

Vacuum Solutions

Application Support

Service

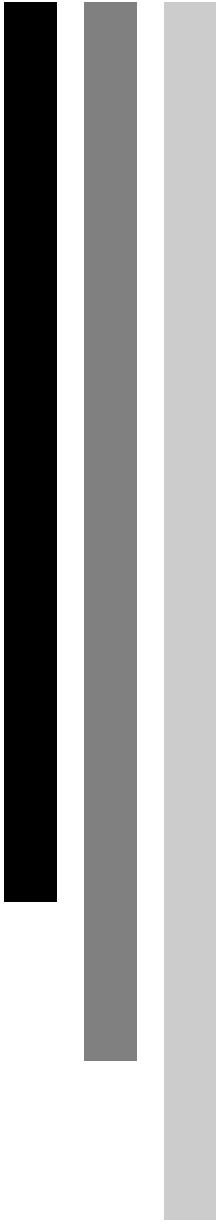


LEYBOLD VACUUM

GA 12.123/3.02



SERVICE OF VACUUM PUMP SYSTEMS
2442 Emrick Blvd. Bethlehem, PA 18020
For Service Call (610) 625-1505
www.polvac.com



COOLVAC
800
1500
3000

Refrigerator Cryopumps

Cat. Nos
892 61/63
892 56
893 21/23

Operating Instructions

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Leybold-Service

If a pump is returned to LEYBOLD; indicate whether the pump is free of substances damaging to health or whether it is contaminated. If it is contaminated also indicate the nature of hazard. LEYBOLD must return any pump without a declaration of contamination to the sender's address.

Under certain operating conditions, dangerous situations may develop while running the pump. If this is the case, please consult our local office.

Warning

Indicates procedures that must be strictly observed to prevent hazards to persons.

Caution

Indicates procedures that must be strictly observed to prevent damage to, or destruction of the appliance.

Figures

The first digit of a reference, (1/2) for example, is the figure number; the second digit is its item number in this figure.

We reserve the right to change the design and the specified data. The figures are not binding.

The COOLVAC is suitable for pumping and regenerating nonflammable gases and hydrogen.

Warning



The standard model of the COOLVAC is not suitable for processes in which

- corrosive gases develop or are generated
- gases other than hydrogen develop which might form flammable mixtures during regeneration



- oxygen develops in higher than atmospheric concentration.



Key to Fig. 1

- 1 Cold head motor with housing and electrical connection
- 2 Helium gas connections
- 3 Forevacuum flange
- 4 Pump housing
- 5 High-vacuum flange
- 6 Baffle
- 7 Thermal radiation shield
- 8 Pump surfaces (cryopanel)
- 9 Relief valve with flange connection

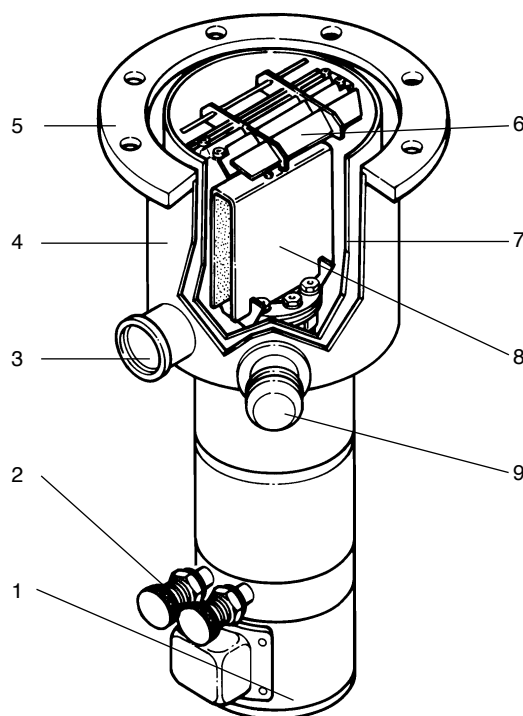


Fig. 1 Schematic diagram of a cryopump

1 Description

Cryopumps are high-vacuum pumps which remove gases and vapors from the vacuum chamber by means of condensation and adsorption on very cold surfaces.

A compressor unit, flexlines, and a backing pump are required to operate a cryopump COOLVAC. The compressor unit supplies the cryopump with helium gas under high pressure to generate the low temperatures. The backing pump is employed to evacuate the cryopump to its starting pressure and to evacuate the vacuum chamber to the cut-in pressure. Furthermore, it is employed to regenerate the cryopump.

Warning



Whenever working on cryopumps, observe the safety instructions given in Section 2.1 of these Operating Instructions and in the Operating Instructions for the compressor unit which is used.

1.1 Design and Function

A refrigerator cryopump essentially consists of cooled pump surfaces, i.e. cryopanel, a two-stage cold head and the pump housing with flanges.

The first stage of the cold head cools the baffle and the thermal radiation shield to a temperature between 45 K and 80 K. The second stage of the cold head cools the pump surfaces to a temperature between 12 K and 20 K.

The inner surfaces of the cryopanel are covered with activated charcoal.

Apart from the high vacuum flanges the pump housing has several other flanges of various sizes to connect the backing pump and other accessories. For type and number of flanges refer to Section 1.3 „Technical Data“.

A relief valve provides protection against unacceptably high overpressures in the pump. It has a DN 40 KF small flange for connection of the gas outlet line.

Pump mechanism

In cryopumps, gases and vapors form on very cold surfaces. The gases are not pumped through the cryopump but instead are retained within the pump chamber.

Water vapor and most hydrocarbons condense on the baffle or the thermal radiation shield at temperatures below 150 K (cryo condensation).

Virtually all other gases condense on the outer surfaces of the cryopanel at temperatures between 12 K and 20 K (cryo condensation).

The gases hydrogen, helium and neon are adsorbed into the activated charcoal on the inner surfaces of the cryopanel at temperatures between 12 K and 20 K (cryo sorption).

In the pressure range from approx. 10^{-3} mbar to 10^{-11} mbar cryopumps operate at a constant pumping speed which depends only on the type of gas. At pressures over $5 \cdot 10^{-3}$ mbar the thermal load on the pump's surfaces from the gas may become so great that it affects the pumping speed.

Sputter-coating cryopumps which operate at pressures in the 10^{-3} mbar range therefore have a cold head with a high refrigerating capacity at the second stage.

As the saturation with condensed and adsorbed gas in the pump increases, the temperature of the pump surfaces increases and the pumping speed drops. It is therefore necessary to regenerate cryopumps at regular intervals so as to remove the entrapped gas.

Generation of low temperatures

The low temperatures are generated in a two-stage cold head. It is connected to a compressor unit via a pair of flexlines. This combination is referred to as a refrigerator.

Leybold refrigerators operate in a closed helium gas cycle according to the Gifford-McMahon process.

In this process, helium gas is first compressed, cooled, and cleaned in the compressor unit and then expanded in the cold head to generate low temperatures.

A rotating control valve controls the intake and expansion of the gas in the cold head. This valve is mounted on the shaft of a synchronous motor which receives its electrical power from the compressor unit.

Temperature measurement

Some COOLVAC cryopumps are equipped with a hydrogen-filled vapor-pressure thermometer which acts as a temperature sensor at the second stage of the cold head. It consists of a measurement chamber, which is attached to the second stage of the cold head and a pressure gauge. Both are linked by a capillary.

Its measurement range covers 14 K to 23 K with an inaccuracy of ± 1 K. The degree of inaccuracy depends on the pressure of the surrounding atmosphere.

Some COOLVAC cryopumps are equipped with a silicon diode which acts as a temperature sensor at the second stage of the cold head.

The measurement range of the silicon diode is ranging from 4 K to 320 K. The measurement signal is picked off at a current feedthrough. The temperature is indicated in Kelvin by a suitable measuring instrument (like the low-temperature instrument LTI 10). If necessary, the measured value can be used for processing by the controller of a system.

Regeneration heaters

Regeneration heaters with thermal protectors are available as options. Each heater plate contains a Pt 100 resistor which functions as a temperature sensor and switches the heating voltage off via the thermal protector when the maximum permissible regeneration temperature is achieved.

The control leads of the heating coils and the Pt 100 emerge from the pump housing through a flange and are connected to the 8-pole current feedthrough on the thermal protector serving as a mating flange. The supply voltages for the thermal protector are provided by the heater power supply unit HU 1.

1.2 Standard Specification

Cryopump with 4.5 m long mains cord with plug for connection to the compressor unit.

The flanges are blanked off with plastic caps for shipping.

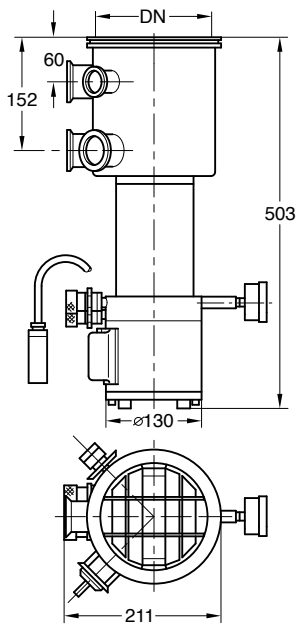
The characteristic of the silicon diode is enclosed with the pumps.

Not included with the cryopump are fasteners and gaskets for the high-vacuum flange or for those flanges which do not carry components like current feedthrough, thermal protector etc.

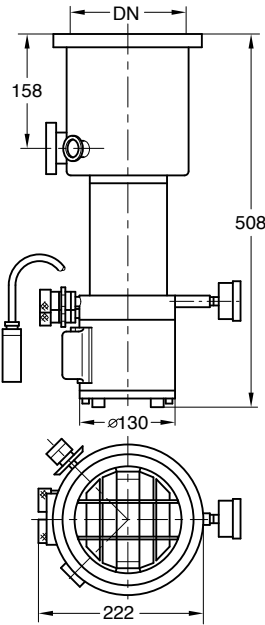
1.3 Technical Data

COOLVAC		800	800	1500	3000
High-vacuum flange	DN	160 ISO-K	160 CF	200 ISO-K	10" ANSI / 320 ISO-K
Forevacuum flange	DN	40 KF	40 CF	40 KF	25 KF
2-pin current feedthrough for silicon diode on flange	DN	25 KF	-	25 KF	-
4-pin current feedthrough for silicon diode on flange	DN	-	-	-	16 KF
Other flange	DN	40 KF	16 CF	40 KF	40 KF
Other flange	DN	40 KF	-	40 KF	16 KF
Safety valve with connection for exhaust gas line		welded in	mounted on DN 16 CF	welded in	welded in
Pumping speed for					
H ₂ O	l·s ⁻¹	2600	2600	4600	10500
Ar	l·s ⁻¹	640	640	1300	2700
N ₂	l·s ⁻¹	800	800	1600	3200
H ₂	l·s ⁻¹	1000	1000	2200	5000
He	l·s ⁻¹	300	300	600	1500
Capacity for					
Ar/N ₂	bar·l	270	270	1000	2300
H ₂ bei 10 ⁻⁶ mbar	bar·l	4,3	4,3	12	28
He	bar·l	0,5	0,5	0,9	1
Built-in cold head	COOLPOWER	2/10	2/10	5/10	12/45
Max. throughput for					
Ar/N ₂	mbar·l·s ⁻¹	4	4	14	25
H ₂	mbar·l·s ⁻¹	2	2	6	12
Crossover value	mbar·l	60	60	210	500
Cool-down time to 20 K	min	70	70	90	70
Weight	kg	12	14	17	35
Silicon diode to measure the temperature at the 2nd stage of the cold head		Optional	Optional	Built-in	Built-in
Regeneration heaters at the 1st and 2nd stage of the cold head		Optional	Optional	Optional	Optional

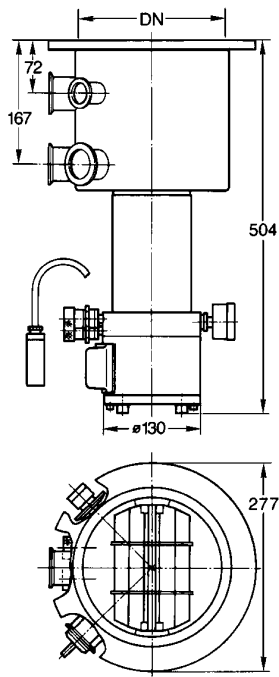
All measurements as to PNEUROP



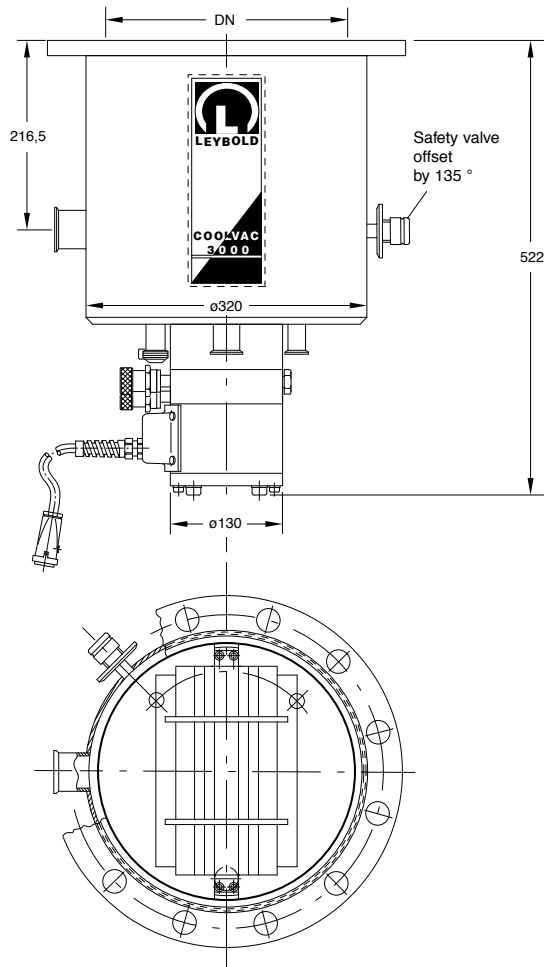
COOLVAC 800 (160 ISO-K)



COOLVAC 800 (160 CF)



COOLVAC 1500



COOLVAC 3000

Fig. 2 Dimensional drawing

1.4 Ordering Information

Cryopumps

COOLVAC		800	800	1500	3000
High-vacuum flange	DN	160 ISO-K 892 61	160 CF 892 63	200 ISO-K 892 56	10" ANSI / 893 21 320 ISO-K 893 23

Compressor units for single operation

RW 2: 220 V, 50 Hz, 1ph	891 96	891 96	891 96	-
RW 3: 208 V, 60 Hz, 1ph	892 96	892 96	892 96	-
RW 4000 EU: 400, 415 V, 50 Hz, 3ph	-	-	-	893 31
RW 4000: 460, 480 V, 60 Hz, 3ph	-	-	-	893 32
RW 4200: 208, 230 V, 50/60 Hz, 3ph	-	-	-	893 33

Compressor units and accessories for multiple operation

see Leybold catalogue

Regeneration heaters

892 20	on request	892 21	892 22
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Flexible pressure lines

Flexible pressure lines FL 4.5 (1/2", 1/2"), 4,5 m long	892 87
Flexible pressure lines FL 9.0 (1/2", 1/2"), 9 m long	892 88

Electrical extension for the cold head connection cable with coupling and plug EL 4.5, 4.5 m long

893 74

LTI 10 low-temperature measuring instrument for operating the silicon diode

890 88

HU 1 heater power supply with 5 m long connection cable to the thermal protector on the regeneration heaters

890 79

Cryo Service Set, case with tools for maintenance work on all cold heads and compressor units

890 93

Backing pumps

TRIVAC or DRYVAC with different motors

see Leybold catalogue

Foreline adsorption trap

for TRIVAC D 8 B	187 05
for TRIVAC D 16/25 B	187 10
for TRIVAC D 40/65 B	187 15
Heating rod for adsorption trap	
for TRIVAC D 8 B	854 21
for TRIVAC D 16/25 B	854 21
for TRIVAC D 40 B	854 23

Further accessories for connecting and operating cryopumps see Operating Instructions for the compressor unit.

Key to Fig. 3

- 1 Exhaust line
 - 2 Backing pump
 - 3 Foreline adsorption trap
 - 4 Forevacuum gauge
 - 5 Temperature measuring instrument
 - 6 Forevacuum gauge
 - 7 High-vacuum gauge
 - 8 Vacuum chamber
 - 9 Cryopump
 - 10 Compressor unit
 - 11 Flexlines
 - 12 Safety valve (relief valve)
 - 13 Bypass line with valve
-
- V1 High-vacuum gate valve
 - V2 Forevacuum valve
 - V3 Forevacuum valve
 - V4 Venting valve
 - V5 Blocking valve for adsorption trap

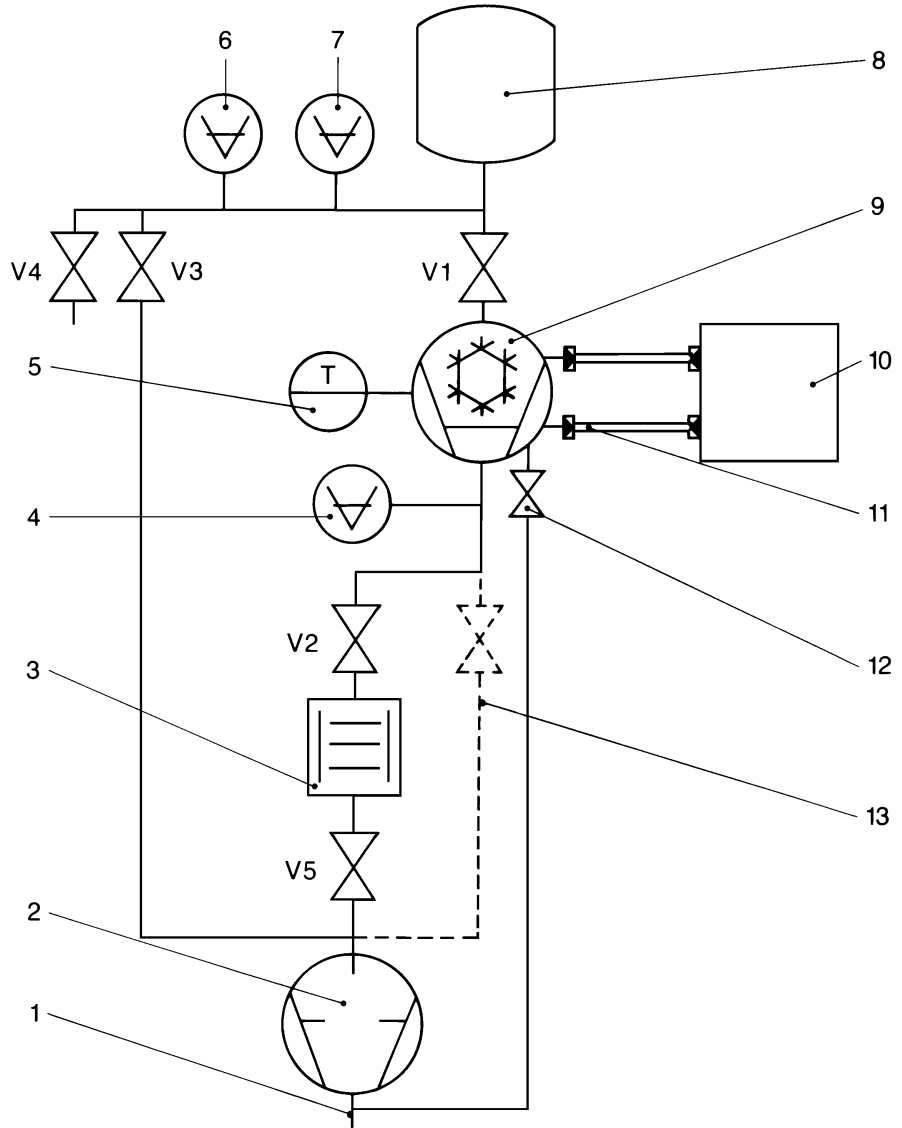


Fig. 3 Schematic diagram of a cryopump system

2 Installation

2.1 Safety Instructions

Mechanical safety

Position the pumps on the high-vacuum flange for shipping.

Caution

Protect the pumps against slipping and tipping over.

Attach lifting tackle to the high-vacuum flange and the cold head motor to lift the pumps

Use lifting devices with sufficient carrying capacity. Never stand beneath the suspended pump while it is being moved.

When installing and commissioning the cryopump pay careful attention to the stability of the pump and vacuum chamber system. Safe attachment of the cryopump when installing in the system or attaching to the vacuum chamber is achieved by means of the high-vacuum flange provided for this purpose.

Protection against extreme cold



To avoid injuries resulting from contact with the extremely cold surfaces (temperature below 120 K) in the interior of the pump, remove the cryopump from its mountings only after it has reached room temperature.

Electrical safety



Disconnect the cryopump, the controls and the compressor unit from the mains power supply before starting any assembly or disassembly work.

The cryopump, the system and all installed components shall be carefully and professionally grounded in order to avoid build-up of electrostatic charges.

Do not lay electrical connection cables across passage-ways and protect them against damage by pointed and sharp objects.

Never install damaged connection cables. Replace damaged cable with new cable immediately.

Be sure to provide strain relief when connecting the cable to the cryopump and the control and monitoring units.

The Leybold units provide facilities for communications between the various electrical components and the customer's system. This interchange of signals is normally effected by way of zero-potential relay contacts or optical couplers. The following safety measures are to be observed when transmitting these control signals (normal voltage range of 24 V):

If signal voltages are to be provided by the customer, then the voltage source used for this purpose shall satisfy the requirements for functional low-voltage signals with positive isolation.

In addition, the permissible values for voltages and currents as specified in the operating instructions for the particular units shall be observed. If, on the other hand, Leybold equipment supplies signal voltages, it is essential that – in downline signal processing – the customer's plant provide positive isolation of these signals from potentially hazardous voltages; these protective measures must be effective even if there is a defect in the system.

If heating circuits or sensors are driven directly, then functional low-voltages with positive isolation from the mains voltage shall also be provided as their voltage supply.

Protection against excess pressures

The cryopump is a gas-binding vacuum pump, which means that the gas molecules drawn out of the vacuum chamber are stored in the cryopump.

When the pump heats up during regeneration or following a power failure, the volume of gas liberated can in just a short period of time become so large that pressure exceeding atmospheric pressure is developed in the vacuum system or the pump housing. It is for this reason that all Leybold cryopumps are fitted with a pressure relief valve which opens if internal pressure rises above atmospheric pressure. This safety valve will open at pressures between 1150 mbar and 1600 mbar, depending on the pump model being used.



The safety valve shall never be blocked or modified.

When dealing with built-in or special-design cryopumps without their own pump enclosure, the owner/operator himself must provide in the system an appropriate safety device which cannot be defeated or blocked.

Protection against hazardous gases

In some vacuum processes gases are used or generated by the process which pose no problem during the pumping phase; the larger volumes which can be liberated when the cryopump heats up (regeneration or power failure) could, however, present a hazard.

It is also known that under certain circumstances mixtures of H_2 with O_2 or of H_2 with the air, for example, may be ignitable and could explode. Mixtures of CO with air, of CO with O_2 , and of CH_4 with O_2 may also exhibit similar properties.

Potential outside ignition sources may be found in electrical components such as ionization vacuum meters, heated and non-enclosed pressure measurement units and defective regeneration heaters which are installed in the vacuum chamber and/or the pump housing. As regards flammable, explosive, toxic or corrosive gases and mixtures of gases, it is necessary to observe special safety measures when the cryopump heats up.



The safety relief valve and the forevacuum pump shall be equipped with an exhaust line to divert hazardous gases or mixtures of gases into a receiver or to the atmosphere, in compliance with applicable safety and environmental protection regulations.



It is for this reason that the cryopump is fitted with a relief valve and a DN 40 KF flange.



Always keep the exhaust line open and free of grime.



Electrical equipment installed in the vacuum chamber, such as regeneration heaters and vacuum gauge heads, shall be fitted with an electrical interlock which will positively interrupt the electrical supply to these units whenever explosive mixtures of gases could arise due to uncontrolled heating of the pump.



The ignition pressure for H_2/O_2 mixtures is at 130 mbar so that total pressure for this gas mixture has to be kept below this value. As an alternate the Lawrence Livermore Laboratory recommends keeping the partial pressure for hydrogen below 17 mbar. This ensures that no explosive H_2/O_2 mixtures can be formed.

Safety regulations

In compliance with applicable safety regulations, the following hazard classes shall be indicated when dealing with dangerous gases.



Flammable gases or mixtures of gases



Explosive gases or mixtures of gases



Toxic gases



Aggressive/corrosive gases

When using flammable, corrosive or toxic gases, conduct a test in accordance with the rules for pressure vessels prior to putting the system into service.



Cryopumps which have been used to pump hazardous gases shall be operated only by persons who are familiar with handling the hazardous substances and who are familiar with the required safety measures.

In Germany the operator shall have passed a test in accordance with the Pressure Vessels Code.

Regenerating cryopumps

Cryopumps without an electrical regeneration system

The cryopumps are warmed up to room temperature by flushing the interior with a dry, pre-heated inert gas (e.g. nitrogen, argon). In this case the temperatures in the cryopump cannot be definitively set and monitored. It is for this reason that gases such as hydrogen and oxygen may be in the pump at the same time.



The formation of explosive gas mixtures will be prevented solely by dilution with the dry inert gas.

Leybold cryopumps with the Leybold electrical regeneration system

The cryopump is brought up to room temperature by heating the first and second cold head stages with electrical heaters. In this case the temperatures in the cryopump can be definitively set and monitored. It is for this reason that the gases previously pumped will be liberated in the following order:

1. Gases which are adsorbed on the pump surfaces (e.g. hydrogen, helium, neon)
2. Gases which condense on the pump surfaces (e.g. nitrogen, oxygen, argon)
3. Gases and vapors which condense on the baffle and radiation shield (e.g. water vapor)

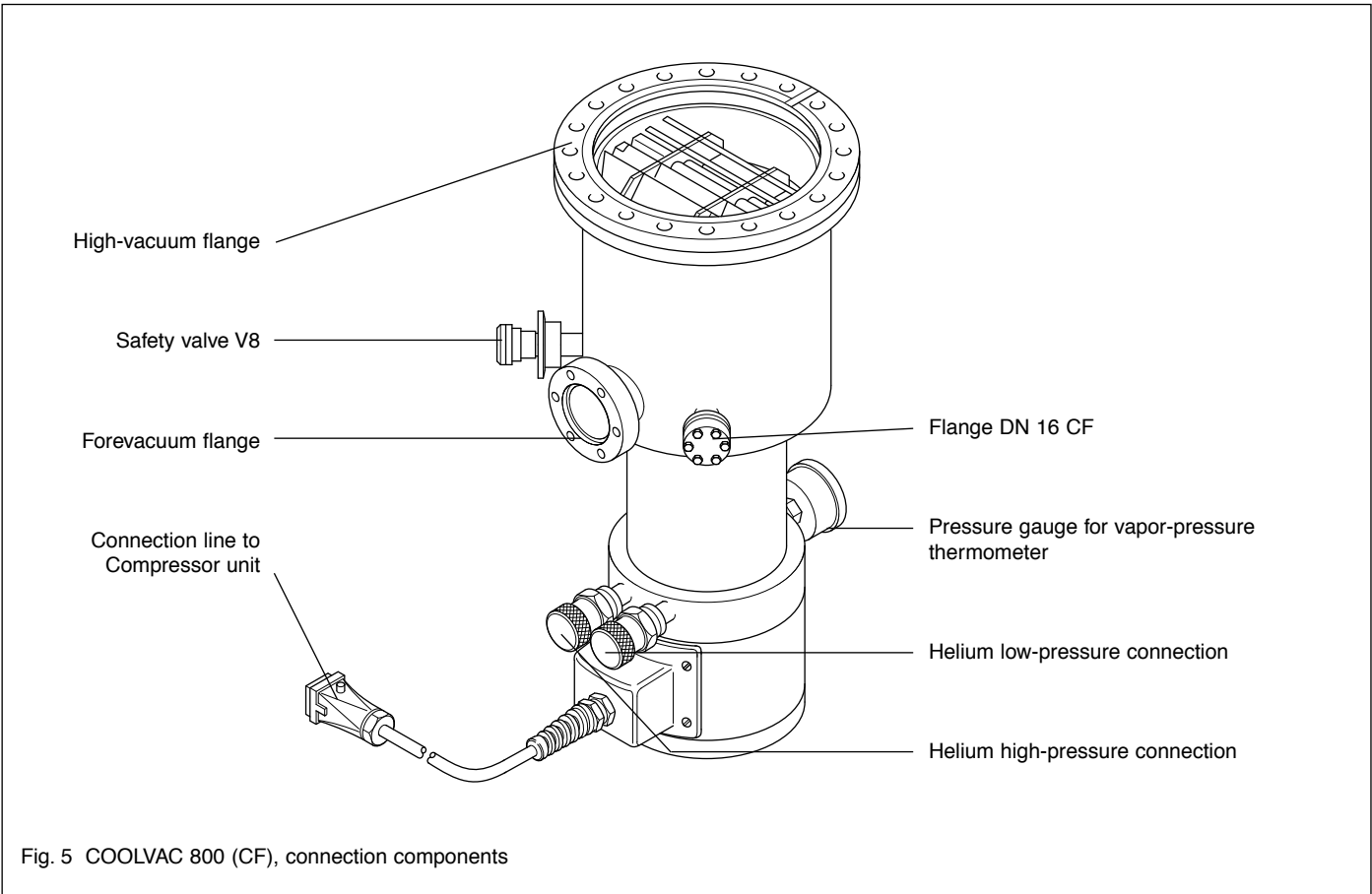
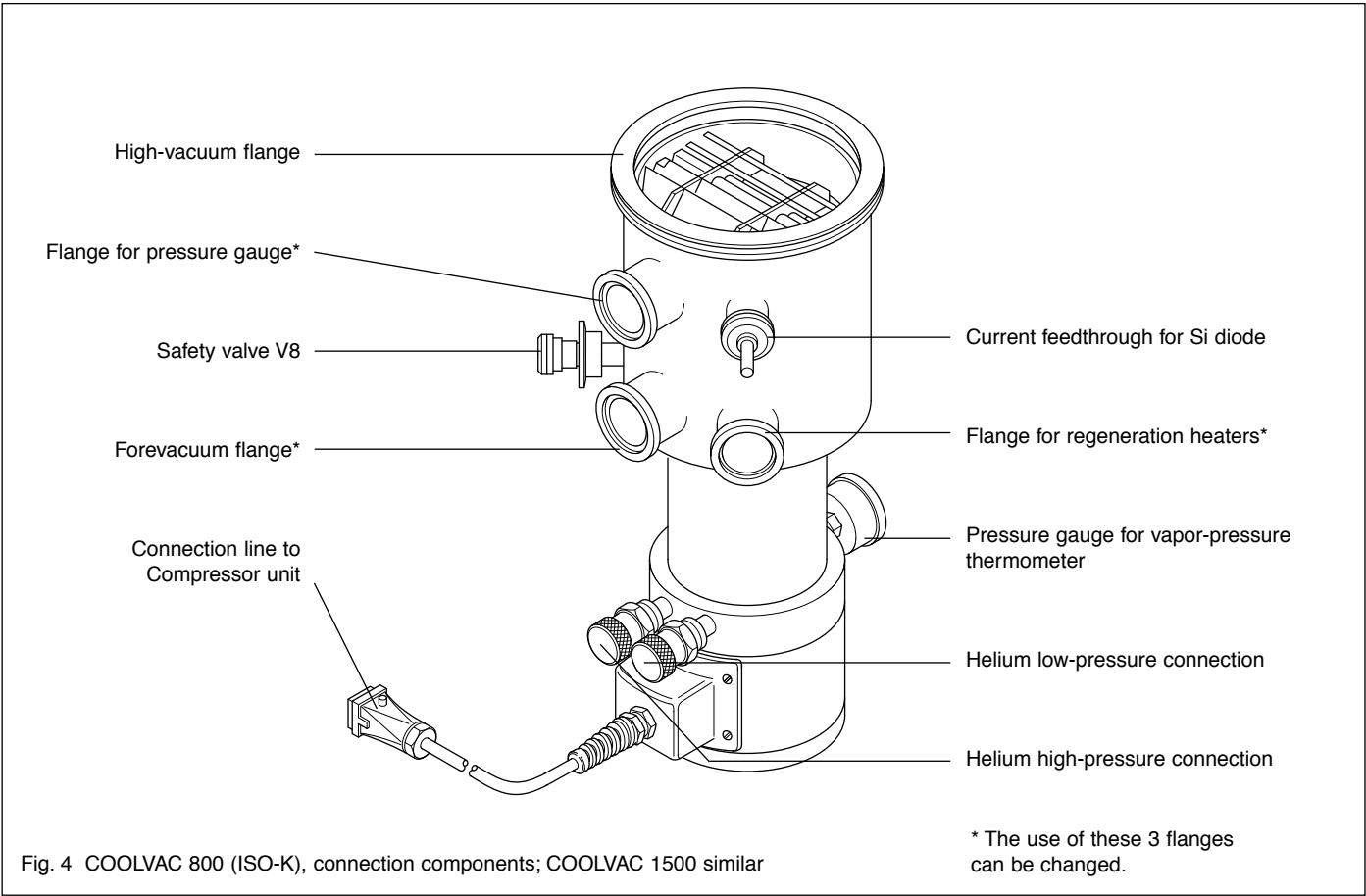
Gases such as hydrogen and oxygen are therefore **not simultaneously** present in the pump.

Using cryopumps in semiconductor manufacture

Using cryopumps in semiconductor manufacture places particularly demanding requirements on the operating personnel. The following gases are among those liberated particularly in sputter processes, plasma etching processes and in ion implantation and other processes:

chlorine, hydrogen chloride, hydrogen fluoride, phosphorous hydride, arsenic hydride and boron fluoride.

To prevent the formation of aggressive substances or mixtures of gases during the regeneration process which could subsequently react with and attack the exhaust gas pipe or the valves, we recommend diluting the gases which have to be removed from the pump with inert gas as soon as the gases exit the pump; pls. consult us.



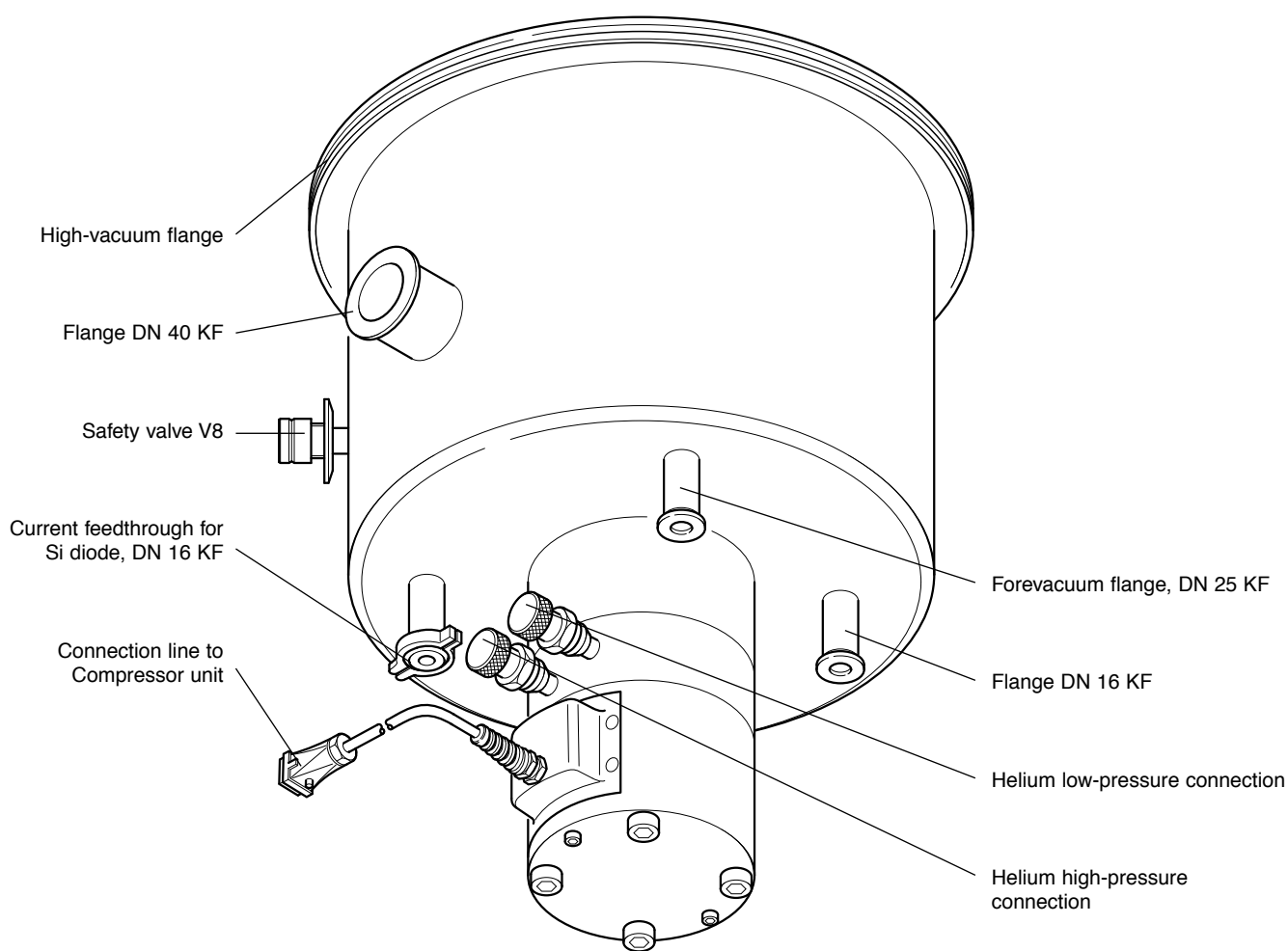


Fig. 6 COOLVAC 3000, connection components

2.2 Installing the Cryopump in the System

We recommend that a high-vacuum gate valve be installed between cryopump and vacuum chamber. The gate valve must be electrically connected in such a way that it closes automatically when the cryopump switches off.

A high-vacuum gate valve reduces system preparation time. With this valve closed, the cryopump can first be evacuated to its starting pressure and the vacuum chamber can then be pumped down to the cut-in pressure ("crossover pressure") during cooldown.

In addition, the gate valve can be closed during regeneration of the cryopump so that the vacuum chamber is constantly at low pressure and does not have to be vented. A high-vacuum gate valve is indispensable during batch operation.

The cryopump with its high-vacuum flange may be installed on the vacuum chamber in any orientation.

Leave a space of 15 cm between the system and the cold head motor for maintenance work, if possible.

Where possible, do not install the cryopump directly beside hot system components.

External magnetic fields at the place of the cold head motor must not exceed 30 mT (mT = milliTesla; 30 mT = 300 Gauß). In the case of stronger magnetic fields contact us for advice.

Since the cold head contains several plastic components it must be protected against X-rays or radioactive radiation. The maximum radiation level should not exceed 2000 Gy (Gy = Gray; 1 Gy = 100 rad).

No unprotected electrical equipment or cables should be installed under the cryopump. During the regeneration process water vapor from the ambient air may condense on the outside of the pump and drip off.

Silicon diode

Use the current feedthrough to connect a suitable measuring instrument (LTI 10, for example).

The silicon diode is sensitive to X-ray radiation or radioactive radiation. Depending on the installation orientation additional measurement errors are possible in the presence of magnetic fields. Please contact us for information on alternative sensors.

Regeneration heaters

Regeneration heaters are available as an option. The regeneration heaters are connected to a suitable power supply unit, like the HU 1, for example, via the five-pole socket on the thermal protector.

The connection is described in the Operating Instructions GA 12.105 "Installation of a regeneration heater in RPK cryopumps" and GA 12.303 "HU 1, Heater Unit".

2.3 Connecting Backing Pump and Relief Valve

The backing pump is used to evacuate the cryopump to the starting pressure, to evacuate the vacuum chamber to the cut-in pressure and to remove the gas released by the cryopump during regeneration.

Selecting the backing pump

The required pumping speed of the backing pump depends on the size of the vacuum chamber and the desired pump-down time. We recommend the two-stage TRIVAC D 8 B to D 25 B rotary vane pumps.

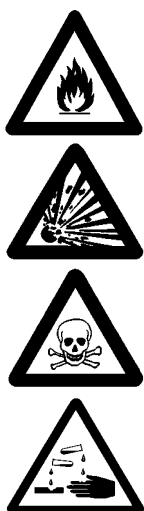
In order to utilize the advantages of hydrocarbon-free pumping we recommend the use of a DRYVAC dry-compressing vacuum pump as a backing pump.

We will be pleased to be of assistance when selecting the backing pump.

Use two forevacuum valves V2 and V3 to connect the backing pump to the vacuum chamber and the cryopump. Valves V2, V3 and V4 should be installed as close as possible to the pump's housing or the vacuum chamber.

Connect exhaust port of the backing pump to an exhaust line.

Warning



The backing pump may discharge dangerous gases during regeneration. For this reason the exhaust of the backing pump must be connected to a suitable exhaust line. Even inert gas can be dangerous in large quantities if it displaces the oxygen in the air we breathe.

Foreline adsorption trap

We recommend installing an adsorption trap (3/3) in the line between the cryopump and the backing pump. The size of the trap depends on the backing pump which is employed.

Such a foreline adsorption trap prevents oil vapors from backstreaming from the backing pump into the cryopump.

The adsorbent in the trap must be regenerated or exchanged at regular intervals.

If no foreline adsorption trap is installed, make certain that the forevacuum valve V2 closes automatically when the forevacuum pressure drops below $4 \cdot 10^{-2}$ mbar. Below this pressure, oil vapor may stream from the backing pump back into the cryopump.

If large quantities of water vapor are released while regenerating the cryopump, install a bypass line (3/13) around the foreline adsorption trap. This bypass line prevents the trap from becoming saturated with water vapor during regeneration.

Relief valve

Connect the relief valve to the exhaust line.

Warning



Never block the relief valve. Hazardous gases may be discharged from the relief valve. For this reason the relief valve must be connected to a suitable exhaust line.

2.4 Connecting the Compressor Unit

Connect the cold head of the cryopump to the compressor unit using flexlines. For this, refer to the Operating Instructions of the compressor unit.

Caution

Do not confuse the high-pressure and low-pressure connections because it could damage the cold head.

Multiple operation

2 or 3 COOLVAC 3000 be connected to one common compressor unit.

During parallel operation the refrigerating capacity may be reduced when compared to stand-alone operation, particularly when the pumps are exposed to external thermal radiation or gas flows, or when particularly low temperatures are required at the second stage of the pump for pumping of helium.

Operation of several cryopumps with a single compressor unit requires the use of an electrical manifold unit so that the pumps may be switched on and off independently and also various couplings are required for the helium supply. For this, please refer to the Leybold catalogue.

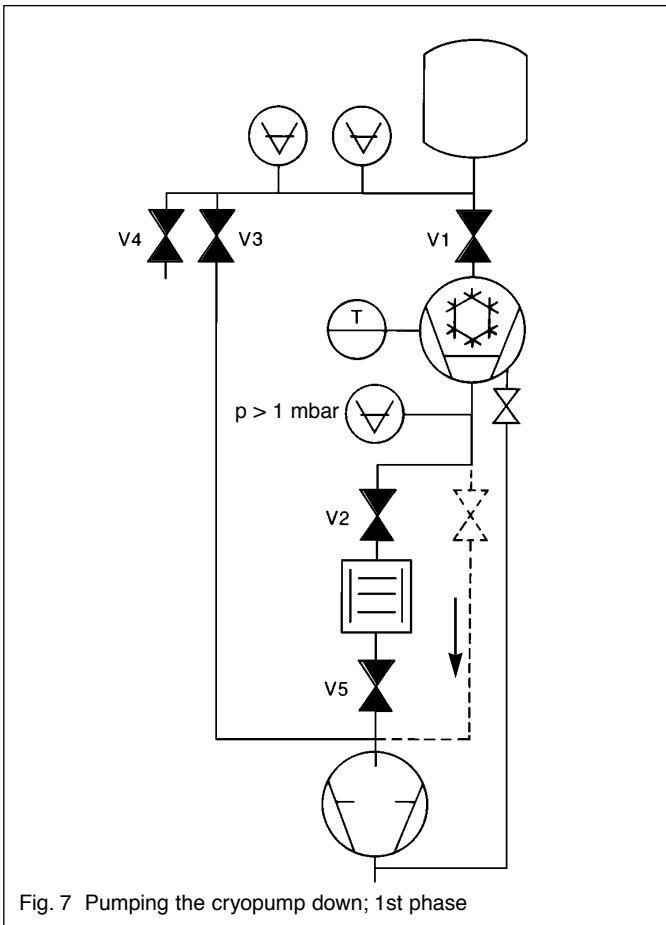


Fig. 7 Pumping the cryopump down; 1st phase

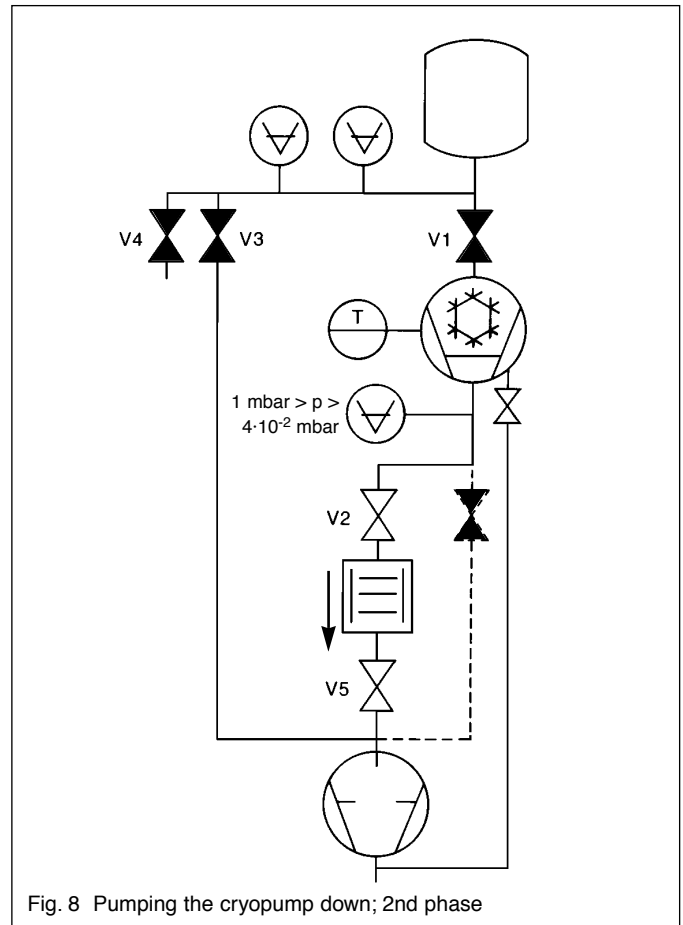


Fig. 8 Pumping the cryopump down; 2nd phase

3 Operation

3.1 Switching on

3.1.1 Pumping the Cryopump down to its Start-up Pressure

Before starting the compressor unit or the cryopump, pump down the cryopump to its starting pressure.

The starting pressure for normal applications is about $8 \cdot 10^{-2}$ mbar. If the starting pressure is too high, the cool-down time may be considerably prolonged or the pump may not reach its operating temperature.

When pumping helium or hydrogen, the starting pressure is $< 8 \cdot 10^{-3}$ mbar.

If pressures in the lower UHV range are to be attained, the starting pressure must be $< 1 \cdot 10^{-4}$ mbar.

If a pump is put into operation for the first time or activated charcoal is saturated with water vapor from the application, rough pumping may take as long as 12 hours. In such cases we recommend heating of the pump surfaces during rough pumping via the regeneration heaters. To do so, the temperature of the cryopanel must not

exceed 320 K. Operate the backing pump with gas ballast.

For rough pumping, close the high-vacuum gate valve V1 and the forevacuum valves V2 and V3. Pump out the cryopump via bypass line (3/13). Close the bypass line at about 1 mbar, open forevacuum valve V2 and pump out the cryopump via the adsorption trap (3/3).

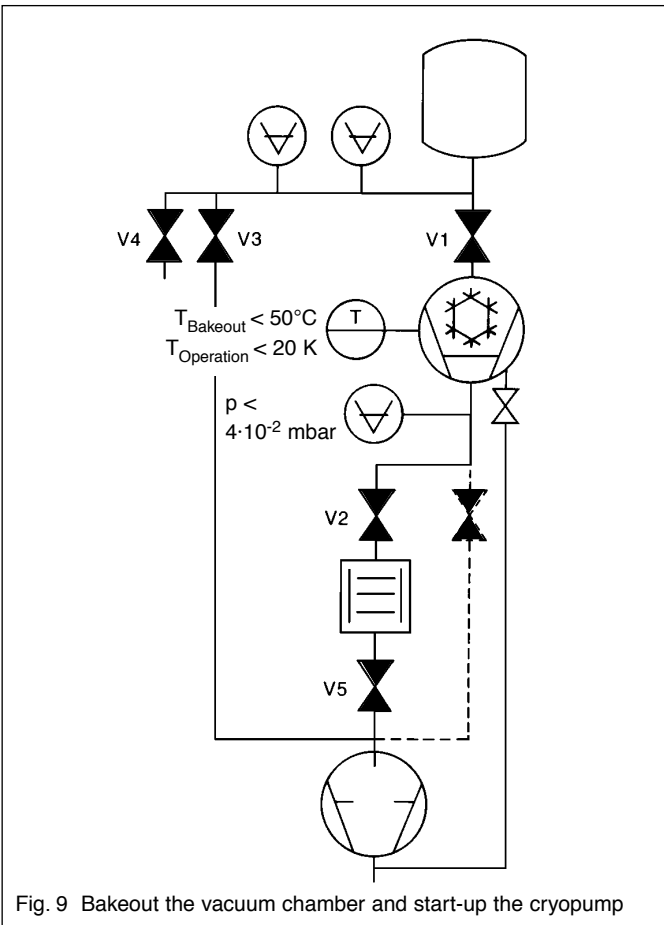
As soon as the starting pressure is attained, close forevacuum valve V2 and switch on the cryopump as detailed in Section 3.1.3.

Caution

If no adsorption trap has been installed, forevacuum valve V2 must be closed at a pressure of $p < 4 \cdot 10^{-2}$ mbar, as otherwise oil vapors may enter the cryopump.

Close blocking valve V5.

Open forevacuum valve V3 and begin to pump out the vacuum chamber.



3.1.2 Bakeout of the Vacuum Chamber

Bakeout is necessary when wanting to attain pressures in the UHV range.

Caution

The temperature at the pump surfaces must not exceed 50 °C (122 °F) during bakeout, hence the temperatures on both sides of the cold head have to be monitored continuously.

3.1.3 Cryopump Start-up and Cooldown

Having attained the starting pressure, switch on the cryopump at the compressor unit. High-vacuum gate valve V1 and forevacuum valve V2 must be closed.

We recommend that the following data be recorded routinely before and after cooldown:

- Hours of operation for the compressor unit
- Ultimate temperature of the cryopump
- Pressure reading on the compressor unit

Also the cooldown time for the cryopump should be noted down.

These data are very helpful for determining the point of time when the cryopump has to be regenerated and in the event of any troubleshooting.

The approximate cooldown time for the cryopump is given in Section 1.3.

The cryopump is ready to operate when the temperature of the second stage is below 20 K.

Only open the high-vacuum gate valve after the vacuum chamber has been evacuated down to the crossover value; for this refer to Section 3.1.4.

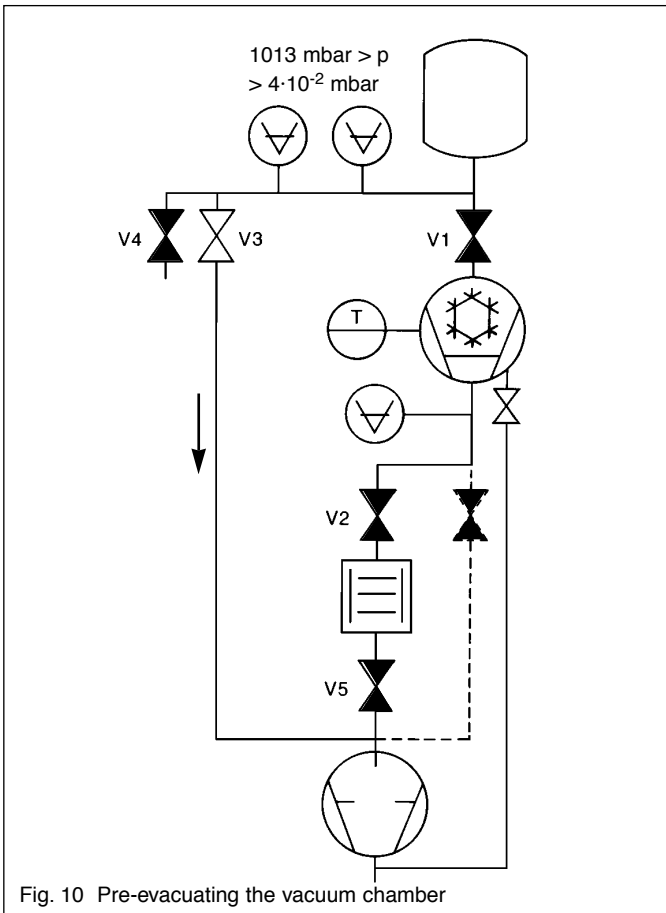


Fig. 10 Pre-evacuating the vacuum chamber

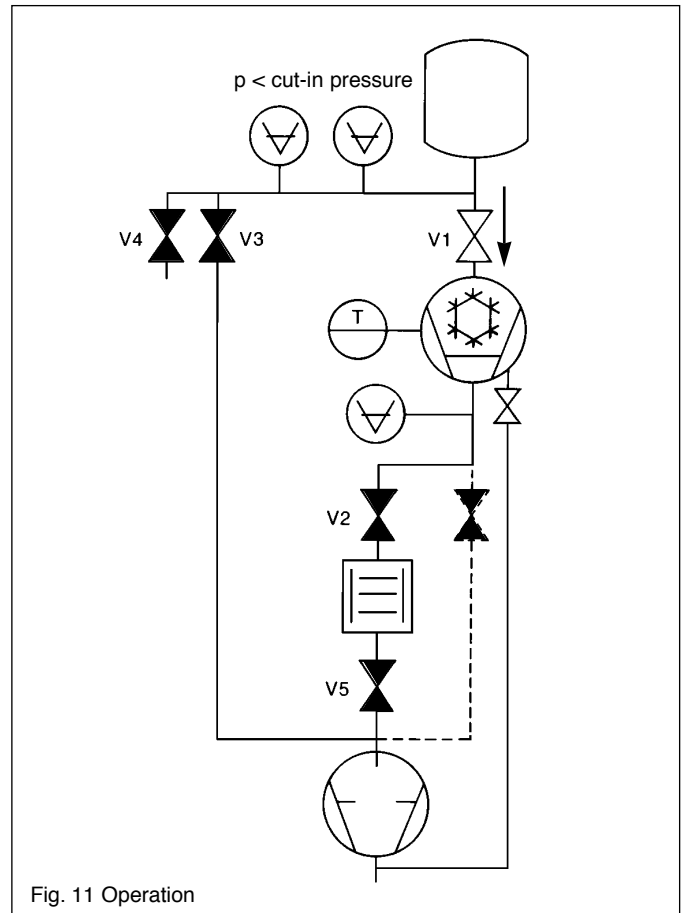


Fig. 11 Operation

3.1.4 Pre-evacuating the Vacuum Chamber and Connecting the Cryopump

Pre-evacuate the vacuum chamber via the open forevacuum valve V3.

Caution

V3 must be closed as soon as a pressure of $4 \cdot 10^{-2}$ mbar has been reached.

If valve V3 is kept open for a longer period of time and when the pressure falls below $4 \cdot 10^{-2}$ mbar, oil vapor from the backing pump may enter the vacuum chamber.

If the vacuum chamber is to be evacuated by the backing pump to pressures below $4 \cdot 10^{-2}$ mbar, adsorption trap (3/3) must be installed between vacuum chamber and backing pump.

Forevacuum valve V3 can be closed and high-vacuum gate valve V1 can be opened as soon as the gas quantity in the vacuum chamber has attained the crossover value of the cryopump.

The crossover value is the maximum quantity of gas in the vacuum chamber that can be pumped by the cryopump without letting the second stage of the cryopump become warmer than 20 K. When opening a cryopump to a vacuum chamber where the crossover value has not been reached, it will then heat up more and more and it

stops pumping.

Switch off the backing pump several minutes after having closed forevacuum valve V3.

The crossover or cut-in pressure is the maximum pressure in the vacuum chamber at which the high-vacuum valve between cryopump and vacuum chamber is permitted to open. It is derived from the crossover value.

$$p_{co} = \frac{q_{co}}{V}$$

$$\text{Cut-in pressure} = \frac{\text{Crossover value}}{\text{Volume of the vacuum chamber}}$$

Example: COOLVAC 3000 connected to a 100 l vacuum chamber.

$$q_{co} = 500 \text{ mbar} \cdot \text{l}$$

$$p_{co} = \frac{500 \text{ mbar} \cdot \text{l}}{100 \text{ l}}$$

$$p_{co} = 5 \text{ mbar}$$

Thus the pressure in the 100 l vacuum chamber must not exceed 5 mbar when closing forevacuum valve V3 and opening the high-vacuum gate valve to the cryopump.

3.2 Operation

Warning



Comply with all safety instructions given in Section 2.1!

Remember the following when operating the cryopump:

- Do not load the cryopump over its crossover value, otherwise it will heat up and pumped gas will be released. After protracted overloading, the cryopump must be restarted as per Section 3.1.
- The pressure in the vacuum chamber during continuous operation should be below $5 \cdot 10^{-3}$ mbar.
- Standard cryopumps where the pump surfaces are covered with activated charcoal are not allowed to pump large quantities of pure oxygen.
- When pumping nitrogen, oxygen and hydrocarbons, the temperature of the second stage of the cold head should be below 23 K; for hydrogen, it should be below 18 K.
- The cryopump must be regenerated when the temperature of the second stage of the cold head exceeds the values indicated or when the ultimate pressure of the pump rises.

The useful life of a cryopump until regeneration will be required can be estimated.

1. Operation at constant pressure

When the flow of gas into the vacuum chamber is maintained at a constant level and when the operating pressure is kept fairly constant, the following applies:

$$t = \frac{C}{S \cdot p}$$

$$\text{Useful life} = \frac{\text{Capacity}}{\text{Pumping speed} \cdot \text{Operating pressure}}$$

Example: A COOLVAC 3000 is to pump argon at 10^{-4} mbar.

$$C_{Ar} = 2300 \text{ bar}\cdot\text{l}$$

$$S_{Ar} = 2700 \text{ l}\cdot\text{s}^{-1}$$

$$t = \frac{2300 \text{ bar}\cdot\text{l}}{2700 \text{ l}\cdot\text{s}^{-1} \cdot 10^{-4} \text{ mbar}}$$

$$t = \frac{2300 \text{ bar}\cdot\text{l}\cdot\text{s}}{2700 \text{ l} \cdot 10^{-4} \cdot 10^{-3} \text{ bar}}$$

$$t = 8\,518\,518 \text{ s} = 99 \text{ days}$$

2. Cyclic operation

When the vacuum chamber is pumped down from the crossover value to the ultimate pressure in each case, the following applies:

$$n = \frac{C}{q_{co}}$$

$$\text{Number of cycles} = \frac{\text{Capacity}}{\text{Crossover value}}$$

Example: A COOLVAC 3000 pumps argon out of a vacuum chamber from the crossover value down to the ultimate pressure each time (see Section 3.1.4: for example, a vacuum chamber of 100 l and 5 mbar in each case).

$$n = \frac{2300 \text{ bar}\cdot\text{l}}{500 \text{ mbar}\cdot\text{l}}$$

$$n = \frac{2300 \text{ bar}\cdot\text{l}}{500 \cdot 10^{-3} \text{ bar}\cdot\text{l}}$$

$$n = 4600$$

3.2.1 Operation in Evaporation Coating Systems/Soldering Furnaces

When using a cryopump in an evaporation coating system or a soldering furnace, do not subject the pump to excessive thermal radiation. The cryopanel must not be heated to more than 20 K when the cryopump is in operation; in case of standstill not more than 310 K. If necessary, cool these parts of the system with water.

For protection against indirect radiation, blacken all surfaces which might reflect heat into the pump's inlet. If the thermal load on the cryopump is too high despite these precautions, use a pump whose baffle and radiation shield are cooled with liquid nitrogen. Installing a baffle in front of the pump's inlet and cooling it with liquid nitrogen or a refrigeration unit lowers the thermal radiation load on the cryopump but this will also reduce the pumping speed.

For more details, pls. contact us.

3.2.2 Operation in Welding Systems

In welding systems the cryopump is subject to loads resulting from great quantities of dust in addition to thermal radiation. This dust covers the baffle and the components of the radiation shield. In some cases it may even reach the surfaces of the cryopanel.

The dust affects operation of the cryopump:

- Dust increases the absorption coefficient of the outer surfaces of the thermal radiation shield, which generally have a mirror finish. The temperature of the thermal radiation shield is increased.
- Dust on surfaces which are covered with activated charcoal reduce the adsorptive capability. Their capacity to remove hydrogen, helium and neon decreases.
- Since dust has a large surface area to adsorb the gases, the pump down response deteriorates.

The only possible countermeasure is to clean the pump routinely. If the activated charcoal panels are contaminated, they must be replaced.

In electron beam welding considerable levels of X-ray radiation are produced. Since the cold head contains some components which are made of plastic, the cold head must be protected against ionizing radiation. The maximum radiation load absorbed should not exceed 2000 Gy (Gy = Gray = $J \cdot kg^{-1}$).

The silicon diodes are also sensitive to X-rays. For alternative sensors please contact us for information.

3.2.3 Operation in Sputter Coating Systems

During the process a pressure ranging from $2 \cdot 10^{-3}$ mbar to 10^{-2} mbar is maintained via controlled gas intake. To prevent the cryopump from being overloaded by the gas intake, the pumping speed must be reduced; possibly by a variable conductance during the process.

The change from a large amount of gas high to virtually no gas creates a varying thermal load and, consequently temperature fluctuations at the thermal radiation shield and the baffle. These temperature fluctuations may cause desorption and recondensation within the pump, thereby impairing the pumping characteristic. The desorption and recondensation processes depend on the type of gas, the operating pressure and the operating temperature of the pump.

The temperature of the first stage of the cold head must be over 50 K during sputtering with argon. At lower temperatures, argon is accumulated at the first stage during the process. It is subsequently desorbed at the end of the process and greatly extends the pumpdown time of the system.

The COOLVAC 3000 is designed for use in sputtering systems.

Its baffle covers only part of the inlet port, producing a higher pumping speed for the sputter gases and H_2 .

It has a cold head with a high refrigerating capacity at the second stage.

The outside of its thermal radiation shield is partially blackened, so that the first stage is somewhat warmer.

It has a great capacity for argon and hydrogen.

3.2.4 Operation in UHV systems

Refrigerator cryopumps have a very high pumping speed for hydrogen and water vapor, and they are well-suited for use in connection with UHV systems at pressures significantly below 10^{-10} mbar.

The inner parts of the cryopump can not be baked out. The components of the cryopump in the vacuum are so cold that gas molecules are unable to leave the pump.

The quantities of gas involved when pumping in the UHV range are so small that the pump will only rarely have to be regenerated. A regeneration will be required as soon as the desired ultimate pressure is no longer attained.

If there is no high-vacuum valve in front of the cryopump, the backing pump of the vacuum chamber may be used for regeneration.

The cryopumps may not be operated as a vacuum pump on the vacuum chamber during bakeout because of insufficient thermal stability of these pumps.

During bakeout the pumps must be separated from the vacuum chamber by a high-vacuum gate valve. This gate valve thermally shields the pump and prevents unacceptable heating up of the pump.

Evacuation of the vacuum chamber during bakeout is possible by an additional high-vacuum pump, a turbomolecular pump, for example.

During bakeout the cryopump should be left running so that it may cool itself. Moreover, after completion of the bakeout cycle it can then regain its operating temperature more quickly.

Operation without a high-vacuum gate valve has some limitations. During the bakeout process the temperature in the cryopump increases. Thus one can no longer be sure that all gases are retained in the pump. This requires the use of an additional high-vacuum pump. However, the running pump will not be damaged and after completion of the bakeout cycle it will provide its full pumping speed once more.

3.3 Regeneration

Since cryopumps are gas-binding pumps, the gas which is retained and stored in the pump must be removed from time to time. This process is referred to as regeneration.

A cryopump must be regenerated when

- the temperature at the second stage of the cold head increases for a longer period of time (> 5 min) above 20 K or
- the attainable ultimate pressure in the vacuum chamber increases or
- in the case of prolonged pump-down times.

We recommend preventive regeneration of the cryopump at regular intervals. The length of the intervals must be determined for each application; two methods of assessment are given in Section 3.2.

To regenerate the cryopump it has to be heated up to room temperature. There are four ways of doing this:

- Heating up without external support
- Admission of dry gas to support heating up
- Purging of the pump with hot gas
- Heating with electrical heaters.

If gases have been pumped which do not present a hazard when heated, we recommend electrical regeneration because this is the fastest and most effective method and because the activated charcoal on the pump surfaces is not saturated with water vapor.

For electrical regeneration, Leybold offers a heater power supply unit HU 1 and regeneration heaters with integrated temperature monitor for integration into the cryopumps.

Described in the following is the regeneration process with the aid of the HU 1. If you wish to use a different method, please contact us for advice.

The duration of a regeneration depends on the size of the pump and the quantity and type of pumped gas. It must be established separately for each application by some experimentation. For a medium-sized pump the normal regeneration time including pump cooldown is 3 to 5 hours.

Warning



During regeneration, comply with all safety instructions in Section 2.1!

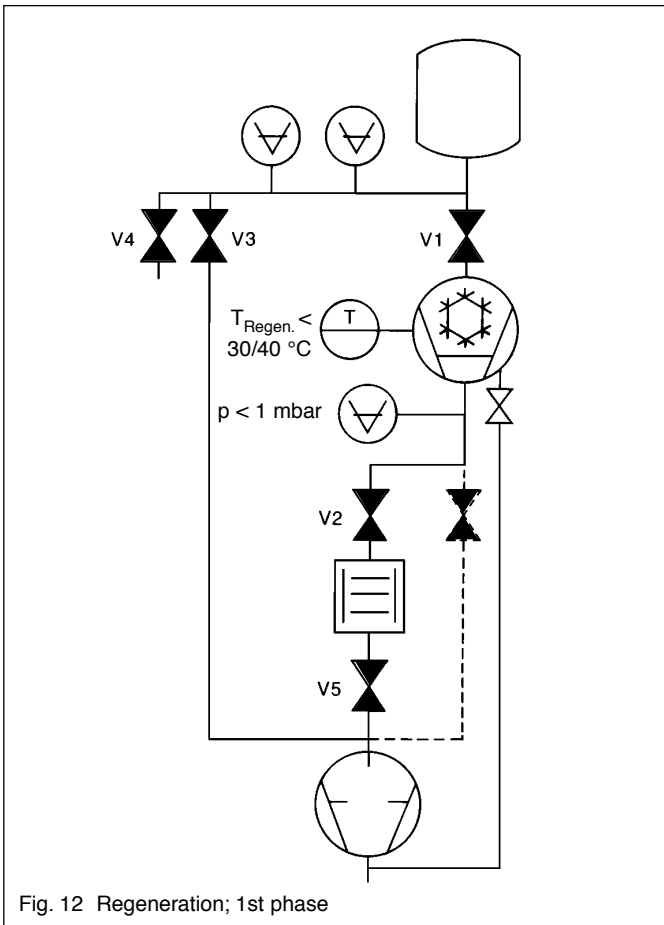


Fig. 12 Regeneration; 1st phase

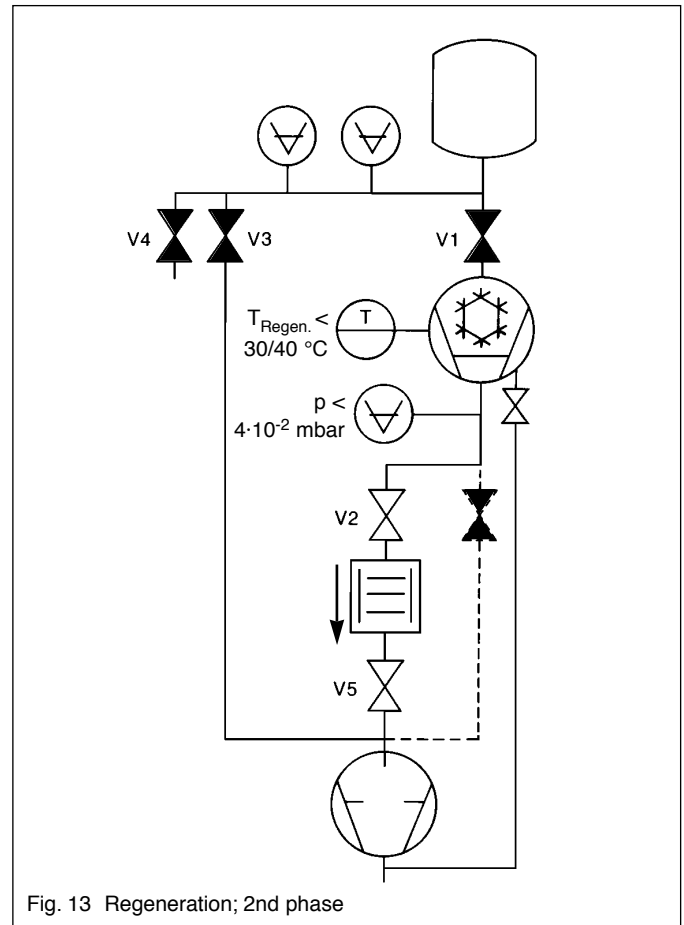


Fig. 13 Regeneration; 2nd phase

Close high-vacuum gate valve V1.
Switch off the cryopump at the the compressor unit.

Caution

The maximum permissible temperature of the pump surfaces is 50 °C (122°F). In the event of frequent heating as it occurs during regeneration, limit the temperature to 30 °C (86°F) at the first stage and to 40°C (104°F) at the second stage. The task of temperature limiting is performed by the temperature monitor.

Switch on the HU 1. Switch on the heater for the first and second stage.

Switch on the backing pump, but keep valve V2 closed.

The pressure in the cryopump rises due to gas desorption. When it reaches 1 mbar, open forevacuum valve V2 and blocking valve V5.

When water vapor is liberated during the regeneration process, the backing pump must be operated with gas ballast. Water vapor is liberated in almost all systems except pure UHV systems and pure sputtering systems.

As soon as the pump reaches a pressure below $4 \cdot 10^{-2}$ mbar at room temperature, regeneration has been completed. For UHV applications, a pressure of approximately 10^{-4} mbar must be attained. Close the valves V2 and V5 and switch off the backing pump.

Switch off the heater for the first and second stage at HU1.

In the case of UHV applications leave the heater for the second stage on for approximately further 30 minutes while the cryopump is cooling down. Any remaining water vapor and hydrocarbons will then freeze out on the baffle and not condense on the activated charcoal on the pump surfaces of the second stage.

Switch on the cryopump at the compressor unit.

The cryopump is ready for operation when the temperature at the second stage of the cold head is equal or less than 20 K.

3.4 Switching off

The cryopump must be regenerated before switching it off; for details see Section 3.3.

Do not expose the cryopump to atmospheric pressure until it has reached at least room temperature. This will prevent the charcoal cryopanel from adsorbing water.

When the cryopump is shut down for a longer period of time, it should either be left under forevacuum pressure or filled to 1000 mbar with dry nitrogen or argon. The flex-lines to the compressor unit should not be disconnected.

3.4.1 Procedure during Brief Interruptions e. g. in Operation Power Failures

During interruptions in operation the cryopump heats up and pumped gases are released. When this causes the pressure in the cryopump to increase above its starting pressure ($8 \cdot 10^{-2}$ approx.), the cryopump cannot reach its operating temperature on its own. It will then have to be pre-evacuated in accordance with Section 3.1 and cooled down.

How long a cryopump can be shut down without the pressure becoming too high depends on the operating temperature and the type and quantity of the pumped gas. When pumping air, a cryopump with an operating temperature of 14 K can be shut down for about 5 minutes.

4 Maintenance

Regularly regenerate or exchange the adsorbent in the foreline adsorption trap. For this please refer to the Operating Instructions of the adsorption trap.

We recommend exchanging the entire regenerator displacer in the cold head after 9,000 hours of operation.

This work can only be performed by LEYBOLD Service or appropriately trained service personnel.

LEYBOLD has practical courses on the maintenance, repair and troubleshooting of cryopumps and other cryotechnical components. Further details are available on request.

A special set of tools (CRYO SERVICE SET, Cat. No. 890 93) is required to perform all maintenance work.

The CRYO SERVICE SET contains Operating Instructions in which all required work is described.

Warning



Improperly performed maintenance work is a danger to safety, service life and operability and may invalidate the guarantee.

4.1 Service at Leybold's

If you send a pump to LEYBOLD indicate whether the pump is free of substances damaging to health or whether it is contaminated. If it is contaminated also indicate the nature of hazard. To do so, you must use a pre-printed form which we shall send to you upon request.

A copy of this form is printed at the end of the Operating Instructions: „Declaration of Contamination of Vacuum Equipment and Components“.

Either fasten this form at the pump or simply enclose it to the pump.

This declaration of contamination is necessary to comply with legal requirements and to protect our staff.

LEYBOLD must return any pump without a declaration of contamination to the sender's address.

5 Troubleshooting

Symptom	Possible Cause	Recommended Corrective Action	Reference Section*
1 The temperature at the cryopanel is too high or cooling down takes too long.	Cryopump is saturated with gas.	Regenerate cryopump.	3.3
	Starting pressure or crossover value/ cut-in pressure was too high.	Adequately rough-pump both pump and vacuum chamber.	3.1
	Worn-out displacer. As a preventive measure, the displacer should be replaced after every 9,000 hours of operation.	Exchange displacer.	Service / 4
	Helium gas is contaminated.	Purge helium system. Clean compressor unit, cold head and flexlines.	Service / 4
	Helium gas pressure is too low.	Add helium to the compressor unit.	Operating Instructions for compressor unit.
	Temperature reading incorrect.	Check readings with a second thermometer. Check calibration of the silicon diode.	
	System or cryopump have developed a leak.	Detect leak and seal it.	
	Baffle or thermal radiation shield have made contact with the pump housing.	Properly install baffle and radiation shield.	
	The indium discs in the cryopump have been damaged due to overheating during regeneration or bakeout.	Repair cryopump.	Service / 4
	Cryopanel, baffle or thermal radiation shield are contaminated.	Clean cryopanel, baffle and thermal radiation shield.	
	Cold head motor is not operating properly.	See symptom 2.	
	Flexlines have not been connected correctly.	Properly connect the flexlines. Connect the high pressure connection of the compressor unit to the high pressure connection on the cryopump. Connect the low pressure connections to each other.	Operating Instructions for compressor unit
	The cryopump has been thermally overloaded by thermal radiation from the vacuum chamber.	Shield off the thermal radiation coming from the vacuum chamber.	
	Ambient temperature too high.	Lower the ambient temperature in the vicinity of the cryopump to under 40 °C (104°F).	
	Saturated adsorber on the compressor unit.	Exchange adsorber, and clean the cold head, if required.	Operating Instructions for the compressor unit/ Service
Compressor unit too small for the cryopump.	Operate the cryopump in connection with the recommended compressor unit.	1.3 / 2.5	

* see indicated Section

Symptom	Possible Cause	Recommended Corrective Action	Reference Section
2 The cold head is running erratically, too loud or too quiet.	Helium circuit is contaminated.	Purge helium system. Clean compressor unit, cold head and flexlines.	Service / 4
	Worn-out displacer or control valve. As a preventive measure, the displacer should be replaced after every 9,000 hours of operation.	Exchange or clean the displacer.	Service / 4
	Faulty cold head motor or not correctly connected.	Exchange the cold head motor or connect it properly.	Service / 4
	Helium gas pressure is too high.	Drain out some helium from the compressor.	Operating Instructions for the compressor unit
	External magnetic field over 30 mT.	Shield off the magnetic field.	
3 The compressor unit switches itself off.	See Operating Instructions for the compressor unit.		
4 The cryopump's ultimate pressure is too high.	Temperature at the cryopanel is too high.	See symptom 1.	
	System or cryopump have developed a leak.	Detect leak and seal it.	
	Degassing surfaces within the system.	Bake out the system.	
	Cryopump contaminated by oil vapors.	Clean the cryopump. Exchange the cryopanel when the activated charcoal is contaminated with oil vapors. Install an adsorption trap or change the adsorbent.	Service / 4 / 2.3
	Erratic operation of the cold head.	See symptom 2.	
5 Roughing of the cryopump takes too long.	The surfaces of the activated charcoal are saturated with water vapor.	Heat the cryopanel during roughing.	
	Leaky relief valve.	Clean the valve or replace it.	
	System or cryopump have developed a leak.	Detect leak and seal it.	
	Pumping speed of the roughing pump is insufficient.	Use a larger roughing pump.	

6 Spare Parts

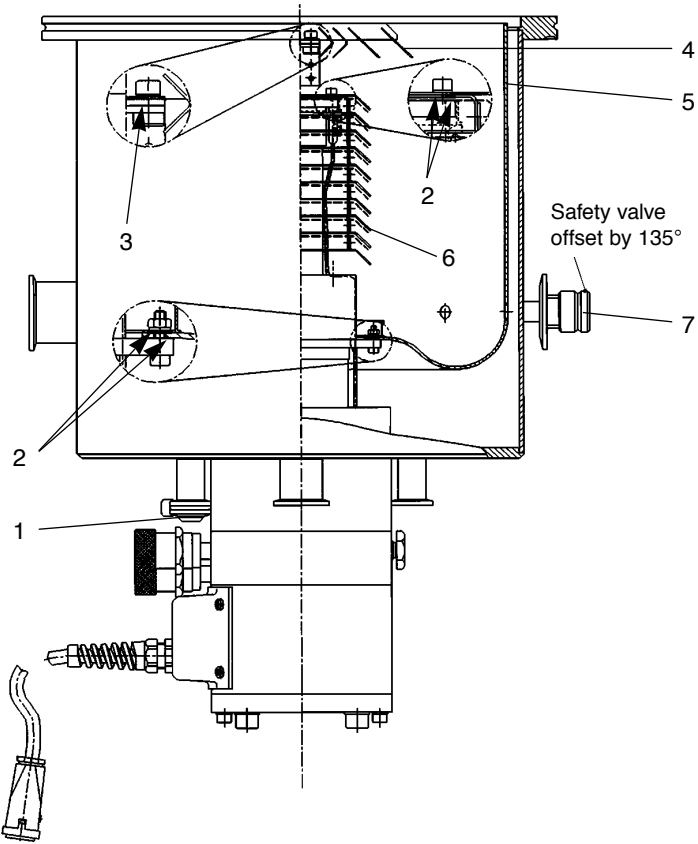


Fig. A COOLVAC 3000,
COOLVAC 800,1500 similar

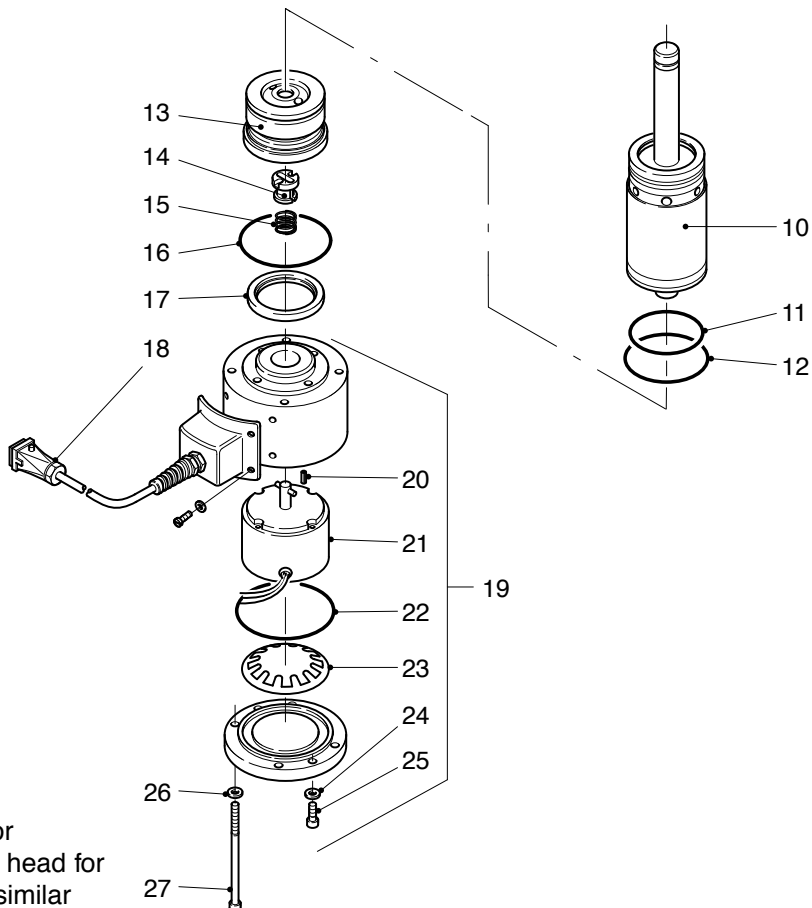
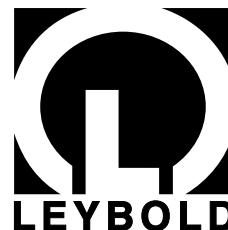


Fig. B Cold head for
COOLVAC 3000, cold head for
COOLVAC 800,1500 similar

Pos.	Quantity			COOLVAC 800,1500,3000 See Fig. A, B		Ref. No.
	COOLVAC			Designation	Data	
	800	1500	3000			
1	1	1		Current feedthrough		200 19 256
1			1	Current feedthrough	with silicon diode	200 20 694
2	12	14	16	Indium washer	ø4,3 Indium	200 19 473
3	4	4	4	Indium washer	ø5,3 Indium	200 19 783
4	1			Baffle		200 19 282
4		1		Baffle		200 19 554
4			1	Baffle		200 20 035
5	1			Radiation shield		200 19 281
5		1		Radiation shield		200 19 544
5			1	Radiation shield	ø297 x 253,5	200 20 034
6	1			Pump surface		200 19 239
6		1		Pump surface		200 19 555
6			1	Pump surface		200 20 036
7	1	1	1	Relief valve	1,1 bar; M24 x 1,5	200 19 764
10	1			Displacer DPU 210	incl. Pos.11,12,14,15,16,22	200 20 501
10		1		Displacer DPU 510	incl. Pos.11,12,14,15,16,22	200 20 478
10			1	Displacer DPU 1245	incl. Pos.11,12,14,15,16,22	200 20 038
11	1	1		O-ring	39,2 x 3 mm NBR	239 63 115
11			1	O-ring	59 x 3 mm NBR	239 50 173
12	1	1		O-ring	47 x 3 mm NBR	239 50 152
12			1	O-ring	83 x 3 mm NBR	200 19 168
13	1			Control disc	Al	403 03 131
13		1		Control disc	Al	200 19 377
13			1	Control disc	Al	200 20 028
14	1			Control valve		200 20 265
14		1	1	Control valve		200 20 264
15	1			Spring	18,4 x 10 mm	221 61 252
15		1	1	Spring	22,4 x 12 mm	221 61 025
16	1	1	1	O-ring	90 x 3 mm NBR	239 50 180
17	1	1	1	Sealing ring	NBR	200 19 774
18	1	1	1	Cable		200 20 593
19	1	1	1	Drive assembly compl.		200 20 687
20	1	1	1	Clamping sleeve	4 x 14 mm DIN 1481	241 09 247
21	1	1	1	Motor	220 V; 50/60 Hz	200 20 216
22	1	1	1	O-ring	90 x 2 mm NBR	239 50 153
23	1	1	1	Spring	ø88 mm	200 19 562
24	2	2	2	Washer	A6,4 DIN 125	221 01 203
25	2	2	2	Cylinder screw	M6 x 20 DIN 912	201 03 510
26	4	4	4	Washer	ø10,5 mm DIN 433	222 02 111
27	4	4	4	Cylinder screw	M10 x 110 DIN 912	200 20 668

EC Manufacturer's Declaration

in the spirit of Appendix IIb to the 89/392/EEC Machinery Guidelines



We, the Leybold Vacuum GmbH, declare herewith that the commissioning of the incomplete machine designated below is prohibited until such time as it has been determined that the machine in which this complete machine is to be installed corresponds with the EC Machinery Guidelines.

At the same time we herewith certify conformity with EEC Directive on Low-Voltages 73/23/EWG.

When using the appropriate Leybold accessories, e.g. compressor units, its accessories or heater components the protection level prescribed in the EMC Guidelines will be attained.

Designation: Refrigerator cryopump

Models:

COOLVAC 800, 1500, 3000

Catalog numbers:

892 61/63

892 56

893 21/23

Cologne, June 27, 1997

Dr. Mattern-Klosson, Cryotechnology
Division Manager

Applicable, harmonized standards:

- EN 292-1 and -2: 1991
Machinery safety – Basic terminology
- EN 1012-2: 1996
Safety requirements for vacuum pumps
- EN 60204-1: 1992
Electrical equipment for industrial machinery

Applied national standards and technical specifications:

- VBG 4/04.79 Electrical operating equipment and plants
- DIN VDE 0113-1/02.93
Electrical equipment for industrial machinery
- AD Brochures A1, A2, B0, W0

Cologne, June 27, 1997

Mr. Greger, Cryopump Engineer

LVGK.0213.02.06.97

Declaration of Contamination of Vacuum Equipment and Components

The repair and/or service of vacuum equipment and components will only be carried out if a correctly completed declaration has been submitted. Non-completion will result in delay. The manufacturer could refuse to accept any equipment without a declaration.

This declaration can only be completed and signed by authorized and qualified staff.

1. Description of Vacuum Equipment and Components

- Equipment type/model: _____
- Code No.: _____
- Serial No.: _____
- Invoice No.: _____
- Delivery date: _____

2. Reason for Return

3. Condition of the Vacuum Equipment and Components

- Has the equipment been used?
yes no
- What type of pump oil/liquid was used? _____
- Is the equipment free from potentially harmful substances?
yes (go to Section 5)
no (go to Section 4)

4. Process related Contamination of Vacuum Equipment and Components:

- toxic yes no
- corrosive yes no
- explosive*) yes no
- biological hazard*) yes no
- radioactive*) yes no
- other harmful substances yes no

*) Vacuum equipment and components which have been contaminated by biological explosive or radioactive substances, will not accepted without written evidence of decontamination!

Please list all substances, gases and by-products which may have come into contact with the equipment:

Trade name Product name Manufacturer	Chemical name (or Symbol)	Dangerous material class	Measures if spillage	First aid in case of human contact
1.				
2.				
3.				
4.				
5.				

5. Legally Binding Declaration

I hereby declare that the information supplied on this form is complete and accurate. The despatch of the contaminated vacuum equipment and components will be in accordance with the appropriate regulations covering Packaging, Transportation and Labelling of Dangerous Substances.

Name of organisation or company: _____

Address: _____ Post code: _____

Tel.: _____

Fax: _____ Telex: _____

Name: _____

Job title: _____

Date: _____ Company stamp: _____

Legally binding signature: _____



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