RDK-408D2 Cold Head

Technical Manual

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U.S.A.

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SAFETY

GENERAL

SHI-APD equipment is designed to operate safely when the installation, operation and servicing are performed in accordance with the instructions in this technical manual. Consult the nearest SHI-APD Service Center with any questions you may have concerning the use or maintenance of this equipment.

SPECIAL NOTICES

Three types of special notices -- WARNINGS, CAUTIONS and NOTES are used in this technical manual.

⚠️ WARNING

WARNINGS call attention to actions or conditions that can result in injury or death.

⚠️ CAUTION

CAUTIONS call attention to actions or conditions that can result in damage to the equipment or in abnormal performance.

舢 NOTE

NOTES give important, additional information, explanations or recommendations related to the appropriate topic or procedure.

WARNINGS and CAUTIONS appear in the text, in rectangles, where they are applicable. Because of their importance, they are summarized in this Safety section, the first section to be read.
WARNINGs

HIGH PRESSURE GAS HAZARDS

Never use compressed helium gas from a cylinder without a proper regulator. Overpressure can cause personal injury if the system equipment ruptures.

When handling pressurized gas lines and other pressurized equipment, always wear eye protection. Never apply heat to a pressurized gas line or other pressurized components.

Disconnect gas lines only when the compressor is stopped. Disconnecting the cold head while it is cold can create excessively high internal pressure as the gas warms. Material failure and uncontrolled pressure release can cause injury.

Allow the cold head to warm to room temperature before disconnecting any gas lines. Liquid helium and cold gas trapped in the cold head can reach a dangerously high pressure as it warms.

Use two wrenches when disconnecting a gas line coupling to avoid loosening the cold head coupling. Gas pressure can project the coupling with enough force to cause injury.

Always vent a gas-charged component before beginning to disassemble its couplings. Gas pressure can launch a loose coupling with enough force to cause injury.

When relieving the vacuum with dry air or nitrogen, backfill only to atmospheric pressure (zero psig). The vacuum shroud is not a pressure vessel. Injury and equipment damage can result.

HIGH VOLTAGE HAZARDS

All electrical supply equipment must meet applicable codes and be installed by qualified personnel.

Disconnect the power to the compressor before troubleshooting the electrical components.

Permit only qualified electrical technicians to open electrical enclosures, to perform electrical checks or to perform tests with the power supply connected and wiring exposed. Failure to observe this warning can result in injury or death.

AVOID INJURY FROM BURNS. During operation, some surfaces under the compressor’s cover become hot. Allow the compressor to cool for 1/2 hour after shutdown before removing the cover for maintenance.

CAUTIONS

PREsERVE YOUR WARRANTy. Modification to equipment without the consent of the manufacturer will void the warranty.

AVOID GAS LEAKS. Check the condition of the gasket seal on the male half of each Aeroquip coupling. Be sure the gasket seal is in place and the sealing surfaces on both the male and female halves are clean before connecting. Replace the gasket seal if it is damaged or missing.
CAUTIONS (continued)

AVOID GAS LEAKS. Keep the gas line couplings aligned when making or breaking a coupling connection. Leaks can occur due to the weight of the gas line or due to a sharp bend near the connection.

PREVENT EQUIPMENT DAMAGE. Damage to gas lines can result from crimping by repeated bending and repositioning.

Do not heat cold head assemblies above 80º C (176º F).

AVOID A MALFUNCTION. Repeatedly charging the system with helium gas rather than locating and repairing gas leaks can cause a malfunction. Impurities are introduced at an abnormal rate and can freeze in the shield cooler.

Do not allow air to get into the helium gas refrigerant of the system. Moisture from the atmosphere can seriously degrade cold head performance.

Avoid trapping contaminants inside the cold head. Do not assemble parts that are in questionable condition.

Never open the vacuum valve when the connected vacuum pump is not running. The cold cold head can cryopump oil into the shroud (non-MRI applications).

AVOID CONTAMINATION. Follow the charging or venting procedures to prevent reversed flow of system gas. Do not charge through the supply coupling. Do not vent through the return coupling. Reversed flow can contaminate the system with compressor oil.
RDK-408D2 Cold Head

The RDK-408D2 Cold Head (Expander) described in this manual is a two-stage cryogenic refrigerator that operates on the Gifford-McMahon refrigeration cycle. The cold head uses helium gas from a helium compressor to produce the cold temperatures. Depending on the imposed heat load, temperatures in the range of 25K to 45K are attained at the first-stage heat station and temperatures in the range of 3.5K to 4.2K are attained at the second stage heat station. Using newly developed rare earth material in the regenerator, the cold head’s second-stage heat station has a refrigeration capacity of 1W at 4.2K.

The cold head has three major components: drive unit, cylinder and the displacer-regenerator assembly located within the cylinder. The cold head is designed and built to metric standards.

To be functional, the cold head is fitted with other parts or equipment so it can remove heat from the connected interfaces.

Applications include laboratory systems for test sample cooling and MRI shield cooler systems.

The typical, complete operating system, using SHI-APD standard components, consists of a helium compressor(s), interconnecting gas lines, the cold head with its interface attachments, and optional instrumentation.

Electricity to power the cold head’s drive motor is supplied from the compressor by the cold head cable.

Pressures are stated as gauge, not absolute. Psig is pounds per square inch gauge and MPa is Megapascals gauge,

\[ \text{MPa} = 145 \text{ Psig.} \]
CONSTRUCTION

The major parts of the cold head are shown in cross section in Figure 1.

Figure 1  RDK-408D2 Cold Head Parts Identification
High-pressure helium gas from the compressor enters the cold head through the supply gas coupling (connector) and flows through passages to the regenerators. The regenerators, cooled during the previous exhaust stroke, cool the incoming gas as it flows through. After the gas exits the regenerator assembly, it flows to the crankcase through the motor housing, and finally, exits the cold head through the return coupling to the return gas line and back to the compressor.

The helium gas expansion in the displacer-regenerator assembly provides the cooling for the first and second stage heat stations.

Refer to Figure 1. The RDK-408D2 Cold Head consists of a cylinder, first stage displacer, second stage displacer, drive mechanism and drive motor. The first stage displacer is connected to a Scotch yoke, which is driven by the motor through a crank and bushing, converting the rotating motion of the motor to reciprocating motion for the displacer.

The crank also drives a rotary valve which controls the timing of the helium gas intake and exhaust, synchronized with the reciprocating motion of the displacer assembly.

The displacer assembly, containing the regenerators, slides within the cylinder and the helium gas, passing through the regenerators, cools the materials within the regenerators. Gas exiting the second stage regenerator can be cooled to 4.2K due to the special rare earth material within the regenerator.

The pressure above and below the displacer is the same except for a small pressure drop across the regenerator when gas is flowing through it. Virtually no physical work is required to move the displacer within the cylinder. No work is done on the gas and the gas does not work on the displacer. Pressure in the system is increased or decreased by the operation of the inlet and outlet valves.
SPECIFICATIONS

Refrigeration Capacity (Typical)

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<tr>
<th></th>
<th>60 Hz</th>
<th>50 Hz</th>
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<tr>
<td>First Stage</td>
<td>50 Watts @ 43K</td>
<td>40 Watts @ 43K</td>
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<tr>
<td>Second Stage</td>
<td>1.0 Watt @ 4.2K</td>
<td>1.0 Watt @ 4.2K</td>
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Helium Gas Pressures

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<th>Compressor Indoor Operation</th>
<th>Compressor Outdoor Operation</th>
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<tr>
<td>Equalization</td>
<td>1.6-1.65 MPa @ 20º C (68º F) (232-239 psig)</td>
<td>1.6-1.7 MPa @ 20º C (68º F) (232-246 psig)</td>
</tr>
<tr>
<td>Supply</td>
<td>2.1-2.3 MPa (304-333 psig)</td>
<td>1.9-2.1 MPa (275-304 psig)</td>
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NOTE
Supply pressures vary depending upon the heat load on the cold head and the ambient temperature.

Environmental Requirements

Ambient operating temperature 5 - 28º C (41 - 82º F)
28 - 35º C (82 - 95º F) with a 5% capacity loss.

Magnetic field limits ≤500 Gauss

Pressure Relief Valve
The cold head has a pressure relief valve set at 1.86-1.96 MPa (270-284 psig) gauge maximum.

Weight (approximate) 18.0 kg (39.6 pounds)

Dimensions (See Figure 2)
- Width 180 mm (7.1”)
- Length 294 mm (11.6”)
- Height 557 mm (21.9”)

Cold Head Power Supply
200 V3~, 0.5 full load amperes, 50 or 60 Hz.
The cold head cable from the compressor supplies power for the drive motor.

Mounting Position
Functions normally in any position. Position is determined by customer’s application. The maximum capacity loss is 15%.

Gas Couplings
Size 8, male, Aeroquip self-sealing couplings on the cold head are color coded to identify their functions as follows:
- Yellow - Helium gas supply to the cold head.
- Green - Helium gas return from the cold head.
**Specifications**

**Refrigerant Quality**
Refrigerant is 99.999% pure helium gas with a dew point less than -62°C (-80°F) at 2.07 MPa (300 psig).

**Supplier Name and Address**
SHI-APD Cryogenics, Inc.
1833 Vultee Street
Allentown, PA 18103-4783
U.S.A.
(610) 791-6700.
Specifications

Dimensions

Dimensions are in millimeters.

Figure 2  RDK-408D2 Cold Head Outline Dimensions
**INSTALLATION**

**Inspection**
Unpack the equipment and inspect it for damage.

Cold heads are shipped fully charged with helium gas. After all system components have been connected, the equalization pressure indicated by the compressor gauge will determine if charging or venting of the system is required.

**Mounting**
Customer’s application determines the mounting position and method. The cold head will function in any position.

Allow sufficient space for installing and removing the interfacing attachments, connecting the gas lines and the vacuum hose, and operating the vacuum valve.

**Interconnections**

**Gas Lines**
Tools required: Open end wrenches 1”, 1 1/8”, 1 3/16”.

<table>
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<td>Retain the threaded dust caps and plugs to re-cover the couplings when they are not in use. They protect the couplings from damage and prevent entry of contaminants.</td>
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1. Using two wrenches, connect one end of the cold head supply gas line to the supply (yellow) coupling on the cold head. Tighten all Aeroquip couplings to $4.8 \pm 0.7 \text{ kgf m (35 \pm 5 ft. lbs.)}$. See Figure 3.

Tighten each coupling before proceeding to the next one.

2. Connect the other end of this gas line to the supply coupling on the compressor.
3. Connect one end of the cold head return gas line to the return (green) coupling on the cold head.

4. Connect the other end of this gas line to the return coupling on the compressor.

![Figure 3 Connect Aeroquip Coupling](image)

**Cold Head Cable**

1. Connect the cold head cable to the electrical receptacle (power connector) on the drive motor housing.

2. Connect the other end to the cold head receptacle on the compressor.

**Evacuate the Shroud**

The insulating, vacuum shroud should be pumped down to about $1 \times 10^{-3}$ torr. A two-stage, oil-sealed mechanical vacuum pump with an ultimate pressure capability in the $10^{-4}$ torr range is satisfactory but mechanical pumps begin to backstream oil when operated close to the molecular flow range. Backstreaming must be prevented to avoid contaminating the shroud by pumping to a pressure no lower than $1 \times 10^{-3}$ torr.

Cleaner types of vacuum pumps, such as liquid nitrogen cold-trapped diffusion pumps, turbomolecular pumps and cryopumps, allow pumping to lower pressures such as $10^{-6}$ torr. The lower pressures reduce the residual heat load on the refrigerator at the start of the cooldown.
OPERATION

Startup
Starting the compressor(s) starts the cold head’s drive motor.

NOTE
Breaking the insulating vacuum while the cold head is below room temperature will cause frosting of the outside vacuum vessel. It is preferable to break the vacuum with dry nitrogen or dry air. This prevents the accumulation of moisture in the vacuum space, facilitating faster, subsequent pump downs.

⚠️ WARNING
EXPLOSION HAZARD. PREVENT INJURY. When relieving the vacuum with dry air or dry nitrogen, backfill only to atmospheric pressure (zero psig). The vacuum shroud is not a pressure vessel. Injury and equipment damage can result.

⚠️ WARNING
EXPLOSION HAZARD. PREVENT INJURY. Never use compressed helium gas from a cylinder without a proper regulator. Overpressure can cause personal injury if the system equipment ruptures. Always wear eye protection when handling pressurized gas lines and other pressurized components.

⚠️ WARNING
PREVENT EQUIPMENT DAMAGE. Do not heat cold head assemblies above 80º C (176º F).
The cold head normally requires little maintenance, but there are maintenance tasks to be performed on a periodic basis. There are internal parts that wear and require replacement after 10,000 hours of operation.

The cold head must be returned to SHI-APD for this maintenance work.

**WARNING**

**PREVENT INJURY.** When handling pressurized gas lines and other pressurized equipment, always wear eye protection. Never apply heat to a pressurized gas line or other pressurized components.

**Disconnect the Gas Lines**

Tools required: Open end wrenches 1", 1 1/8", 1 3/16"

**WARNING**

**EXPLOSION HAZARD.** Allow the cold head to warm to room temperature before disconnecting any gas lines. Liquid helium and cold gas trapped in the cold head can reach a dangerously high pressure as it warms.

**WARNING**

**AVOID INJURY.** Use two wrenches when disconnecting a gas line coupling to avoid loosening the cold head coupling. Gas pressure can project the coupling with enough force to cause injuries.

1. To disconnect the gas lines, always use two wrenches. Use one wrench to hold the cold head coupling. Use the second wrench on the gas line coupling to break the connection. See Figure 4.

2. After breaking the connection, hold the coupling adapter with one wrench. Remove the gas line coupling from the cold head coupling with the second wrench. See Figure 5. Screw dust caps and plugs finger tight on the cold head and the gas line couplings.

![Figure 4](image1)  **Figure 4** Break the Gas Line Coupling from the Cold Head

![Figure 5](image2)  **Figure 5** Disconnect the Gas Line Coupling from the Cold Head
Remove the Cold Head

Follow the MRI or laboratory equipment manufacturer’s instructions and procedures to remove the cold head.