Product Manual

Engineer to Order
Vacuum Insulated Pipe

Designed and Built by:

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Revision Log

Revision Level	Date	Description
C	07/08/2014	Convert to new layout and add Design Guide Section
D	11/13/2014	Update Pro Rigid data in Design Guide section and update trademarks
E	02/19/2015	Update Flex Technical Specifications in the Design Guide Section
F	07/15/2015	Remove warranty section (duplicate of the Terms and Conditions) change Design Guide section to match Spec Sheets
G	09/17/2015	Update Installation section to include hanger support intervals, combine Unpacking the Pipe and Preparing for Installation into new Pre-Installation section.
H	04/19/2016	Page 16 Installation bullet 2b change “halocarbon” to “Dow Corning High Vacuum”.
I	04/24/2017	Added “Do NOT use this grease for O_2 service” to note on page 14. Remove all instances of MVIP and replace with VIP. Remove Pro and Select wording. Add Appendix A - Field Installation Procedure.

Preface

General

Chart is the world's leading designer, manufacturer and installer of standard and custom Vacuum Insulated Pipe (VIP) systems. Our industry-leading 40 years of experience covers the spectrum of traditional industry applications, from heat-leak sensitive helium lines to highly engineered aerospace applications. Our vacuum insulated pipe systems are built in an ISO 9001:2008 approved manufacturing facility. This sophisticated facility shares manufacturing with our tank product lines, giving us the resources and flexibility to adjust our pipe manufacturing capacity to market demands. This enables us to keep our lead times and costs down while maintaining superior product quality. Our wide product offering of pipe and accessories allows us to engineer the optimum system solutions for any liquid application.

Product Advantages

- **Complete Integrated Systems:** From vacuum insulated tank and piping components to controls to application equipment, Chart has the experience and expertise to deliver a complete, turnkey cryogenic delivery system.
- **Quality Manufacturing:** Our equipment is built for efficiency and built to last. Our experience and ISO 9001:2008 certification ensures that your job is completed to the highest quality standards and on schedule.
- **Flexible Modular Solutions:** Chart delivers the quality and flexibility you need, with pre-engineered Vacuum Insulated Pipe standard modules from which you can design your VIP system with the guidance of the Chart Modulator Ordering Software website or knowledgeable Chart sales staff.
- **Customer-Engineered Solutions:** If you need a robust, customer-engineered VIP system, our planning team will document your system specifications and our engineering team will propose the most efficient and economical Vacuum Insulated Pipe solution to meet your system's performance requirements.
- **Installation and Startup:** Certified technicians provide installation and training to assure long-term, trouble-free operation.

Product Manual

Thank you for your purchase of Chart Vacuum Insulated Pipe. Chart has designed and fabricated your pipe system with attention to detail and utilizing the leading cryogenic technologies to ensure a highly efficient and reliable pipe system.

This manual is intended for use by Chart VIP customers. It is important to read and understand the information in this manual before installing or operating the pipe system. This manual is provided by Chart to its customers as a courtesy and, except as expressly provided in this manual, Chart makes no warranties, express or implied, regarding the contents in this manual. Chart assumes no responsibility for any outcomes as a result of using this manual.

Any information contained in other manuals for equipment supplied by third party manufactures (including, but not limited to valves, actuators, relief valves, etc.) shall take precedence over information contained within this manual with respect to that third party equipment.

Service

Chart's Vacuum Insulated Pipe has been designed for years of safe and dependable operation. In the event service is required, please contact Chart at:

Chart Inc.
407 7th Street NW
New Prague, MN 56071 USA
www.chartindustries.com
Phone: 1-888-877-3093

Design Modification

DO NOT use this product in any manner not consistent with the instructions outlined in this manual!

NEVER alter the design, or perform service that is not consistent with the instructions outlined in this manual, without the prior written approval of Chart!

ALWAYS refer to the manual supplied by the component manufacturer for the most accurate and current information regarding that item and its particular use. Each vacuum insulated pipe system may use different components (such as valves) based on the required performance of the system. Different brands of components may be used for various purposes. Any information in the component manufacturer's manual shall take precedence over information contained in this manual.

Additional copies of this manual are available by contacting Chart in New Prague, MN or by going to Chart's website (www.chartindustries.com).

Terms

Throughout this manual safety precautions will be designated as follows:

Warning! ***Description of a condition that can result in personal injury or death.***

Caution! ***Description of a condition that can result in equipment or component damage.***

Note: *A statement that contains information that is important enough to emphasize or repeat.*

Acronyms / Abbreviations

The following acronyms / abbreviations are used throughout this manual:

BTU	British Thermal Unit
CGA	Compressed Gas Association
CO_2	Carbon Dioxide
GPM	Gallons per Minute
KG	Kilogram
kJ	Kilojoule
LN_2	Liquid Nitrogen
LCO_2	Liquid Carbon Dioxide
LO_2	Liquid Oxygen
LPM	Liters per Minute
MAWP	Max Allowable Working Pressure
NFPA	National Fire Protection Association
PN	Part Number
PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch (Gauge)
SCF	Standard Cubic Feet
SCM	Standard Cubic Meters
VIP	Vacuum Insulated Pipe
VS	Vacuum Section

Safety

Strict compliance with proper safety and handling practices is necessary when using a cryogenic system. We recommend that all our customers re-emphasize safety and safe handling practices to all their employees and customers. While every possible safety feature has been designed into the system and safe operations are anticipated, it is essential that the user of the cryogenic system carefully read and fully understand all WARNINGS and CAUTION notes listed in this safety summary and enumerated below. Also read the information provided in the Safety Bulletin for Oxygen and Inert Gases following this Safety Summary. Periodic review of the Safety Summary is recommended.

Warning! ***Vacuum insulated pipe systems are designed to contain pressurized, ultra-cold cryogenic liquids and/or extremely cold gas. These systems should only be worked on by trained personnel to avoid serious injuries such as freezing, oxygen deficient atmospheres and extremely high pressures.***

Warning! ***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 not protected by an over-pressure relief valve will experience extremely high pressures and significant safety concerns.***

Warning! ***Before working on any section of a vacuum insulated pipe system, it is critical to positively confirm the section or entire system is depressurized and drained of all liquid. Even a section with residual cold gas will warm up and develop positive pressure in a short period of time. One must NEVER assume that a section contains no pressure.***

Warning! ***If you are at all unsure of how to safely work on this system, STOP and contact Chart immediately.***

Caution! ***As with any cryogenic system, it should be observed that any non-insulated piping can get extremely cold and should not be touched by exposed skin. If the system requires maintenance, it should be shutdown and allowed to warm up.***

Caution! ***Before removing parts or loosening fittings, empty the cryogenic piping system of liquid and release any vapor pressure in a safe manner.***

External valves and fittings can become extremely cold and may cause painful burns to personnel unless properly protected. Personnel must wear protective gloves and eye protection whenever removing parts or loosening fittings. Failure to do so may result in personal injury due to the extreme cold and pressure in the system.

Warning! ***Accidental contact of liquid gases with skin or eyes may cause a freezing injury similar to a burn.***

Handle liquid so that it will not splash or spill. Protect your eyes and cover skin where the possibility of contact with liquid, cold pipes and equipment, or cold gas exists. Safety goggles or a face shield should be worn if liquid ejection or splashing may occur or cold gas may issue forcefully from equipment. Clean, insulated gloves that can be easily removed, and long sleeves are recommended for arm and hand protection. Cuffless trousers should be worn over the shoes to shed spilled liquid.

Warning! ***If clothing is splashed with liquid oxygen it will become highly flammable and easily ignited while concentrated oxygen remains.***

Such clothing must be aired out immediately, removing the clothing if possible, and should not be considered safe for at least 30 minutes.

Warning! If the pipe system is going to be used in oxygen service now, or at any time in the future, use only replacement parts that are compatible with liquid oxygen and have been cleaned for oxygen use.

Do not use regulators, fittings, hoses, etc., which have been previously used in a compressed air environment. Similarly, do not use oxygen equipment for compressed air. Failure to comply with these instructions may result in serious damage to the equipment.

Caution! Before locating oxygen equipment, become familiar with the relevant EU Directives or NFPA Standard No. 55 (www.nfpa.org), "Compressed Gases and Cryogenic Fluids Code" and with all local safety codes.

The NFPA standard covers general principles recommended for the installation, storage, use and handling of compressed gases and cryogenic fluids in portable and stationary containers, cylinders, equipment and tanks in all occupancies.

Safety Bulletin

Portions of the following information are extracted from Safety Bulletin SB-2 from the Compressed Gas Association, Inc. (CGA). For the full text of Safety Bulletin SB-2 and for more information about oxygen atmospheres, refer to Safety Bulletin SB-2 from the CGA. Additional information on nitrogen and argon and liquid cylinders is available in CGA Pamphlet P-9. Write to the Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202 or visit their website at www.cganet.com.

Oxygen Deficient Atmospheres

The normal oxygen content of air is approximately 21%. Depletion of oxygen content in air, either by combustion or by displacement with inert gas, is a potential hazard and users should exercise suitable precautions.

One aspect of this possible hazard is the response of humans when exposed to an atmosphere containing only 8 to 12% oxygen. In this environment, unconsciousness can be immediate with virtually no warning.

When the oxygen content of air is reduced to about 15 to 16%, the flame of ordinary combustible materials, including those commonly used as fuel for heat or light, may be extinguished. Somewhat below this concentration, an individual breathing the air is mentally incapable of diagnosing the situation because the onset of symptoms such as sleepiness, fatigue, lassitude, loss of coordination, errors in judgment and confusion can be masked by a state of "euphoria" leaving the victim with a false sense of security and well being.

Human exposure to atmosphere containing 12% or less oxygen leads to rapid unconsciousness. Unconsciousness can occur so rapidly that the user is rendered essentially helpless. This can occur if the condition is reached by an immediate change of environment, or through the gradual depletion of oxygen.

Most individuals working in or around oxygen deficient atmospheres rely on the "buddy system" for protection - obviously the "buddy" is equally susceptible to asphyxiation if he or she enters the area to assist the unconscious partner unless equipped with a portable air supply. Best protection is obtainable by equipping all individuals with a portable supply of respirable air. Life lines are acceptable only if the area is essentially free of obstructions and individuals can assist one another without constraint.

If an oxygen deficient atmosphere is suspected or known to exist:

1. Use the "buddy system." Use more than one "buddy" if necessary to move a fellow worker in an emergency.

2. Both the worker and "buddy" should be equipped with self-contained or airline breathing equipment.

Oxygen Enriched Atmospheres

Warning! In an oxygen enriched atmosphere flammable items burn vigorously and could explode.

An oxygen-enriched atmosphere occurs whenever the normal oxygen content of air is allowed to rise above 23%. While oxygen is nonflammable, ignition of combustible materials can occur more readily in an oxygen-rich atmosphere than in air; and combustion proceeds at a faster rate although no more heat is released.

It is important to locate an oxygen system in a well ventilated location since oxygen-rich atmospheres may collect temporarily in confined areas during the functioning of a safety relief device or leakage from the system.

Oxygen system components, including but not limited to, containers, valves, valve seats, lubricants, fittings, gaskets and interconnecting equipment including hoses, shall have adequate compatibility with oxygen under the conditions of temperature and pressure to which the components may be exposed in the containment and use of oxygen. Easily ignitable materials shall be avoided unless they are parts of equipment or systems that are approved, listed, or proven suitable by tests or by past experience.

Compatibility involves both combustibility and ease of ignition. Materials that burn in air may burn violently in pure oxygen at normal pressure, and explosively in pressurized oxygen. In addition, many materials that do not burn in air may do so in pure oxygen, particularly when under pressure. Metals for containers and piping must be carefully selected, depending on service conditions. The various steels are acceptable for many applications, but some service conditions may call for other materials (usually copper or its alloy) because of their greater resistance to ignition and lower rate of combustion.

Similarly, materials that can be ignited in air have lower ignition energies in oxygen. Many such materials may be ignited by friction at a valve seat or stem packing, or by adiabatic compression produced when oxygen at high pressure is rapidly introduced into a system initially at low pressure.

Nitrogen and Argon

DANGER

Warning! Nitrogen and argon vapors in air may dilute the concentration of oxygen necessary to support or sustain life.

Nitrogen and argon (inert gases) are simple asphyxiates. Neither gas will support or sustain life and can produce immediate hazardous conditions through the displacement of oxygen. Under high pressure these gases may produce narcosis even though an adequate oxygen supply sufficient for life is present.

Nitrogen and argon vapors in air dilute the concentration of oxygen necessary to support or sustain life. Inhalation of high concentrations of these gases can cause anoxia, resulting in dizziness, nausea, vomiting, or unconsciousness and possibly death. Individuals should be prohibited from entering areas where the oxygen content is below 19% unless equipped with a self-contained breathing apparatus. Unconsciousness and death may occur with virtually no warning if the oxygen concentration is below approximately 8%. Contact with cold nitrogen or argon gas or liquid can cause cryogenic (extreme low temperature) burns and freeze body tissue.

Persons suffering from lack of oxygen should be immediately moved to areas with normal atmospheres. SELF-CONTAINED BREATHING APPARATUS MAY BE REQUIRED TO PREVENT ASPHYXIATION OF RESCUE WORKERS. Assisted respiration and supplemental oxygen should be given if the victim is not breathing. If cryogenic liquid or cold boil-off gas contacts worker’s skin or eyes, the affected tissue should be flooded or soaked with tepid water (105-115ºF or 41-46ºC). DO NOT USE HOT WATER. Cryogenic burns that result in blistering or deeper tissue freezing should be examined promptly by a physician.

Personal Protective Equipment (PPE)

The following personal protective equipment is recommended when working around cryogenic liquid:

- Safety glasses with side shields to prevent cryogenic liquid from splashing into the eyes
- Chemical / Liquid resistant gloves to prevent cryogenic burns on exposed hands
- Long sleeve shirts to protect the arms
- Cuffless trousers worn over closed shoes

Vacuum Insulated Pipe Design Guide

Scope

Determining the scope of your system is an important step in design. Answering the following questions will give you the information you need before you login to the Modulator VIP Ordering Software and place your order.

- What is the starting point (i.e. Apps Unit, Existing VIP, Transfer Hose, etc.)?
- What is the liquid service application this system will be used for (i.e. LN_2 Doser, LN_2 Test Chamber, LO_2, etc.)?
- Will you need liquid or gas or both?
- What type of supply tank and connections will you need?
- Do you require a cryovent (liquid service in 10 seconds or less will require a cryovent)?
- Do you require a constant supply of liquid?
- What is the expected usage of product?
- What type of connection is required at the use point?
- Do you require a shut off valve?
- Are any transfer hoses required?
- What is the maximum allowable working pressure (MAWP)(i.e. 0-150, 150-250, 250-400, etc.)?
- Do you have requirements for any special testing?

Approach to System Design

- Determine the basic routing of the liquid nitrogen system. Chart will provide any needed assistance.
- Develop an isometric sketch or plan and elevation views of the vacuum insulated pipe (VIP) layout. This step is necessary to determine the exact components required.
- Size the pipe and components by determining expected current and future flow rates. Chart can assist once the flow requirements are known. Plan now for potential system expansion.
- Be sure to note wall penetrations so that couplings are positioned properly for ease of assembly.
- Installation restrictions for length of sections should also be noted.

Configuration (Size Limitations)

The configuration of a Built-To-Order section of VIP is restricted only by shipping and installation constraints. Typically, installation conditions impose more limitations than do shipping constraints. For shipping purposes, all pipe sections should fall within an 8x8x40 foot envelope.

Rigid vs. Flexible VIP

Rigid VIP has lower heat leak and is less expensive than flexible VIP. The prudent use of flexible VIP sections:

- Minimizes alignment problems during installation and operation.
- Eliminates the necessity of precise field measurement.
- Provides a simple means for disassembly of the system for service or modification.
- It may be used in a lateral-offset manner to eliminate overstress conditions.

Valves used at the end of a run or drop are normally extended packing cryogenic valves. Vacuum jacketed valves are more expensive, and should be limited to in-line service.

Features of a typical system include:

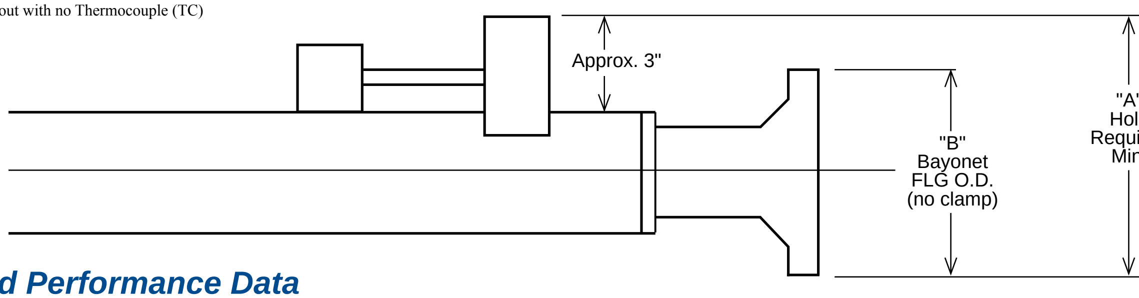
- Bayonet couplings for ease of installation.
- Equivalent flow flexible sections for changes of direction and elevation.
- Vacuum jacketed in-line valves to isolate branch runs for selective shutdowns.
- Capped bayonet couplings for future expansion.
- Flexible drops with internal trapped ends for efficient operation and rapid response to cycling equipment.
- Cryovent at end of run to keep main header cold and liquid readily available to use points.

Rigid VIP Analysis

Rigid Technical Specifications

Smart Number	Inner Pipe Size	Outside Jacket Diameter*	Actual Flow Diameter	Standard Overall Lengths	"A" Hole Required to Accommodate Pump Out**	"B" Bayonet FLG O.D. (no clamp)	Weight / Length
PR-08-PR	½"	2"	0.710	2,3,4,5,6,15,18,20',30'	5.75"	2.755"	3.0 lb/ft (3.4 kg/m)
PR-16-PR	1"	3"	1.185"	2,3,4,5,6,15,18,20,30'	6.75"	3.761"	4.5 lb/ft (6.2 kg/m)
PR-24-PR	1 ½"	3 ½"	1.770"	3', 4', 5', 6', 10', 15', 18', 20', 30'	7.50"	4.396"	5.5 lb/ft (7.4 kg/m)
PR-32-PR	2"	3 ½"	2.245		7.75"	4.923"	6.0 lb/ft (8.4 kg/m)

* Not including pump out.
** Pump out with no Thermocouple (TC)



Rigid Performance Data

Smart Number	Cool Down			Static Heat Leak		LN_2 Bayonet Pair Heat Leak	
	kJ/m	kg/m*	lb of LN_2/ft	BTU/hr/ft	Watt/m	BTU/hr	Watt
PR-08-PR	39	0.20	0.13	0.32	0.31	14.1	4.13
PR-16-PR	58	0.29	0.19	0.48	0.46	20.8	6.09
PR-24-PR	85	0.43	0.29	0.58	0.56	22.1	6.47
PR-32-PR	107	0.54	0.36	0.79	0.76	19.3	5.65

*LN_2 at one bar

Rigid LN_2 Flow Guideline

Smart Number	Pipe Size	100 ft	200 ft	300 ft	400 ft	500 ft
PR-08-PR	½" PS	4.8 gpm	3.5 gpm	2.9 gpm	2.6 gpm	2.2 gpm
PR-16-PR	1" PS	29.0 gpm	20.0 gpm	16.0 gpm	12.0 gpm	11.0 gpm
PR-24-PR	1 ½" PS	63.0 gpm	50.0 gpm	42.0 gpm	38.0 gpm	36.0 gpm
PR-32-PR	2" PS	110.0 gpm	80.0 gpm	70.0 gpm	62.0 gpm	58.0 gpm

Rigid Pressure Drop (psi/ft)*

Smart Number	Flow (gal/min)							
	2	5	10	25	50	75	100	150
PR-08-PR	0.006	0.039	0.154	0.964				
PR-16-PR		0.003	0.011	0.063	0.262	0.570	1.014	
PR-24-PR			0.001	0.008	0.040	0.070	0.125	0.280
PR-32-PR				0.002	0.009	0.193	0.034	0.077

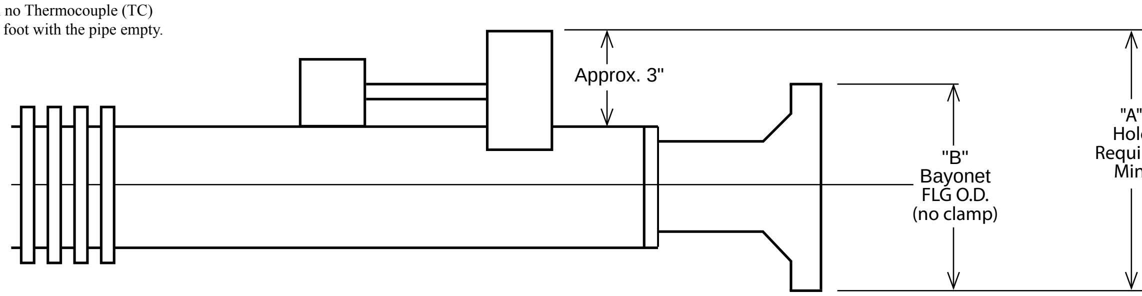
*Pressure drop numbers listed do not account for elevation changes. Chart recommends pressure drop be kept to 5 psi or less.

Flexible VIP Analysis

Flex Technical Specifications

Smart Number	Inner Flex Diameter	Minimum Bend Radius	Outer Jacket Diameter*	Actual Flow Diameter	Standard Overall Lengths	"A" Hole Required to Accommodate Pump Out **	"B" Bayonet FLG O.D. (no clamp)	Nominal O.D. with Braid	Weight*** / Length
PR-08-PF	¾"	12"	2"	¾"	6', 10', 15', 20', 25', 30', 60'	5.75"	2.755"	2 11/16"	2.2 lb/ft (3.2 kg/m)
PR-16-PF	1 ¼"	16"	3"	1 ¼"		6.75"	3.761"	4 1/16"	3.9 lb/ft (5.7 kg/m)
PR-24-PF	2"	20"	4"	2"	8', 10', 15', 20', 25', 30'	7.50"	4.396"	5 ⅛"	6.6 lb/ft (9.7 kg/m)
PR-32-PF	2"	20"	4"	2"		7.75"	4.923"	5 ⅛"	6.6 lb/ft (9.7 kg/m)

* Not including pump out.
** Pump out with no Thermocouple (TC)
*** Weight is per foot with the pipe empty.



Flex Performance Data

Smart Number	Cool Down			Static Heat Leak		LN_2 Bayonet Pair Heat Leak	
	kJ/m	kg/m*	lb of LN_2/ft	BTU/hr/ft	Watt/m	BTU/hr	Watt
PR-08-PF	72	0.37	0.24	0.977	0.94	14.1	4.13
PR-16-PF	135	0.69	0.45	1.44	1.38	20.8	6.09
PR-24-PF	225	1.15	0.75	1.74	1.67	22.1	6.47
PR-32-PF	225	1.15	0.75	2.37	2.28	19.3	5.65

*LN_2 at one bar

Flex LN_2 Flow Guideline

Smart Number	Pipe Size	100 ft	200 ft	300 ft	400 ft	500 ft
PR-08-PF	½" PS	3.0 gpm	2.0 gpm	1.6 gpm	1.4 gpm	1.2 gpm
PR-16-PF	1" PS	6.5 gpm	5.0 gpm	4.0 gpm	3.7 gpm	3.5 gpm
PR-24-PF	1 ½" PS	20.0 gpm	12.0 gpm	10.0 gpm	9.0 gpm	8.0 gpm
PR-32-PF	2" PS	42.0 gpm	32.0 gpm	28.0 gpm	25.0 gpm	20.0 gpm

Flex Pressure Drop (psi/ft)*

Smart Number	Flow (gal/min)						
	2	5	10	25	50	75	100
PR-08-PF	0.012	0.077	0.307	1.919			
PR-16-PF		0.009	0.034	0.213	0.852		
PR-24-PF			0.004	0.060	0.110	0.115	0.400
PR-32-PF			0.004	0.060	0.110	0.115	0.400

*Pressure drop numbers listed do not account for elevation changes. Chart recommends pressure drop be kept to 5 psi or less.

Use Point Consideration

Operating efficiency is greatly affected by the design of use points. Because of the cyclical mode of operation in most applications, gas traps should be incorporated to keep cryogenic liquid out of the non-vacuum insulated segments of the system between use cycles.

Multiple use point configurations should be designed as illustrated in Figures 1 and 2.

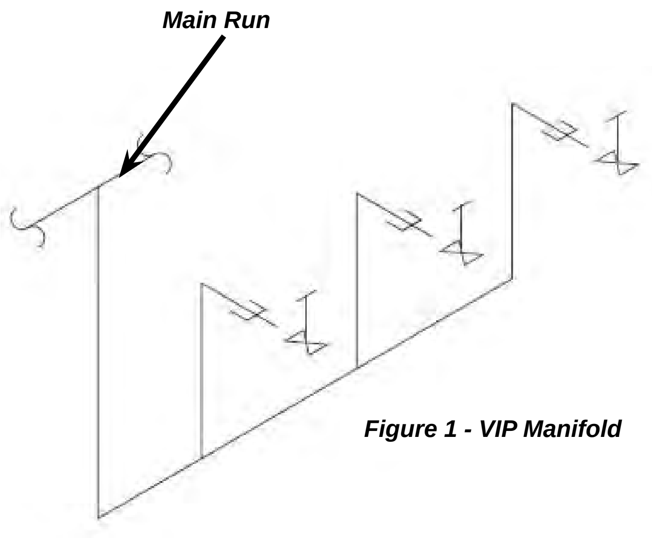


Figure 1 - VIP Manifold

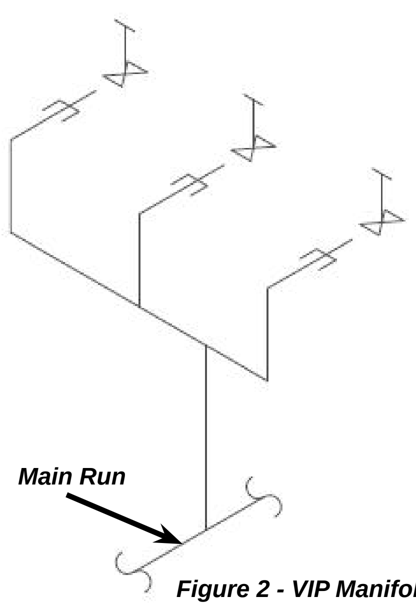


Figure 2 - VIP Manifold

Trap End

Single drop use points also require trap ends. While Figure 3 shows a suitable trap end installation the preferred method is the Chart Trap End as illustrated in Figure 4. This is less expensive and requires less space than that illustrated in Figure 3.

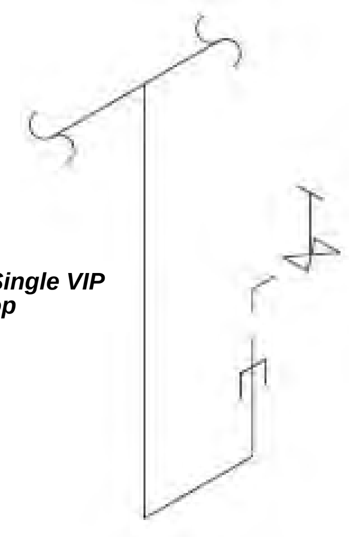


Figure 3 - Single VIP Drop

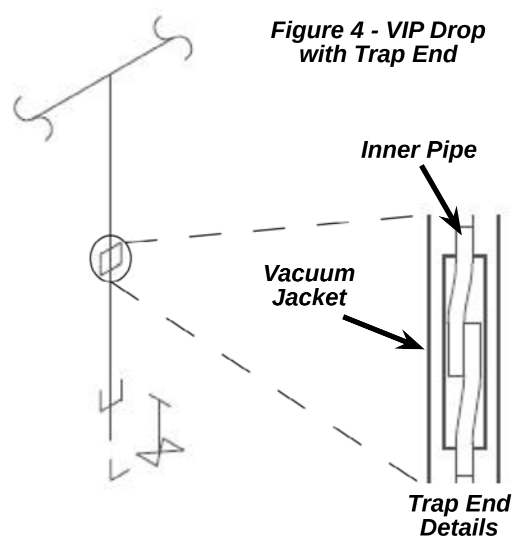


Figure 4 - VIP Drop with Trap End

Installation

Pre-Installation

Unpacking the Pipe

Upon arrival of the pipe system, it is advised to immediately inspect for any signs of damage. If any damage occurred in shipping, claims must be filed with the shipping carrier immediately. It is suggested to inspect the pipe before it is removed from the truck. If damage is found, alert the driver and document with pictures and proper description before the driver leaves the premises. Please contact Chart immediately to determine if the damage is severe enough that the pipe will need re-work or repair.

Things to check for upon arrival include:

- Dents in the outer jacket of the pipe
- Damaged vacuum gauge tube
- Male bayonets should have protective sleeves over them
- Female bayonets should have protective caps over them
- Count the number of sections and compare to the number of sections shown on the drawing to be sure you have received a complete shipment
- Proper number of bayonet clamps/flanges and O-rings
- Proper number of cryovents
- Any other components that were defined to ship loose.

When unpacking the pipe, caution should be used to ensure the pipe is not damaged by hammers, pry bars, screwdrivers, saws, or any other tools that may be used for the packaging or securing of the pipe for shipment.

When removing the pipe from the truck, one should take note of the section of pipe and its total geometry. Watch for items such as valves, pressure relief risers, vacuum pump-out ports or flexible pieces that may stick out in other directions and be prone to damage as it is lifted off the truck and set aside.

Caution! ***When removing the pipe from the truck, gently set it on the ground. Do not drop the pipe off the truck! When transporting the pipe through the job site, be sure to carry with care. Take care to not run into walls or drag the pipe on the ground or floor.***

Do not remove any of the bayonet protective pieces until the actual installation. This will help ensure damage is not done inadvertently between the time of unloading and installation.

Prior to installation, the pipe sections should be stored in a location that will prevent dirt, water or other debris from getting inside the pipe. Similarly, it should be stored in a place that is generally out of the way of frequent traffic to reduce the risk of damage. Chart recommends not storing the pipe in direct sunlight when not in service.

Preparing for Installation

Before beginning the installation, the technicians should ensure they have the proper tools and equipment available. The following serves as a basic list of the most commonly needed tools and equipment. Each installation is different and some may require additional tools

- Pipe hangers
- Threaded rod
- Beam clamps
- Vacuum grease
- Combination box-end wrench set
- Screwdrivers
- Man-lift
- Ladders
- Nitrogen gas source for purge and / or pressure test
- Proper safety equipment

The installation technicians should survey the site and walk the intended route of the pipe system to be sure there is nothing prohibiting them from doing the installation. If the installation requires a shutdown of a section of an existing pipe system (or the whole system), the technicians should make sure that all affected parties are made aware of the shut-down and the expected duration of the shut-down prior to starting the work.

Supporting the Pipe

When supporting the pipe system, a few things need to be considered. The first is the proper support span (distance between supports) and the weight of the pipe that is being supported. The following table gives approximate weights per foot of the pipe, depending on the size.

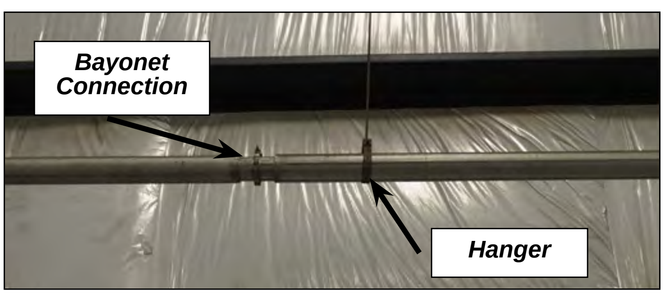
Note: *These weights are only approximate and can vary due to the presence and number of valves, actuators, etc.*

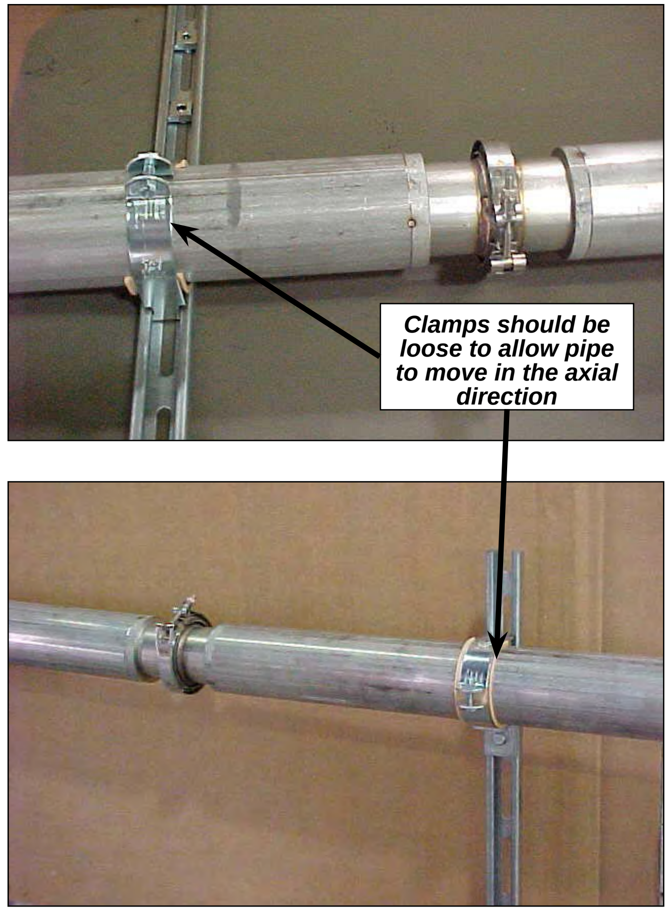
Pipe Size	Approx. weight/foot with Liquid Nitrogen*
1/2” inner line (2” outer jacket)	3-1/4 lb/ft
1” inner line (3” outer jacket)	5 lb/ft
2” inner line (4” outer jacket)	7-1/2 lb/ft
3” inner line (5” outer jacket)	14-1/4 lb/ft
4” inner line (6” outer jacket)	17-1/2 lb/ft
Larger than 4” inner line	Consult Chart

*Consult Chart for weights of pipe with any other liquid.

Supports should be placed close enough to handle the above weight loads, depending on the load capacity of the support system being used. Furthermore, Chart recommends that each section of pipe have a minimum of two supports to relieve any stress on the bayonets. Hangers and supports should be installed at intervals of six to ten feet, and at all change of direction points. To ensure adequate support of the bayonets at least one hanger should be placed within one foot of the bayonet.

The following pictures show installations where the bayonet connection is well supported.

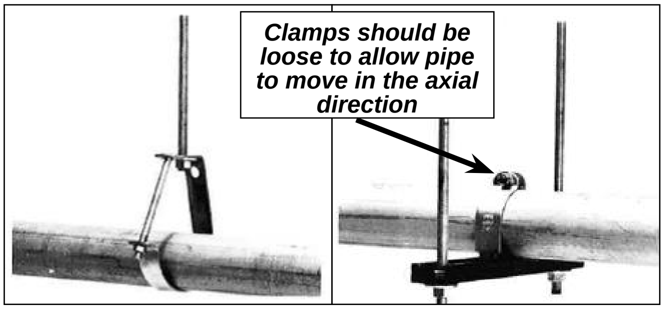




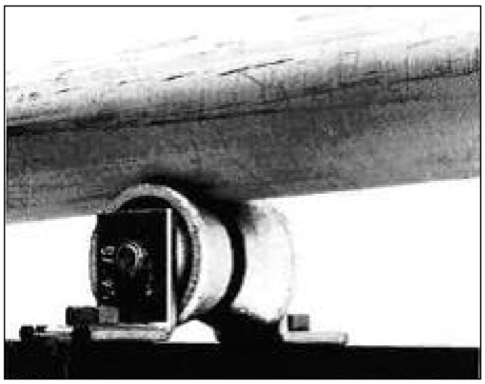
In addition to weight loads, the support system used must account for the possibility of movement of the system. For example, pipe installed on the top of a roof will get very warm in hot climates on sunny days. As the outer jacket warms up, it will expand along the length of the pipe. The installation should provide a support means that accommodates this movement as well as provisions to account for this movement at the point the pipe penetrates down into the building.

Similarly, for external bellows pipe systems, the relative movement between the inner and outer jackets is taken up in the outer jacket. As such, the outer jacket will move by design. A support system (such as rollers, hangers, etc.) must be used to allow this movement and prevent damage of the pipe[1]. Examples of roller and hanger supports are shown in the following pictures.

[1]On average, a pipe system may move approximately 1” per 28’ of linear length. However, each pipe system should be evaluated independently for proper movement and support.



Hanger Supports



Roller Support

Caution! ***External bellows pipe systems must use a support system that allows for the outer jacket to move. If this is not done, damage to the bayonets could occur.***

Note: *There should not be any welding to the outer jacket. Doing so will void the warranty of the pipe.*

Assembling the Bayonets

Caution! ***Assembly of bayonets should not require much force. If there is any resistance, STOP and consult Chart to avoid any damage to the bayonets.***

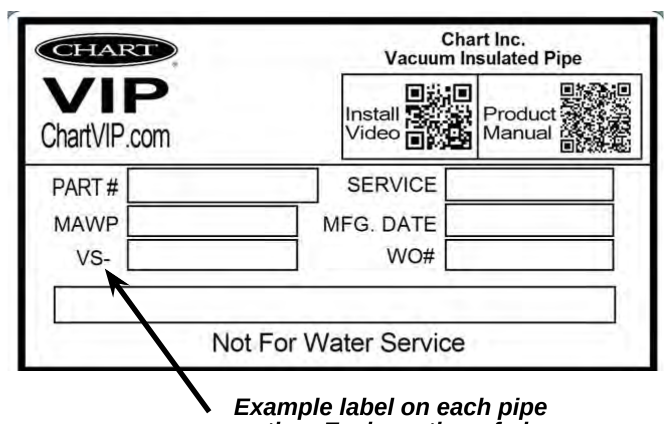
When properly installed, Chart's bayonet fittings are designed to provide a very reliable connection that is extremely leak resistant and thermally efficient. Please use the following procedure for the assembly of the bayonets:

1. Confirm the bayonet pair (male/female) being installed is correct.

Male Bayonet

Female Bayonet

2. Consult the Chart-supplied system drawing to determine which section (noted by VS-#) is intended to connect to which other section. The VS-# that is shown on the system drawing refers to the VS-# that appears on the label on the pipe. An example of this label is shown here:



Example label on each pipe section. Each section of pipe will have its own VS (vacuum section) number.

Note: *If MVE/VIP bayonets are used, once the bayonets are installed and get cold the pipe will require 24 hours to warm up before the bayonets can be pulled apart. Assembling the wrong bayonets could result in significant installation delays!*

3. Remove the bayonet protective sleeve (on male bayonet) and cap (on female bayonet). Inspect the inner and outer surfaces for any signs of damage, dirt, water or debris. If any such problem is found, clean the bayonets with water. Be sure the bayonets are <u>completely</u> dry (inside and out) before installing. If other physical damage exists, consult the factory before attempting installation.

4. Prior to engaging a bayonet set, ensure that the male and female halves are exactly in alignment.

Caution! If bayonets are not properly aligned, the installation will be much more difficult and could ultimately result in damage to the bayonets.

5. Apply a thin film of vacuum grease to the supplied O-ring.

Note: *The proper vacuum grease and O-rings can be purchased at www.chartparts.com. The Chart part number for the grease is AAA0306.* ***Do NOT use this grease for O_2 service.***

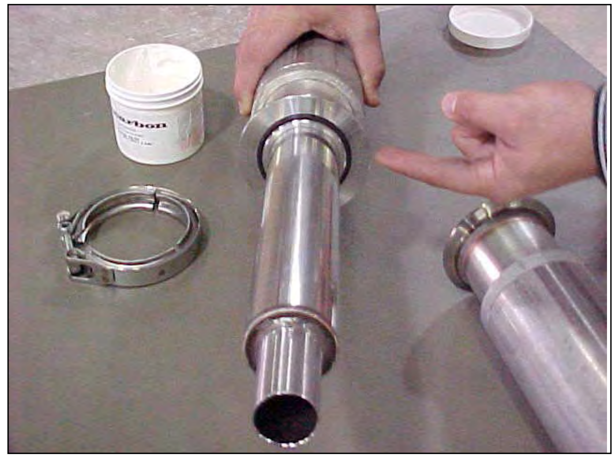
The following table lists the proper part numbers for O-rings based on the bayonet size.

Bayonet Size	O-ring PN
MVE/VIP Pro Design	
MVE/VIP Pro 1/2” x 1-1/2”	2322231
MVE/VIP Pro 1” x 2-1/2”	2322291
MVE/VIP Pro 1-1/2” x 3”	2322341
MVE/VIP Pro 2” x 3-1/2”	2300321
CVI Design	
CVI 1” x 2-1/2”	30-0000-15231
CVI 1-1/2” x 3	30-0000-15238
CVI 2” x 4”	30-0000-15246
CVI 3” x 5”	30-0000-15254
CVI 4” x 6”	30-0000-15261

Caution! Do not use <u>hydro</u>carbon (auto) grease.

Caution! Do not apply a grease of any kind to the bayonet itself.

6. Install O-ring into the groove that is machined into the male bayonet flange.



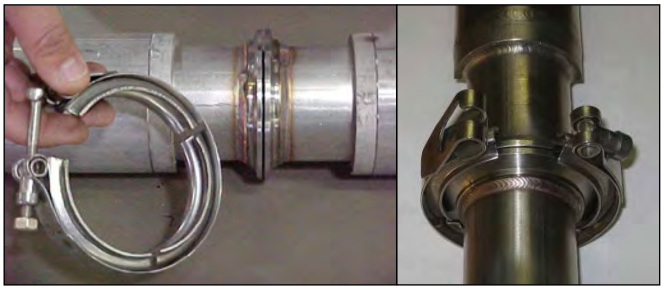
Note: *CVI design bayonets have the O-ring groove machined into the female bayonet flange rather than the male bayonet flange.*

7. Connect the bayonet halves together until the female bayonet flange contacts the O-ring.

Caution! Do not twist the bayonets to get them to engage.

Caution! Do not force the bayonets together with a chain, hammer, come-along, or any other means. If the bayonets do not go together easily, stop and call the factory for assistance.

8. Spread open the V-band clamp and put it around the bayonet flange set as shown in the following picture:



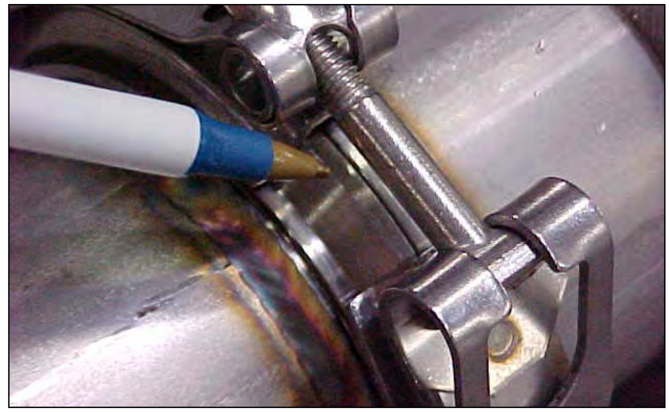
9. Insert the T-bolt through the round receiving end and tighten the nut to secure.

10. While tightening the nut, lightly tap around the V-band clamp with a small rubber mallet. This will help ensure that the V-band clamp tightly secures and pulls the bayonet flanges together.

11. Tighten nut to the following torque values:

Inner Pipe Size	*Torque Value (in-lbs)*
1/2"	50
1"	50
1-1/2"	50
2"	75

12. The flanges should engage until there is a very small gap between the male and female flanges.



After all of the bayonets have been connected and the support hangers are secure, install any non-vacuum insulated components such as brass valves, etc[2]. Note that any small leaks in the threaded plumbing connections, or through the end use equipment valves, etc., can cause frost and/or ice to form on the threaded connections. It is very important to make sure these connections are confirmed to be leak free.

Installation of Split Back-up Flanges

1. If applicable, remove protective covers from bayonets.

Note: *If piping system is in service, remove all pressure from system before removing V-retainer clamps.*

2. Refer to Figure 5 (below):

   a. Verify bayonet nose and flanges are not damaged.

   b. Apply thin layer of Dow Corning High Vacuum grease to O-ring. Do not use standard, hydrocarbon-based grease.

   c. Install O-ring in O-ring groove.

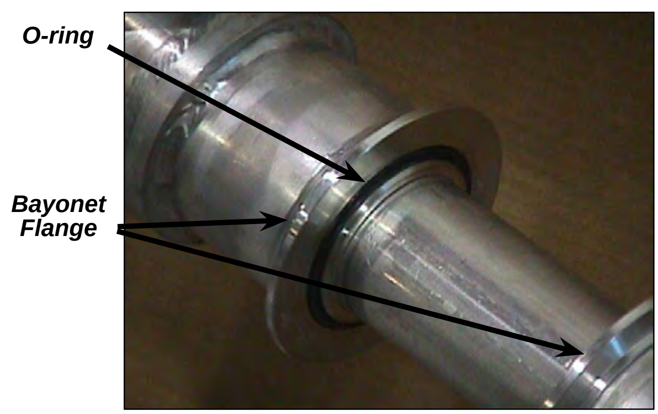


Figure 5

[2]*It is recommended to use a Teflon tape, properly installed, on any threaded connections.*

3. Engage male bayonet into mating female.
   - Do not twist bayonets during engagement
   - Do not force. If force is required, disengage and inspect bayonets
   - Engage bayonets until flanges are within ~1/16” of touching
4. Back-up flanges have a machined surface that matches bayonet flange (see Figure 6).

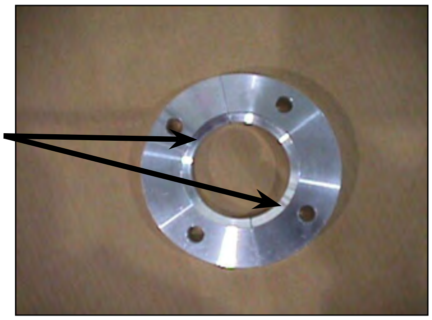


Figure 6

5. Back-up flanges are installed with left and right sides twisted 90° in relation to each other (see Figure 7).

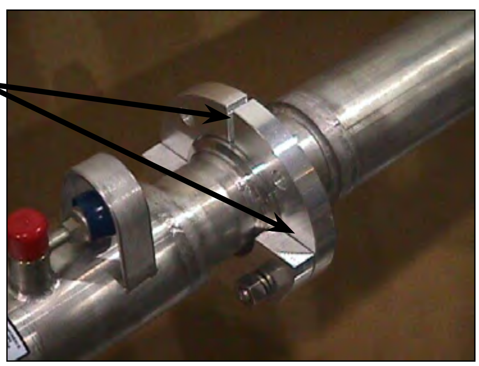


Figure 7

6. Install stainless steel bolts, each using lock washer and nut. Assure flanges fit tightly to bayonet flanges. Tighten bolts securely.

Completed assembly

Bend Radius Limits of Flexible Pipe

Flexible pipe is often used in pipe systems to facilitate installation and connection to the bulk tank or end use equipment. In some cases, flexible pipe may have been used to help go around an obstruction in the path of the pipe such as a support column or existing electrical or HVAC equipment. In other cases, flexible pipe may have been used to help make small adjustments in the pipe as well as bend 90° rather than using a rigid elbow. It is important to not over-bend the flexible pipe. If the flexible pipe is bent beyond its bend radius, it is likely to cause a thermal short or develop a leak. The following table shows the minimum bend radius for the different size pipes. If a smaller bend radius is required, a rigid 90° elbow should be used in the design.

Inner Flex Size	*Minimum Bend Radius*
3/8” ID x 1” ID Transfer Hose	8”
1/2” Pipe Size	12”
1” Pipe Size	16”
1-1/2” Pipe Size	20”
2” Pipe Size	20”

Relief Valve Discharge

It should be recognized that the automatic pressure relief valves could discharge at any time. Care should be taken to consider the orientation of the relief valve discharge so that it does not spray extremely cold gas and/or cryogenic liquid on sensitive surfaces or onto personnel. Automatic pressure relief valves that are installed outdoors should be done in a manner that prohibits rain, dirt, snow or ice to accumulate on the end of the valve. It is the responsibility of the customer to check these relief valves and ensure that they are pointed in the proper direction. Although Chart installs the relief valves during manufacturing of the pipe, we have no way of knowing the surrounding atmosphere at installation to be able to modify the installation orientation.

Warning! The automatic pressure relief valve can discharge extremely cold gas and/or cryogenic liquid at any time. The discharge of these valves MUST be oriented in a way so as not to spray on any personnel.

The line pressure relief valves installed by Chart are intended to be used in a manner that they discharge freely to atmosphere. Adding plumbing to the exit of a relief valve can reduce the over-all relieving capacity.

Slope of Pipe System

The performance of the pipe system can be greatly affected by the slope of the pipe sections. If the pipe system has a cryovent, the pipe should be installed such that the pipe slopes vertically up to the cryovent to allow the gas bubbles to naturally rise up to the cryovent. The amount of slope recommended is 1" per 50' span. This slope is usually achieved by adjustment of the support and/or hanger system.

Start-Up/Commissioning

Following a proper start-up procedure is very important to minimize the chances of pressure spikes within the system, as well as reduce the probability of getting impurities or debris introduced into the system, lodged in valve seats, etc. Once the system has been fully installed, the following general procedure should be followed to start-up the system. The exact procedure will vary depending on the specific system, equipment involved, etc.

Caution! System start-up should only be performed by properly trained technicians who fully understand cryogenics and pressure and who follow strict safety guidelines.

The general start-up procedure is as follows:

1. Ensure a properly sized pressure relief valve[3] is installed between any and all locations where liquid can become trapped.
2. If the system has any cryovents, close the isolation valve on the outlet side to prohibit flow through the cryovent during the initial start-up process.
3. Close all use point valves throughout the system.
4. Slowly open the system supply valve ½ turn and allow pressure to fill the pipe system slowly. Closely monitor the pressure in the system for any signs of pressure above the MAWP[4] of the pipe.
   a. If product does not start flowing into the pipe system after ½ turn of the valve, open another ¼ turn. If again, no product is flowing, open the valve another ¼ turn, etc.
   b. If the valve is opened completely and no product is flowing, ensure the main supply valve is open and contact Chart.
5. When product has stopped flowing into the pipe and the system is at supply pressure, walk the system and check for any leaks.
6. If no leaks are found, slowly open a use point valve at the location farthest from the supply.

Warning! Ensure there are no personnel in the vicinity of the venting gas/liquid stream. Also ensure there is proper ventilation so as not to produce an oxygen deficient atmosphere.

7. When a continuous stream of liquid exits at the farthest use point, close that use point valve and open the next use point valve upstream.
8. Continue sequentially opening use point valves until all use points have been purged through and a liquid stream is present.
9. Open the cryovent isolation valve approximately half way.
10. Allow the cryovent to cool down for one hour.
11. Fully open the cryovent isolation valve.

[3]*Each section of pipe has an identification label that documents the MAWP of the pipe. The pressure relief valve should be set at a pressure equal to or less than the MAWP of the pipe.*

[4]*The MAWP is indicated on the label of each section of pipe.*

Components

Each vacuum insulated pipe system may use different components based on the required performance of the system. In addition, different brands of components (such as valves) may be used for various purposes. Please refer to the manual supplied by the component manufacturer for the most accurate and current information regarding that item. Any information in the manufacturer's manual shall take precedence over information contained in this manual.

Cryovents

Cryovents are designed to help remove residual gas from the pipe system, keeping it full of liquid during periods of no use. When properly installed, cryovents will greatly reduce the amount of time required to get quality liquid at the point of use.

Cryovent with vacuum insulated inlet and outlet

The cryovent is a vacuum insulated mechanical float device. As vapor accumulates in the cryovent, the float drops and allows the gas to vent out of the cryovent. When all of the gas has vented out, liquid fills the cryovent reservoir, lifting the float and closing the valve.

In normal operation, the cryovent will open and close in a cyclical manner to keep the pipe system full of liquid. The frequency of the opening and closing will be determined by the length of the pipe system, the slope of the pipes, the amount of liquid being used by the system, the amount of non-vacuum insulated pipe in the system and ambient conditions. It is normal for a cryovent to vent more or less frequently on some days than it does on other days.

The vapor coming out of the cryovent is extremely cold. Unless a Chart cryovent heater or insulated pipe is used on the exhaust of the cryovent, it should be expected to have frost and/or ice accumulate on the exit of the cryovent.

Note: *The cryovent is not designed to operate at or near 150 psi.*

Caution! ***Care should be taken to evaluate where the cryovent exhaust is located. Extremely cold vapor will come out of the cryovent. Should the cryovent fail for any reason, there is a chance that cryogenic liquid could come out of the cryovent exhaust. The exhaust should be designed in such a way so that there is no risk of personal injury or property damage should such a failure occur.***

Warning! ***The cryovent is not a pressure relief device. It will not protect the pipe system from over-pressure conditions. Only automatic pressure relief valves should be used as pressure relief devices.***

Warning! ***The cryovent will vent various amounts of vapor. Care should be taken to make sure the room is properly ventilated so as not to produce an oxygen deficient (in nitrogen or argon service) or an oxygen enriched (in oxygen service) atmosphere.***

Installation of Cryovent Heaters

Slide the O-ring and the cryovent exhaust gas heater onto the outlet bayonet of a Chart cryovent. Preferably, position the electrical box at the 12:00 position. Connect the two bayonets together using the clamp provided with the cryovent. Plug the cord into a 120 volt receptacle. The receptacle must be protected by a fuse or circuit breaker.

If installing an outdoor heater a ground fault interrupter should NOT be used. The electrical supply should be routed through waterproof conduit into the conduit elbow. The ground should be connected to the grounding terminal in the conduit elbow.

Warning! ***Due to large amounts of heat being distributed, the perforated metal will become hot. The 1" diameter circle directly above the heater will become extremely hot. DO NOT TOUCH!!***

The cryovent exhaust gas heater is made to run continuously. If not run continuously while nitrogen is flowing, frost and ice may form. For longest heater life, it is recommended that the heater is unplugged when the nitrogen system is shut down for extended periods.

During system start up, the cryovent can be isolated using Chart cryovent heater valve kit PN 11835572. After system start up is complete, the valve kit components must be removed. All pressure should be released before the valve kit components are removed.

If work or maintenance is being done around the cryovent exhaust gas heater, caution should be taken to prevent being burned.

Hot labels are placed on the cryovent exhaust gas heater to provide caution to those working in the area. The hot labels are not placed directly at the hottest points due to the perforated metal. The hot point is directly above the heater and is about 1” in diameter. This part of the perforated metal will get hot. Therefore, if work is to be done around the cryovent exhaust gas heater, caution should be taken. Heater can also be unplugged if the risk of being burned is at hand. If heater is unplugged for extended periods of time, frost and ice may form.

Warning! Heater becomes extremely hot and will cause severe burns! DO NOT put hand inside heater guard!

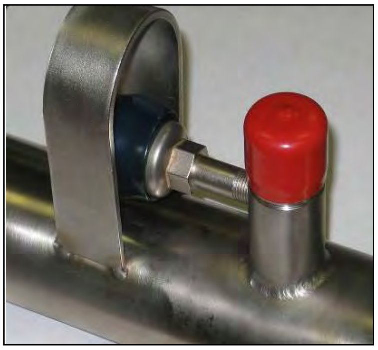
Python® Vacuum Insulated Pipe

The Python vacuum insulated pipe connections are field welded, and the modules can be reused by cutting and welding. Exterior bellows offer improved flow and reduced pressure drop while accommodating up to 400°F temperature differential. The insulation system begins with a radiation shield, joint pre-formed foam, and a durable stainless steel outer jacket.

For installation of Python piping please refer to the Installation Manual PN 11822026 located at www.chartparts.com.

Vacuum Gauge Tubes

Vacuum gauge tubes are used to check the condition of the vacuum space at any given time. The standard vacuum gauge tube Chart uses is a Hastings DV-6 (shown in the following picture with a protective red vinyl cap beneath the protective stainless steel strap). To check the vacuum, simply remove the vinyl cap and connect the appropriate meter to the gauge tube and check the reading.



The gauge tube is a sensitive instrument that should not be tampered with. Any abuse to the gauge tube may cause a loss of vacuum in that section. If the gauge tube should ever need to be replaced, it should be replaced only by a Chart technician as it involves dropping the vacuum on the section. If the vacuum is not dropped properly, the insulation space can become contaminated and thus permanently damage the section of pipe.

Vacuum Insulated Valves

Some pipe systems include vacuum insulated valves. These valves are manufactured by a third party. Contact Chart to obtain any detailed information regarding the valves used in your system.

Pneumatic Actuators

Some pipe systems include pneumatic actuated valves. These actuators are manufactured by a third party. Depending on the brand and model of pneumatic actuator, it may require low (~30 psi) or high (~80 psi) control pressure to operate. Contact Chart to obtain any detailed information regarding the actuators used in your system.

Pressure Relief Valves

Automatic pressure relief valves are installed in the system for safety purposes to prevent an over-pressure condition. If the pressure in the pipe system exceeds the setting on the relief valve, the relief valve will open and discharge vapor and/or liquid to reduce the pressure in the pipe system. When the pressure in the pipe system drops back below the setting of the relief valve, the relief valve will close. If the pressure in the pipe system has dropped well below the setting of the relief valve and the relief valve has not stopped discharging vapor and/or liquid, it may be necessary to change the relief valve. It is a good idea to have a few spare relief valves on site as spare parts. Be sure to only use cryogenic rated pressure relief valves. Relief valves can be purchased online by visiting www.chartparts.com.

Note: *A relief valve must be located anywhere liquid can be trapped (such as between two valves that can be turned off). This is needed to vent the gas if both valves are closed.*

Note: *Any liquid carbon dioxide (LCO_2) systems require special relief valves. Consult the factory for the proper valves for LCO_2 service.*

DANGER

Warning! ***Maintenance to any cryogenic piping system should only be performed by trained and qualified professionals. These pipe systems may be pressurized, contain liquid or gaseous nitrogen and seriously injure personnel if not handled with proper safety precautions.***

Maintenance

The vacuum insulated pipe system is designed to provide many years of performance with regular inspection and minimal maintenance.

Warning! ***Maintenance to any cryogenic piping system should only be performed by trained and qualified professionals. These pipe systems may be pressurized, contain liquid or gaseous nitrogen and seriously injure personnel if not handled with proper safety precautions.***

System Inspection

It is a good idea to walk along the entire length of the pipe system, from the storage tank to the end-use equipment at least once per year. When inspecting the system, one should look for any of the following:

- Frost or ice spots

Note: *Frost on any vacuum insulated components may be normal. If frost, ice or condensation appear, that location should be monitored along with the ambient temperature and humidity for the next few weeks. If a vacuum meter is available, it would be good to take vacuum readings as well. Frost, sweat or ice can occur for various reasons such as those listed below.*

  - At any non-insulated connection
  - At bayonet flanges, given certain ambient temperature and humidity conditions
  - On pipe sections, given certain ambient temperature and humidity conditions

- Evidence that the relief valves have been tampered with in any way
- Signs of a leak
- External damage such as dents

Check and/or Replace Relief Valves

The relief valves should be visually inspected at least once per year. When inspecting the valves, check for any signs of the following:

- Relief valve removed
- Pressure setting of relief valve higher than the MAWP of the pipe
- A plug in the exit of the relief valve
- Dirt or debris in the exit of the relief valve
- Gas leaking out of the relief valve, or out of the threaded connection at the bottom of the relief valve

If the relief valve needs to be replaced, please use the following procedure:

1. Identify a use point or other connection downstream from the relief valve that can be opened to discharge pressure to atmosphere.
2. Open the point identified in #1 slightly so that some vapor is being discharged to atmosphere.
3. Close an isolation valve upstream from the relief valve location.
4. Wait until vapor is no longer discharging from the location identified in step #1.
5. When the vapor has stopped discharging, open that location fully to confirm there is no pressure in the system. Leave this location open during the removal of the defective relief valve.
6. Using the proper sized wrench, remove the defective relief valve by turning the wrench counterclockwise.
7. Remove any obvious strands of Teflon tape from the pipe threads on the pipe system.
8. Verify the set pressure of the new relief valve is appropriate for this system.
9. Apply new Teflon tape to the threads of the new relief valve[5].
10. Tighten the new relief valve into the port on the pipe system.

[5]*It is recommended to not have Teflon tape on the first thread of the relief valve.*

11. Close the valve or location identified in step #1.

12. Slowly re-open the isolation valve closed in step #3.

13. Check for any leaks at the new relief valve.

Disassembly of Bayonets

If the bayonets need to be disassembled, please use the following procedure:

1. Drain the system of liquid nitrogen and allow to warm-up for approximately 24 hours.

2. Before attempting to remove a bayonet, open the pipe system to atmosphere at a convenient use point to ensure there is no residual pressure in the line at the point where the bayonet is going to be disassembled.

3. Make sure no person is directly in front of the bayonet being removed.

DANGER **_Warning!_** **_Never stand, nor put any body part directly in-line with any pipe system component when it is being disassembled._**

4. Slowly loosen the nut on the bayonet V-band retainer clamp.

DANGER **_Warning!_** **_Stop and listen and feel for any evidence of gas leaking through the bayonets. If any is detected, stop immediately and remove all pressure from the system._**

5. Remove the nut from the V-band clamp bolt.

6. Remove the V-band clamp from the bayonet flanges.

7. Slowly pull the two bayonet halves apart.

Caution! **_The bayonets should come apart easily. If they are difficult to remove, wait another 4 hours to allow the parts to further warm-up and try again. If, after 30 hours of no liquid in the pipe system, it is still very difficult to get the bayonets apart, stop and call Chart._**

Caution! **_Do not twist the bayonets to get them apart._**

8. It is recommended to replace the used O-ring with a new O-ring when the bayonets are re-installed. The O-ring part numbers are given in the installation section of this manual and can be purchased on-line at www.chartparts.com.

9. Place a protective cover over both of the bayonet halves to avoid any damage to the parts, or getting any dirt, debris or water inside the bayonets and pipes.

Appendix A

Field Installation Procedure for Welded Field Joints

The following procedure outlines the field assembly for welded field joints. This procedure assumes that the pipe sections are positioned and properly supported.

Equipment and Supplies Required

1. Welder
    a. Protective equipment
    b. Welding rod - stainless steel
    c. Purge gas - argon / nitrogen
2. Mass Spectrometer leak detector
    a. Helium tracer gas
    b. Vacuum hose to connect evacuation fixture to Mass Spec
    c. Hose Clamps
    d. Vacuum grease (PN AAA0306)
    e. End closures for pipe (rubber stopper or equivalent)
3. Solvent / cleaner (denatured alcohol or equivalent)
4. Vacuum pump
    a. Evacuation fixture (PN 3514839)
    b. Vacuum hose to connect evacuation fixture to vacuum pump

Procedure

1. Preparation
    a. Verify that inner pipe ends, weld pads and cover are free from damage.
    b. Slide cover onto pipe such that inner pipe is fully accessible (see Figure 1).

Figure 1

2. Inner pipe welding

Note: *This is a pressure bearing weld and as such may have code requirements such as certified welder and weld procedure, pressure test, NDT and third party inspection. Refer to applicable regulations).*

    a. Clean the weld areas of the inner pipe with the solvent / cleaner.
    b. Connect welding purge gas to flow through inner pipe. Flow gas until inside of inner pipe is inerted.
    c. Weld inner pipe joint. This must be a full penetration weld.
    d. Weld all inner pipe joints in the system (see Figure 2).

Figure 2

3. Leak test

   a. Mass Spec leak test:

      - Connect the Mass Spec machine test port to one end of the piping system.
      - Plug the other openings on the piping system (see Figure 3).

Figure 3

      - Evacuate and leak test the system. Each field weld should be carefully tested. Joint must show no indication of leakage on the $1x10^{-8}$ SCC/sec scale (see Figure 4).

Figure 4

   b. Pressure test:

      - If a pneumatic or hydro pressure test is required it should be done at this time.

4. Insulation and getters

   a. Clean and insulate the joint immediately prior to closing up the joint and welding the cover.

   b. Using the solvent / cleaner carefully clean the entire area that will be enclosed by the cover.

   c. Attach the molecular sieve packets (aluminum foil packets - 1-1/2” x 3”) to the inner pipe using clean, bare copper wire (see Figure 5).

Figure 5

      - Use the following number of sieve packets based on inner pipe size:

        1/2” PS - 1 packet

        1” PS - 2 packets

        1-1/2” PS - 3 packets

        2” PS - 4 packets

        3” PS - 6 packets

   d. Using an awl or weld rod, pierce 15 - 25 holes in each packet. Be careful that the molecular sieve remains contained by the packet (see Figure 6).

Figure 6

   e. Use the multi-layer super insulation to insulate the visible inner pipe.

      - Use two individual sets of approximately 10 layers each that are the width of the non-insulated inner pipe and long enough to wrap around the inner pipe approximately 1-1/4 turns. Install the first set of 10 layers. Install the second set of 10 layers so that the overlap area is at a different location from the first set. The insulation should be held in place using the clean, bare copper wire. The insulation should be snug but not compressed (see Figure 7).

Figure 7

f. Place one Paladium Oxide (PdO) packet (brass screen) inside the cover (see Figure 8).

Figure 8

g. Slide the cover into place, centered on the weld pads. Locate to pumpout (evacuation port) such that the evacuation fixture can be attached and operated.

5. Cover weld

a. Weld the cover to the weld pad with a 1/8” fillet weld. Weld the entire circumference of each cover to weld pad joint (see Figures 9 & 10).

Figure 9

Figure 10

6. Mass Spec leak test

a. Use the evacuation fixture to connect the Mass Spectrometer to the field joint pumpout.

- Use the vacuum grease to lightly lubricate the pumpout o-rings. A thin film is sufficient.
- Place one o-ring in the bottom of the pumpout body (welded to the cover). Place the second o-ring in the o-ring groove of the pumpout plug.
- Screw the pumpout plug onto the threaded end of the evacuation fixture operator. Do not tighten the threaded connection beyond light contact (see Figure 11).

Figure 11

- Connect the evacuation fixture to the pumpout and mass spec leak test the field joint and welds. Joint must show no indication of leakage on the $1x10^{-8}$ SCC/sec scale (see Figure 12).

Figure 12

- After joint is shown to be leak free, use the fixture operator to push the pumpout plug into the body. Unthread the operator from the plug and disconnect the evacuation fixture from the pumpout.

7. Evacuation

a. Reconnect the evacuation fixture to the pumpout and thread the operator into the pumpout plug.

b. Connect the evacuation fixture to the vacuum plug. Evacuate the hose and fixture.

c. Use the operator to lift the plug into the fixture (lift fully). A prop may be required to hold the operator open (see Figures 13 & 14).

Figure 13

Figure 14

d. Evacuate the field joint for 4 hours minimum.

e. Seal off the pumpout. Use the fixture operator to push the pumpout plug into the body. Unthread the operator from the plug and disconnect the evacuation fixture from the pumpout.

f. Place the plastic cover over the pumpout (Figure 15).

Figure 15