

**TORRMMASTER®**

**TM500 LN2  
CRYOPUMP**



**INSTRUCTION MANUAL  
For**

**Serial Number**

**CUSTOMER**

**PHPK/CVI Sales Order**



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# SECTION ONE

## SPECIFICATIONS

### 1.1 TM500 LN2 CRYOPUMP

- Pumping Speeds: Liters/second

Water vapor	30,000
Nitrogen	10,500
Argon	8,500
Hydrogen	13,000
- Instrumentation: 1 Silicon Diode Temperature Sensor
- Crossover: 550 Torr liters of N<sub>2</sub>
- Capacity: Condensable gases greater than 3,000 standard liters at 5 x 10<sup>-6</sup> Torr (nitrogen, argon, oxygen, water, ect.)  
Non-condensable gases 12 standard liters at 5 x 10<sup>-6</sup> Torr (hydrogen, helium, neon)
- Maximum Argon throughput at 20K: 1580 scc/min  
20 Torr liter/second  
Liquid Nitrogen (LN<sub>2</sub>) Consumption: 2 GPH steady state room temperature load
- Weight: (with integral coldhead): Approximately 210 pounds
- 
- Length: 25-7/8" inches
- Maximum diameter: Flange: 27.5 inches 20" ANSI  
Vacuum Housing: 20-13/16 inches  
Expander Motor Housing: 12-3/4 inches
- Cryopump cooldown: 120 minutes  
Shroud cooldown to 77K: 40-45 minutes
- Orientation for operation: Any

## 1.2 INTERFACES

- 6-pin twist lock Bendix connector for silicon diode temperature sensors and thermocouple.
- Flange Dimensions: 2 3/4" OD x 3/8" thick, 4 bolt
- Roughing Flange: KF40
- Pressure Relief: 2-3 psig poppet valve with KF40 flange
- System Flange: 20 inch ANSI flange with Viton o-ring  
27.5" OD x 20.813" ID with 25"BC, 20 each 1.25" dia bolt holes  
21.95" ID x 0.210" thick Viton o-ring
- Purge Tube: 1/4" Parker Ultra-seal fitting
- Accessory Port: 2-3/4" 4 bolt flange, 3/8" thick or KF40
- LN<sub>2</sub> supply: 2 each 1/2 " NPT female fittings –or-  
2 each 1/2 " vacuum jacketed bayonets

## 1.3 AVAILABLE ACCESSORIES

- Silicon diode temperature readout
- 
- Solenoid purge valve
- 
- Purge gas heater
- 
- Nitrogen vent valve for controlling the LN<sub>2</sub> flow through the shroud

## SECTION TWO

### 2.0 THEORY OF OPERATION

A cryogenic pump is a high vacuum pump based on the cryopumping and cryosorption principals. Cryopumping is the formation of vacuum by condensation of gases on a cryogenically cooled surface, i.e.; a surface so cold (typically 20K level) that the vapor pressure of the gases are below 10<sup>-9</sup> Torr. Cryosorption is the adsorption of gas molecules by weak Van der Waals forces on cryogenically cooled very large specific surface materials like activated carbon. The cooling power required is supplied by either cryogenic liquids like He, H<sub>2</sub>, Ne, and N<sub>2</sub> or cryogenic refrigerators or a combination of the two.

Cryopumps with inlet flanges larger than 20 inches in diameter typically use liquid nitrogen for cooling the radiation shield and a two stage closed cycle Gifford McMahon refrigerator for cooling of the 15K array.

### 2.1 REFRIGERATION CYCLE (GIFFORD McMAHON)

During each cycle, incoming high-pressure helium is metered by the spool valve to the displacer/regenerator assembly where it is pre-cooled by the residual cold in this assembly. Then the valve opens to the exhaust position, the captive high-pressure helium expands out of the displacer/regenerator assembly imparting the cooling from expansion and exhausting through the valve and drive housing, over the motor (cooling it), and out through the return gas connector to the compressor. This cycle provides the two levels of refrigeration to the first and second stage cold stations.

### 2.2 CRYOPUMP CROSSOVER

Crossover is that system gas volume at which it is possible to change from roughing pumps to the high vacuum cryopump without overloading the cryopump.

### 2.3 CROSSOVER DERIVATION

The crossover pressure ( $P_c$ ) is derived by dividing the crossover of the cryopump, expressed in torr liters, by the volume of the system to be pumped, expressed in liters. The dividend of this equation is a pressure expressed in torr, which can be directly read on a vacuum gauge. See respective data sheet for cryopump crossover values.

- Example: A vacuum system has a calculated volume of approximately 1,000 liters. The crossover for a TM500 LN2 is 560 Torr liters. Therefore the crossover pressure is:

$$P_c = \frac{560}{1,000} = 0.56 \text{ Torr or } 560 \text{ mTorr (microns)}$$

**NOTE:** It is wise to calculate the crossover point of the chamber the pump will be used on. To simply rough the chamber to 50 millitorr, can either be too much or too little. Under-pumping the chamber can overload the cryopump when the gate valve is opened. Over-pumping the chamber could allow roughing pump oil to backstream into the chamber. This oil would then contaminate the cryopump.

**REMEMBER:** A vacuum gauge near the roughing line will read differently than a gauge across the chamber from the roughing pump.

## **2.4 OIL BACKSTREAMING**

Too much roughing can lead to mechanical pump oil backstreaming into the chamber and the cryopump. The additional time necessary to arrive at 50 millitorr may be unnecessary since it may be possible to crossover fairly high in the torr range.

## **2.5 GAS OVERLOAD**

Too little roughing will load the cryopump with a greater gas volume than it can handle. This will stall the pump, rendering it incapable of recovery without regeneration. Finally, calculating crossover relates to a chamber gas load approximating normal atmospheric composition. If you do not know the gas constituents in your system, the equation can be made more conservative by reducing the torr liter increased or decreased depending on the application. Call CVI if you have any questions concerning crossover.

## **2.6 OVERVIEW OF COMPONENTS**

### **2.7 REFRIGERATOR**

The Torr Master cryopump consists of a CGR511 refrigerator inserted into a securely attached to a vacuum housing. Affixed with screws to the refrigerator inside the vacuum housing are the two cryocondensing/cryoadsorption arrays. Closed circuit liquid nitrogen piping cools both the chevron and radiation shield.

### **2.8 INTERCONNECTING COMPONENTS**

The refrigerator is connected to the compressor module with two flexible stainless steel gas lines. One line supplies helium to the refrigerator and one line returns helium to the compressor. A power cable for the expander motor in the refrigerator is also connected to the compressor.

### **2.9 VACUUM HOUSING**

The vacuum housing of a TorrMaster cryopump is fabricated from 304 stainless steel. The vacuum system flange has an o-ring groove machined into its face. On the opposite end of the system flange are provisions for a KD40 roughing port, an accessory port, a purge tube with 1.4" o-ring face seal fitting, a 2-3 psig pressure relief valve to prevent over pressurization from vaporized condensate during regeneration, electrical feedthrough for a silicon diode temperature sensor and a flange for mounting the CGR refrigerator.

### **2.10 CHEVRON AND FIRST STAGE SHIELD**

Inside the vacuum housing are the cryoarrays (Figure 3). First visible is the chevron baffle. They are conductively cooled to a nominal 80K by a serpentine tube welded to the assembly. Liquid nitrogen flows through the tube cooling it. There is no reliance on the closed-cycle refrigerator to cool these arrays. The chevron baffle has two functions. It provides thermal shielding for the 15K array located behind it and it also cryocondenses water and hydrocarbon vapors. The cryopump is designed so that, during cooldown, the chevron baffle and radiation shield are cooled to below 273K faster than the second stage array. This avoids contamination of the 15K array by water and hydrocarbon vapors because these materials will first condense on the chevron baffle and radiation shield. The radiation shield inhibits thermal radiation above 80K from warming the 15K array

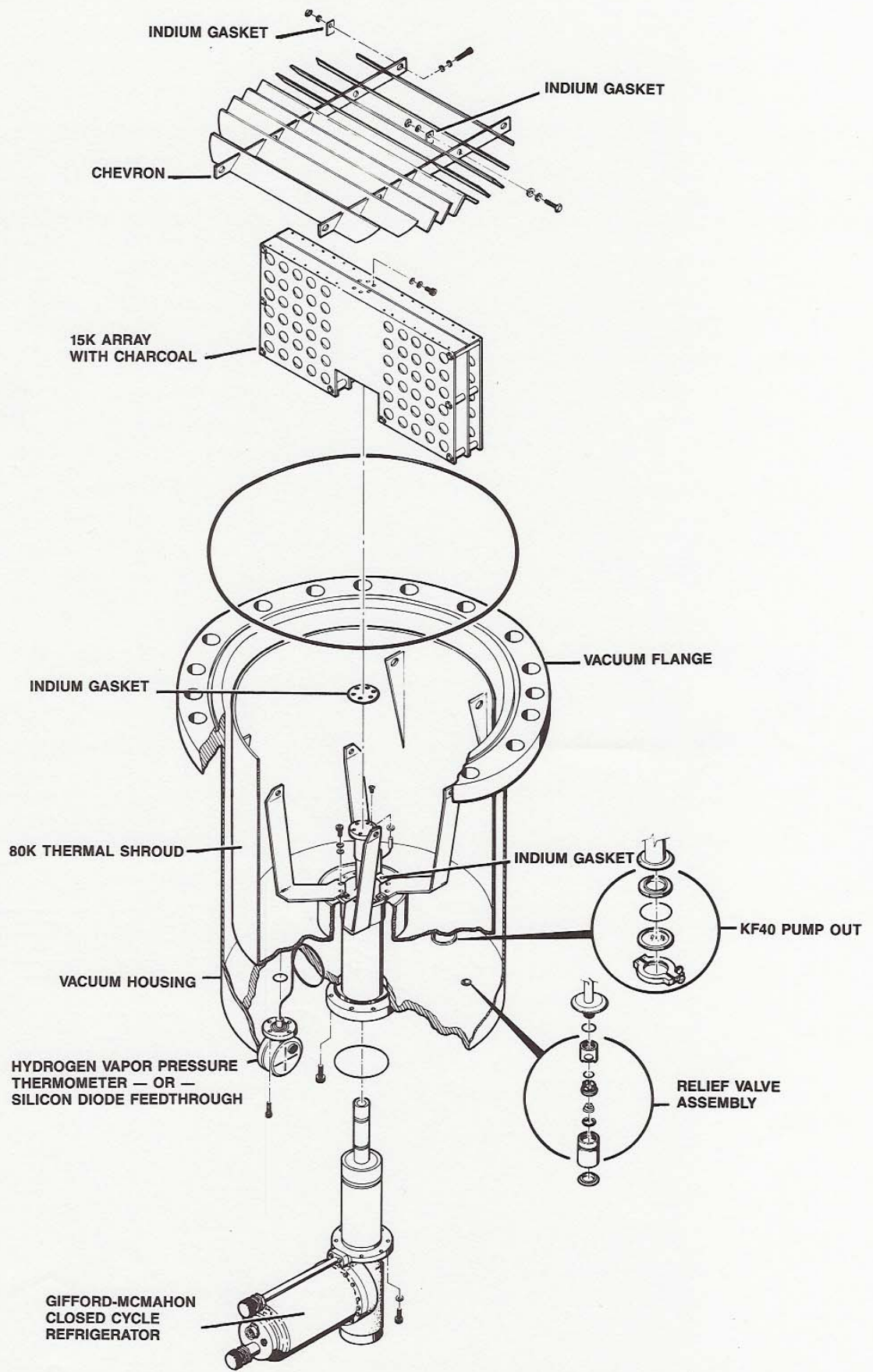
### **2.11 15K ARRAY**

The 15K array is composed of two components- a cryocondensing surface and a cryoadsorption surface. The cryocondensing surfaces are the surfaces with holes in them and the large flat sail that is partially visible behind the chevron baffle. This surface condenses all vapors present in the pump, except hydrogen, helium and neon. It is this surface where the bulk of nitrogen, argon, and oxygen condense. On the blind side of the panel is a bed of activated carbon. This is where hydrogen, helium and neon are cryoabsorbed. The perforations allow hydrogen, helium and neon better access to the activated charcoal. By backing up each perforated panel with the flat sail, gases penetrating the holes in the perforated panel strike the sail panel, release some of their energy to the cryogenic surface and then are deflected to the charcoal. Gases that are condensed stick on the sail panel keeping the charcoal clear for adsorbed gas. The perforations are sized and spaced to allow for a high probability of entry by hydrogen, helium or neon molecules.

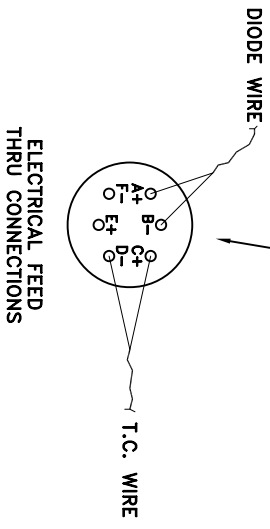
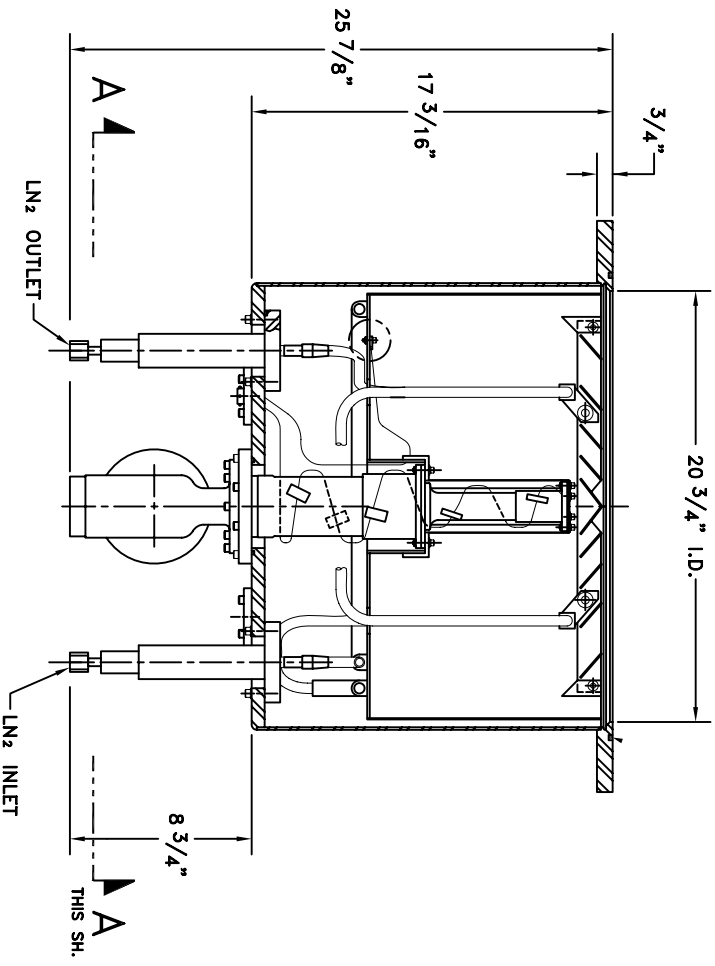
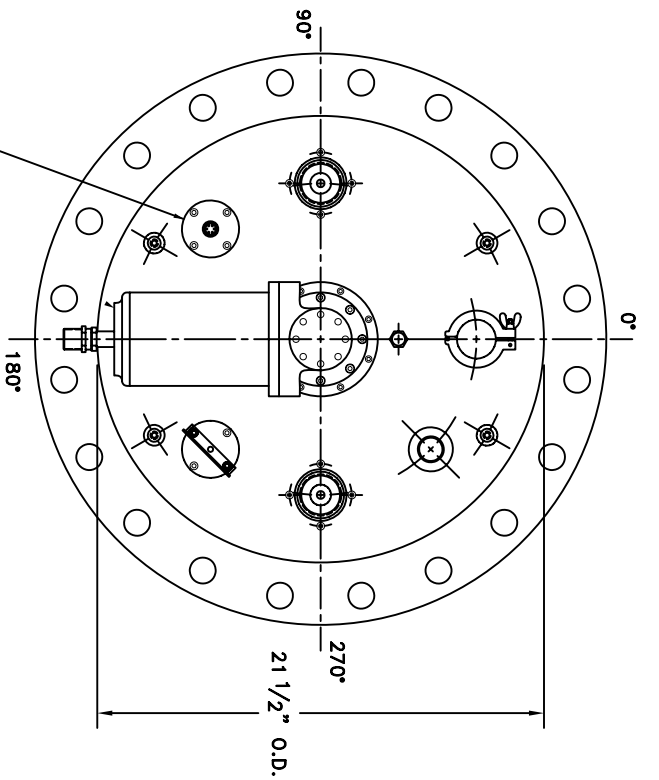
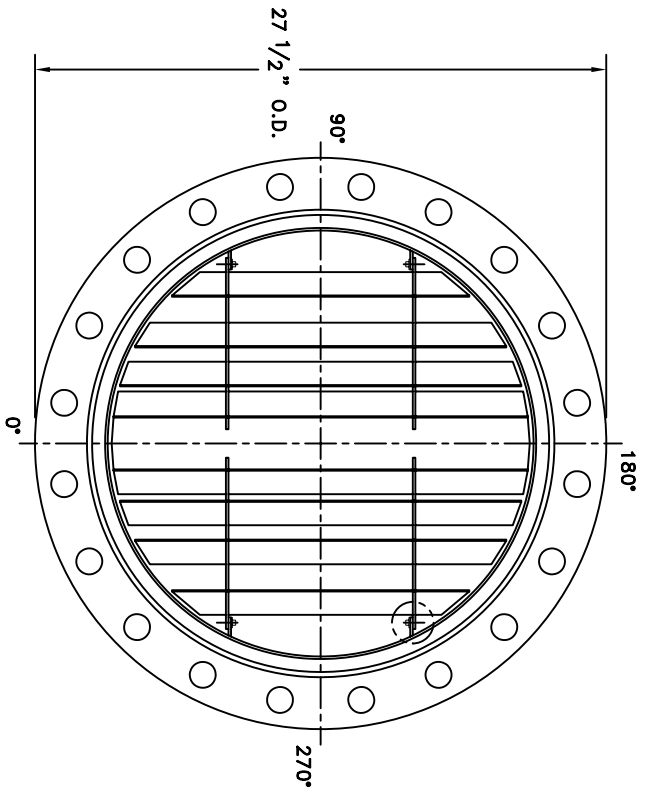
## **FIGURE 1    TM500 LN2 LEGEND**

1.     Gifford McMahon Closed Cycle Refrigerator
2.     Vacuum Housing
3.     80K Thermal Shroud
4.     15K Array with Charcoal
5.     Chevron
6.     Vacuum Flange
7.     KF40 Pump-out Port
8.     Safety Relief Valve
9.     Vapor Bulb or Instrument Feed Through
10.    Indium Gasket





TM500 PARTS IDENTIFICATION



## SECTION THREE

### 3.0 INSPECTION AND INSTALLATION

#### 3.1 GENERAL

Inspect all components for visible shipping and handling damage. If damage is observed, notify shipper at once.

##### 3.1.1 CRYOPUMP INSPECTION

- Inspect the refrigerator housing and cryopump vacuum housing.
- If your cryopump is equipped with a hydrogen vapor bulb, ensure that the needle is pointing to the calibration dot on the gauge face.
- Remove the protective flange cover and check the chevron baffle and panels for any damage.
- Check the system flange and o-ring groove.
- If the cryopump is not being installed immediately, replace the protective cover.

##### 3.1.2 FLEXIBLE GAS LINE INSPECTION

Check for kinks and broken braid strands. These hoses are mass spectrometer leak checked and pressurized at the factory to  $210 \pm 5$  psig. Do not remove the self-sealing fittings. The dust caps should be left on until time of installation.

##### 3.1.3 COMPRESSOR INSPECTION

Check for helium pressure loss. Pressure should be  $210 \pm 5$  psig. Check for oil leaks.

## 3.2 CRYOPUMP INSTALLATION

### 3.2.1 GENERAL

The cryopump will operate and may be installed in any orientation. PHPK/CVI strongly recommends that a high-vacuum valve be installed between the cryopump and chamber. This valve will isolate the cryopump from the chamber. During cooldown, the valve will reduce the amount of residual gas that must be adsorbed by the 15K carbon surface by exposing the cryopump to the smallest possible gas volume. If there is a high background of residual gas (no high vacuum valve) the capacities for non-condensable gases will be significantly reduced.

This can necessitate more frequent regeneration. During regeneration, the high vacuum valve will be useful in preventing the introduction of pumped gases back into the chamber. A high vacuum valve is also very useful for troubleshooting the vacuum system.

A roughing port is available on the cryopump. This is used to rough the cryopump when it is valved off from the system. The limited conductance of the space between the 80K array and vacuum housing precludes pumping on chambers through the cryopump. This conductance limitation produces a pressure differential between the system and the back of the cryopump that can lead to a long pump-down cycle. If the pressure is measured only on the chamber, it is possible for the vacuum level in the back of the cryopump to be below 50 millitorr, which can result in oil backstreaming from the roughing pump into the back of the cryopump. This situation should be avoided as the pump oil will eventually migrate to the 15K array and yield it inoperative.

### 3.2.2 PUMP MOUNTING

Install the cryopump as follows:

- Remove the protective flange cover.
- Clean the inlet flange, o-ring groove and inlet o-ring with a clean, lint-free cloth.
- Apply a thin film of high quality, low-vapor pressure vacuum grease to the inlet o-ring for the pump.

**CAUTION: Use a minimum amount of vacuum grease. It is a collector of dirt and other contamination which can lead to vacuum leaks or chamber contamination.**

- Install the o-ring on the inlet flange of the pump.
- Install and bolt the cryopump to the vacuum chamber flange. Tighten the bolts evenly and in a diametric pattern to insure good o-ring compression.
- Attach the roughing pump line to the KF40 roughing port on the end of the vacuum housing. This line requires a vacuum valve.

**WARNING:** The safety valve on the cryopump vacuum housing normally vents to atmosphere. If the cryopump is used to pump gases that require special handling, a KF40 flange has been provided to connect to a vent line. The inside dimensions of the vent line must clear the 1-1/4 inch (31.75mm) diameter by 2-1/2 inch (63.5 mm) length of the safety valve for proper operation.

**CAUTION:** Before operating remove the blue safety valve cover if the valve will be used for regeneration. Grasp the blue dust cap firmly and pull it straight off with rotating motion.

**WARNING:** Do not install a hot filament gauge on the cryopump side of the valve, as this could be a source of ignition.

### 3.2.3 FLEXIBLE GAS LINE INTERCONNECTION PROCEDURE

Proceed with component interconnections in the following order;

- Remove the self-sealing coupling dust caps from the supply and return fittings on the compressor and refrigerator. Also remove the dust caps from the flexible gas lines. Be sure the seals are in position inside the couplings.
- Using the two wrenches supplied, connect the flexible gas lines to the compressor and coldhead as indicated in A through D below.

**CAUTION:** The minimum bend radius for the flexible gas lines is six inches (15cm). Avoid twisting the hose or running it over sharp bends during component interconnection.

**NOTE:** If a coupling starts to leak, screw the two halves together faster. One drop of oil can be used to lubricate the threads of the self-sealing fitting if the connection is hard to make. USE NO MORE. Do not lubricate the threads with grease. If the plating flakes off the fitting, it will combine with the grease and become abrasive. The grease will also collect other dirt.

**CAUTION:** Always connect the flexible gas lines to the compressor first. This prevents contamination of the refrigerator. If there is a leak in a flexible gas line, it is unlikely the entire charge volume of the compressor will be depleted before the leak is detected. The refrigerator charge volume is small enough that it may be quickly depleted.

- A. Connect the helium low pressure line (blue) to compressor low pressure connection (blue).
- B. Connect the helium high pressure line (red) to compressor high pressure connection (red).
- C. Connect helium high pressure line (red) to refrigerator high pressure connection (red).
- D. Connect helium low pressure line (blue) to refrigerator low pressure connection (blue).
- E. Read the static charge pressure on the HIGH and LOW gauges. This pressure should be  $210 \pm 5$  psig at 75° F (24°C).

### **3.2.4 EXPANDER CABLE CONNECTION PROCEDURE**

With the system power off, connect the power cable to the refrigerator expander motor and compressor.

**NOTE: Never connect or disconnect the refrigerator expander power cable while the compressor is running. This can present a shock hazard and can damage the expander motor.**

### **3.2.5 SILICON DIODE CONNECTION PROCEDURE**

If applicable, connect the silicon diode readout connection. The diode is wired to the pump connector feedthrough.

### **3.2.6 MAIN POWER CABLE CONNECTION PROCEDURE**

Plug in the main power cable. Refer to Compressor Manual for the appropriate power requirements.

**NOTE: Do not start the unit until reviewing the start-up/cooldown procedures in Section 4.0.**

### **3.3 LIQUID NITROGEN SUPPLY AND RETURN CONNECTIONS**

It is advisable to have a valve installed in the LN<sup>2</sup> supply line. A valve appropriate to the type of LN<sup>2</sup> supply your system has should be used.

If the cryopump is supplied with ½” NPT female fittings, connect a mating male fitting to the female coupling on the pump. Use two wrenches to avoid deforming the piping on the cryopump. The LN<sub>2</sub> supply can be connected to either fitting on the base of the cryopump. Performance is not affected appreciably by which fitting is the LN<sub>2</sub> inlet.

If 1.2” vacuum insulated bayonet fittings are supplied:

Remove the protective wrapping from the male and female bayonets.

Clean the OD of the male and the ID of the female bayonet with an approved solvent applied with a clean, lint-free rag. Allow both parts to dry.

Inspect the male tube for nicks, scratches or dents. (Shallow scratches may be removed by lightly polishing with fine emory cloth. Repeat the cleaning procedure above. If deep scratches, dents or nicks exist the bayonet is not suitable for use. Contact CVI about replacement. Do not install the bayonet, it may leak.

Clean the o-ring using the procedure in the second step above. DO not use acetone; it will cause the o-ring to swell.

Inspect the o-ring for scratches, cracks or flat spots. Replace if necessary.

Apply a very thin film of high quality low vapor pressure vacuum grease to the o-ring and install it in the o-ring groove on the bayonet.

Align the male and female bayonet and gently slide them together (making sure the o-ring stays in position). The bayonet will easily slide together if properly aligned. If any resistance occurs, do not force bayonets together. Recheck the piping alignment, adjust pipe hangers and supports as needed and try to slide bayonet together again.

Tighten the retaining nut securely. Generally a good tight fit is sufficient to provide a good seal.

### 3.3.1 LIQUID NITROGEN SUPPLY SECTION

There are generally three types of in house LN<sub>2</sub> supply systems available for cooling the radiation shield of the cryopump:

1. Closed loop LN<sub>2</sub> systems. These will have a large LN<sub>2</sub> supply Dewar with circulation pumps moving the LN<sub>2</sub> to the use points and back to the Dewar. Just before the LN<sub>2</sub> returns it to the Dewar it is often subcooled to lower its temperature and gaseous nitrogen is separated from the liquid nitrogen before returning to the storage Dewar.
2. Open loop pressure transfer. These systems will have a LN<sub>2</sub> supply Dewar that delivers cryogen by utilizing the boil-off gases above the liquid level of the Dewar to force LN<sub>2</sub> out of the Dewar. Effectively this means that LN<sub>2</sub> could be available at a delivery pressure equal to the pressure in the supply Dewar.
3. Open loop gravity transfer. Similar to the system in number 2, gravity transfer relies on the height of the supply Dewar above the use point to develop pressure to deliver the LN<sub>2</sub>. This type of system often originates off a phase separator in a large LN<sub>2</sub> distribution system.

**NOTE: It is important to know what type of LN<sub>2</sub> supply you have.**

This cryopump requires good quality single phase LN<sub>2</sub> that has a temperature below 105K to operate efficiently and properly. LN<sub>2</sub> above this temperature or containing a lot of entrained bubbles will not refrigerate the radiation shield enough to limit the amount of black-body radiation that will be directed at the 15K second stage array. If the thermal radiation the second stage array is subjected to is high, the pumping efficiency of the array will be greatly affected.

Liquid Nitrogen can have a wide range of temperatures depending on the pressure that it is supplied at. 77K (Kelvin) at 196C is the temperature of an open vessel on LN<sub>2</sub>. This would be close to the temperature of a gravity transfer LN<sub>2</sub> system. The pressure transfer LN<sub>2</sub> system could have a much higher temperature and the closed-loop circulating LN<sub>2</sub> system will generally have a temperature somewhere between these two.

At a supply pressure of 40 psig the TM500 LN<sub>2</sub> cryopump consumes 2 GPH of LN<sub>2</sub> during steady state room temperature operation. Steady state means there are no large transient heat loads or high persistent heat loads coming in to the pump. During normal operation LN<sub>2</sub> consumption could be expected to be between 3 and 5 GPH. This would depend on the amount of thermal load the pump is subjected to. This pump was designed with a LN<sub>2</sub> refrigerated radiation shield to deal with the special applications where thermal loading is too high for a pump refrigerated only with closed-cycle cryocoolers. The LN<sub>2</sub> cooled radiation shield/chevron are not attached to the 1<sup>st</sup> stage of the coldhead. Without the thermal load of the radiation shield/chevron the refrigerator can be designed to deliver more refrigeration to the 15K arrays. With LN<sub>2</sub> removing the 1<sup>st</sup> stage thermal load the TM500 LN<sub>2</sub> cryopump will utilize the additional 2<sup>nd</sup> stage refrigeration capacity to pump considerably more gas over a longer period of time than a cryopump without LN<sub>2</sub> radiation shield cooling in the same size range.



### **3.3.2 GASEOUS NITROGEN VENT VALVE ASSEMBLY**

If the LN<sup>2</sup> supply system for the cryopump is a continuous flow system with a return to the supply Dewar proceed to Section 4. If the supply circuit will be utilizing a vent device, continue:

To assure that the radiation shield in the cryopump is cooled uniformly it is necessary to keep the LN<sup>2</sup> plumbing on the shield flooded with cryogen. To do this, gas bubbles generated in the LN<sub>2</sub> as it removes heat from the pump must be vented from the LN<sub>2</sub> above the liquid level of the cryopump. This can be accomplished with a flat, electric or pneumatic liquid level control device.

- Install a stand-pipe that terminates above the liquid level of the cryopump.
- Install a venting device at the top end of this stand-pipe

## SECTION FOUR

### 4.0 OPERATION

#### 4.1 GENERAL

The previous section dealt with the inspection and installation of a TorrMaster® TM500 cryopump on the user's vacuum system. The user must read and understand that chapter and this one before operating the cryopump to ensure the system will function properly.

#### 4.2 PRE-START CHECK LIST

Before proceeding, be certain that:

- Water lines are connected (if applicable)
- Water is flowing at the proper rate (if applicable)
- Gas supply and return lines are properly connected.
- Power connections are made to the compressor and refrigerator
- The cryopump is at ambient temperature and pressure
- Static pressure is  $210 \pm 5$  psig at 70°F (21°C) on CBST6.0
- A vacuum gauge is installed in the roughing line between the cryopump and roughing valve to observe rate-of-rise during the cryopump roughing cycle and to avoid rough pumping below 50 millitorr.

**CAUTION: The vacuum gauge may be a source of ignition and should be isolated from the cryopump if a combustible mixture is present.**

- The roughing line has a vacuum valve between the cryopump and mechanical pump to isolate the cryopump while it is at high vacuum.

#### 4.3 CRYOPUMP EVACUATION / RATE-OF-RISE TEST

**CAUTION: Take measures during rough pumping to assure oil vapors from the mechanical vacuum pump do not backstream into the cryopump. These vapors can quickly contaminate the activated carbon.**

- Ensure the check list in Section 4.2 has been completed then:

A. Close the high vacuum system valve.

**NOTE: If there is no high vacuum valve between the cryopump and vacuum system, the amount of rough pumping will be dependent on chamber size and the pumping speed of the roughing pump. It may not be possible to rough to 50 millitorr. In this case, rough to the best vacuum possible, insuring that the roughing line pressure does not drop below 50 millitorr.**

B. Begin roughing the cryopump to a pressure not less than 50 millitorr. This is done to produce an insulating vacuum within the cryopump housing. Without this “insulation” the cryopump will frost up on the outside during cooldown and is likely not cool below 200K.

**NOTE: A newly installed cryopump or one that has been in contact with the atmosphere may take longer to pump down. This is because of water adsorbed into the activated carbon on the 15K array.**

C. Conduct a RATE-OF-RISE test. When 50 millitorr is reached, close the roughing line valve. Observe the rate of pressure rise on the system vacuum gauge or on the cryopump vacuum gauge if a high vacuum valve is in use.

D. If the rate-of-rise is less than 15 millitorr/minute, start the cryopump.

E. If the rate-of-rise is greater than 15 millitorr/minute, repeat steps B and C.

F. If the pump-down takes an unusually long time or does not occur at all, refer to Section Six.

**CAUTION: Never leave the roughing valve open during cryopump operation. This could contaminate the cryopump with mechanical vacuum pump oil.**

#### **4.4 CRYOPUMP START-UP AND COOLDOWN**

- Confirm that start-up pressure of 50 millitorr has been reached.
- Confirm the cryopump roughing valve is closed.

**CAUTION: Be certain the roughing line valve and the high vacuum valve (if applicable) are closed.**

- Confirm that cooling water is on.
- Log helium pressures, cryopump temperature and elapsed time reading.
- Start the compressor and liquid nitrogen flow.

**CAUTION: If the pump fails to cool down in 90 minutes or frost is evident on the vacuum housing, it is likely an insulating vacuum has not been attained. Refer to Section Six.**

- If there is a system high vacuum valve, rough pump the vacuum system to the appropriate crossover point on data sheet. If the system does not have a high vacuum valve, begin process when the cryopump has reached an operating temperature below 20K.
- Close the vacuum system roughing valve.
- Check the system rate-of-rise and crossover against prior records.
- Open the high vacuum valve when the cryopump is at operating temperature.

## 4.5 SHUTTING OFF THE CRYOPUMP

- Close the system high vacuum valve
- Turn off the LN<sub>2</sub> supply valve.
- Turn the compressor off.

**CAUTION: Do not expose the cryopump arrays to ambient air until it has warmed up. To do so will saturate the activated carbon surface with water vapor, which will require prolonged roughing in order to achieve a good start-up vacuum for the next cooldown cycle.**

- Check relief valve for obstruction.
- Make sure the vent valve is open, NOT to allow LN<sub>2</sub> to be trapped.
- If there is no high vacuum valve and access must be gained into the chamber, dry nitrogen or argon can be bled into the cryopump through the regeneration purge tube to break the vacuum. This will cause the cryopump to warm up more rapidly by providing heat through thermal conduction from the warm components of the vacuum system.

**NOTE: Do not break the vacuum with helium. It is very difficult to pump this gas with a cryopump.**

**NOTE: Do not open the cryopump roughing valve at high vacuum. Doing so may contaminate the cryopump with mechanical pump oil.**

## 4.6 STORAGE

- If a TorrMaster® TM500 cryopump is to be stored while attached to the vacuum system, it is advisable to purge the cryopump with dry nitrogen or argon and leave it at a slight positive pressure. If possible, close the high vacuum valve above the cryopump after purging.
- If the cryopump is to be removed from the vacuum system, replace the protective shipping cover and seal the pump.
- Both of these procedures will aid in keeping the activated carbon surface free of water.
- If possible, store the cryopump with flexible gas lines and compressor attached. Periodic checking of the pressure gauge on the compressor will indicate if there is a leak requiring attention.

### **WARNING:**

When shipping or storing the water cooled model at temperatures below the freezing point, blow out any trapped cooling water in the compressor unit with compressed air.

## SECTION FIVE

### 5.0 REGENERATION

A cryopump traps gases on its cryopanel by condensation and adsorption. In time, this layer of condensate accumulates to a thickness sufficient to affect the cryopump's performance. When this occurs, the cryopump must be regenerated.

Regeneration involves warming the cold, internal components of the cryopump to ambient temperature. This causes the condensed and adsorbed gases to evolve so they can be removed from the cryopump.

There are obvious indicators that a cryopump requires regeneration. Assuming the compressor and refrigerator are operating satisfactorily, these primary indicators are:

1. Degradation of vacuum system performance. This is often observed as an increase in pump-down time to operating vacuum or the inability of the cryopump to handle the system gas load without a rise in system pressure.
2. Increase in the second stage operating temperature as observed on the silicon diode temperature sensor. A temperature in excess of 20K indicates regeneration may be necessary to maintain capacity for non-condensable gases.

**WARNING:** Insure the appropriate steps have been taken for handling the gases pumped. Toxic, flammable or corrosive gases can be recovered during regeneration using the KF40 flange on the safety relief valve. Do not use a hot filament gauge or a thermocouple gauge on the cryopump if flammable gases have been pumped.

**NOTE:** Remove the blue protective cover on the safety valve before installing the KF40 flange. This cover pulls straight off with a twisting motion.

**CAUTION:** Never warm the cryopump to more than 150°F (66°C, 338K). This will adversely affect the indium gaskets, silicon diode and regenerator / displacer parts.

**CAUTION:** Do not use helium for regeneration. It is the most difficult gas to cryopump. Large amounts of residual helium after regeneration may extend or prevent cooldown and shorten the interval between regeneration.

## 5.1 METHODS OF REGENERATION

After closing the high vacuum valve (if present) and turning off the cryopump there are several options available for regeneration.

1. Allow the cryopump to warm to ambient temperature unassisted. This requires from 5-10 hours depending on the amount of pumped gas.
2. Break vacuum with a clean, dry gas and allow the pump to warm to ambient temperature. Nitrogen or argon are two commonly used gases and are injected through the purge tube. This procedure will shorten regeneration time in step 1 by 10-20 percent.
3. Break vacuum and purge the cryopump by injecting 1 to 2 cfm (1.5 to 3 m<sup>3</sup>/h) clean, dry gas at 5-6 psig (0.3-0.4 bar) until the pump warms to ambient temperature. This procedure will shorten the regeneration in step 1 by 20-30 percent and is most commonly used.
4. Break vacuum and purge the cryopump by injecting 1 to 2 cfm (1.5 to 3 m<sup>3</sup>/h) clean, dry gas at 5-6 psig (0.3-0.4 bar) that has been heated to no more than 150°F (66°C). Continuously purge until the cryopump is at ambient temperature. This procedure will shorten the regeneration time in Step 2.

**NOTE: To insure removal of water, you may wish to warm the cryopanel to 90°F (32°C, 305K). This temperature is indicated using the silicon diode readout.**

5. Apply heat to the exterior of the cryopump using a heat tape or mantel. Maintain a cryopump vacuum housing surface temperature up to 150°F (66°C) until the cryopanel is at ambient temperature. Do not exceed a temperature of 150°F (66°C). Higher temperatures will damage the pump, and effect the calibration of the silicon diode temperature sensor.
6. Apply heat to the exterior of the cryopump using a heat tape or mantel. Maintain a cryopump vacuum housing surface temperature up to 150°F (66°C). Simultaneously break vacuum and purge the cryopump by injecting 1 to 2 cfm (1.5 to 3 m<sup>3</sup>/h) clean, dry gas at 5-6 psig (0.3-0.4 bar) until the cryopanel is at ambient temperature.

When the cryopanel has been returned to ambient temperature, discontinue regeneration.

Rough the cryopump according to start up procedure.

Restart the cryopump according to start up procedure.

**NOTE: In applications where large quantities of water vapor are pumped, regeneration with a gas purge is recommended to ensure continued performance effectiveness of the arrays.**

## 5.2 REGENERATION INTO A PARTIAL VACUUM MAINTAIN LESS THAN 5 TORR IN THE CRYOPUMP

The above regeneration cycles can be further enhanced by making arrangements to regenerate into a partial vacuum. Regeneration into partial vacuum allows gas species to be removed from the cryopump as they evolve. This procedure assists in preventing the interaction of gas species during evolution and the accumulation of water in the liquid phase. While regeneration into a partial vacuum does prolong the warm up cycle, it does reduce the time necessary to pump out the cryopump for initial startup.

This procedure helps insure that the activated carbon on the 20K cryoarray does not get contaminated or water-saturated. There are several options available for regeneration into a partial vacuum. Any of the previous regeneration procedures can be used in conjunction with regenerating into a partial vacuum.

## 5.3 REGENERATING FOR UHV CONDITIONS

For some vacuum applications it is desirable to regenerate the cryopump utilizing another high vacuum pump, such as a turbo pump. By keeping the cryopump vacuum at  $10^{-6}$  torr during regeneration a high degree of cleanliness is assured for the cryopump. While warm up is extended due to the reduced convection in the pump, cooldown is very fast because there is no load on the refrigerator other than the mass of the arrays. This method will allow the pump to operate repeatedly at vacuum levels in excess of  $10^{-8}$  Torr.

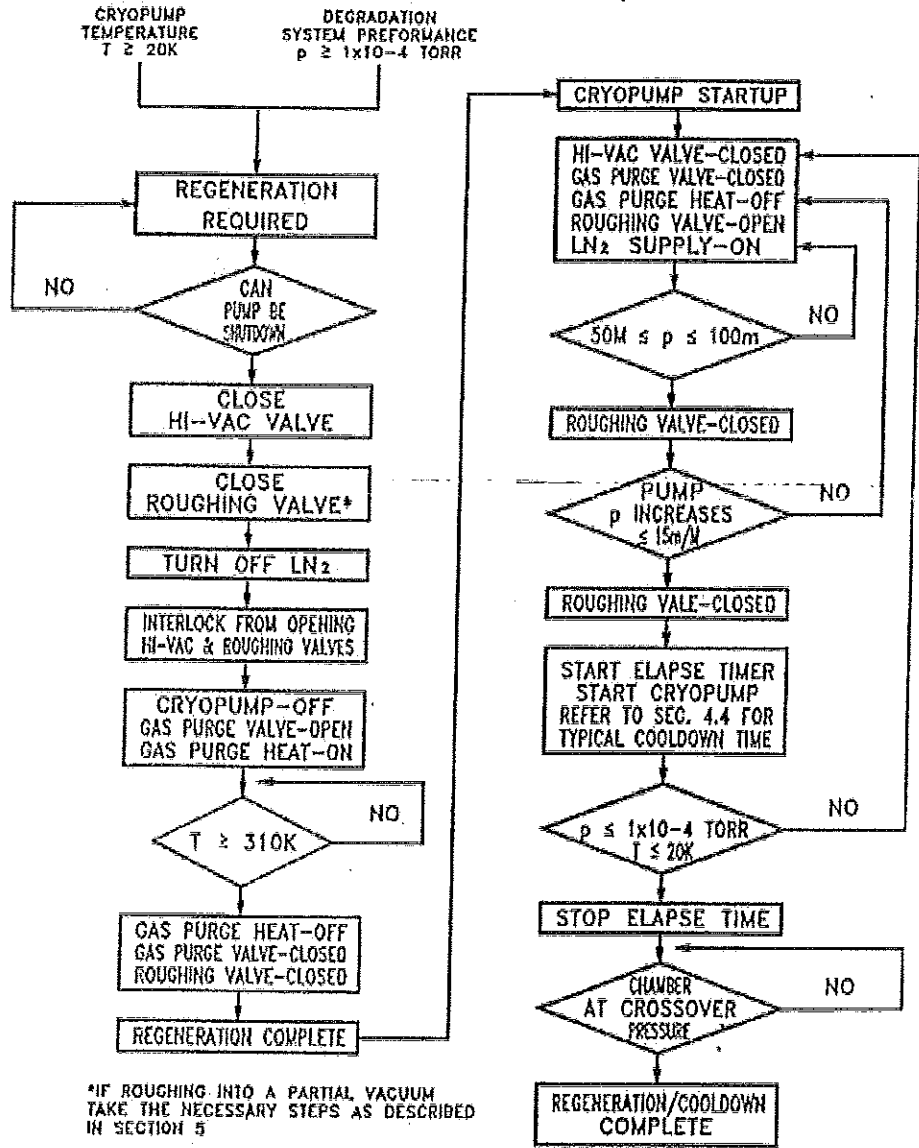
**Note:** When the cryopump is evacuated in the preparation for cooldown note the 2<sup>nd</sup> stage temperature. If there is a high degree of water remaining in the carbon then by evaporation cooling this 2<sup>nd</sup> stage temperature will drop. This can be used as an indicator of how much moisture there still remains in the carbon, i.e.; the degree of cleanliness and the regeneration effectiveness.

**Note:** Elapsed time to regeneration and the length of time for regeneration are strongly application dependant. Variables that can effect these times must be considered in any calculation. Some are: Amount of water pumped in relation to other component gases; heat load on the cryopump from ion gauges, chamber heaters, plasmas, evaporation sources or high ambient temperature; dominant gas load -hydrogen is hard to pump but easy to regenerate, water is easy to pump but hard to regenerate - relative gas loads of each effect regeneration and capacity.

### \*\*\*\* WARNING\*\*\*\*

Always use a clean roughing system when regenerating to avoid oil backstreaming into a cryopump. Oil vapors that reach the charcoal will stay there permanently, damaging the cryopumps capacity for non-condensable gases.

# REGENERATION CYCLE FLOW CHART/LN<sub>2</sub> CRYOPUMPS



\*IF ROUGHING INTO A PARTIAL VACUUM TAKE THE NECESSARY STEPS AS DESCRIBED IN SECTION 5

p=CRYOPUMP PRESSURE  
M=MICRONS T=CRYOPUMP TEMPERATURE  
K=DEGREES KELVIN (OK=-273)



## SECTION SIX

### TROUBLESHOOTING

#### 6.0 TORRMAS<sup>®</sup> TROUBLESHOOTING

Often the first indication of trouble in a vacuum system will be an observed loss of operating vacuum. This rise in pressure often goes undetected until it becomes severe enough to cause a shutdown. The use of a log book to monitor system characteristics is useful in spotting problems before they become serious.

The loss of operating vacuum in a system can generally be attributed to one of two factors:

- Malfunction in the system – check for leaks and inoperative components
- Failure of the vacuum pump

The troubleshooting procedures which follow are meant to help you, the user, characterize a problem and take corrective action. Many more of the common and some of the not-so-common problems are covered.

#### - IMPORTANT -

If there is some question concerning the characterization of a problem or a concern about the correction required, please call PHPK/CVI at (614) 488-6191 and ask for TorrMaster<sup>®</sup> cryopump technical assistance. When you call, please have the following information available to assist us in answering your questions:

- Model Number : **TM500**
- Serial Number :
- Operating Data such as:
  - Voltages, current, phase
  - Pressure – high, low, and static
  - Operating hours
  - Coolant flow and temperature
  - Vacuum levels generated
  - Regeneration frequency
- Operating Conditions
- Diagnosis of the Problems

These data will greatly assist PHPK/CVI personnel in discussing your problem and arriving at a solution.

<u>PROBLEM</u>	<u>POSSIBLE CAUSE</u>	<u>ACTION REQUIRED</u>
<b>COOLDOWN PROBLEM</b>		
Compressor and Coldhead are running but the cryopump does not cooldown OR cools down more slowly than expected.	Flexible gas lines may not be properly connected. (The pressure gauges may not be pulsing).	Check self-sealing fitting interconnections
	Insufficient helium gas flow	Check helium static pressure
	Incorrect instrumentation hookup	Check diode installation and hookup. Diode terminates on pins A and B on the cryopump electrical feedthrough. OR Check that the hydrogen vapor pressure thermometer is working and calibrates to the green dot when warm
	Lack of sufficient insulating vacuum in the cryopump. NOTE: This is often evidenced by the development of frost on the outside of the cryopump.	Check rate-of-rise
		Check that the roughing and HI-Vac valve are sealed when closed
		Check that the regeneration purge gas valve is closed
		Check that the cryopump pressure relief poppet valve is not leaking. Look for debris on the seal.
		Check the system vacuum pressure. Rough pump or regenerate the cryopump if necessary
	The cryopump is possibly contaminated from a large gas influx or incomplete regeneration	Regenerate the cryopump
	There is a large amount of residual helium remaining inside the cryopump. Has the chamber been recently leak checked?  YES NO	Regenerate the cryopump Call PHPK/CVI for assistance
	There is a high radiant heat load on the cryopump through the front baffle.	Check for line-of-sight or conductive thermal radiation to the cryopump. Install a shield if necessary
	The coldhead motor is running in reverse	Check for proper wire terminations in expander power cable. This is important if the cable is extended or modified.
	Mechanical fault in the compressor.	Check operating pressures of the compressor.
	The second stage seal may be worn on units that are several years old.	Call PHPK/CVI for assistance
<b>CRYOPUMPING PROBLEM</b>		
There is a sudden loss of cryopumping capacity.	Insufficient helium gas flow	Check helium static pressure
	Loss of helium charge.	Check helium static pressure
		Check for system helium leaks.
	The cryopump is possibly contaminated from a large gas influx or incomplete regeneration	Check vacuum system for source of influx. Check for necessity of regeneration. Purge vacuum system if necessary. This must be done if helium is in high concentration.  Regenerate the cryopump
	There is a loss of insulating vacuum.	Check vacuum system integrity. Is there a valve open that should not be?
		Correct the problem and regenerate the cryopump.
	Introduction of a large gas load of hydrogen, neon, or helium	Purge the vacuum system and cryopump. Regenerate the cryopump.
	Gross helium contamination locking up refrigerator drive mechanism. This is often accompanied or preceded by abnormal distressing sounds from the coldhead.	Decontaminate the refrigerator.
	Compressor malfunction.	Call PHPK/CVI for assistance
	Expander mechanism malfunctioned.	Call PHPK/CVI for assistance
	Loss of mechanical connection between the coldhead and arrays.	Inspection of array mountings. Replacement of the indium gaskets and tightening of the fasteners if necessary.

There is a gradual loss in cryopumping capacity.	Contamination of the array components from process by-products.	Clean or replace the array components.
<b><u>PROBLEM</u></b>	<b><u>POSSIBLE CAUSE</u></b>	<b><u>ACTION REQUIRED</u></b>
	Saturation of the carbon array with helium	Long term purge and regeneration to remove as much residual helium as possible. Final alternative is replacement of arrays.
	Contamination of the carbon array components with oil. Caused by rough pumping below 50 millitorr or by opening the roughing line while at high vacuum.	Replace the second stage panel and carbon surface assembly. Wipe the interior of the cryopump and the roughing line clean, using an appropriate solvent. Check operation of the roughing line valve and install a backstreaming trap if necessary.
	Gradual loss of helium charge.	Check gauges and recharge if necessary.
	The second stage seal may be worn on units that are several years old.	Call PHPK/CVI for assistance
Cryopump is running warmer than 20K and the chamber pressure is high	Gas load exceeded condensation capability of the cryopump.	Regenerate the cryopump
	High partial pressure of non-condensable gases (hydrogen, helium, neon) in the vacuum system. These can exceed adsorptive capability of the cryopump.	Regenerate the cryopump. Preferred manner is with a purge. Cooldown and check with previous runs. It may be necessary to regenerate more than once.
	Saturated cryopanel, possibly from a large gas influx caused by improper crossover, operator error or incomplete regeneration.	Regenerate the cryopump. Preferred manner is with a purge. Cooldown and check with previous runs. It may be necessary to regenerate more than once.
	Condensed process residue on the cryopanel.	Attempt to regenerate the residue away. If this does not work, clean off what residue is accessible and attempt regeneration. If this does not work, replace the contaminated arrays.
	Infra-red radiation into or onto pump from bake-out or deposition sources.	Identify source of radiation and shield pump in some manner.
	Vacuum leak.	Check the system for a leak. Possible areas: A. Roughing valve fully closed? B. Cryopump safety relief valve fully seated? C. Regeneration purge gas valve fully seated? D. Hi-Vac valve main seals & bonnet seals do not leak?
Cryopump is running colder than 20K and the chamber pressure is high.	Saturation of the carbon surface with hydrogen or helium or the attainment of the condensation capability of the cryoarrays. This will often be evidenced by the formation of frost on the outside of the cryopump.	Regenerate the cryopump.
	High partial pressure of non-condensable gases (hydrogen, helium, neon) in the vacuum system. These can exceed adsorptive capability of the cryopump.	Regenerate the cryopump. It is preferable to use the purge method of regeneration.
	Loose components inside the cryopump. The loss of thermal conductivity can be great enough to inhibit the condensation or adsorption of gases.	Regenerate the cryopump to room temperature. Inspection of array mountings. Replacement of indium gaskets and tightening of the fasteners if necessary.
There is good system vacuum but temperature reading is above 20K	Loss of mechanical connection between the coldhead heat station and the temperature sensor.	Inspection of the sensor mounting is necessary when the pump is at room temperature. Replacement of the indium gasket and tightening of the fastener is necessary.

## **LIQUID/GAS DIFFERENTIATING CRYOGENIC CONTROL VALVE**

### **INSTALLATION**

The CVI L/G Differentiating Control Valve is self-supporting, self-contained unit.

Installation can be accomplished by-

1. Wrapping the 1/4 “ MNPT nipple provided at base of valve with Teflon tape and threading it into a mating connection. Care should be taken when making the threaded connection, do not torques the valve body or body extension tube. Tightening should be accomplished using only the 1/4 “nipple.
2. No additional support is required except in cases of high vibration or possibilities of shock. If additional support is required, attachment should be made only to operator bolts (contact CVI.
3. If gas discharge is not to be vented to the atmosphere, please contact CVI prior to manifolding.
4. The control valve has been adjusted and tested prior to shipment. No additional adjustments should be necessary. Please contact CVI prior to any adjustments.

### **OPERATION**

The Liquid/Gas Differentiating Valve is designed to vent boil-off gases such as that generated from a cryogenic piping system. The valve requires no electrical or house air supply connection. A gas supply/pressure tap employs process stream pressure to operate the pneumatic diaphragm of the normally closed cryogenic valve. A capillary tube detects liquid or gas discharge which is translated to a  $\Delta P$  in the pressure regulator. The pressure regulator operates upon supply gas from the pressure tap. A proportional controlling effect is achieved from this arrangement which eliminates surging gas/liquid differentiating cryogenic valve is free from freeze-up in that the important design features of the Model V-1300 series valve are used to control the cryogen.

Minimum Control Pressure:	6 PSI
Maximum Control Pressure:	150 PSI
Inlet Connection:	1/4 “ Male Pipe Thread
Shipping Weight:	25 Pounds

## GN<sub>2</sub> VENT VALVE

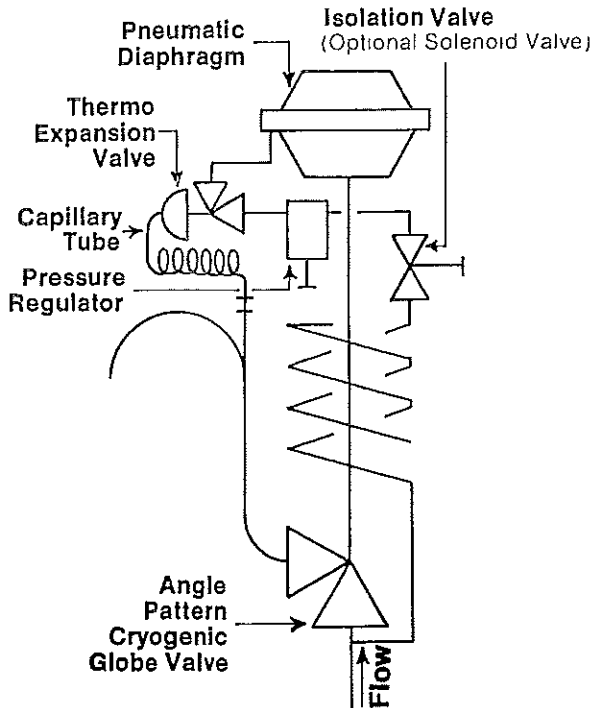
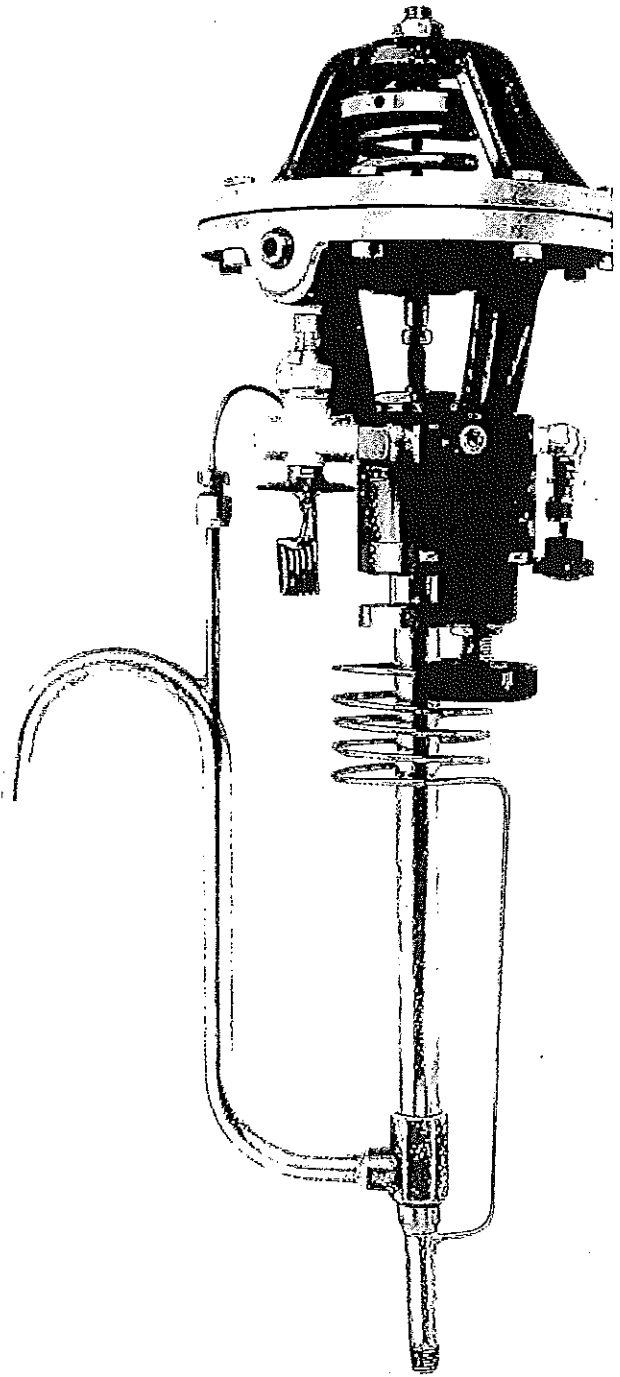
The quality of a cryogen can be noticeably improved at the discharge point by venting gas from two-phase flow. The CVI liquid/gas differentiating cryogenic control valve is designed to vent generated gas, such as from a cryogenic piping system or storage tank, without discharging the liquid.

The "vent" valve also can be used in any application where differentiating between gas and liquid is required, such as automatic cool-down on the discharge end of cryogenic equipment. The easily installed valve requires no electrical or house air supply connection.

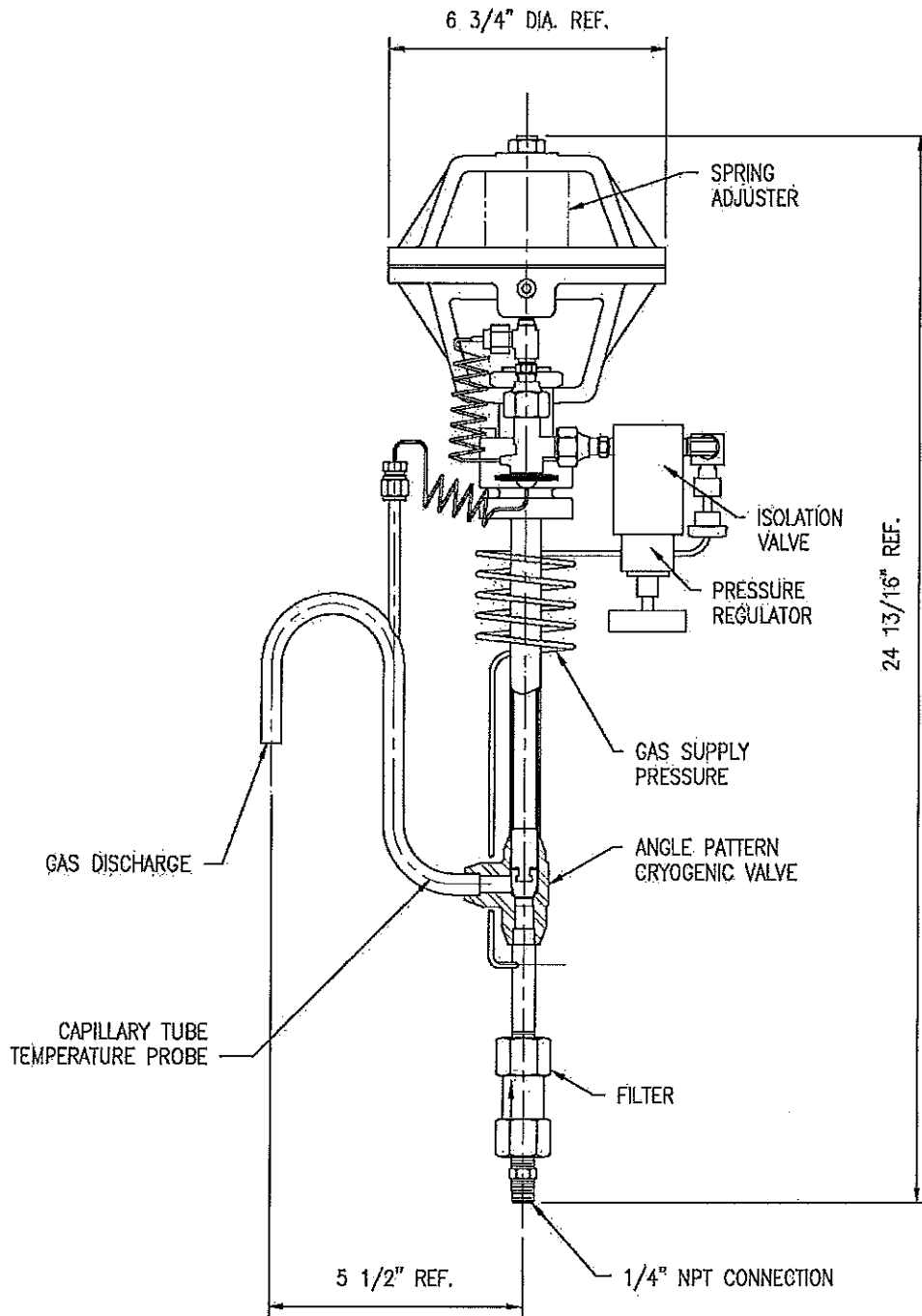
The gas supply/pressure tap employs process stream pressure to operate the pneumatic diaphragm of the normally closed cryogenic valve. A capillary tube detects liquid or gas discharge at the valve throat and translates the  $\Delta T$  to  $\Delta P$  through the pressure regulator to the pneumatic operator of the valve. This design achieves a proportional controlling effect, eliminating surging gas/liquid discharges.

A small gas supply valve can be closed for shut-down. When remote operation is needed, an optional solenoid isolation valve can be supplied for this purpose.

The liquid/gas differentiating cryogenic control valve is free from freeze-up, utilizing all the design features of the CVI Model V-1300 Series to control the cryogen.



Minimum control pressure: 6 psi  
Maximum control pressure: 150 psi  
Inlet connection: 1/4-in. male pipe thread



INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF PHPK AND IS NOT TO BE DISCLOSED OR TRANSMITTED TO UNAUTHORIZED PARTIES.

WEIGHT	WORK ORDER	CONTRACT NO.	PART NUMBER	NO. REQ'D	NEXT ASSEMBLY	SIZE
DRAWN		TOLERANCES		<b>PHPK</b> PHPK TECHNOLOGIES COLUMBUS, OHIO TITLE ASSEMBLY, FINAL, CRYOGENIC CONTROL VALVE LIQUID/GAS DIFFERENTIATING		
CHECKED		FRACTION	±1/8"			
ENGINEER		.XX	±.01			
REVIEWED		.XXX	±.005			
REL. DATE		ANGULAR	±1/2"	SIZE	DRAWING NO.	CHG.
DIMENSIONS ARE PROVIDED PRIOR TO SURFACE TREATMENTS UNLESS NOTED.			B	87-001-320	-	
				SCALE 3"=1'-0" (1=4)	SHEET 1 OF 1	

**IF YOU NEED TO RETURN EQUIPMENT CONTACT:**

**PHPK Technologies Inc./ CVI  
2111 Builders Place  
Columbus OH 43204 USA**

**Telephone: (614) 486-4750  
Fax: (614) 486-4950  
Email: [info@phpk.com](mailto:info@phpk.com)**

**Ask for TorrMaster® Cryopump Service**

**Before shipping any equipment to PHPK/CVI be certain to obtain an RMR number. This will allow PHPK/CVI to process your equipment in an efficient and timely manner.**

**Please include:**

**Model Number: TM500 LN2**

**Serial Number:**

**Customer Name:**

**Pack return items in their original packaging.**

**Ship items prepaid. Equipment will be returned to customer by the same carrier using the same class of service unless otherwise stated on any repair purchase order. Warranty repairs will be returned freight absorbed, using the same class of service.**

**NOTE: If items are going air freight, be sure to fill out a Hazardous Material form for those items containing compressed helium (compressor, cryopumps, refrigerators and flexlines).**

**Please include a brief explanation of the reason for return.**