CRYOGENIE

APPENDICE C : Principes de fonctionnement

DONNEES TECHNIQUES POUR REFRIGERATEURS A HELIUM EN CIRCUIT FERME DE CRYODYNE®

Le processus de refroidissement (cycle) des réfrigérateurs à hélium CRYODYNE est analogue aux réfrigérateurs ménagers communs. Dans ces derniers, un fluide de travail (gaz de fréon) est comprimé, la chaleur de compression est retirée par des échangeurs de chaleur refroidis à l'air et le gaz est ensuite décompressé afin de le refroidir en dessous de la température ambiante. Ce simple processus de compression-expansion suffit pour le réfrigérateur commun, où les températures tournent autour de 0° C. Toutefois, les systèmes CRYODYNE doivent fonctionner de manière effective et continue, à des températures d'environ 6°K. Atteindre des températures aussi basses requière des échangeurs de chaleur hautement performants et l'utilisation d'un fluide de travail (gaz d'hélium) permet de rester fluide à des températures approchant le zéro absolu (-273.1 °C, 0°K).

Tous les systèmes CRYODYNE comprennent une unité de compression lubrifiée à l'huile, refroidie à l'eau ou à l'air, avec système de séparation d'huile (les vapeurs d'huile de pompage se solidifieraient à des températures cryogéniques et obstrueraient les échangeurs de chaleur du réfrigérateur) l'unité de réfrigération (placée loin du compresseur) opère à des vitesses basses, avec beaucoup de jeu. Il y a des valves et des joints à température ambiante.

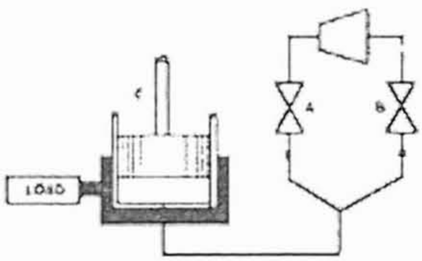


Figure 1 Circuit de refroidissement élémentaire

Le flux d'hélium dans le réfrigérateur est cyclique. La séquence des opérations peut être illustrée par un unique cylindre et piston (Figure 1).

Une source de gaz comprimé est connectée sur le dessous du cylindre C à travers la valve d'arrivée A. La valve B est dans la conduite d'échappement qui mène au côté de faible pression du compresseur. Avec le piston en bas du cylindre, la valve B (échappement) fermée et la valve A (arrivée) ouverte, le piston est forcé vers le haut et le cylindre se remplit de gaz compressé. Lorsque la valve A est fermée et la valve B ouverte, le gaz s'étend dans la conduite de refoulement à basse pression et se refroidit. Le gradient de température à travers le mur du cylindre qui en résulte, cause un flux de chaleur de la charge vers le cylindre. Le résultat étant que le gaz se chauffe à sa température originale. Avec la valve B ouverte et la valve A fermée, le piston est abaissé, ce qui déplace le gaz restant dans la conduite d'échappement et le cycle est terminé.

Ce système élémentaire, bien qu'il fonctionne, ne produirait pas les températures extrêmement basses requises. C'est pourquoi le gaz entrant doit être refroidi avec le gaz d'échappement avant qu'il n'atteigne le cylindre. Ceci est accompli dans le réfrigérateur CRYODYNE par un régénérateur, qui extrait de la chaleur du gaz entrant, la stocke puis la relâche dans le courant d'échappement (Figure 2).

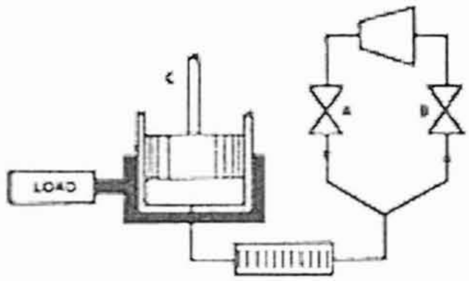


Figure 2 Circuit de refroidissement avec régénérateur

Un régénérateur est un échangeur qui renverse le flux à travers lequel l'hélium passe alternativement dans chaque direction. Il est rempli avec du matériel avec une grande surface extérieure, une grande chaleur spécifique et une faible conductivité thermique qui acceptera facilement la chaleur de l'hélium (si la température de l'hélium est plus élevée) et la donnera facilement à l'hélium (si la température de l'hélium est plus basse).

Dans une opération à régime établi, un système de ce type exhibe un tracé pour la température comme dans la Figure 3. Les étapes du cycle sont :

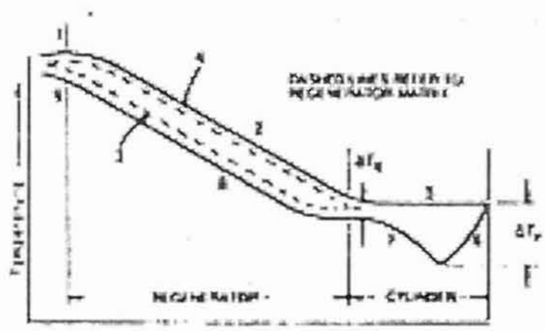


Figure 3 Tracé de la température pour un réfrigérateur Cryodyne à un étage

a. Avec le piston au plus bas de son mouvement, le gaz comprimé entre par la valve A à température ambiante (1).
b. Pendant que le piston s'élève, le gaz passe à travers le régénérateur. La matrice absorbe la chaleur du gaz (chauffe de 3 à 4) et le gaz refroidit.
c. Toujours à sa pression d'arrivée, le gaz refroidit remplit l'espace sous le piston. La température du gaz à ce point (5) est à peu près la même que celle de la charge.
d. La valve A se ferme et la valve d'échappement B s'ouvre, permettant au gaz de s'étendre et ce faisant de se refroidir plus (6). La chute de température (ΔT_r) est responsable pour l'effet de réfrigération.
e. La chaleur quitte la charge et passe par les murs du cylindre pour chauffer le gaz à une température (ΔT_e) légèrement au-dessous de celle à laquelle il est entré dans le cylindre (7).
f. Lorsque le gaz passe à travers le régénérateur, il reçoit de la chaleur de la matrice et chauffe (8) et la matrice est refroidie (4) à (3).

g. Le piston descend, poussant le gaz froid qui reste hors du cylindre et à travers le régénérateur. Toutefois, vu que le régénérateur n'est pas efficace à 100%, il y a toujours une différence de température entre le gaz et la matrice; donc, à n'importe quel point du diagramme, le gaz d'échappement reste légèrement plus froid que le gaz d'arrivée
h. Le gaz à basse pression part à travers la valve B à température ambiante, approximativement (9).
i.

Dans le système de la Figure 2, le piston aurait besoin d'un joint d'étanchéité et devrait être conçu pour résister à des forces déséquilibrées. Une version plus pratique de ce cycle est montré en Figure 4. Ce système utilise un cylindre à double ogive et un piston allongé fait d'un matériau avec faible conductivité thermique.

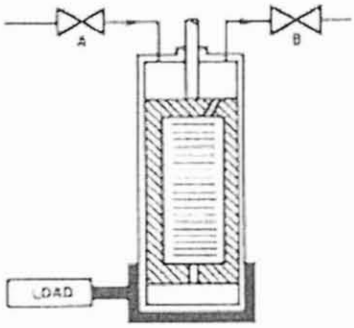


Figure 4 Réfrigérateur à un étage amélioré

Etant donné que les pressions au-dessus et au-dessous sont essentiellement les mêmes, le piston n'a pas besoin de joint d'étanchéité. Le piston est maintenant appelé un piston de circulation, car il ne fait simplement que déplacer l'air d'un bout du cylindre à l'autre, il n'y a pas de travail mécanique et on dit que le système utilise un cycle sans travail. Le régénérateur est placé dans le piston de circulation pour éviter de la tuyauterie inutile et minimiser les pertes.

Le réfrigérateur montré dans la Figure 4 peut atteindre des températures entre 30 et 77K. Vu que beaucoup des applications du réfrigérateur CRYODYNE sont en dessous de cette température, on peut ajouter un second et même un troisième étage pour produire des températures en dessous de 10K.

L'addition d'un second étage (Figure 5) permet une réfrigération jusqu'à 6 K.

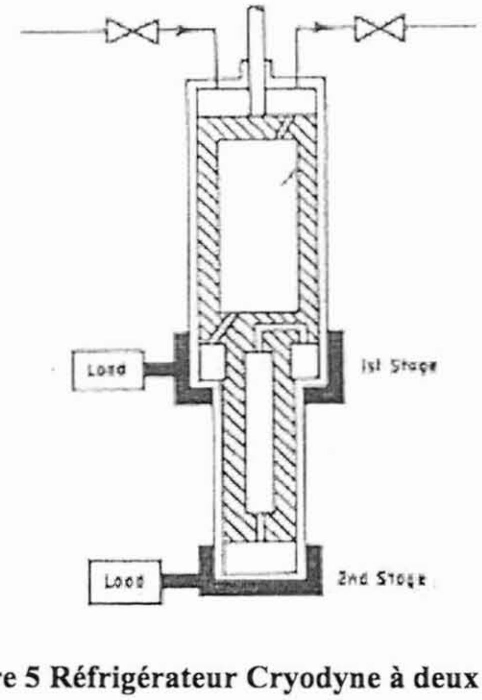


Figure 5 Réfrigérateur Cryodyne à deux étages

Appendix C
Principles of Operation

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

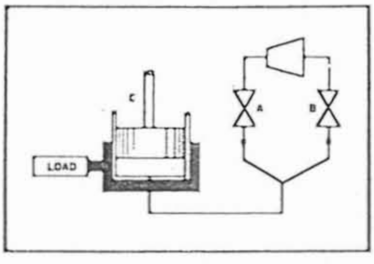


Figure 1 Elementary Cooling Circuit

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

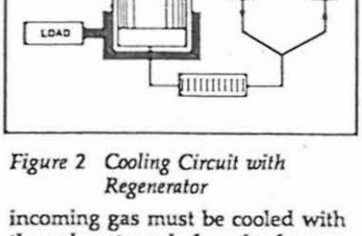


Figure 2 Cooling Circuit with Regenerator

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:

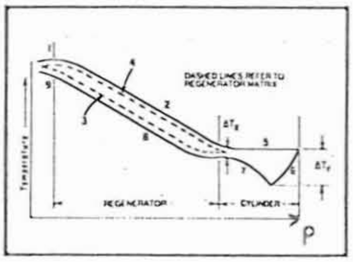


Figure 3 Temperature Profile of a Single-Stage Cryodyne Refrigerator

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

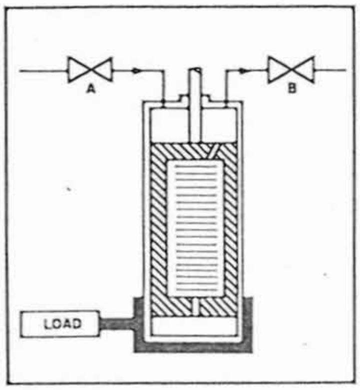


Figure 4 Improved Single Stage Refrigerator

does so (6). The temperature drop (ΔT_r) is responsible for the refrigerating effect.
e. Heat flows from the load through the cylinder walls, warming the gas to a temperature slightly (ΔT_r) 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).

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

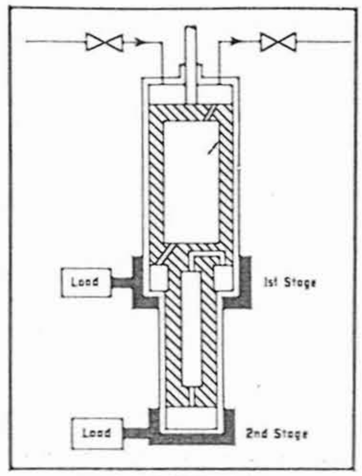


Figure 5 Two-Stage Cryodyne Refrigerator

an elongated piston made from a material of low thermal conductivity.

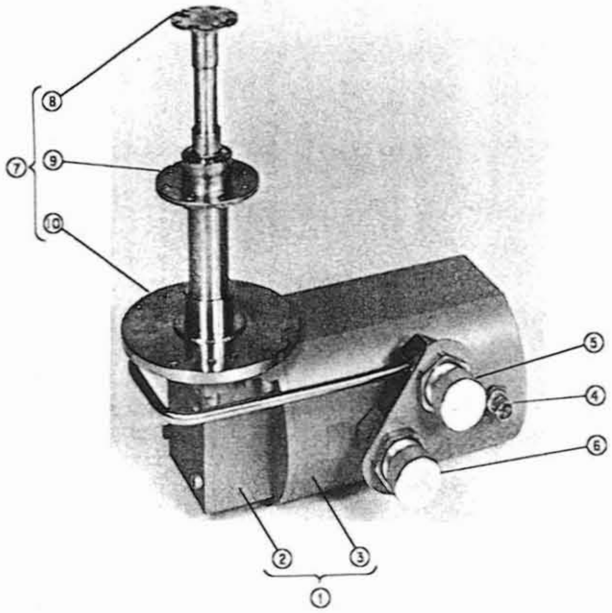
Since the pressures above and below the piston are substantially equal, the piston needs no pressure seal. The piston is now more correctly called a "displacer," because it merely moves gas from one end of the cylinder to the other; no mechanical work is introduced, and thus the system is said to use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

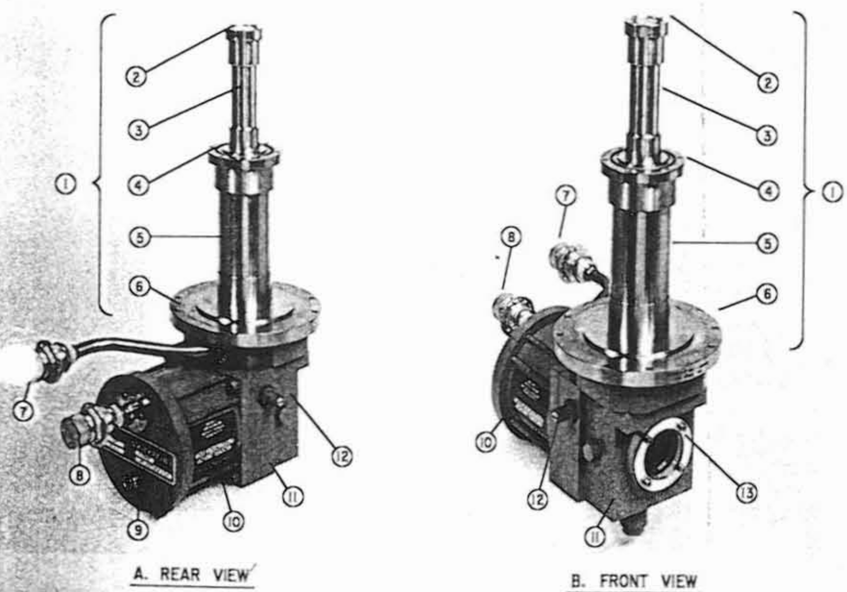
CTI-CRYOGENICS

266 Second Avenue, P.O. Box 9171,
Waltham, MA 02254-9171
Telephone: (617) 890-9400 | Telex 92-3442



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-State Cold Station
10. Top Flange

Figure 1.2 The Model 22 Cold Head



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 the drive mechanism)
12. Pressure Relief Valve
13. Sight Glass

Figure 1.3 The Model 350CP Cold Head

Table 1.1 Cold Head and Interconnections Specifications (Continued)

Refrigeration Capacity

Figures 1.4 and 1.5, page 6, are graphs showing typical refrigeration capacities of the Model 22C Cryodyne refrigerator at 60 Hz and 50 Hz respectively. The graphs in Figures 1.6 and 1.7, page 7, show typical refrigeration capacities of the Model 350C Cryodyne refrigerator at 60 Hz and 50 Hz respectively.

The refrigeration capacities depicted in the above figures (Figures 1.4 through 1.7) represent typical performance from a refrigeration system utilizing the full capabilities of the Model 8300 Compressor.

> **For Your Information --**
>
> When the refrigerator is supplied with 50-Hz power, a slight reduction in cold head performance may be observed, compared with the performance obtained with 60-Hz power.

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

Table 1.2 Compressor Specifications

Dimensions
18.00 inches (457 mm) Length
13.38 inches (340 mm) Width
15.30 inches (389 mm) Height (Less Casters)

Weight (including cartridge)
128 lbs. (58 kg) approximate

Weight (shipping) (including cartridge)
131 lbs. (59 kg) approximate

Helium pressure

Static: 245-250 psig (1690-1725 kPa) at 70 to 80°F (21 to 27°C)
Return: normal operation: 105* psig (725 kPa) at operating temperature

Ambient operating temperature range
50 to 100°F (10 to 38°C)

Interface
Compressor control power receptacle: Mates with compressor control power cable plug from controller.
Compressor power receptacle: Mates with compressor or power cable plug from controller.
Cooling water inlet and outlet connections: Mates with 1/2-14 NPT fitting (fittings are supplied).
Gas-supply connector: 1/2-inch self-sealing coupling (female) (Mates with cartridge)
Gas-return connector: 1/2-inch self-sealing coupling (male)

Helium filtration cartridge service schedule
Replace every 12 months

Cooling water requirements
90°F (32°C) maximum discharge temperature
Refer to Figures 3.7 and 3.8, pages 16 and 17, for parameters.

*This number is a nominal value between 100 and 110 psig. The number defines the centerpoint of the gauge needle swing (± 15 psig), which oscillates approximately 75 times/minute.

Table 1.3 Model 8001 Controller Specifications

Dimensions
19.18 inches (488 mm) Length
13.38 inches (340 mm) Width
5.85 inches (149 mm) Height

Weight
30 lbs. (14 kg)

Power requirements (when operating Model 8300 Compressor)

CONTROLLER MODEL NO.	NOMINAL	HZ	PHASE	NOMINAL OPERATING CURRENT (AMPS)	OPERATING VOLTAGE RANGE (VOLTS) 60 HZ	OPERATING VOLTAGE RANGE (VOLTS) 50 HZ	INRUSH CURRENT (2 SECS. MAX.) (AMPS)	POWER CONSUMP. (KW)
8001	208/230	50/60	1ϕ	9.0	198-250	180-220	36	1.8

Customer-supplied electrical service must be in accordance with all local, state, and national codes and standards.

Controller input-power cable (customer supplied)
Recommended Type SO-2 conductor, 600V, neoprene jacket and 14-gauge wire
Install per Figure 3.2, page 12, schematic, ensuring compliance with all national, state and local standards.

Interface
Cold-head power receptacles: Mates with plugs on cold-head power cables.
Compressor input-power receptacle: Mates with twist lock plug number NEMA: L6-15R.
Compressor power receptacle: Mates with plug on compressor power cable.
Compressor low voltage control receptacle: Mates with plug on low voltage control cable.

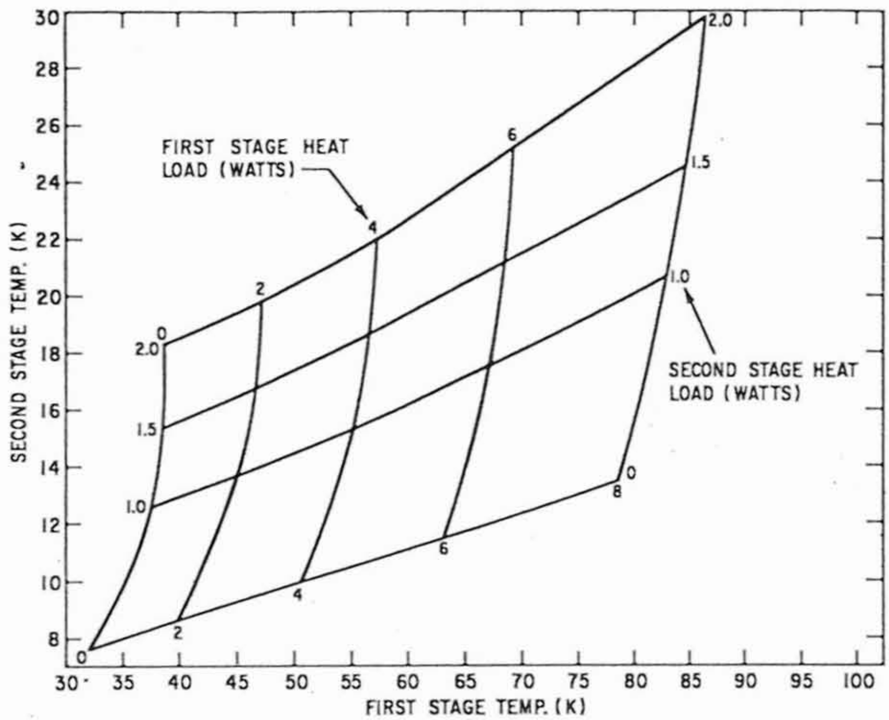


Figure 1.4 Typical refrigeration capacity of the Model 22 Cryodyne Refrigerator (60 Hz)

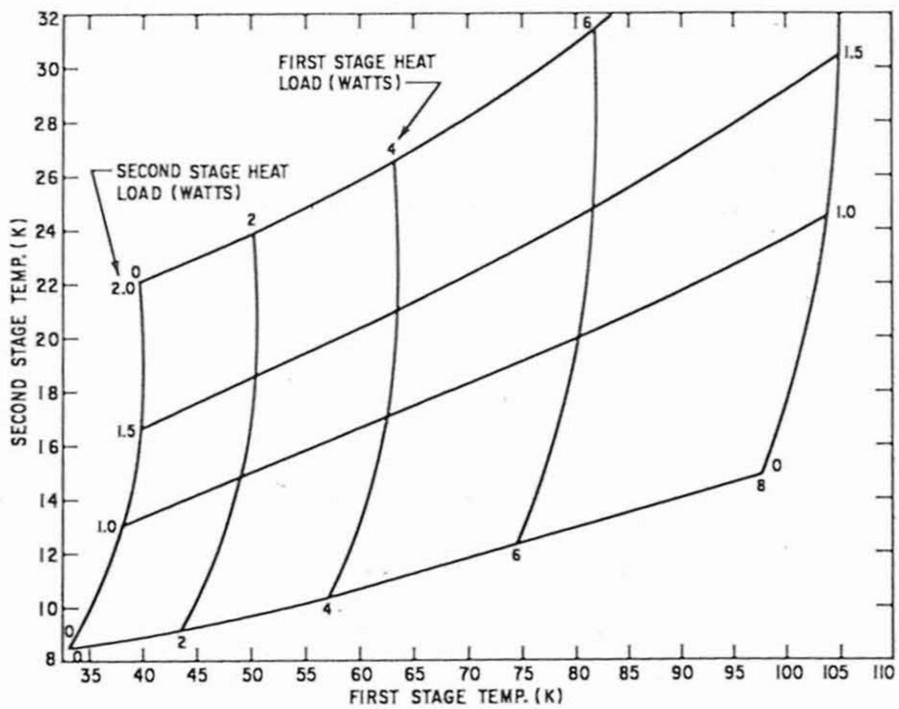


Figure 1.5 Typical refrigeration capacity of the Model 22 Cryodyne Refrigerator (50 Hz)

Section 2: Inspection

2.1 General

For Your Information --

These instructions have been produced to allow you to fold out cold head, controller and compressor photographs and drawings shown on pages 2 and 55, while using the following sections.

On receipt, remove the Cryodyne refrigeration system components from their shipping cartons and inspect them for evidence of damage as described in the following sections. The compressor has a shipping bolt in `ed through the compressor bottom shipping cushion to support the compressor pump from vibration and shock during shipment. To remove the shipping bolt and bottom shipping cushion, proceed as follows.

1. Carefully tilt and set the compressor on its front grille so the shipping bolt is accessible.
2. Loosen and remove the shipping bolt from the underside of the bottom shipping cushion and remove the cushion from the compressor. Retain the shipping bolt and cushion for use during future compressor shipment.

Caution --

Always place the compressor back on its bottom shipping cushion and install the shipping bolt (wrench-tight) whenever you ship the compressor by common carrier. This will prevent damaging the compressor pump during transportation.

- Report damage to the shipper at once.
- Retain shipping cartons for storage or return shipment.

2.2 The Cold Head

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

2.3 Connecting Piping and Interconnecting Electrical Cables

Inspect the piping and electrical cables for damage by examining the overall exterior.

Caution --

Do not bend the flexible connecting piping to less than a 6-inch radius.

2

2.4 The Compressor

Inspect the compressor overall exterior for damage, and evidence of oil leakage.

Check the helium pressure gauge. The gauge should indicate 245 psig (1690 kPa) minimum at 70°F. If the gauge reads less than 245 psig contact the Product Service Department.

2.5 The Controller

Inspect the controller for damage by examining the overall exterior.

2.6 Installation and Scheduled Maintenance Tool Kit

As part of your Cryodyne refrigeration system, you will find one each of the items listed below included in the Installation and Scheduled Maintenance Tool Kit, P/N 8032040G013, for the Model 8300 Compressor.

1. 3/4-inch, 1 inch, 1 1/8-inch, and 1 3/16-inch Armstrong open-end wrenches for self-sealing coupling.
2. 7/64-inch, 3/32-inch Hex ball-end speed wrenches.
3. Four gasket seals, Aeroquip 22008-4, and twelve gasket seals, Aeroquip 22008-8, for the self-sealing couplings.
4. One sheet of 1-1/2-inch x 3-inch by 0.005-inch thick indium gasket material, P/N 3543738P002.
5. Cartridge depressurization fitting, P/N 3592444.
6. One pair of protective gloves.

2.7 Additional Supplied Equipment

Included with your Cryodyne refrigeration system are the following supplied equipment.

1. Controller input-power receptacle, NEMA part number L6-15R.
2. Controller/compressor power and control interconnecting cables.
3. Set of spare fuses.
4. Two barbed fittings for compressor cooling water connection.
5. Cartridge support bracket, P/N 8052029 (with cartridge attaching hardware).
6. Two shoulder screws for side mounting of the controller on compressor.

Section 3: Installation

3.1 Model 8300 Compressor

Your Model 8300 Compressor consists of three separate modules: a compressor, a Model 8001 Controller, and a helium filtration cartridge. Installation of your Model 8300 Compressor is an easy task requiring no special tools other than those supplied in the Installation and Scheduled Maintenance Tool Kit.

Included with your compressor are two barbed fittings and a cartridge support bracket, P/N 8052029 (with cartridge attaching hardware).

Preparing the Model 8001 Controller

1. Assemble the controller input-power cable using the CTI-supplied controller receptacle plug. Follow Figure 3.2, page 12, being sure to comply with all national, state, and local codes. Do not connect the controller to the power source at this time. All of the preparation procedures must be completed before electrically connecting the controller.

2. Refer to Table 1.3, page 5, for electrical power requirements. Then, using a voltmeter measure the phase-to-phase voltage from the power source. Follow Figure 3.3, page 12, and prepare power selector switch (S2) and 50/60 Hz selector switch (S3) on the controller.

   PLEASE NOTE: If your cold head is a Model 22C, always set the 50/60 Hz selector switch (S3) to the 60 Hz position, *regardless of whether the line frequency is 50 Hz or 60 Hz*. Your cold head will not function properly if switch (S3) is in the 50 Hz position.

   If your cold head is a Model 350CP, set switch (S3) to 50 Hz or 60 Hz, as appropriate.

3. If your installation requires side mounting the controller on the compressor, then proceed as follows:

   a. Remove the two shipping screws from the side of the compressor cover to which the controller is to be mounted. The shipping screws are installed on each side of the compressor cover approximately six inches below the top.

   b. Install the two shoulder screws (supplied with compressor) into the cover screw holes. Tighten screws securely.

   c. Loosen jam nuts and extend the compressor mounting feet until weight of compressor is just off the casters. Tighten the jam nuts after establishing correct adjustment.

   d. Position and install the controller on the shoulder screws by aligning the cutouts on the bottom of the controller with the shoulder screws.

4. Connect the compressor low voltage control cable and the controller-to-compressor power cable to the electrical connectors on the rear panel of the controller and compressor as shown in the component interconnection diagram, Figure 3.4, page 13.

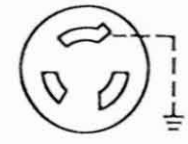
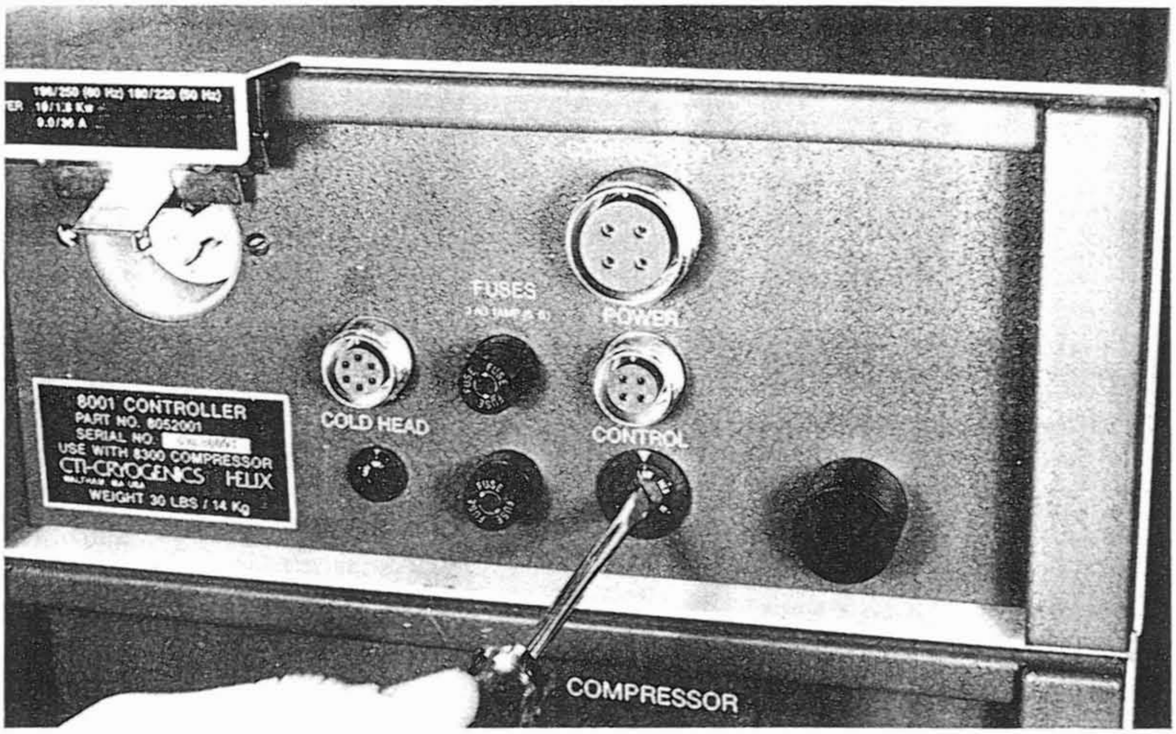
8000 SERIES CONTROLLER	CTI-SUPPLIED RECEPTACLE P/N	CABLE MATERIAL (CUSTOMER)	SCHEMATIC
8001	NEMA: L6-15R	SO-2 Conductor, 600-V Neoprene Jacket and 14-gauge wire	2-POLE, 3-WIRE  NEMA Reference: Receptacle: L6-15R Plug: L6-15P

Figure 3.2 Wiring requirements for Model 8001 Controller input-power cable



SWITCH S2 POSITION	OPERATING VOLTAGE RANGE	
	60 HZ	50 HZ
LOW	198-220 VAC	180-210 VAC
MED	220-240 VAC	210-220 VAC
HI	240-250 VAC	NOT APPLICABLE

Figure 3.3 Preparing the controller

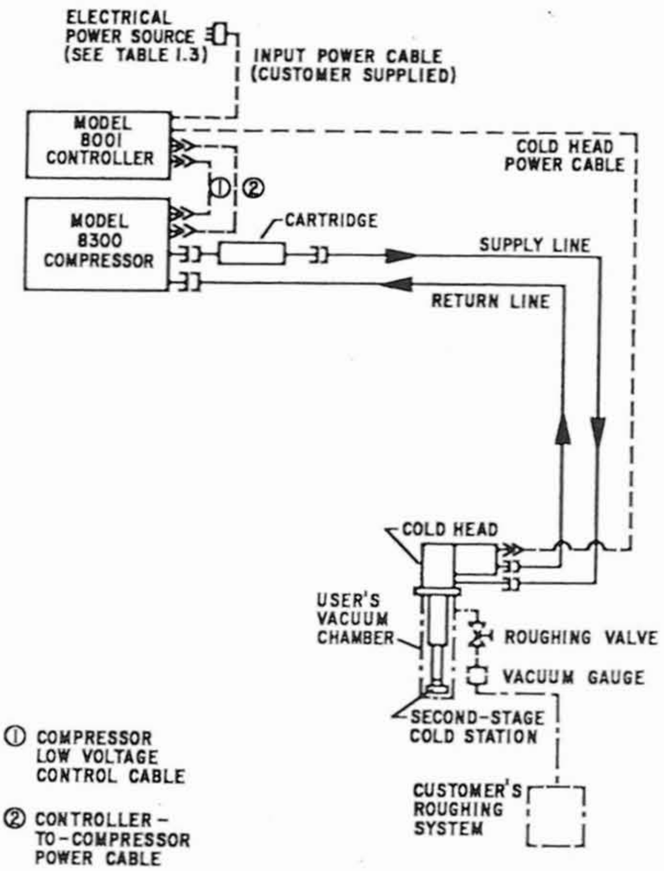


Figure 3.4 Typical component interconnection diagram

Installing the compressor cartridge

> **For Your Information --**
>
> If remote cartridge location is desired, contact your sales representative or the Product Service Department to order appropriate interconnecting lines. Connect the interconnecting line between the compressor and cartridge, following the procedures in this Section.

Connect the cartridge to the compressor gas supply connector located at the rear of the compressor. Refer to Figure 3.5, page 14, and,

1. Install the cartridge support bracket over the compressor gas supply connector. Align and position the two openings on the bracket with the two support hangers on the compressor rear panel. Push the bracket down until the bracket is properly supported by the hangers.

2. Remove the dust caps from the self-sealing coupling halves at each end of the cartridge.

3. Check the self-sealing connector flat rubber gasket to make sure that it is clean and properly positioned.

4. Make the first turns by hand and then firmly seal the connection using the two wrenches until the fittings bottom. Refer to Figure 3.6, page 15 for proper coupling of the self-sealing connection.

> **Caution --**
>
> Make sure to hold fast on the left coupling nut while tightening the right coupling nut, as shown in Figure 3.5, page 14.

5. Using two of the wrenches supplied in the Installation and Scheduled Maintenance Tool Kit, make the connection quickly to minimize minor gas leakage.

6. Secure the cartridge to the support bracket with two bolts, washers and nuts (supplied).

3

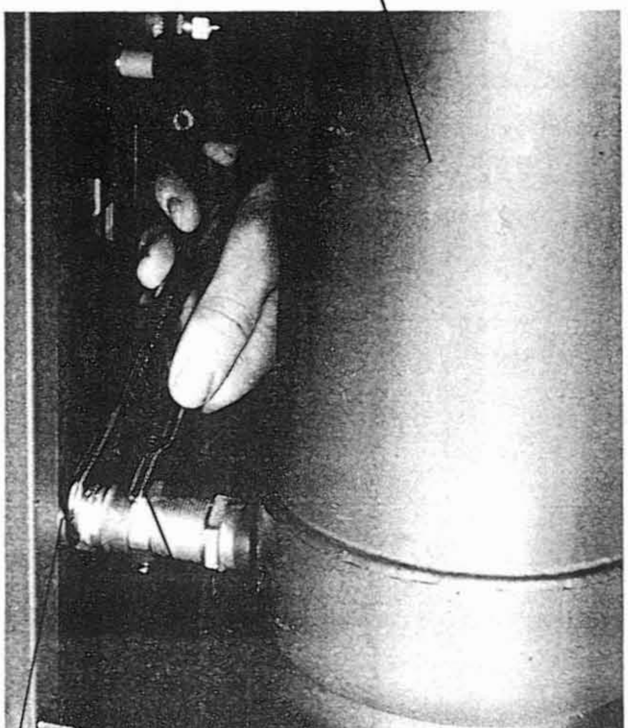


Figure 3.5 Installing the cartridge

Cooling Water: Preparation

If flexible water hose connections are used, install the barbed fittings supplied with the compressor on the input and output connections:

1. Apply a light coating of standard plumbing thread sealant on the barbed fitting threads.
2. Tighten fittings onto 1/2-inch FPT input and output connections. DO NOT OVERTIGHTEN.
3. Connect flexible hoses to the fittings and secure with hose clamps.

If hard piping is desired, install the water lines directly onto the compressor 1/2-inch FPT input and output connections. DO NOT OVERTIGHTEN.

> **Caution --**
>
> Make sure that all water connections are tight.

Cooling Water: General Considerations

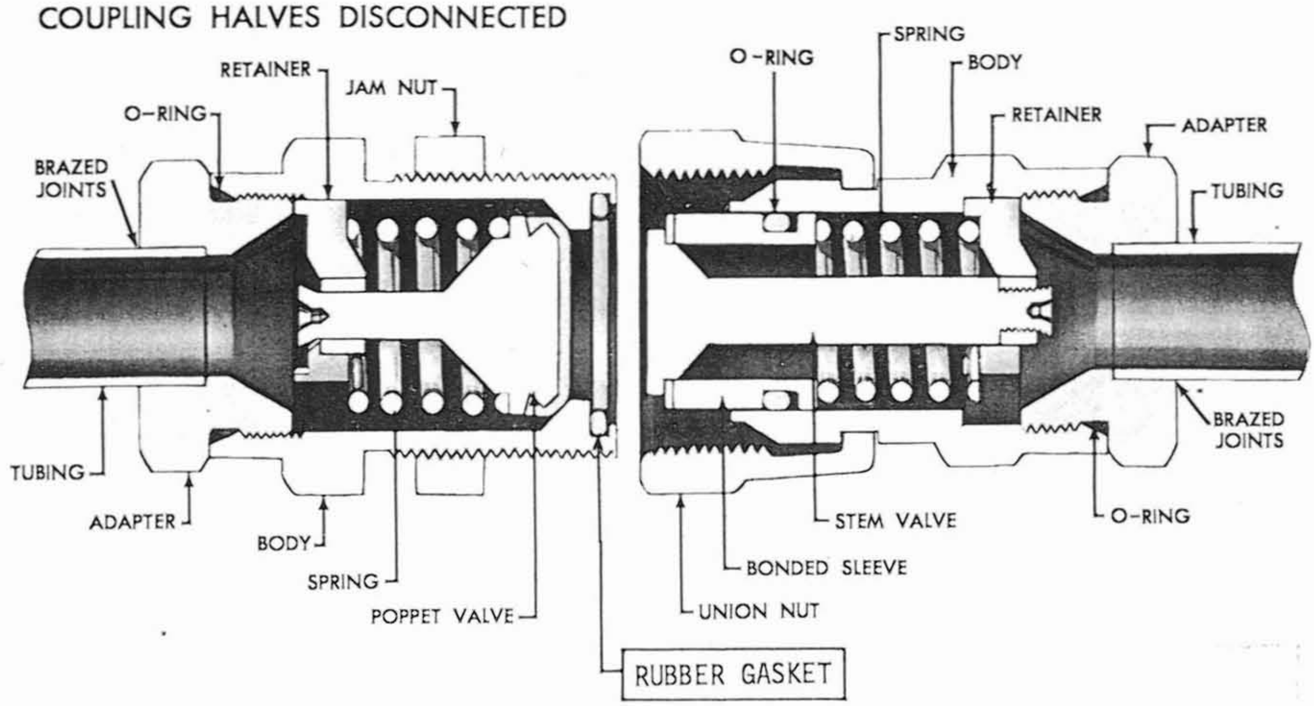
> **For Your Information --**
>
> Adjust your water flow to maintain an optimum discharge water temperature of 90°F with a minimum input pressure of 4 psi. For detailed water requirements, see below.

1. Cooling water must meet flow and pressure requirements as indicated in the following subsections.
2. Cooling water having a pH value of 6.0 to 8.0 and a calcium-carbonate concentration of less than 75 ppm, the quality of typical municipal drinking water, is acceptable. If the cooling water has a pH value lower than 6.0 or a calcium-carbonate concentration higher than 75 ppm, water conditioning may be required.
3. To conserve water, the cooling water should be shut off when the compressor is not running.

> **Caution --**
>
> If cooling water below 50°F (10°C) is allowed to run through the compressor while the compressor is not operating, the compressor oil will change viscosity and thicken, and may cause the compressor to overheat and shut off at startup. In this event, repeatedly restart the compressor and allow it to run until it has shut off several times. The oil temperature will rise and thereby allow continuous compressor operation.

4. Drain and purge water from the compressor before shipping it back to the factory or subjecting it to freezing conditions. Purge water from the compressor by blowing compressed air, regulated to 30 to 40 psig (200 to 275 kPa) into the compressor output connection and allowing water to exit from the water input connections.

COUPLING HALVES DISCONNECTED



COUPLING HALVES CONNECTED

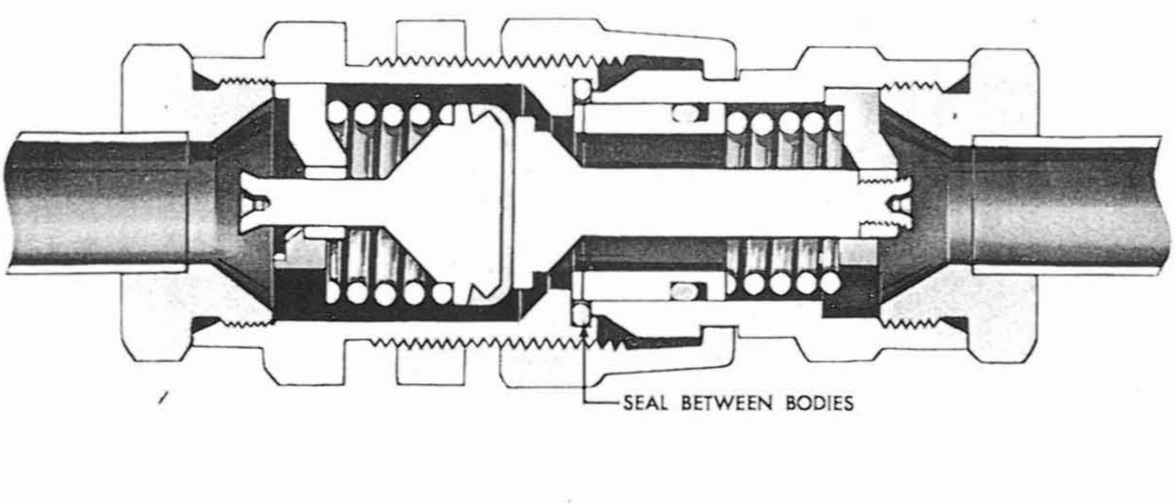


Figure 3.5 View of disconnected and connected self-sealing couplings

$$°C = (°F - 32)\frac{5}{9}$$

Cooling Water: Flow and Pressure Requirements

> **Caution --**
>
> If your water supply pressure falls below 2 psig due to back pressure, the compressor will overheat and shut down.

Use the two graphs in Figure 3.7 to determine the maximum acceptable cooling water supply pressure drop at different flow rates and temperatures. Find the maximum pressure:

1. Determine the temperature variation of the cooling water. Allow ± 10°F to the present water temperature if a variation cannot be ascertained. Plot the high and low temperatures on the vertical axis of the lower graph.

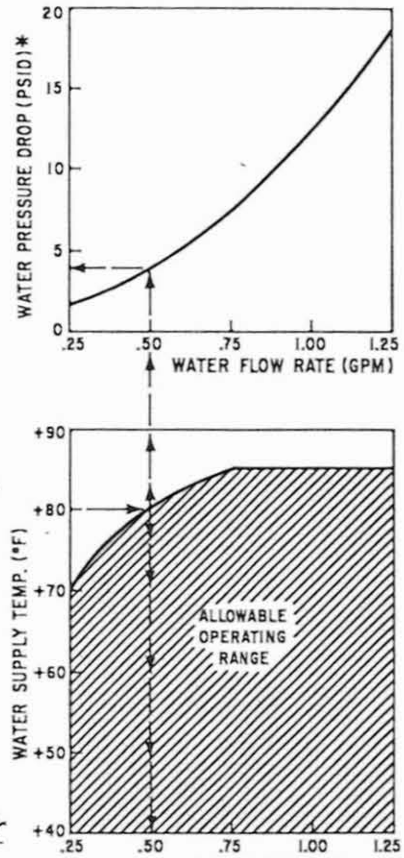
   The example describes cooling water that varies between 40 and 70°F.

2. Determine the optimum water flow rate by drawing a horizontal line from the upper temperature variation figure on the lower graph to the upper curve of the allowable operating range indicated by cross hatching. Draw a line from this intersecting point straight down to the horizontal axis to find the optimal flow rate.

   The example shows a solid arrow extending from 80°F and intersecting the allowable operating range. Dashed arrows pointing downward indicate a water flow rate of 0.5 gallons per minute.

3. Determine the maximum cooling water supply pressure drop by drawing a line straight up from the flow rate in the lower graph to the upper graph. At the point at which this line intersects the upper graph, draw a line leftward to the vertical axis and find the maximum required water supply pressure drop.

The example shows dashed arrows extending from the lower to the upper graph. On the upper graph the dashed arrows intersect the graph curve at approximately 4 psid.



* WITHOUT CONSIDERATION OF ANY DISCHARGE BACK-PRESSURE CONDITIONS (SEE TEXT)

Figure 3.7 Model 8300 Compressor cooling water flow and pressure requirements

Cooling Water: Temperature Rise

> **Caution --**
>
> The temperature of the cooling water as it leaves the compressor should never exceed 100°F.

Use the graph in Figure 3.8 to determine the rise in cooling water temperature as it passes through the compressor. This information is used by plant engineering personnel to determine cooling water requirements.

Find the temperature rise:

1. Draw a vertical line upward from the horizontal axis of the graph at the water flow rate determined from the previous section, until it hits the graph curve.

   The example shows dashed arrows pointing upward to the graph curve from 0.50 gpm on the water flow rate axis. 1,89 lt/min

2. At the point where the dashed arrows intersect the graph curve, draw a straight line to the left to obtain the increase in output water temperature.

   The example shows a temperature increase of 20°F.

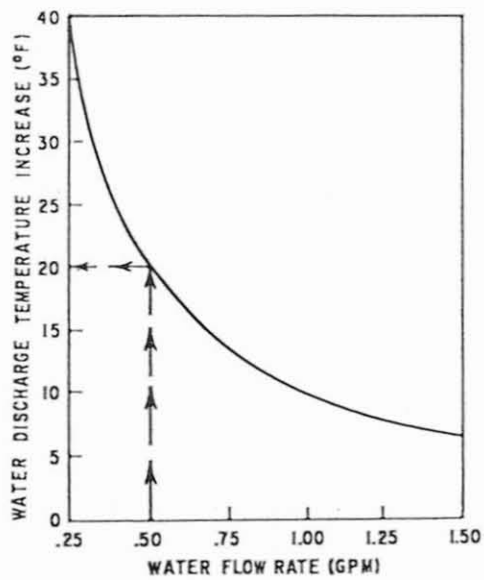


Figure 3.8 Model 8300 Compressor water discharge temperature increase (°F)

3.2 Cold Head Installation

The 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 surface of the cold-head cold stations. A small vacuum leak will cause higher-than-normal cold-station operating temperatures, combined with a gradual temperature increase; a large vacuum leak may prevent satisfactory cooldown. Your rough pump system should be isolated from your vacuum system, once cooldown has started, by closing the roughing valve shown in Figure 3.4, page 13. This valve should be of a high-vacuum isolation type (Hi-Vac valve) for isolation of your vacuum system during rough pumping, cooldown, and operation.

CTI-CRYOGENICS recommends that a suitable pressure relief valve be installed in your vacuum system to prevent any possible positive pressure rise during warmup.

Installing the Cold Head to the Vacuum System

Proceed as follows to install the cold head in your vacuum system. Refer to Appendix H, page 51, for the major interface dimensions of the Model 22 or Model 350CP Cold Head.

1. After cleaning all sealing surfaces, install the O-ring in the groove for the O-ring in your vacuum system flange.

2. Mount the cold head to the flange, and be sure that all mounting bolts are torqued to specified values.

Connecting the Cold Head to the Compressor

> **Warning --**
>
> Do not connect the controller to its power source until all connections have been made between the components of the Cryodyne refrigeration system.

Make the connections between the cold head and compressor:

1. Remove all dust plugs and caps from the supply and return lines, compressor, and cold head. Check all fittings.

2. Connect the helium return line from the gas-return connector on the rear of the compressor to the gas-return connector on the drive-unit displacer assembly on the cold head.

3. Connect the helium supply line from the supply connector on the cartridge to the gas-supply connector on the drive-unit displacer assembly on the cold head.
4. Attach the supply and return line identification decals (CTI supplied) to their respective connecting piping ends.

Verify proper helium supply static pressure by confirming that the helium pressure gauge reads 245-250 psig (1690-1725 kPa) in an ambient temperature range of 60 to 100°F (16 to 38°C).

If the indicated pressure is higher than 250 psig (1725 kPa), reduce the pressure as follows:

1. Remove the flare cap from the gas charge fitting located on the rear of the compressor.
2. Open the gas charge valve very slowly. Allow a slight amount of helium gas to escape until the helium pressure gauge reads 250 psig (1725 kPa).
3. Close the gas charge valve and reinstall the flare cap.

If the indicated pressure is lower than 245 psig, (1690 kPa), add helium gas as described in Section 6.2, page 29.

The last step required for installation is making electrical connections:

> **Warning --**
> The switch on the front of the controller must be in the OFF position before making any and all electrical connections.

1. Connect the cold head power cable to the rear panel of the controller and the other end to the electrical power connector on the cold head.
2. Plug the controller input power cable into the power source.
3. Your Cryodyne refrigeration system is now ready for operation.

Section 4: Operation

Caution --

Do not begin Cryodyne refrigeration system operation until all steps in the inspection and installation procedures have been completed and confirmed.

4.1 Before Startup

Operating Log

It is highly advisable to create and maintain a detailed operating log. The record will assist in troubleshooting, should problems arise. Figure A.1, page 35, is a sample operating log included for your use.

Temperature Indication

The second-stage cold station temperature is measured by one of two optional devices: a diode temperature sensor or a hydrogen-vapor-pressure gauge.

While the Cryodyne refrigerator can be operated without temperature indication, it is advisable to install the temperature indicator to facilitate accurate operating characteristics. Refer to Appendix D, page 43 for a detailed description of the temperature indicator.

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). Use indium foil (0.002 to 0.005-inch thick) between the mating surfaces to improve thermal conduction.

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

4.2 Startup and Cooldown

1. Confirm that the roughing valve is closed.
2. Turn on the system power ON/OFF switch on the controller.
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 a second-stage cold station, is specified in Table 1.1, page 3. The cooldown time will increase approximately 15 minutes for each pound-of-mass increase of the attached load. If the cold head cooldown times is not within specified requirements refer to Table 5.1, page 24, Cold Head Troubleshooting Procedures.

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

For Your Information --

How the Cold Head Operates

The cold head consists of a two-stage cold head cylinder and drive unit displacer assembly, Figure 1.3, page 2, that together produce closed-cycle refrigeration at temperatures that range from 60 to 120K for the first-stage cold station to 10 to 20K for the second-stage cold station, depending on operating conditions. Within the drive unit are located the crankcase and drive motor, which is a direct-drive constant-speed motor operating 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

During operation, high pressure helium from the compressor enters the cold head at the helium supply connector, and flows through the displacer-regenerator assembly, crankcase, and motor housing before exiting through the helium gas return connector and returning to the compressor. Helium expansion in the displacer-regenerator assembly provides cooling at the first and second stage cold stations.

Refer to Appendix C, page 41, for detailed information on the principles of operation.

Compressor Gas and Oil Flows

Refer to Figure 4.1, page 21, while reviewing this subsection.

Helium returning from the cold head enters the compressor, and a small quantity of oil is injected into the gas stream, thereby overcoming helium low specific heat and inability to carry heat produced during compression. Helium is then compressed and passed through a heat exchanger for removal of compression-caused heat. The helium flows through a bulk oil separater, oil-mist separator, and helium filter cartridge, where oil and contaminants are removed.

A differential pressure relief valve in the compressor limits the operating pressure differential between the helium supply and return lines, thereby allowing compressor operation without cold head operation. When cold head operation reaches a steady-state condition, further pressure regulation is unnecessary.

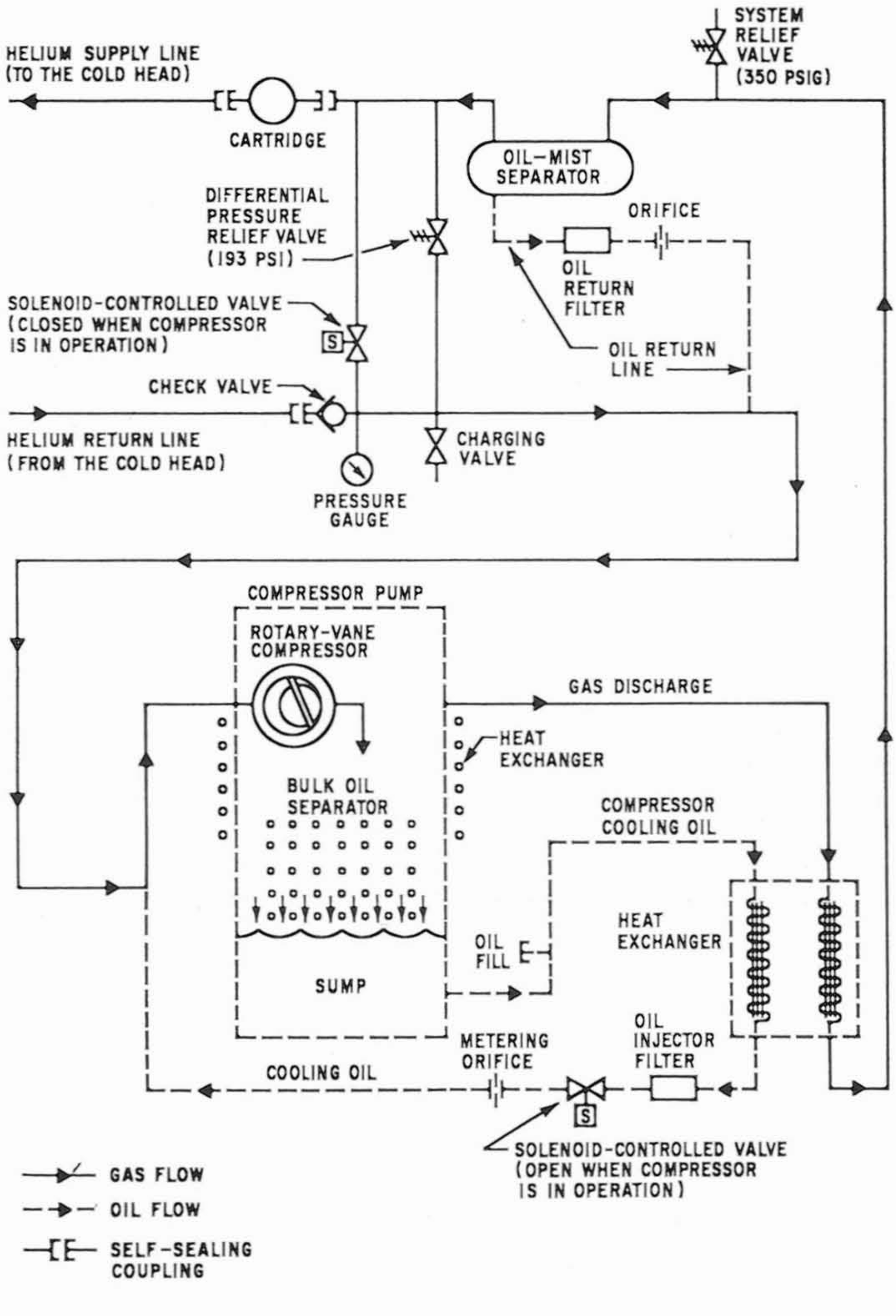


Figure 4.1 Flow diagram of the Model 8300 Compressor

4

4.3 Normal Operation

The Cryodyne refrigeration system is designed to operate without operator assistance.

The helium supply 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, between 100 and 110 psig (690-760 kPa), refer to Section 5, page 23, Troubleshooting Procedures.

4.4 Cryodyne Refrigerator Shut-down Procedures

1. Close the Hi-Vac valve in your vacuum system.
2. Turn off the system power ON/OFF switch on the controller.
3. Allow the cold head to warm up to ambient temperature.

For Your Information --

It will take many hours to warm the cold-head cylinder to ambient temperature with no heat load present. If you desire a rapid warmup, break the vacuum with a clean, dry gas, such as nitrogen or argon. If this method is used, leave the Hi-vac valve open to allow the expanding gas to escape as the cylinder warms.

4.5 Storage

The cryodyne refrigeration system is fully protected during storage if kept under positive helium pressure and all component connections left connected. Periodically check the helium return pressure gauge on the compressor. If the gauge reads below 245 psig (1690 kPa), add helium as described in Section 6.2 under Adding Helium Gas, page 29.

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