ULVAC

Cryogenic Water Pump
CDPL Series
Instruction Manual

Export Control Policy

Vacuum pumps that pump nitrogen gas at pumping speed of 15000L/S or more fall under row 2(35) of appended table 1 of Japan's Export Trade Control Order, which is based on international export control regimes. Also, when applying a refrigerator system to a cryocooler for optical sensors, the cryocooler falls under row 10(2) of appended table 1 of Japan's Export Trade Control Order as well.

Customers must follow all related rules and regulations such as Foreign Exchange and Foreign Trade Act and take appropriate procedures when exporting or re-exporting those products.

D/N.MBCDPL0E, 2017MY01 **ULVAC CRYOGENICS INCORPORATED**

Introduction

Thank you for choosing our products. This instruction manual gives information and precautions on handling, installation, operation, and maintenance of the product.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. To ensure proper use of this product, read this instruction manual carefully and keep this manual close at hand so that you can use for reference during operation.

If you purchased our other products and/or optional devices with this product, read relevant instruction manuals carefully.

1. About the personnel who are involved in handling our products

All personnel involved in handling our products should take a general safety education and training that is officially accepted in the country where our product is used. The personnel are also required to have specialized knowledge/skills and qualification on the electricity, the machinery, the cargo handling, and the vacuum. Especially, the personnel should be familiar with handling a cryopump in order to use it safely. Since we offer a training session (which is subject to fees) as needed for people who use cryopumps for the first time, please do not hesitate to contact our Service Engineering Division to join the training session.

2. Warranty

2.1 Gratis warranty period and Warranty coverage

【Gratis warranty period】

Note that an installation period of less than one year after installation in your company or your customer's premises or a period of less than 18 months (counted from the date of production) after shipment from our company, which is shorter, is selected.

【Coverage】

(1) Failure diagnosis

As a general rule, diagnosis of failure should be done on site by customer. However, ULVAC CRYOGENICS or our service network can perform this service for an agreed fee upon the customer's request. There will be no charge if the cause

of the breakdown is found to be a fault of ULVAC CRYOGENICS.

(2) Damage during transportation

When damage by delivery/transportation is admitted, the product will be repaired free of charge within the range of the guarantee expressed in the sales contract.

(3) Breakdown repairs

There will be a charge for breakdown repairs, replacements and on-site visits for the following seven conditions. In those cases the cost shall be your own expense even though the product is within the warranty period.

① Breakdowns due to improper storage or handling, careless accident, software or hardware design by the customer.
② Breakdowns due to modifications of the product without consent of the manufacturer.
③ Breakdowns due to maintenance of the product without authentic parts or breakdowns resulting from using the product outside the specified specifications of the product.
④ Breakdowns due to contamination or corrosion caused by user's use conditions.
⑤ Breakdowns due to natural disasters (such as fire, earthquake, flood, lightning, salt damage, and so on) , environmental pollution, irregular voltage, and /or usage of undesignated power source.
⑥ Breakdowns that are outside the terms of warranty.
⑦ Consumables and/or replacement service.

Since the above services are limited to within Japan, diagnosis of failures, etc are not performed abroad. If you desire the after service abroad, please contact ULVAC CRYOGENICS and consult us for details in advance.

2.2 Exclusion of opportunity loss from warranty liability

Regardless of the gratis warranty term, compensation to opportunity losses incurred to your company or your customers by failures of ULVAC CRYOGENICS products and compensation for damages to products other than ULVAC CRYOGENICS products and other services are not covered under warranty.

2.3 Repair period after production is discontinued

ULVAC CRYOGENICS shall accept product repairs for seven years after production of the product is discontinued.

3. Service Form

After the products are delivered, please fill out the following information in the blanks. If you have any questions or technical problems, please feel free to contact the nearest Customer Support Center or headquarters. Please refer to "Service Network".

Cryopump／Super trap Model	: _____
Cryopump／Super trap Serial No.	: _____
Refrigerator Model	: _____
Refrigerator Serial No.	: _____
Compressor Model	: _____
Compressor Serial No.	: _____
Temperature controller／Thermal display Model	: _____
Temperature controller／Thermal display Serial No.	: _____
Option Part Model	: _____
Optional Part Serial No.	: _____

4. Notes for repair and maintenance requests

We may decline your request for the repair or the maintenance of our products if you refuse to give us information about the presence of the hazardous substance and/or contaminant.

Also, please be aware that we do not accept liability for damages by the contaminant, which might be caused during transportation to our office or the nearest customer support center. To avoid such accident, please pay careful attention to packing of the product

5. In case of breakdown and accident

When breakdown or accident occurs, we may ask for keeping the product on site as it is or retrieving the product to investigate its cause. Also we may ask for reporting the detailed process and/or the operating condition. When unidentified malfunction was generated, please contact our Service Engineering Division or

the nearest customer support center with reference to the chapter of Service Network. We ask for cooperation about the above.

6. General Precautions

(1) It is strictly prohibited to duplicate, open, and transfer this instruction manual or any of its parts to a third person without written permission from ULVAC CRYOGENICS.

(2) Information in this document might be revised without a previous notice for the specification change and the improvement of the product.

(3) If you have any questions or comments on this document, please do not hesitate to contact us. The phone numbers of local customer support centers are listed at the end of this manual.

Safety Considerations

Our products have been designed to provide extremely safe and dependable operation when properly used. Following safety precautions must be observed during normal operation and when servicing them.

WARNING **A warning describes safety hazards or unsafe practices which could result in severe injury or loss of life.**

CAUTION **A caution describes safety hazards or unsafe practices which could result in personal injury or equipment damage.**

Toxic gas or chemicals used.
There is a risk of severe injury upon contact.

Corrosive chemicals used.
There is a risk of severe injury upon contact.

Flammable gas used.
There is a danger of fire or burn injury.

Explosive gas used.
There is a risk of fire or explosion.

Hazardous voltage .
Electric shock may cause severe injury or loss of life.

Hot heating part present.
There is a risk of burn injury.

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Safety Instructions

The following precautions must be observed before designing pumping systems equipped with the CDPL or operating the CDPL system.

1. Rupture of cylinder by corrosion

The cylinder of refrigerator is mainly made of stainless steel and copper.

Special precautions must be taken when pumping corrosive gas which may be produced by plasma reaction, sputtering, etc. in chamber, and corrodes cylinder materials.

For maximum performance of the refrigerator, the stainless steel cylinder thickness is very thin. During normal operation, the pressure of helium gas in the refrigerator is approximately 2 - 2.5 MPa (gage) and if the corrosion develops, the cylinder may rupture at weak portion.

☆If the super trap is used to pump corrosive gases, periodic pressure proof test is recommended.

☆ULVAC CRYOGENICS INC. tests the pressure proof of cylinder by increasing the gas pressure 1.5 times as high as the operating pressure.

2. Assembly and disassembly of refrigerator

The refrigerator contains helium gas of high-pressure and high purity.

When disassembling your refrigerator, please contact our customer support section, your local ULVAC TECHNO, Ltd., CS center, or ULVAC Kyusyu Corp. for technical assistance.

Take the following special precautions for maintenance or disassembly of the refrigerator.

1. Discharge the helium gas completely using discharging adapter from self-sealing coupling of both helium return and supply flexible hose.
2. Make sure that the helium gas pressure is indicated 0 MPa (gage) and then loosen the bolt.

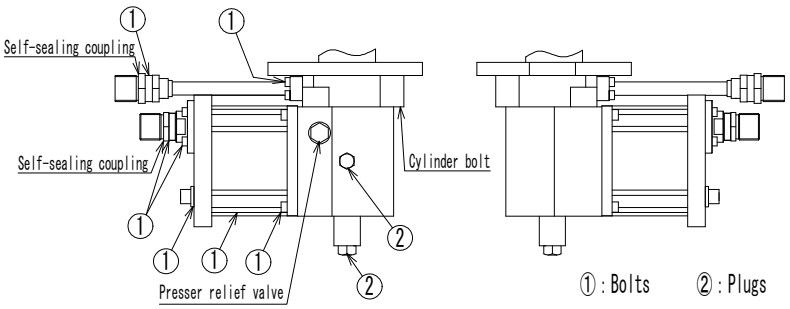
NOTE: Do not loosen the bolts and plugs pointed by arrows in Figure 4 before discharging the helium gas. Ignoring this note may cause severe injury or equipment damage.

Follow the precautions below when assembling the refrigerator by yourself.

1. Tighten the bolts of each part in the diagonal carefully.
2. The cylinder bolts (M6×6) have the heaviest load by high-pressure helium gas. The torque for cylinder bolts of RS80/RMS80T need 11.6N·m (118kgf·cm).
3. Fill the refrigerator with the helium gas slowly confirming that there is no defect.
4. When adding the helium gas, please follow all the instructions described in this manual.

Ensure that the bolts are securely tightened. Loosened bolts or bolts under the regulation torque could cause severe injury or equipment damage.

RM type Refrigerator



R type Refrigerator

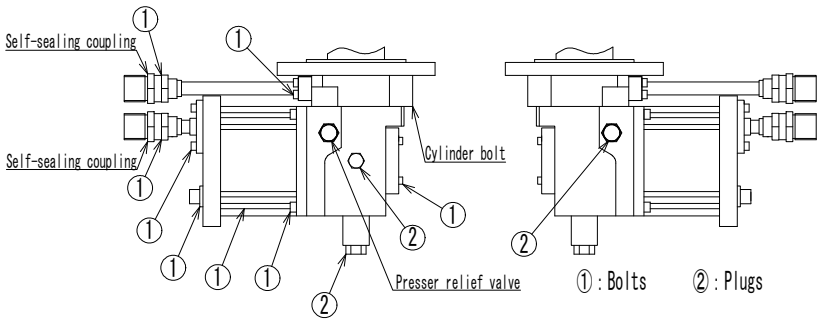


Figure 1　Bolt Locations

3. Do not charge the system with excessive helium gas

For regeneration, our CDPL use high-pressure helium gas circulated in the refrigerator system. Charging with helium gas more than the specified value does not increase the refrigerator performance. Conversely, the pressure relief valve could blow out if helium gas pressure exceeds the specified value. Excessive charging of helium gas could result in leakage and defect of the CDPL system.

Do not charge helium gas more than specified.

4. Power source

Refer to the Table 1-1 in the instruction manual of compressor unit for required power source.

- Install ground-fault interrupter.
- Use the UCI-supplied power cable. Do not connect other equipment from the same power source.
- Make sure to connect the earth wire to a ground terminal.

5. Condensation of water vapor

Water vapor may condense on the CDPL mount or CDPL when vacuum level is lowered during normal operation, cool-down or during warm-up at regeneration.
DO NOT place electrical devices under the CDPL to avoid short-circuit or break down of the devices. It is recommended to place a saucer to catch water drops.

6. Temperature notice

The maximum allowable temperature of the CDPL is 70ºC(343K).
Excessive temperature may cause damage to the product.
Always monitor the temperature of the sensor inside the CDPL so that it does not exceed 70ºC(343K).

Particularly, when the heat source from the customer's equipment might raise the temperature sensor inside the CDPL above 70ºC (343K) while it is suspended, turn ON the CDPL and keep the temperature at around the room temperature (approx. 20ºC (293K)).
Also, make sure not to give heat from customer's equipment to the CDPL while the CDPL system is turned off.

Thermo-electromotive force of K Thermocouple（mV）

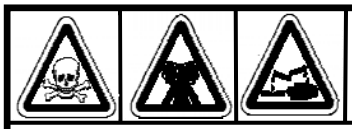
The reference junction : 20ºC

Temp.(ºC)	0	2	4	6	8
10	-0.401	-0.321	-0.241	-0.161	-0.080
20	0.000	0.081	0.162	0.243	0.324
30	0.405	0.487	0.568	0.650	0.732
40	0.814	0.896	0.978	1.060	1.143
50	1.225	1.308	1.390	1.473	1.556
60	1.638	1.721	1.804	1.887	1.970
70	2.053				

Reference : JIS C 1602-1995

Disposal Consideration

Regulations and the ordinance concerning industrial waste treatment are provided in the country and region to discard. When disposing our products, please process abandonment according to relevant regulations and ordinance, etc.



WARNING

When it seems that the cryopump or refrigerator has been used to evacuate a toxic or dangerous material, you must contact a safety supervisor before discarding, and discard it after removing the poisonous material according to directions of the safety supervisor.

We will offer you Material Safety Data Sheet (called MSDS) of our products upon your request. If you have any questions, please contact our Service Engineering Division or the nearest customer support center.

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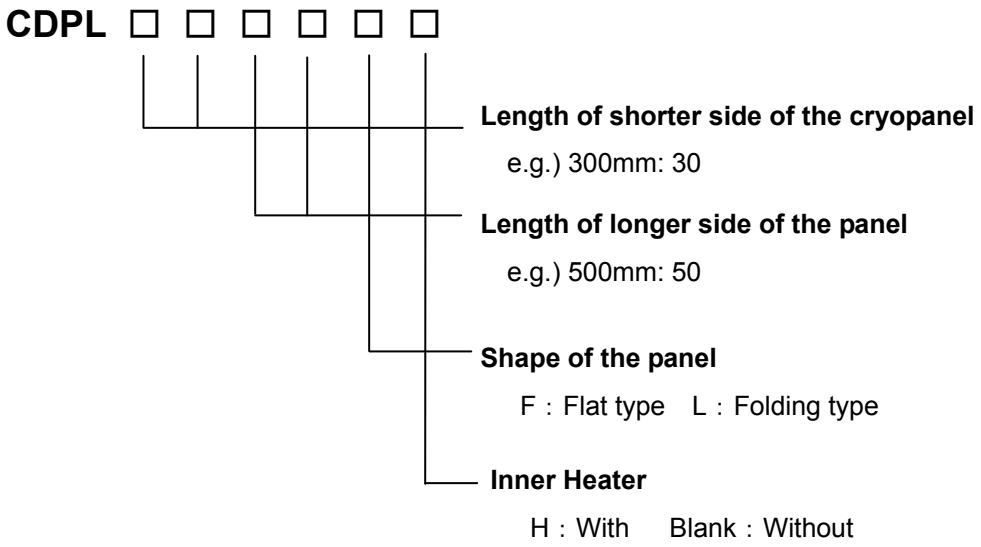
1. GENERAL DESCRIPTIONS

1-1. Overview

The CDPL System is equipped with closed-cycle helium refrigeration system to allow the cold panel to be cooled down with simple operation. Blackening treatment is added to the cold panel surface to yield high level of heat absorption.
As shown in Figure 1-1 and 1-2, the CDPL System consists of a CDPL assembly (including a cold head unit), a compressor unit, connecting pipes (flexible hoses), a super trap temperature controller (or other optional devices), and necessary cables.

■Model Codes of CDPL



1-2. Standard system

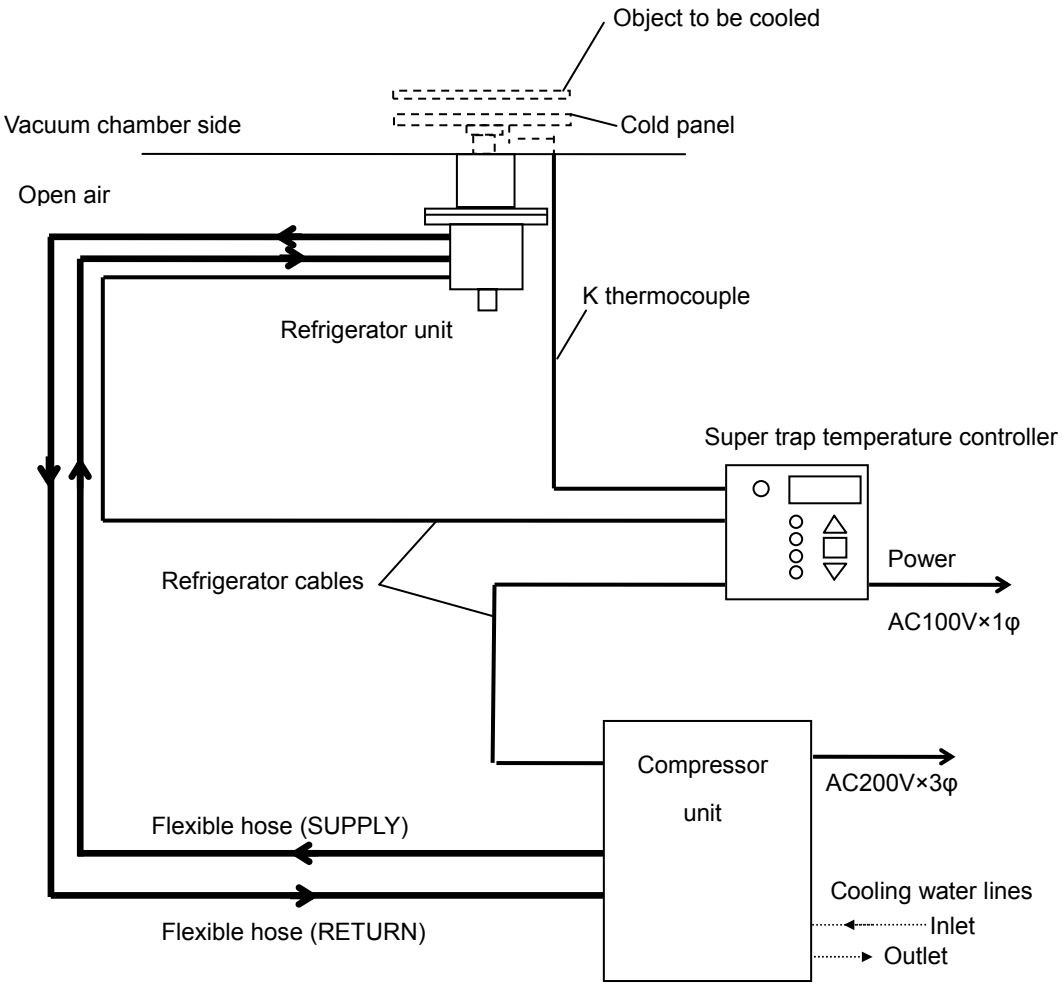
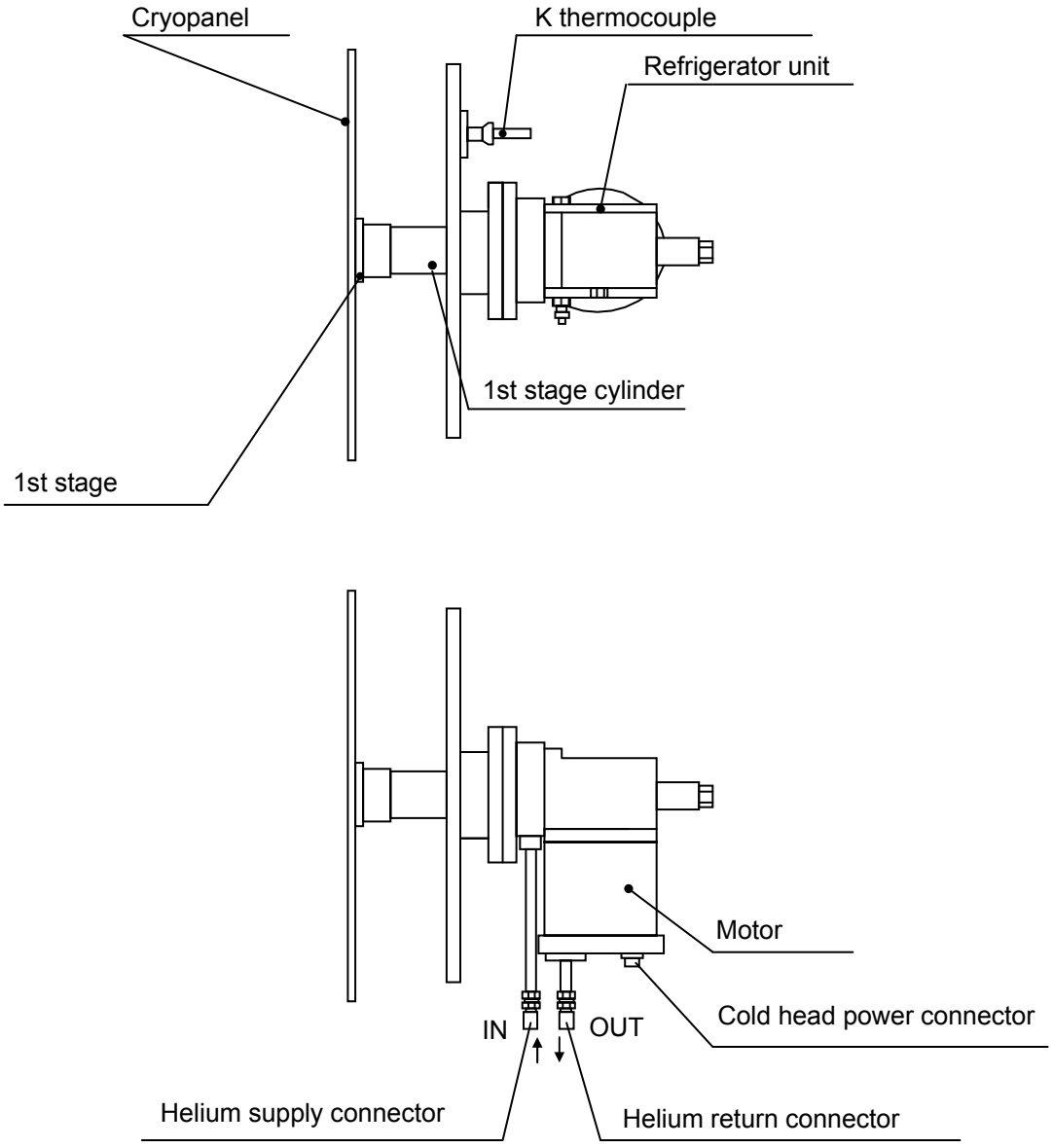


Figure 1-1 Standard CDPL System



For the external drawing of your CDPL systems, please refer to the attached “Specifications”.

Figure 1-2 Part Names

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2. INSPECTION

2-1. Shipping List

Our products are fully inspected before shipment. However, please make sure that there is no damage or shortage of delivered items by checking the model number and the external view of the products.

◇When you purchase the product as CDPL system, normally five cartons will be delivered.

Table 2-1 Carton Contents for CDPL system

Content	Quantity	Carton
Cold panel, Accessories (screws, etc)	(*1)	1
Refrigerator Unit	1	1
Accessories (Including super trap temperature controller)	(*2)	1
Compressor Unit	1	1
Instruction manual	1	1
Specifications (External Drawing) booklet	1	

(*1) The attachments vary depending on the model.

(*2) The accessories vary depending on the model of your CDPL
Refer to the compressor unit instruction manual for details.

◇When you purchase a CDPL assembly alone, normally three cartons will be delivered.

Table 2-2 Carton Contents for CDPL Assembly

Content	Quantity	Carton
CDPL, CDPL accessories (screws, etc)	(*1)	1
Refrigerator Unit	1	1
Instruction manual	1	1
Specifications (External Drawing) booklet	1	

(*1)The attachments vary depending on the model.

2-2. Inspection

Take out the CDPL and other components from the shipping carton and check the following.

1. Any damages or dents to the exterior, or accessories.
2. Any damages to the K (CA) thermocouples or inner heater.

3. INSTALLATION

3-1. Attach CDPL to a Vacuum Chamber

◆ Attach CDPL to Your Vacuum System

✧ You can install CDPL on the vacuum system in any orientation.

✧ If the chamber has any heat source, make sure that the CDPL dose not face directly to the heat source. Put a heat shield if needed. Consult with our sales representatives about the shape of the shield. (Refer to Figure 3-1 for recommended mounting locations.)

✧ Before installation, consider maintenance space for the CDPL. Refer to Figure 3-3 for recommended maintenance space.

✧ The CDPL and the refrigerator will be delivered separately. Attach the CDPL to the refrigerator as follows:

1. Take out the CDPL and refrigerator from the cartons. Do not touch the CDPL without gloves on hands.
2. Clean the surface of the CDPL mounting port (flange) at the vacuum chamber and mount the gasket (O-ring or metal gasket) either on the vacuum chamber side or CDPL side, and then mount the refrigerator with bolts.
   Make sure that the bolts are tightened firmly.
3. Place indium sheet to the heat station of the refrigerator before attaching the CDPL.
4. Attach indium sheets to the crimping terminals at the tip of the K thermocouples. Refer to Figure 3-2 and the CDPL Specifications (External Drawing) and mount the K thermocouples as instructed.
5. Check that all bolts are firmly tightened to the specified torque and conduct leak test.

CAUTION

- If K thermocouples are loosely attached or indium sheets are not placed, they may fail to measure temperature accurately and it may result in damage to the CDPL or refrigerator. Caution is especially needed with the CDPLs with inner heaters.
- Always use new indium sheet, never reuse them.

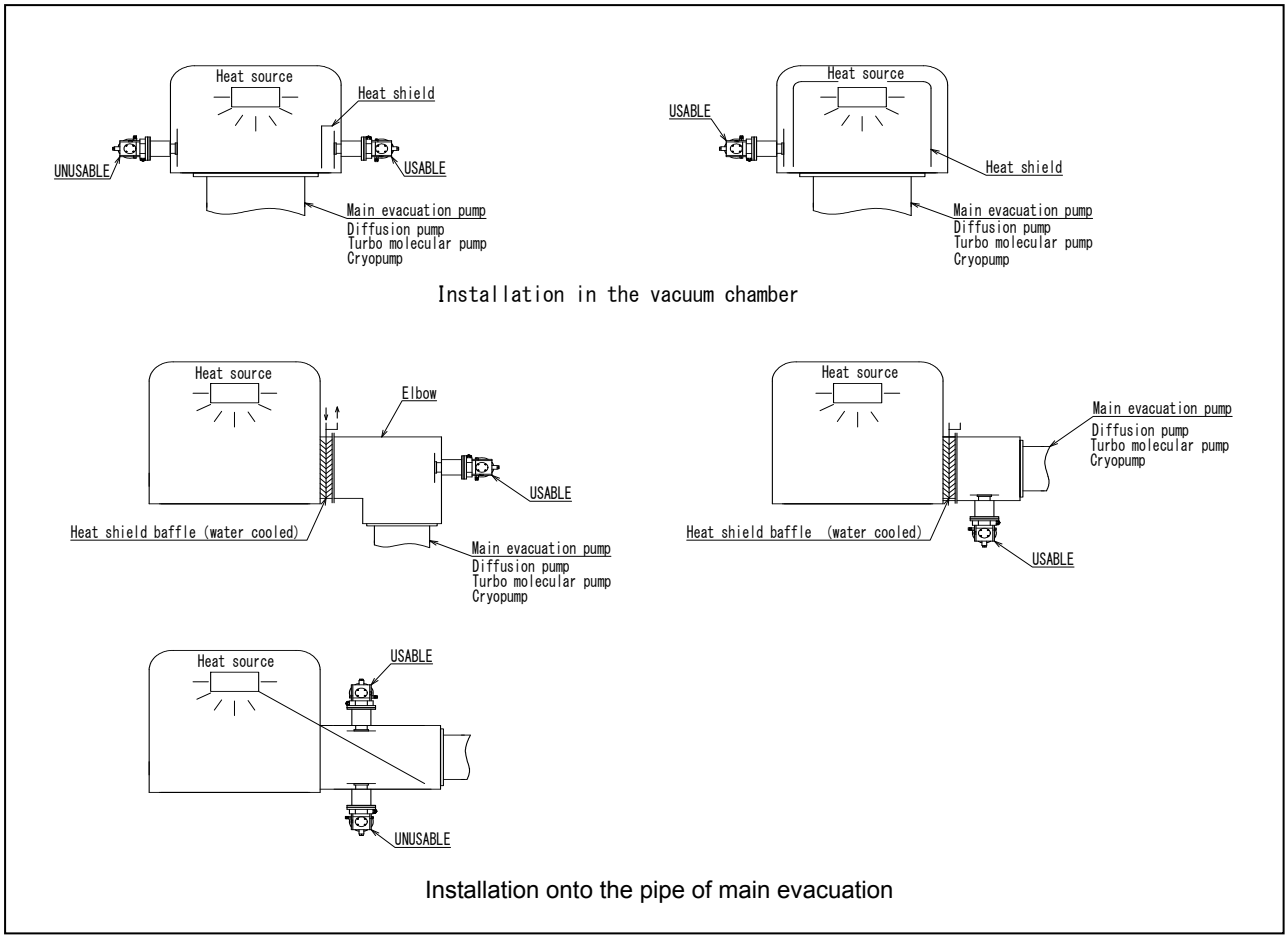


Figure 3-1 Installation to the Vacuum System with Heat Source

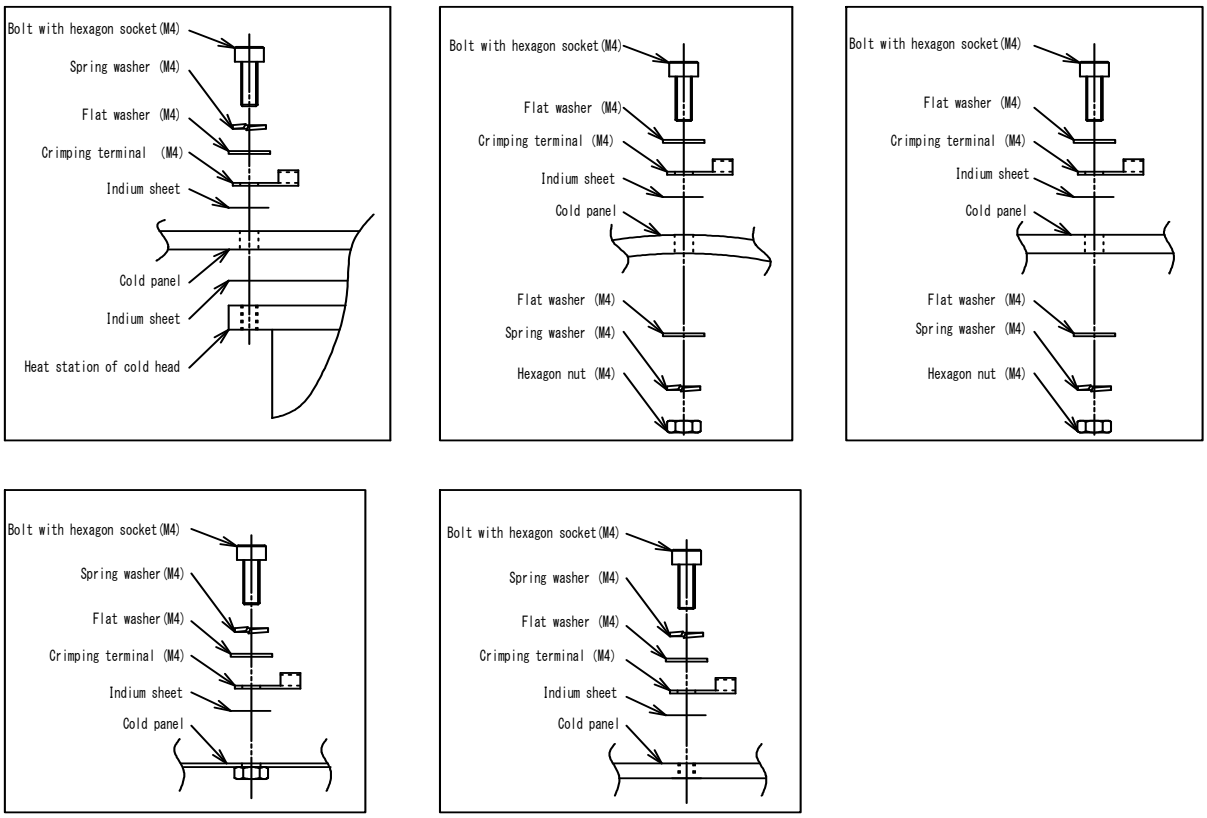
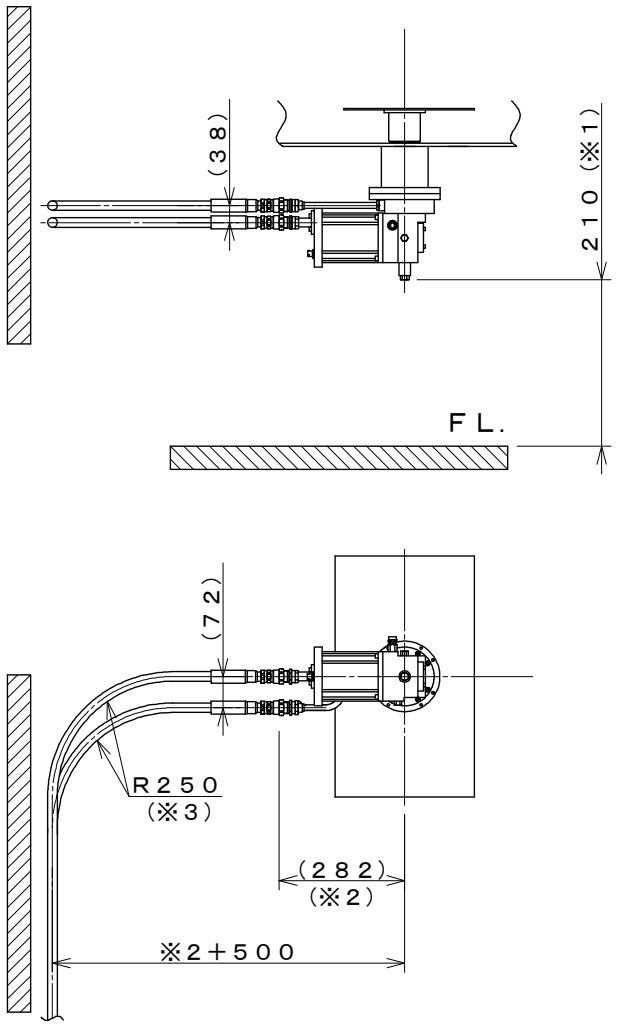


Figure 3-2 K thermocouple Installation



NOTE

(※1) The dimensions above are recommended space for cold head maintenance without removing the CDPL from the vacuum system.

(※2) Low vibration types require larger maintenance space. Refer to the CDPL Specifications (External Drawing).

(※3) It is 350mm when you use the optional bendable flexible hoses. Refer to Appendix B for details.

Figure 3-3 Installation & Maintenance Space

3-2. Connecting CDPL to a Compressor Unit (Connecting Flexible Hoses)

CAUTION

- Read through the handling notes in Appendix B about the flexible hoses.
- When connecting flexible hoses, always use two single open end spanners with width across flat 26mm and 30mm.
- Do not forcibly bend or twist flexible hoses to prevent damage or helium leakage.
- Do not connect and disconnect self-sealing coupling frequently. It may cause gas leakage. If there is leakage, flexible hoses may need to be replaced depending on the case.

1. Remove all dust plugs and caps from the supply and return flexible hoses, compressor unit and CDPL. Clean flat rubber gaskets on the self-sealing couplings to be free from dust or metallic powder.
2. Connect the flexible hoses between the compressor unit and the CDPL as follows (see Figure 3-4):
   a. Connect the helium-gas supply flexible hose to the helium-gas supply connector (SUPPLY) on the compressor unit. Connect the helium-gas return flexible hose to the helium-gas return connector (RETURN) on the compressor unit.
   b. Connect the helium-gas supply flexible hose to the helium-gas supply connector (SUPPLY) on the CDPL. Connect the helium-gas return flexible hose to the helium-gas return connector (RETURN) on the CDPL.
3. Check the helium gas pressure of the compressor unit. If the pressure is higher than the specified value, release the helium gas by opening the gas charge valve **slowly**. If the pressure is lower than the specified value, charge helium gas as described in Section 6.3 in this manual.

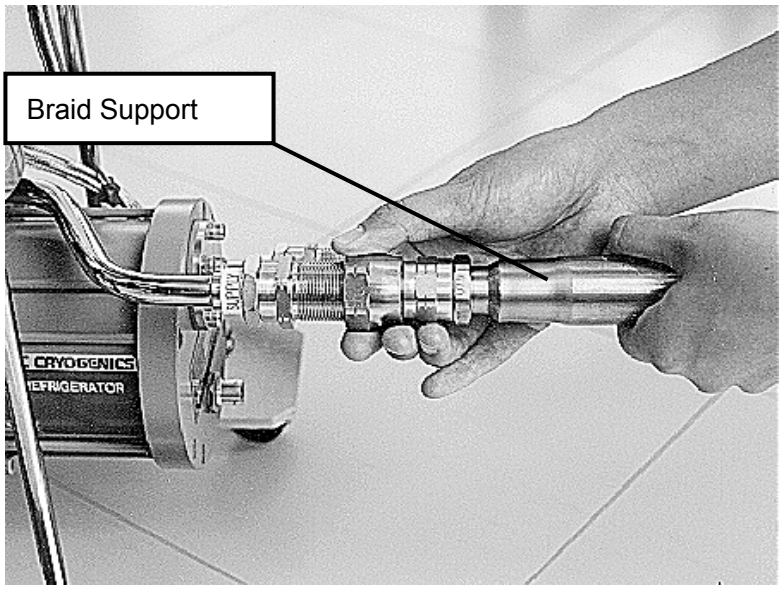
3-3. Connecting Electrical Cables

WARNING

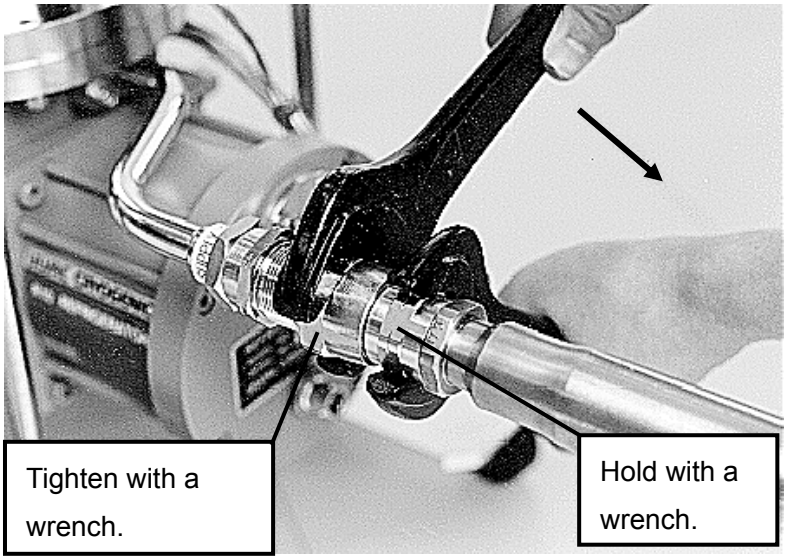
- Do not connect the compressor unit power cable until all other connections have been made between the components and the CDPL system.

1. Connect the CDPL and the compressor unit with the refrigerator power cable.
2. Connect the ground wire.

3. Connect the input power cable of the compressor unit to the power source.
4. The ways to turn on the compressor vary depending on the models.
   Refer to the compressor unit instruction manual for more information.



①Hold the braid support straight and tighten the self-sealing coupling by hand.



②Tighten the self-sealing coupling using two wrenches **until the fittings are firmly sealed and the nut will not rotate any more.** When using torque wrench, the recommended torque value is 20N・m.

Figure 3-4 Connecting Flexible Hoses

3-4. Disconnecting Flexible Hoses

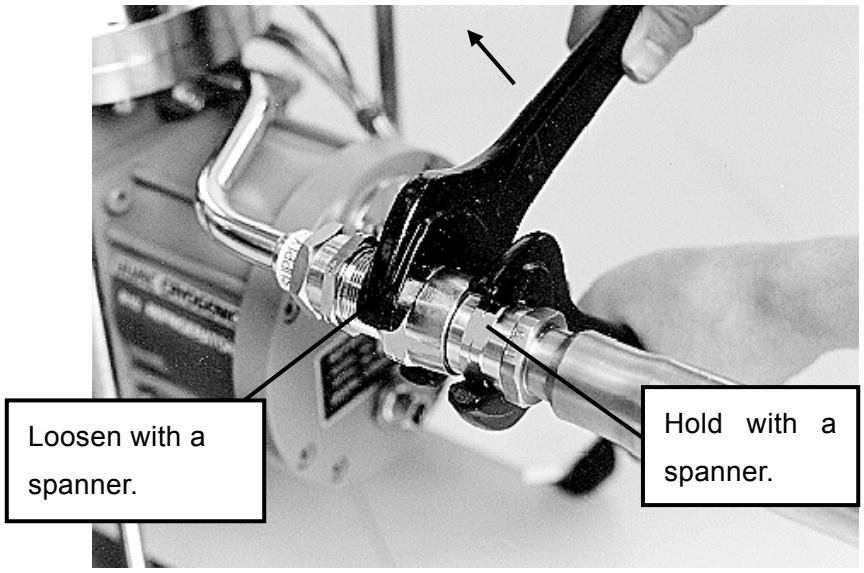
CAUTION

To disconnect flexible hoses, always use two single open ended spanners with width across flat 26mm and 30mm.

1. Shut down the compressor unit.
2. Disconnect flexible hoses after the CDPL is warmed up to room temperature (Figure 3-5).

CAUTION

If you remove the flexible hoses before the CDPL reaches to the room temperature, helium gas kept in the refrigerator increases its pressure as the temperature rises inside the refrigerator and the pressure relief valve may blow. It may cause helium leakage.
However, when helium circuit decontamination of the refrigerator unit needs to be carried out, disconnect the flexible hoses from helium gas supply and return connectors of the compressor unit right after shutdown.
Refer to Section 6.4 for more details.



Loosen the self-sealing coupling using two spanners and then by hand.

Figure 3-5 Disconnecting Flexible Hose

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4. OPERATION

4-1. Before Startup

Before starting operation, please check the following:

1. The flexible hoses and cables are properly connected.
2. Each gauge is mounted on the intended port.
3. The helium gas pressure gauge on the compressor unit reads the specified value.

It is recommended to keep an operating log to notice the first sign of trouble as soon as possible. This will help you to get prompt technical assistance from us. The operating log is attached to Appendix A.

4-2. Rough Pumping

1. Turn ON the roughing pump.
2. Open the roughing valves and then rough pump the vacuum chamber which the CDPL is attached to. Rough pump the vacuum chamber to the pressure that maintains the vacuum insulation. (10^{-1}~10^{-2}Pa)

4-3. Startup and Cool-down

1. Turn ON the compressor unit to start up the CDPL.

† For Your Information †

Confirm the cold head motor is running smoothly by the sound of its internal devices. When the cool-down operation becomes steady, the noise from cold head becomes smaller. On the other hand, the sound from helium gas inlet and outlet (choo-choo sound) becomes louder.

2. When the temperature of a CDPL reaches 220K (*1), the cool-down (*2) is completed.

(*1) The default value (the factory setting) of the cool-down completion (READY) of the super trap temperature controller is 220K. When the CDPL temperature is controlled by temperature controller, the refrigerator turns ON (REF ON) at 200K and turns OFF (REF OFF) at 190K.

(*2) Refer to the attached CDPL Specification for the cool-down time.

CAUTION

The set values (READY, REF ON, and REF OFF) may vary depending on the usage condition and the installation configuration of the CDPL. Refer to attached CDPL Specification for the set values.

Refer to the super trap temperature controller instruction manual for how to change the set values.

3. Record the cool-down time to reach 220K and the gas pressure of the compressor unit at 220K in your operating log.

CAUTION

If the CDPL becomes incapable of maintaining high-vacuum, water vapor will be condensed on the CDPL case along with cool down. It can cause short-circuit if there are electrical devices (such as electrical circuit) under the CDPL.

† For Your Information †

In case the radiation heat load is high, the cool-down time will be longer.

4-4. Normal Operation

The CDPL can be run without attendance of an operator.
However, please keep your operating log regularly.

1. Confirm that the CDPL has reached 220K(*1) or lower.
2. When the pressure of vacuum chamber has reached the target pressure, proceed with vacuum process such as sputtering, deposition, or substrate transfer.

(*1) 220K is the default (factory setting) and may changed depending on your usage condition and/or installation configuration of the CDPL.

Table 4-1 CDPL Operating Parameter (Room Temperature：20°C)

	UNIT	Stop	Normal Operation(*2)
K Thermocouple	mV	0	<−2.8
(CDPL temp.)	K	293	<220

(*2) The operation under unloaded condition.

CAUTION

If the CDPL becomes incapable of maintaining high-vacuum, water vapor will be condensed on the CDPL case. It can cause short-circuit if there are electrical devices (such as electrical circuit) under the CDPL.

4-5. Shutdown Procedures

1. Turn OFF the compressor unit and the CDPL.
2. After the CDPL has reached room temperature, open the vacuum chamber to the air.

CAUTION

- Exposing vacuum chamber to air before the CDPL returns to room temperature (273K or more) causes water condensation on the CDPL. It is recommended to place a saucer under the CDPL to catch water droplet.
- When using a heater to defrost the CDPL, be sure to control the heater so that the CDPL temperature will not rise above 70°C.

4-6. How to store CDPL

◆When storing with vacuum system attached

The vacuum chamber should be kept in a vacuum state(10 to 100Pa), or filled with dry nitrogen with a dew point of -40°C or below or argon at a pressure a little higher than atmosphere.

◆When storing without vacuum system

1. Before removing the CDPL from the vacuum chamber, make sure that the CDPL reaches the room temperature.
2. Disconnect the flexible hoses after the CDPL reaches room temperature,.
3. Place protective covers/caps on the mounting flange and helium gas connectors.
4. The CDPL should be kept away from direct sun light, high temperature, humidity, dust, vibration, radiation, wind or rain.

◆When shipping CDPL

Put all covers and caps as they were delivered. Avoid excessive shock.

◆Other considerations

Connect the refrigerator cable and operate for about 10 minutes every 6 months. This helps rubricate the bearings used inside of the cold head with grease.

If the CDPL is left unattended for more than one year, perform decontamination of helium gas inside the refrigerator.

4-7. Handling of Hazardous Materials

WARNING

◆When pumping toxic gas, corrosive gas, combustible gas, or explosive gas, please be sure to take sufficient safety measures based on relevant laws and regulations, and do so on the user's responsibility.

In addition, ensure that the pressure inside the CDPL does not exceed atmospheric pressure with those gases during regeneration. Please contact us before handling these hazardous gases.

◆When transporting CDPL that has pumped hazardous materials, take appropriate measures according to the laws or regulations of relevant countries or regions.

5. WARM-UP

5-1. Overview

Warm up is needed to return the CDPL to room temperature.
Gases or water vapor will not be condensed or adsorbed on the CDPL at the default temperature (the default set values of super trap temperature controller: READY 220K, REF ON 200K, and REF OFF 190K).

CAUTION

Gases or water vapor may be condensed on the CDPL depending on the usage conditions or temperature settings. In such a case, follow the same regeneration procedures as water or gases condensed.

5-2. Warm-up Time

Perform warm-up when one of the operating parameters becomes the following state:

- When the CDPL does not absorb heat to meet the specification.
- At CDPL maintenance.
- At the vacuum equipment/system maintenance.

5-3. Warm-up Procedures

There are “Unassisted Warm-up” and “Assisted Warm-up.” (Refer to Section 5.4.)

1. Turn off the compressor unit and the CDPL.
2. Warm up the CDPL(*1).

The chamber can be pumped with main exhaust pump during warming up.

However it takes long to warm up in vacuum state.

(*1) Refer to the attached “Specifications” for the warm-up time required for your CDPL.

CAUTION

- It is recommended to place a saucer to receive water drop in the vacuum chamber if water drops may fall from CDPL to vacuum chamber while warming up.
- During warming up, water vapor will be condensed on the vacuum chamber and CDPL mounting part. Short-circuit might be caused if there are electrical devices (such as electrical circuit) under them.

5-4. Assisted Warm-up

◆ Introducing Inert Purge Gas (use nitrogen gas with a dew point of -40°C or below or argon.)

Using nitrogen gas with a dew point of -40°C or below (or argon) for warm-up makes a regeneration procedure more efficient than unassisted warm-up (stop the CDPL and leave it until it reaches room temperature).

Introduce inert purge gas as follows:

1. Close the main valve and shut down the CDPL. Then, introduce inert gas at ambient temperature into the CDPL inside the vacuum chamber.
2. When the CDPL reaches room temperature, stop introducing inert purge gas.

◆ Using the Inner Heater

In addition to the methods above, using an optional band heater or inner heater enables warm up time even shorter.

ULVAC CRYOGENICS INC. offers several types of standard band heaters such as RBH type and silicon rubber type. The RBH band heater self controls the temperature around 70 to 80°C. The silicon rubber heater turns its power ON/OFF with its

thermostat settings. Please refer to the instruction manual of your heater for more information.
When using an inner heater, make sure to control the temperature with our Super Trap Heater Controller (optional) such as STC-2A series. The warm-up completion temperature should be set at 300K. Refer to the controller instruction manual for details.

If you wish to control the temperature with your own procedures, please contact us in advance.

CAUTION

Maximum allowable temperature of the refrigerator unit is 70°C. When you use a heater, make sure to control the heater temperature so that the cold stages of the refrigerator do not exceed 70°C. If they exceed 70°C, inside of the refrigerator may be damaged by the heat resulting in replacement.
As our standard band heaters are self temperature control type, they can be used without any temperature control instrument. However, when you use different types of heaters, make sure to keep the temperature lower than 70°C by using a temperature controller, overheat alarm function, or by observing and controlling the energizing time.



WARNING

The heater surface becomes extremely hot. Be sure to take necessary measures to prevent fire and burn injury and also display warnings to call attention.

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6. MAINTENANCE

6-1. Scheduled and Unscheduled Maintenance

A CDPL requires the following maintenance.

◇Scheduled Maintenance : Refrigerator unit parts replacement
Compressor Unit adsorber replacement
Insulation performance check of heaters for regeneration

◇Unscheduled Maintenance : CDPL cleaning
Adding helium gas
Helium gas circuit decontamination

Following equipments and helium gas are necessary for maintenance.

	Item	Volume	Item code
1	Helium charging adapter kit (Regulator, Charging hose 2.4M, Charging adopter)	1	A700B5101000
2	<Items independently available> Regulator (for helium gas) Charging hose 2.4M Charging adapter	 1 1 1	 A700A5101700 A700A5101800 A700B5101100
3	Helium gas (with purity of 99.999% or above)	−	−

Table 6-1 Maintenance Parts and Intervals

S: Scheduled maintenance U: Unscheduled maintenance or parts replacement at fault

Item		Parts	Interval (h)	Remarks
CDPL				
U	CDPL cleaning	CDPL	When needed	When reassembling, always use new indium sheet.
S	Insulation performance check of heater for regeneration (*1)	Heater unit or CDPL assembly (*2)	Every month	Must be replaced when it is below 10MΩ.
Refrigerator unit			RS80T, RMS80T	
S S S S S S	Seal kit replacement Driver assembly Replacement Motor bearing replacement Cylinder bolt replacement Compressor spring replacement Displacer replacement	Seal kit Driver bearing Valve bearing Set screw Motor bearing Cylinder bolt Compressor spring 1st /2nd stage of displacer	20,000h	The maintenance cycle may vary depending on the ways of operation. Contact us for detail.
S	Valve body replacement	Intake/Exhaust valve body	At fault	
U	Other parts replacement	Other parts	At fault	
Compressor Unit				
S	Adsorber Replacement	Adsorber	Refer to the compressor unit documentation.	

(*1) This is only applicable to a CDPL system with a heater.

(*2) Depending on the specification, CDPL assembly replacement may be required.

6-2. CDPL Maintenance

In many cases, CDPL performance degradation is caused by contamination. If CDPLs are contaminated, the thermal emissivity will be lowered, resulting in less absorption of heat.
It is recommended to check contamination once a week.

◆Cleaning CDPL

Follow the steps below to perform CDPL cleaning:

1. Remove the CDPL from the chamber and put it on a mat which is dust or metallic powder-free. This is to avoid damaging the surface of the mounting flange. Hold the CDPL so that it will not fall over.
2. Wipe the CDPL with a clean soft cloth or blow air. If the stain will not come off, replace the CDPL.

CAUTION

・Do not wipe the blackening processed surface with alcohol. It may peel or remove the treatment.

3. Be sure to attach the K thermocouple properly back to CDPL when cleaning or replacing CDPL. Refer to Chapter 3, Section 1.

CAUTION

・When mounting the thermocouple crimping terminal on the cold panel, hold the base of the crimping terminal and tighten the screw. (M4 tightening torque:1.5N・m)
・There are two type of thermocouples; for temperature control and overheat protection (cold panels with heaters only). Mount them to the right places, respectively.
・Do not pull the sheathed wire of thermocouple. It may break when stress is added at the base.
・If the thermocouple is mounted too loose, it cannot measure accurate temperature and may cause overcooling or overheating, resulting in damaging the refrigerator or deterioration of pumping performance.

◆Maintenance of Heaters for Regeneration

(Only applicable to a CDPL system with heaters)

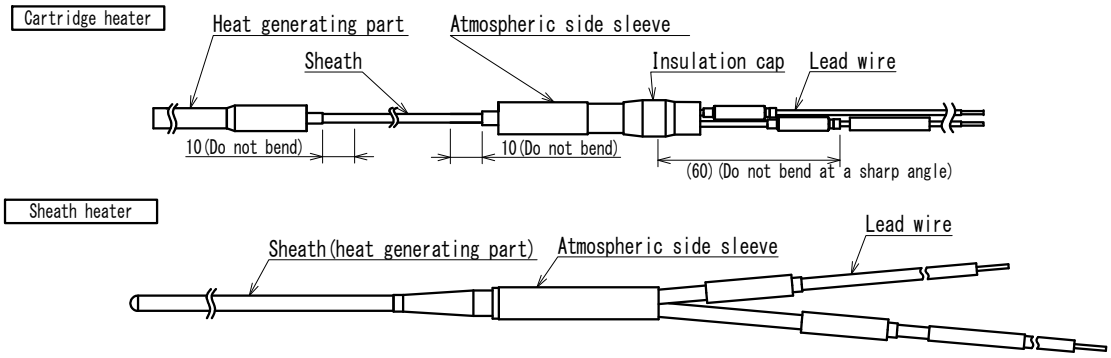

Figure 6-1 Heater Components

There are two types of heater which are used in a CDPL system; a cartridge heater or a sheathed heater.

Figure 6-1 shows the name of each component.

1. Measure the insulation resistance value and resistance value before disassembling the heater.
2. Check the installation condition of the heater.
   For cartridge heater: check that the mounting bolts are tightened properly (not loose).
   For sheathed heater: check if the sheathed wire is cracked or burnt.
3. If insulation property is deteriorated or there is any breaking of wire, the heater must be replaced.
4. Connect the heater properly and do not forget to put the insulation cap (only for a cartridge heater).

CAUTION

Both types of heaters, sheathed and cartridge, may experience deterioration in insulation properties due to aging. Be sure to install a ground-fault circuit interrupter at the vacuum system, and conduct periodic inspections of the insulation properties to prevent short circuit. If insulation property is deteriorated, please replace the heater.

Inspection should be conducted before turning on electricity to check that the insulation resistance between the outside of atmospheric side sleeve and the lead wire is 10MΩ or more (DC 500V Megger).

WARNING

The replacement of heaters must be undertaken by authorized and trained electrician/mechanical personnel familiar with the maintenance methods of cryopumps, super traps and inner heaters. Follow the precautions below when handling the heater. Servicing for the heater failure caused by an improper installation will be at your expense even within the warranty period.

- When conducting a maintenance work after applying current, do not start the work until the temperature of the CDPL and the heater comes down to the room temperature.
- Always use hands to bend the sheathed wire and do not straighten it back.
- Do not bend the sheathed wire either at the base of atmospheric sleeve or the base of heat generation part.
- Do not bend the sheathed wire smaller than a specified minimum bending radius (cartridge heater: more than R10 / sheathed heater: more than 5 times of sheath diameter.)
- If the mounting block of the cartridge heater is loose, the heat generation part does not attach firmly to the block and will overheat which causes disconnection or deterioration of insulation property. Tighten the bolts firmly at a specified torque.
  (M3 tightening torque: 1N・m)
- After maintenance work, conduct a insulation resistance check and continuity check and keep record of the result.

6-3. Charging Helium Gas

Customers are requested to supply equipments for charging helium gas (regulators, charging hoses, adopters) that can be used at 2.0MPaG.

CAUTION

If the helium pressure gauge of the compressor unit shows 0MPaG, contamination caused by air or moisture may occur in the system. If it occurs, contact our Service Engineering Division or customer support center.

When helium gas pressure is lowered, it is necessary to add helium gas. Check the cause of the pressure reduction before adding helium gas. If there is a leakage, take an adequate measure before charging. Improperly connected self-sealing coupling might be one of the causes of the leakage.

◇It is recommended to use the regulator which shows the range of 4-6 MPaG as outlet pressure.

◇The gas charge inlet of the compressor unit is 1/4B male flare.

◇Use helium gas with purity of 99.999% or more.

Fill helium gas as follows:

1. When mounting the regulator on a new helium bottle, perform the following procedures in order to purge the air and fill helium gas in the gas line between the regulator and the bottle valve.
   (1) Open the regulator a little. The regulator can be opened commonly by turning the handle clockwise.
   (2) Slowly open the bottle valve, and purge the air in the gas line for several seconds.
   (3) Close the regulator.

CAUTION

If the bottle valve is opened ignoring the above procedure (1), the air between the regulator and the bottle valve diffuses in the helium bottle and lowers the purity of helium gas.

2. Remove the front panel of the compressor unit.
3. Connect the helium charging hose as follows:
   (1) Connect the charging hose to the regulator.
   (2) Loosely connect the charging hose to the charge inlet on the compressor unit so that helium gas can be slightly blown out here.
   (3) Open the regulator until the outlet pressure reaches 0.1 to 0.2MPaG. Allow helium gas to flow out from the charging hose for about half a minute. Meanwhile, open the charge valve slightly in order to drive out the air that exists between the charge valve and the charge inlet.
   (4) Tighten the flair nut at the end of charging hose and close the charge valve. Helium gas charge in the line between the regulator and the charge valve on the compressor has been completed.

4. Adjust the outlet pressure of the regulator at 1.8MPaG. Pressure relief valve has to be mounted as well as the regulator. The set pressure of the pressure relief valve is 2.4MPaG.
5. Open the charge valve slowly and perform the following instruction according to the state of the compressor.
   a. If the compressor unit is running under normal operating conditions, replenish it with the pure helium gas until it reaches the operation pressure described in the compressor instruction manual.
   b. If the compressor unit is not running, replenish it with the pure helium gas until it reaches the static pressure described in the compressor instruction manual.

CAUTION

If helium gas has been charged more than the prescribed pressure of 1.9MPaG or more, the pressure relief valve on the refrigerator may work. Therefore charge helium gas slowly so that the pressure relief valve will not work. The pressure relief valve in the compressor unit is set at 2.5MPaG.

6. Close the charge valve after charging helium gas.
7. Close the regulator and remove the charging hose from the charge inlet.
   The helium gas charging for the compressor has been completed with this.

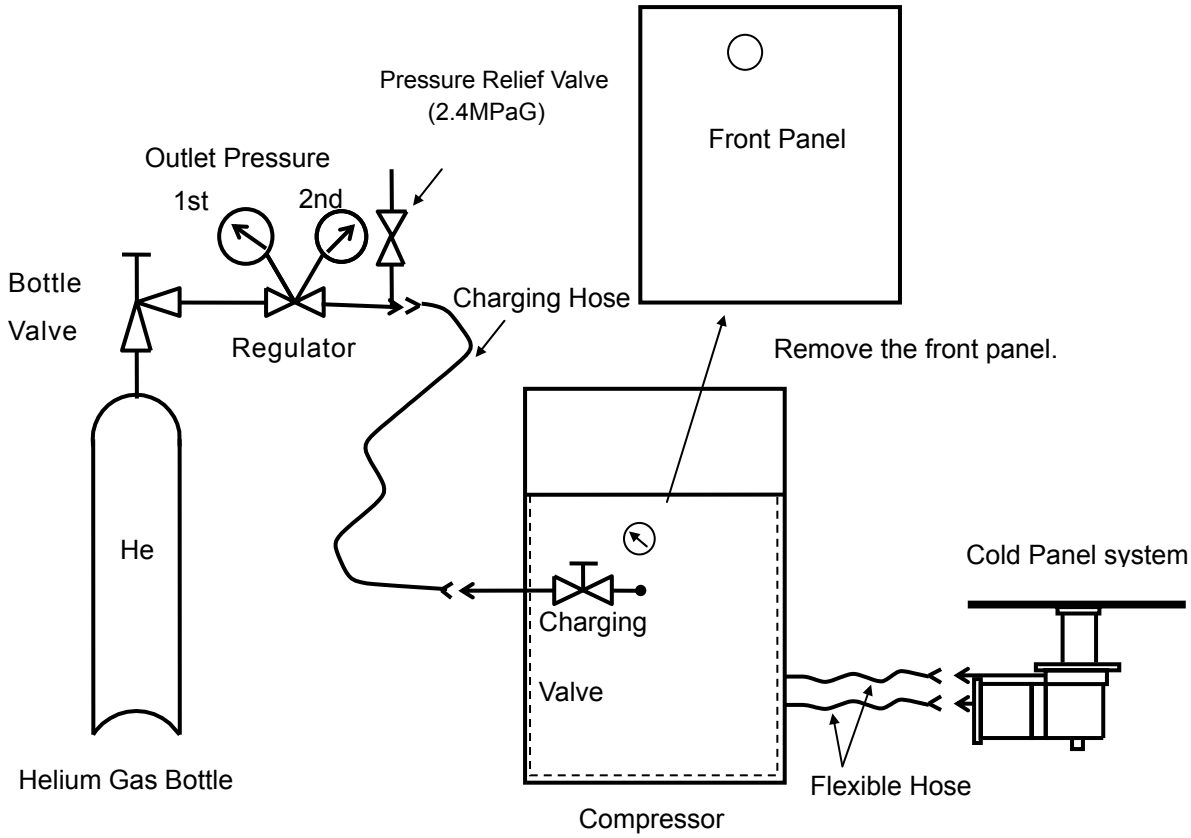

Figure 6-2 Charging Helium Gas

6-4. Helium Circuit Decontamination

When helium gas in the CDPL system is contaminated, it is necessary to replace the gas in the system with pure helium gas.（Refer to Appendix A- Troubleshooting.）

Contamination of helium gas in the CDPL system is caused by inadequate helium charge at the time of refrigerator unit maintenance. If impurities in helium gas are coagulated and deposited into the refrigerator, the performance of refrigerator could be deteriorated and abnormal vibration of the motor (called Step-out*) may occur. Follow the steps below for decontamination.

*Step-out: means that a refrigerator motor has an irregular or intermittent movement.

1. Turn ON the CDPL system (refrigerator unit) and keep it running for three to four Ωhours.
   a. Start the compressor unit.

NOTE:

Since all impurities in the helium gas are condensed and solidified within the refrigerator during operation of the CDPL (refrigerator), a certain amount of cool-down time is required before beginning the decontamination procedures.

If an irregular and abnormal sound or a big vibration arises during the cool-down, proceed to the next step (2) immediately.

2. Shut down the CDPL (refrigerator unit)

   a. Turn off the compressor unit.

3. Right after shutdown of the system, disconnect the helium SUPPLY and RETURN flexible hoses at rear of the compressor unit (see Figure 6-3).

   NOTE:

   It is important to remove flexible hoses right after shutdown in order to prevent re-diffusion of the impurities that have been condensed and solidified in the refrigerator unit.

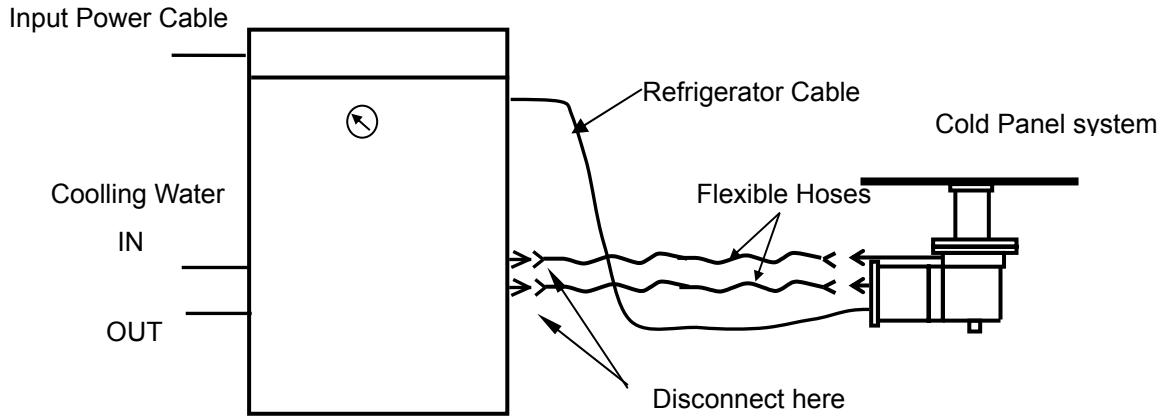

Figure 6-3 Disconnecting Flexible Hose

4. Attach the charging adaptor to the disconnected end of the helium SUPPLY and RETURN flexible hoses. (See Figure 6-4).
5. Reduce the pressure in the refrigerator unit and the flexible hoses to a level of 0.3MPaG by opening the valve (V1) of the charging adaptor.

NOTE:

As helium gas is cooled down in the refrigerator unit, the density of the gas increases. After shutdown of the refrigerator, the helium gas in the refrigerator returns to room

temperature from cryostatic temperature accompanied by gradual rise of inner pressure. The unit has a pressure relief valve which opens at the inner pressure of 1.9MpaG and more. Once the pressure relief valve opens, a leakage is likely to occur depending on the surrounding environment such as dust. Therefore, ensure to reduce the inner pressure right after shutdown of the refrigerator in order to prevent the pressure relief valve from working.

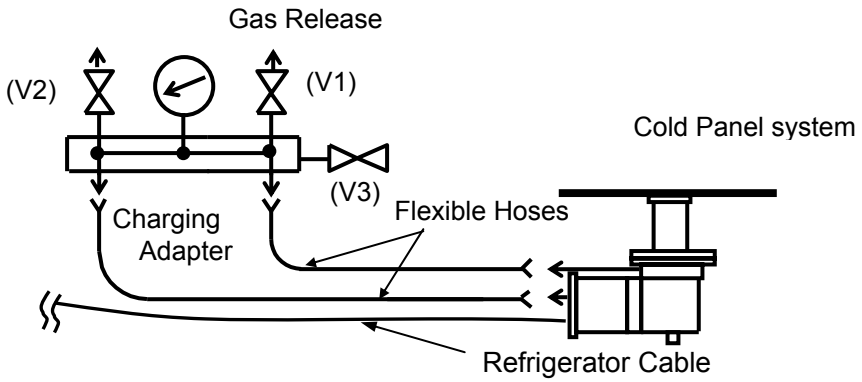

Figure 6-4 Connecting Charging Adaptor

6. Warm up the CDPL (refrigerator unit). Warm up the CDPL to the room temperature and leave it until the inside of the refrigerator reaches room temperature. It normally takes several hours for the inside of the refrigerator to warm up after the CDPL has reached the room temperature. The recommended warm up time is eight hours or more.

CAUTION

If CDPL is exposed to air during warm up, the CDPL could adsorb large amount of moisture, resulting in longer roughing time.

† For Your Information †

Performing the assisted warm-up procedures described in Section 5.4 in this manual can reduce the warm-up time.

Before proceeding to the next procedure, make sure that the CDPL reaches room temperature.

7. Connect the helium bottle and the regulator. Replace the air remained between the helium bottle valve and the regulator with helium gas as instructed in Section 6.3 Charging Helium Gas.

Use helium gas with purity of 99.999% or more.

8. Perform decontamination as follows:

Before proceeding decontamination, prepare the rough pumping system as indicated in Figure 6-5. A roughing pump with the pumping speed of 20L/min or more and the ultimate pressure of 10Pa is recommended.

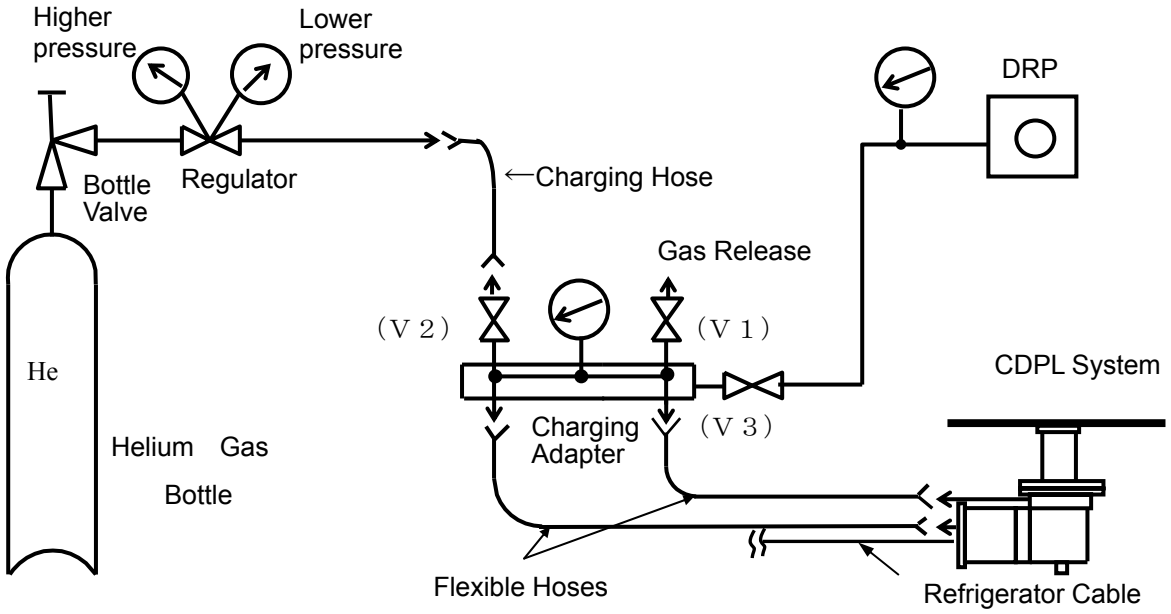

Figure 6-5 Decontamination Procedure (1)

a. Loosely connect the charging hose to the charge valve (V2) on the charging adapter.
b. Open the regulator until the outlet pressure reaches 0.1 to 0.2 MPaG. Allow helium gas to flow out from the charging hose for about half a minute. Meanwhile, open the charge valve (V2) slightly in order to drive out the air trapped in the charge valve.
c. Tighten the flair nut at the end of charging hose and close the valve (V2).
d. Start the roughing pump and open the valve (V3) slightly. Exhaust the helium gas in the refrigerator unit while maintaining pressure below an allowable value of the roughing pump. After the pressure is lowered below the atmospheric pressure, fully open the valve (V3). The maximum allowable pressure for ULVAC's compact oil-sealed rotary pump and dry pump is 0.01MPaG. Monitor the pressure of the roughing pump head with an appropriate pressure gauge.

CAUTION

Make sure to open the valve slowly when exhausting the gas beyond the atmospheric pressure in order to maintain the pressure of the pump head below an allowable value. If you open it quickly and widely, the roughing pump may break down.

e. After rough pumping for more than 30 minutes, close the valve (V3).
Stop the roughing pump to bring it back to the atmospheric pressure.

f. Adjust the outlet pressure of the regulator at 1.8MPaG. Then open the valve (V2). Charge helium gas until the pressure gauge on the charging adopter shows 1.5MPaG, and then close the valve (V2).

g. Start the compressor unit to operate the refrigerator unit.
When operating the refrigerator unit, the helium gas is circulated through the refrigerator, the flexible hoses, and the charging adopter. See Figure 6-6.

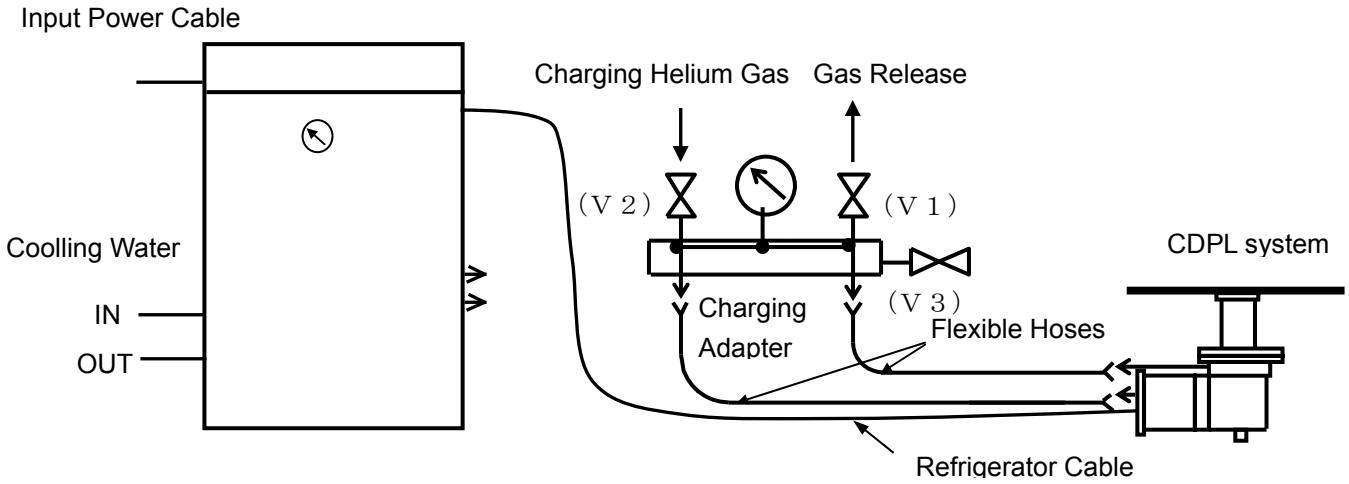

Figure 6-6 Decontamination Procedure (2)

CAUTION

Do not operate the refrigerator unit when it is at negative pressure. It may cause a vacuum discharge in the motor of the refrigerator, and bring about a breakdown.
Helium gas must be charged before starting the refrigerator.

h. Keep the refrigerator running and open the valve (V1). Depressurize to 0.4MPaG and then close the valve (V1).

i. Keep the refrigerator running and repeat the following operation 25 times slowly.
   1) Open the valve (V2) and charge helium gas until the pressure gauge shows 1.5MPaG then close the valve (V2).
   2) Open the valve (V1) and depressurize to 0.4MPaG then close the valve (V1).

By taking the helium gas in and out 25 times, the purity of helium gas within the refrigerator unit and the flexible hoses will improve.

9. Shut off the refrigerator unit. Charge helium gas to the refrigerator unit and the flexible hoses until it reaches the specified fill pressure of the compressor unit.
10. Remove both SUPPLY and RETURN flexible hoses from the charging adopter.
11. Make sure that the flat rubber gasket of the self-sealing coupling is properly attached. Then reconnect each flexible hose to the compressor unit. (See Figure 6-7)

CAUTION

The pressure relief valve on the refrigerator blows if the charge inlet of SUPPLY /RETURN at the compressor unit and SUPPLY /RETURN flexible hoses are not correctly connected and the servicing will be needed. Make sure that they are connected properly.

12. Confirm that the pressure gauge of the compressor unit indicates the specified pressure. If not, charge helium gas through the charging valve of the compressor unit, or adjust the pressure by discharging helium gas.
13. Restart the CDPL (refrigerator unit).

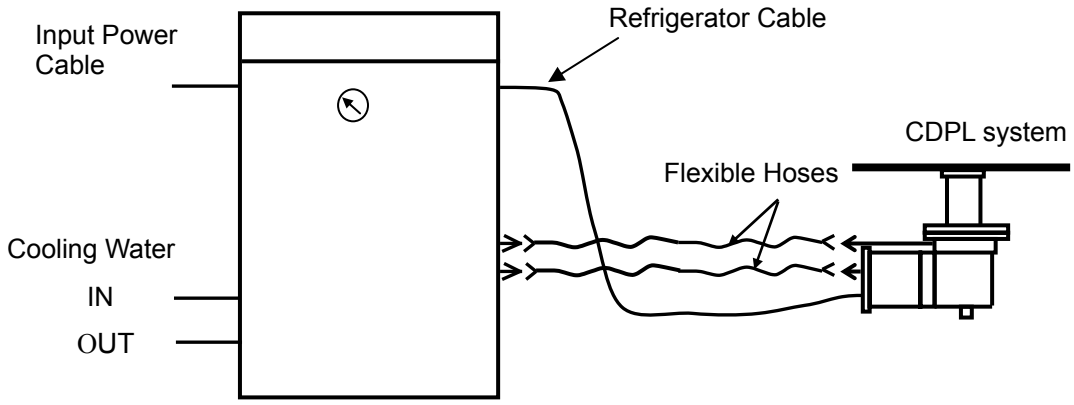

Figure 6-7 Connecting Flexible Hoses

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Appendix A

TROUBLESHOOTING

1. TROUBLESHOOTING

The major factors of CDPL failure are temperature rise and pressure rise. Those failures occur via two different routes as follows.

(1)Refrigerator unit failure → Reduced refrigeration capacity → CDPL temperature rise → Lowered CDPL performance

(With refrigerator unit failure, the temperature rise occurs suddenly in minutes or hours)

(2)Contamination of CDPL→Thermal load increase→CDPL temperature rise →Lowered CDPL performance

(Although the temperature rise varies according to the usage, it generally occurs slowly in months or years.)

Refer to Table A-1 for detailed troubleshooting procedures. Please contact us or your local customer support centers when it is difficult to specify the cause of the trouble.

Table A-1 Troubleshooting Procedures

Problem	Possible Cause	Corrective Action
Ⅰ. Both CDPL and compressor unit do not start up.		Refer to the instruction manual of compressor unit for details.
Ⅱ. Compressor unit starts up but CDPL does not. Or, CDPL stops while compressor unit is running.	1) Refrigerator cable is not connected to refrigerator unit.	Turn off the compressor unit and connect the refrigerator cable to the refrigerator unit. **CAUTION** Do not connect the refrigerator cable to the refrigerator unit without turning OFF the compressor unit. It may damage the refrigerator motor.
	2) Helium gas is heavily contaminated.	Perform decontamination procedures described in Sec.6.4. Use helium with purity of 99.999% or above.
	3) Mechanical defects on the refrigerator unit drive motor. ① Motor shaft damage ② Drive motor circuit failure ③ Bearing damage	Contact your local customer support center.
Ⅲ. CDPL does not cool down to the set temperature.	1) Helium pressure is lowered.	Charge helium gas.
	2) Flexible hoses between the refrigerator unit and the compressor unit are not connected properly.	Check that flexible hoses are connected to the refrigerator unit.

Ⅲ. CDPL does not cool down to the set temperature. (Continued)	3) Self-sealing couplings are not connected properly.	Check that all the self-sealing couplings are connected properly.
	4) Helium gas is severely contaminated. (Cooling capacity is deteriorated.)	Perform the helium circuit decontamination. Use helium with purity of 99.999% or above. (See Section 6.4.)
	5) Excessive thermal load on the CDPL.	Put a heat shield between the heat source and the CDPL. (See Figure 3-1)
	6) Leakage occurs. Gas load is too large by the leakage. 1. Air leakage from the vacuum chamber. 2. Helium leakage from the refrigerator.	Find the leakage by a helium leak detector or mass spectrometer. ・Find the leakage by bubbling method with soap water or sniffer method with a helium leak detector. ・Separate each device and apply pressure. Find the device which has the leakage by its decreasing pressure.
	7) Components inside the CDPL is connected loosely. 1. Temperature measuring part of the K thermocouple is loosely connected. 2. The CDPL is mounted loosely,	Disassemble the CDPL and connect the temperature measuring part properly. Replace the indium sheet if necessary. Disassemble the CDPL and tighten all the screws firmly. Check the indium sheet and replace it if necessary.
	8) Refrigerator failure.	Contact us.
	9) Compressor failure.	Refer to the instruction manual of the compressor unit.

Table A-1 Super Trap Troubleshooting Procedures (Continued)

Problem	Possible Cause	Corrective Action
Ⅳ. Cold head drive motor is making irregular or intermittent motion.	1) Helium gas is severely contaminated.	Perform helium circuit decontamination. Refer to Section 6.4.
	2) Low input voltage to the motor.	Please contact us.
Ⅴ. The panel temperature does not rise at warm-up time during regeneration. (Applicable to CDPL with a heater)	1) Insulation failure.	1) Measure insulation resistance regularly and replace it with new one when deteriorated. 2) Keep the atmospheric side sleeve of the heater dry.
	2) Disconnection	1) Measure insulation resistance regularly and replace it when deteriorated. 2) Check regularly that the mounting bolt and/or screw are tightened properly

Table A-2 Operating Log

CDPL S/N	**CDPL OPERATING LOG**	Date:
		Measurer
COMPRESSOR S/N		Room temp. ℃
REFRIGERATOR UNIT S/N		Power V x ϕ

Measuring condition			Compressor unit			CDPL		Remarks
Date	Time	Elapsed time	High pressure helium Gas [MPaG]	Current [A]	Cooling water flow rate [L/min(*)]	Output power [mV]	Temperature [K]	

(*) Set a meter on each compressor unit to measure cooling water flow rate.

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Appendix B

FLEXIBLE HOSE

ULVAC CRYOGENICS INC. offers two types of flexible hoses; one is a standard flexible hose which is not bendable and the other is bendable.

1 Specifications

1.1 Specifications of standard flexible hose (non-bendable)

- Gas : Helium Gas（Purity：99.999％ or more）
- Pressure : Maximum 2.45MPaG
- Temperature : 0 to 70°C
- Material : SUS304
- Length : 3000mm (standard)
- Minimum Bend Radius : 250mm
- Recommended Torque for Connecting : 20N･m

※Tighten until the self seal coupling will not turn any more.

- Connection : 1/2B self-sealing coupling

1.2 Specifications of bendable flexible hose

- Gas : Helium Gas（Purity：99.999％ or more）
- Pressure : Max. 2.45MPaG
- Temperature : 0 to 70°C
- Material : SUS304
- Length : 3000mm (standard)
- Minimum Bend Radius : 350mm
- Maximum stroke：100mm
- Number of allowable bend times：1 million times or more
- Recommended Torque for Connecting : 20N･m

※Tighten until the self seal coupling will not turn any more.

- Connection : 1/2B self-seal coupling

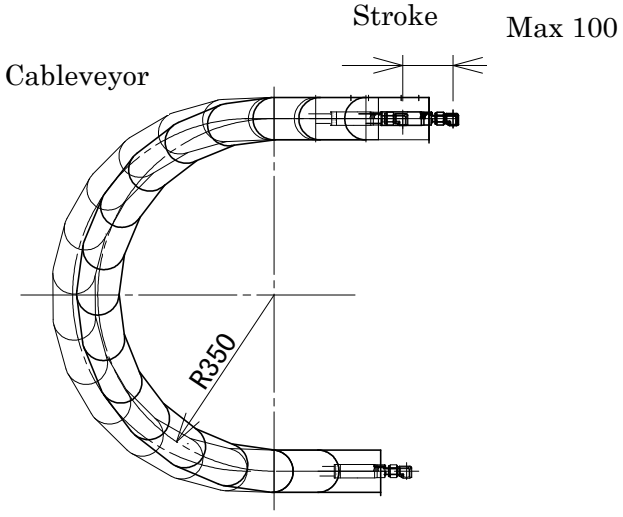
2 Precautions for Handling

2.1 Precautions for handling standard (non-bendable) flexible hoses.

- When carrying, hold the braid support of the hose. If the flexible part is bent forcibly at an acute angle, it may be damaged.
- Avoid twisting the flexible hose especially when making continuous bending piping.
- When storing, keep away from excess moisture and salt to prevent corrosion. Do not put heavy things on the flexible hoses to avoid distortion or crushing.

2.2 Precautions for handling bendable flexible hoses.

- When carrying the flexible hose, hold the braid support of the hose. If the flexible part is bent forcibly at an acute angle, it may be damaged.
- Avoid twisting the flexible hoses especially when making continuously bent connection.
- When storing, keep away from excess moisture and salt to prevent corrosion. Do not put heavy things on them to avoid distortion or crushing.
- Cover bendable flexible hoses with protective materials such as cableveyors.

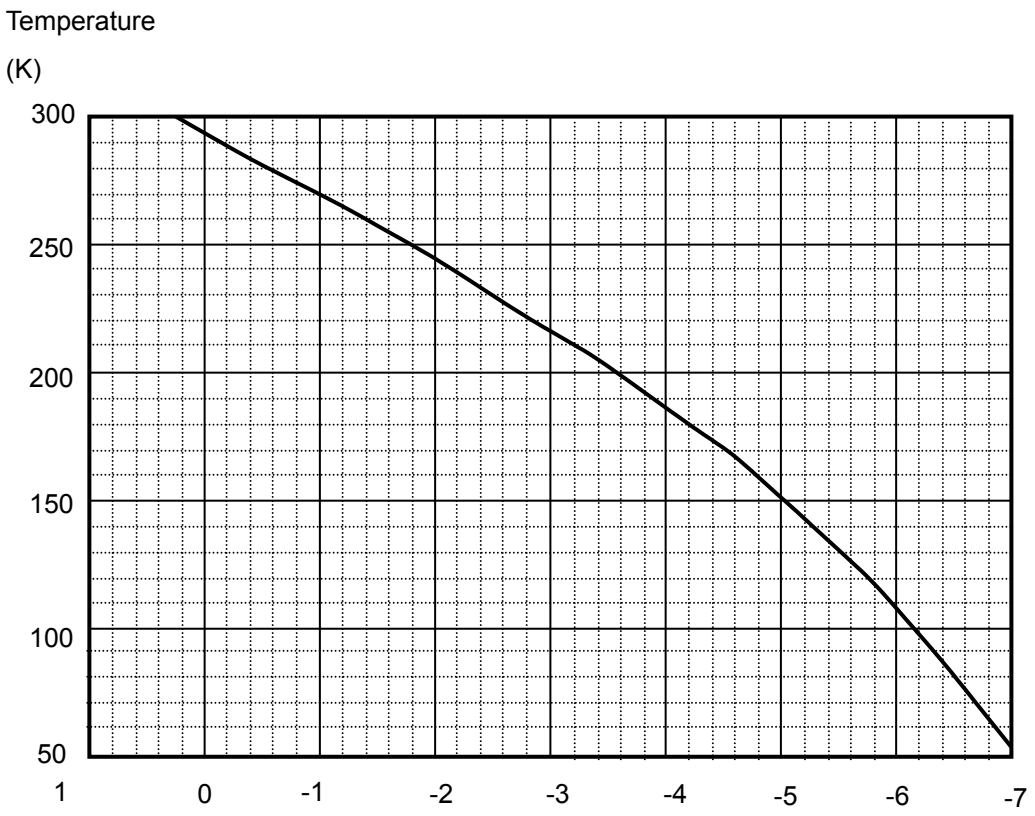


- Bendable flexible hoses make larger sound than non-bendable ones when the cryopumps are in operation. This is the normal state.

Appendix C

CONVERSION OF THERMOMETER READINGS

1 . K(CA) Thermocouple Electromotive Force



(Ambient Temperature : 20ºC)

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Appendix D

PRINCIPLE OF REFRIGERATOR OPERATION

Helium gas is used as heat-medium gas of a refrigeration cycle in our refrigerator systems, because it does not liquefy even at 10K.

First, helium gas is compressed into high pressure, cooled by water-cooling or air cooling to the room temperature in the compressor unit, and flows into the regenerator when the valve A opens. Then the helium gas flown into the regenerator is cooled by exchanging heat with the regenerator and led to an expansion chamber with rise of the displacer. Next, the valve B opens as the valve A closes allowing the high-pressure helium gas in the expansion chamber to flow into the low pressure part of the compressor unit because of the difference in pressure. During this process, the pressure and temperature of the helium gas in the expansion chamber falls (Simon expansion). The cool, low-pressure helium gas is discharged completely from the expansion chamber by the descent of the displacer. As the helium gas passes through the regenerator again, it will be warmed up to room temperature and return to the compressor. Conversely at this time, the regenerator is cooled down. In this way, the refrigeration cycle returns to the initial state. By repeating this refrigeration cycle, cryogenic temperature is obtained.

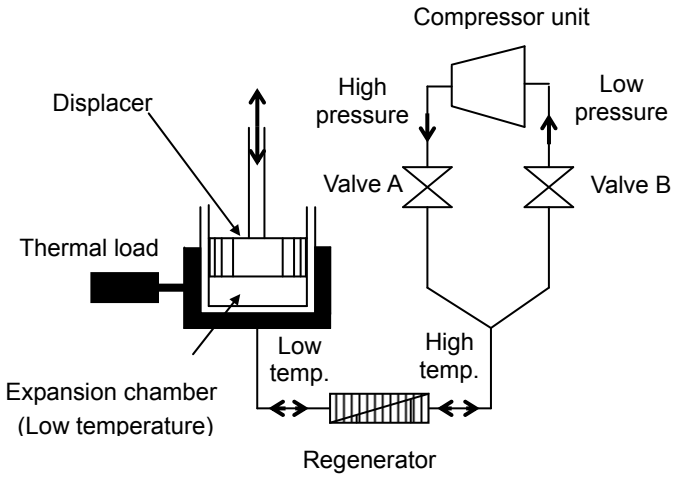

Figure D-1 Principle of Refrigeration

G-M Cycle

Gifford and McMahon developed the concept of G-M cycle in the late 1950's. In the driving method of G-M cycle, there are a way which drives mechanically and a way which drives using the differential-pressure of the operational gas. Since the GM cycle is efficient, drive speed can be slow. In addition, the load to the seal inside is light, it is highly efficient and reliable refrigeration cycle. The refrigeration cycle with the mechanical driving system adopted by ULVAC CRYOGENICS INC is explained as follows.

Figure D-2 shows the principle of G-M cycle & P-V chart (P: pressure, V: volume in the expansion chamber).

A The displacer is first positioned at the bottom of the cylinder.
The low-pressure valve is closed and the high- pressure valve is opened.

↓

a The compressed helium is introduced into the warm end and the cold end (the expansion chamber) of the cylinder.

↓

B Pressure inside the cylinder increases.

↓

b When moving a displacer up, the clod end (expansion room) is filled up with the helium gas of room temperature, being cooled by the regenerator.

↓

C The volume of the cold end (the expansion chamber) is now maximum.
At this time the high- pressure valve is closed and low-pressure exhaust valve opened.

↓

c The compressed helium in the cold end (the expansion chamber) is expelled through the regenerator resulting in the temperature decrease by Simon expansion.

↓

D The cold end reaches the lowest pressure.

↓

d The displacer is moved to the initial lower position and the low-temperature helium is transferred to the compressor. The temperature of the gas returns to room temperature by heat exchange between the regenerator.

↓

A One cycle of the helium gas circulation is completed.
The P-V diagram of idealized G-M cycle shows a quadrangle.

The ideal refrigeration ability "Q_{ideal}" is as follows when indicating the period of one cycle as "t" minutes:

$$Q_{ideal} = W / t$$

In the actual refrigerators, the structure with two stages is adopted in order to gain cryogenic temperature of 15K or lower as shown in Figure D-3. In order to simplify structure, the regenerator is built into the inside of the displacer, and it is unifying. In addition, they are designed so that the differential pressure is not applied to the 1st stage sealing, which lessens the burden to the sealing. This leads to the lighter load to the seal, long life and high reliability.

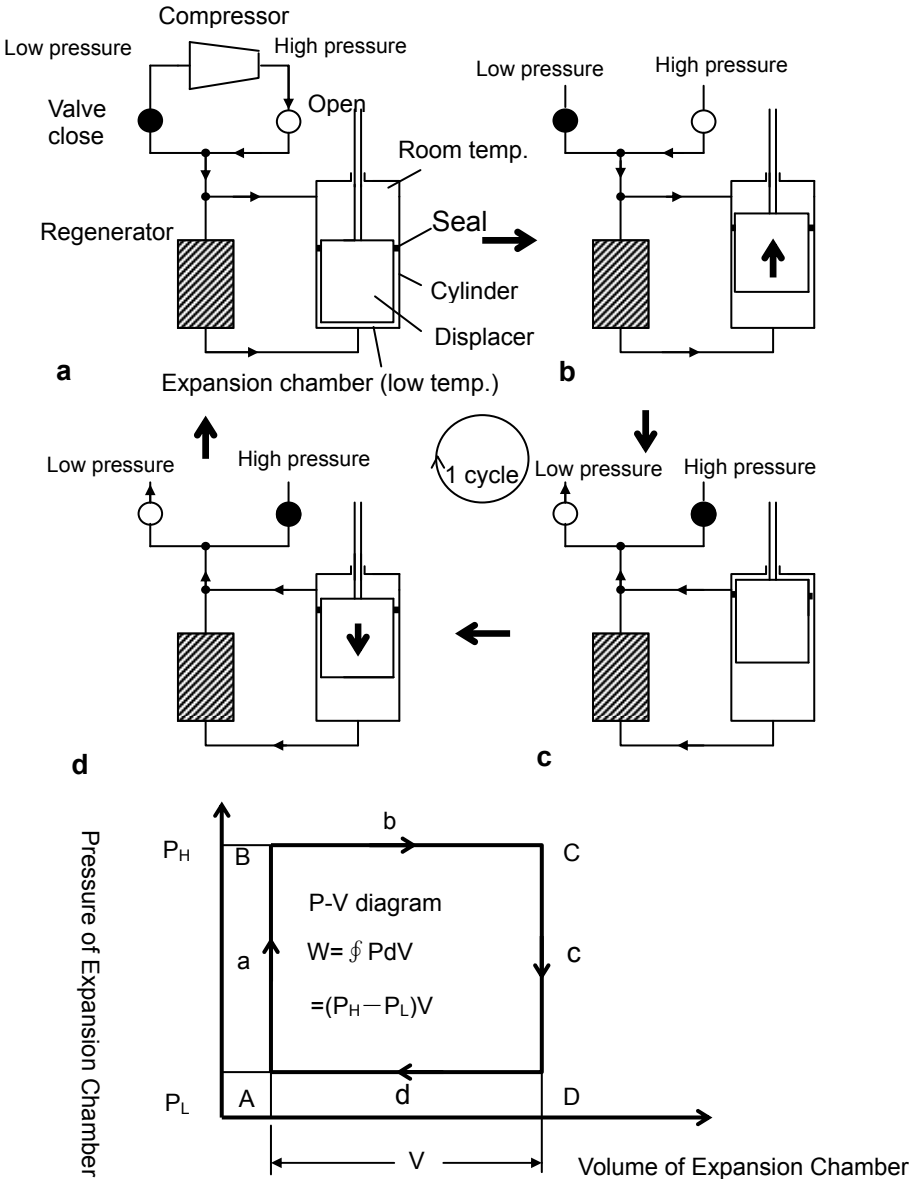

Figure D-2 Principle of G-M Cycle Operation

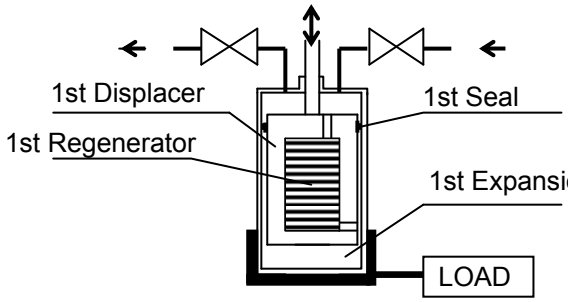

Figure D-3 Single-stage Refrigerator

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Revision History

Date	Revision No.	Contents
2014-09-02	2014.09	First edition
2017-05-17	2017MY01	“Safety Instructions” has been modified 6. MAINTENANCE has been revised. “Appendix D” Description of refrigerator unit has been modified.

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