CTI-CRYOGENICS
HELIX TECHNOLOGY CORPORATION

Multiple Uses of Model 22C/350C Cryodyne® Refrigerators

Installation, Operation and Servicing Instructions

8040272
Rev. 100 (7/2002)

HELIX TECHNOLOGY CORPORATION
www.helixtechnology.com

Any correspondence regarding this document should be forwarded to:

Helix Technology Corporation
Mansfield Corporate Center
Nine Hampshire Street
Mansfield, Massachusetts 02048-9171 U.S.A.

Telephone: (508) 337-5000
FAX: (508) 337-5464

The following Helix Technology Corporation trademarks and service marks may appear in this document:

Conductron™	Convectron®	Cryodyne®	Cryogen®
Cryogenerator®	Cryo-Torr®	CTI-Cryogenics®	FastRegen™
GOLDLink®	Granville-Phillips™	GUTS®	Helix Technology.. Your Vacuum Connection℠
Helix®	Micro-Ion®	Mini-Ion™	On-Board®
RetroEase®	RetroFast®	Stabil-1®	Stabil-Ion®
ThinLine™	TurboPlus®	Vacuum Assurance℠	

SAFETY CONSIDERATIONS

Your Cryodyne® Cryocooler has been engineered to provide extremely safe and dependable operation when properly used. Certain safety considerations need to be observed during the normal use of your cryocooler equipment. Warning blocks within the Manual text pinpoint these specific safety considerations. Warnings are defined as hazards or unsafe practices which could result in severe injury or loss of life.

⚠WARNING

HIGH VOLTAGE is present within the system and can cause severe injury from electric shock.

1. Disconnect the system from all power sources before making electrical connections between system components and also before performing Troubleshooting and Maintenance procedures.
2. Ensure that all electrical power switches on the controller/compressor units are in the off position before connecting the compressor unit to its power source.
3. Never connect the cold-head power cable to the cold head while the compressor is running.

HIGH GAS PRESSURE is present within the system and can cause severe injury from propelled particles or parts.

1. Do not modify or remove the pressure relief valves, either on the cold head or within the helium compressor.
2. Always depressurize the adsorber to atmospheric pressure before disposing of it.
3. Always bleed the helium charge down to atmospheric pressure before servicing or disassembling the self-sealing gas half-couplings.

BEFORE INSTALLING, OPERATING OR SERVICING EQUIPMENT, READ THIS MANUAL WHICH CONTAINS IMPORTANT SAFETY INFORMATION.

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Figures

Tables

Revision Status

Revision		Page
B	Revised pg. 1-4 and G-2 according to DEO 10634	3/95

Section 1 Introduction

1.1 General

The Model 22C/350C Cryodyne®Cryocooler provides reliable refrigeration at cryogenic temperatures for long, continuous periods. This cryocooler consists of multiple combinations of either the Model 22 and/or the Model 350CP Cold Heads.

For clarity purposes, due to the many variations of Model 22 and 350CP Cold Heads that can be combined with a compressor as a multiple cryocooler system, the cryocooler system will be identified throughout this manual as the "Model 22C/350C Cryodyne Cryocooler".

The Model 22C/350C Cryodyne Cryocooler, which uses helium as the refrigerant, is designed to interface with many kinds of apparatus that require cryogenic temperatures. The use of a Cryodyne cryocooler as a source of cryogenic temperatures offers a degree of freedom in the design of such interfacing apparatus (in particular, size and operational flexibility) that is generally unobtainable when a liquid refrigerant is employed. One immediate advantage of a Cryodyne cryocooler is that the cold head can be operated in any orientation without loss of performance. After the end of an operating period of the cryocooler, the cold head cold stations can be raised to ambient temperature in a relatively short time.

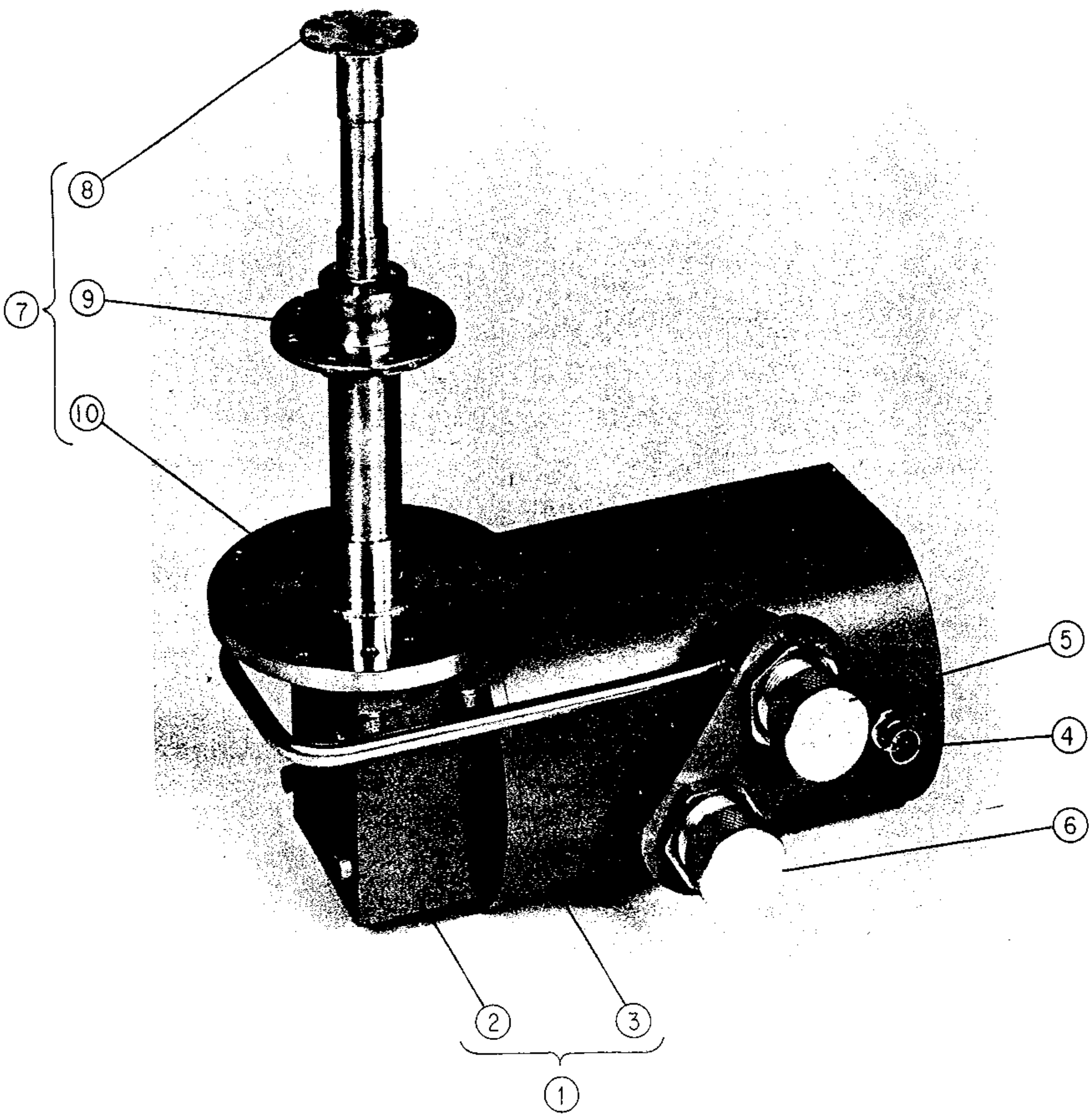
This manual provides instructions for initial inspection and installation, operation, and servicing of the Model 22C/350C Cryodyne Cryocooler. Your cryocooler is highly-reliable and rugged unit that requires a minimum of servicing. Functional descriptions of the major assemblies that comprise the cryocooler are detailed in Section 4. Servicing instructions are covered in Sections 5 and 6. Section 5 covers troubleshooting in simplified tabular format. Section 6 presents unscheduled maintenance instructions; no scheduled maintenance is required for the cryocooler.

1.2 Model 22/350C Cold Heads

Figures 1.1 and 1.2 show front and rear overall views of the cold heads, with identification of the major external components.

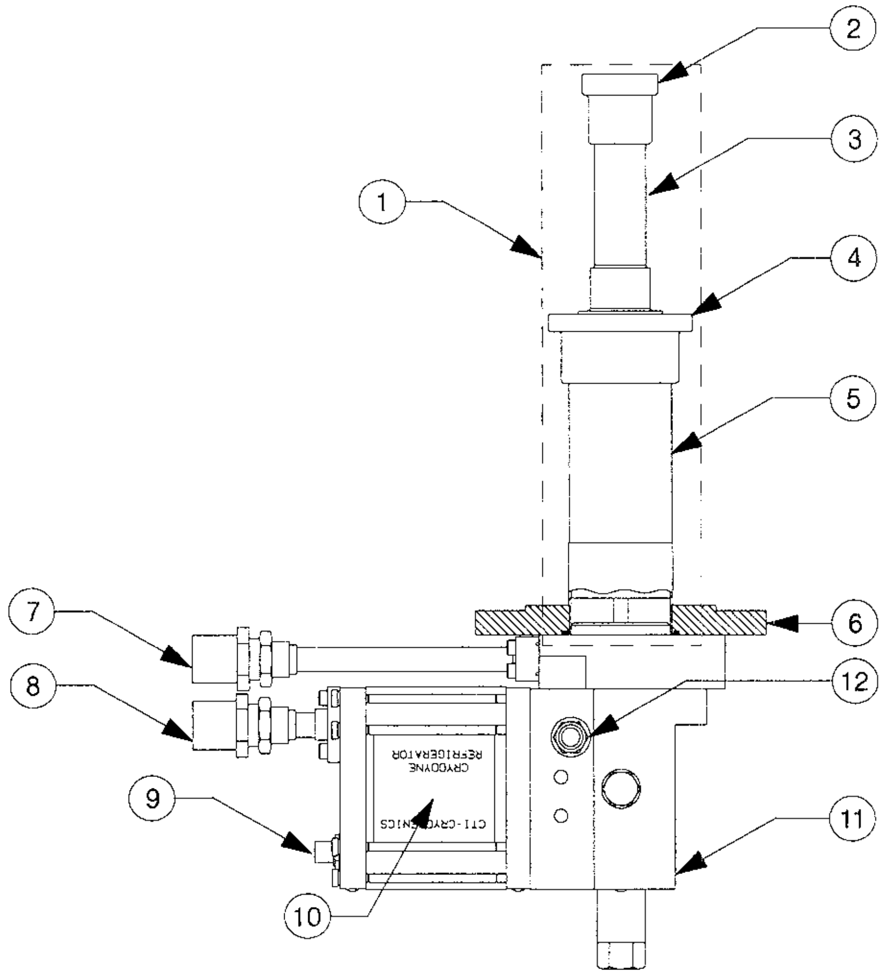
1.3 Specifications

Table 1.2 is a summary of specifications for the Model 22C/350C Cryodyne Cryocooler.



1. Drive Unit
2. Crankcase (Houses the Drive Mechanism)
3. Drive Motor
4. Power Connector
5. Gas Supply Connector
6. Gas Return Connector
7. Cylinder
8. Second-Stage Cold Station
9. First-Stage Cold Station
10. Top Flange

Figure 1.1 The Model 22 Cold Head



Legend

1. Cylinder
2. Second Stage Cold Station
3. Second Stage Cylinder
4. First Stage Cold Station
5. First Stage Cylinder
6. Top Flange
7. Helium Gas Supply Connector (with dust cap)
8. Helium Gas Return Connector (with dust cap)
9. Electrical Power Connector
10. Drive Motor
11. Crankcase (houses drive mechanism)
12. Pressure Relief Valve

Figure 1.2 The Model 350CP Cold Head

Table 1.1 Specifications for the Model 22C/350C Cryodyne Cryocooler

Cold Head

Dimensions (approximate):

COLD HEAD	LENGTH IN. (MM)	WIDTH IN. (MM)	HEIGHT IN. (MM)
Model 22	9.1 (231)	6 (152)	11.25 (286)
Model 350CP	11.9 (302)	6 (152)	18.50 (470)

Weight (approximate):

COLD HEAD	LBS.	KG
Model 22	14	6.5
Model 350CP	33	15.0

Power requirement	Supplied from the compressor
Ambient-temperature operating range	60°F to 100°F (16°C to 38°C)
Interface Data:	
Gas-supply connector	1/2-inch self-sealing coupling
Gas-return connector	1/2-inch self-sealing coupling
Orientation	The cold heads may be operated in any orientation.

Refrigeration Capacity:

Figures 1.3 and 1.4 are graphs showing typical refrigeration capacity of a Model 22C Cryodyne Cryocooler (at 60 Hz and 50 Hz respectively). The graphs in Figures 1.5 and 1.6 show typical refrigeration capacity of Model 350C Cryodyne Cryocooler at 60 Hz and 50 Hz.

Table 1.1 Specifications for the Model 22C/350C Cryodyne Cryocooler (Cont.)

Cold Head (Cont.)

The refrigeration capacities depicted in the above figures (Figures 1.3 through 1.6) represent typical performance from a multiple cryocooler system utilizing the full capabilities of the 8500 Compressor. Refrigeration capacities will increase for cryocooler systems which use less than full compressor output.

Temperature stability under constant load: ± 1.0K
(At the second-stage cold station)

No-load cooldown time to 20K:

Model 22C	25 minutes; 60 Hz power 30 minutes; 50 Hz power
Model 350C	40 minutes; 60 Hz power 50 minutes; 50 Hz power

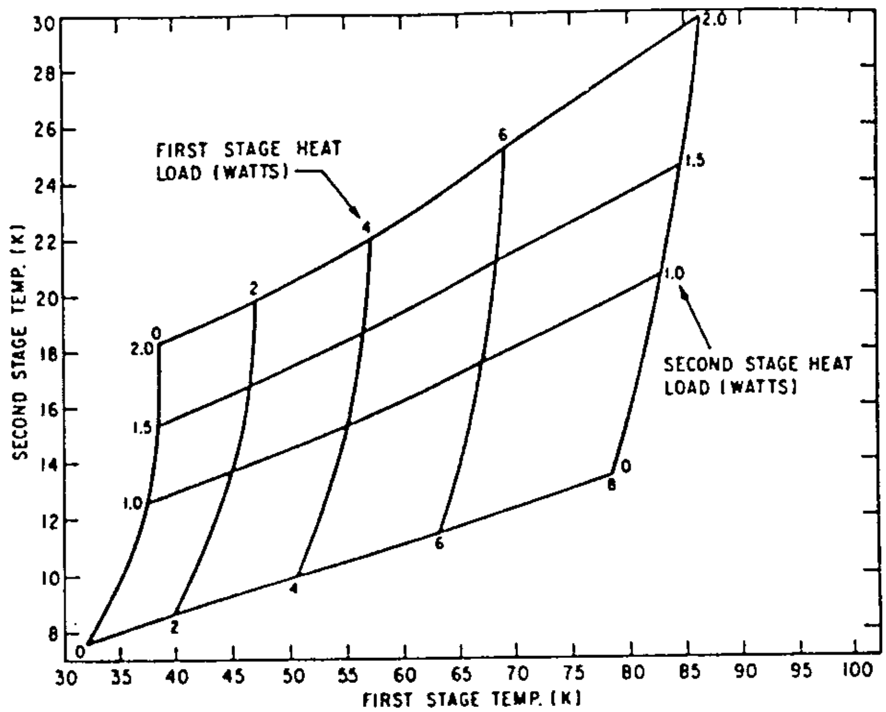


Figure 1.3 Typical refrigeration capacity of the Model 22C cryodyne cryocooler (60 Hz)

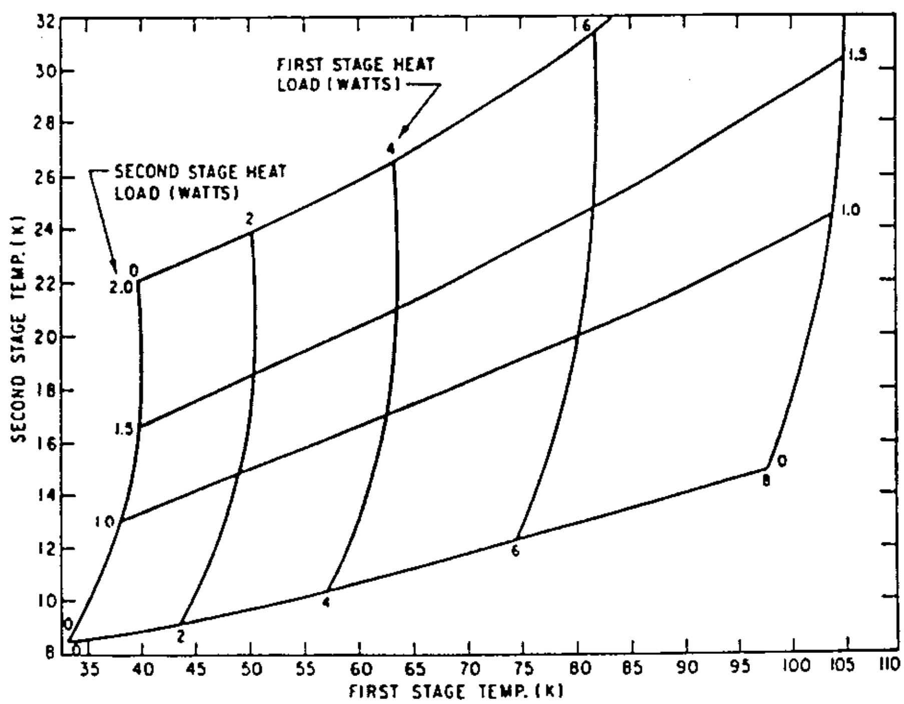


Figure 1.4 Typical refrigeration capacity of the Model 22C cryodyne cryocooler (50 Hz)

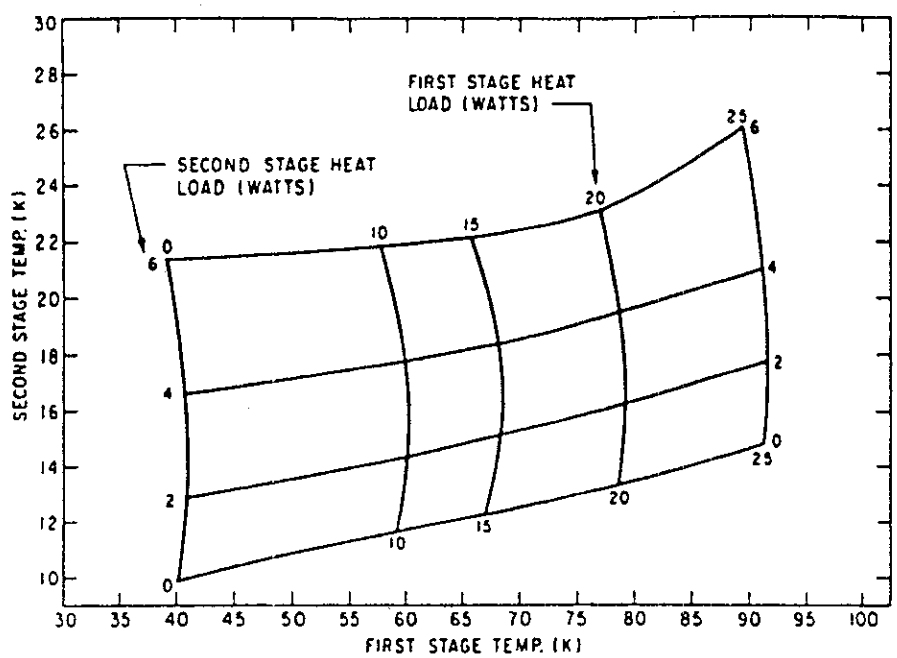


Figure 1.5 Typical refrigeration capacity of the Model 350C cryodyne cryocooler (60 Hz)

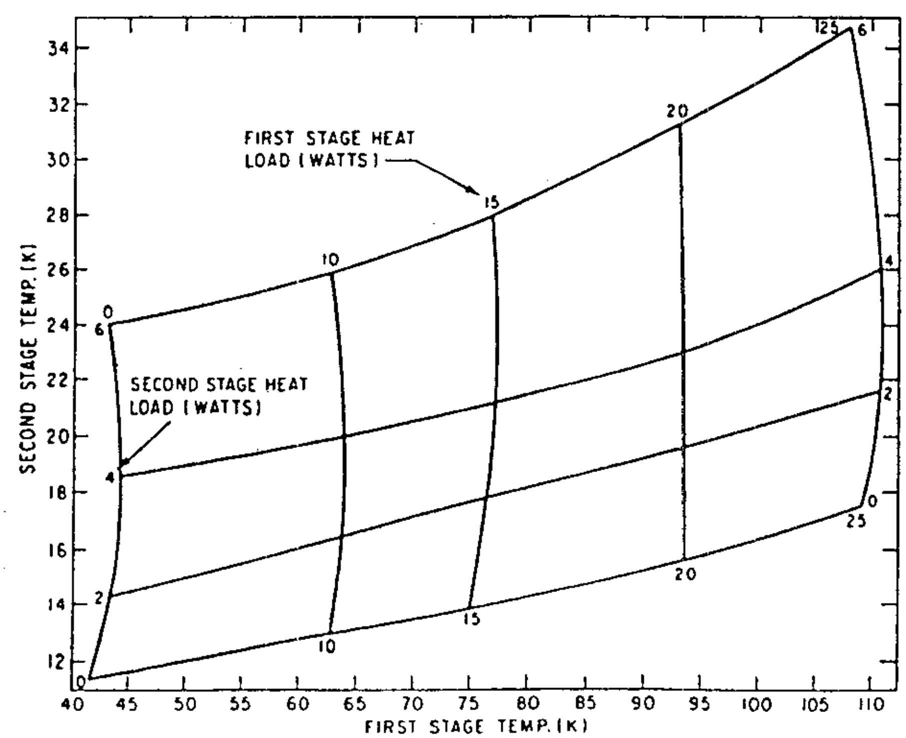


Figure 1.6 Typical refrigeration capacity of the Model 350C cryodyne cryocooler (50 Hz)

Section 2
Inspection and Installation

2.1 Inspection

Upon receipt, inspect the Model 22C/350C Cryodyne Cryocooler for evidence of damage as described below.

Report damage to the shipper at once.

Retain shipping cartons for storage or return shipment.

Inspect the exterior of each cold head for evidence of damage. Examples of such evidence are a bent cold station and a dented cylinder.

2.2 Cold Head Installation

Proceed as follows to install each cold head in your vacuum system. Refer to Appendix K, for the major interface dimensions of the Model 22/350CP Cold Heads.

1. Using a clean, lint-free cloth moistened with solvent such as acetone, carefully clean the groove for the O-ring in the mounting flange of your vacuum system.
2. Using a clean, dry cloth, ***sparingly*** lubricate the O-ring with low-vapor-pressure grease; for example, Apiezon "L" grease. Do not clean the O-ring with solvent.
3. Install the O-ring in the O-ring groove.
4. Carefully install the cold head on the mounting flange of your vacuum chamber.

Each cold head and related components must have adequate vacuum integrity for proper operation in your vacuum system. Inadequate vacuum will result in an unwanted gas conduction heat load from the room temperature vacuum housing to the cold surfaces of the cold head cold stations. A small vacuum leak will cause high-than-normal cold station operating temperatures, combined with a gradual temperature increase; a large vacuum leak may prevent satisfactory cooldown. The rough-pumping system should be isolated from your vacuum system, once cooldown has started, by closing the roughing valve.

It is recommended that a suitable pressure relief valve be installed in your vacuum system to prevent any possible positive pressure rise during warm-up.

2.3 Connecting the Cryocoolers to the Compressor

A component interconnection diagram for a multiple cryocooler installation is shown in Appendix I. Refer also to Figures 1.1, 1.2 and 1.3 for the location of components discussed below.

⚠WARNING

Do not connect the compressor to its power source until all connections have been made between the components of the cryocooler.

Make the connections between the cryocoolers and compressor:

1. Remove all dust plugs and caps from the supply and return lines, compressor, and cold heads. Check all fittings.
2. Install all helium tees to the compressor or cold heads.
3. Connect the helium return line from the gas-return connector on the rear of the compressor to the gas-return connector on the cold head.
4. Connect the helium supply line from the gas-supply connector on the rear of the compressor to the gas-supply connector on the cold head.
5. Verify proper helium supply static pressure by confirming that the helium pressure gauge reading and ambient temperature range are as specified in the Model for the CTI compressor being used.

   This static pressure applies to a typical multiple cryocooler installation using 10-foot interconnecting lines. If your installation has longer interconnecting lines, then contact the Product Service Department for assistance in calculating the static pressure.

   If the indicated pressure is higher than what is specified in your compressor manual, reduce the pressure as follows:

   a. Remove the flare cap from the gas charge fitting located on the rear of the compressor.

   b. Open the gas charge valve very slowly. Allow a slight amount of helium gas to escape until the helium pressure gauge reads the value indicated in your compressor manual.

   c. Close the gas charge valve and reinstall the flare cap.

   If the indicated pressure is lower than the specified value, add helium gas as described in Section 6.2.

6. The last step required for installation is making electrical connections:

⚠WARNING

The system power switch on the compressor must be in the OFF position before making any and all electrical connections.

   a. Connect the cold head power cable(s) to the rear panel of the compressor and the other end to the electrical power connection on each cold head.

   b. Plug the compressor input power cable into the power source.

Section 3
Operation

Do not begin the Model 22C/350C Cryodyne Cryocooler operation until all steps in the inspection and installation procedures have been completed and confirmed.

3.1 Operating Log

It is highly advisable to create and maintain a detailed operating log. The record will assist in troubleshooting should problems arise. Appendix A contains a sample operating log for your use. You may wish to make photocopies of this sample log.

3.2 Installing the Load

The load can be either attached directly to the cold station concerned or coupled to it with heat wicks (braided copper straps). Indium foil that is 0.002 to 0.005 inch thick should be used between the mating surfaces to improve thermal conduction.

When the installation of the load has been completed, rough-pump your vacuum chamber down to 5×10^{-2} torr or better. Then close the roughing valve prior to starting the cooldown of the cryocooler. Upon cooldown, the refrigerator will cryopump residual gases in the chamber and an insulating vacuum between 10^{-4} and 10^{-5} torr will be achieved.

3.3 Start-up and Cooldown Procedures

1. Ensure the roughing valve is closed.
2. Turn on the system power ON/OFF switch to operate the compressor and cold heads. Record helium pressure and temperature reading during the initial cooldown.
3. During cooldown, record the operating log data at 15-minute intervals. To ensure minimum cooldown time, do not apply electrical power to any load during the cooldown.

The cooldown time associated with a normal cooldown with no load attached to the second-stage cold head is specified in Table 1.1. The cooldown time will increase approximately 15 minutes for each pound-of-mass increase of the attached load.

Pressure regulation during a cooldown is automatic. The compressor will vary during cooldown but will usually attain steady values nominally within 45 minutes after cooldown.

3.4 Normal Operation

The components of the cryodyne cryocooler are designed to operate without operator assistance. During the first 100 hours of operation a slight drop in compressor pump oil level may occur, but a drop is of no concern as long as the oil level is visible. If oil level is not visible, contact the Product Service Department.

The helium return pressure gauge should be checked once a week and the reading noted in the operating log. If the gauge reading falls outside the satisfactory operating range as specified in your compressor manual, refer to Section 5, Troubleshooting Procedures.

⚠CAUTION

Never exceed operating compressor return pressure higher than the value specified for your compressor. Compressor damage can occur.

3.5 Shutdown Procedures

1. Close the Hi-Vac valve between the cold head and its vacuum chamber.
2. Turn off the system power ON/OFF switch on the compressor to shut down the compressor and cold heads. If you desire to individually shut down a cold head, a remote switching circuit should be installed. Contact the Product Service Department for assistance.
3. It will take many hours to warm the cold head cylinder to ambient temperature with no heat load present. If a rapid warm-up is desired, break the vacuum with a clean, dry gas, such as nitrogen or argon. If this method is used, leave the valve open to allow the expanding gas to escape as the cylinder warms.

3.6 Storage

The cryocooler is fully protected during storage if kept under positive helium pressure and all components left connected. Periodically check the helium return pressure gauge on the compressor. If the gauge reads below the specified value in your compressor manual, add helium as described in Section 6.2.

If the cold head is removed from your vacuum system, be careful not to damage the cold head cylinder and sealing surfaces.

Section 4
Functional Description

This Section presents additional detail description of each cold head and the compressor. Knowledge of the content of this Section is not required in order to operate your cryocooler. The information is included in this Manual for the benefit of those readers who desire a more comprehensive understanding of the functional operation of the Cryodyne cryocooler.

4.1 Model 22/350CP Cold Heads (see Figures 1.1 and 1.2)

The function of each cold head is to produce continuous closed-cycle refrigeration at temperatures that, depending upon the heat load imposed, are in the range of 40K to 100K for the first-stage cold station and in the range of 10K to 20K for the second-stage cold station.

The cold head has three major components: the drive unit; the cylinder; and the displacer-regenerator assembly, which is located inside the cylinder.

The drive unit consists of the following subassemblies: the drive motor; the crankcase; and the drive mechanism, which is located inside the crankcase. The drive unit actuates the displacer-regenerator assembly and controls the flow of helium into and out of the cold head.

The motor employed is a direct-drive, constant-speed motor that operates at the following speeds for 50 or 60 Hz power applications.

COLD HEAD	FREQUENCY (HZ)	MOTOR RPM
Model 22	50 60	167 200
Model 350CP	50 60	60 72

Each motor housing has two connectors: one is the electrical power connector, through which power is supplied; the other is the helium-gas return connector.

Functionally, the incoming high-pressure helium gas from the compressor enters the cold head through the helium-gas supply connector. The gas then passes into the displacer-regenerator assembly, flows out through the displacer-regenerator assembly, into the crankcase, through the motor housing, and finally through the helium-gas return connector to the compressor. The helium gas expansion in the displacer-regenerator assembly provides cooling at the first and second-stage cold stations, each at different temperatures.

Refer to Appendix C for a detailed explanation on the principles of operation.

Section 5
Troubleshooting

5.1 Troubleshooting the Cold Head

Most of the problems in the troubleshooting tables are followed by several possible causes and corrective actions. The causes and corresponding actions are listed in their order or probability of occurrence. 1) is most likely, 2) is next most likely, etc.

Maintaining a log of the readings (see Appendix A, Figure A.1) of the temperature indicator during normal operation is a valuable tool in troubleshooting the cold head. Values higher than 20K indicate that the second-stage cold station is too warm. A temperature below 20K means the cold head is cold enough for operation.

5.2 Technical Inquiries

Please refer to page ii of this manual for a complete list of the CTI-CRYOGENICS' world wide customer support centers.

Table 5.1 Cold Head Troubleshooting Procedures

Problem	Possible Cause	Corrective Action
1) The cold head fails to cool down to the required operating temperature, or takes too long to reach that temperature.	1) Low system charge pressure in the compressor.	1) Refer to Adding Helium Gas, Section 6.2.
	2) Vacuum leak in your vacuum system.	2) Check your vacuum system for leaks.
	3) Excessive heat load.	3) Eliminate excessive heat load.
	4) Contamination of the helium gas.	4) Refer to Decontamination Procedures, Section 6.2.
2) The cold head drive unit fails to run, even though the compressor is operating.	1) Lack of power from the compressor.	1) a. Ensure that the system power ON/OFF switch on the compressor is on. b. Ensure that the cold head power is properly attached to the electrical power connector of the cold head drive unit. c. Contact the Product Service Department for assistance.
	2) An internal malfunction in compressor.	2) Contact the Product Service Department for assistance.
3) The cold head drive unit operates erratically, usually accompanied by considerable noise.	1) Contamination of the helium gas.	1) Decontaminate per Section 6.2.
	2) Internal malfunction of the cold head.	2) Contact the Product Service Department for assistance.

Section 6
Unscheduled Maintenance

Two types of unscheduled maintenance may be required from time to time. These are 1) the addition of helium gas to the cryodyne cryocooler, and 2) helium circuit decontamination.

6.1 Maintenance Equipment

Your CTI-CRYOGENICS compressor is supplied with appropriate maintenance equipment and disposable supplies for servicing this unit. In addition, you should have a Maintenance Tool Kit, P/N 8140000K001, that provides wrenches, etc. for connecting self-sealing Aeroquip couplings between the cold head(s) and the compressor. The specific contents of this kit are listed in Appendix B.

6.2 Adding Helium Gas

Refer to the Maintenance section of the manual for your CTI-CRYOGENICS compressor for detailed instructions on adding helium gas to your cryodyne cryocooler.

6.3 Helium Circuit Decontamination

Contamination of the helium-gas circuit is indicated by sluggish or intermittent operation (ratchetting) of the cold head drive mechanism. With severe contamination the cold head drive may seize and fail to operate. One of the major sources of contamination is using helium gas of less than the required purity. When performing the decontamination process, use only 99.999% pure helium gas, and the regulator and charging line must be properly connected and purged.

This decontamination procedure will remove contaminants from the cold head and/or compressor thereby restoring performance. The coldtrapping of contaminants inside the cold head during this procedure will also decontaminate the compressor if the contamination of the system is not severe. Separate decontamination of the compressor is required whenever the compressor has been opened to atmosphere, or the pressure has dropped to zero.

6.4 Cold Head Decontamination Procedures

1. Cool down the cold head and operate it for one to three hours. If the system will not cool down, proceed to step 2. Operating the cold head will isolate the contaminants by "freezing" them in the cold head. The contaminants in the helium gas circuit of the refrigerator tend to become frozen inside the cold head. The longer the cold head is operated beyond the one-hour period, the greater is the amount of contamination that becomes isolated inside the cold head.
2. Shut down the cold head per Section 3.5.
3. ***Immediately*** disconnect the helium supply and return lines from the gas-supply and gas-return connectors located at the rear of the compressor. Leave them attached to the cold head.
4. Attach the maintenance manifold to the disconnected ends of the helium return and supply lines.

5. Reduce the pressure in the cold head to a level of 30 psig by using the maintenance manifold. Reducing the pressure in the cold head below 30 psig (200 kPa) may introduce more contaminants into the helium circuit.
6. Allow the second-stage of the cold head to warm up to room temperature. The warm-up time can be decreased by backfilling the vacuum chamber to one atmosphere with dry argon or nitrogen gas. Using the gas heater, CTI P/N 8080250K020, will reduce the warm-up time about 50 percent, and will maintain the gas temperature below 150°F (66°C) limit.
7. Once the cold head has reached room temperature, attach a two-stage regulator (0-3000/0-400 psig) and charging line to a helium bottle (99.999% pure). DO NOT OPEN THE BOTTLE VALVE AT THIS TIME. Purge the regulator and charging line as instructed in steps a through d below. Do ***not*** use helium gas that is ***less than 99.999% pure.***
   a. Open the regulator a small amount by turning the adjusting knob clockwise until it contacts the diaphragm, then turn approximately 1/8 to 1/4 turn more, so that the regulator is barely open.
   b. Slowly open the bottle valve, and purge the regulator and line for 10 to 15 seconds. Turn the regulator knob counterclockwise until the helium stops flowing.
   c. Loosely connect the charge line to the 1/8-inch Hoke valve on the maintenance manifold.
   d. Purge the charge line again, as in step a, for 30 seconds, and tighten the charge line flare fitting onto the Hoke valve while the helium is flowing.

This procedure is required to ensure that both the regulator and the charging line will be purged of air and that the air trapped in the regulator will not diffuse back into the helium bottle. For best results, CTI suggests a dedicated helium bottle, regulator, and line, which are never separated, for adding helium.

8. Perform in sequence:
   a. Backfill the cold head with helium to a static charge pressure of 200-205 psig (1380-1415 kPa) by adjusting the regulator to the required pressure, and opening the Hoke valve on the manifold. Close the Hoke valve when the pressure is correct.
   b. Depressurize the cold head to 30 and 50 psig (200 and 330 kPa) by slowly opening the ball valve and allowing the helium to bleed out slowly. Do ***not*** reduce the pressure to ***less than*** 30 psig or the cold head may be further contaminated.
   c. Perform the flushing steps a and b four times.
   d. Pressurize the cold head to the static charge pressure specified in your compressor manual and run the cold head drive motor for 10 to 30 seconds by actuating the cold head ON/OFF switch to on.
   e. Perform steps b through d four times for a total of 25 flushes and a total of 5 drive-motor runs.
9. Verify that the cold is pressurized to the same static charge pressure as determined in step 8d above.
10. Disconnect the maintenance manifold from the helium return and supply lines.
11. Reconnect the helium return and supply lines to the return and supply connectors located at the rear of the compressor. The cold head is now ready for operation.

Appendix A

Operating Log

The operating log sheet included as Table A.1 in this Appendix should be reproduced for your use with the Model 22C/350C Cryodyne Cryocooler. It is important to maintain an operating log, especially when operating the cryocooler for the first time or in a new installation. Readings of the compressor pressure gauge and the vacuum chamber should be recorded during cooldown, and also while the cryocooler is operating under normal load conditions. (Readings of the cold station temperature, as well as the cooldown time from ambient temperature to 20K, should also be recorded, if a means for obtaining such data is available.)

These records may be extremely useful later, both in recognizing degradation of performance and in troubleshooting. During start-up and cooldown, data should be recorded at 10-minute intervals. During normal operation, these data should be recorded daily.

TABLE A-1
OPERATING LOG SHEET

Date__________

Sheet__________ of __________

Serial Numbers

Cold Head__________ Electrical: Volts______ Hz______ Test No.__________ Run No. __________

Compressor Unit__________ Test Technician__________

Reading				Ambient Temp. (°K)	Cold-Station Temperature (°K)	Pressure (psig)	Vacuum In User's Vacuum Chamber (torr)	NOTES
Date	No.	Time	Elapsed Time					

Appendix B

Installation Tool Kit
(Kit No. 8032040G016)

ITEM NUMBER	QUANTITY	DESCRIPTION
1	1	1 inch open-end wrench, Armstrong, for self-sealing coupling
2	1	1 1/8-inch open-end wrench, Armstrong, for self-sealing coupling
3	1	1 3/16-inch open-end wrench, Armstrong, for self-sealing coupling
4	1	Depressurization Fitting, 1/2 inch

Appendix C

Principles of Operation

The following Technical Data sheet explains the principles of operation by which the cold head and compressor employed in the Cryodyne cryocooler achieve cryogenic levels of refrigeration.

TECHNICAL DATA CRYODYNE® CLOSED CYCLE HELIUM REFRIGERATORS

The cooling process (cycle) of CRYODYNE Helium Refrigerators is analogous to that of common household refrigerators. In the latter, a working fluid (freon gas) is compressed, the heat of compression removed by air-cooled heat exchangers, and the gas is then expanded to produce cooling below the ambient temperature. This simple compression-expansion process will suffice for the household refrigerator, where temperatures in the sub-zero fahrenheit range are required. However, CRYODYNE systems must operate effectively and routinely at temperatures down to 6K (-449°F). Attainment of such extreme low levels requires highly efficient heat exchangers, and the use of a working fluid (helium gas) that remains fluid at temperatures approaching absolute zero (-459.6°F, -273.1°C, 0K).

All CRYODYNE systems comprise an air-cooled or water-cooled, oil-lubricated compressor unit with oil separation system (carry-over oil vapors would solidify at cryogenic temperatures and plug the heat exchangers of the refrigerator); and a refrigerator unit (remotely located from the compressor), which operates at slow speeds, has ample clearances, and

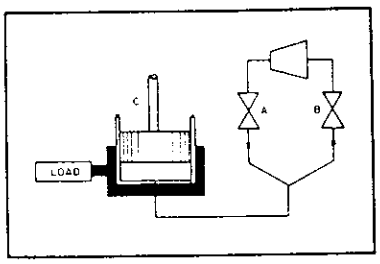


Figure 1 Elementary Cooling Circuit

has room-temperature valves and seals.

The flow of helium in the refrigerator is cyclic. The sequence of operations can be illustrated by a single cylinder and piston (Figure 1).

A source of compressed gas is connected to the bottom of cylinder C through inlet valve A. Valve B is in the exhaust line leading to the low-pressure side of the compressor. With the piston at the bottom of the cylinder, and with valve B (exhaust) closed and valve A (inlet) open, the piston is caused to move upward and the cylinder fills with compressed gas. When valve A is closed and valve B is opened, the gas expands into the low-pressure discharge line and cools. The resulting temperature gradient across the cylinder wall causes heat to flow from the load into the cylinder. As a result, the gas warms to its original temperature. With valve B opened, and valve A closed, the piston is then lowered, displacing the remaining gas into the exhaust line, and the cycle is completed.

This elementary system, while workable, would not produce the extreme low temperatures required for uses to which the CRYODYNE refrigerators are applied. Thus the

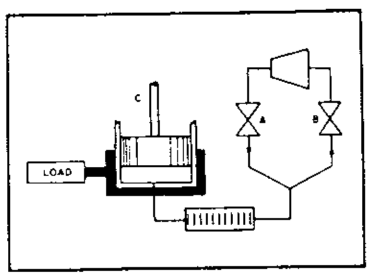


Figure 2 Cooling Circuit with Regenerator

incoming gas must be cooled with the exhaust gas before the former reaches the cylinder. This is accomplished in the CRYODYNE refrigerator by a regenerator, which extracts heat from the incoming gas, stores it, and then releases it to the exhaust stream (Figure 2).

A regenerator is a reversing-flow heat exchanger through which the helium passes alternatively in either direction. It is packed with a material of high surface area, high specific heat, and low thermal conductivity, that will readily accept heat from the helium (if the helium's temperature is higher) and give up this heat to the helium (if the helium's temperature is lower).

In steady-state operation, a system of this type exhibits the characteristic temperature profile of Figure 3. The steps of the cycle are as follows:

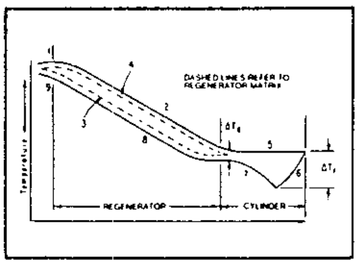


Figure 3 Temperature Profile of a Single-Stage Cryodyne Refrigerator

a. With the piston at the bottom of its stroke, compressed gas enters through valve A at room temperature (1).
b. As the piston rises, the gas passes through the regenerator. The matrix absorbs heat from the gas (warming from 3 to 4), and the gas cools.
c. Still at inlet pressure, the cooled gas fills the space beneath the piston. The gas temperature at this point (5) is about the same as that of the load.
d. Valve A closes and exhaust valve B opens, allowing the gas to expand and cool further as it does so (6). The temperature drop (ΔT_1) is responsible for the refrigerating effect.
e. Heat flows from the load through the cylinder walls, warming the gas to a temperature slightly (ΔT_1) below that at which it entered the cylinder (7).
f. As the gas passes through the regenerator, it warms up (8) as it receives heat from the matrix, and the matrix is cooled (4) to (3).
g. The piston descends, pushing the remaining cold gas out of the cylinder and through the regenerator. However, because the regenerator is not 100 percent efficient, there is always a temperature difference between the gas and the matrix; thus, at any point shown in the diagram, the exhaust gas remains slightly cooler than the inlet gas.
h. The low-pressure gas leaves through valve B at approximately room temperature (9).

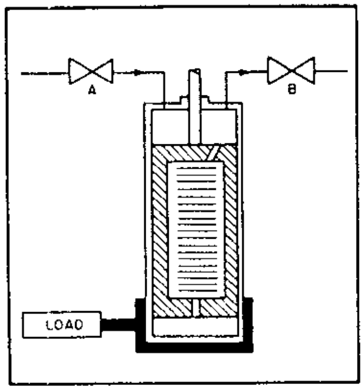


Figure 4 Improved Single Stage Refrigerator

In the system of Figure 2, the piston would require a pressure seal and would have to be designed to withstand unbalanced forces. A more practical version of this cycle is shown in Figure 4. This system uses a double-ended cylinder and an elongated piston made from a material of low thermal conductivity.

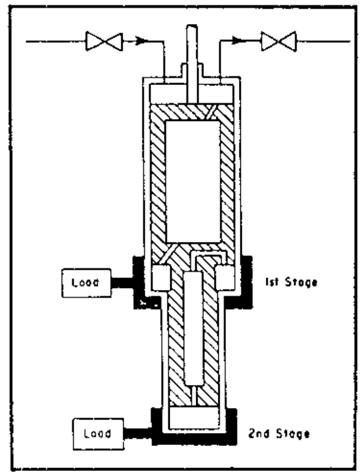


Figure 5 Two-Stage Cryodyne Refrigerator

Since the pressures above and below the piston are substantially equal, the piston needs no pressure seal. The piston is now more correctly called a "displacer," because it merely moves gas from one end of the cylinder to the other; no mechanical work is introduced, and thus the system is said to use a "no-work" cycle. The regenerator is placed inside the displacer to avoid unnecessary piping and to minimize heat losses.

The refrigerator shown in Figure 4 can achieve temperatures in the 30-77 K range. Since many of the applications of the CRYODYNE refrigerator are below that temperature, we can add a second, and even a third stage to produce temperatures below 10K.

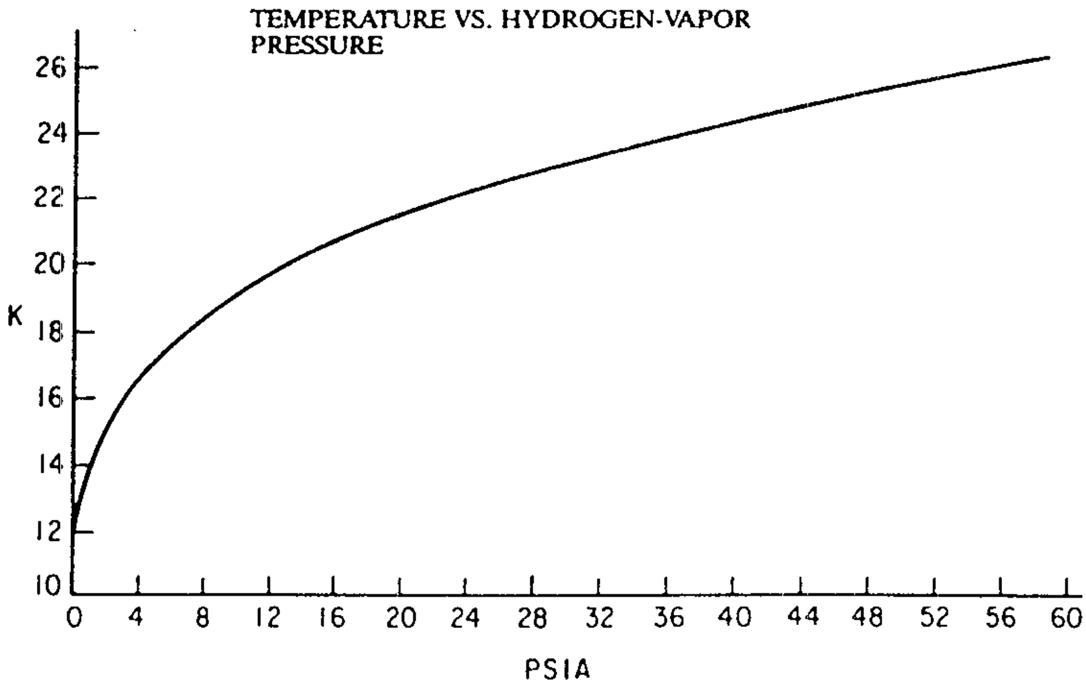
The addition of a second stage (Figure 5) permits useful refrigeration down to 6 K.

Appendix D

Conversion of Hydrogen-Vapor-Pressure Gauge Readings to Temperature

Use the data given below to convert a reading of the hydrogen-vapor-pressure gauge (in psia) to the temperature of the second-stage cold station (in degrees Kelvin).

The hydrogen-vapor-pressure gauge should not be used to measure temperatures higher than 26K.



PSIA	K	PSIA	K
0	Less than 12	15	20.5
1	13.9	18	21.1
2	15.2	21	21.7
3	16.0	24	22.2
4	16.7	27	22.6
5	17.2	30	23.1
6	17.7	35	23.7
7	18..1	40	24.3
8	18.5	45	24.8
10	19.2	50	25.3
12	19.7	55	25.8

Appendix E

Establishing Gas Charge Pressure of Multi-Cryocooler Installations

To establish the helium gas charge pressure of a multiple cryocooler installation using interconnecting lines longer than ten feet proceed as follows:

1. Interconnect the Cryodyne cryocooler components as described in Section 2.4.
2. Attach a helium bottle, regulator, and charging line to the compressor as described in Section 6.2.2, under Adding Helium Gas, step 1 through 3.
3. Turn on the system power ON/OFF switch. If the remote energizing feature is installed (refer to Appendix G) place the remote ON/OFF switches to on so the cold heads will run.
4. Note the helium pressure gauge reading immediately after start-up it should read 50-100 psig (345-690 kPa).
5. If necessary add helium gas, refer to Section 6.2.2, or reduce the helium gas pressure as described in Section 2.4.
6. Allow the cold heads to operate until a cooldown temperature of 20K or less is reached. Adjust the helium pressure if necessary as described in step 5 until the helium pressure gauge reads 80-100 psig (550-690 kPa) while the compressor is operating.
7. Shut off the compressor and cold heads. Allow the system to reach ambient temperature, this usually takes approximately four to five hours.

   Note: Record the compressor static pressure in your operating log. This is the static pressure for your particular installation and should be used for checking compressor performance or when troubleshooting the installation.

8. Ensure that the helium charge valve on the compressor is tightly closed. Then shut off the helium pressure regulator or the helium bottle. Remove the charging line from the male flare fitting and reinstall the flare cap.

Appendix F

Component Interconnection for Multiple Cryodyne Cryocoolers

Figure F.1 depicts a typical multiple cryocooler installation. As shown in this figure, an electrical power cable is connected to each cold head; also, the components are helium connected in parallel (all supply fittings piped together and all return fittings piped together). Table F.1 in this Appendix is a generic equipment list for components required for each particular multiple cryocooler configuration used with a CTI-CRYOGENICS 8500™ Compressor. For further assistance, contact CTI-CRYOGENICS Applications Engineering.

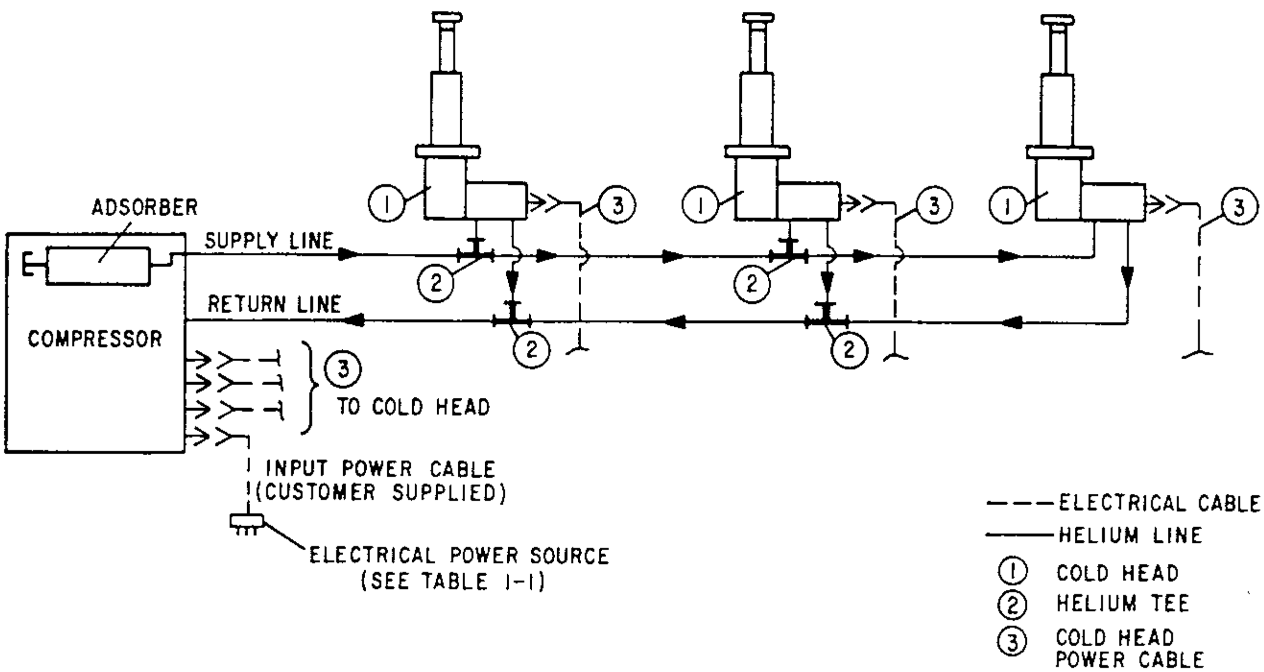


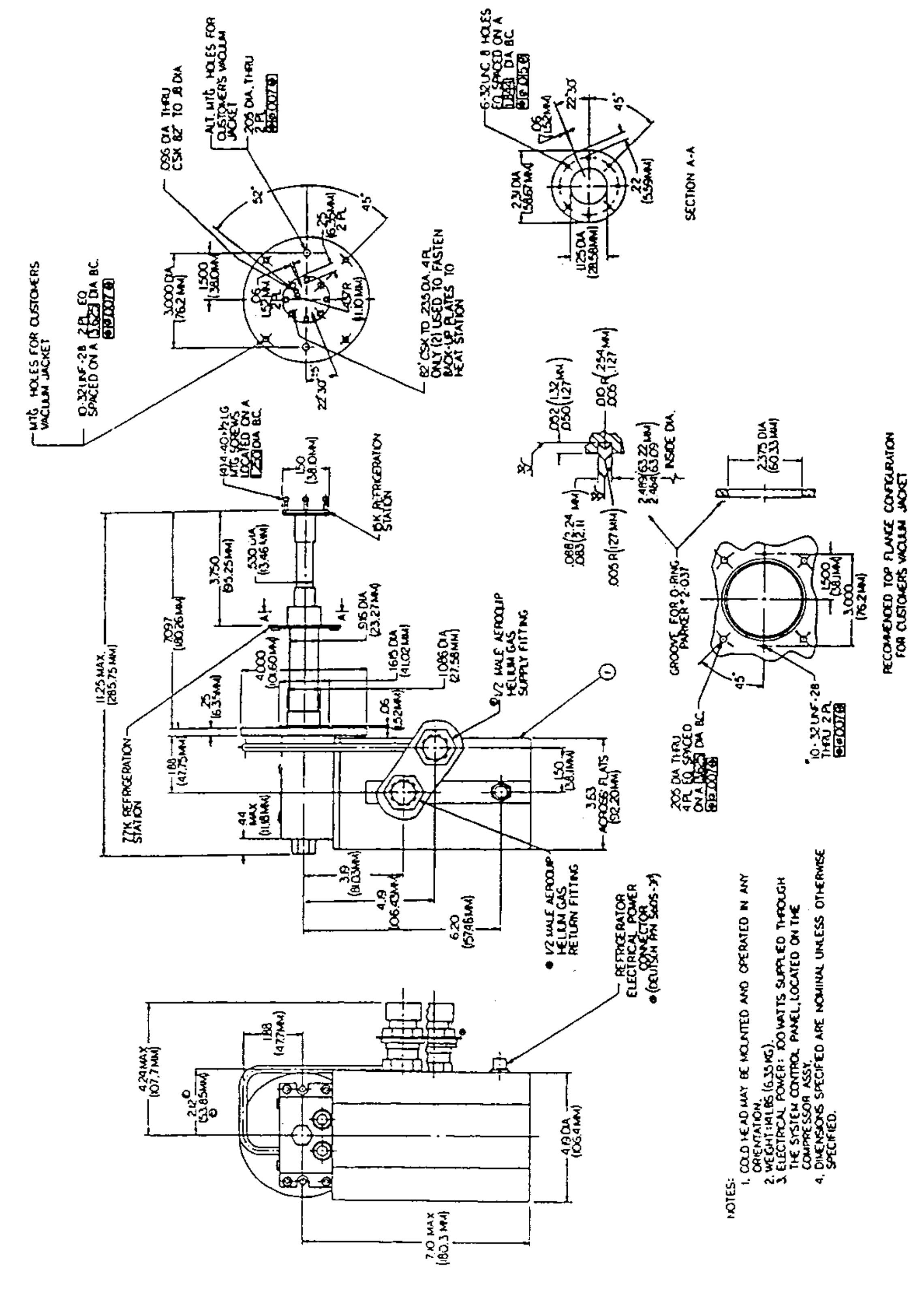
Figure F.1 Multiple cryocooler installation with 8500™ compressor

Table F.1 Equipment List for Multiple Cryocooler Usage

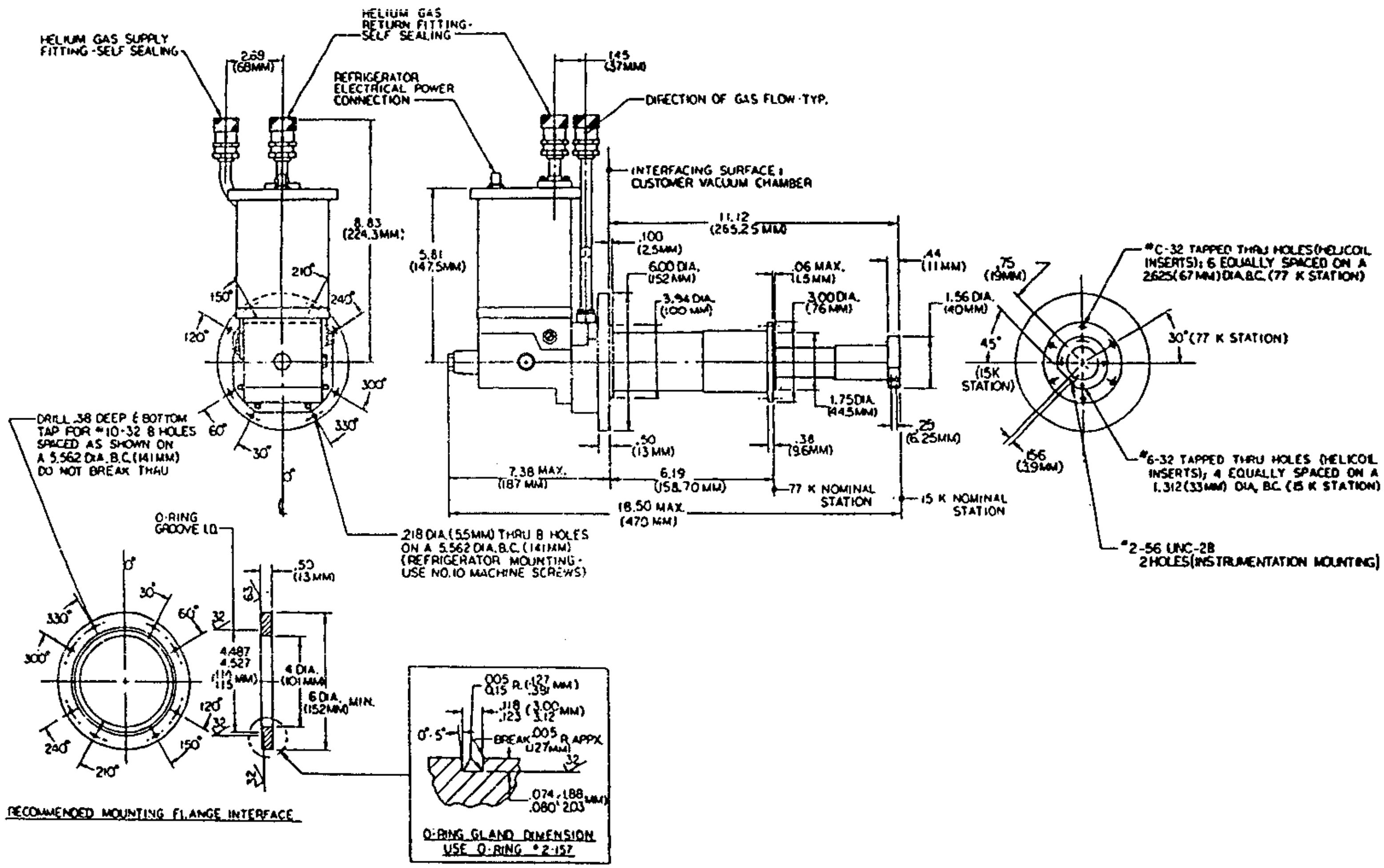
MODEL 22/350C CRYOCOOLER SYSTEM COMPONENTS											
ITEM	CRYOCOOLER(S) SYSTEM	8300™ COMPRESSOR	MODEL 22 COLD HEAD	MODEL 350CP COLD HEAD	1/2" FLEX LINE	MANUAL	TOOL KIT	SINGLE REF CABLE	HELIUM TEE	DOUBLE REF CABLE	TRIPLE REF CABLE
1	M-222	1	2		4	1	1	2	2		
2	M-223	1	3		6	1	1	1	4	1	
3	M-224	1	4		8	1	1		6	2	
4	M-225	1	5		10	1	1		8	1	1
5	M-352CP	1		2	4	1	1	2	2		
6	M-350 & M-22	1	1	1	4	1	1	2	2		
7	M-350 & M-222	1	2	1	6	1	1	1	4	1	
8	M-350 & M-223	1	3	1	8	1	1		6	2	
9	M-352 & M-22	1	1	2	6	1	1	1	4	1	

Appendix G

Model 22/350CP Cold Head Interface Drawings



INSTALLATION/INTERFACE
MODEL 22 REFRIGERATOR
Drawing 8104001 Rev. D



INSTALLATION/INTERFACE
MODEL 350 REFRIGERATOR
Drawing 3695576 Rev. C

Appendix H - Customer Support Information

Customer Support Center Locations

To locate a Customer Support Center near you, please visit our website ***www.helixtechnology.com*** on the world wide web and select *CONTACT* on the home page.

Guaranteed Up-Time Support (GUTS)

For 24 hour, 7 day per week Guaranteed Up-Time Support (GUTS) dial:

800-367-4887 - Inside the United States of America

508-337-5599 - Outside the United States of America

Product Information

Please have the following information available when calling so that we may assist you:

- Product Part Number
- Product Serial Number
- Product Application
- Specific Problem Area
- Hours of Operation
- Equipment Type
- Vacuum System Brand/Model/Date of Manufacture

E-mail

For your convenience, you may also e-mail us at:

techsupport@helixtechnology.com