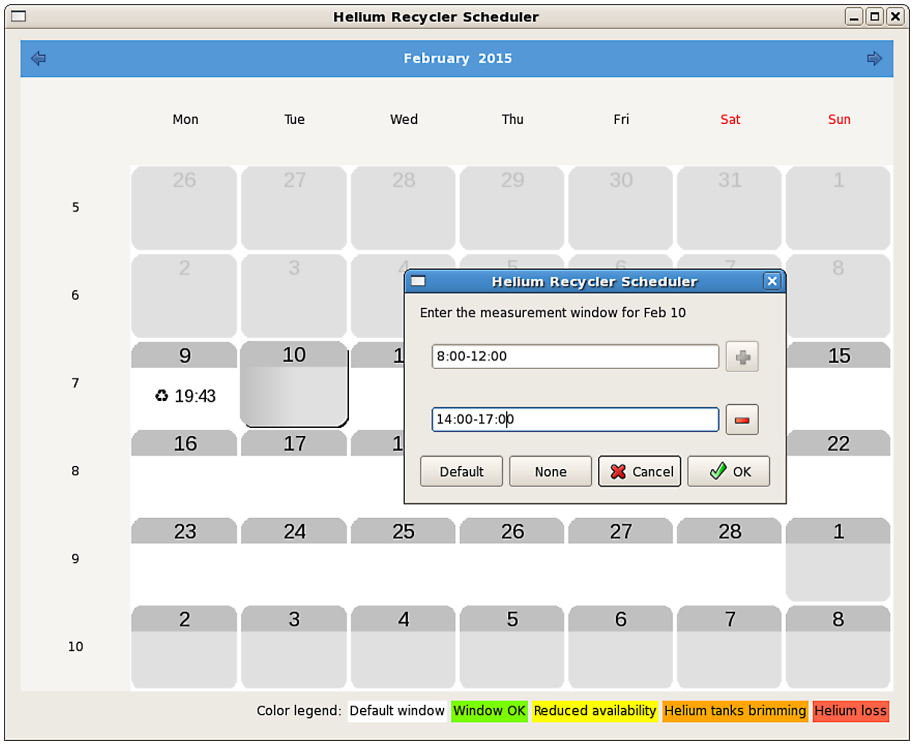


Figure 4.11 Example of a 7-hour measurement window divided into two parts

In this example, the gas collection phase/MEG measurements can also temporarily last longer than 7 hours, the maximum total duration being limited to 12 hours per day. However, if you increase the window length, you also need to make the subsequent liquefaction period longer than 17 hours to keep the measurement time budget in balance.

If you repeatedly increase the daily window length beyond 7 hours, it eventually becomes necessary to allow the internal helium recycler to liquefy even during the daytime, or finally, to reserve a complete day for liquefaction only. Otherwise, the helium gas storage tanks will get full, the extra gas will exit via the safety relief valve, and helium refill will be needed sooner than planned.

Example: Prolonging a MEG measurement

Your measurement windows are originally scheduled for Monday 9-17 and Tuesday 9-17, and these windows are realizable. That is, the day indicators of the helium recycler scheduler are green, which means full availability (figure *4.12*). On Monday, you need to prolong the measurement to 18 p.m. (figure *4.13*). In this case, you can consider the following options for Tuesday:

- Postponing the measurement window to a later time, for example, to 10-18 (figure *4.14*) to allow more time for liquefaction during the night
- Decreasing the length of the measurement window, for example, to 9-15 to allow more time for liquefaction after the measurement on Tuesday.

With the above changes for Tuesday, you still ensure full availability from Wednesday onwards. If you do neither of these changes, but obey the original schedule (9-17) on Tuesday, your measurement time for Wednesday will be decreased.

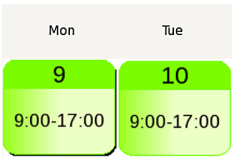


Figure 4.12 The original measurement windows for Monday and Tuesday

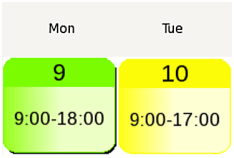


Figure 4.13 The prolonged measurement window for Monday

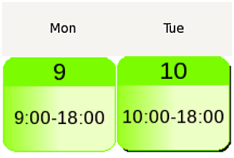


Figure 4.14 The postponed measurement window for Tuesday

Example: Reserving the weekend for liquefaction

Your MEG laboratory is typically run so that no patients are handled during weekends. Thus, all of the weekend, even the daytime, is free to be used for liquefaction. All of your measurement windows are scheduled on weekdays for 9-18.

As the week progresses, helium accumulates into the helium gas storage tanks. The day indicators of the helium recycler scheduler change from green to yellow, and from yellow to orange to signal reduced availability. However, as the whole of the Saturday and Sunday can be used for liquefaction, the next week starts as green, which means full availability.

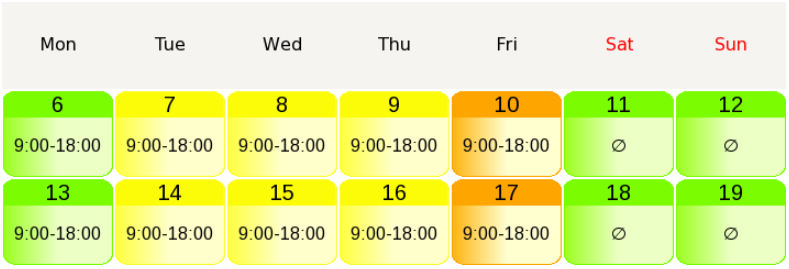


Figure 4.15 The weekly view of the helium recycler scheduler

Note: *The actual additional daily measurement time achieved with the weekly schedule in this example depends on the actual performance of the system, as well as on the number of the helium gas storage tanks in the system.*

Maximizing the daily measurement time

The actual available daily measurement time depends, for example, on these factors:

- The position of the probe unit during liquefaction
- The number of position changes during the day
- The time since the last preventive maintenance operation.

To maximize the daily measurement time, you are recommended to take note of these tips:

- Allow a liquefaction period of 1-3 hours in the middle of the day, that is, use two measurement windows per day.
- Always set the probe unit to the liquefaction position for the night. Liquefaction capacity depends on the tilt angle of the cryocooler cold head, the capacity being at its highest when the probe unit is in the liquefaction position (cold head vertical), and at its lowest in the upper seated position.
- Do not move the probe unit between different measurement positions more often than necessary. Position changes increase helium boil-off and, therefore, fill the helium gas storage tanks faster.
- Do not keep the probe unit in the upper seated position longer than necessary.

Note: *If you notice that you have forgotten to set the probe unit to the liquefaction position and liquefaction has already started, you are recommended to change the position, even though liquefaction is already ongoing (that is, the cryocooler compressor is on).*

It is typical of all cryogenic liquefaction systems that liquefaction capacity reduces gradually over time because impurities collect in the recondenser inside the system. The recondenser can be re-generated as a service operation, which recovers the liquefaction capacity to its original level.

4.2. Graphical user interface

The graphical user interface for the daily use of the internal helium recycler consists of three icons on the Data Acquisition (DACQ) workstation. The icons are available on the desktop as well as in the **Neuromag application** folder.

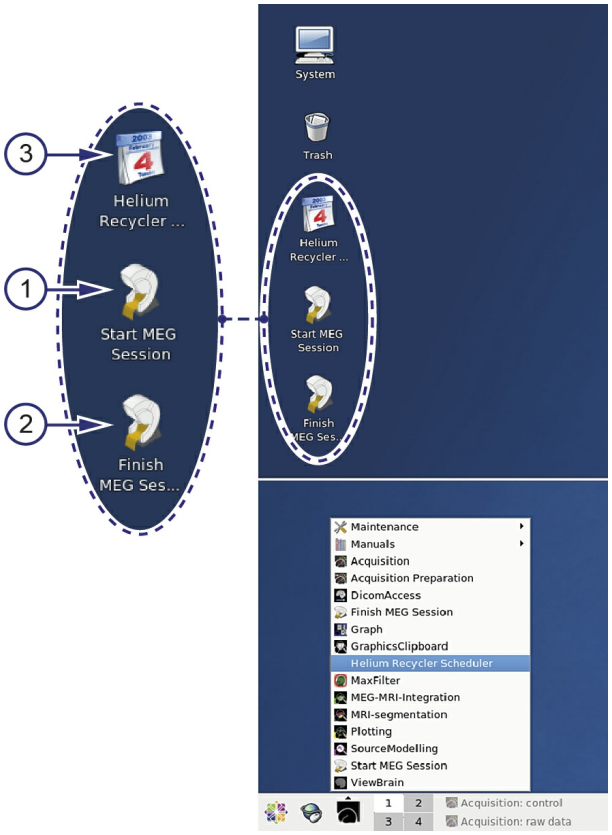


Figure 4.16 Graphical user interface of the internal helium recycler

(1) Start MEG session

(2) Finish MEG session

(3) Helium Recycler Scheduler

Start MEG session (1)

The **Start MEG session** command button tells the internal helium recycler that you want to start a MEG measurement immediately. It creates a new 3-hour measurement window, which starts immediately. If liquefaction is ongoing, it will stop immediately. The helium recycler scheduler will react to the schedule change and tell you the remaining schedule for the current day.

If you obey the default measurement schedule, you do not need to use the **Start MEG session** button at all because liquefaction automatically operates only outside the scheduled measurement windows.

The **Start MEG session** button is useful, for example, in the following situations:

- You want to start the upcoming MEG measurement ahead of schedule, and liquefaction is still ongoing.
- There are no more measurement windows scheduled for the day, but you need to do a MEG measurement.

Note: *You are recommended not to use the **Start MEG session** button repeatedly. If you create several new measurement windows outside the default measurement schedule, the helium gas storage tanks will get full, and the MEG system will start to lose helium.*

Finish MEG session (2)

The **Finish MEG session** command button tells the internal helium recycler that you are ready with your MEG measurement and want to stop the ongoing measurement window immediately. The helium recycler scheduler will react to the schedule change and tell you the remaining schedule for the current day.

You do not need to use this button at the end of every measurement, but when you do, the internal helium recycler gets more time for liquefaction. This way, you may get more time for MEG measurements in the subsequent days.

Helium Recycler Scheduler (3)

The **Helium Recycler Scheduler** icon opens the Helium recycler scheduler application.

4.2.1. Helium recycler scheduler

In the Helium recycler scheduler, you can make changes to the default measurement schedule and monitor the status of the internal helium recycler. Changes to the measurement schedule are possible two months into the future.

The Helium recycler scheduler shows a calendar view of the coming days.

The calendar view is not updated automatically. To see the latest view, you need to open the application again or make a change to the measurement schedule.

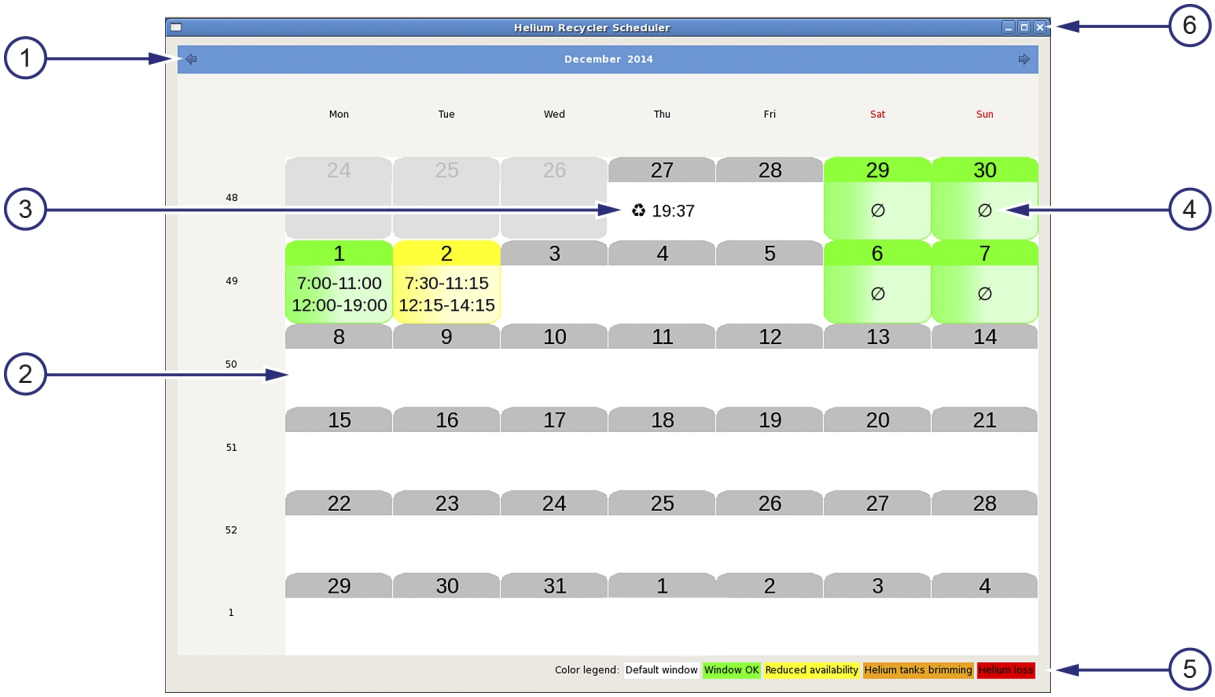


Figure 4.17 Calendar view of the Helium recycler scheduler

(1) Month selection buttons
(2) Day indicators
(3) Liquefaction start time for the current day
(4) Symbol of zero measurement windows for the day
(5) Color codes for the measurement time budget status
(6) Close button

Month selection buttons (1)

You can use the month selection buttons to change the month.

Day indicators (2)

The day indicators show the schedule requests for the day and their effect on the measurement time budget.

An empty day indicator with a white background means that the day obeys the default measurement schedule. For more information on the color codes, see below.

You can make changes to the day's measurement schedule by double-clicking a day indicator in the calendar view. The following dialog box then opens and shows the day's current schedule (either the default or changed measurement schedule).

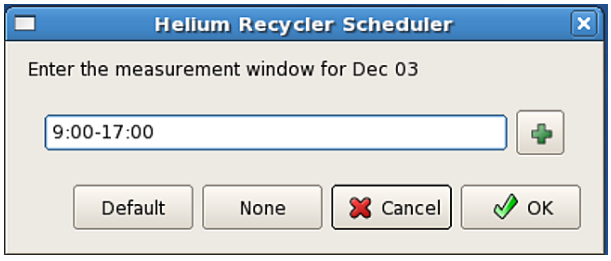


Figure 4.18 Dialog box with one measurement window entry

Button	Function
+ (plus)	Creates a second measurement window entry for the day.
Default	Restores the default measurement schedule for the day.
None	Deletes all measurement windows scheduled for the day.
Cancel	Closes the dialog box without changes.
OK	Approves the schedule change.

The format for typing a window entry is *hh(:mm)-hh(:mm)*. Minutes are optional.

If you want to divide the day's measurement window into two parts, you need to click the **+** (plus) button to create a second window entry. To remove the second window entry, you need to click the **-** (minus) button.

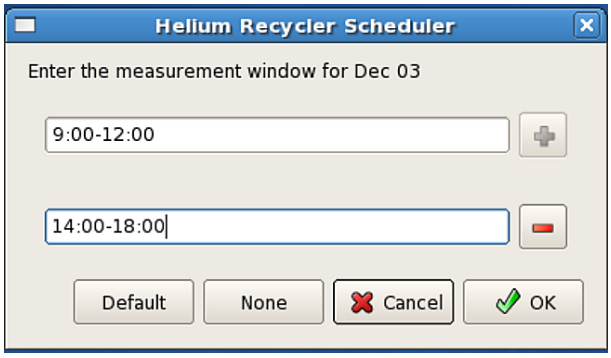


Figure 4.19 Dialog box with two measurement window entries

A measurement window can also span the night. That is, the measurement window begins before midnight and ends on the following day. Example: "21:00-02:00". The day indicator shows a "+1" sign next to the window time.

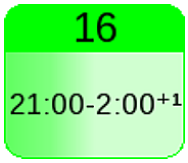


Figure 4.20 Day indicator of a measurement window that spans the midnight

Liquefaction start time for the current day (3)

The control unit of the internal helium recycler monitors the liquefaction capacity in different probe unit positions. The liquefaction start time for the current day shown in the calendar view is the estimated start time for the cryocooler at which the cryocooler is capable of reaching the minimum storage tank pressure (empty tanks) in time before the measurement window of the following day starts, provided that you keep the probe unit in the same position it is in when the estimate is calculated (that is, the current position).

Thus, the control unit gives the worst-case estimate and does not assume that the probe unit is moved to the liquefaction position. As the liquefaction capacity is the lowest in the upper seated position, the biggest discrepancy between the estimated start time and the required start time, assuming that the probe unit is moved to the liquefaction position after the measurement, is when the probe unit is used in the upper seated position.

Therefore, it is possible to continue measurements past the estimated liquefaction start time without needing to re-schedule the following day, provided that you move the probe unit to the liquefaction position after the measurement. If you ignore the start time and continue the measurement, the color code for the following day changes to reduced availability (yellow) or helium tanks brimming (orange), depending on the available tank volume. This, however, is corrected when you move the probe unit to the liquefaction position after the measurement, and the control unit senses the liquefaction position.

Color codes (5)

The calendar view shows the measurement time budget status with the following color codes.

Table 4.6 Color codes in the calendar view

Color	Text	Meaning
White	Default window	The day obeys the default measurement schedule. The measurement time budget is in balance.
Green	Window OK	The day's measurement schedule differs from the default measurement schedule, but the measurement time budget is still in balance.
Yellow	Reduced availability	The day's measurement time budget is not in balance because not all the helium in the helium gas storage tanks has been liquefied during the previous liquefaction period. The situation will not cause helium loss yet.
Orange	Helium tanks brimming	The helium gas storage tanks will get nearly full during the day. Liquefaction cannot start at the desired time, but the situation will not cause helium loss yet. This situation can be caused by an overly long MEG measurement on the previous days or the current day, or insufficient liquefaction time between the days.
Red	Helium loss	The helium gas storage tanks will become completely full during the day. The MEG system will start to lose helium. Helium refill will be needed sooner than planned. ***Note:*** *To prevent helium loss, you are recommended to:* • *Decrease the length of the upcoming measurement window, or* • *Extend the liquefaction times in between the windows.*
Gray	-	Days of the past month

Close button (6)

You can close the Helium recycler scheduler application at any time. You must always close the application after you have made a change to the measurement schedule.

4.3. Typical workflow

A typical workflow with a MEG system equipped with the internal helium recycler consists of the following phases.

When you arrive at the MEG system to start a MEG measurement:

1. Make sure that liquefaction has ended.
    - Listen for the sound of the cryocooler. If you do not hear the sound, it means that liquefaction has ended. This is the typical situation when the performance of the internal helium recycler is optimal.
    - ***Note:*** *You can start preparing the patient even while liquefaction is still ongoing, but you cannot make any signal quality checks yet because the internal helium recycler creates heavy magnetic disturbances when in operation.*
2. Set the probe unit to the desired measurement position.
3. Do the necessary signal quality checks as instructed in *Elekta Neuromag® TRIUX User's Manual*.
4. Do the measurement preparations.
    - For more information on measurement preparation, see *Elekta Neuromag® TRIUX User's Manual*.
5. Prepare the patient for the measurement.
    - For more information on patient preparation, see *Elekta Neuromag® TRIUX User's Manual*.
6. Perform your daily operations in a normal fashion.
    - If your measurement window for the day is divided into two parts with a liquefaction break of 1-3 hours, it is not necessary to the change the probe unit to the liquefaction position for the break.
7. After the last measurement of the day, set the probe unit to the liquefaction position for the night.
    - ***Note:*** *If you notice that you have forgotten to set the probe unit to the liquefaction position and liquefaction has already started, you are recommended to change the position, even though liquefaction is already ongoing (that is, the cryocooler compressor is on).*
8. Make sure that you keep the DACQ workstation on.
    - The DACQ workstation must be on for the internal helium recycler to sense the position of the probe unit.

5. Using the internal helium recycler

5.1. Changing the probe unit position

5.1.1. Setting probe unit from liquefaction position to lower seated position

After liquefaction has ended, you need to set the probe unit to the desired measurement position to be able to start a MEG measurement.

Before you start

- Make sure that no one is underneath the Dewar during the position change and that the Dewar can move freely to the lower seated position.

To set the probe unit to the lower seated position (tilted 60° from horizontal):

1. Press the **UP** button on the back side of the probe unit for a few seconds.
    - The amber **Tension** indicator comes on to show that the Dewar is released from the latches.
2. Keep pressing the **UP** button until you hear the latches to lock.
3. Press the **DOWN** button until the Dewar stops over the latches and the green **OK** indicator comes on.
    - If any other indicators besides the green **OK** indicator come on, you need to troubleshoot the probe unit. For troubleshooting instructions, see *Elekta Neuromag® TRIUX User's Manual*.

5.1.2. Setting probe unit from liquefaction position to upper seated position

After liquefaction has ended, you need to set the probe unit to the desired measurement position to be able to start a MEG measurement.

Before you start

- Make sure that no one is underneath the Dewar during the position change and that the Dewar can move freely to the uppear seated position.

To set the probe unit to the upper seated position (tilted 68° from horizontal):

1. Press the **UP** button on the back side of the probe unit for a few seconds.
    - The amber **Tension** indicator comes on to show that the Dewar is released from the latches.
2. Keep pressing the **UP** button past the lower seated position until the Dewar reaches the uppermost position and the movement stops.
3. Press the **DOWN** button until the Dewar stops over the latches and the green **OK** indicator comes on.
    - If any other indicators besides the green **OK** indicator come on, you need to troubleshoot the probe unit. For troubleshooting instructions, see *Elekta Neuromag® TRIUX User's Manual*.

5.1.3. Setting probe unit from liquefaction position to supine position

After liquefaction has ended, you need to set the probe unit to the desired measurement position to be able to start a MEG measurement.

Before you start

- Make sure that no one is underneath the Dewar during the position change and that the Dewar can move freely to the supine position.

To set the probe unit to the supine position (0° from horizontal):

1. Press the **UP** button on the back side of the probe unit for a few seconds.
    - The amber **Tension** indicator comes on to show that the Dewar is released from the latches.
2. Pull down the latch release bar on the back of the probe unit and keep it pulled down.
3. Press the **DOWN** button until the Dewar stops over the latches and the green **OK** indicator comes on.
    - After the Dewar has rotated downwards and passed the latch position, you can release your hand from the latch bar.
    - If any other indicators besides the green **OK** indicator come on, you need to troubleshoot the probe unit. For troubleshooting instructions, see *Elekta Neuromag® TRIUX User's Manual*.

5.1.4. Setting probe unit from supine position to liquefaction position

When you have finished the MEG measurements for the day, you need to set the probe unit to the liquefaction position (25° from horizontal) to allow liquefaction to start.

Before you start

- Remove the bed from the probe unit.
- Make sure that no one is underneath the Dewar during the position change and that the Dewar can move freely to the liquefaction position.

To set the probe unit to the liquefaction position from the supine position:

1. Press the **UP** button on the back side of the probe unit until you hear the latches to lock.
2. Press the **DOWN** button until the Dewar stops over the latches and the green **OK** indicator starts blinking.

5.1.5. Setting probe unit from upper/lower seated position to liquefaction position

When you have finished the MEG measurements for the day, you need to set the probe unit to the liquefaction position (25° from horizontal) to allow liquefaction to start.

Before you start

- Remove the chair from the probe unit.
- Make sure that no one is underneath the Dewar during the position change and that the Dewar can move freely to the liquefaction position.

To set the probe unit to the liquefaction position from the lower or uppear seated position:

1. Press the **UP** button on the back side of the probe unit for a few seconds.
    - The amber **Tension** indicator comes on to show that the Dewar is released from the latches.
2. Pull down the latch release bar on the back of the probe unit.
3. Keep the latch release bar down and press the **DOWN** button.
4. Keep pressing the **DOWN** button. When the probe unit has passed the 60° position latches, release the latch release bar without releasing the **DOWN** button.
    - If you started from the lower seated position, the probe unit passes the 60° position latches in about 3 seconds of driving down.
    - If you started from the upper seated position, the probe unit passes the 60° position latches in about 6 seconds of driving down.
5. With the latch release bar released, keep pressing the **DOWN** button until you hear the latches to lock.
6. Keep pressing the **DOWN** button until the Dewar stops over the latches and the green **OK** indicator starts blinking.

5.2. Making changes to the measurement schedule

5.2.1. Extending the current measurement window

You can extend the current measurement window to postpone the start of the liquefaction period.

Extending a measurement window is useful, for example, if the window is approaching the end, but you need some more time to finish the measurement. You will receive a notice on the DACQ (Data Acquisition) workstation indicating this situation.

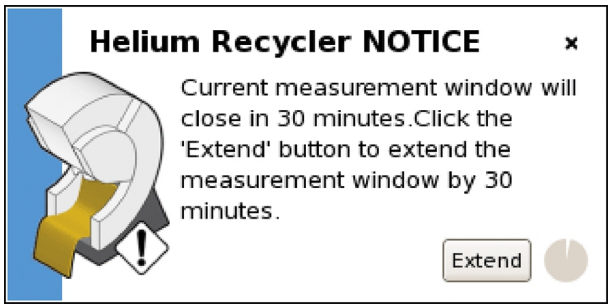


Figure 5.21 Notice: Prompt for extending the current measurement window

Note: *You are recommended not to extend measurement windows considerably or repeatedly. If a MEG measurement continues for much longer than defined in the default measurement schedule, the helium storage tanks will get full, and the MEG system will start to lose helium.*

To extend a measurement window:

- In the notification window that appears, click the **Extend** button.
    - The current measurement will continue for 30 minutes more.
- Alternatively, you can define a new stop time for the measurement window using the Helium recycler scheduler.

5.2.2. Starting a measurement window immediately

If necessary, you can start a measurement window immediately using the **Start MEG session** button.

An immediate start is useful, for example, in the following situations:

- You want to start the upcoming MEG measurement ahead of the schedule, and liquefaction is still ongoing.
- There are no more measurement windows scheduled for the day, but you need to do a MEG measurement.

Note: *You are not recommended to use the **Start MEG session** button repeatedly. If you create several new measurement windows outside the default measurement schedule, the helium storage tanks will get full, and the MEG system will start to lose helium.*

To start a measurement window immediately:

- On the Data Acquisition (DACQ) desktop, click the **Start MEG Session** button.
    - The Helium recycler scheduler moves the forthcoming measurement window to start immediately, or, if no measurement windows are scheduled to start on the current day, creates a new 3-hour measurement window, starting immediately.

5.2.3. Stopping a measurement window immediately

If you finish a MEG measurement well in advance, you can shorten the current measurement window to allow liquefaction to start earlier than defined in the measurement schedule.

To stop a measurement window immediately:

- On the Data Acquisition (DACQ) desktop, click the **Finish MEG session** button.
    - The Helium recycler scheduler will react to this change of schedule and tell you the remaining schedule for the current day.

5.2.4. Adding or editing a measurement window

You can schedule a measurement window to start at a certain point of time in the future, or edit an existing measurement window in the calendar view.

To add or edit a measurement window:

1. Open the Helium recycler scheduler.
2. If needed, change the month using the arrow buttons at the top of the calendar.
3. Double-click the desired day.
4. In the dialog box that opens, type the desired start and stop times for the measurement window.
    - If you want to divide the day's measurement window into two parts, you can click the + (plus) button to create a second window entry. For more detailed information on scheduling pauses to measurement windows, see the corresponding procedure.
5. Click **OK**.
    - The color code for the day changes.
6. Examine the new color code for the current day and the following days.
    - If any of the days show red, you are strongly recommended to decrease the window length to make sure that the performance of the internal helium recycler stays optimal.
7. Close the Helium recycler scheduler.

5.2.5. Deleting a measurement window

You can also schedule no MEG measurements for a day. This way the internal helium recycler can liquefy as long as needed, at any time needed, until the next measurement window is due to start.

To schedule no MEG measurements for a day:

1. Open the Helium recycler scheduler.
2. Double-click the desired day.
3. In the dialog box that opens, click the **None** button.
    - A 'Ø' symbol shows on the calendar.
4. Close the Helium recycler scheduler.

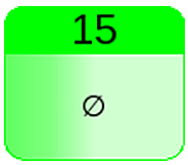


Figure 5.22 Symbol of zero measurement windows for the day

5.2.6. Scheduling a pause to a measurement window

You can schedule a pause to a measurement window and continue the measurement after the pause, for example, to postpone the patient times later to the evening.

During the pause, the internal helium recycler liquefies a small amount of helium. This is necessary to maintain the measurement time budget. Because of this, you must make sure that the pause meets these requirements:

- The pause must be at least one hour long, and no more than three hours.
- Together, the two measurement windows before and after the pause must not be longer than 12 hours.

To schedule a pause to a measurement window:

1. Open the Helium recycler scheduler.
2. Double-click the desired day.
3. In the dialog box that opens, click click the **+** (plus) button.
    - A second window entry appears.
4. To the first window entry, type the new stop time for the window that occurs before the pause.
5. To the second window entry, type the new start time for the window that is to occur after the pause.
6. Click **OK**.
7. Close the Helium recycler scheduler.

If the day is already divided into two measurement windows by default, just type the desired new window times into the dialog box.

5.2.7. Removing a scheduled pause between two measurement windows

You can remove a scheduled pause between two measurement windows if you think that the pause is no longer necessary.

To remove a scheduled pause:

1. Open the Helium recycler scheduler.
2. Double-click the desired day.
3. In the dialog box that opens, click the - (minus) button.
    - The second window entry goes out of view.
4. On the remaining window entry, type the new stop time for the measurement, if necessary.
5. Click **OK**.
6. Close the Helium recycler scheduler.

5.2.8. Restoring the default measurement window

You can restore the default measurement window for a day any time.

To restore the default measurement window:

1. Open the Helium recycler scheduler.
2. If needed, change the month using the arrow buttons at the top of the calendar.
3. Double-click the desired day.
4. In the dialog box that opens, click the **Default** button.
5. Close the Helium recycler scheduler.

5.3. Notifications

The internal helium recycler gives its users notifications about noteworthy changes in its operating conditions in real time. You are recommended to read all notifications carefully and take the recommended action(s).

There are two types of notifications:

- Notices
- Alert messages

Notices

Notices mostly inform you of changes made to the daily measurement schedule. Notices are mostly targeted to the MEG user.

Notices show in the bottom-right corner of the Data Acquisition (DACQ) desktop, where they automatically pop up over any other open windows.

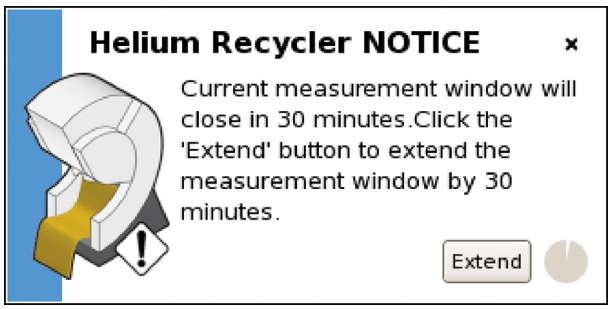


Figure 5.23 Example of a notice window

When you get a notice, you have two options:

- You can dismiss the notice either by clicking any area (except for the **Extend** button) on the notice window, or by clicking the close button (x).
- You can click the **Extend** button in the notice window. A decreasing circulator indicator alongside the button shows you the remaining reaction time.

Note: *Not all notice windows include the **Extend** button. Such notices automatically disappear from the screen after 15 minutes. Make sure that you nevertheless react to these notices as well.*

Alert messages

Alert messages inform the MEG key user and MEG service engineer about instant problematic operating conditions related to the internal helium recycler. Alert messages are delivered to these users via e-mail or as SMS messages.

You are not expected to reply to the address where the notification emails are sent from.

5.3.1. Notices

There is a recommended action for each notice.

Table 5.7 List of notices

Notice	Meaning	Recommended action
Losing helium from helium gas storage tanks.	The helium gas storage tanks are full. The MEG system is losing helium currently.	1. Stop the MEG measurement, if it is ongoing. 2. If possible, remove any measurement windows from the helium recycler scheduler to allow liquefaction to start as soon as possible. Keep in mind that helium loss can cause a hastened helium refill. In addition, if you make MEG measurements for several hours with the helium gas storage tanks full, the internal helium recycler will need maintenance sooner than planned. This notification is also delivered to the MEG key user.
Not losing helium anymore from gas storage tank.		
Remember to set probe unit to liquefaction position.	You must remember to set the probe unit to the liquefaction position for the night.	Set the probe unit to the liquefaction position for the night.
Helium loss estimated to start at <hh:mm>	The helium gas storage tanks will become full during the current measurement window.	1. Try to complete the measurement before the indicated time. 2. After the measurement, click the **Finish MEG Session** button to allow liquefaction to start as soon as possible.

Notice	Meaning	Recommended action
Tomorrow's measurement window is not achievable. You need to close today at <hh:mm> or start tomorrow at <hh:mm>	There is not enough time to liquefy enough helium before the following day. Therefore, it is not possible to do MEG measurements as planned in the measurement schedule on the following day.	Try to complete the MEG measurement before the indicated time, or reschedule the next day's measurement to start a bit later, at the indicated time.
Full measurement window is now available.		
Current measurement window will close in 30 minutes. Click the 'Extend' button to extend the measurement window by 30 minutes.	The current measurement window will close in 30 minutes.	If it is necessary to continue the MEG measurement longer than 30 minutes, click the **Extend** button in the notice window.
Cryocooler needs to start now! Stop the measurement, or click the 'Extend' button to continue measuring. Otherwise, the cryocooler will start after the given time-out.	You must allow liquefaction to start immediately, or otherwise the upcoming measurement windows cannot occur as planned in the measurement schedule.	Stop the MEG measurement.
Cryocooler needs to start in 15 minutes, or otherwise helium loss will occur.	The helium gas storage tanks will become completely full in 15 minutes. After this, the MEG system will start to lose helium.	Stop the MEG measurement.
Internal helium recycler test alert.	Notification delivery and connections are being tested.	No actions required.

5.4. LED indicators

5.4.1. LEDs on the position indicator display

You can monitor the operation of the probe unit lifting mechanism with the help of the position indicator display on the wall behind the probe unit.

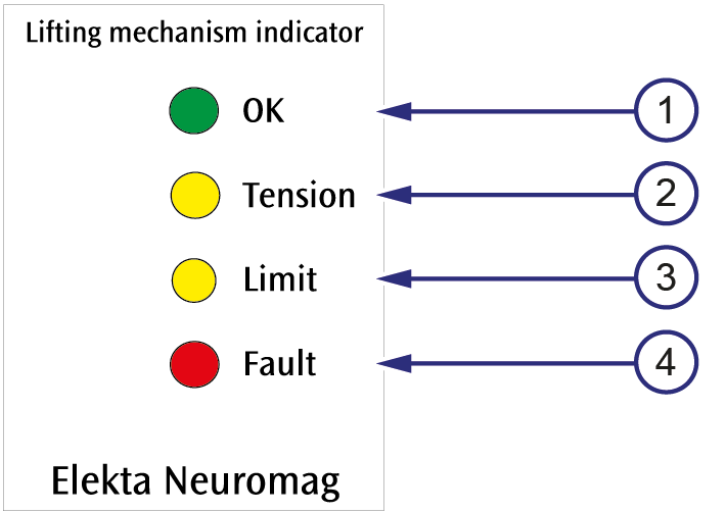


Figure 5.24 Position indicator display

No	Indicator	Meaning
1	Green light **OK**, continuous	Allowed measurement position (supine, lower seated or upper seated). Probe unit position secured.
	Green light **OK**, blinking	Liquefaction position. Not intended to be used for patient measurements.
2	Amber light **Tension**	Probe unit position not secured. The weight of the Dewar cradle causes tension to the ropes of the lifting mechanism. This is normal during up/down movement. When the tension of the ropes is released (and light goes off), the downward movement of the motor stops.
3	Amber light **Limit**	Dewar cradle is at the upper limit of the upward movement, and the motor stops. Only downward movement is possible. This is normal during up/down movement.
4	Red light **Fault**	Abnormal condition because of malfunction in the lifting mechanism and/or the fiber optic sensors that monitor the position. Contact Elekta service.

WARNING 5.15

Do not put a patient under the probe unit except when the green OK light on the position indicator display is continuously lit. If the green OK light is still blinking, the probe unit is in the liquefaction position. The liquefaction position is not intended to be used for patient measurements.

5.5. Troubleshooting

5.5.1. Measurement windows get shorter

Symptom(s): The Helium recycler scheduler often shows yellow, orange or red color codes even though you obey the default measurement schedule.

Possible cause(s)	Solution(s)
The probe unit has not been set to the liquefaction position often enough.	• Make sure that the daily measurement window is no longer than 7 hours. • Make sure that you set the probe unit to the liquefaction position for every night. ◦ Liquefaction is more efficient in this position. • If the problem persists, ask the MEG key user to contact Elekta service for the examination of the liquefaction rate.

5.5.2. MEG signal quality decreases

Symptom(s): The MEG signal quality is poor especially towards the evenings.

Possible cause(s)	Solution(s)
The liquefaction periods of the past days have been too short to allow a sufficient liquefaction rate.	• Make sure that the daily measurement window is no longer than 7 hours.
The probe unit has a low total amount of helium available. Some of the helium may have leaked.	• Measure the liquid helium level on the DACQ (Data Acquisition) workstation. ◦ For instructions, see *Elekta Neuromag® TRIUX User's Manual*. • If the helium level is lower than 30%, ask the MEG key user to refill helium from a bottle, or contact Elekta service.

5.5.3. Helium recycler scheduler does not open

Symptom(s): An error message appears when you click the **Helium Recycler Scheduler** icon on the DACQ (Data Acquisition) workstation.

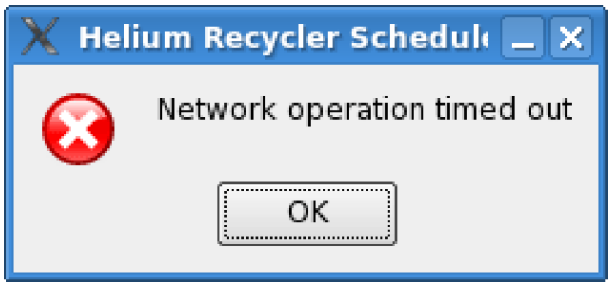


Figure 5.25 Helium recycler scheduler error message 1

Figure 5.26 Helium recycler scheduler error message 2

Possible cause(s)	Solution(s)
The control software of the internal helium recycler is not running.	Inform the MEG key user.
The Internet connection between the helium recycler cabinet and the DACQ workstation is down.	Inform the MEG key user.

6. Maintenance

6.1. Maintenance operations – MEG user

Obey the recommended maintenance program for the MEG system described in *Elekta Neuromag® TRIUX User's Manual*.

6.1.1. Cleaning

- Clean the probe unit and related accessories as described in *Elekta Neuromag® TRIUX User's Manual*.
- In addition, clean the outer surface of the hose reel with a damp cloth using soap water or ordinary mild dish care detergent. You can also use chloramine or alcohol-based disinfectant/sanitizer, if necessary.

6.2. Maintenance operations – MEG key user

The MEG key user is responsible for the following maintenance operations of the internal helium recycler.

Table 6.8 Maintenance operations required of the MEG key user

Interval	Maintenance operation
According to need	Doing a liquid helium refill
One week	Monitoring the liquid helium level

6.2.1. Doing a helium refill

In normal operating circumstances, helium refill is not necessary when the internal helium recycler is in use. However, it is possible to add liquid helium into the system, if needed. For optimum performance, the liquid helium level must stay between 30% and 60%, when measured in the supine position.

Alternatively, you can add helium gas to the helium gas storage tanks via the FILL port on the pressure regulator panel.

6.2.1.1. Adding liquid helium to the system

Before you start

- Read and obey the complete safety instructions for safe handling of liquid and gaseous helium in this manual and *Elekta Neuromag® TRIUX User's Manual*.
- Make sure that you have enough of liquid helium available. For a complete refill, you need at least 90 liters of liquid helium in the storage container. Taking into account the cooling of the siphon and transfer losses, you need about 40 liters of liquid helium to fill the Dewar to 30%-60%.
- Make sure that you have enough time to complete the filling procedure. Liquid helium refill must be made during an ongoing measurement window, and there must be at least 2 hours left until the next liquefaction period is to start.

- You are recommended to shut down the control software and restart it again after completing the refill. This way the long-term helium leakage detection will not generate false alarms concerning the helium level change.

Note: *Using magnetic tools and electrical equipment like hot air guns inside the magnetically shielded room (MSR) is not recommended. If absolutely necessary, they must be kept more than 1 meter away from the sensor array. For sensor detrapping, see Elekta Neuromag® TRIUX User's Manual.*

WARNING 6.16

Beware of the extremely cold, non-life-supporting helium gas.

Necessary tools

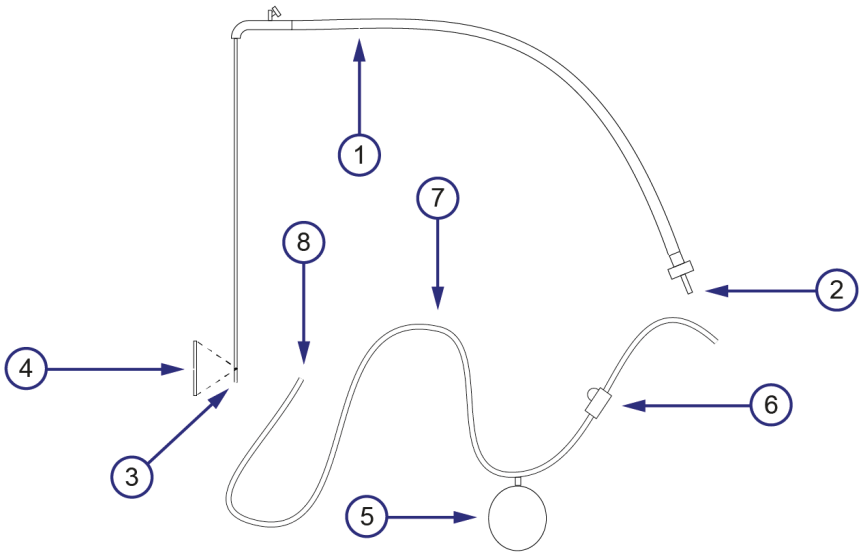


Figure 6.27 Parts needed in liquid helium transfer

(1) Flexible siphon
(2) Siphon tip
(3) Filter unit
(4) Extension tube (optional)
(5) Manual pressurizing unit
(6) Hose clamp valve
(7) Transfer exhaust silicon hose
(8) Connection to storage Dewar venting port *

* You can leave the other end of the silicon hose free.

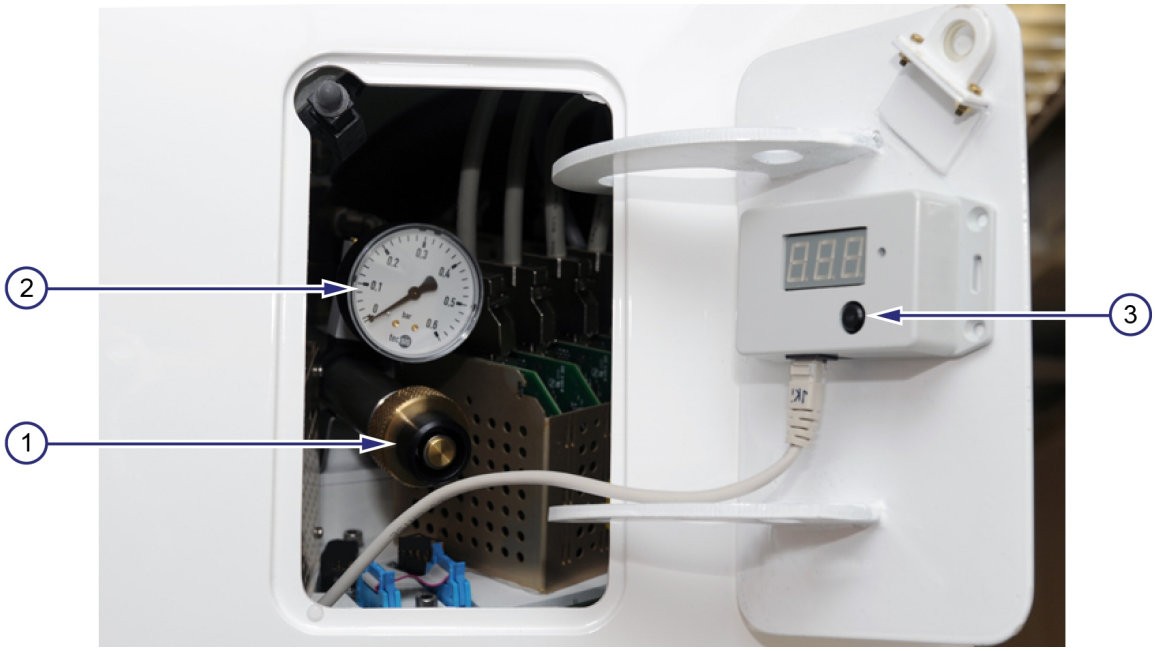


Figure 6.28 The liquid helium filling port on the upper part of the probe unit front face

(1) Fixed L-siphon port with plug
(2) Pressure gauge
(3) Liquid helium level local display

Figure 6.29 The plastic cap for flexible siphon

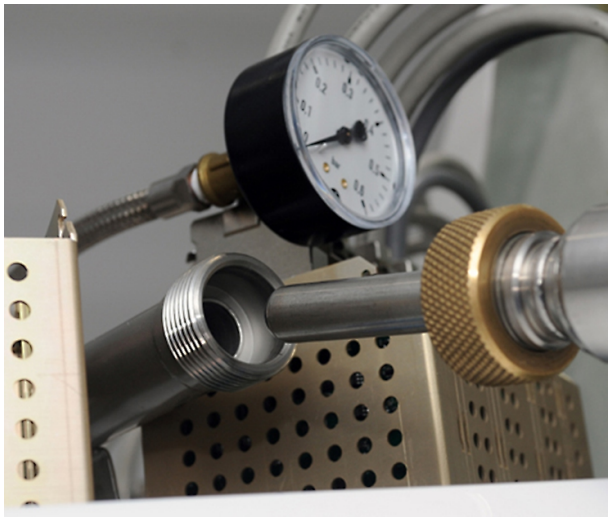


Figure 6.30 Putting the flexible siphon into the fixed siphon

Filling procedure:

1. Make sure that the cryocooler is not in operation and will not start for at least 2 hours.
2. Set the probe unit to the supine position.
3. Close the BV4 valve on the pressure regulator panel inside the helium recycler cabinet.
4. Open the refill bypass valve in the helium gas line outside the MSR.
5. Move the storage container to the MSR entrance and connect the exhaust of the storage container to the transfer exhaust hose.
    - The hose includes a rubber balloon pump (manual pressurizing unit) and a plastic hose clamp valve (see figure 6.28).
6. Close the hose clamp valve, and then open the exhaust valve on the storage container and let the pressurizing unit balloon fill up. Close the exhaust valve, open the hose clamp valve, and squeeze the balloon.
    - Do this procedure 2 - 3 times to flush air out of the transfer hose and balloon.
7. Close the hose clamp valve and the safety relief valve of the storage container.
8. Clean your hands.
9. Make sure that the filter unit at the tip of the thin, stiff part of the transfer siphon is in place (see figure 6.28).
    - If needed, you can use the siphon extension tube to reach the bottom of the transfer Dewar. The extension tube is mounted between the filter unit and the vertical part of the siphon.
10. Put on thick protective gloves supplied in the Cryogenic accessories kit, and do the following:
    1. Lower the transfer siphon very slowly into the storage container.
    2. Make sure that the transfer exhaust hose is blocked with the plastic hose clamp valve.
    3. Make sure that the relief valve of the storage container is closed. Let the helium gas flow through the siphon to get air out of it and to pre-cool it. Be careful of the extremely cold gas stream.
    4. When the helium gas flow starts to resemble a white flame, open the hose clamp and temporarily plug the open end of the transfer siphon with the plastic plug supplied (see figure 6.30). Continue to lower the siphon to the bottom of the storage container.
11. Move the storage container into the MSR. Leave the door open.

12. Use thick protective gloves, and do the following. Be careful of the cold helium flowing out.
    1. Remove the plastic cap covering the siphon tip.
    2. Loosen the plug at the fixed L-siphon port of the probe unit.
    3. Replace the plug as quickly as possible with the tip of the flexible siphon (see figure 6.30). During the short interval when the fixed siphon on the probe unit is unplugged, there should be helium flowing out of the fixed siphon as well as from the flexible siphon. If this is not the case, there can be a plug of frozen air in the siphon. In that case, troubleshoot the siphon.
    4. Secure the siphon in place by tightening the knurled sleeve nut on the siphon. Do not overtighten. Turn ¼ turn counterclockwise once the thread has reached the bottom to avoid jamming.
    5. Place the plug of the L-siphon to a place where it is easily available, for example, the plug holder at the cover of the refill opening.
13. Block the transfer balloon exhaust hose with the plastic clamp again and pump gently with the rubber balloon.
    1. Monitor the pressure from the probe unit of the MEG system pressure gauge (see figure 6.28). Do not let the pressure rise over 0.1 bar (10 kPa). The pressure rises quickly at first. When the flow of liquid starts after a few minutes, the pressure goes down for a moment and then rises again to approximately 0.04 – 0.07 bar (4 - 7 kPa), depending on the flow impedance of the refill exhaust line. After the liquid starts flowing, you can usually pump the balloon continuously until the transfer is complete.
    2. Monitor the liquid helium transfer progress on the liquid helium level local display. When the desired helium level is reached, release the transfer exhaust hose clamp valve and let the pressure stabilize for a couple of minutes. Switch off the display.
14. When the pressure has decreased, do the following:
    1. Remove the siphon from the probe unit. Have the plug ready.
    2. Pull the tip of the siphon out and insert the plug as quickly as possible.
    3. Tighten the plug. Do not overtighten. Turn ¼ turn counterclockwise once the thread has reached the bottom to avoid jamming.
    4. Move the storage container out of the MSR and lift the siphon out. Use gloves to avoid frost bite.
    5. Close the exhaust valve on the storage container.
    6. Disconnect the transfer hose and open the relief valve on the storage container.
15. Open the BV4 valve.
16. Close the refill bypass valve.
17. Examine the operating mode of the internal helium recycler from the LEDs on the door of the helium recycler cabinet.
    - The lower LED must be green to indicate the window mode. However, it is possible that the internal helium recycler has switched to the fail-safe mode because of the abnormal Dewar pressure readings during the refill. In that case, set the internal helium recycler back to the normal mode using the service GUI.
18. Return the storage container to its place and make sure that all that valves in the container are in the correct positions: the siphon port closed, the pressurizing port closed, and the safety relief valve open.

Note: *You are not recommended to change the probe unit position immediately after the transfer because the thermal insulation on the exhaust lines is very cold and can break easily. Wait one hour before you change the probe unit position.*

6.2.1.2. Adding gaseous helium to the system

As an alternative to adding liquid helium in the system, you can add helium gas to the helium gas storage tanks via the FILL port on the pressure regulator panel. For maximum capacity, helium must be added when the storage tank pressure is at its lowest.

Before you start

- Read and obey the complete safety instructions for safe handling of liquid and gaseous helium in this manual and *Elekta Neuromag® TRIUX User's Manual*.
- Reserve time for liquefaction after filling the tanks. The time needed depends on the amount of helium added, and you can estimate it based on pressure plot diagrams (starting pressure and slope).
- You are recommended to shut down the control software and restart it again after completing the refill. This way the long-term helium leakage detection will not generate false alarms concerning the helium level change.

Necessary tools

- Helium gas cylinder, purity 40 ppm (A cylinder of 200 bar and 50 liters is about 3.6 liters of liquid helium.)
- Gas cylinder pressure regulator capable of 8 bar output pressure
- Helium refill line for connecting the regulator output to the FILL port on the pressure regulator panel

Filling procedure:

1. Connect the regulator output to the helium refill line.
2. Open the regulator valve to let some gas flow through the line to flush air out.
3. Connect the helium refill line to the FILL port while still letting the gas flow through the line.
4. Tighten the connections.
5. Check the regulator settings.
    - The output pressure should be close to the storage tank pressure. Adjust, if necessary.
6. Open the BV9 valve on the pressure regulator panel and the regulator valve to fill the tanks.
7. Adjust the regulator output pressure to reach the required storage tank pressure.
8. When the required pressure has been reached, close the BV9 valve and the regulator valves.
9. Disconnect the helium refill line from the FILL port.
10. Set the internal helium recycler to the cool-down mode to liquefy all the gas in the tanks.
    - The internal helium recycler automatically returns to the normal mode when the pressure low limit in the tanks has been reached.

6.2.2. Monitoring the liquid helium level

You are recommended to monitor the liquid helium level weekly.

When the internal helium recycler is in use, the liquid helium level varies periodically. With the daily measurement schedule and liquefaction periods in balance, the period is 24 hours. If helium gas is let to accumulate in the helium gas storage tanks, for example, during the week, and the accumulated gas is liquefied during the weekend, the period is seven days.

To monitor the liquid helium level:

1. Measure the liquid helium level using the Helium program.
    - You can find the Helium program in the maintenance folder in the DACQ (Data Acquisition) workstation and on the **Tools** menu of the Data Acquisition program.
    - For detailed instructions on using the Helium program, see *Elekta Neuromag® TRIUX User's Manual*.
2. Analyze the results.
    - The liquid helium level reading depends on the probe unit position. Therefore, you have to, for example, compare the highest helium levels achieved in the liquefaction position between successive periods. A falling trend of the highest level values indicates a small helium leakage in the helium gas storage system. For optimum performance, the liquid level must be between 30% and 60%, when measured in the supine position.

7. MEG key user tasks

7.1. Service GUI

The service GUI of the internal helium recycler runs on the control PC inside the helium recycler cabinet. Via the service GUI, you can change the operating mode of the internal helium recycler as well as examine application log files, history plots, and configure the behavior of the internal helium recycler.

On the site, you can access the service GUI by:

- Using the touch screen and virtual keyboard
- Using a keyboard and mouse connected to a USB port inside the cabinet.

You can also access the service GUI remotely via:

- Full console access, for example, an SSH connection
- The TeamViewer remote access software.

The service GUI has a touch screen with command buttons (2) on two rows. To move between the rows, use the scroll bar (1) on the right.

Figure 7.31 Service GUI

(1) Scroll bar

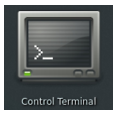
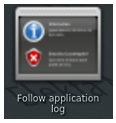
(2) Command buttons

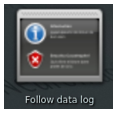
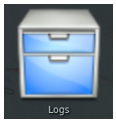
(3) Access to the command line window

(4) Access to TeamViewer

Command buttons (2)

Table 7.9 Command buttons of the service GUI

Button	Name	Function
	Normal mode	Starts normal operations from fail-safe mode, maintenance mode or cool-down mode, or starts the control software after shutdown. ***Note:*** *If you activate the normal mode from the shut-down state, it can take about one minute for the normal operations to start. A notification shows on the screen after the normal mode command has been completed and tells you of any problems found.*
	Maintenance Mode	For MEG service engineers' use only. Starts the maintenance mode, in which the cryocooler compressor and pressure regulator unit are off.
	Cool-down Mode	Starts the cool-down mode, i.e. continuous liquefaction until all the helium gas in the helium gas storage tanks has been liquefied. ***Note:*** *You can deactivate the cool-down mode by activating any other operating mode at any time.*
	Shutdown	For MEG service engineers' use only. Terminates the control software of the internal helium recycler.
	History Plot	Makes graphs of the system performance for the previous four days. Mainly useful for troubleshooting purposes and performance trending.
	Helium Recycler Scheduler	Opens the Helium recycler scheduler application for planning the daily MEG measurements and liquefaction periods.
	Annotate	Opens a dialog box where you can type short free-text annotations. Annotations show in history plots, and can be used to mark useful information for troubleshooting or performance trending. Annotations are bound to the time when the annotation was typed.
	Notes	Opens a text editor for making notes.
	Control Terminal	Opens a terminal connection to the control software, where the user can perform any operations, for example, make temporary changes to the configuration of the internal helium recycler.
	Follow application log	Opens a window where you can monitor application log entries in real-time. The entries contain details about the control unit's events. You can close the window any time by clicking the close button on the upper-corner.

	Follow data log	Opens a window where you can monitor the log files of the pressure and temperature transducers in real-time. You can close the window any time by clicking the close button on the upper-corner.
	Logs	Opens a log directory in the file explorer.
	Virtual Keyboard	Opens the virtual keyboard.

Access to the command line window (3)

Opens a command line window.

Access to TeamViewer (4)

Opens the TeamViewer software. If this icon is visible in the service GUI, remote access to the service GUI is on. For detailed instructions on using the TeamViewer software, see the manufacturer's manual.

7.1.1. Opening a remote connection to service GUI

You can access the service GUI remotely using the TeamViewer software. The whole service GUI desktop is available via TeamViewer.

Before you start:

- Download and install the software at http://www.teamviewer.com.
- Find out the Partner ID of the helium recycler cabinet.
    1. Click the **TeamViewer** button on the touch screen in the helium recycler cabinet.
    2. The Partner ID shows in the **Your ID** field. Write the Partner ID down.
    3. The Partner ID will not change, so give it to all who need to access the service GUI remotely.

To open a remote connection:

1. Start TeamViewer on your remote computer.
2. In the **TeamViewer** window, type the Partner ID of the helium recycler cabinet into the **Partner ID** field, and then click **Connect to Partner**.
3. When the system prompts for a password, type a password.
    - The password is defined locally for security reasons.
4. When you are finished with the remote access, close the **TeamViewer** window.

7.1.2. Acknowledging service GUI notifications

When you start the normal mode or do a shutdown via the service GUI, you get a notification that shows you the status of the internal helium recycler. It is a good practice to acknowledge notifications as follows.

1. Read the notification.
    - You can see the complete notification by clicking on the green message repository icon at the bottom bar (1).

2. If the notification contains a fatal error (FATAL), error (ERROR), warning (WARN), or note (NOTE), take the necessary actions to correct the situation.
3. Acknowledge the notification by clicking the desired close button.
    - The upper close button (2) acknowledges all unacknowledged notifications in the message repository.
    - The lower close button (3) only acknowledges the notification that is currently open.
    - Acknowledged notifications are removed from the message repository.

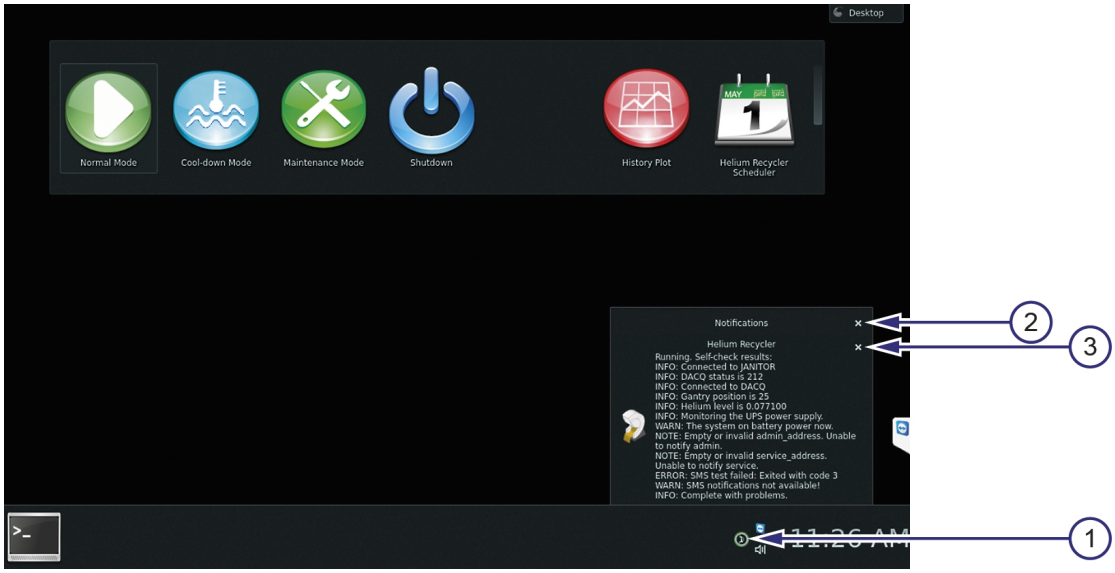


Figure 7.32 Example of a service GUI notification

7.1.3. Configuring the internal helium recycler

7.1.3.1. Configuration files

You can configure the behaviour of the internal helium recycler via configuration variables. The default values for the variables are loaded from configuration files, each of which contains a specific set of variables.

Table 7.10 Configuration files of the internal helium recycler

File	Accessible to	
	MEG service engineer	MEG key user
`/neuro/cryo/setup/cryocontrol_system.defs` Contains the hardware configuration of the internal helium recycler. Configured by Elekta service upon the MEG installation. No changes to this file are normally needed after the installation.	Yes	No
`/neuro/cryo/setup/cryocontrol_conf.defs` Contains various site-specific settings, such as network addresses. Configured by Elekta service upon the MEG installation.	Yes	Yes
`/neuro/cryo/setup/cryocontrol_logger.defs` Contains the default operation settings of the site, mainly, the default measurement schedule.	Yes	Yes
`/neuro/cryo/setup/cryocontrol_calendar.defs` Contains the calendar reservations for measurement windows. Mainly modified automatically by the Helium recycler scheduler application.	Yes	Yes
`/neuro/cryo/setup/cryocontrol_suspended.defs` Contains the current estimates for the boiling rate and the liquefaction rate. Updated automatically by the control software.	Yes	No

7.1.3.2. Making a permanent change to a configuration file

Via the command line, you can make permanent changes to the variable values of a configuration file.

Note: *You need to restart the control software for the changes to come into effect.*

1. In the service GUI, click the **Command Line** button.
2. Go to the configuration file directory.
   - `cd /neuro/cryo/setup/`
3. Open a text editor, for example, kwrite.
4. Open the correct configuration file.
   - Example: `kwrite cryocontrol_conf.defs`
5. Edit the variables in the file as needed.
   - Each variable must be on its own line, and each line must have the variable name first on the line, and then the variable value after the variable name.
   - If the variable contains a textual value, use quotes (“) around the value.
   - If the variable contains a decimal value, use dot (.) to separate decimal places.
   - If the line begins with a hash (#), the rest of the line is ignored.
6. After editing, save the file.
7. Close the editor and the command line window.
8. To make the changes effective, restart the control software.
   1. Click the **Shutdown** button.
   2. After the control software reports that it has shut down, start it again by clicking the **Normal mode** button.

7.1.3.3. Making a temporary change to the configuration

You can also make temporary changes to variable values in the configuration of the internal helium recycler.

Note: *Temporary changes to variable values come into effect immediately after you have typed a command, but they are not saved into any configuration file. Temporary changes stop to be in effect when you close the server connection.*

1. In the service GUI, click the **Control Terminal** button to log in to the control software, or alternatively, open a telnet connection.
   - Password for access to the control software: "pass homunculus122"
   - Command for telnet: `telnet localhost cryod`
2. In the control terminal window, list the values of the variables.
   - Command: `vars`
   - The variables are listed as shown in the figure below. The variable names are in the second column and their values on the third column.
3. Change the values of the desired variables.
   - Command: `vara <variable> <value>`, where `<variable>` is the name of the variable (without quotes) and `<value>` the new value for the variable.
   - Use quotes (“ “) for textual variables, including phone numbers and IP addresses. Do not use quotes for numerical values.

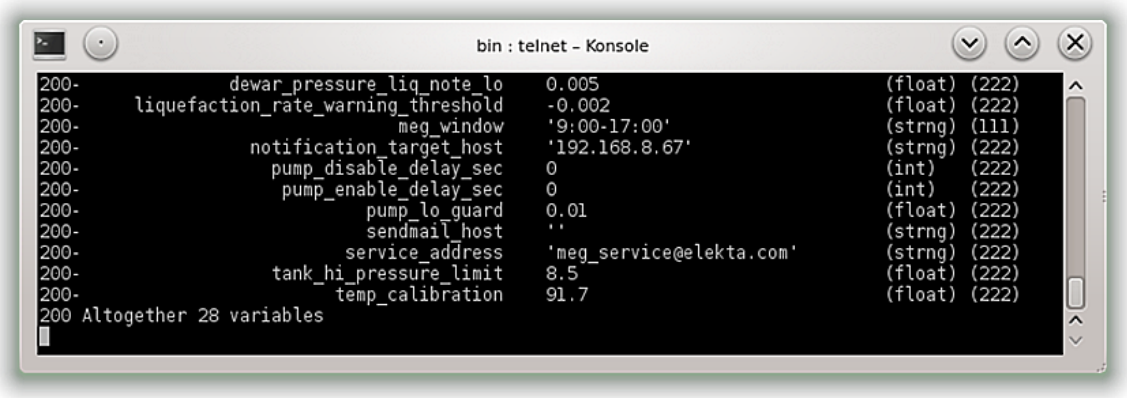


Figure 7.33 Example of variable values in the control terminal window

7.1.3.4. Configuring the default measurement window

You can configure the default measurement window by modifying the respective configuration variable in the configuration file.

1. In the service GUI, click the **Command Line** button.
2. Go to the configuration file directory.
   - `cd /neuro/cryo/setup/`
3. Open a text editor, for example, kwrite.
4. Open the correct configuration file.
   - `kwrite cryocontrol_logger.defs`

5. Type the desired window time(s) into the variable.
    - Example: `def_meg_window "9:00-17:00"`.
    - Minutes are optional. Example: `"9-17"`. If you use minutes, separate them with a colon. Example: `"9:00-17:00"`.
    - If you want to divide the default measurement window in two, use a comma to separate the windows. Example: `"9-12,14-18"`.
6. Save the file.
7. Close the editor and the command line window.
8. To make the changes effective, restart the control software.
    1. Click the **Shutdown** button.
    2. After the control software reports that it has shut down, start it again by clicking the **Normal mode** button.

7.1.3.5. Configuring notification addresses

You can configure the notification addresses by modifying the respective configuration variables in the configuration file.

1. In the service GUI, click the **Command Line** button.
2. Go to the configuration file directory.
    - `cd /neuro/cryo/setup/`
3. Open a text editor, for example, kwrite.
4. Open the correct configuration file.
    - `kwrite cryocontrol_logger.defs`
5. Edit the following variables.
    - sendmail_host "...": Replace the ellipsis with the DNS name/IP address of an email server that is to be used for sending email notifications.
    - admin_address: Edit to contain one or more cellular numbers/email addresses for the MEG key user of the site, separated by a : -character (colon). Examples: `"+15151234567"`, `"admin@example.com"`.
    - service_address: Edit to contain one or more cellular numbers/email addresses for the Elekta service person responsible for tier-1 problem resolution.
6. Save the file.
7. Close the editor and the command line window.
8. To make the changes effective, restart the control software.
    1. Click the **Shutdown** button.
    2. After the control software reports that it has shut down, start it again by clicking the **Normal mode** button.

7.1.3.6. Configuring network addresses

The network addresses are configured during the installation, but it is possible that you need to change some of these addresses later.

1. In the service GUI, click the **Command Line** button.
2. Go to the configuration file directory.
    - `cd /neuro/cryo/setup/`
3. Open a text editor, for example, kwrite.

4. Open the correct configuration file.
    - `kwrite cryocontrol_logger.defs`
5. Edit the following variables.
    - dacq_host: Edit to contain either the DNS name or the IP address of the DACQ workstation running the DACQ servers.
    - notification_target_host: Edit to contain either the DNS name or the IP address of the workstation that is to receive the user notifications. Usually the same as the dacq_host.
    - sendmail_host: Replace the ellipsis with the DNS name/IP address of an email server that is to be used for sending email notifications.
6. Save the file.
7. Close the editor and the command line window.
8. To make the changes effective, restart the control software.
    1. Click the **Shutdown** button.
    2. After the control software reports that it has shut down, start it again by clicking the **Normal mode** button.

7.1.3.7. Doing a notification delivery test

When you have changed the notification or network address configuration, it is a good practice to verify that the actual delivery works.

1. In the service GUI, click the **Control Terminal** button to log in to the control software, or alternatively, open a telnet connection.
    - Password for access to the control software: "pass homunculus122"
    - Command for telnet: `telnet localhost cryod`
2. In the control terminal window, type command: `alarm test`.
3. Check that the notification arrives to the DACQ (Data Acquisition) workstation, and to the configured admin_address and service_address.

7.1.4. History plots

If requested by Elekta service, you can use the **History Plot** icon to make graphs of the system performance during the previous four days. You can make, open and close the plots any time.

The **History Plot** button opens three different plots in separate windows:

- Pressure plot
- Dewar temperature plot
- Pump and compressor temperature plot.

Note: *Plot windows are not updated in real-time. To refresh the latest values, you need to click the **History Plot** button again.*

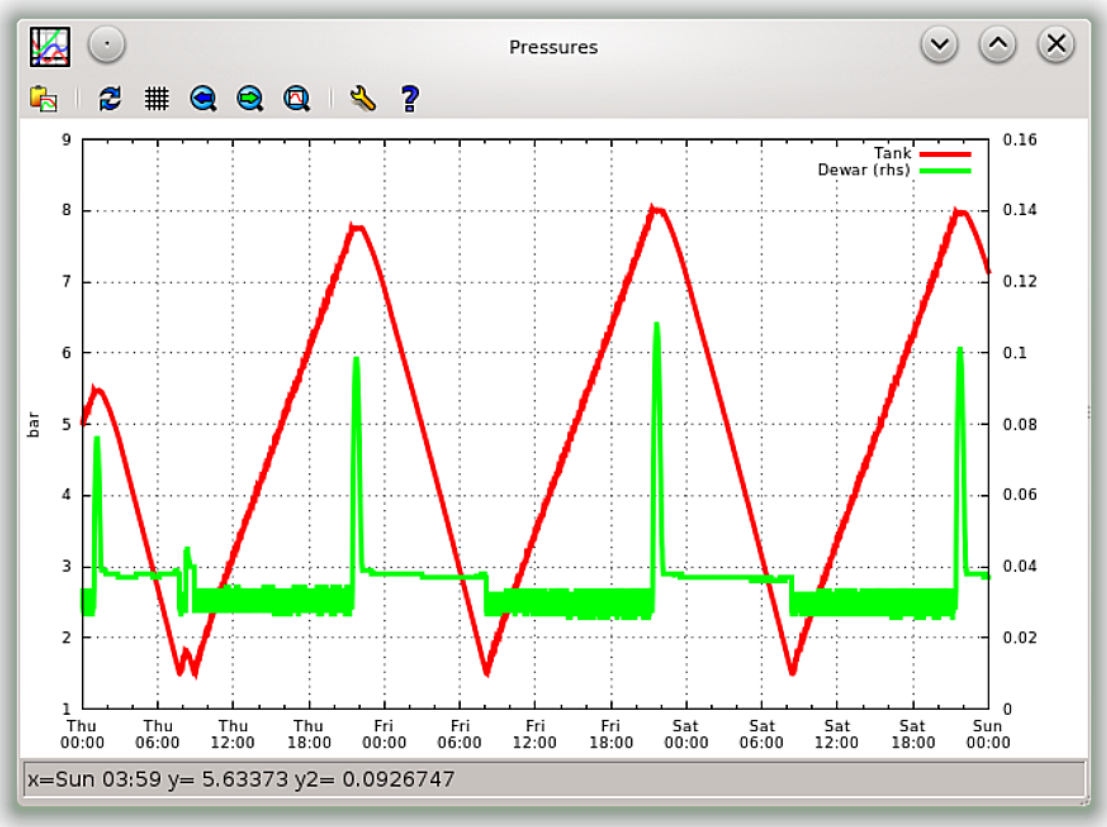


Figure 7.34 Example of a pressure plot

Button	Name	Function
	Window menu	Opens the window control menu for the plot window.
	On all desktops	Locks the plot window to be visible on all virtual desktops (if used).
	Maximize	Maximizes the plot window to full screen.
	Minimize	Minimizes the plot window to the button bar.
	Close	Closes the plot window.
	Copy the plot to clipboard	Copies the plot to the clipboard.
	Replot	Redraws the graph. Useful, for example, after you have resized the plot window.
	Toggle grid	Shows or hides the background grid.
	Previous view	Redraws the previous plot view, if you have zoomed the view.
	Next view	Redraws the next plot view, if you have clicked the **Previous view** button.
	Autoscale	Redraws the plot by applying such scales that you can see the full image.
	Open the configuration dialog	Opens the plot settings.
	Open the help dialog	Opens a help.

When you move the mouse over a plot, the status line at the bottom of the plot window shows the values corresponding to the mouse location.

You can also zoom a plot area by right-clicking the upper corner of the desired area, and then the lower corner of the area.

7.2. Pressure regulator panel

The pressure regulator unit controls the helium gas pressure and flow in the MEG system both during gas collection and liquefaction. Under special conditions, for example, maintenance, start-up and shutdown operations, the valve settings of the pressure regulator unit can be adjusted manually via a panel in the helium recycler cabinet.

The figure below shows the valve settings of the pressure regulator panel during normal operation of the internal helium recycler.

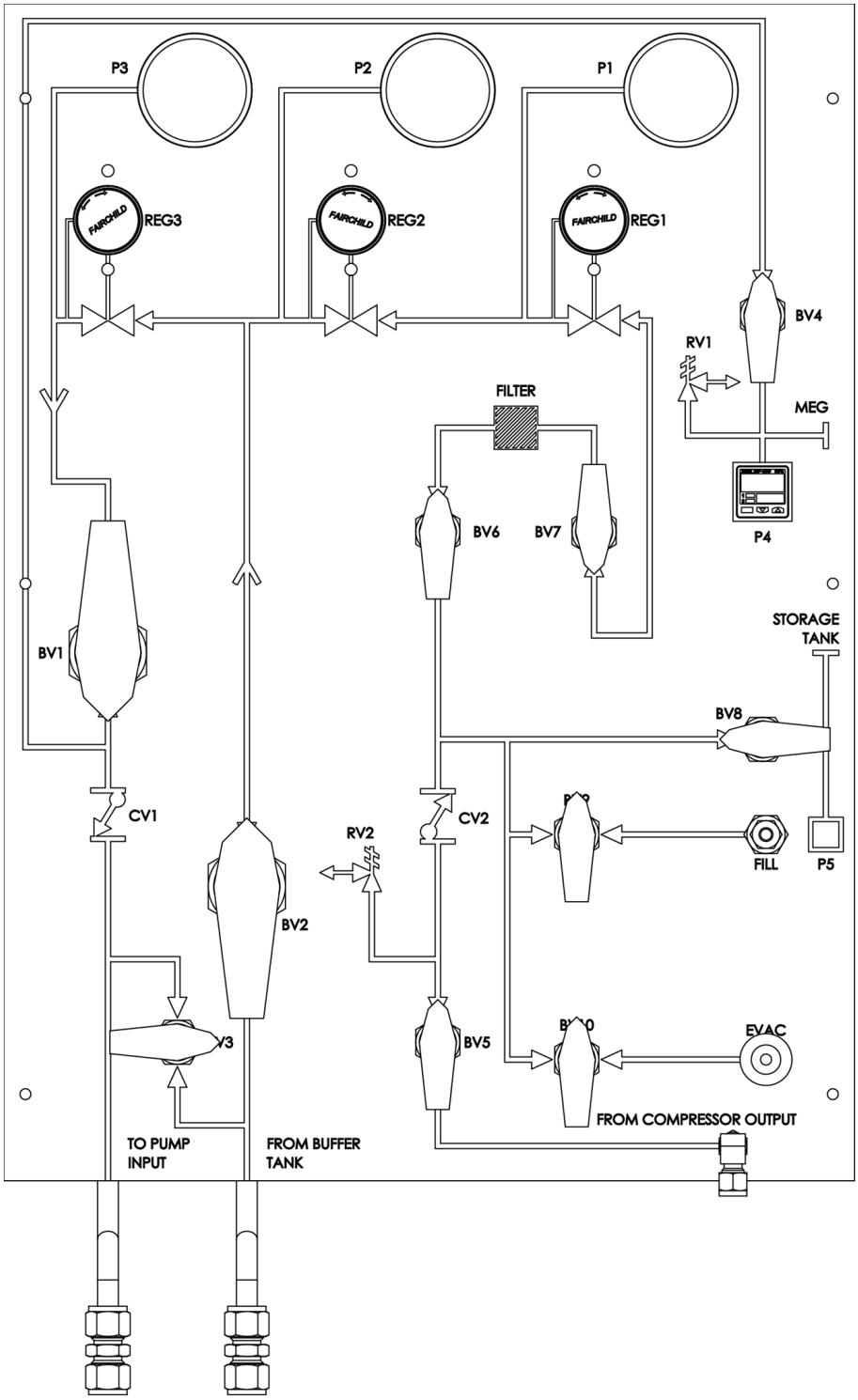


Figure 7.35 Layout of the pressure regulator panel during normal operation. The valves on the buffer tanks (not shown in the figure) are closed.

Item	Description
P1...P3	Pressure gauges for pressure regulators REG1...REG3
P4	Pressure transducer for the Dewar pressure
P5	Pressure transducer for the storage tank pressure
REG1...REG3	Pressure regulators
BV1...BV10	Ball valves
C1...C2	Check valves
RV1...RV2	Relief valves
EVAC	Evacuation port
FILL	Fill port
FILTER	Particle filter
MEG	Connection to the Dewar (on the backside), for the helium gas line
STORAGE TANK	Connection to the helium gas storage tanks (on the backside), for the helium gas line

The main components of the pressure regulator panel are the three pressure regulators (REG1...REG3). They drop the gas pressure from up to 10 bars in the helium gas storage tanks to a few tens of millibars in the Dewar. The panel also has built-in relief valves for both the Dewar and the helium gas storage tank inputs, pressure transducers, and connections to the buffer tanks in the helium recycler cabinet.

The connection to the Dewar (MEG) is next to the Dewar pressure transducer (P4) behind the right-hand side of the panel. Next to the Dewar connection, there is also a relief valve (RV1) that limits the pressure in the Dewar connection below 100 mbar (10 kPa). Ball valve BV4 can be used to isolate the Dewar from the helium gas storage system, for example, during a possible helium refill. Similarily, the connection to the helium gas storage tanks (STORAGE TANK) below the Dewar connection has a pressure transducer (P5) and a ball valve (BV8) for isolating the tanks from the helium recycler cabinet.

During liquefaction, helium gas flows from the helium gas storage tanks via BV8 and BV6, a particle filter, BV7, the pressure regulators (REG1...REG3), BV1, and BV4 to the Dewar. During gas collection, the storage pump in the upper buffer tank is on and pumps helium from the Dewar via BV4 and CV1 to the buffer tanks. The gas line from the buffer tank via BV2 connects a part of the pump output flow back to the input via REG3, preventing the Dewar pressure from falling below the setpoint of REG3. When the buffer tank pressure reaches a pre-defined limit, the storage compressor in the lower buffer tank is switched on, and pumps the gas from the buffer tanks to the helium gas storage tanks via BV5 and CV2. Relief valve RV2 limits the output of the storage compressor below a pressure of 10 bar (1.0 MPa).

Ball valves BV9 and BV10 close the FILL and EVAC ports, respectively. Ball valves BV1, BV2, BV5, and BV6 protect the pressure regulators (REG1-REG3) during the purging of the storage tanks and buffer tanks. Ball valve BV3 can be opened to equalize the pressure between the pump input and output during the purging of the buffer tanks.

7.3. Notifications

The internal helium recycler gives its users notifications about noteworthy changes in its operating conditions in real time. You are recommended to read all notifications carefully and take the recommended action(s).

There are two types of notifications:

- Notices
- Alert messages

Notices

Notices mostly inform you of changes made to the daily measurement schedule. Notices are mostly targeted to the MEG user.

Notices show in the bottom-right corner of the Data Acquisition (DACQ) desktop, where they automatically pop up over any other open windows.

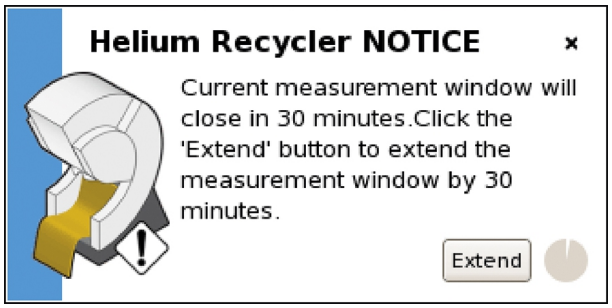


Figure 7.36 Example of a notice window

When you get a notice, you have two options:

- You can dismiss the notice either by clicking any area (except for the **Extend** button) on the notice window, or by clicking the close button (x).
- You can click the **Extend** button in the notice window. A decreasing circulator indicator alongside the button shows you the remaining reaction time.

Note: *Not all notice windows include the **Extend** button. Such notices automatically disappear from the screen after 15 minutes. Make sure that you nevertheless react to these notices as well.*

Alert messages

Alert messages inform the MEG key user and MEG service engineer about instant problematic operating conditions related to the internal helium recycler. Alert messages are delivered to these users via e-mail or as SMS messages.

You are not expected to reply to the address where the notification emails are sent from.

7.3.1. Alert messages

There is a recommended action for each alert message.

Table 7.11 List of alert messages

Notification	Meaning	Recommended action
Storage pump or storage compressor is overheating! Their power is now off and recycler is in fail-safe mode.	The storage pump or the storage compressor is running too hot. The control software has cut out the power to prevent further damage. If the problem persists, helium loss will occur.	Contact Elekta service immediately.

Notification	Meaning	Recommended action
Error in cryocooler! Recycler is now in fail-safe mode.	The cryocooler compressor is not operating correctly. It is not safe for the internal helium recycler to continue operating. If the problem persists, helium loss will occur.	1. Examine the LCD display on the cryocooler compressor for further details on the error. 2. See the manufacturer's manual for instructions on how to resolve the error. 3. When you have resolved the error, activate the normal mode via the service GUI.
Cryocooler is offline! Recycler will try an automatic recovery when power is on again.	The control PC cannot detect the cryocooler compressor. Possible reasons: • A power failure has occurred. • The cryocooler compressor has been switched off on purpose. • A cable between control PC and the cryocooler compressor is disconnected. • There is a fault in the cryocooler compressor. If this situation happens during gas collection, it does not have any consequences if the cryocooler returns online before liquefaction is to start. If this situation happens during liquefaction, liquefaction is stopped. The storage pump is enabled to capture any boiling helium. If the power resumes, the cryocooler continues normal operations automatically.	• If there is a power failure, wait for it to pass. The internal helium recycler continues normal operations automatically. • If the situation takes place during liquefaction and lasts for a long time, examine the helium level in the helium gas storage tanks. If it is high, remove the following day's measurement windows to liquefy all the helium. • Make sure that the cryocooler compressor is switched on. • Make sure that the cable between the cryocooler compressor and the helium recycler cabinet is connected and intact.
Cryocooler is online again.		
Dewar is near underpressure! Recycler is now in fail-safe mode.	The control software cannot read the values of the Dewar pressure transducer, or the values are not within acceptable limits. It is not safe for the internal helium recycler to continue operating. If the problem persists, helium loss will occur.	Contact Elekta service.
Dewar pressure is high! Relief valve cannot limit the pressure!	The values of the Dewar pressure transducer are higher than expected. The internal helium recycler continues operating, but may indicate a minor problem which should be investigated.	1. Examine if there are any reasons why this might have actually happened in the Dewar. 2. If the situation does not normalize during the day, contact Elekta service.

Notification	Meaning	Recommended action
Dewar pressure is not available! Recycler is now in fail-safe mode.	The control software cannot read the values of the Dewar pressure transducer, or the values are not within acceptable limits. It is not safe for the internal helium recycler to continue operating. If the problem persists, helium loss will occur.	Contact Elekta service.
Storage tank pressure is not available! Recycler is now in fail-safe mode.	The control software cannot read the values of the storage tank pressure transducer, or the values are not within acceptable limits. It is not safe for the internal helium recycler to continue operating. If the problem persists, helium loss will occur.	Contact Elekta service.
Abnormal liquefaction rate.	The helium level in the helium gas storage tanks is not decreasing expectedly.	• Make sure that the probe unit is in the liquefaction position. • Make sure that the cryocooler compressor and cold head are functioning normally. • Make sure that the valves on the pressure regulator panel are correctly set for normal operations.
Liquefaction rate normal again.		
The recycler is now on battery power.	The helium recycler cabinet has lost the line power. The UPS keeps the cabinet powered up for 15-30 minutes, but will then run out of battery.	Find out the reason and try to restore the line power to the helium recycler cabinet.
Line power has been restored.		
Losing helium from helium gas storage tanks.	The helium gas storage tanks are full. The MEG system is losing helium currently.	1. If a MEG measurement is ongoing, stop the measurement. 2. If possible, remove any measurement windows from the helium recycler scheduler to allow liquefaction to start as soon as possible. Keep in mind that helium loss can require a hastened helium refill. In addition, if you make MEG measurements for several hours with the helium gas storage tanks full, the internal helium recycler will need maintenance sooner than planned.
Not losing helium anymore from gas storage tank.		

Notification	Meaning	Recommended action
Abnormal boil-off rate.	The helium boil-off rate is higher than expected, or abnormally low.	The boil-off rate can temporarily rise if the probe unit position is changed repeatedly many times. In this case, the boiling rate typically returns to the normal level within 15-30 minutes. If the problem persists, contact Elekta service. Examine the history plots to see how the situation has developed. The plots can give you cues for the possible causes.
Boil-off rate is normal again.		
Disk space is getting low.	The control PC is running out of disk space.	Contact Elekta service.
Link to DACQ workstation is down.	The control software cannot send notifications or detect the measurement schedule. Thus, the cryocooler can start in the middle of a MEG measurement and disturb the signal quality.	Examine the connections between the DACQ workstation and the control PC.
Internal helium recycler test alert.	Notification delivery and connections are being tested.	No actions required.

7.4. LED indicators

7.4.1. LEDs on the helium recycler cabinet door

There are two LED indicators on the door of the helium recycler cabinet: FAIL-SAFE and OPERATING MODE. The LED combinations show the current operating mode of the internal helium recycler.

Table 7.12 LED combinations on the helium recycler cabinet door

LED name		Meaning
FAIL-SAFE	**OPERATING MODE**	
Off	Green	Operating in the normal mode.
Off	Alternating green/yellow	Operating in the normal mode, but a MEG measurement is ongoing and preventing liquefaction.
Off	Alternating green/red	Operating in the normal mode, but losing helium from the helium gas storage tanks because of an ongoing MEG measurement.
Off	Blinking green	Operating in the cool-down mode.
Blinking red	Blinking green	Operating in the cool-down mode, but temporarily stopped because of problems.
Blinking red	Alternating green/yellow	Powering up or self-checking.
Blinking red	Green	Operating in the normal mode, but the cryocooler compressor is offline, so liquefaction is impossible.
Off	Yellow	Operating in the maintenance mode. No liquefaction takes place.
Red	Off	Operating in the fail-safe mode. No liquefaction takes place.
Off	Off	No operation (shut down).

7.5. Troubleshooting

7.5.1. Helium recycler scheduler does not open via the service GUI

Symptom(s): An error message appears when you click the **Helium Recycler Scheduler** button on the service GUI or try to open the application via a remote connection.

Figure 7.37 Helium recycler scheduler error message 3

Possible cause(s)	Solution(s)
The control software of the internal helium recycler is not running. The switch on the CPU module is in the **Stop** position.	Turn the switch on the CPU module to the **Run** position.

7.5.2. Control software is not running

Symptom(s):

- The control unit does not work. The history plots do not show any data.
- The LED indicators on the door of the helium recycler cabinet are off.
- An error message shows on the service GUI when you try to start the Helium recycler scheduler application via the service GUI.

Possible cause(s)	Solution(s)
The switch on the CPU module is in the **Stop** position.	Turn the switch on the CPU module to the **Run** position.

7.5.3. Liquefaction starts later than expected

Symptom(s): Liquefaction starts later than expected.

Possible cause(s)	Solution(s)
A MEG measurement is still ongoing. An ongoing MEG measurement prevents liquefaction from starting.	Make sure that the MEG measurement is not left running after you have completed working on the DACQ (Data Acquisition) workstation.
The sensor tuning application is still running, for example, auto-tuning. A running sensor tuning application prevents liquefaction from starting.	Make sure that you close the sensor tuning application after you have completed the tuning.
The internal helium recycler is unable to sense the liquefaction position.	The DACQ workstation must be on for the internal helium recycler to sense the position of the probe unit. Switch on the DACQ workstation and make sure that you keep it on during weekends as well.

7.5.4. Liquefaction starts in the middle of a MEG measurement

Symptom(s): Liquefaction starts suddenly in the middle of a MEG measurement, without any notification to the MEG user.

Possible cause(s)	Solution(s)
The Ethernet connection to the DACQ (Data Acquisition) workstation is broken.	Examine the control software logs for possible problems in the Ethernet connection to the DACQ workstation.
The IP address of the DACQ workstation is incorrect in the control software.	Make sure that the IP address of the DACQ workstation is correct.
The firewall of the DACQ workstation is blocking the incoming notifications.	Make sure that the firewall configuration of the DACQ workstation allows connections to services 11122, 16122 and 16123 from the control PC.

7.5.5. Liquefaction does not start at all

Symptom(s): Liquefaction does not start for several days.

Possible cause(s)	Solution(s)
The internal helium recycler has been accidentally left in the maintenance mode or fail-safe mode.	• Activate the normal mode via the service GUI. • Examine whether the helium gas storage tanks are full. ○ If the tanks are full, you need to activate the cool-down mode to liquefy the accumulated helium before you can do any more MEG measurements. • Examine all cabling.

7.5.6. Recovering from fault situations

In all problems related to helium recycling, always first read the operating mode of the internal helium recycler from the LED indicators on the door of the helium recycler cabinet.

7.5.6.1. Recovering from a short power failure

The helium recycler cabinet is equipped with an uninterruptible power supply (UPS), which provides the cabinet with power for about 15-30 minutes. The cryocooler compressor is connected to a separate power line and does not have a UPS. Thus, the cryocooler compressor can lose the line power regardless of the helium recycler cabinet.

When a power failure shorter than the helium recycler cabinet's UPS time occurs:

- The control software detects the loss of line power and notifies the MEG key user.
- If the cryocooler compressor has also lost the line power, it is reported to the MEG key user.
- If a MEG measurement is ongoing, it is not affected, unless the MEG system has lost the line power, too.
- Gas collection continues normally because the UPS keeps the helium recycler cabinet up and running.

Required actions:

- Wait for the line power to restore.
    - When the line power restores, you get a notification, and the cryocooler compressor returns online automatically.

7.5.6.2. Recovering from a long power failure

The helium recycler cabinet is equipped with an uninterruptible power supply (UPS), which provides the cabinet with power for about 15-30 minutes. The cryocooler compressor is connected to a separate power line and does not have a UPS. Thus, the cryocooler compressor can lose the line power regardless of the helium recycler cabinet.

When a power failure longer than the helium recycler cabinet's UPS time occurs:

- The control software detects the loss of line power and notifies the MEG key user.
- If the cryocooler compressor has also lost the line power, it is reported to the MEG key user.
- If a MEG measurement is ongoing, it is not affected, unless the MEG system has lost the line power, too.
- Gas collection will stop.

Required actions:

1. Wait for the line power to restore.
    - When the line power restores, the helium recycler cabinet powers up automatically and resumes the normal operation mode with all the previously scheduled measurement windows. The cryocooler compressor returns online automatically.
2. Power up the MEG system cabinets and the DACQ (Data Acquisition) workstation manually.

7.5.6.3. Recovering from a power failure affecting only cryocooler compressor

The helium recycler cabinet is equipped with an uninterruptible power supply (UPS), which provides the cabinet with power for about 15-30 minutes. The cryocooler compressor is connected to a separate power line and does not have a UPS. Thus, the cryocooler compressor can lose the line power regardless of the helium recycler cabinet.

When a power failure affecting only the cryocooler compressor occurs:

- A cryocooler error is reported to the MEG key user.
- Gas collection continues normally because the helium recycler cabinet still has line power.

Required actions:

1. Wait for the line power to restore.
    - When the line power restores, the cryocooler compressor returns online automatically.
2. Read the amount of helium gas in the helium gas storage tanks from the pressure gauges on the tanks.
3. If the tanks are very full, click the **Cool-down Mode** button on the service GUI to liquefy the gas accumulated during the power failure.

7.5.6.4. Powering down the internal helium recycler

In fault situations, you may have to power down the internal helium recycler for rebooting.

- To power down the internal helium recycler for rebooting:
    - In the helium recycler cabinet, keep the UPS power button of pressed down for a few seconds. For details, see the UPS manufacturer's manual.
    - Turn the main power switch on the cryocooler compressor to **Off**.

7.5.6.5. Powering up the internal helium recycler

In fault situations, you may have to power up the internal helium recycler again. After the power-up, the internal helium recycler will continue in the same mode in which it was before the power was switched off.

Note: *You are recommended to make sure that the valves on the pressure regulator panel are set as shown in figure 7.38. If the valves are set to any other positions, the storage pump or compressor can break, if they start unintentionally.*

To power up the internal helium recycler:

1. Make sure that the valves on the pressure regulator panel are set as shown figure *7.38*.
    - This valve configuration is safe for the pumps and compressors.
2. Make sure that the configuration mode switch selector on the cryocooler compressor is set to the remote control mode (mode 2).
3. Turn the main power switch on the cryocooler compressor to **On**.
4. In the helium recycler cabinet, keep the UPS power button pressed down for a few seconds.
    - For details, see the UPS manufacturer's manual.
5. Wait for the control PC to power up automatically.
    - The control PC power-up takes about one minute.
6. To verify that the system started up, monitor the LEDs on the door of the helium recycler cabinet.
    - The LED indicating the latest active operating mode comes on.
7. To continue normal operations, click the **Normal Mode** button on the service GUI.

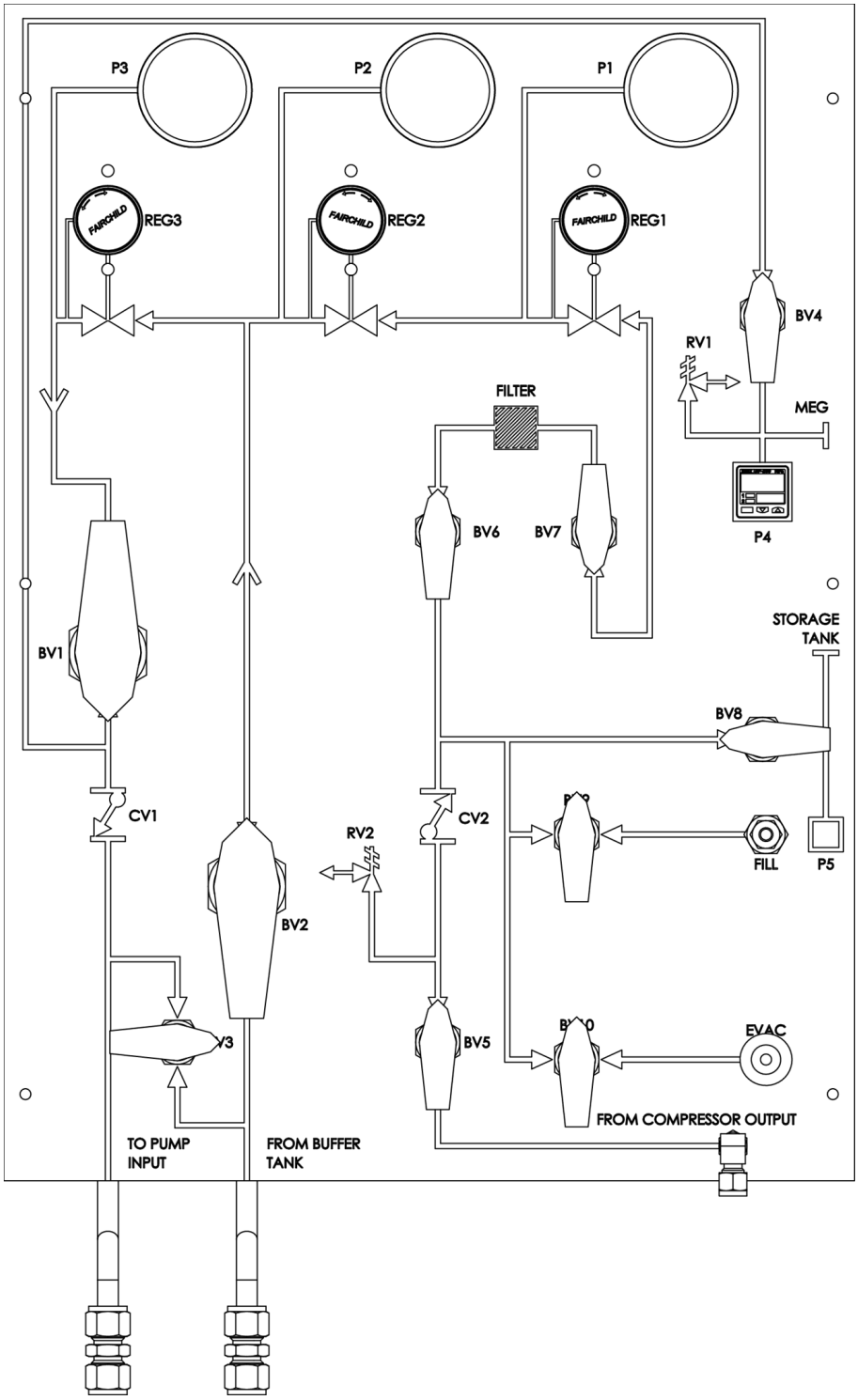


Figure 7.38 Layout of the pressure regulator panel during normal operation, with the buffer tank valves closed

8. Technical data

This section contains the supplementary technical data for the internal helium recycler. For the complete technical data of the Elekta Neuromag® TRIUX MEG system, see *Elekta Neuromag® TRIUX Technical Manual*.

8.1. Power requirements

Table 8.13 Power requirements

Module	Input power range	Power (W) ** Operation/Start-up
Cryocooler, model F70H	380...415 V (50 Hz, 3-phase) 480 V (60 Hz)	7000/8500 @ 50 Hz 8000/9000 @ 60 Hz
Cryocooler, model F70L	200 V (50/60 Hz)	
Helium recycler cabinet	100 V, 115 V, 200 V, 230 V, 240 V (50/60 Hz) *	1200/2000
* The voltages are converted to 230 V by the isolation transformer of the helium recycler cabinet.		
** The total power consumption depends on the system configuration.		

8.2. Grounding requirements

The helium recycler cabinet is connected to the main grounding point of the MEG system upon the installation. No further actions are required of the user.

8.3. Environmental conditions

Table 8.14 Environmental conditions

	Operation (performance guaranteed)	Operation (performance not guaranteed, IEC 60601-1 requirements fulfilled)	Storage and transport
Temperature	MSR: +20°C...+24°C Operator area: +20°C...+30°C	+10°C...+40°C	+0°C...+40°C
Relative humidity	40%...70% RH, non-condensing	30%...75% RH, non-condensing	10%...95% RH, non-condensing *
Maximum operating altitude	-	2000 m	-
* Special packaging instructions must be obeyed (available from Elekta).			

8.4. Performance data

Helium refill interval

In normal operating circumstances, no liquid helium needs to be added into the system during the one-year service interval. The system is regenerated and refilled in the annual preventive maintenance.

Loss of helium in between refills

Helium level decrease of approximately 10% because of diffusion and minor leaks is normal during the one-year service interval. However, it is possible that the system loses a larger amount of helium because of, for example:

- Power failures
- Intentionally made long MEG measurements
- Hardware or software failures
- Misuse.

For optimum performance, the liquid helium level must stay between 30% and 60%, when measured in the supine position. If needed, liquid helium can be added into the system. Alternatively, it is also possible to add gaseous helium to the helium gas storage tanks.

Lifetime of helium gas storage tanks

The lifetime, that is, the date when the tanks need to be replaced, is marked on a label attached to the tanks. The lifetime is calculated based on the maximum number of refill cycles specified by the tank manufacturer.

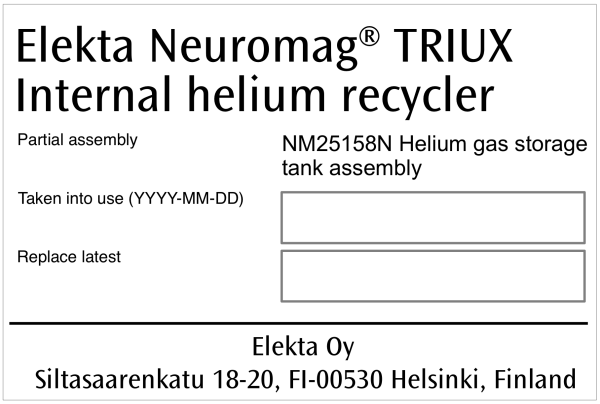


Figure 8.39 Helium gas storage tank assembly label

Storage tank pressure

Pressure in normal operating circumstances (configurable)	1.5-8.5 bar (0.15-0.85 MPa)
Maximum operating pressure	10 bar (1.0 MPa)
Maximum allowable pressure	11 bar (1.1 MPa)

8.5. Electromagnetic compatibility

8.5.1. Cables, transducers and other accessories

The external cables connected to the helium recycler cabinet may affect electromagnetic compatibility. They include the following cables.

- Mains power cable of the helium recycler cabinet (length 10 m)

- Control cables between helium recycler cabinet and filter cabinet (cryocooler Pt100 thermometer cable, cryocooler RuO thermometer cable, and cryocooler control signal cable; max. lengths 50 m)
- Cryocooler control interface cable set between cryocooler compressor and helium recycler cabinet (length 18 m, 22.5 m, or 25 m)
- Ethernet cable between helium recycler cabinet and DACQ workstation

Note: *The use of accessories, transducers, and cables other than those specified, with the exception of accessories, transducers, and cables sold by the manufacturer of the system as replacement parts for internal components, may result in increased emissions or decreased immunity of the system.*

For the external cables of the Elekta Neuromag® TRIUX MEG system, see *Elekta Neuromag® TRIUX Technical Manual*.

8.6. Dimensions and weights of helium recycler modules

Table 8.15 Dimensions and weights of helium recycler modules

Module	Width mm (in.)	Length/Depth mm (in.)	Height mm (in.)	Weight kg (lbs)
Probe unit (supine/upper seated position)	950 (37)	1340/1660 (53/65)	2020/2240 (80/88)	450 (992)
Hose reel	1250 (49)	140 (6)	1650 (65)	60 (132)
Filter cabinet (adjustable height)	1000 (40)	405 (16)	1500–1900 (59–75)	155 (342)
Cryocooler compressor	500 (20)	500 (20)	500 (20)	100 (220)
Helium recycler cabinet (with handles)	600 (24)	600 (24)	2050 (81)	225 (496)
Isolation transformer for the helium recycler cabinet	270 (11)	470 (19)	230 (9)	40 (88)
Helium gas storage tank (EU market area)	550 (22)	550 (22)	1470 (58)	96 (212)

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Corporate Head Office:

Elekta AB (publ)
Box 7593, SE-103 93 Stockholm,
Sweden

Tel +46 8 587 254 00
Fax +46 8 587 255 00

info@elekta.com

Regional Sales, Marketing and Service:

North America

Tel +1 770 300 9725
Fax +1 770 448 6338

info.america@elekta.com

Europe, Middle East, Africa,
Eastern Europe, Latin America

Tel +46 8 587 254 00
Fax +46 8 587 255 00

info.europe@elekta.com

Asia Pacific

Tel +852 2891 2208
Fax +852 2575 7133

info.asia@elekta.com

ELEKTA