INSTALLATION AND SERVICE MANUAL

VACUUM INSULATED PIPE SYSTEMS FOR LIQUID NITROGEN

½" TO 2" BAYONET SYSTEMS

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1.0 INTRODUCTION

Thank you for your purchase of CryoWorks Vacuum Insulated Pipe (VIP). Our reputation in the industry for providing high-quality vacuum insulated pipe and clear, concise installation instructions is very important to us. Our intention is to provide as much information as possible in order for an installer to install our vacuum insulated pipe safely and appropriately. Please contact us with any questions or suggestions, we are here to help your project go smoothly.

Throughout the manual, there are symbols to draw your attention to specific items. See the following for what these symbols mean.

Please read through the entire manual prior to starting an installation. There are many tips and precautions throughout the manual that will help your installation go smoothly and safely.

This is a “quick tip” and is intended to do just that.

This is a symbol that shows severe cold condition.

This symbol is intended to make one aware of a hazard or caution.

This manual is intended to familiarize an installer with guidelines to safely and properly install CryoWorks vacuum insulated liquid nitrogen (LN2) pipe systems.

YOUR COMMENTS ARE APPRECIATED

In an effort to continually improve our technical literature and to ensure we are providing useful information; we would very much appreciate any comments and suggestions for improvements to our product manuals or to our products themselves. Please send any comments you may have to the following email address:

service@cryoworks.net

CryoWorks, Inc. – 951-360-0920

2.0 GLOSSARY OF TERMS

LN2	Liquid Nitrogen	**SCH**	Schedule (thickness of pipe)
GN2	Gaseous Nitrogen	**PTFE**	Polytetrafluoroethylene
O2	Oxygen	**MNPT**	Male National Pipe Thread
PPE	Personal Protective Equipment	**FNPT**	Female National Pipe Thread
P&ID	Piping and Instrumentation Diagram	**POU**	Point of Use
POC	Point of Connection	**GFCI**	Ground Fault Circuit Interrupter
LOTO	Lock Out – Tag Out	**SRV**	Safety Relief Valve
ID	Inside Diameter	**ESOV**	Emergency Shut Off Valve
OD	Outside Diameter	**PS**	Phase Separator
NPS	Nominal Pipe Size	**MAWP**	Maximum Allowable Working Pressure

3.0 REFERENCES

- ANSI/CGA P-18-2013 Standard for Bulk Inert Gas Systems 4th edition
- NFPA 704
- ASME B31.3

4.0 LN2 CHARACTERISTICS

- Colorless
- Odorless
- Inert
- -320°F
- Expansion ratio of 700 to 1 (liquid expands 700x into gas)
- MSDS # 001040, UN 1977

5.0 SAFETY

5.1 GENERAL SAFETY

The main hazards associated with LN2 are extremely cold temperature -320°F (-196C,77K), potential of causing oxygen depletion, potential of bursting sealed environments.

5.1.1 When working with or around LN2, severe burns and/or frostbite can occur if skin comes in contact with the -320°F liquid, cold gas, or non-insulated pipe components. Use PPE such as cryogenic rated gloves, a face shield, and a chemical apron. If cryogenic liquid or cold boil-off gas contacts skin or eyes, the affected tissues should be promptly flooded or soaked with tepid water (105-115°F; 41-46°C). **DO NOT USE HOT WATER.**

5.1.2 Due to LN2's high expansion rate (700 parts GN2 to 1-part LN2), any release of LN2 or GN2 into an enclosed environment will begin to displace the breathable air. When using LN2 in an enclosed environment, such as a room where portable LN2 tanks are filled, an oxygen monitor (see section 10.5) must be installed and proper room ventilation provided. Individuals should be prohibited from entering areas where the oxygen content is below 19.5% unless equipped with a self-contained breathing apparatus. Persons suffering from lack of oxygen should be immediately moved to areas with normal atmospheres. A self-contained breathing apparatus may be required to prevent asphyxiation of rescue workers. See below for results of oxygen percent levels.

Oxygen percent at sea level (atmospheric pressure = 760 mmHg)	Effects
20.9	Normal
19.0	Some adverse physiological effects occur, but they are unnoticeable.
16.0	Increased pulse and breathing rate. Impaired thinking and attention. Reduced coordination.
14.0	Abnormal fatigue upon exertion. Emotional upset. Faulty coordination. Poor judgment
12.5	Very poor judgment and coordination. Impaired respiration that can cause permanent heart damage. Nausea and vomiting.
<10	Inability to perform various movements. Loss of consciousness. Convulsions. Death.

Notes:
1. Adapted from ANSI Z88.2, American National Standard for Respiratory Protection [34].
2. These indications are for an average healthy person at rest. Factors such as individual health (being a smoker, etc.), degree of physical exertion, and high altitudes can affect these symptoms and the oxygen levels at which they occur.

WARNING: Exposure to atmospheres containing 8% to 10% or less of oxygen brings about unconsciousness without warning so quickly that an individual cannot help or protect themselves. Lack of sufficient oxygen can cause serious injury or death.

Table 1 – Oxygen Percentage at Sea Level and its Effects

5.1.3 Due to LN2's high expansion rate (700 parts GN2 to 1-part LN2), the possibility of an over-pressurization exists. Any configuration which allows a trapped volume of cryogenic liquid or cold gas must be protected by a pressure relief valve. As the cold liquid/gas gains heat, the contents will expand and increase in pressure. A section of pipe or components not protected by a safety relief valve (SRV) will experience high pressures. This expansion may result in a rupture of the pipe, component, or vessel.

6.0 RECEIVING AND UNPACKING

The pipe systems are typically shipped via a dedicated truck or shipped in wooden crates. Sometimes the crates can be very large.

Information on the size and type of the crate is available from CryoWorks ahead of time so one can prepare for any special equipment to offload and also to secure a staging area prior to installation. Keep in mind that the crate will need to be disposed of after the pipe is uncrated.

Upon arrival of the pipe system, immediately inspect the shipment for any signs of damage. If any damage occurred in shipping, claims must be filed with the shipping carrier immediately.

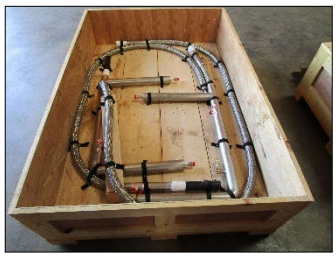
Note any damage with the driver while onsite, document damage by taking pictures, identify serial numbers, and type of damage. Contact CryoWorks immediately to determine if the damage is severe enough that the pipe will need rework, repair, or replacement.

Things to check upon arrival:

- Dents on the pipe, bent or bowed pipe, damage to vacuum gauge tubes, valves, safety relief valves, and miscellaneous components. Make sure the protective covers are on male and female bayonets.
- When un-crating the pipe, caution shall be used to ensure the pipe is not damaged by the improper use of a hammer, pry bar, screwdriver, saw, razor knife, or any other tool that may be used for un-crating. Remove any exposed screws/nails prior to removing the pipe from the crate.

CAUTION: Do not damage, puncture, or pierce vacuum jacket pipe or flex as this will void the warranty.

- Verify that all pipe section numbers match those printed on the packing list. Unpack any associated parts and verify that they match those parts itemized on the packing list. Verify that all parts are accounted for against a print or system drawing. Contact CryoWorks if there are any missing parts.



Picture 1 – Crated Shipment

Picture 2 – Palletized / Cardboard Box

Picture 3 – Dedicated Truck

7.0 INSTALLATION PREPARATION

7.1 STAGING

Secure an area ahead of time that is suitable for staging the pipe sections and components. Avoid setting the pipe directly on the ground by using wood blocks or other soft material. Be careful not to drop the pipe or drag it on the ground.

Do not overbend flex hoses or sections as this will void the warranty. Handle the pipe sections carefully while transporting to ensure the minimum bend radius is not exceeded (see Section 8.2, Table 3)

7.2 PROJECT/ROUTING ACCESS

Be sure that there is a clear pathway to get sections of pipe from the staging area to the work areas (hallways, doorways, elevators, equipment, other utilities, etc.). If installing above a ceiling, determine how to place a section of pipe through ceiling obstacles. If inserting pipe through core holes, make sure there is clearance (on one side) to slide the pipe through.

In some cases, you may have to "see-saw" a section of pipe into position or bring it up in an un-obstructed area first (i.e., drop tile ceiling grids).

7.3 DRAWINGS

All pipe system drawings are available ahead of time, contact CryoWorks if a drawing is required. The drawings may be in the form of a plan view, isometric view, or P&ID (consult your CryoWorks contact person for details). The drawings may include a bill of materials, dimensions of the pipe system, and key building reference points (column lines, floors, ceilings, walls, etc.). Each section of pipe will have a section number and corresponding serial number identified on the drawing to create a "road map" for where all the sections are to be installed.

For custom engineered, one-off, or systems designed with non-CryoWorks components, the system drawings may include project-specific details, notes, and additional installation requirements.

The drawings will show locations of where the bayonet connection points are placed. This will be helpful in determining the chronological order of the pipe section installation (see 8.1 strategy and 8.5 bayonet assembly sections below).

Piping systems may require utilities such as electricity, control wiring, or compressed air/gas for pneumatic actuators. Make sure all utilities are addressed ahead of time. See Related System Components Section 10.

8.0 INSTALLATION

8.1 STRATEGY

The installer must strategize which sections of the system should go in first (i.e., an elbow section penetrating through a core hole may be a good starting point).

The pipe sections will connect together using bayonets (see section 8.5). In doing so, the pipe sections will have to be placed a short distance apart and then engaged by sliding two sections together. Because of the close tolerance of the bayonets, the sections of pipe must be aligned with each other and supported but not secured in order for two sections to engage. **Keep the protective wrapping on the pipe until ready to engage the pipe sections.** The male bayonet is susceptible to damage if unprotected. It is highly advisable for installers to familiarize themselves

with the system drawings prior to commencing work, particularly where the bayonet joints are, and which section incorporates a male or female bayonet.

After the entire system is installed, fine-tune any areas that require added support or adjustment.

If connecting to an existing pipe system or removing existing piping, make sure the piping is not pressurized. This may require that the entire pipe system be shut off at the source. If removing a capped bayonet downstream of a valve on a pressurized system, release the pressure inside the cap by opening an upstream valve or via the blow-down valve (if available). **DO NOT DISCONNECT ANY FITTINGS WITHOUT VERIFICATION OF ZERO PRESSURE OTHERWISE SERIOUS INJURY MAY OCCUR.** Place an appropriate LOTO device on the source valve and follow site LOTO procedures prior to connecting to an existing POC.

8.2 PIPE WEIGHTS, DIMENSIONS, AND FLEX BEND RADIUS DIMENSIONS

The tables below are helpful for determining weight loads, support sizing, support spans, core hole sizing, real estate for flexible bends, etc. Normally, the pipe will be schedule (SCH) 5, but occasionally SCH 10. The following tables do not incorporate weights of added components such as valves, actuators, Keepfulls, etc.

Vacuum Insulated pipe is always designated by the inner line size, not the outer.

Use the outer jacket size for sizing support mechanisms.

INNER PIPE SIZE SCH5 (NPS)	OUTER PIPE SIZE SCH5 (NPS)	APPROX. WEIGHT/FT WITH LN2
½"	2" (2 3/8" Nominal OD)	2.4 Lbs.
1"	3" (3 ½" Nominal OD)	4.2 Lbs.
1 ½"	3 ½" (4" Nominal OD)	5 Lbs.
2"	4" (4 ½" Nominal OD)	5.8 Lbs.

Table 2 – Rigid Pipe Size and Weights

The flexible pipe sizes below are used correspondingly to the pipe size table above.

FLEX INNER LINE SIZE	FLEX OUTER JACKET SIZE	TOTAL WEIGHT/FT	STANDARD BEND RADIUS
0.75" ID Used with ½" Pipe	2.24" Nominal OD	1.8 Lbs.	11"-15"
1.25" ID Used with 1" Pipe	3.28" Nominal OD	3.1 Lbs.	15"-20"
2" ID Used with 1 ½" AND 2" Pipe	4.86" Nominal OD	4.9 Lbs.	22"-30"

Table 3 – Flex Size Radius

8.3 PIPE SUPPORTS (SYSTEMS WITH INTERNAL EXPANSION JOINTS)

Consult local building codes and any customer requirements when choosing the support method and spacing.

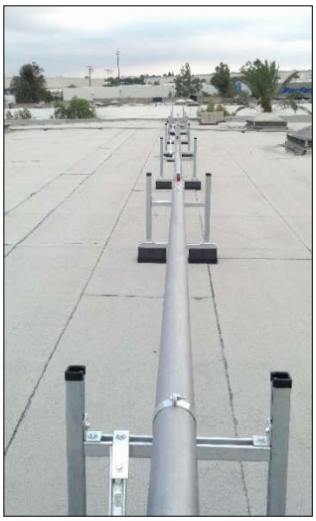
Generally speaking, the LN2 pipe system can be supported with conventional pipe support materials such as strut channel, pipe clamps, beam clamps, threaded rod, clevis, J-hangers, etc. It is recommended to use cadmium plated steel, zinc-plated steel, aluminum, SS, rubber, or plastic materials for supports that come in contact with the jacket pipe. Use the outer jacket sizing chart above for identifying the size of support materials. Do not use rubber or plastic materials for supporting a non-insulated inner pipe.

DO NOT WELD TO THE PIPE AS THIS WILL VOID THE WARRANTY

Supports should be placed in such a way to eliminate any bowing or flexing at bayonet locations. For ½" to 2" systems, typical spacing is every 6'-8'. Additional supports should be considered for sections incorporating components such as valves, Keepfulls, etc. (See Related System Components section 10).

The support system must account for the possibility of movement of the system. For example, piping exposed to the sun will expand along the length of the pipe. The installation should provide a support means (rollers, hangers, clamps that allow movement, etc.) that accommodates this movement as well as provisions to account for anchor points, such as pipe penetrations into the building.

The pipe system can move approximately 1" for every 100' of a straight run when exposed to seasonal temperature fluctuations and direct sun exposure. For systems that have **External Expansion Joints**, consult CryoWorks for alternative support details.



Picture 4 – Synthetic Roof Pipe Support

Picture 5 – Strut Pipe Clamp Support

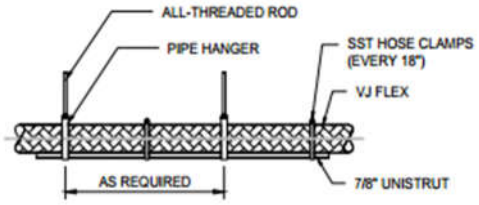
Picture 6 – Loop Hanger Pipe Support

Picture 7 – Roller Pipe Support

8.4 SLOPING

Sloping the cryogenic piping systems is critical to ensuring quality liquid is delivered to the equipment. When systems are installed with Keepfull Vent Devices, the piping should always slope up towards the Keepfull(s). Keepfulls are located at all system high points and will continually vent gas from the discharge vent. The Keepfull incorporates an internal mechanical float that shuts when liquid has filled the system. Since the liquid is constantly boiling off, gas bubbles need to be able to percolate up to the Keepfull. When installing the pipe, minimum sloping of 1/8" per foot up to the Keepfull is recommended (Note: from both directions - if the Keepfull is between pipe sections). System drawings will generally call out sloping requirements and/or elevations.

On flexible sections, make sure there are no sags, dips, or rises in the flex portion that may cause a trap (even slight variations of these will have an impact on performance). It is advisable to support the flex with continuous structural support using strut channel and hose clamps.



Picture 8 – Structural Support with Strut Channel and Hose Clamps

8.5 BAYONET ASSEMBLY

Bayonet assemblies are a means of attaching vacuum insulated pipe sections together. No welding or brazing is required. Each bayonet connection utilizes an O-ring and a bayonet clamp. Bayonet Connections are designed for lower pressure applications up to 150 PSIG. During cryogenic transfer, gas from the process liquid is vaporized in this long narrow cavity, forming a vapor seal that is at the process stream temperature at one end and ambient temperature at the other. The vapor seal isolates the elastomer type mechanical seal from cryogenic temperatures. This unique feature minimizes "heat-leak, eliminates frosting, and allows for the rapid assembly and disassembly of the piping spool sections.

8.5.1 CryoWorks has two styles of bayonet connections:

The Close Tolerance Style Assembly provides a close tolerance fit between the male and female counterparts, forming a thin cylindrical cavity. See section 8.5.5 for drawing and mate-up details.

The Invar Tip Style Assembly provides a long heat path from the outer jacket to the inner pipe, an Invar tip (dissimilar metal) seal at the end of the male bayonet, and an O-ring seal at the flange. See section 8.5.6 for drawing and mate-up details.

DO NOT unwrap the protective wrapping from the bayonets until the pipe is in place, and the bayonet connection is ready to be engaged.

DO NOT use a knife or sharp object to cut the wrapping off as this may score the male bayonet and/or the O-ring flanges.

DO NOT let debris or water contaminate the bayonets or the pipe interior.

8.5.2 Inspect the male bayonet and the flange faces for any signs of denting, scoring, or damage prior to engagement. Contact CryoWorks immediately if any damage is present.

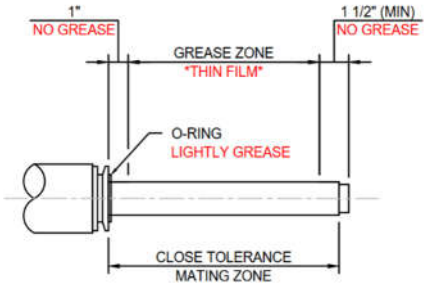
8.5.3 Wipe clean the male bayonet, female bayonet ID, both flanges, and the O-ring with a lint-free cloth. Inspect the O-ring for any signs of damage. Reclean surfaces if any grease is present from a prior installation. Replace the O-ring if any imperfections are found.

The following installation steps require the use of vacuum grease. This grease could pose a risk to highly sensitive equipment, depending on the application. As a policy, CryoWorks recommends the use of vacuum grease for both overall reliability and system performance. If the end-user requires that a different grease be used, or no grease at all, the installer should consult with CryoWorks before proceeding with installation. Use gloves during installation to keep pipe, hands, and application clean.

8.5.4 After cleaning and inspecting the O-ring, lubricate with **LIGHT FILM** of vacuum grease (Dow Corning High Vacuum Grease #970 or equivalent: Typically supplied with the pipe shipment) and insert into the O-ring groove of the male bayonet flange. Note: Some third-party O-ring grooves may be located on the female flange.

Picture 9 – Bayonet Assembly

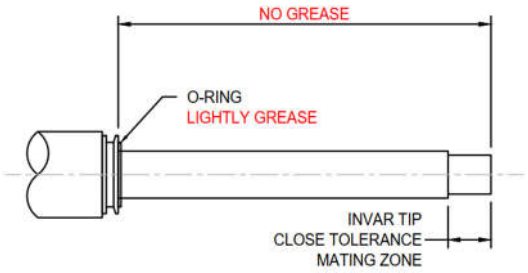
8.5.5 **Close Tolerance Style Bayonet Assembly –** See drawing below and follow details. Lubricate the male bayonet with a **THIN FILM** of grease to within a 1 ½" of the tip. If grease bunches up at the flanges during install, too much grease has been used. If this is the case, disengage bayonets, clean the male and female bayonets to remove grease with alcohol or approved solvent, restart bayonet installation procedure.



Picture 10 – Close Tolerance Style Male Bayonet

Be careful not to apply grease near the tip. If the grease is extruded into the flow stream upon pipe engagement, it can become brittle and break off into the pipe system, which may cause valves and equipment downstream to malfunction. This is especially important for bayonets that have been engaged, disassembled, and re-engaged. After a bayonet connection has been disengaged, removal of the grease from both bayonets (internal of female, and external of the male) is required. Bayonet reassembly shall follow the standard instructions above after the grease removal step. The installation process must not allow too much grease to form on the tip of the bayonet or between the bayonet flanges.

8.5.6 **The Invar Tip Style Assembly** - See drawing below and follow details.



Picture 11 – Invar Tip Style Male Bayonet

8.5.7 *Make sure the two pipe sections are **lined up perfectly parallel** prior to bayonet engagement.* Begin by pulling the two sections together by hand without twisting; smooth engagement may require slight maneuvering of each spool section. When the flanges are within an inch of each other, re-inspect the O-ring to make sure it is seated in the groove and then fully engage the sections. Do not use excessive force if the bayonets do not fully engage, contact CryoWorks immediately. Once the bayonet assembly is fully engaged, it is acceptable to rotate the pipe segment to best align components (i.e., SRVs, evac ports, valves, etc.).

Do not let the pipe sag or drop while only a small amount of the male bayonet is inserted, as this can dent the male bayonet, causing permanent damage.

Picture 12 – Bayonet Assembly

Picture 13 – Bayonet Assembly

8.5.8 Back out the nut on the bayonet clamp and install the bayonet clamp around the mated flanges. Make sure the v-band is centered on the flanges all the way around. If the nut is Stainless Steel, it is advisable to lubricate the threads so galling does not occur. Hand tighten the nut with hand tools (do not use high-speed electric tools as this may create galling on the threads). Simultaneously tap the circumference of the clamp with a non-metallic mallet to evenly distribute the band tension; use caution not to hit the piping. Continue this process until the nut reaches the target torque value:

- 5 ft-lbs. for 1/2" through 1 ½" bayonets.
- 7 ft-lbs. for 2" bayonets.
- Note: **Torque value in **FOOT** Lbs. of torque.

Picture 14 – Bayonet Assembly

Picture 15 – Bayonet Assembly

8.6 EVACUATION PORTS

The evacuation ports are used during manufacturing to facilitate the vacuum process. The pipe sections are shipped with red dust caps on the ports to keep out debris. The dust caps should not be removed. Under the dust caps are the vacuum seal plug/O-ring inserts. Each port comes from the factory with a small amount of vacuum grease spread over the insert to help keep the O-ring from drying out.

DO NOT REMOVE THE BRASS INSERT FROM THE EVAC PORT! Doing so will release the vacuum on the pipe section and will void the warranty. Use caution when installing the pipe sections so that the ports do not become damaged. Sometimes the ports will have a vacuum thermocouple gauge tube (TC) attached. The TCs are for measuring the vacuum level via a hand-held vacuum meter. Use caution when installing the pipe sections so that the TCs do not become damaged.

Picture 16 – Evacuation Port

Picture 17 – Evacuation Port

Picture 18 – Evacuation Port

8.7 LABELING

Consult local building codes and any customer requirements when choosing the labeling method and spacing. Label color, font, and spacing may differ by application, customer, or local jurisdiction.

Generally speaking, LN2 pipe should be identified with labels that have black letters on a yellow background. Directional flow arrows should also accompany the identification labels. Some labels are adhesive, and some wrap around an entire pipe. Most of the industry requires labels located every 20', before and after wall penetrations, and after a change of directions—reference NFPA 704.

Picture 19 – Liquid Nitrogen Label

8.8 NON-VACUUM INSULATED COMPONENTS/CONNECTIONS

Pipe threads are a commonly used connection type from vacuum insulated to non-vacuum insulated piping or components [i.e., valves (see section 10.4.2), equipment, source tanks, etc.]. Only use materials that are suitable for cryogenic service (i.e., brass, copper, or stainless-steel fittings; do not use carbon steel, cast iron, plastics, etc.). Use a thread sealant that is rated for cryogenic temperatures, such as a PTFE impregnated sealant (paste or tape form is acceptable).

When applying a threaded sealant, do not apply near the end of male threads. If the sealant is extruded into the flow stream, it can become brittle and break off, which may cause valves and equipment downstream to malfunction.

8.9 MECHANICAL INSULATION OF NON-VACUUM INSULATED COMPONENTS

It is recommended that non-vacuum insulated components and fittings be mechanically foam insulated. This procedure is usually performed by professional insulation contractors that are familiar with cryogenic applications and can recommend insulating types, designs, thickness, and sizing. Contact CryoWorks for advice or referrals if needed. Here are some bullet point guidelines to follow when using foam insulation.

- Use only foam materials designed for cryogenic temperatures (foam glass, closed-cell foam, expanded polyurethane foam, etc.).
- Size the wall thickness of the foam insulation to the size of the component (usually 2" – 4").
- Wrap the insulation with a waterproof barrier such as aluminum or PVC.
- Seal all seams and any openings with a waterproof flexible sealant to mitigate moisture intrusion.
- Overlap the foam insulation from the non-vacuum insulated components over the vacuum insulated by 6" or more.
- **DO NOT** extend the foam insulation onto SRV risers.
- **DO NOT** extend the foam insulation onto valve handle risers or valve bonnets (see section 10.4.2 below).
- **DO NOT** extend the foam insulation near or over vacuum evacuation ports (see section 8.6).

Note: *Foam insulated connections need to be periodically re-installed for maximum performance. After some time, moisture intrusion and expansion/contraction of the ice and pipe system derogate the insulation performances. A tell-tale sign when the insulation needs to be re-done is when ice or frost starts to form on the outside shell of a foam insulated assembly.*

9.0 START-UP AND COMMISSIONING

9.1 PRESSURE TESTING

The following pressure test procedure is recommended; however, check with local codes and building facility requirements that may require additional testing requirements.

1. Verify that the entire system and associated components are installed. Walk down the system.
2. If the system has Keepfulls, **remove the 1/8" check valve** at the end of the vent discharge and replace with a brass 1/8" MNPT plug.
3. Verify that all point of use valves on the system are shut.
4. Establish a means to introduce nitrogen gas into the pipe system. Pressure test items you may need are: compressed GN2, pressure regulator, brass or stainless steel fittings (brass is preferred), flex hose, ball valve, pressure gauge, etc.
5. Pressurize the system with GN2 to the designated operating pressure and hold.

   DO NOT exceed 110% of the systems rated MAWP (see pipe section tags for MAWP located near each spool evacuation port). Do not exceed the rated pressure for any added components not supplied by CryoWorks.
6. Hold pressure for one hour. The system should have no decrease in pressure. If pressure drops, locate, and fix the leak (i.e., missing 0-ring on joint, leaky threads on fittings, etc.). Repeat testing until pressure hold test is successful.
7. Release pressure. If removed, re-install the SRVs, valves, and check valves on the Keepfulls.

9.2 START-UP PROCEDURE

The following start-up procedure should be performed only after a successful pressure test is conducted. This procedure is a general guide. Specific start-up procedures may be required for extensive or complicated systems. If any ancillary components are electronically controlled, refer to their respective manuals for their individual start-up procedures.

1. Verify the pipe system is securely installed and pressure tested.
2. Verify all liquid clamps on the bayonet joints are tightened properly.
3. Verify all safety relief valves are re-installed following pressure testing. Reference section 10.6
4. Verify that the plugs have been removed from all Keepfull devices (if provided) following pressure testing.
5. Verify all Keepfull devices (if provided) have their respective heaters installed and plugged into an appropriate live power source.
6. Verify the O2 monitors (if provided) are live and working correctly, including local visual and audible alarms. Reference section 10.5.1

7. Verify that all control valves (if provided) function as intended (i.e., O2 monitoring control, remote operation push buttons, EMS).
8. Verify all Point of Use valves are in the closed position.
9. Verify that **ALL** pneumatic valves (if provided) are in the closed position in order to test the valve seat during the start-up process.
10. Close **ALL** manual valves.
11. Verify there is enough LN2 in the liquid source tank for the initial start-up and that the pressure is set to the designated system operating pressure.
12. **Do not proceed if the pressure is above 150 psi or the lowest SRV setting on the pipe system!**
13. If the pipe system is connected to a bulk tank, verify that the pressure building circuit on the tank is set to the **minimum** system operating pressure. In addition, verify that the economizer circuit on the tank is venting to atmosphere and is set to a **maximum** system operating pressure (must be higher than the pressure building circuit). This is typically done by the tank/gas supplier.
14. Provide adequate communication of the start-up process to the people in the building. Caution them that the LN2 system will be turned on and to stay clear of point-of-use valves (follow any client safety protocols). It is advisable to have watch guards with communication devices in the point of use areas so they can communicate any hazards that may arise while the system is turned on.
15. Slowly crack open the main tank withdrawal valve until you hear flow, after 10 minutes, open to allow the system to pressurize up to the first shut system valve (i.e., emergency shut-off pneumatic valve, branch isolation valve, etc.).
16. Systematically verify that there is no pressure leakage past the seats of any valves on the system. Start with the valve closest to the liquid source. After the first valve verification, move onto the next valve that is in-line until all valves have been confirmed that they are not leaking by the seat, including point of use valves.
17. Fully open the main tank valve and then back the handle in ½ turn (standard practice for all manual valves).
18. If the system incorporates a Keepfull(s), check to make sure they are venting gas. Depending on the size of the system, it may take many hours for the entire system to cool down via a Keepfull. Once the system is cooled down, the Keepfull(s) should be venting intermittently.
19. After the system is cooled down and has been on and/or operational for 24 hours, walk the entire system again to make sure there are no leaks at bayonet joints or pipe fittings. Check that the Keepfull(s) are intermittently venting without liquid coming out. Visually inspect each pipe section for condensation or ice build-up (some condensation on a bayonet clamp can be normal under certain atmospheric conditions). Contact CryoWorks if condensation or ice develops on the pipe areas that are not near the bayonet clamps (this would be indicative of a possible vacuum issue).
20. The system can be kept on (if desired) and is now ready for use.

10.0 RELATED SYSTEM COMPONENTS

10.1 SUBMITTALS

Submittals for system components are available on request or at www.CryoWorks.net. Contact CryoWorks for details.

10.2 KEEPFULL DEVICES

CryoWorks Keepfull Vent Device has an internal mechanical float that drops to allow accumulated gas to vent. Once all of the gas vents, the float rises to seal off the vent orifice. This simple design requires no field adjustments, no sensors, no pneumatics, and no electronics. The result of a properly installed system with a Keepfull is liquid on demand by keeping the system flooded with LN2. When a system is idle, it is normal for the Keepfull to have intermittent periods of venting. There is a check valve on the end of the bayonet discharge point that keeps moisture from entering into the system (1/8" MNPT, 1 PSI differential). The check valve can be removed for pressure testing. It is imperative that the Keepfull devices are located at all system high points and are in working condition (see section 8.4).

MAKE SURE THE KEEPFULL IS ROTATED SO THAT THE DISCHARGE BAYONET IS LOCATED AT THE TOP. DO NOT ROTATE THE KEEPFULL FROM THE VERTICAL POSITION.

Make sure there are no process pipe utilities or equipment located directly under or in front of the Keepfull discharge to prevent damage in the unlikely event that liquid nitrogen comes out of the Keepfull. Terminate the exhaust gas in a safe location to eliminate the risk of personnel exposure or damage to equipment.

Picture 20 – Keepfull Vent Device

10.3 STANDARD VENT HEATER

A Vent heater reduces the risk associated with large ice balls that would normally form on the discharge of a Keepfull. They slide onto the Keepfull's discharge bayonet or onto a vacuum insulated vent line that ends with a male bayonet. A standard vent heater is not intended to be a vent gas heater; it is designed to eliminate ice formation at the vent point. The assembly heaters come with a standard 6' long electrical service cord and a standard 3-prong male plug connector (US = 120 VAC, NEMA 5-15). The cord can be removed to facilitate hard wiring. If this is done, make sure the electrical connection is flexible with enough slack to enable the entire heater assembly to be removed from the Keepfull for maintenance and band heater replacement. The standard voltage of the heater is 110VAC/300w. It is important to note that heater elements may trip sensitive electrical circuits with GFCIs installed. See note from Engineering below.

Make sure flammable or combustible materials are kept away from the heater.

DO NOT attach anything to the heater; they are intended to exhaust into free air.

Picture 21 – Standard Vent Heater

10.3.1 Ambient Vent Heater (AVH)

The general purpose of the AVH is for indoor use where the cold discharge gas needs to be warmed prior to venting—typically used for long-distance vent lines to eliminate the need for insulation or for venting into exhaust ducts. Our AVH provides an ice-free (ambient temperature) vent gas, minimizing safety hazards such as falling ice, water drips, large ice accumulation, and roof damage. These heaters come with a wall-mounted control panel. The standard voltage of the heater is 110VAC/1500W. The assembly comes with a standard 6' long electrical service cord and a standard 3 prong male plug connector (US = 120, NEMA 5-15). It is important to note that heater elements can trip sensitive GFCI electrical circuits. It is recommended that the heater is connected to non-GFCI circuit.

Picture 22 – Ambient Vent Heater

Engineering note on GFCI's:

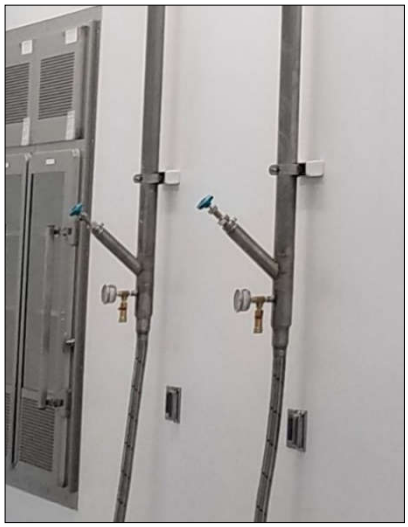
Changes in current in conjunction with the large temperature changes the element can see during normal operation can cause standard attached GFCI units to trip. In some cases, a GFCI trip may not be associated with a heater element failure or short circuit. Per the National Electric Code (NEC) section 210.8 (see "Exception to (3)") it is permitted to install Ground Fault Protection for Equipment in lieu of Protection for Personnel if a branch circuit is dedicated to a de-icing heater and sections 426.28 and 427.22 are followed, as applicable. This can possibly be done with an adjustable limit ELCI that can be changed from trip points of 6mA, 10mA, and 30 mA (compared to a GFCI for personnel protection which trips at 5mA). A local certified electrician should be contacted to ensure that the removal of the GFCI is done safely (if GFCI is already installed), and any additional equipment is installed properly and is code compliant.

10.4 SHUT-OFF VALVES

10.4.1 Vacuum Insulated Manual Valve

These valves come in T-pattern, Y-pattern, and angle pattern styles. They must be installed with the stem angled at least 30 degrees or more from the horizontal. This will eliminate liquid from flowing into the valve bonnet, which can increase system heat leak and potentially cause a leak or condensation at the valve bonnet. Valve maintenance and removal of valve internals should be considered when orienting valve stem during installation.

Picture 23 – T-Pattern Shut off Valve



Picture 24 – Y-Pattern Shut off Valve

10.4.2 Non-Vacuum Insulated Manual Valve (Bronze Cryogenic Globe Valve)

It is acceptable to install these manual valves in the horizontal or vertical position but make sure the valve stem is never pointing down (this will result in liquid contacting the valve stem seals and collection of debris against the stem). It is common that these valves come with an integral SRV. After installation, the SRV riser should be in the vertical position (see examples below). The valves can be mechanically insulated if desired (see section 8.9 Mechanical Insulation of non-vacuum Insulated components).

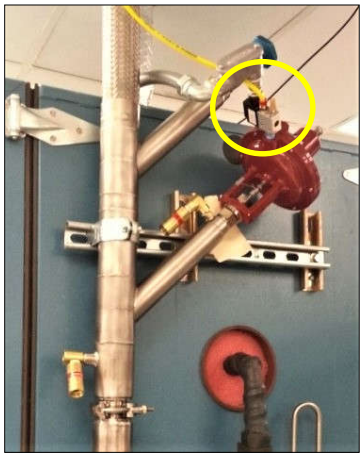
Picture 25 – Bronze Cryogenic Globe Valve

Picture 26 – Bronze Cryogenic Globe Valve

10.4.3 Actuated Valves

Most actuators require GN2 or compressed air to actuate the valve. Check the system drawing or the actuator pressure requirements for correct pneumatic pressure. Most of the actuators will have a ¼" threaded 3-way 24V or 110V solenoid that is commonly tied into a control circuit (O2 monitor, push-button switch for remote actuation, customer signal, etc.). Some actuators will have a positioner that is controlled with a 4-20ma signal. See pictures below of actuated valve installations.

Picture 27 – Actuated Valve



Picture 28 – Actuated Valve

Picture 29 – Actuated Valve

10.5 OXYGEN MONITORING

10.5.1 Monitors

Oxygen monitors are typically required and always highly recommended for areas where liquid nitrogen is used (see safety section 5.0). Refer to the monitor manual for wiring instructions. A typical mounting is surface mount to a wall. Because cold nitrogen gas is heavier than air, it is recommended to install the monitors about 3-4 feet above a floor. Placement of the monitors in areas where equipment will normally discharge nitrogen gas into the environment should be carefully reviewed for nuisance alarms (i.e., opening a lid off a storage freezer or door to an environmental chamber). The monitor comes with a removable standard 110V cord and a built-in 24V transformer. Many projects and EH&S groups require the monitors to be hard-wired, which will require removing the cord and providing a 24VAC power source.

This component comes with a separate manual. Consult CryoWorks for wiring schematics, multi-unit controllers, and design assistance.

Picture 30 – Oxygen Monitor

10.5.2 Horn / Strobe Assembly

The horn and strobe assembly is an audible and visual indicator built into one unit. These are signaled and powered by the O2 monitor and are 24VAC. Refer to the monitor manual for wiring instructions. The units are generally installed onto a standard electrical junction box, either surface-mounted or flush-mounted. Ideal locations: they can be located outside of each entrance into an area that is using LN2 and on the ceiling inside the room based on CGA P-18 and customer-specific requirements.

Picture 31 – Horn/Strobe Assembly

10.5.3 Warning Labels / Signage Examples

A sign should accompany each horn/strobe to instruct personnel of the hazard and to not enter the area during an alarm. See examples: **Reference CGA P-18 and NFPA 704.

Pictures 32a thru 32c – Warning Labels / Signage Examples

10.5.4 Push-Button E-Stop (Emergency Stop)

E-stop buttons are used to remotely actuate a valve in case of an emergency. They can be wired as an independent switch, or in conjunction with an Oxygen Monitor to control an emergency shut-off valve (ESOV). They are most effective when mounted in easily accessible locations near exits.

Picture 33 – Push Button E-Stop

10.6 SAFETY RELIEF VALVES (SRV)

These are sometimes referred to as pressure relief valves. Safety Relief Valves (SRV) are ideally suited for use as "Blocked Line Safeties" in cryogenic systems. The SRV is a spring loaded over-pressure protection device. Selection, or sizing of the valve can be based on many different relief scenarios, with thermal relief being a common scenario in cryogenic systems. SRVs are also referred to as Pressure Relief Valves or Pressure Relief Devices.

The SRVs are designed into the pipe system prior to installation and generally come installed via pipe threads. Proper heat path, gas pockets, and discharge orientation, and discharge location are considered during the design phase. Adding equipment onto the CryoWorks system without consultation is not recommended.

****Warning:** Make sure the relief valve discharge is not pointing in the direction of personnel, equipment, etc. Pipe-away adaptors with female pipe threads are available that will facilitate piping the discharge gas to a safe area if the vent gas will cause depletion of oxygen in the local environment. If the vent gas will be piped away from the SRV, ensure that the safety valve model used does not have a weep hole.

10.7 PHASE SEPARATORS

Refer to the Phase Separator manual for instructions on your specific model. Follow the placement dimensions on the system drawing for the installation location. Utilize the provided support tabs for phase separator mounting. The controller is typically mounted on a wall at eye level.

11.0 MAINTENANCE

11.1 PIPE INSPECTION

With regular inspection, a vacuum insulated pipe system is designed to last many years with minimal maintenance. It is recommended to visually inspect the entire pipe system at least a couple times per year. Refer to any component or equipment manuals for their respective recommended maintenance (i.e., Phase Separators, Dosing Units, Oxygen Monitors, Valves, Heaters, etc.).

11.1.1 Excessive Condensation, Frost, or Ice.

If any of these conditions are found on the surfaces of the pipe or bayonet connections, contact CryoWorks at (951) 360-0920. Under certain circumstances, these conditions may be normal. Take pictures of the condition and document serial numbers, if possible. Ice or frost at non-vacuum insulated connections can be normal. If ice or frost develops on the surface of a foam insulated connection, the insulation will need to be replaced or repaired (See section 8.9).

11.1.2 LN2 Leaks

If an actual liquid leak is identified, immediately shut down the system. Let the system warm up to ambient temperature (typically takes 12-24 hours) to safely work on a system. Leaks may be caused by loose fittings, an un-tightened bayonet clamp, cracked/dirty O-ring, leaking valve or SRV, etc. Contact CryoWorks if further assistance is needed.

11.1.3 Safety Relief Valves

Visually inspect any SRVs for leaks, dirt or debris in the exhaust port, encapsulation in ice, tampering, etc. If an SRV needs to be replaced, make sure there is no pressure inside the pipe system prior to replacing it.

11.1.4 Heaters

A heater element will burn out in time, much like a light bulb. If ice accumulation is evident on a heater, it could be that the power has been disrupted, or the heater element is burned out. In all cases, it is recommended to shut off the liquid source prior to replacing a heater element. To replace the element on a standard heater: turn off the LN2, turn off the power source, open the junction box and undo the wire nuts, loosen the band heater via a hex key, and slide the element off and out of the heater cage. Replacement is the reverse. Consult the manual of the ambient vent line heater for its maintenance. See troubleshooting chart 12.1 near the end of this manual.

11.1.5 Keepfull

The Keepfulls should be intermittently exhausting gas when equipment is not drawing liquid. It is normal for a Keepfull to constantly exhaust gas during times of heavy flow. Visually inspect the Keepfulls for any liquid exiting the discharge point. If this condition exists, shut the system down if the liquid is creating a hazardous environment. See troubleshooting chart 12.1 near the end of this manual.

11.1.6 Life Safety

O2 monitors, ESO buttons, ESOVs, ventilation systems, and building management systems (BMS) should be routinely checked to make sure they are operating properly and as designed. Most O2 monitors have a cell inside them that will need to be replaced at some interval. Refer to the specific monitors' manual for recommended cell replacement and/or calibration.

12.0 PIPE SYSTEM TROUBLESHOOTING

12.1 REFER TO COMPONENT MANUALS FOR NON-PIPE TROUBLESHOOTING.

Condition	Possible Cause	Solution
Bayonets will not engage	Tolerances are too tight.	Contact CryoWorks for consultation
	Pipe sections are not aligned.	Move adjoining pipe around until the bayonets are perfectly aligned. See section 8.5.7.
Ice on bayonet connection	Loose clamp allowing liquid or cold gas to escape.	Warm up the system to ambient. Tighten clamp. See torque specs – section 8.5.8.
	O-ring is cracked or misaligned.	Warm up the system to ambient. Replace O-ring.
	Male bayonet is pointing upwards in the vertical.	Design issue. Contact CryoWorks for a solution.
	Loss of vacuum on a spool	Replace spool.

Condition	Possible Cause	Solution
Liquid leaking at mechanical connections	Loose threaded fittings or gaskets.	Re-do fittings with proper threaded sealant and pressure test. See section 8.8.
Keepfull is leaking liquid out of discharge	Ice on seat of Keepfull.	Shut-off system and purge Keepfull (and pipe system if possible) with warm or ambient nitrogen gas. Contact CryoWorks for detailed procedure.
	Debris on seat of Keepfull.	Shut-off, depressurize and drain system. Remove Keepfull and flush with alcohol or cleaning solution, dry and re-install. Contact CryoWorks for detailed procedure.
Ice ball on heater element	Power to heater is off.	Verify correct voltage to heater.
	Tripping circuit.	Verify amperage load on circuit is not too high.
	Tripping ground fault circuit interrupter.	Remove GFCI. See section 10.3.
	Burned out element.	Replace element.
SRV is exhausting gas and/or liquid	SRV pressure rating is too low.	Shut off system, check SRV pressure rating against system design pressure, and consult CryoWorks.
	System pressure is too high.	Lower system pressure.
	Liquid is trapped between valves.	Normal operation. Possible design considerations. Contact CryoWorks.
Condensation, frost, or ice on entire pipe section (not related to weather)	Vacuum is soft or deteriorated.	Replace pipe section.
Pneumatic valves not opening	No electric signal to valve solenoid.	Correct signal issue to solenoid.
	No or low pneumatic pressure.	Check for correct pressure, leaks in pressure circuit, or upstream supply valve shut-off.
	Solenoid is damaged.	Replace solenoid.
	Actuator is leaking air.	Replace or rebuild actuator.

Condition	Possible Cause	Solution
No pressure at point-of-use valves	Valve closed upstream.	Open valves.
	No pressure in source tank.	Fill tank, check tank pressure build, and economizer settings. Contact Gas Supplier.
No liquid at point-of-use valves	No liquid in source tank.	Fill tank. Contact Gas Supplier.
	Pipe system connected to incorrect valve on source tank.	Verify liquid withdrawal valve and re-connect.
	Excessive heat leak into pipe system.	Remove heat source. Contact CryoWorks for consultation.
	Improper sloping	Make sure all piping is sloped up to each Keepfull (no dips, sags, or traps).
	Keepfull not venting	Make sure Keepfulls are located at all system high points and that they are venting properly. Check for debris or clogs if no gas is venting. Contact CryoWorks.

13.0 WARRANTY

13.1 WARRANTY STATEMENT

See CryoWorks Doc. No. CDSSAL-00127 for our full Terms and Conditions of Sale.
https://cryoworks.net/cryoworks-resources/

14.0 SERVICE

CryoWorks, Inc. has installation and service technicians to help. If service or installation is desired, please call the main office at (951) 360-0920 or email service@cryoworks.net.