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CRYOGENIC

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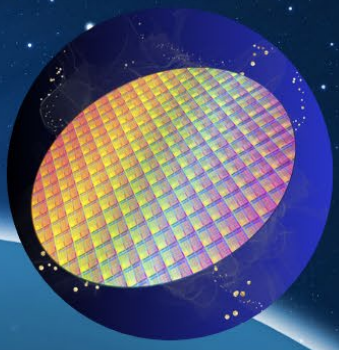

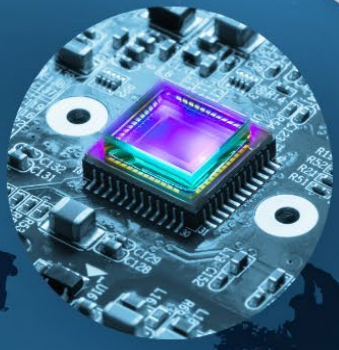

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Stay cool under pressure

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Table of Content

Page No.

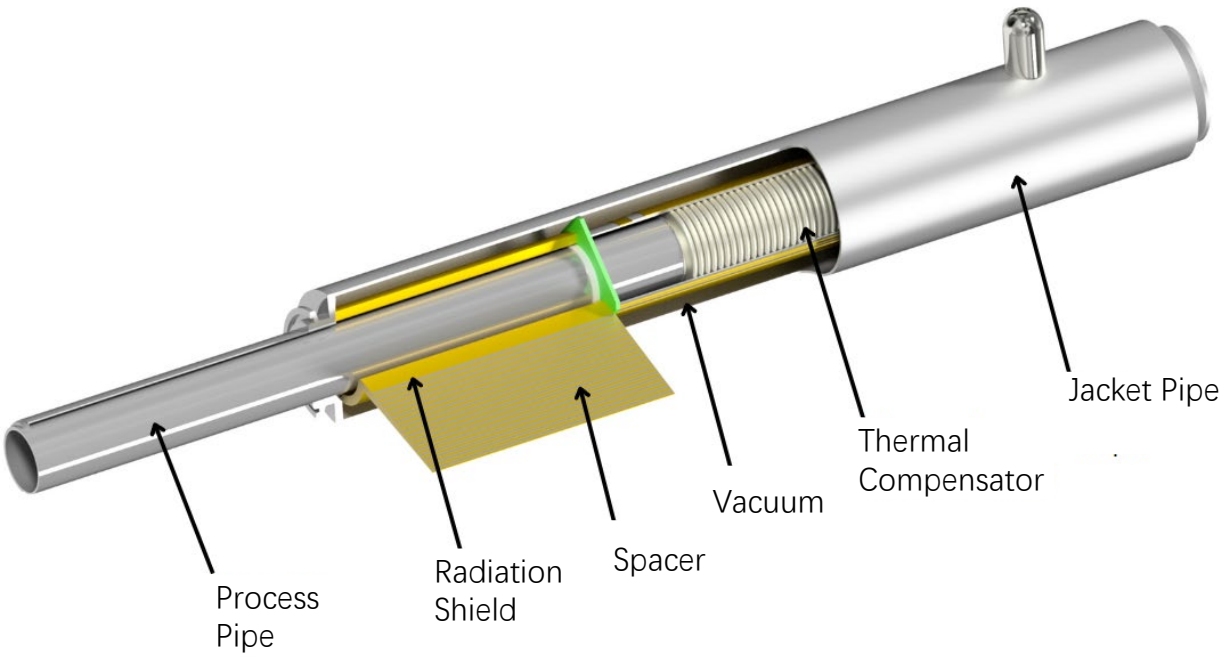
Vacuum Jacketed Technology

Introduction

Vacuum Jacketed Pipes, also known as VJPs, were first developed in the early 1900s. However, the technology did not become commercially available until the 1960s when it was used to insulate cryogenic transfer lines. Since then, VJPs have been widely used in various industries, including in the transportation of liquefied natural gas (LNG), in the food and beverage industry, in the semiconductor industry, and in medical applications. In recent years, VJPs have also gained popularity in building construction for their energy-efficient properties.

Vacuum Jacketed Pipes (VJPs) have come a long way in terms of insulation technology. Over the years, there have been many advancements in the materials and design used in VJPs, which have greatly improved their insulating capabilities.

One major development has been the use of advanced insulation materials, such as multilayer insulation. VJPs have also benefited from advances in manufacturing technology. For example, modern VJPs are produced using advanced welding techniques and automated manufacturing processes, which ensure a high level of quality control and consistency in the production process. However, despite these advancements, it is not possible to completely eliminate heat transfer (leaks) in any system.

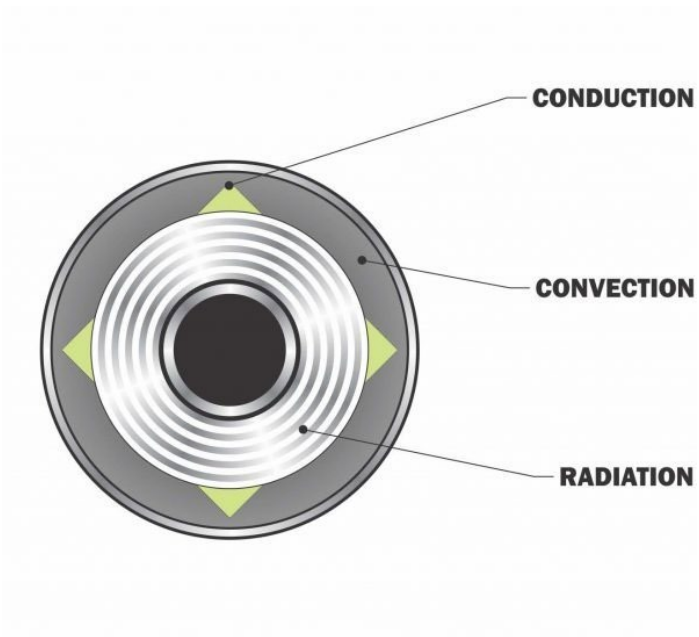


Heat Leaks

The technology in transfer piping for LN2 and other cryogenic fluids has made substantial advances since the early 1990s. Not only are today's transfer lines better insulated to minimize the heat leaks and loss of LN2 through evaporation, but they are also easier to install and are virtually maintenance-free.

Two types of vacuum jacketed piping (VJP) systems (also referred to as vacuum insulated) — rigid and flexible — are available for process plant installations where long runs of piping are required to transfer LN2 from a bulk storage vessel at the back of the plant to one or several use points.

Primarily, VJP is designed to reduce heat leaks by addressing three modes of heat transfer: conduction (both solid and molecular conduction), convection, and radiation.



Conduction - CSM VJP reduces conduction by using low conductivity radial supports to prevent the inner pipe from touching the outer pipe.

Convection - is prevented by removing the gas molecules from the space between the inner and the outer pipe at high vacuum 10^{-5}Torr. Vacuum helps reduce molecular conduction to near zero.

Radiation - the inner pipe is wrapped with multiple layers of reflective radiation shield and low conductive spacer material to reduce radiation heat transfer.

The inner pipe which carries the cryogenic liquid is wrapped with multiple layers of super-insulation, consisting of alternating layers of radiant heat barrier material and non-conductive spacer material. Also, the vacuum annulus contains molecular sieve and getter materials to absorb gas molecules to further improve the vacuum quality and lengthen the vacuum life. Most importantly, the space between the two lines is evacuated and then sealed in a static vacuum system or by an on-site vacuum pump in dynamic vacuum system.

You can download more information about multi-layer insulation from CSM blog site *www.csm-cryogenic.com/cryo-blog/super-insulation-technology*

Major Challenge in Vacuum Jacketed Technology

When liquid nitrogen is transported through a vacuum jacketed pipe (VJP) system, heat transfer can occur due to imperfections or defects in the vacuum jacket design, construction or gradual loss of insulation performance due to hydrogen and other molecules outgassing within the vacuum insulation system.

There are 4 main mechanisms which contribute to outgassing:

1. Vaporisation of the actual surface material itself

2. Desorption — this is the reverse process of adsorption; the release of molecules bound at the surfaces of the material

3. Diffusion — this is the movement of molecules from the inner structure of the material to the surface

4. Permeation — this is the movement of molecules from the external atmosphere through the jacket pipe wall to the vacuum surface

Outgassing

Outgassing, which is the process by which gases trapped within the VJP system are released over time. As the gases within the VJP system are released, they can reduce the vacuum pressure within the system, which can result in a reduction in the thermal insulation performance of the VJP. This is because the vacuum pressure within the VJP system is critical to its thermal insulation properties. A high vacuum level (lower vacuum pressure) reduces the thermal conduction between the inner and outer pipes, which helps to maintain the temperature of the transported fluid.

To mitigate the effects of outgassing, CSM use materials that have low outgassing rates, maintain high vacuum quality within the VJP system, and perform proper cleaning and degassing of the materials used in the VJP. In addition, VJP manufacturers may also incorporate getter & molecular sieve materials into the VJP system.

Getters & Molecular Sieve

Getters & molecular sieves are materials that are used in vacuum jacketed pipes (VJPs) to absorb or trap gases, including those released through outgassing, to help maintain the vacuum quality within the VJP system and preserve its thermal insulation properties. However, if the getters become exhausted, their ability to absorb or trap gases is diminished, which can lead to a loss of insulation performance in the VJP.

Exhaustion of getters can occur due to a variety of factors, including exposure to gases that cannot be absorbed or trapped by the getter material, gas saturation, or simply the natural degradation of the getter material over time.

When a getter becomes exhausted, it can no longer effectively absorb or trap gases, and any remaining gases within the VJP system can begin to degrade the vacuum quality. This can lead to an increase in thermal conduction between the inner and outer pipes.

Thermal Conductivity for Vacuum Jacketed Pipe (VJP)

CSM VJP deploys high-quality multilayer insulation (MLI) materials with controlled thicknesses of 0.06mm for the fiberglass spacer and 6 micrometers for the aluminum foil. The fiberglass spacer is composed of a material with a low conductance of less than 1.0 W/m2-K. Additionally, the aluminum foil undergoes special treatment to achieve an emissivity of less than 0.04.

For a well-evacuated MLI, The K_{ta} value obtained is approximately $1.1 \times 10^{-2} mW/m \cdot K$ at vacuum pressure of $1 \times 10^{-4}\ torr$, at mean temperature, $T_m = \frac{300+77}{2} = 188.5 \approx 190K$.

The apparent thermal conductivity may be determined from

$$k_{ta} = \frac{1}{(\frac{N}{\Delta x})}\left[h_c + \left(\frac{e}{2-e}\right)\sigma\left(T_H^2 + T_C^2\right)(T_H + T_C)\right]$$, Where

h_c is the solid conductance of the spacer material

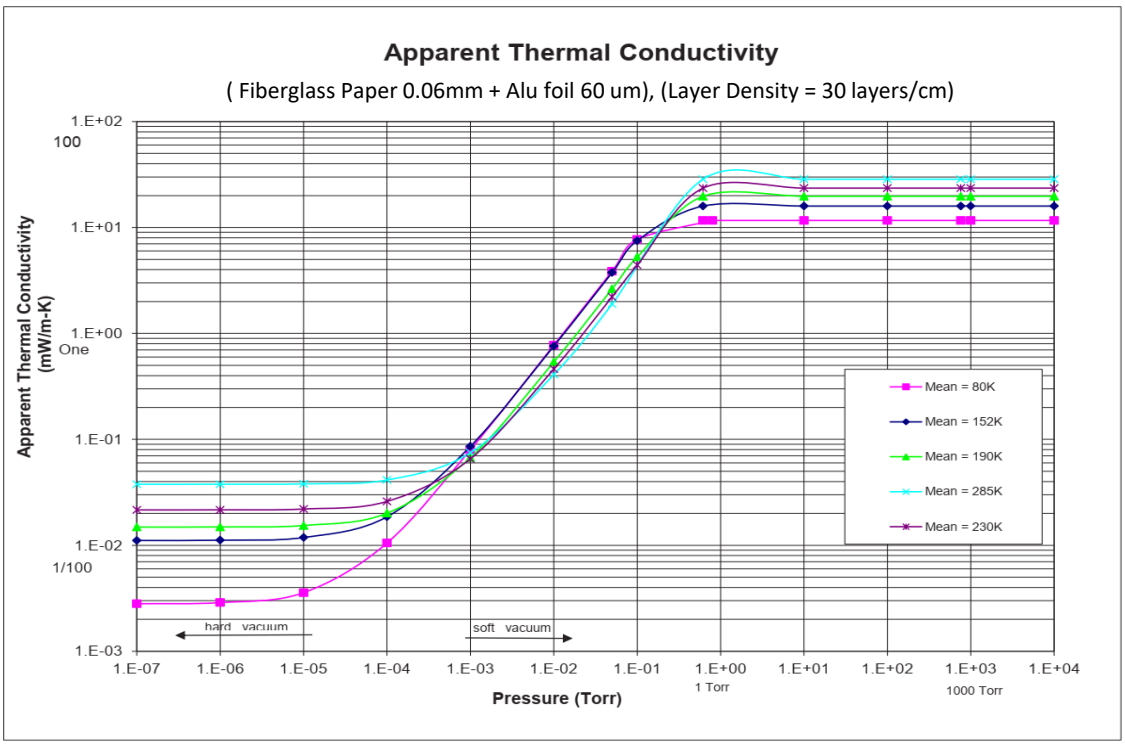
σ is the Stefan-Boltzmann constant

$\sigma = 0.1714 \times 10^{-8}\ Btu/h\text{-}ft^2\text{-}°R^4 = 5.669 \times 10^{-8}\ W/m^2\text{-}K^4$

e is the emissivity of the radiation shields

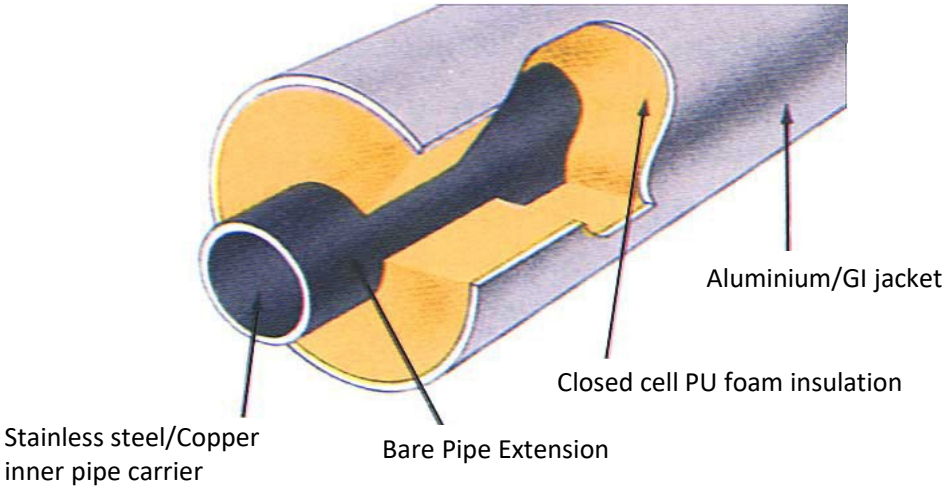
T_H and T_C are the boundary temperatures of the insulation (absolute temperature)

$N/\Delta x$ is the layer density (one "layer" is defined as one sheet of foil plus one sheet of spacer material)



Thermal Conductivity for Foam Insulated Pipe (FIP)

For decades, the accepted method of insulating cryogenic transfer pipe (typically copper or schedule 10s stainless steel pipe) was to use foam insulation covered by a protective polyvinyl chloride layer. This type of insulation is inexpensive and works well when new, providing typical heat transfer rates above 10 – 20W/m (10 - 20 BTU/hr/ft) at LN2 temperatures. However, its performance deteriorate rapidly within five years, and becomes less effective in preventing vaporization of the liquid as the product ages.



If you are using liquid nitrogen (LN2) in your processing operation and your transfer lines are more than 5 years old, you might be losing money every day. You probably see ice spot or frost along the pipeline and a water puddle on the floor, but it won't alarm you that something is amiss. Instead, what typically happens is that you will gradually use more and more LN2 with each passing year without even realizing.

The following theoretical model has been developed (Bootes & Hoogendoorn 1987) to predict the thermal conductivity of closed cell foams:

$$k_t = 0.4(1-\Phi)\, k_s + k_g + 4F_e\, d\, \sigma\, T_m^3$$ where,

Φ is the porosity of the foam (volume of void per unit total volume

k_s is the thermal conductivity of the solid foam material

k_g is the thermal conductivity of the gas within the cavities

d is the thickness of the foam

σ is the Stefan-Boltzmann constant

$$\sigma = 0.1714\times10^{-8}\,\text{Btu/hr-ft}^2\text{-R}^4 = 5.669\times10^{-8}\,\text{W/m}^2\text{-K}^4$$

T_m is the mean insulation absolute temperature = $1/2 \text{ x } (T_H + T_C)$

F_e is the emissivity factor

$\frac{1}{F_e} = \frac{d}{d_c}\left(\frac{1+r-t}{1-r+t}\right) + 1$, Where

r is the reflectivity of the foam material

t is the transmissivity of the form material

d_c is the size of the foam cells

Typical values for the reflectivity and transmissivity of polyurethane foam are 0.034 and 0.493, respectively. Cell sizes on the order of 0.01-0.02 in. (0.25-0.50mm) can easily be achieved.

In this example, we estimate thermal conductivity for polyurethane foam insulation having a porosity of 0.96 operating between 300K (540°R) and 80K (144°R). The thermal conductivity of the solid material is 0.288 W/m-K, and the thermal conductivity of the gas (CO_2) in the foam is 0.0166 W/m-K. The thickness of the foam layer is 150mm (5.91 in.), and the size of the cavities within the insulation is 0.50mm (0.02 in.). The reflectivity and transmissivity may be assumed to be the same as polyurethane.

The emissivity factor is calculated as:

$$1 / F_e = d / d_c \text{ x } [(1 + r - t) / (1 - r + t)] + 1$$

$$1 / F_e = 150/0.50 \text{ x } [(1 + 0.034 - 0.493) / (1 - 0.034 + 0.493)] + 1 = 111.2$$

$$F_e = 0.00899$$

The mean temperature of the insulation is T_m=1/2 x (300+88) =190K.

The thermal conductivity K_t of the foam insulation is estimated as:

$$K_t = (0.40 \text{ x } (1-0.96) \text{ x } 0.288) + 0.0166 + (4 \text{ x } 0.00899 \text{ x } 0.150 \text{ x } (5.669 \times 10-8) \text{ x } 1903)$$

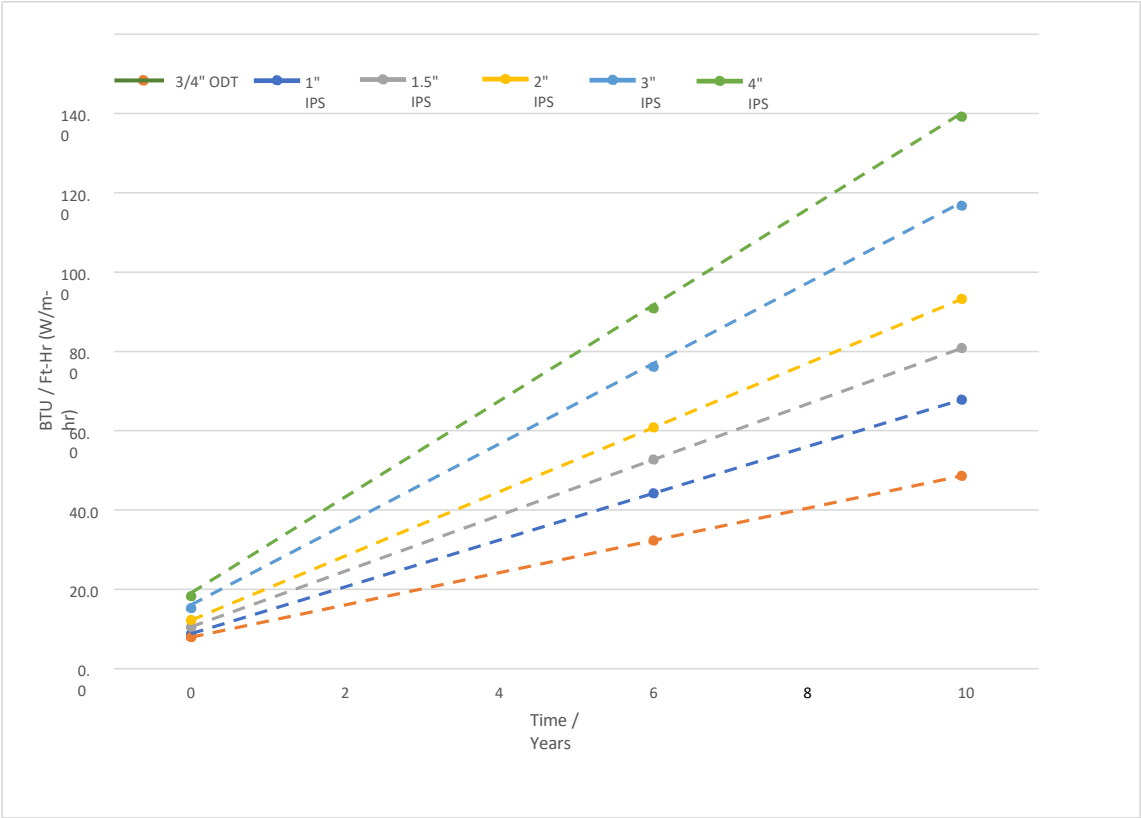
$$K_t = 0.00461+0.0166+0.00210$$

$$K_t = 23.31 \text{ mW/m-k}$$

In comparison to vacuum jacketed pipe, polyurethane foam insulation incurs k_s (the first term) of 20% of the total heat transfer, gaseous conduction k_g (the second term) is 71%, and radiation (the third term) is 9% of the total.

On the other hand, in vacuum jacketed pipe, the MLI produce K_{ta} value of $1.1 \times 10^{-2} mW/m \cdot K$, with the bulk of heat transfer occurs via radiation, accounting for approximately 99%.

Estimated Heat Leak Performance for PU foam insulation in 10 Years



Above heat leak data in this document are derived from a test using boil-off calorimeter system in accordance to ASTM standards C1774, C740, C335.

Making A Smart Choice

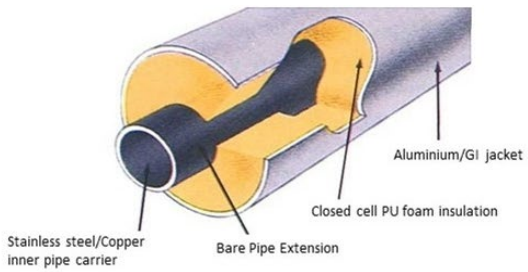
Value vs. Cost of Heat Leak

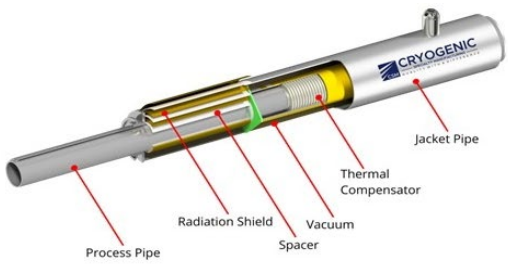
Due to the extreme temperature difference between liquid nitrogen and ambient air, a large amount of heat will transfer even through a very short section of uninsulated or poorly-insulated pipe component very quickly. This can have a substantial impact on the entire system.

Even though the loss is not immediately visible nor is it significant for one day, but over time that loss can add up to thousands of dollars. Increased heat leak at any point in the system can cause two-phase fluid that increases pressure drop, causing irregular flow of liquid, which reduces the overall flow rate. Two- phase flow will create significantly higher pressure drops through the pipe system, irregular liquid delivery, results in warmer liquid at the cryogen use point and shortens the life of valve seats and other components within the system.

Getting the Return on Your Investment

Although the initial purchase price of a VJP system can be higher than for non-vacuum insulated FIP, VJP systems typically provide a quick payback by reducing operating costs. These systems can significantly minimize the liquid losses caused by heat leaks, provide a longer life cycle than conventional foam-insulated copper piping, and do not decrease in performance over time. They can also increase production efficiency by improving the quality of the LN2 flowing through the lines (delivering colder LN2 to the use point) and can improve process safety by eliminating frosty and dripping conditions.





Heat Leak / Performance Comparison Chart

The table below summarizes the comparison of heat leaks between the Vacuum Insulated stainless steel pipe and the PU insulated copper pipe of various sizes:

Line Size	Vacuum Jacketed Pipe BTU/HR/FT (Watt / mtr)	Insulated Copper BTU/Hr/ft (Watt / mtr)		Bare Copper BTU/Hr/ft
		New	After 5 Yrs Old	
¾" ODT	0.42	7.9	32.3	165
1" IPS	0.49	8.8	44.2	280
1 ½" IPS	0.52	10.5	52.7	397
2" IPS	0.69	12.2	60.8	530
3" IPS	1.20	15.2	76.1	769
4" IPS	1.40	18.2	90.8	1000

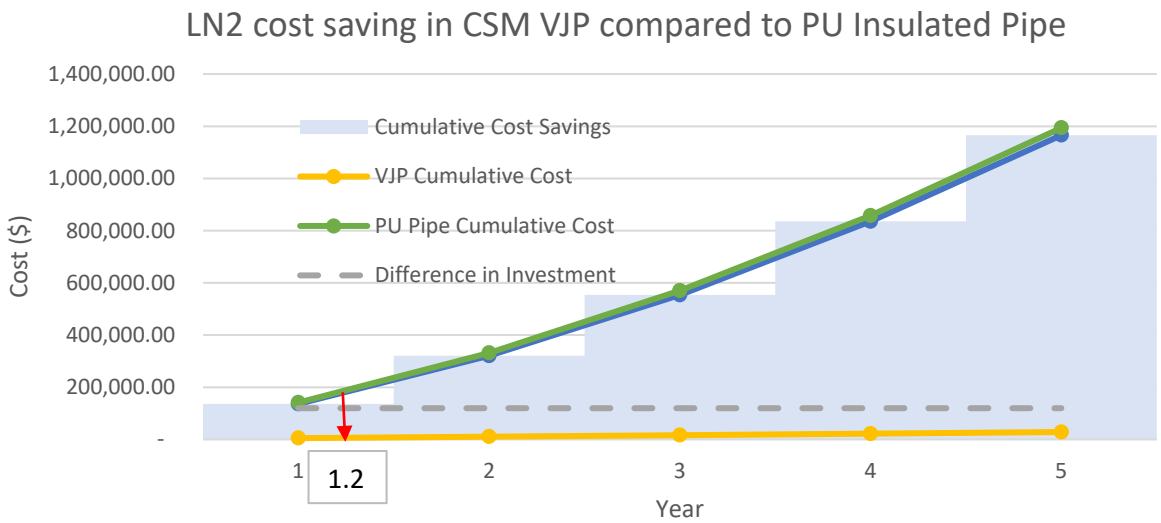
Case #1:

Consider a food production company that utilizes a 30-meter (100-foot) run of vacuum jacketed pipe (VJP), along with a 0.5-meter (2-foot) connection of foam-insulated pipe.
For the VJP with a diameter of 1.0 inch, the typical heat transfer rate is approximately 0.5W/m (0.52 BTU/hr/ft). Thus, the total heat leak for the 30-meter run of VJP can be calculated as 30 x 0.5 = 15W (52 BTU/hr).
On the other hand, for the foam-insulated copper pipe, the typical heat transfer rate is around 20W/m (20 BTU/hr/ft). Consequently, the heat leak for the 2-foot section of foam-insulated copper pipe can be determined as 0.5 x 20 = 10W (40 BTU/hr).

Result:
The 2% length of foam insulated copper pipe section is responsible for 40% of the total heat leaks into the entire 30 meters of VJ piping system.

Case #2:

A semiconductor plant is currently undertaking a project involving a 100meters (300ft) of 1.5"NB piping system to supply liquid nitrogen to six units of HALT/HASS equipment. They have received two quotations: one for a copper piping system with 3" PU insulation priced at $40,000.00, and another for an SS304L vacuum insulated piping system priced at $160,000.00.
To conduct a ROI (Return on Investment) analysis, the project engineer needs to estimate the heat leaks and LN2 loss for both systems. The analysis is based on the assumption that the cost of LN2 will average $0.50 per Liter over the next ten years. The results of the ROI analysis are presented below.



A comparison of liquid nitrogen losses between the two piping systems reveals that the vacuum insulated system significantly reduces losses compared to the copper piping system. As a result, the company can justify the additional investment cost of $120,000.00 for the vacuum insulated system with ROI within just 1.2 years.

CSM Cryogenic Pipe Solution

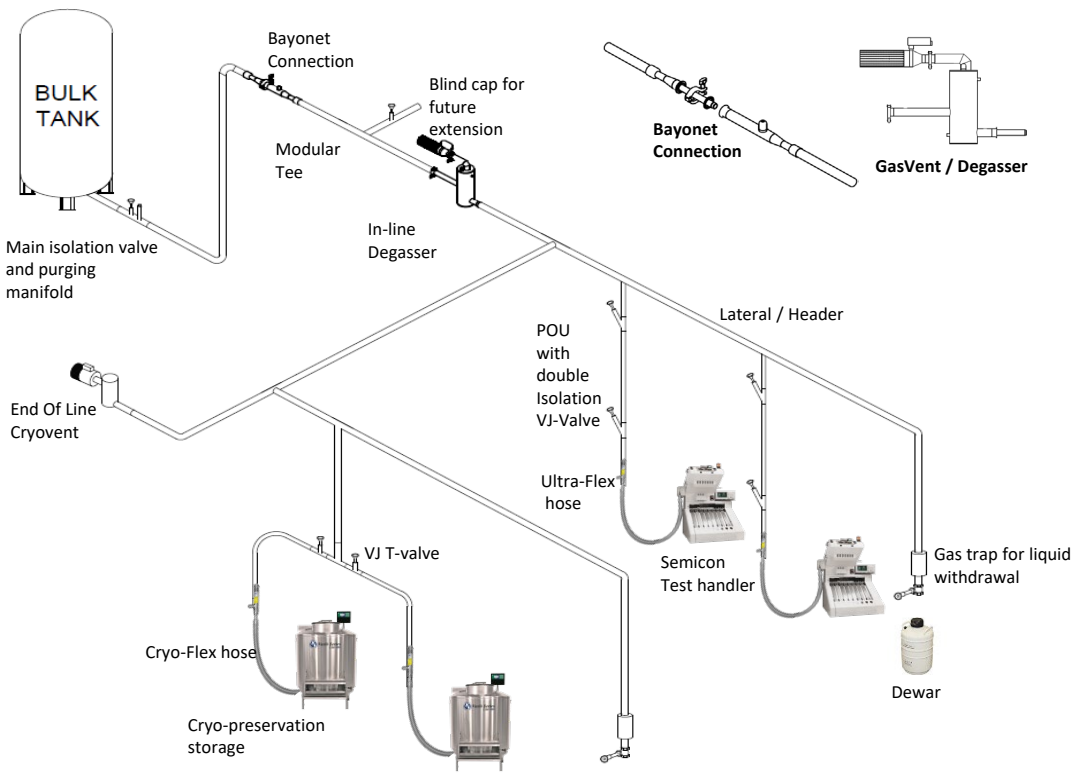
Introduction

The transfer of liquid cryogens such as liquid nitrogen over any distance in a plant, whether indoors or outdoors, requires special piping insulation. Issues that need to be considered in cryogenic liquid transfer includes the economic loss of cryogen through evaporation and quality degradation of the cryogen delivered at the point of use.

Under normal operational circumstances, the liquid in the system is constantly vaporizing into gaseous nitrogen due to constant heat leak. The accumulated gas in the pipeline will result in excessive gas within the transfer system which causes:

1. Diminished cryogen cooling capacity, warmer liquid with higher enthalpy
2. Excessive vapor phase resulted in higher gas content in liquid
3. Inconsistent delivery of liquid nitrogen due to plug and slug flow conditions
4. Variation in cool-down time from one point to another
5. Increased in operating cost due to higher heat loss

Typical Cryogenic Piping Installation



Rigid Vacuum Jacketed Pipe

Rigid VJP is easier to install than traditional foam insulated copper pipe and is designed to be maintenance-free for a minimum of 10 years, with no system heat leaks performance deterioration over that period. Pipe sections are joined with vacuum-insulated bayonet connectors that provide frost-free connections.

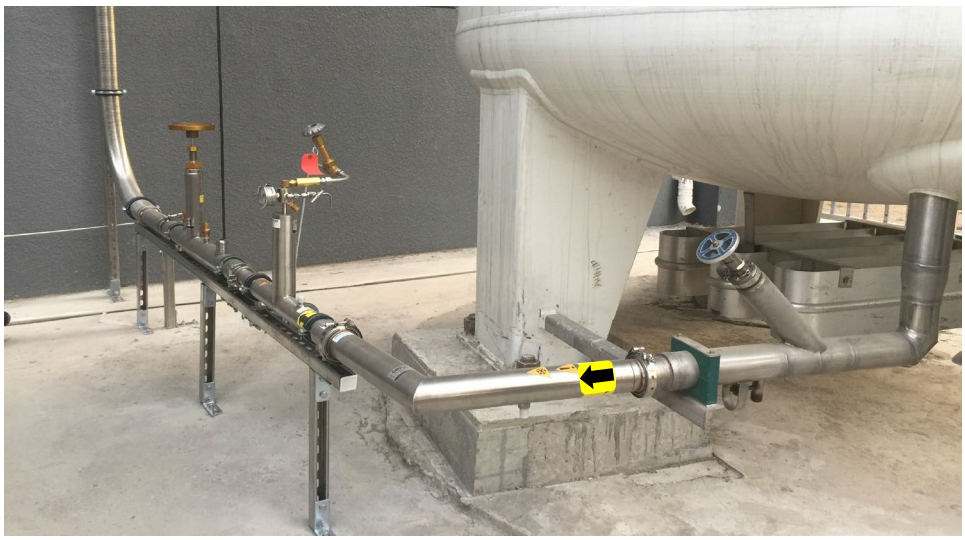
The thermal barrier between the inner and outer lines are so effective that the outer pipe remains at room temperature even while -196˚C (-320˚F) liquid nitrogen is flowing through the inner line. Rigid VJP can also be exposed to direct sunlight without affecting the system's performance.

CSM provides various pipe standard option of rigid VJP, such as Rigid-T (ASTM/EN tube sizes) with C-series bayonet connection; and Rigid-P (ASTM pipe sizes) with B-series bayonet or Welded connection.

Flexible Vacuum Jacketed Pipe

Pre-engineered modular flexible vacuum jacketed transfer hose has added advantage over the rigid VJP, especially when system upgrade is frequently done. This option is cost saving as the flexibility of the pipe reduces the necessity for precise system layout measurements. It allows the whole system to be easily reused if use-point locations and plant layout are changed. Flexible can be added if required to the existing system without major rework expenses. Additionally, flexible VJP can be coiled for shipment by air freight, thus eliminate the need for expensive logistics.

CSM provides various flexible VJP options to suit different flexibility requirement. Semi-Flex is a semi-rigid VJP but spool length up to 18 meters with modest bend radius for on site installation without necessary to use an elbow. Cryo-Flex is more flexible but limited to shorter spool length below 4 meters, usually use as tie-in hose to bulk storage tank or equipment, or a flexible section to overcome offset or misalignment in a Rigid VJ Piping system.



Semi-Flex liquid nitrogen piping system at a semiconductor facility

Advantages of CSM Vacuum Jacketed Pipe

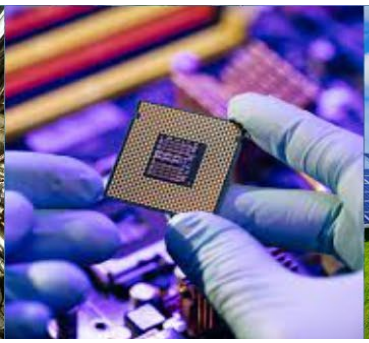
- Significant reduction in loss of liquid cryogen caused by heat leaks.
- Quick return on investment in new vacuum jacketed pipe installation.
- Virtually no decrease in thermal performance of vacuum jacketed pipe over 10 years.
- The Cryorigid vacuum jacketed pipe system is maintenance free for 10 years minimum.
- Longest life cycle backed by a 10-year warranty.
- Increase in freezing capacity due to improved quality of liquid nitrogen.
- Consistent delivery of liquid nitrogen at the use points due to reduction of vapor content.
- Improved process safety due to elimination of frosty and dripping conditions.

What We Offer

- A 5 + 5 years warranty on all Cryorigid vacuum jacketed pipe.
- On-site measurements.
- Most efficient layout of the vacuum jacketed pipe system required for your application.
- Detailed proposal describing every component of the vacuum jacketed pipe system.
- Manufacturer's specifications of the system presented for your review.
- Isometric CAD drawing showing every detail of the proposed system.
- A Heat Leak Guide to show LN2 losses of current foam insulated copper pipe system.
- Break-even analysis on anticipated return on investment and long-term financial benefits to operation's bottom line.
- Cash flow analysis to show immediate effect the new system will have on your plant operation.

Cryogenic Application






Thin Film Deposition

Introduction

Thin film deposition in high vacuum is a specialized technique used to create thin film coatings in a low-pressure environment. High vacuum conditions are essential for certain applications, particularly when dealing with sensitive materials or when precise control over the deposition process is required. The pressure levels in high vacuum systems typically range from around 10^-3 to 10^-8 Torr (1 Torr is approximately equal to atmospheric pressure). Low-pressure environment is crucial for thin film deposition because it helps minimize unwanted interactions between the coating material and the surrounding gases.

Thin Film Applications

High vacuum thin film deposition finds applications in various industries, including semiconductor manufacturing, optics, electronics, and advanced coatings. Some examples include:

- Semiconductor Devices: High vacuum techniques are used to deposit thin films for microelectronics, such as transistors, interconnects, and memory devices.
- Optical Coatings: High vacuum deposition is crucial in producing anti-reflective coatings, mirror coatings, and filters for optical devices like lenses, telescopes, and cameras.
- Thin Film Solar Cells: High vacuum methods are employed to create thin films for solar cells, such as CIGS (copper indium gallium selenide) and CdTe (cadmium telluride) solar cells.

Thin Film Deposition Techniques

Various deposition techniques can be employed in high vacuum environments, including:

a. Physical Vapor Deposition (PVD): In *evaporation*, the coating material is heated to its vaporization temperature, and the vaporized atoms or molecules condense on the substrate to form a thin film. In *sputtering*, energetic ions bombard a target material, causing its atoms to be ejected and subsequently deposited on the substrate.

b. Chemical Vapor Deposition (CVD): precursor gases react to form a solid thin film on the substrate surface. High vacuum offer better control over the reactions and can lead to high-purity films.

c. Atomic Layer Deposition (ALD): precursors are introduced sequentially in a cyclical manner, allowing for precise control of film thickness and excellent conformality.

Polycold Applications

Polycold techniques can significantly improve vacuum pump down time in thin film deposition processes. Vacuum pump down time refers to the duration it takes to reduce the pressure inside the vacuum chamber to the desired operating level. Polycold system produce very low temperatures surfaces to trap water vapor and condensing gases, that otherwise are challenging to traditional vacuum pumps such as turbomolecular pumps or diffusion pumps.

Polycold techniques also result in a lower base pressure inside the vacuum chamber, improve the quality of the deposited films, see Tube video *https://youtu.be/sGk4uM6_w7k*

Challenges in Polycold System

While Polycold systems offer several benefits, they also come with their own set of challenges. Some of the major challenges associated with Polycold systems include:

1. Condensation and Frost Formation: During cryogenic cooling, condensation and frost can form on the cold surfaces of the refrigerant hoses, causing unsafe work environment, cold burn injury and wet floor.

2. System Reliability and Downtime: Heavily frozen refrigerant hoses usually experiences premature fatigue crack causing process downtime, increase maintenance cost, costly refrigerant refills, danger of refrigerant leakage to environment, and compromised work environment safety.

3. Power Consumption: Cryogenic cooling systems can be energy-intensive, poor insulation on refrigerant hoses leads to higher power consumption.

4. Complexity and Cost: Polycold systems can be complex and require specialized components such as cryogenic cooling units and control systems. This complexity can lead to higher upfront costs and maintenance expenses, making them a significant investment for research laboratories and industrial facilities.

CSM Solution – PolyFlex

Poly-Flex heralds a new era in polycold hose technology, offering minimal heat leaks, top-tier safety, and exceptional durability. Its robust spiral-wrapped jacket ensures resilience in rugged Polycold Cryochiller applications. This innovation operates with either self-contained static vacuum or dynamic vacuum using external customer process vacuum.

In semiconductor industries, Poly-Flex slashes energy consumption in thin film deposition processes. It's more than an innovation—it's a revolution. With its groundbreaking features, Poly-Flex redefines hose technology, enhancing efficiency, reliability, and safety like never before.

Features & Benefits

The Poly-Flex transfer hose represents a significant advancement in hose technology, addressing and eliminating the common issues associated with traditional polycold hoses.

No Icing, Frosting, or Condensation:

Say goodbye to problems like icing, frosting, and condensation. The Poly-Flex hose is designed to maintain a consistent temperature, ensuring that these issues are a thing of the past.

Energy Savings and Efficiency:

Its lightweight stainless steel construction has a remarkable cooling efficiency, minimizing cool-down loss. This results in energy savings and a reduced load on cryochillers during initial start-up.

Unmatched Flexibility and Ease of Use:

Poly-Flex boasts exceptional flexibility for both installation and maintenance. With the industry's lowest static and dynamic bend radius, it stands out among all polycold hoses on the market.

Extreme Cold Flexibility:

Operating even at temperatures as low as -120°C, the vacuum-insulated design ensures the hose remains flexible. This eliminates the risk of rupture or breakage when flexing, adding durability and reliability to its impressive capabilities.

Enhanced Safety with Stainless Steel Protection:

The tough and anti-kink stainless steel spiral wrap outer covering offers not only durability but also heightened safety. This eliminates the potential hazards caused by broken or loose wires, which are common in traditional wire-braided sleeve polycold hoses.

Molecular Beam Epitaxy (MBE)

What is MBE

Molecular Beam Epitaxy or MBE is an Ultra-High-Vacuum (UHV)-based technique for producing high quality epitaxial structures with monolayer control.

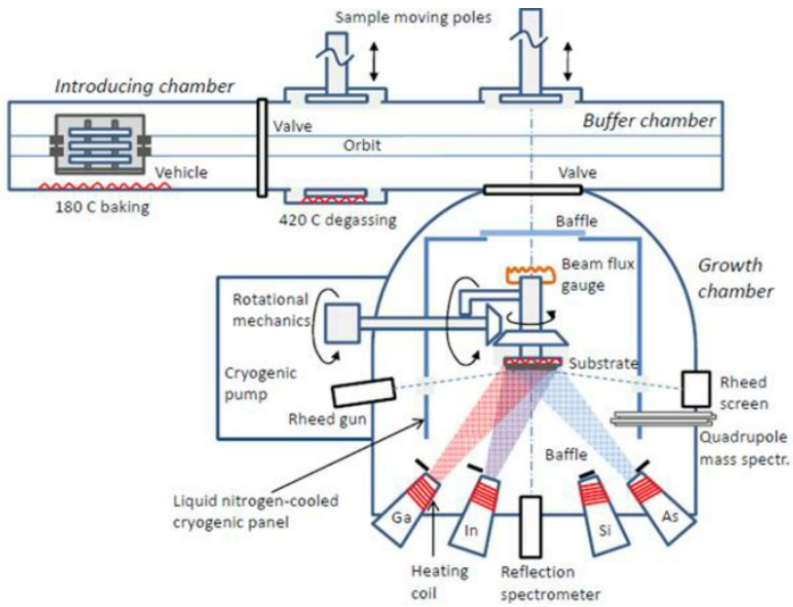
Since its introduction in the 1970s as a tool for growing high-purity semiconductor films, MBE has evolved into one of the most widely used techniques for producing epitaxial layers of metals, insulators, and superconductors as well. Today MBE is an indispensable tool in compound semiconductor industry, both at research and production level.

A typical MBE growth rates for group III-V type semiconductors are of the order of 1 um/hour, obtained for group III partial pressures of ~10e-6 torr. With atomic density in the crystal about 10e22.cm-3, this means that to reduce the impurity concentration below 10e15.cm-3, the impurity partial pressures must be reduced below ~10e-12 Torr.

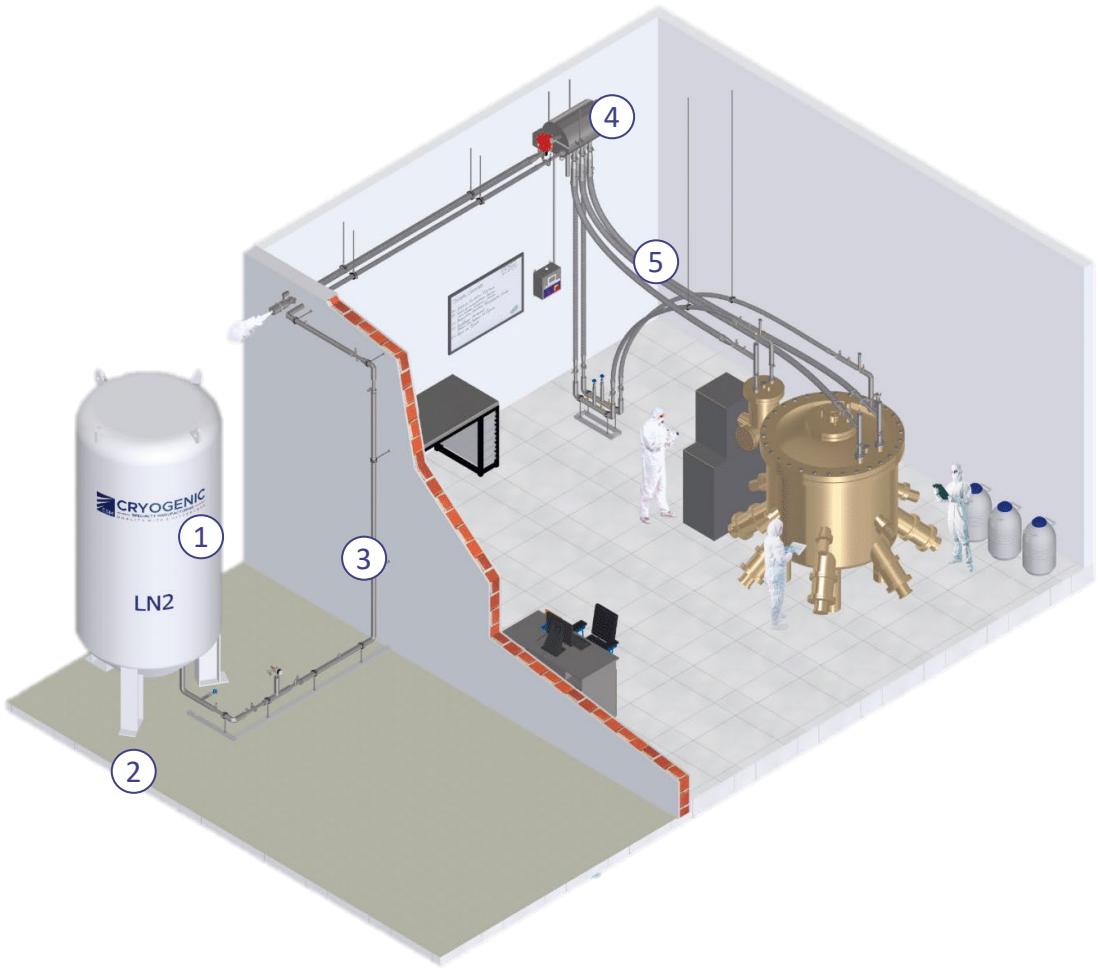
Liquid N2 is very important component for successful operation of MBE. MBE system relies on Liquid N2 cryopanels, built internally around both the main chamber wall and the source flange. Since MBE is a cold wall technique, cryopanels are used to prevent re-evaporation of molecules from parts other than the hot effusion cells.

Besides, they provide thermal isolation among the different cells, as well as additional pumping of the residual gas. Low vapor pressure liquid N2 supply within cryopanels during wafer growing process is paramount to ensure impurities partial pressure are maintain consistently below 10e-12 Torr.

CSM-Cryogenic, has developed a very advanced closed loop liquid nitrogen circulation system for Molecular Beam Epitaxy MBE wafer growing process with benefits not seen with other traditional supplier.



CSM Products for LN2 system in MBE facility



An MBE production requires an LN2 storage tank (1) with a capacity that should be determined based on the LN2 consumption by the MBE system and the LN2 delivery frequency. Typically, a small research MBE system consumes 50-250L/day, while a large MBE system may require 4000L/day. It is highly recommended to utilize a low-pressure (2 to 3 bar) bulk storage tank equipped with a vacuum-insulated withdrawal valve (2). For the pipework (3), it is preferable to use semi-flexible or rigid Vacuum Jacketed Pipe to minimize heat loss of liquid nitrogen, which significantly contributes to the operational cost of MBE production. The piping system can be either static or dynamic vacuum, requiring a small dedicated vacuum pump to maintain vacuum integrity. To ensure the delivery of pure liquid nitrogen to the MBE cryopanel, it is advised to incorporate a phase separator (4) and Triax hoses (5). A well-designed liquid nitrogen system can lead to significant cost savings and achieve a typical return on investment (ROI) of less than one year. For system design and maintenance, it is recommended to consult CSM Cryogenic. Consult CSM Cryogenic for your next LN_2 system design.

Closed Loop LN_2 Circulation System in MBE Process

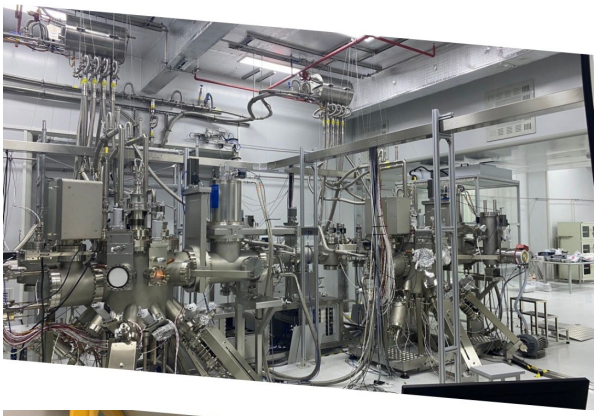
How does Close Loop Liquid Nitrogen System works

CSM design LN2 close loop circulation system for many MBE system in the world, such as Riber, DCA and Veeco. It has been widely use in many customers for compound semiconductor device development such as infra-red, optical communication and many others. Our system is available in static vacuum or dynamic vacuum insulation. A complete close loop system consist of phase separator with multiple outlets, triax hoses, modular fittings and vacuum jacketed valve for liquid nitrogen flow control and isolation.

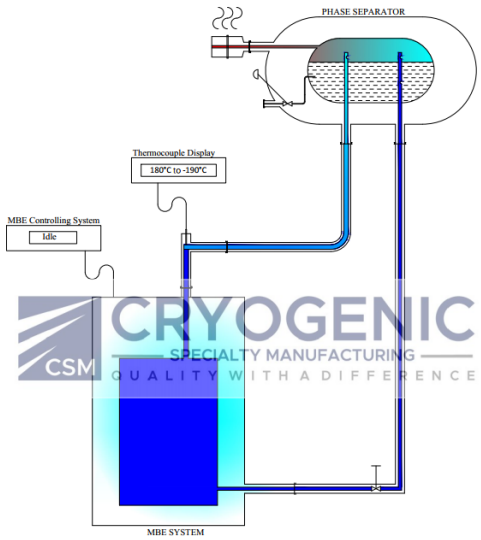
CSM closed loop LN2 circulation system for MBE is maintained at atmospheric pressure at all time. The controller allow the phase separator to self-regulate the LN2 supply flow rate to MBE in a close loop manner, keeping cryopanel filled with liquid nitrogen at different operating conditions.

CSM close loop LN2 system allows the following benefits:

- LN2 saving up to 30%
- Efficient cryopanel cooling to -196 °C
- Ease of LN2 operation - self regulating LN2 flow rate according thermal load at various stages of MBE system operation
- No dewar handling
- Safety



Closed Loop LN_2 Circulation System in MBE Process



MBE at Standby Mode

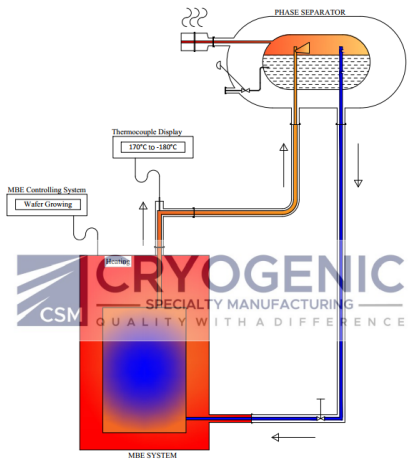
At this stage, the LN2 system is at thermo-equilibrium with cryopanel and process chamber is at room temperature. Cryopanel is insulated under Ultra-High Vacuum environment, and it is at the lowest heat load. The LN2 consume by the cryopanel at this stage is minimum, usually half the amount consumes during the wafer growing stage.

The LN2 flow rate within the close loop system is directly proportioned to heat flux surrounding the cryopanel.

CSM LN2 circulation system will supply single phase “pure liquid” via Triax-Feed line and maintaining cryopanel at temperature -196 °C with density of 0.81, and two phase “warm liquid-vapor mixture” in coax-return line at temperature between -180 °C to -196 °C and density of 0.70 ~ 0.77 depend on the heat load at the cryopanel.

*Note: LN2 flow consumption during standby mode is provided by MBE manufacturer. LN2 system supplier has the responsibility to ensure the phase separator and piping system is engineered and sized to meet MBE flow requirement.

Closed Loop LN_2 Circulation System in MBE Process



MBE at Wafer Growing Mode

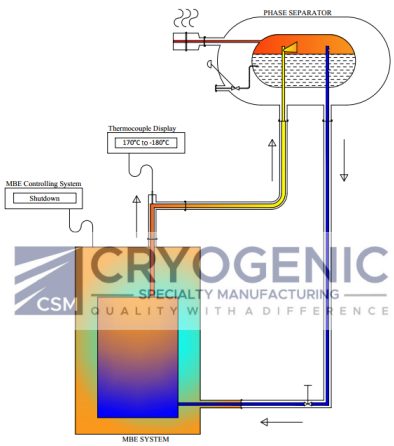
At this stage, thermal load is the highest and so does LN2 flow rate and consumption. During wafer growing, cryopanel absorbs heat load from the growth chamber. The heat load varies depend on type of wafer growing process.

The pure LN2 in cryopanel will begins to boil and become two phase liquid-vapor mixture. The warmer liquid begins to rise in the cryopanel and return to phase separator through the coax-return line. The warmer liquid subsequently undergoes phase separation into pure liquid and warm vapor.

The phase separator keep pure liquid nitrogen in reservoir for feeding back into the MBE cryopanel, while warm vapor is vented out to the atmosphere.

During this time, cryopanel is constantly fed with cold LN2 from the phase separator in an increasing amount via the Triax-Feed line until a thermo-equilibrium is achieved. The LN2 feeding flow rate is controlled by the LN2 system in an independent and autonomous fashion in response to MBE heat load variation.

CSM LN2 circulation system is capable to maintain a constant cold liquid phase in cryopanel at temperature -196 °C, and warmer “liquid-vapor” phase in coax-return line at between -170 °C to -190 °C subject to the heat load at the cryopanel.



MBE at End of Wafer Growing

Once the wafer growing process is interrupted or stopped, the heat load to the cryopanel will gradually reduce. The liquid feed flow rate will reduce in proportion to the heat load.

The fresh LN2 is fed continuously in reducing fashion into the cryopanel until a thermo-equilibrium is achieved.

The LN2 circulation system is capable to maintain pure liquid phase in Triax-Feed line at temperature -196 °C, and warmer “liquid-vapor” phase in coax-return line at between -175 to -190 °C depend on heat load at the cryopanel.

LN2 losses in MBE operation

The usage of LN2 represents a significant expense in operating an MBE laboratory. Designing an efficient LN2 cooling system is crucial and involves more than a simple fluid transport setup. Typically, an LN2 cooling system transports LN2 from a dedicated bulk storage tank outside the building to the MBE system's cryopanel. Within the delivery system, LN2 experiences two types of losses: Heat Leak Loss and Flash Loss.

Heat loss occurs due to heat leaks and N2 gas enthalpy within the system. Poorly insulated connections or piping can lead to localized heat leaks, causing LN2 to evaporate into N2 gas. The N2 gas carries heat and permeates the entire pipework system, exacerbating LN2 loss. To minimize this, it is recommended to use vacuum insulated technology throughout the LN2 delivery system, including valves, pipework, and connections. Regular checks and maintenance of vacuum insulation integrity are also crucial.

The second type of loss is flash loss, which occurs when the pressure of LN2 reduces from the bulk tank to the phase separator. This pressure change causes a fraction of the LN2 to flash off as N2 gas. To reduce flash loss, it is advisable to store LN2 in the storage tank under low pressure, sufficient for delivering LN2 to the intended destination at the desired flow rate.

The presence of both GN2 and LN2 in the piping system creates a two-phase flow, which hampers cryopanel cooling due to the presence of N2 gas. To address this, a phase separator is typically employed to separate the gas and liquid phases, ensuring the delivery of high-purity LN2 to the MBE cryopanel.

The phase separator stores LN2 at atmospheric pressure (the most efficient pressure for MBE cooling) and utilizes gravity to drive pure LN2 into the cryopanel via Triax Hose. The fresh LN2 absorbs heat in the cryopanel for cooling purposes. An additional Triax Hose, known as Coax Hose, is designed to efficiently vent the generated N2 gas from the cryopanel without interrupting the entry of pure LN2. This setup allows the cryopanel to achieve optimum efficiency in cooling.

The ideal LN2 cooling system comprises:

- Low-pressure LN2 storage tank with vacuum insulated withdrawal valve
- Vacuum insulated pipework and isolation valve
- Phase separator (operating at atmospheric pressure) with modulating liquid level
- Vacuum insulated Triax hose and Coax hose
- Vacuum insulated N2 vapor venting line from the phase separator to the outdoors.

Cryopreservation In Life Sciences

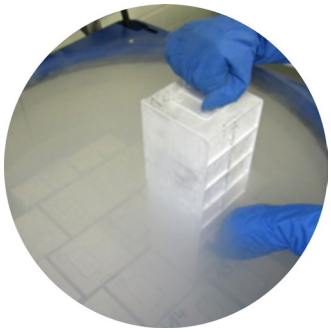
What is Cryopreservation

Cryopreservation, a remarkable scientific process, holds the key to preserving life at sub-zero temperatures. This technique has revolutionized fields ranging from medicine to biology, offering new avenues for organ transplantation, fertility treatments, and even the conservation of endangered species.

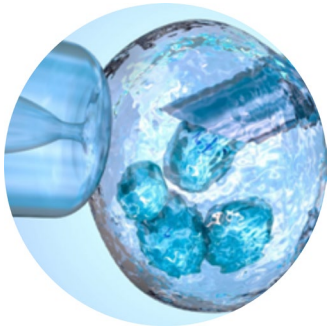
Defining Cryopreservation

Cryopreservation involves the preservation of living cells, tissues, or even whole organisms by cooling them to extremely low temperatures, typically below -130°C (-202°F) or even colder. At such frigid temperatures, biochemical reactions slow down to a near halt, effectively preserving the biological material in a state of suspended animation.

Applications in Medicine



One of the most significant applications of cryopreservation is in the field of medicine. Organ transplantation, a critical medical procedure, often faces challenges due to the limited availability of compatible donor organs. Cryopreservation has the potential to address this issue by allowing for the storage of organs for longer periods, increasing the chances of finding suitable recipients.



Furthermore, in the realm of reproductive health, cryopreservation has enabled advancements in fertility treatments. Sperm, eggs, and embryos can be cryopreserved, allowing individuals to preserve their fertility for later use. This is especially beneficial for those undergoing cancer treatments or other medical procedures that may affect their reproductive capabilities.

Biological Research and Conservation

Cryopreservation plays a crucial role in biological research and conservation efforts. Scientists can store cell lines, tissues, and genetic material for future studies, enabling ongoing research even after the original samples are long gone. This is particularly valuable for understanding diseases, conducting experiments, and advancing various scientific fields.

The conservation of endangered species also benefits from cryopreservation. By preserving genetic material from endangered animals, scientists can safeguard biodiversity and potentially reintroduce species back into their natural habitats in the future.

Liquid Nitrogen Piping Systems for Cryopreservation

In the realm of cryopreservation, where the preservation of biological materials hinges on extreme cold, the role of liquid nitrogen piping systems is paramount. Super insulated piping systems provide a robust solution that aligns technological ingenuity with the intricate demands of preserving biological materials. By addressing the challenges posed by heat leaks and temperature variations, CSM contributes to advancing the field of cryopreservation and ensuring that the promise of extreme cold continues to unlock new possibilities for medical, research, and conservation endeavors.

CSM specializes in designing and manufacturing super insulated piping systems with extremely low heat leaks, allowing for the transfer of liquid nitrogen from storage tanks to freezer units. The main benefits of their innovative systems include:

1. Reduced Vapor Formation: By minimizing heat leaks, CSM's piping systems help reduce vapor formation within the pipeline. This reduction in vapor formation ensures a consistent and uninterrupted supply of liquid nitrogen to the freezer, preventing disruptions in the normal supply process.

2. Mitigated Warm Vapor Intrusion: The low heat leak design also minimizes warm vapor intrusion into the freezing unit. This intrusion, if left unchecked, could disrupt the freezing temperature within the unit and compromise the biological viability of preserved materials.

3. Consistent Temperature and Pressure: CSM's piping systems ensure a dependable supply of liquid nitrogen to the freezer, maintaining a consistent low temperature and low-pressure environment. This consistency is crucial for optimal cryopreservation outcomes.

LN2 system Enquiry Form

Date: _____

Project:			
Client:			
Plant Location:			
Expected Start Date of Project:		Expected Date for System Handover:	

1. Pipeline System Information

1.1 LN2 Storage Tank: (1) Capacity: _____ Liter (2) Pressure: _____ barG

1.2 Tank Withdrawal Valve: ☐ Vacuum Jacketed ☐ Non-Vacuum Jacketed

1.3 Piping length: _____ meter

1.4 Type of Piping: ☐ Rigid ☐ Flex

1.5 Vacuum Insulation Type: ☐ Static ☐ Dynamic

1.6 Point of Use: (1) Quantity: _____ nos (2) Tie-in Flex hose Length: _____ meter (3): Pressure required _____ barG

1.7 Conditioning Equipment: ☐ Phase separator ☐ Electronic Cryovent ☐ Mechanical Cryovent

2. Process Equipment Information

2.1 Application Type: ☐ Semicon ☐ Life Sciences Others: _____

2.2 Brand & Model Info:

2.3 Required Flowrate for each machine: _____ kg/hr

2.4 Quantity: _____ nos

3. Cleanroom Information

3.1 Pipe routing: ☐ SubFab ☐ Below Raise Floor ☐ Above Ceiling ☐ Under Ceiling

3.1 Ceiling Height: _____ meter Raise Floor Height: _____meter

3.2 Working Height above the Ceiling: _____ meter; Ceiling type: ☐ Walkable ☐ Non-walkable

3.3 Roof Height: _____ meter

3.4 Production Area: _____ m^2

4. Project General Information

4.1 Type of application: ☐ semiconductor ☐ Life sciences Others: _____

4.2 Date Process Equipment arrive at site: ___/___/_____

4.3 Hand over date of LN2 supply system: ___/___/_____

4.4 Key contact person coordinating for LN2 supply system specification and purchase (Tender):

4.5 Drawings required: Equipment Layout ☐ Building ☐ Pipe routing ☐ System P&ID ☐

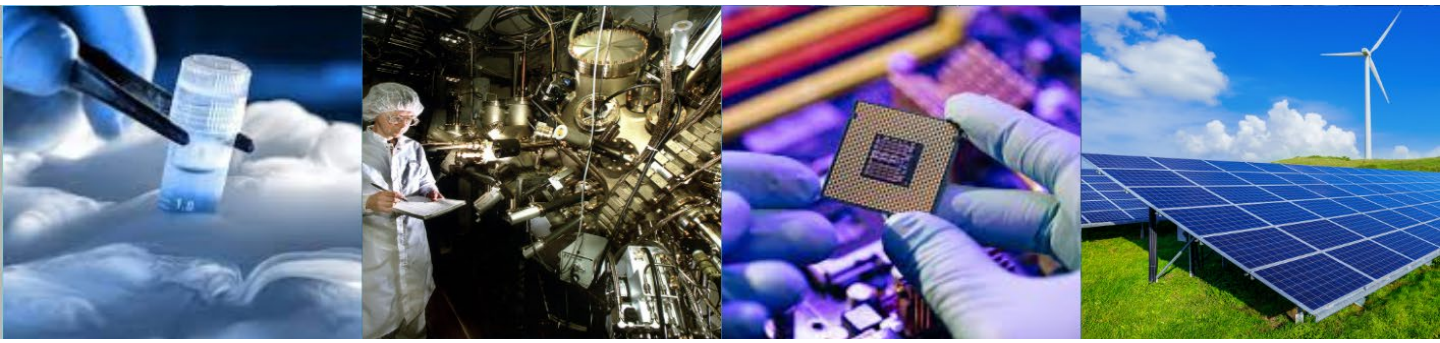
5. Customer Information

5.1 Name:

5.2 Contact No:

5.3 Email:

Cryogenic Piping



Cryogenic *Transfer Pipe*

StatiRigid-P

Constructed in modular sections with smooth inner bore *pipe* size, StatiRigid comes with periodic internal bellows to minimize pressure drop and improve flow characteristics. It has the lowest heat leak and lowest cooldown loss in its class.

Suitable for use in a wide variety of industrial applications such as Electronic Assembly & Test, Food & Beverage, Petrochemical, Industrial Gas Plant, LNG etc.

StatiRigid-T

StatiRigid Pipe & Tube

Engineered as modular sections, these stainless steel coaxial vacuum insulated piping spools are joined together with close tolerance bayonet connections, forming a complete cryogenic transfer system.

Each section is evacuated, sealed and tested for vacuum integrity to ensure minimal heat gain. StatiRigid-*P* comes with internal bellows at required intervals to serve as thermal expansion compensators according to EJMA calculation. The pipe comes with smooth inner bore to minimize pressure drop and improve flow characteristics.

Installation for StatiRigid can be done easily both indoor and outdoor, by incorporating flexible sections strategically to offset misalignments.

CSM offers a complete line of components including in-line venting devices, phase separators and gas traps to maximize the cryogenic system performance.

Close Tolerance Bayonet

Features and Benefits

- StatiRigid pipe is easy to install due to its modular design
- Greater thermal efficiency compared to foam insulated pipes by more than 10 times
- Excellent flow characteristics make StatiRigid an ideal as main supply pipe and as header pipe
- Super insulation and proprietary chemical getters ensures long lasting vacuum integrity
- Fabricated by mechanized welding system process ensuring consistent weld quality

StatiRigid Technical Specifications

Model	Inner Rigid Pipe Size	Nominal Jacket OD*	Actual Flow Diameter	Standard Overall Lengths	Hole Required to Accommodate Pump Out**	Bayonet Clamp OD (F)	Weight / Length
R5T	¾" ODT 19.05mm	2" PS (60.3mm)	16.6mm	6' (1.8m) 10' (3.0m) 15' (4.5m) 20' (6.0m) 40' (12.0m)	4" (100mm)	51mm	2.0lb/ft (3.0kg/m)
R5P	½" PS 21.3mm	2" PS (60.3mm)	18.0mm		4" (100mm)	65mm	2.2lb/ft (3.3kg/m)
R10T	1-1/8"ODT 29.00mm	2.5" PS (73.0mm)	26.6mm		5 " (120mm)	65mm	3.1lb/ft (4.6kg/m)
R10P	1" PS 33.4mm	3" PS (88.9mm)	30.0mm		5 " (120mm)	78mm	4.0lb/ft (5.9kg/m)
R15P	1 ½" PS (48.3mm)	3 ½" PS (101.6mm)	1.770" PS (45mm)		6" (150mm)	91mm	4.9lb/ft (7.3kg/m)
R20P	2" PS (60.3mm)	3 ½" PS (101.6mm)	2.245" PS (57mm)		7 " (180mm)	120mm	5.2lb/ft (7.8kg/m)
R30P	3" PS (88.9mm)	5" PS (141.3mm)	3.334" PS (85mm)		8" (200mm)	145mm	9.7lb/ft (14.4kg/m)

*Not including POV pump out valve , **Pump out valve with no Thermocouple (TC)

StatiRigid Performance Data

Model	Cool Down			Static Heat Leak		LN2 Bayonet Pair Heat Leak	
	KJ/m	Kg/m*	lb of LN2/ft	**BTU/hr/ft	**Watt/m	**BTU/hr	**Watt
R5T	59	0.4	0.26	0.42	0.40	4.0	1.2
R5P	85	0.6	0.38	0.45	0.43	8.1	2.4
R10T	88	0.6	0.39	0.49	0.47	8.1	2.4
R10P	139	0.9	0.62	0.50	0.48	7.8	2.3
R15P	204	1.4	0.91	0.52	0.50	9.2	2.7
R20P	256	1.7	1.15	0.71	0.69	11.3	3.3
R30P	482	3.2	2.15	1.25	1.20	16.7	4.9

*LN2 at 3 Bar (45psi) @ -181deg C
**LN2 at 5 Bar (72psi)

StatiRigid LN2 Flow Guide Line

Model	Nominal Flowrate @30m, ΔP 0.1Bar			Maximum Flowrate @30m, ΔP 0.3Bar		
	gpm	lpm	kg/hr*	gpm	lpm	kg/hr*
R5T	3.1	11.7	500	5.2	19.8	850
R5P	3.7	14.0	600	6.1	23.3	1000
R10T	9.2	35.0	1500	17.8	67.7	2900
R10P	13.5	51.3	2200	24.6	93.3	4000
R15P	38.1	144.7	6200	73.7	280.0	12000
R20P	73.7	280.0	12000	128.9	490.0	21000
R30P	214.9	816.7	35000	380.7	1446.7	62000

* Based on liquid nitrogen at 6.0Bar (90psi) saturation pressure for 30m (100ft) piping length, exclude pressure drop due to elevation changes

StatiRigid Pressure Drop (bar/meter)*

Model	Flow (kg/hr)							
	450	1200	2200	3400	11400	17000	23000	34000
R5T	0.0028	0.0185	0.060	0.142				
R5P	0.00194	0.0126	0.041	0.096				
R10T		0.0018	0.0056	0.0129	0.140			
R10P		0.00094	0.0030	0.0069	0.074	0.162	0.295	
R15P			0.0004	0.0009	0.0093	0.0204	0.037	0.080
R20P				0.00028	0.0028	0.0061	0.0109	0.0237
R30P					0.00036	0.00077	0.0014	0.0030

*Note: 1. LN2 at 3 Bar (45psi) @ -181deg C
2. Pressure drop numbers listed do not account for elevation changes. CSM recommends pressure drop be kept to 0.3 bar or less
3. This table is intended to be used as a guide only and should not be substituted for a complete analysis.

StatiRigid-P Sizing Chart

The following table can be used as an initial estimate of required pipe size. It is strongly suggested that a detailed analysis of the actual expected pressure drop be considered with respect to the allowable pressure drop for the process of interest.

	Equivalent Length of Pipe Meters (Ft)									
LPH	15m 50′	30m 100′	45m 150′	60m 200′	75m 250′	90m 300′	105m 350′	120m 400′	135m 450′	150m 500′
450	R5T	R5T	R5T	R5T	R5T	R5T	R5T	R5T	R5T	R5T
900	R5T	R5T	R5T	R5T	R5P	R5P	R10T	R10T	R10T	R10T
1400	R5T	R5P	R10T	R10T	R10T	R10T	R10P	R10T	R10T	R10T
1800	R5T	R10T	R10T	R10T	R10T	R10T	R10P	R10T	R10T	R10T
2300	R10T	R10T	R10T	R10T	R10T	R10T	R10P	R10P	R10P	R10P
3400	R10T	R10T	R10T	R10P	R10P	R10P	R15P	R15P	R15P	R15P
4500	R10T	R10T	R10P	R15P	R15P	R15P	R15P	R15P	R15P	R15P
5700	R10T	R10P	R15P	R15P	R15P	R15P	R15P	R15P	R15P	R15P
6800	R10P	R15P	R15P	R15P	R15P	R15P	R15P	R15P	R15P	R15P

Notes:
1.This table is intended to be used as a guide only and should not be substituted for a complete analysis.
2.Suggested sizes assume an allowable pressure drop of 0.3 bar (4.5psi).
3.Equivalent length of pipe (metre) = Length of pipe + (1.5 x # of elbows and tees) + (12 x # of valves)
Example: System requires 2300 LPH through a pipe system that has 45m of pipe, 4 elbows, 2 tees and 1 valve.
Equivalent length of pipe = 45 + 1.5m x (4 +2) + 12m x (1) = 66m (200ft). Table look-up with 2300 LPH and 66m thus suggested pipe size is R10T (29mm ID).
4. Add 0.07 bar (1psi) pressure drop for every 0.9 metre (3ft) of vertical rise with LN2.

Liquid Nitrogen Properties						
	WEIGHT		GAS		LIQUID	
	Pound (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1.0	0.4536	13.803	0.3627	0.1481	0.5606
1 Kilogram	2.205	1.0	30.42	0.7996	0.3262	1.2349
1 SCF Gas	0.07245	0.3286	1.0	0.02628	0.01074	0.04065
1 Nm3 Gas	2.757	1.2506	38.04	1.0	0.4080	1.5443
1 Gal Liquid	6.745	3.060	993.11	2.447	1.0	3.785
1 L Liquid	1.782	0.8083	24.60	0.6464	0.2642	1.0

Nm3 (normal cubic meter) measured at 1 atmosphere and 0°C.
SCF (Standard Cubic Feet) gas measured at 1 atmosphere and 21°C.
Liquid measured at 1 atmosphere and boiling temperature.
All values rounded to nearest 4/5 significant numbers.

AT ATMOSPHERIC PRESSURE:
Boiling Temperature: -196°C -320°F
Heat of Vaporization: 198.8 KJ/Kg (85.6 BTU/lb)
Liquid Density: 0.806 Kg/L (6.745 lb/gal)

StatiRigid-*P*

Constructed in modular sections with smooth inner bore pipe size, StatiRigid-P comes with periodic internal bellows for thermal compensation and designed to minimize pressure drop and improve flow characteristics. It has the lowest heat leak and lowest cooldown loss in its class.

Suitable for use in a wide variety of industrial applications such as Electronic Assembly & Test, Food & Beverage, Petrochemical, Industrial Gas Plant, LNG etc.

All StatiRigid-P products come with CSM renowned customer service, from conceptual design to implementation, and are backed by a 5 year or optional extended 10 years vacuum warranty

StatiRigid-P

Engineered as modular sections, these stainless steel coaxial vacuum insulated piping spools are joined together with close tolerance bayonet connections, or welded connection forming a complete cryogenic transfer system.

Each section is evacuated, sealed and tested for vacuum integrity to ensure minimal heat gain. StatiRigid-P comes with internal bellows at required intervals to serve as thermal compensators with 10,000 fatigue cycles calculated based on EJMA standard. The pipe comes with smooth inner bore to minimize pressure drop and improve flow characteristics.

Installation for StatiRigid-P can be done easily both indoor and outdoor, by incorporating CryoFlex sections strategically to offset misalignments.

CSM offers a complete line of components including in-line venting devices, phase separators and gas traps to maximize the cryogenic system performance.

StatiRigid-P with Ultraflex & Degasser to Semiconductor IC Test Handler

Features and Benefits

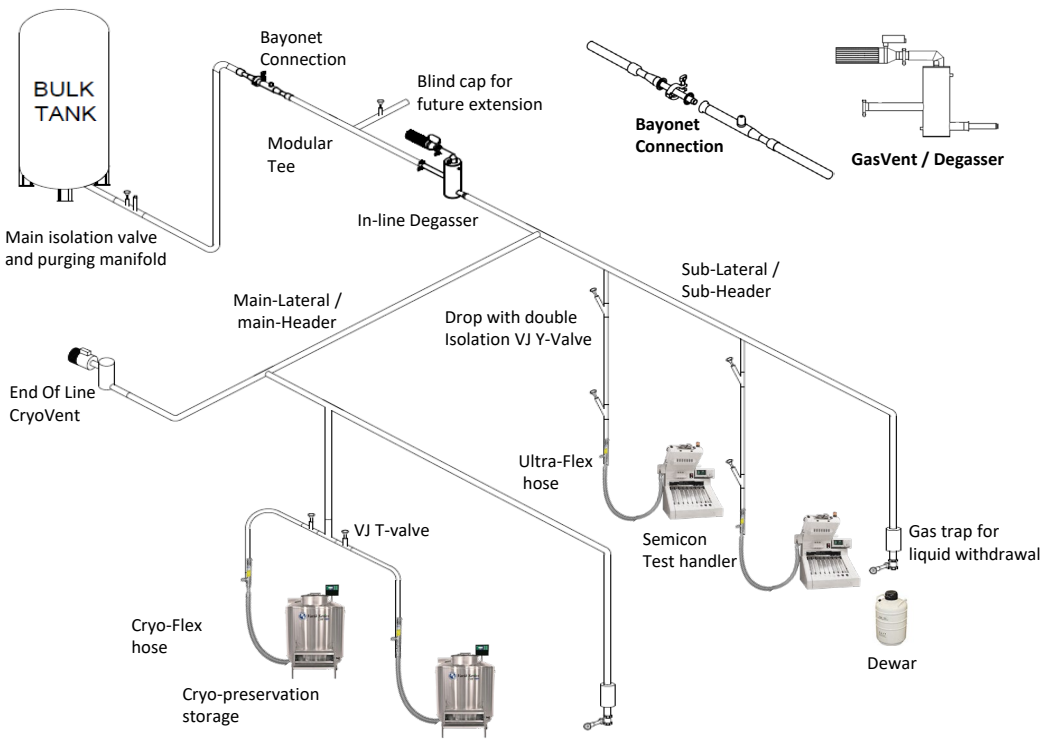
- StatiRigid-P pipe is easy and cost effective to install due to its modular design
- Greater thermal efficiency compared to foam insulated pipes by more than 40 times
- Excellent flow characteristics make StatiRigid-P an ideal as main supply pipe and as header pipe
- Super insulation and proprietary chemical getters ensures long lasting vacuum integrity
- Fabricated by mechanized welding system process ensuring consistent weld quality

StatiRigid-P Specifications

Model	R5P	R10P	R15P	R20P	R30P	R40P
Process Pipe (Sch 5)	0.5" IPS (21.3mm OD)	1" IPS (33.4mm OD)	1.5" IPS (48.3mm OD)	2" IPS (60.3mm OD)	3" IPS (88.9mm OD)	4" IPS (114.3mm OD)
Jacket Pipe (Sch 5)	2.0" IPS (60.3mm OD)	3.0" IPS (88.9mm OD)	3.5" IPS (101.6mm OD)	3.5" IPS (101.6mm OD)	5" IPS (141.3mm OD)	6" IPS (168.3mm OD)
Steady State Heat Leak	0.45 btu/hr/ft (0.43 watts/m)	0.50 btu/hr/ft (0.48 watts/m)	0.52 btu/hr/ft (0.50 watts/m)	0.71 btu/hr/ft (0.69 watts/m)	1.25 btu/hr/ft (1.20 watts/m)	1.31 btu/hr/ft (1.26 watts/m)
Bayonet Heat Leak	8.1 btu/hr (2.4 watts)	7.8 btu/hr (2.3 watts)	9.2 btu/hr (2.7 watts)	11.3 btu/hr (3.3 watts)	16.7 btu/hr (4.9 watts)	-
Welded Joint Vacuum Jacketed Heat Leak	-	5.46 btu/hr (1.60 watts)	5.76 btu/hr (1.69 watts)	9.21 btu/hr (2.70 watts)	13.09 btu/hr (3.84 watts)	18.48 btu/hr (5.42 watts)
Welded Joint PU Insulated Heat Leak	-	50.98 btu/hr (14.95 watts)	60.49 btu/hr (17.74 watts)	72.05 btu/hr (21.13 watts)	90.81 btu/hr (26.63 watts)	109.87 btu/hr (32.22 watts)
Maximum Operating Pressure (*Bayonet)	200 psig (13.8 bar)	150 psig (10.3 bar)	150 psig (10.3 bar)	150 psig (10.3 bar)	150 psig (10.3 bar)	150 psig (10.3 bar)
Weight (exclude Bayonet)	2.2 lbs/ft (3.3 kg/m)	4.0 lbs/ft (5.9 kg/m)	4.9 lbs/ft (7.3 kg/m)	5.2 lbs/ft (7.8 kg/m)	9.7 lbs/ft (14.4 kg/m)	11.9 lbs/ft (17.7 kg/m)
Maximum Length	Maximum spool length 40' (12.2 m)					
Material Construction	Stainless Steel Series 300					
Standard Testing	Dimensional check Helium leak test at 1.0 x 10^{-9} cc/s					
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services					

Options include TC vacuum gauge tubes on each section, Low Loss Gas Trap

Typical StatiRigid-P, Engineered Modular Piping System



Rigid-*T*

Rigid-T comes with high-purity tubes compliance to semiconductor or Biopharmaceutical specification with minimum contamination to customer process.

The spool fabrication is done in a clean and controlled environment with orbital welding procedure.

Both inner & outer pipe surface are polished, degreased, ultrasonic cleaned, and final-rinsed with high purity RO water, before it is used in process application.

All Rigid-T products come with CSM renowned customer service, from conceptual design to implementation, and are backed by a 5 year or optional extended 10 years vacuum warranty

Rigid-T with Degasser to biomedical freezer

Rigid-T with Ultraflex hose to cryokinetic semicon wafer cleaning equipment

Rigid-T

Engineered as modular sections, these stainless steel coaxial vacuum insulated piping spools are joined together with close tolerance bayonet connections, forming a complete cryogenic transfer system.

Each section is evacuated, sealed and tested for vacuum integrity to ensure minimal heat gain. Rigid-T comes with internal bellows at required intervals to serve as thermal expansion compensators according to EJMA 10,000 cycle fatigue calculation.

Installation for Rigid-T can be done easily both indoor and outdoor, by incorporating flexible sections strategically to offset misalignments.

CSM offers a complete line of components including in-line venting devices, phase separators and gas traps to maximize the cryogenic system performance.

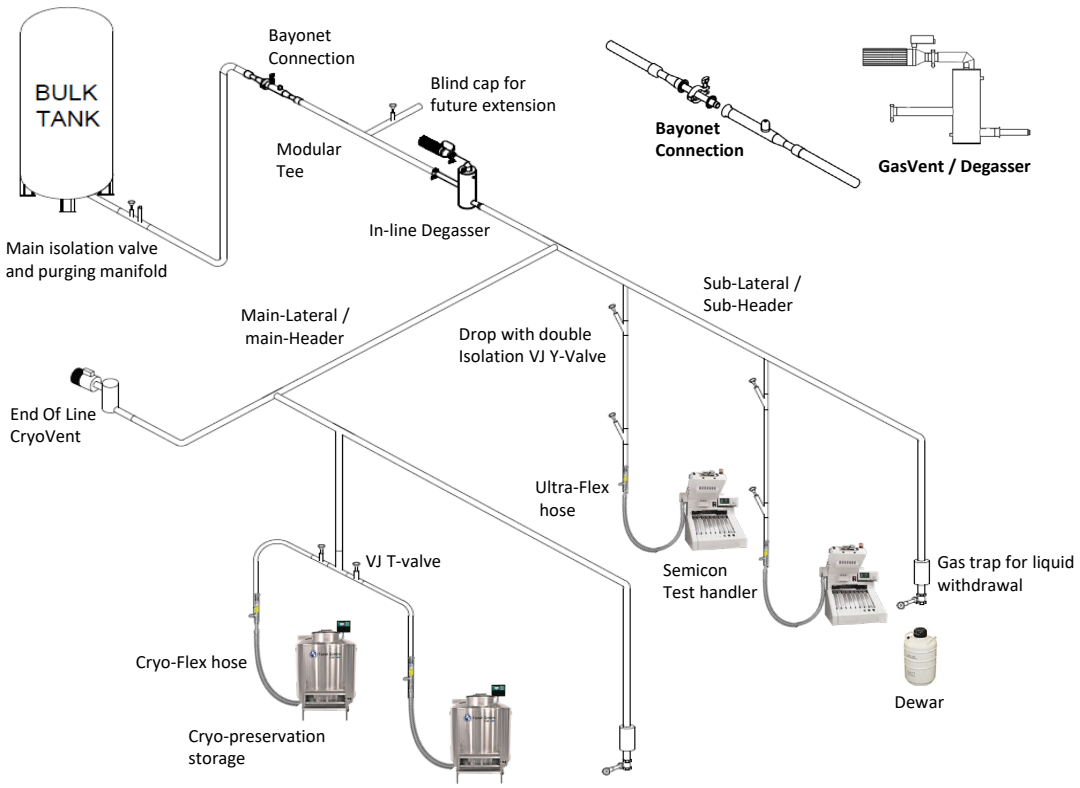
Features and Benefits

- Fabricated by orbital welding to ensure process integrity
- Polished outer jacket provides clean pipe surface for cleanroom requirement
- Rigid-T pipes are durable, easy to install and practically maintenance free
- Excellent flow characteristics make Rigid-T an ideal for pipe mains
- Super insulation and proprietary chemical getters ensures long lasting vacuum integrity

Rigid-T Specifications

Model	R2T	R5T	R10T	R15T
Process Tube	0.5" ODT (12.7 mm OD)	0.75" ODT (19.05 mm OD)	1.125" ODT (29 mm OD)	1.5" ODT (38.1 mm OD)
Jacket Pipe (Sch 5)	1.5" IPS (48.3 mm OD)	2" IPS (60.3 mm OD)	2.5" IPS (73.03 mm OD)	3" IPS (88.9 mm OD)
Steady State Heat Leak	0.17 btu/hr/ft (0.16 watts/m)	0.42 btu/hr/ft (0.40 watts/m)	0.49 btu/hr/ft (0.47 watts/m)	0.62 btu/hr/ft (0.59 watts/m)
Bayonet Heat Leak	6.1 btu/hr (1.8 watts)	4.0 btu/hr (1.2 watts)	8.1 btu/hr (2.4 watts)	7.8 btu/hr (2.3 watts)
Max. Operating Pressure	150 psig (10.3 bar)	150 psig (10.3 bar)	150 psig (10.3 bar)	150 psig (10.3 bar)
Weight (exclude Bayonet)	1.8 lbs/ft (2.7 kg/m)	2.0 lbs/ft (3.0 kg/m)	3.1 lbs/ft (4.6 kg/m)	4.4 lbs/ft (6.5 kg/m)
Vacuum Insulation Type	Static or Dynamic Vacuum			
Maximum Length	Max. single line length 40' (12.2 m)			
Material Construction	Stainless Steel Series 300			
Standard Testing	Dimensional Check Heat leak checked 1 x 1 0 - 9 cc/s			
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services			

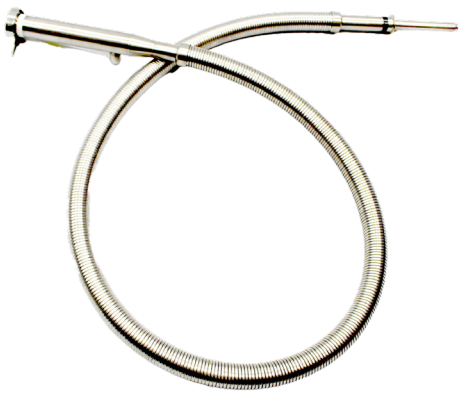
Typical Rigid-T, Engineered Modular Piping System



Cryogenic Transfer Hose

Semi-Flex

Cryo-Flex



Ultra-Flex

CSM provide transfer hoses with various flexibility to suit different piping needs and applications.

All hoses comes with static vacuum as standard and dynamic vacuum as option. Static vacuum hose is vacuum sealed at the factory, providing many years of trouble free vacuum insulation. All hoses comes with high quality wear resistant stainless steel outer braid or kink resistant spiral wrap protection cover.

Semi-Flex

Semi-Flex, a semi-rigid bendable pipe with optimal flexibility is suitable for long distance piping system application, an alternative to traditional rigid piping. It's lightweight stainless steel construction reduces cool-down losses to an absolute minimum. Available in sizes of DN16 (1/2") & DN25 (1") and lengths ranging from 6m to 30m.

Cryo-Flex

Cryo-Flex is designed to meet high flow capacity without compromising its flexibility. Mainly used to overcome misalignment in rigid piping system; and as a final tie-in to equipment.

Cryo-Flex are available in many sizes from DN16 up to DN50 to meeting almost all the standard or custom requirements.

Ultra-Flex

Ultra-Flex is a ultra-flexible vacuum insulated hose with low to medium flow applications. It has the lowest dynamic bend radius among all cryogenic hoses in the market. Mainly used to transfer liquid nitrogen from dewar to equipment.

Cryo-Flex are available with sizes from DN8 up to DN12 to meet most the applications.

Features and Benefits

- Superior vacuum insulation eliminates moisture, condensation and frost build-up
- Due to very low heat gain, liquid nitrogen losses can be reduced by 10 to 20 times
- Product flexibility facilitates installation especially above ceilings and below raised floors

Semi-Flex / Cryo-Flex Technical Specifications

Model	Inner Flex Pipe Size	Nominal Jacket OD*	Min. Bend Radius (SemiFlex)	Actual Flow Dia.	Max Lgth	Hole Required to Accommodate Pump Out**	Bayonet Clamp OD (F)	Nominal OD with Braid	Weight / Length (SemiFlex)
F16	DN 16 (16.2mm)	DN40 (52.1mm)	200mm (450mm)	16.2mm	6 m ~ 30m	100mm (4")	51mm	53mm	2.3kg/m (1.44kg/m)
F25	DN 25 (25.1mm)	DN50 (62.8mm)	300mm (550mm)	25.1mm		100mm (4")	64mm	63mm	3.18 kg/m (1.94kg/m)
F32	DN32 (34.2mm)	DN65 (81.2mm)	450mm	34.2mm		120mm (4.5")	64mm	82mm	4.5 kg/m
F40	DN40 (40.0mm)	DN100 (120mm)	600mm	40.0mm		150mm (6")	91mm	120mm	7.9 kg/m
F50	DN50 (50.1mm)	DN100 (120mm)	720mm	50.1mm		180mm (7")	120mm	120 mm	8.2 kg/m

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

Semi-Flex / Cryo-Flex Performance Data

Model	Cool Down (SemiFlex)			Static Heat Leak		LN2 Bayonet Pair Heat Leak	
	KJ/m	Kg/m*	lb of LN2/ft*	BTU/hr/ft	Watt/m	BTU/hr	WATT
F16	64 (22)	0.43 (0.15)	0.29 (0.10)	1.4	1.3	4.0	1.2
F25	125 (59)	0.84 (0.40)	0.56 (0.27)	1.5	1.4	8.1	2.4
F32	135	0.90	0.60	1.6	1.5	7.8	2.3
F40	252	1.68	1.13	1.8	1.7	9.2	2.7
F50	292	1.95	1.31	1.7	1.6	11.3	3.3

*LN2 at 3 Bar (45psi) @ -181deg C

Semi-Flex / Cryo-Flex LN2 Flow Guide Line

Model	*Nominal Flowrate @ ΔP 0.1Bar			*Maximum Flowrate @ ΔP 0.3Bar		
	gpm	lpm	kg/hr	gpm	lpm	kg/hr
F16	1.2	4.7	200	2.1	8.2	350
F25	4.3	16.3	700	7.4	28.0	1200
F32	9.8	37.3	1600	18.4	70.0	3000
F40	14.7	56.0	2400	25.8	98.0	4200
F50	27.0	102.7	4400	51.0	193.7	8300

- Based on liquid nitrogen at 6.0Bar (90psi) saturation pressure for 30m (100ft) piping length, exclude pressure drop due to elevation changes
- Above flow rate is based on corrugation profile of CryoFlex. SemiFlex flow rate to multiply with factor 0.9

Semi-Flex / Cryo-Flex Pressure Drop (bar/meter)*

Model	Flow (kg/hr)						
	450	1200	2200	5500	11400	17000	23000
F16	0.0155	0.109	0.369				
F25	0.0011	0.008	0.027	0.167	0.718		
F32		0.0015	0.005	0.0319	0.137	0.304	
F40			0.0024	0.0152	0.065	0.144	0.265
F50			0.00064	0.0040	0.0171	0.0380	0.069

*Pressure drop numbers listed is based on liquid nitrogen at 6.0 Bar (90psi) saturation pressure, do not account for elevation changes. CSM recommends pressure drop be kept to 0.3 bar or less.

Ultra-Flex

U-flex transfer hose offers high flexibility, sturdy & kink-resistant spiral wrap outer jacket, suitable for rough handling usage such as cryogenic liquid cylinder (LGC / dewar) refilling; and liquid withdrawal from pressurized dewar to test handler.

Smooth spiral wrap design ensures zero risk of hand injury due to wire piercing commonly occur in traditional wire braided hose

All Ultra-Flex comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Ultra-Flex Transfer Hose

Ultra-Flex *transfer* hose is a ultra-flexible, vacuum insulated LN2 transfer hose with high flexibility. It has the lowest dynamic bend radius among all cryogenic hoses in the market.

Due to its lightweight stainless steel construction, cool-down loss can be reduced to an absolute minimum.

Ultra-Flex hoses are protected by a tough and anti-kink stainless steel spiral wrap outer covering, its non wire braid prevent potential operator injury due to sharp wire found in traditional braided sleeve.

Typical hoses are manufactured with pipe thread ends or female flare 1/2" JIC/CGA fittings or C5 bayonet. These hoses are used in a wide variety of applications including tool connections with portable dewars supplying LN2 to test handlers, LN2 doser, or any moving reservoirs and custom OEM applications.

Ultra-Flex application in Test Handlers

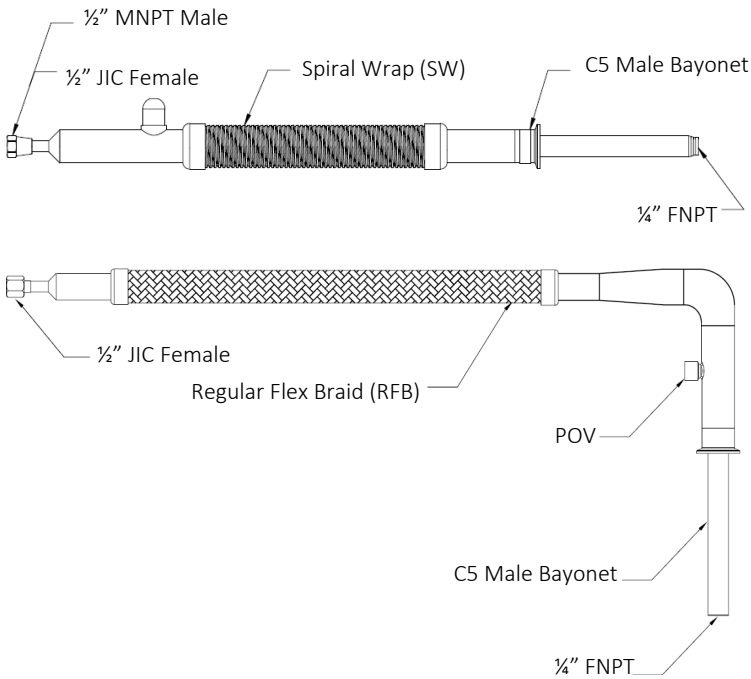
Features and Benefits

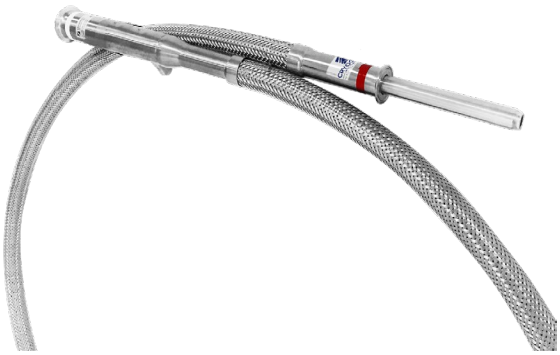
- Tees, elbows, bayonets and valves can be incorporated with Ultra-Flex transfer hose for a customized LN2 piping system application
- Both flexible and rigid sections can be combined as one spool
- Select hoses are stocked for immediate delivery
- Super insulation and proprietary chemical getters ensures long lasting vacuum integrity
- Each hose is evacuated (10 -6 torr), helium leak checked (1 x10 -9 std cc/sec) and liquid nitrogen cold shocked before shipping
- Vacuum insulation eliminates frost, ice and related safety hazards

Ultra-Flex Specifications

Model	UF8	UF12
Inner Diameter (I.D.)	DN 8 5/16" (8.2 mm)	DN 12 ½" (12.1 mm)
Outer Diameter (O.D.)	DN 25 (39.0 mm)	DN 32 (49 mm)
Steady State Heat Leak	2.7 btu/hr/ft (2.6 watts/meter)	3.2 btu/hr/ft (3.0 watts/meter)
Bayonet Heat Leak	4.3 btu/hour (1.2 watts)	4.3 btu/hour (1.2 watts)
Max. Operating Pressure	150 psi (10.3 bar)	150 psi (10.3 bar)
Weight	0.7 lbs/ft (1.1 kg/m)	0.8 lbs/ft (1.2 kg/m)
Min. Flexible Bend Radius	8" (203 mm)	10" (254 mm)
Min. Static Bend Radius	6" (152 mm)	8" (203 mm)
Vacuum Insulation Type	Static Vacuum with MLI, Absorbent and Getters	
Protective Outer Covering	SW - Spiral Wrap (Standard) RFB - Regular Flex Braid (Option)	
Material Construction	Stainless Steel Series 300	
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s	
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services	

Typical Ultra-Flex Transfer Hose





Semi-Flex
Static

Pre-engineered modular Semi-Flex transfer hose has added advantage over the traditional rigid VJP, especially when system upgrade is frequently done. This option is cost saving as the flexibility of the pipe reduces the necessity for precise system layout measurements. It allows the whole system to be easily reused if use-point locations and plant layout are changed. Semi-Flex can be added if required to the existing system without major rework expenses.

Semi-Flex facilitate users to design and construct their own LN2 delivery system with minimum piping engineering experience or knowledge.

All Semi-Flex comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a 5 year vacuum warranty; 1 year defect warranty

Semi-Flex Static Transfer Hose

Semi-Flex, a semi-rigid bendable pipe with optimal flexibility is suitable for long distance piping system application, an alternative to traditional rigid piping. It's lightweight stainless steel construction reduces cool-down losses to an absolute minimum.

Semi-Flex hoses are protected by a high quality and wear resistant stainless steel braided outer covering. Typical hoses are manufactured with pipe thread ends or bayonet connection.

These hoses are used in a wide variety of applications as main transfer hose for LN2 such as food freezing, semiconductor test handlers, MBE and LN2 dosing applications.

Related Products:

Modular Valve

Modular Tee

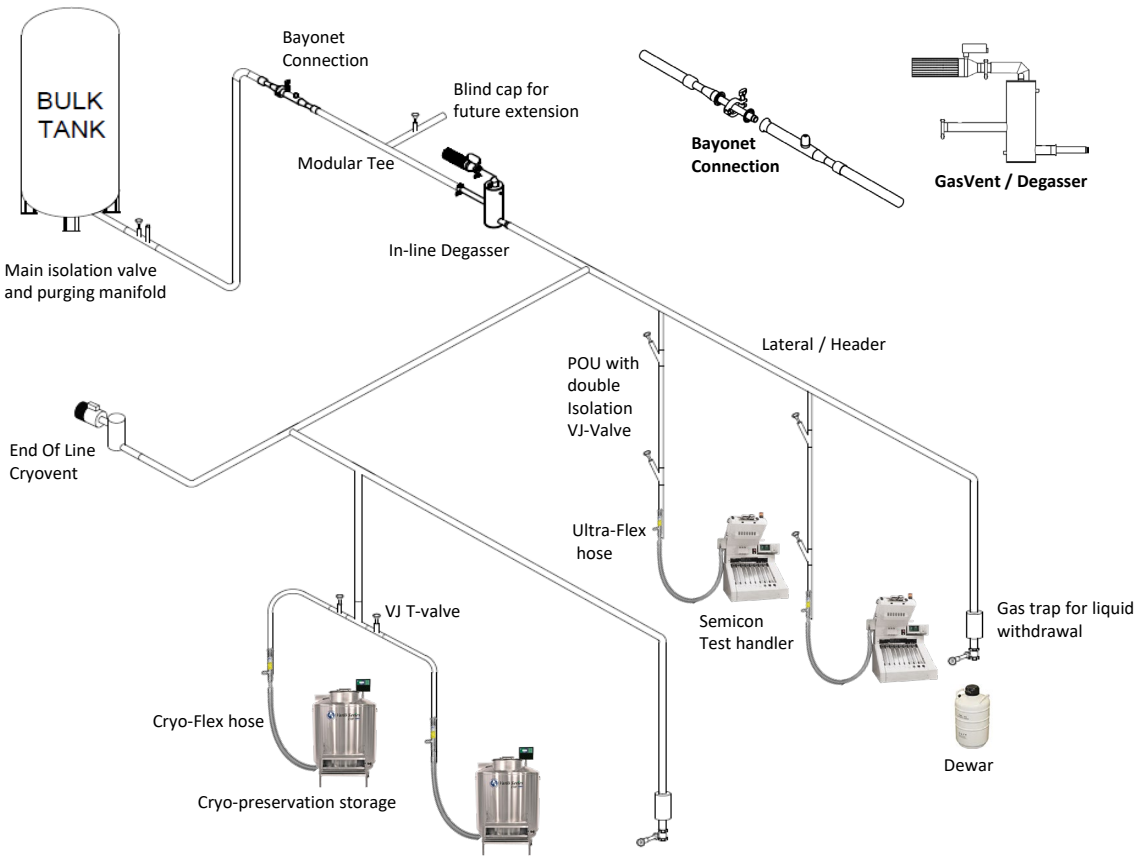
Features and Benefits

- Semi-Flex can be coiled for shipment by air freight, thus eliminate the need for expensive logistics
- Tees, elbows, bayonets and valves can be incorporated with *Semi-Flex* transfer hose for a customized LN2 piping system application
- Select hoses are stocked for immediate delivery
- Super insulation and proprietary chemical getters ensures long lasting vacuum integrity
- Each hose is evacuated (10 -6 torr), helium leak checked (1 x10 -9 std cc/sec) and liquid nitrogen cold shocked before shipping
- Vacuum insulation eliminates frost, ice and related safety hazards

Semi-Flex Static Specifications

Model	SF16	SF25	SF32	SF40	SF50
Inner Diameter	DN 16 ⅝" (16.2 mm)	DN 25 1" (25.1 mm)	DN 32 1⅜" (34.2 mm)	DN 40 1 ½" (40 mm)	DN 50 2" (50.1 mm)
Outer Diameter	DN 40 (52.1 mm)	DN 50 (62.8 mm)	DN 65 (81.2 mm)	DN 100 (120 mm)	DN 100 (120 mm)
Steady State Heat Leak	1.4 btu/hr/ft (1.3 watts/m)	1.5 btu/hr/ft (1.4 watts/m)	1.6 btu/hr/ft (1.5 watts/m)	1.8 btu/hr/ft (1.7 watts/m)	1.7 btu/hr/ft (1.6 watts/m)
Bayonet Heat Leak	4.0 btu/hr (1.2 watts)	8.1btu/hr (2.4 watts)	8.1 btu/hr (2.4 watts)	9.2 btu/hr (2.7 watts)	11.3 btu/hr (3.3 watts)
Max. Operating Pressure	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)
Weight	1.0 lbs/ft (1.4 kg/m)	1.3 lbs/ft (1.9 kg/m)	3.0 lbs/ft (4.5 kg/m)	5.3 lbs/ft (7.9 kg/m)	5.5 lbs/ft (8.2 kg/m)
Min. Bend Radius (Static)	12" (30 cm)	16" (40 cm)	18" (45 cm)	24" (60 cm)	28" (72 cm)
Vacuum Insulation Type	Static or Dynamic Vacuum				
Maximum Length	Single Spool 59 ft (18.00 m)				
Protective Outer Covering	RFB - Regular Flex Braid				
Material Construction	Stainless Steel Series 300				
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s				
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services				

Semi-Flex Static, Pre-engineered Modular Vacuum System



Semi-Flex *Dynamic*

Pre-engineered modular Semi-Flex transfer hose has added advantage over the traditional rigid VJP, especially when system upgrade is frequently done. This option is cost saving as the flexibility of the pipe reduces the necessity for precise system layout measurements. It allows the whole system to be easily reused if use-point locations and plant layout are changed. Semi-Flex can be added if required to the existing system without major rework expenses.

Semi-Flex facilitate users to design and construct their own LN2 delivery system with minimum piping engineering experience or knowledge.

All Semi-Flex comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a 5 year vacuum warranty; 1 year defect warranty

Semi-Flex Dynamic Transfer Hose

Semi-Flex, a semi-rigid bendable pipe with optimal flexibility is suitable for long distance piping system application, an alternative to traditional rigid piping. It's lightweight stainless steel construction reduces cool-down losses to an absolute minimum.

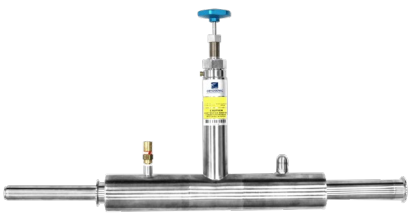
Semi-Flex hoses are protected by a high quality and wear resistant stainless steel braid outer covering. Typical hoses are manufactured with pipe thread ends or bayonet connection.

These hoses are used in a wide variety of applications as main transfer hose for LN2 such as food freezing, semiconductor test handlers, MBE and LN2 dosing applications.

Features and Benefits

- Tees, elbows, bayonets and valves can be incorporated with *Semi-Flex* transfer hose for a customized LN2 piping system
- Both flexible and rigid sections can be combined as one spool
- Select hoses are stocked for immediate delivery
- Special MLI system ensure fast pump down speed to < 10 -4 Torr
- Each hose is helium leak checked (1 x10 -9 std cc/sec) and liquid nitrogen cold shocked before shipping
- Vacuum insulation eliminates frost, ice and related safety hazards

Related Products:



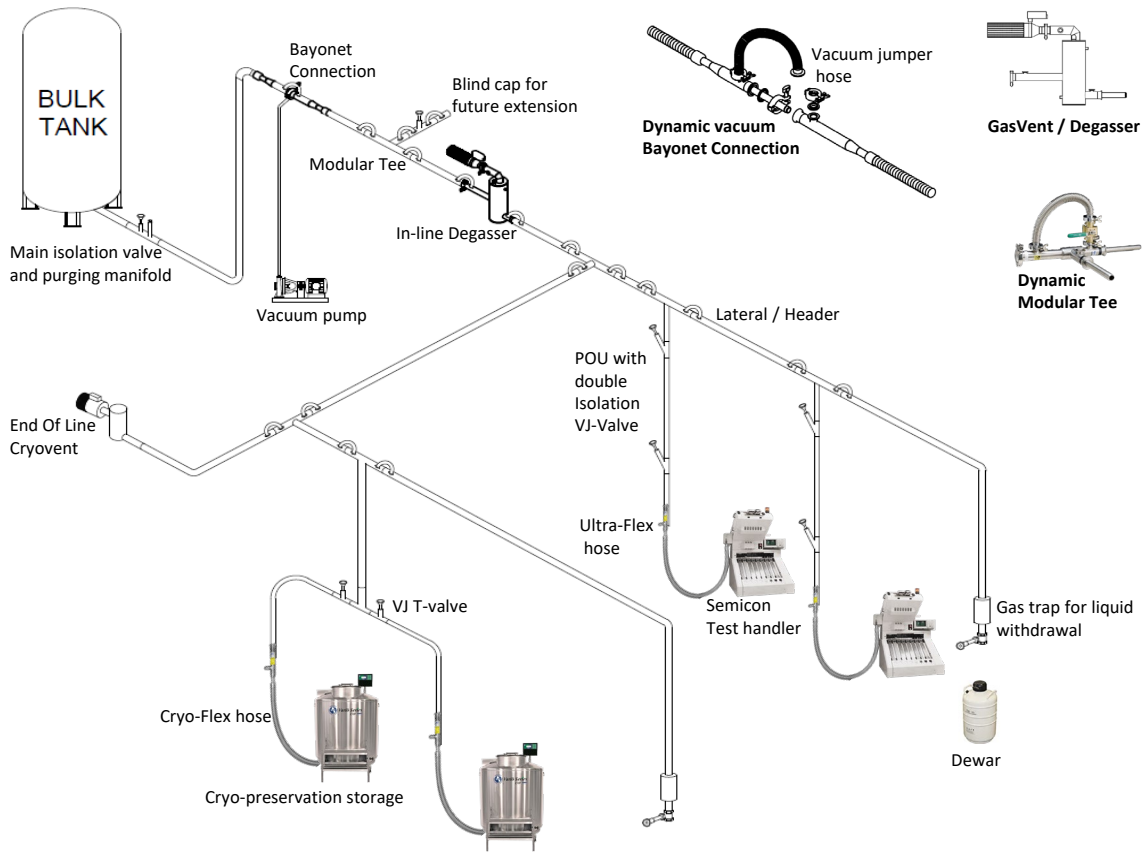
Modular T- valve

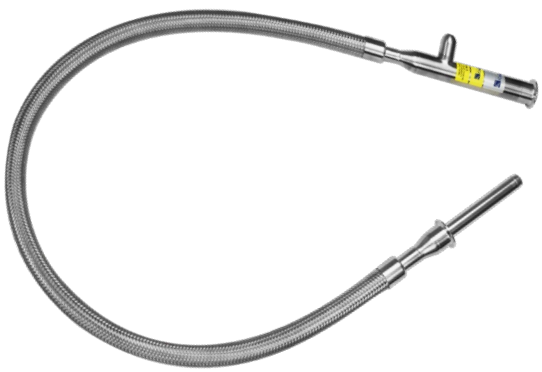
Modular Tee with Jumper Hose & Zone Valve in dynamic vacuum set up

Semi-Flex Dynamic Specifications

Model	SF16	SF25	SF32	SF40	SF50
Inner Diameter	DN 16 ⅝" (16.2 mm)	DN 25 1" (25.1 mm)	DN 32 1⅜" (34.2 mm)	DN 40 1 ½" (40 mm)	DN 50 2" (50.1 mm)
Outer Diameter	DN 40 (52.1 mm)	DN 50 (62.8 mm)	DN 65 (81.2 mm)	DN 100 (120 mm)	DN 100 (120 mm)
Steady State Heat Leak	1.4 btu/hr/ft (1.3 watts/m)	1.5 btu/hr/ft (1.4 watts/m)	1.6 btu/hr/ft (1.5 watts/m)	1.8 btu/hr/ft (1.7 watts/m)	1.7 btu/hr/ft (1.6 watts/m)
Bayonet Heat Leak	4.0 btu/hr (1.2 watts)	8.1btu/hr (2.4 watts)	8.1 btu/hr (2.4 watts)	9.2 btu/hr (2.7 watts)	11.3 btu/hr (3.3 watts)
Max. Operating Pressure	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)
Weight	1.0 lbs/ft (1.4 kg/m)	1.3 lbs/ft (1.9 kg/m)	3.0 lbs/ft (4.5 kg/m)	5.3 lbs/ft (7.9 kg/m)	5.5 lbs/ft (8.2 kg/m)
Min. Bend Radius (Static)	12" (30 cm)	16" (40 cm)	18" (45 cm)	24" (60 cm)	28" (72 cm)
Vacuum Insulation Type	Static or Dynamic Vacuum				
Maximum Length	Single Spool 59 ft (18.00 m)				
Protective Outer Covering	RFB - Regular Flex Braid				
Material Construction	Stainless Steel Series 300				
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s				
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services				

Semi-Flex Dynamic, Pre-engineered Modular Vacuum System





Cryo-Flex

Flexible transfer hose mainly used to overcome misalignment in rigid piping system; and as a final tie-in from rigid piping to equipment such as bulk tank & process equipment

All hoses comes with static vacuum as standard or dynamic vacuum as option. Static vacuum hose is vacuum sealed at the factory, providing many years of trouble free vacuum insulation

All Cryo-Flex products come with CSM renowned customer service, from conceptual design to implementation, and are backed by a 3 year vacuum warranty; 1 year defect warranty

Related Products:

Dynamic Vacuum option

Cryo-Flex Transfer Hose

Cryo-Flex is a vacuum insulated stainless steel flexible hose designed to meet high flow capacity without compromising its flexibility.

Engineered as modular section with close tolerance bayonet connections. It can be used on its own, or as part of StatiRigid sections for misalignment offset. Cryo-Flex pipe is evacuated and sealed at the factory as a static vacuum and is available in dynamic vacuum.

Cryo-Flex are available in wide variety of sizes from DN16 up to DN50 to meet most the standard or custom requirements.

CSM offers a complete line of components such as in-line venting devices, phase separators and gas traps to maximize the system performance.
Cryo-Flex is used in a wide variety of applications including biotech, cryogenic storage, food and beverage, nanotech, environmental temperature chambers and R&D applications.

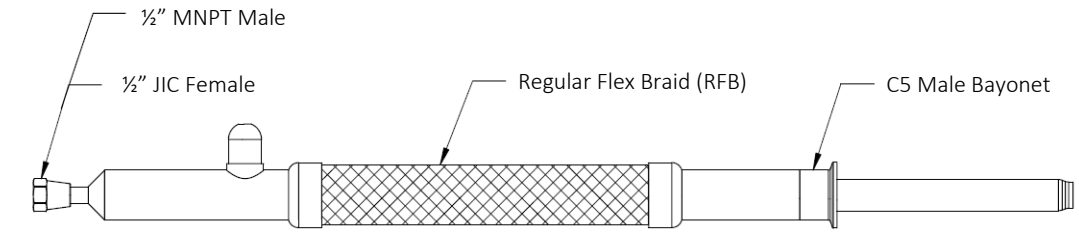
Features and Benefits

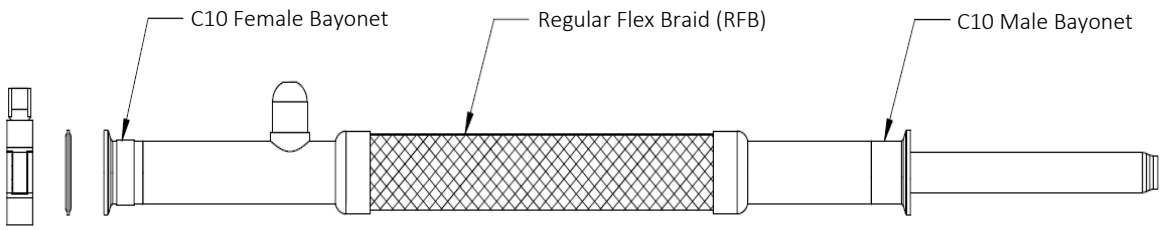
- Superior vacuum insulation eliminates moisture, condensation and frost build-up
- Due to very low heat gain, liquid nitrogen losses can be reduced by 10 to 20 times
- Quick delivery of LN2 to equipment improves cooling performance and production cycle time.
- Flexibility of Cryoflex facilitates installation especially above drop tile ceilings and below raised test floors

Cryo-Flex Specifications

Model	CF16	CF25	CF32	CF40	CF50
Inner Diameter	DN 16 ⅝" (16.2 mm)	DN 25 1" (25.1 mm)	DN 32 1⅜" (34.2 mm)	DN 40 1 ½" (40 mm)	DN 50 2" (50.1 mm)
Outer Diameter	DN 40 (52.1 mm)	DN 50 (62.8 mm)	DN 65 (81.2 mm)	DN 100 (120 mm)	DN 100 (120 mm)
Steady State Heat Leak	1.4 btu/hr/ft (1.3 watts/m)	1.5 btu/hr/ft (1.5 watts/m)	1.4 btu/hr/ft (1.4 watts/m)	1.8 btu/hr/ft (1.7 watts/m)	1.7 btu/hr/ft (1.6 watts/m)
Bayonet Heat Leak	4.0 btu/hr (1.2 watts)	8.1btu/hr (2.4 watts)	8.1 btu/hr (2.4 watts)	9.2 btu/hr (2.7 watts)	11.3 btu/hr (3.3 watts)
Max. Operating Pressure	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)
Weight	1.6 lbs/ft (2.4 kg/m)	2.1 lbs/ft (3.2 kg/m)	3.0 lbs/ft (4.5 kg/m)	5.3 lbs/ft (7.9 kg/m)	5.5 lbs/ft (8.2 kg/m)
Min. Bend Radius (Static)	8" (20 cm)	12" (30 cm)	18" (45 cm)	24" (60 cm)	28" (72 cm)
Vacuum Insulation Type	Static or Dynamic Vacuum				
Maximum Length	Max. single line length 33' (10 m)				
Protective Outer Covering	RFB - Regular Flex Braid				
Flow Rate / Pressure Drop	Consult factory				
Material Construction	Stainless Steel Series 300				
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s				
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services				

Typical Cryo-Flex Transfer Hose





Triax-Flex™

Triax-Flex transfer hose specifically designed to eliminate two-phase flow of LN2 to use points. Fully stainless steel construction with highest flexibility in the industry.

Modular sections allow for easy of assembly and disassembly and provide greater flexibility in piping system arrangement

Available in Static or Dynamic Vacuum System

All Triax-Flex products comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Related Products:

Modular T- valve

Modular Tee with Jumper Hose & Zone Valve in dynamic vacuum set up

Triax-Flex Transfer Hose

Triax-Flex ® transfer hose when use together with atmospheric Phase Separator system delivers liquid nitrogen (LN2) in pure liquid form at atmospheric pressure. This system ultimately eliminates two-phase flow to use points by constantly venting gaseous vapor to the atmosphere via phase separator. By separating vapor and venting them prior to liquid delivery, only sub-cooled LN2 will be delivered to each use point through gravity.

Triax-Flex ® are commonly used in applications where single-phase liquid is critical to the production process such as MBE, LN2 Doser, Cryopreservation or any critical process that demands pure LN2 supply.

Triax-Flex® is available in either static or dynamic vacuum insulation. For Dynamic Triax-Flex®, it requires an external pump to continuously evacuate its vacuum annular space to ensure its vacuum insulation integrity. Both static and dynamic systems come with Triax female bayonet connection, elbow, tee, valve or customize connections e.g. A5, A10 or TAL, to the point of use.

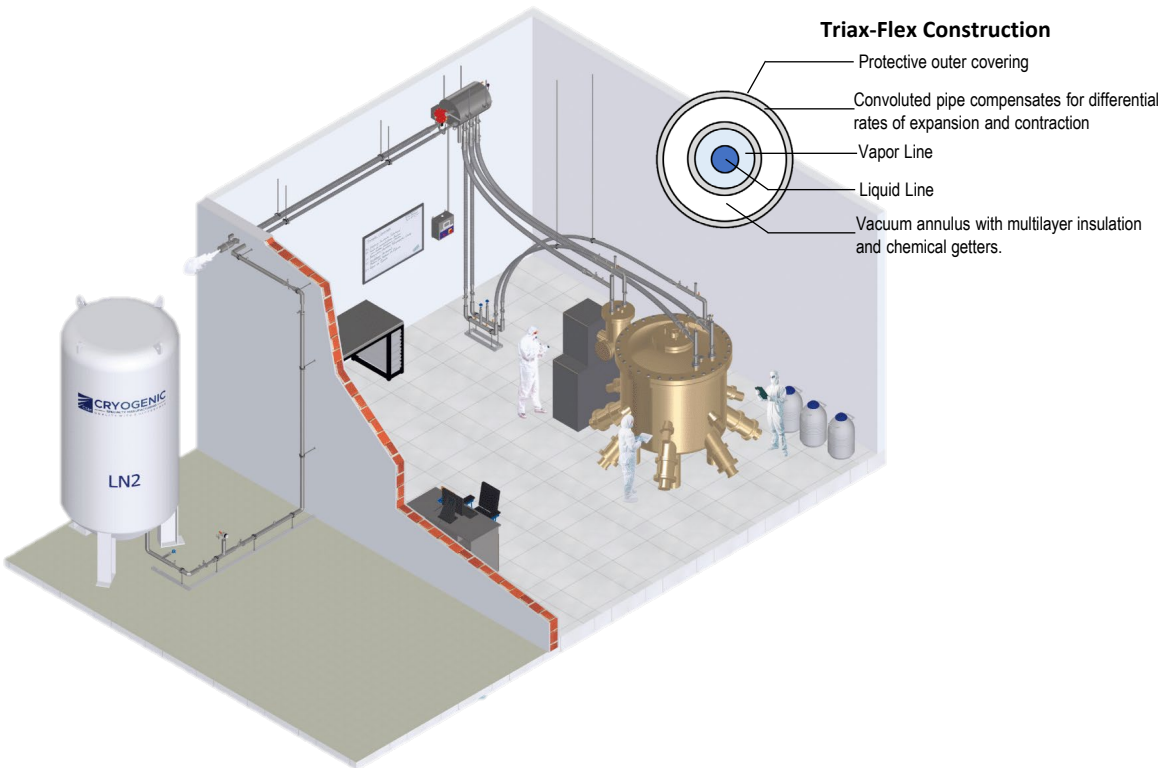
Features and Benefits

- Superior vacuum insulation eliminates moisture, condensation and frost build-up
- Due to very low heat gain, liquid nitrogen losses can be reduced by 10 to 20 times
- Quick delivery of LN2 to equipment improves cooling performance and production cycle time.
- Bendable nature facilitates installation in tight spaces such as research laboratory

Triax-Flex Specifications

Hose Model	TF16	TF25	TF32
Inner Diameter (I.D.)	DN 16 ⅝" (16.2 mm)	DN 25 1" (25.1 mm)	DN 32 1-⅜" (34.2 mm)
Outer Diameter (O.D.)	DN 40 (52.1 mm)	DN 50 (62.8 mm)	DN 65 (81.2 mm)
Steady State Heat Leak	1.4 btu/hr/ft (1.3 watts/m)	1.5 btu/hr/ft (1.5 watts/m)	1.6 btu/hr/ft (1.5 watts/m)
Bayonet Heat Leak	4.0 btu/hour (1.2 watts)	8.1 btu/hour (2.4 watts)	8.1 btu/hour (2.4 watts)
Max. Operating Pressure	200 psi (13.8 bar)	200 psi (13.8 bar)	200 psig (13.8 bar)
Weight	1.6 lbs/ft (2.4 kg/m)	2.1 lbs/ft (3.2 kg/m)	3.0 lbs/ft (4.5 kg/m)
Min. Bend Radius (Flexible)	12" (300 mm)	16" (400 mm)	24" (450 mm)
Min. Bend Radius (Static)	10" (250mm)	12" (300 mm)	20" (500 mm)
Vacuum Insulation Type	Static or Dynamic Vacuum		
Protective Outer Covering	RFB - Regular Flex Braid. SW - Spiral Wrap		
Flow Rate / Pressure Drop	Consult factory		
Material Construction	Stainless Steel Series 300		
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s		
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services		

Typical Triax-Flex Installation in MBE



Poly-Flex
for Polycold

Poly-Flex heralds a new era in ***polycold*** hose technology, offering minimal heat leaks, top-tier safety, and exceptional durability. Its robust spiral-wrapped jacket ensures resilience in rugged Polycold Cryochiller applications. This innovation operates with either self-contained static vacuum or dynamic vacuum using external process vacuum.

All Poly-Flex comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Poly-Flex Transfer Hose

The Poly-Flex transfer hose revolutionizes hose technology by addressing core problems in traditional polycold hoses. It eliminates icing through super insulation technology. Its lightweight stainless steel construction minimizes cool-down loss, cutting energy use and cryochiller stress during system start up. Exceptional flexibility eases installation and upkeep, boasting the industry's leading bend radius. Poly-Flex stays pliable in extreme cold, mitigating rupture risks at cold operating temperature. Safety is paramount, ensured by a robust stainless steel spiral wrap that neutralizes wire hazards in competitive wire braided polycold hose.

Typical hoses are manufactured with male/female seal-lok or HVCR or KF40 / KF50 clamp connection to PVD process chamber.

Available as single or twin refrigerant hose within a vacuum jacket.

Applications

These hoses are used in applications involve thin film deposition process such as CVD, PVD and ALD vacuum chamber operated with polycold cryochiller.

Poly-Flex application in PVD

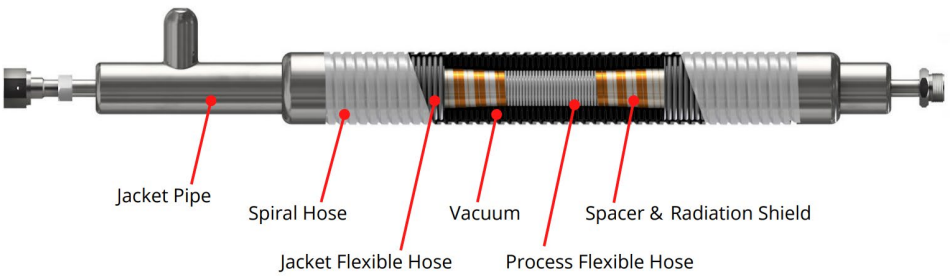
Features and Benefits

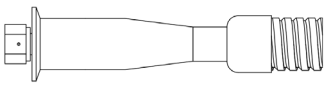
- Vacuum insulation eliminates condensation, frosting, ice and related safety hazards
- Super insulation and proprietary chemical getters ensures long lasting vacuum integrity
- Each hose is evacuated (10 -7 torr), helium leak checked (1 x10 -9 std cc/sec) and liquid nitrogen cold shocked tested before shipping
- Tees, elbows, bayonets and valves can be incorporated with Poly-Flex transfer hose for a customized application
- Both flexible and rigid sections can be combined as one spool
- Select hoses are stocked for immediate delivery

Poly-Flex Specifications

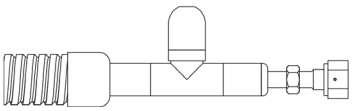
Model	PF8	PF12	PF8-Twin
Inner Diameter (I.D.)	DN 8 5/16" (8.2 mm)	DN 12 ½" (12.1 mm)	DN 8 5/16" (8.2 mm)
Outer Diameter (O.D.)	DN 25 (39.0 mm)	DN 32 (49 mm)	DN 50 (39.0 mm)
Steady State Heat Leak	2.7 btu/hr/ft (2.6 watts/meter)	3.2 btu/hr/ft (3.0 watts/meter)	3.8 btu/hr/ft (3.6 watts/meter)
Chamber conn. Heat Leak	4.3 btu/hour (1.2 watts)	4.3 btu/hour (1.2 watts)	4.3 btu/hour (1.2 watts)
Max. Operating Pressure	450 psi (31.0 bar)	450 psi (31.0 bar)	450 psi (31.0 bar)
Weight	0.7 lbs/ft (1.1 kg/m)	0.8 lbs/ft (1.2 kg/m)	0.7 lbs/ft (2.1 kg/m)
Min. Flexible Bend Radius	8" (203 mm)	10" (254 mm)	15" (375 mm)
Min. Static Bend Radius	6" (152 mm)	8" (203 mm)	10" (250 mm)
Vacuum Insulation Type	Dynamic Vacuum or Static Vacuum with MLI, Absorbent and Getters		
Protective Outer Covering	SW - Spiral Wrap (Standard) RFB - Regular Flex Braid (Option)		
Material Construction	Stainless Steel Series 300		
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s		
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services		

Typical Poly-Flex Transfer Hose - Single

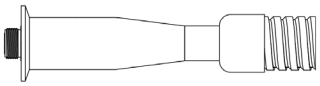




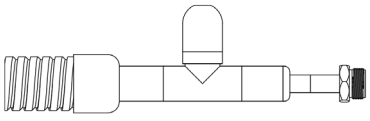
KF40 / KF50 Chamber conn,
Female seal-lok ½" or ¼" HVCR



Cryochiller conn, Female
seal-lok ½" or ¼" HVCR



KF40 / KF50 Chamber conn,
Male seal-lok ½" or ¼" HVCR



Cryochiller conn,
Male seal-lok ½" or ¼" HVCR

He-Flex

for Liquid Helium

Helium transfer hose is used to transfer liquid helium from a storage dewar to a cryostat or any point of usage. The flexibility overcomes misalignment between dewar and equipment, ease the work to connect and disconnect the transfer system.

All hoses comes with static vacuum as standard. Static vacuum hose is vacuum sealed at the factory, providing many years of trouble-free vacuum insulation. Option for dynamic vacuum is available upon request.

All He-Flex products come with CSM renowned customer service, from conceptual design to implementation, and are backed by a 3 year vacuum warranty; 1 year defect warranty

He-Flex is frequently used for Liquid Helium transfer

He-Flex Transfer Hose

He-Flex is a vacuum insulated stainless steel flexible hose designed to meet optimal flow capacity, minimizing heat gain, low cooldown loss, without compromising its flexibility.

He-Flex incorporates low mass bellow and low mass MLI. Moreover, proprietary MLI wrapping process with controlled tensioning enables He-Flex to achieve high performance insulation and lowest cooldown in its class. Engineered as modular section with extra long close-tolerance bayonet or extended withdrawal tube connections. It can be used on its own, or as part of He-Rigid sections for misalignment offset. He-Flex hose is evacuated and sealed at the factory with static vacuum to 10^{-6} mbar.

He-Flex are available in wide variety of sizes from DN18 up to DN25 to meet most standard or custom requirements in liquid helium applications. He-Flex is also available with liquid nitrogen shielding.

CSM offers a complete line of components such as helium valve box, phase separators and gas venting devices to maximize system performance.

He-Flex is used in a wide variety of scientific, medical, and deep-space exploration applications, such as cryostats in NMR spectroscopy, MRI scanners, and superconducting magnets.

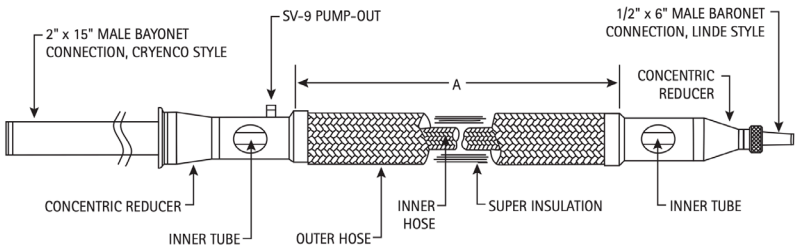
Features and Benefits

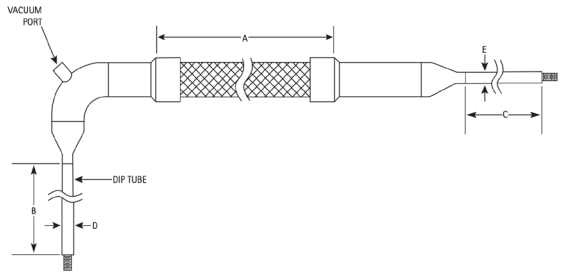
- Superior vacuum insulation eliminates moisture, condensation and frost build-up
- Due to very low heat gain, liquid helium losses is minimized
- Optimal delivery of LHe to equipment improves cycle time of experiments.

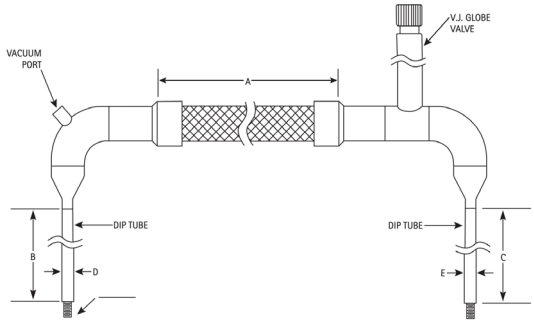
He-Flex Specifications

Model	He-08	He-12	He-16	He-25
Inner Diameter	DN 8 5/16” (8.2 mm)	DN 12 ½” (12.1 mm)	DN 16 ⅝” (16.2 mm)	DN 25 1” (25.1 mm)
Outer Diameter	DN 32 43.0 mm	DN 40 (52.1 mm)	DN 50 (62.8 mm)	DN 65 (81.2 mm)
Steady State Heat Leak	0.8 btu/hr/ft (1.05 watts/m)	1.1 btu/hr/ft (.96 watts/m)	1.4 btu/hr/ft (1.3 watts/m)	2.2 btu/hr/ft (2.1 watts/m)
Bayonet Heat Leak	5.0 btu/hr (1.5 watts)	5.0 btu/hr (1.5 watts)	5.0 btu/hr (1.5 watts)	6.0 btu/hr (1.8 watts)
Max. Operating Pressure	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)	200 psig (13.8 bar)
Weight	0.7 lbs/ft (1.1 kg/m)	1.6 lbs/ft (2.4 kg/m)	1.7 lbs/ft (2.6 kg/m)	2.3 lbs/ft (3.5 kg/m)
Min. Bend Radius (Static)	8” (20 cm)	10” (25 cm)	12” (30 cm)	18” (45 cm)
Vacuum Insulation Type	Static and Dynamic Vacuum; Liquid Nitrogen Heatshield (option)			
Maximum Length	Max. single line length 33’ (10 m)			
Protective Outer Covering	RFB - Regular Flex Braid or Spiral wrapped			
Flow Rate / Pressure Drop	Consult factory			
Material Construction	Stainless Steel Series 300			
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s			
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification			

Typical He-Flex Transfer Hose







Bayonet Connections

Close Tolerance Bayonets

Close tolerance with extreme low heat leak, frost and condensation free vacuum insulated bayonet connections, designed for cryogenic systems down to 4 kelvin.

All Bayonet Connections come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Vacuum Insulated Bayonets

CSM uses a highly efficient cryogenic connection for vacuum insulated piping systems. Constructed in stainless steel, the bayonet connection utilizes an extremely close tolerance design between the male and female bayonet to minimize convective heat transfer. The thin-walled bayonet reduces overall conductive heat transfer compared to other competitive products. This bayonet tube insertion length is increased with better heat barrier to eliminate condensation or frosting at the clamp joints due to high humidity environment. These design features translate to lowest heat leak and preserve liquid cryogen quality.

Typical Applications

- Vacuum Insulated Rigid Lines.
- Vacuum Insulated Flex Lines.
- Vacuum Jacketed Modular Valve or Fitting components.

Modular Static Vacuum Tee

Features and Benefits

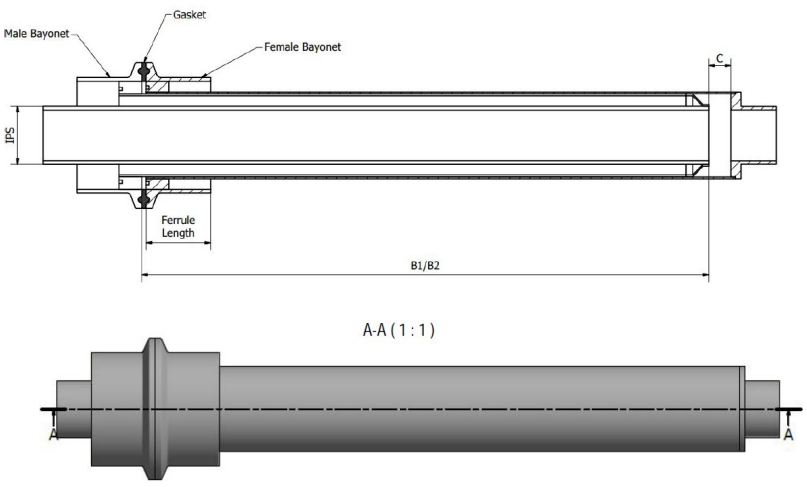
- Frost and condensation free connections
- Minimization of heat leak
- Easy to install or disassemble, both at cold and warm condition
- Compatible with hygienic type clamping system for leak free operation
- Can be installed in any orientation
- Bayonets can be assembled much quicker compared to traditional welding joint, significantly lowering your installation costs

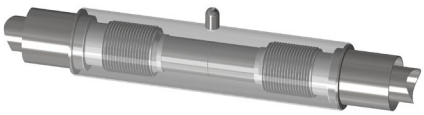
Bayonet Specifications

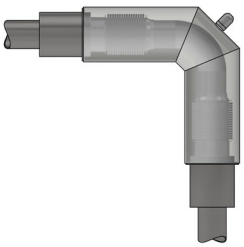
Sizes	Max Design Pressure psi (bar)	Male Weight lbs (kg)	Female Weight lbs (kg)	Bayonet Heat Leak BTU / Hr (W)	Inner & Outer Jacket Pipe Construction
C2	200 (14)	0.09 (0.04)	0.15 (0.07)	6.1 (1.8)	S/S300
C5	200 (14)	0.44 (0.20)	0.46 (0.21)	4.0 (1.2)	S/S300
C10	200 (14)	0.75 (0.34)	0.79 (0.36)	8.1 (2.4)	S/S300
C15	200 (14)	1.12 (0.51)	1.10 (0.50)	7.8 (2.3)	S/S300
B5	200 (14)	0.53 (0.24)	0.49 (0.22)	8.1 (2.4)	S/S300
B10	200 (14)	1.28 (0.58)	1.21 (0.55)	7.8 (2.3)	S/S300
B15	200 (14)	2.18 (0.99)	2.16 (0.98)	9.2 (2.7)	S/S300
B20	200 (14)	2.80 (1.27)	2.65 (1.20)	11.3 (3.3)	S/S300
B30	200 (14)	6.13 (2.78)	5.53 (2.51)	16.7 (4.9)	S/S300

Bayonet Dimensions

Bayonet Type	Bayonet Size	Inner Pipe Diameter	Ferrule size (Clamp F)	Dimensions	
				B1 (Special)	B2 (Standard)
C2	⅜"ODT	⅜", ½" OD (8, 12.7mm)	KF16 / KF25	$4^{3}/_{16}$" (105mm) RIBER $7^{1}/_{16}$" (155mm) Dr. Eberl	-
C5	¾" ODT	¾"OD (19.1mm)	1½" (51mm)	$7^{1}/_{16}$" (180mm)	8-⅝" (220mm)
C10 / B5	1⅛" ODT / ½"PS	1⅛OD (29.0mm) ½"NB (21.3mm)	2" (64mm)	$7^{1}/_{16}$" (180mm) 8-⅝" (220mm)	10-0" (250mm)
C15 / B10	1½"ODT / 1"PS	1½"OD (38.1mm) 1"NB (33.4mm)	2½"(78mm)	9-⅝" (245mm)	$11-^{13}/_{16}$" (300mm)
B15	1½"PS	1½"NB (48.3mm)	3" (91mm)	-	14-0" (363mm)
B20	2"PS	2"NB (60.3mm)	4" (119mm)	-	15¾" (390mm)
B30	3"PS	3"NB (88.9mm)	5" (145mm)	-	15¾" (479.5mm)







Welded Connections

Vacuum insulated welded connections with extreme low heat leak, frost and condensation free, designed for cryogenic systems down to 4 kelvin. Suitable for liquid hydrogen and LNG application

All welded connections come with CSM renowned customer service, from conceptual design to implementation, and are backed by a 10 years warranty

Vacuum Insulated Welded Connections

CSM uses a highly efficient field-welded cryogenic connection for vacuum insulated piping systems. Vacuum insulated welded connection ensures lowest heat leak by providing a continuous vacuum insulation between the spool sections. Constructed in stainless steel, the vacuum insulated welded connections are designed with high-quality long heat path transition to be installed with our standard low profile sleeve tube. These design features translate to lowest heat leak and preserve liquid cryogen quality.

Fully welded connection ensure full working pressure up to 35 Bar and suitable for extreme hazardous working environment like petrochemical complex or ASU plant. Connection insulation can be done either by low heat leaks vacuum insulation or polyurethane foam insulation.

Onboard fuel and bunkering piping system for LNG or liquid hydrogen

Typical Applications

- LNG vacuum insulated rigid lines
- LHy vacuum insulated flex lines
- Applicable for all cryogenic medium with temperature down to 4 Kelvin

Features and Benefits

- Frost and condensation free connections
- Minimization of heat leak
- Easy to install at compact working spaces
- Can be installed in any orientation
- Welded connection ensures high durability & vibration resistant
- Available in Vacuum jacketed or Polyurethane insulation options

Welded Connection Specifications

Sizes	Max Design Pressure psi (bar)	Vacuum Jacketed Heat Leak BTU / Hr (W)	PU Insulated Heat Leak BTU / Hr (W)	Inner & Outer Jacket Pipe Construction
W10	500 (35)	5.46 (1.60)	50.98 (14.95)	S/S300
W15	500 (35)	5.76 (1.69)	60.49 (17.74)	S/S300
W20	500 (35)	9.21 (2.70)	72.05 (21.13)	S/S300
W25	500 (35)	9.34 (2.74)	78.29 (22.96)	S/S300
W30	500 (35)	13.09 (3.84)	90.81 (26.63)	S/S300
W40	500 (35)	18.48 (5.42)	109.87 (32.22)	S/S300

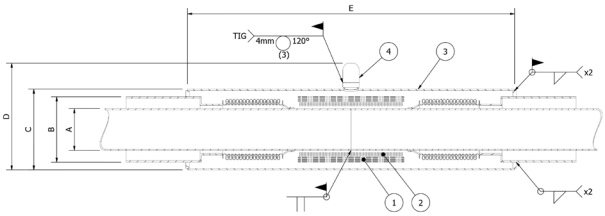
Welded Connection Dimensions

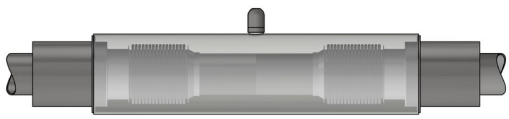
Sizes Mm	Inner Pipe Diameter A	Vacuum Jacket Diameter B	Vacuum Jacket Sleeve Diameter C	Overall Height D	Vacuum Jacket Sleeve Tube Length (Straight) E	Vacuum Jacket Sleeve Length (Elbow) F	Vacuum Jacket Sleeve Horizontal Length (Tee) G	Vacuum Jacket Sleeve Vertical Length (Tee) H
W10	1" NB (33.4mm)	2 ½" NB (73.0mm)	3 ½" NB (101.6mm)	5.8" (146.8mm)	20.5" (520.0mm)	11.8" (300.0mm)	22.8" (580.0mm)	10.6" (270.0mm)
W15	1 ½" NB (48.3mm)	3" NB (88.9mm)	4" NB (114.3mm)	6.3" (159.5mm)	21.3" (540.0mm)	12.2" (310.0mm)	23.2" (590.0mm)	11" (280.0mm)
W20	2" NB (60.3mm)	4" NB (114.3mm)	5" NB (141.3mm)	7.4" (186.5mm)	22" (560.0mm)	12.6" (320.0mm)	24.4" (620.0mm)	11" (280.0mm)
W25	2 ½" NB (73.0mm)	4" NB (114.3mm)	5" NB (141.3mm)	7.4" (186.5mm)	23.6" (600.0mm)	13.4" (340.0mm)	25.2" (640.0mm)	11.8" (300.0mm)
W30	3" NB (88.9mm)	5" NB (141.3mm)	6" NB (169.3mm)	8.4" (213.5mm)	23.6" (600.0mm)	13.4" (340.0mm)	25.2" (640.0mm)	11.8" (300.0mm)
W40	4" NB (114.3mm)	6" NB (168.3mm)	8" NB (219.1mm)	10.5" (264.5mm)	27.6" (700.0mm)	15" (380.0mm)	28.3" (720.0mm)	13.4" (340.0mm)

Welded Connection Material Supply List

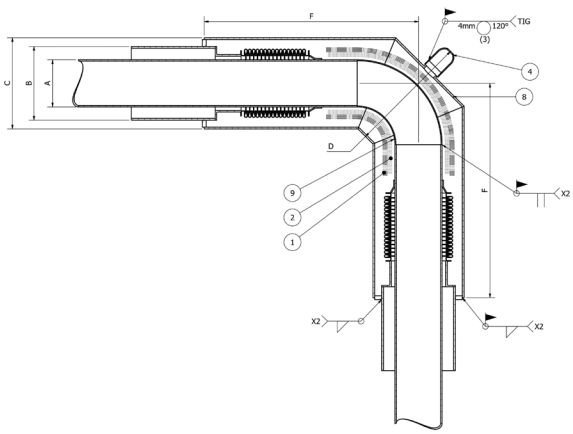
No	Name
1	Multi-Layer Insulation
2	Molecular Sieve
3	Vacuum Jacketed Sleeve Tube (Straight) c/w Vacuum Port
4	Vacuum Port Plug Assembly
5	Vacuum Grease
6	Pump Out Valve Operator
7	Vacuum Jacketed Sleeve Tube w/o Vacuum Port
8	Vacuum Jacketed Sleeve Tube (Elbow) c/w Vacuum Port
9	Process Elbow (Sch 5S)
10	Vacuum Jacketed Sleeve Tube (Tee) c/w Vacuum Port
11	Process Tee (Sch 5S)

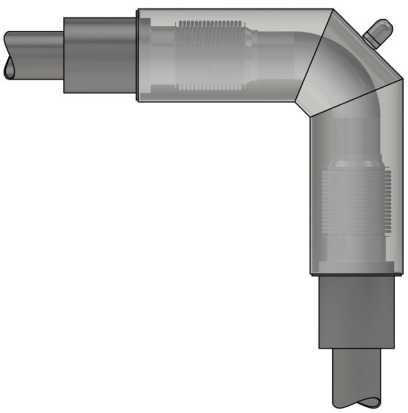
Welded Straight Connection



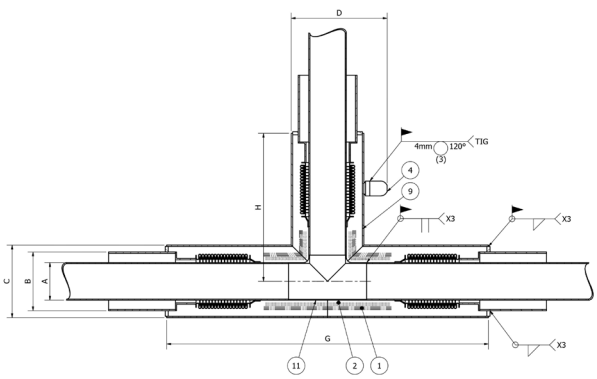


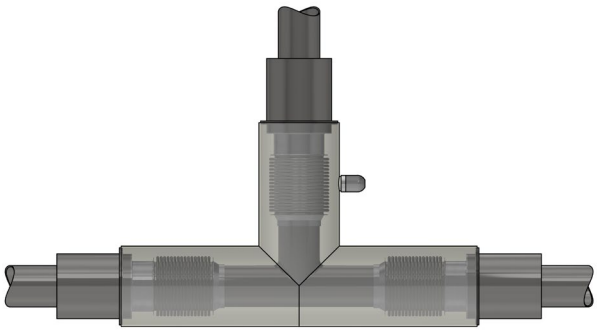
Welded Elbow Connection

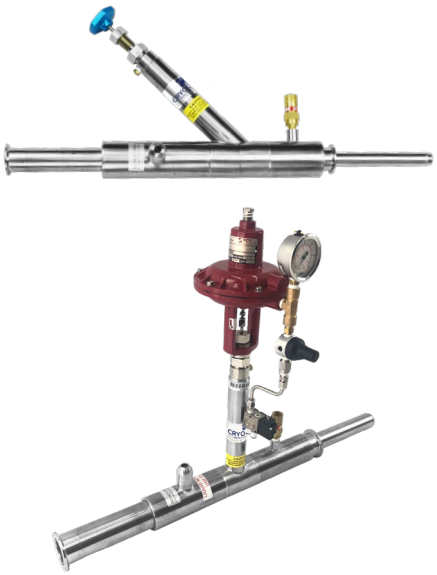




Welded Tee Connection







Modular Valves

Pre-engineered modular valve has added advantage over the traditional rigid VJP, especially when use with Semi-Flex system. This option provide simplicity and cost saving as it reduces the necessity for precise system layout measurements. It also allows the valve to be easily reused if use-point locations and plant layout are changed.

Modular valve facilitate users to design and construct their own LN2 delivery system with minimum piping engineering experience or knowledge.

All Modular Valves come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

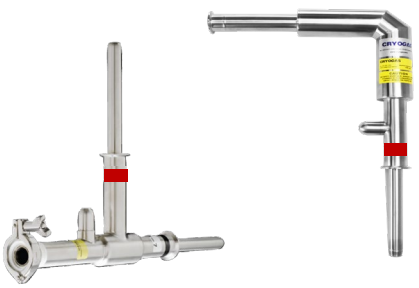
Vacuum Insulated Modular Valves

CSM vacuum insulated valves are recommended when system efficiency and elimination of frost, ice and moisture are essential. The initial cost is greater for the vacuum insulated option, but the savings outweigh the investment in less than a year.

By using a vacuum insulated valve, one can expect a maintenance free operation that does not require frequent replacement of PU foam insulation. Vacuum insulated Modular Valve guarantees extremely low heat leak for minimum liquid boil-off compared to foam-insulated valve by at least 20 times. Thus liquid vaporization loss is reduced and liquid quality is maintained up to the point of use.

Modular valves are commonly used in both Stati-Rigid and Semi-Flex piping systems with Dynamic or Static vacuum technology.

Related Products:



Modular Fittings

Benefits and Features

- Available in T or Y pattern for horizontal or vertical installation
- Pneumatic actuators can be ordered on valves for remote control
- Low operation torque for bubble tight shut-off
- Cryogenic stem packing with live loaded design to compensate thermal contraction & expansion to prevent premature leakage
- Integral bonnet purge thermal relief port to eliminate extra fittings requirement and corresponding leak point
- Plug to stem stabilizer to ensure longer life cycle for the valve seat
- Replaceable KEL-F seat seal for lower maintenance & repair cost on the valve
- Contoured flow plugs available for flow regulation
- 5 years vacuum warranty for static vacuum

Modular Valves Specifications

Model	Valve Size	MAWP	Flow Coefficient CV		Cooldown Mass lbs (kg)		Valve Heat Leak@20 K BTU / Hr (W)	Bayonet Heat Leak BTU / Hr (W)	Valve Construction
			Y-Valve	T-Valve	Y-Valve	T-Valve			
C504	C2	150 psig	N/A	1.1	N/A	0.1 (0.05)	2.4 (0.7)	6.1 (1.8)	S/S300
C204	C5	300 psig	5.7	2.6	0.5 (0.2)	0.7 (0.3)	4.5 (1.4)	4.0 (1.2)	S/S300
C208	C10	300 psig	25	16.3	1.8 (0.8)	3.3 (1.5)	10.4 (3.1)	8.1 (2.4)	S/S300
C212	C15	300 psig	42	31	6.2 (2.8)	9.1 (4.2)	21.8 (6.4)	7.8 (2.3)	S/S300
C216	B20	300 psig	59.4	42.3	10.5 (4.8)	13.5 (6.2)	27.3 (8.0)	11.3 (3.3)	S/S300

Valve Sizing Flow Calculations: *Basic Liquid Flow Formula* $C_v = Q_L\sqrt{\frac{SG}{\Delta P}}$

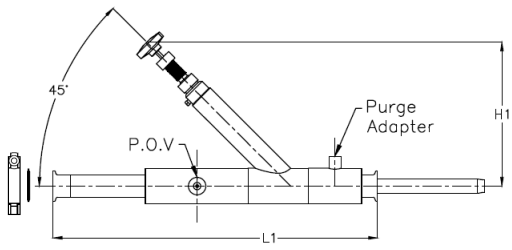
C_v = Flow Coefficient
Q_L = Flow (GPM)
SG = Specific Gravity
ΔP = Pressure Drop (PSIA)

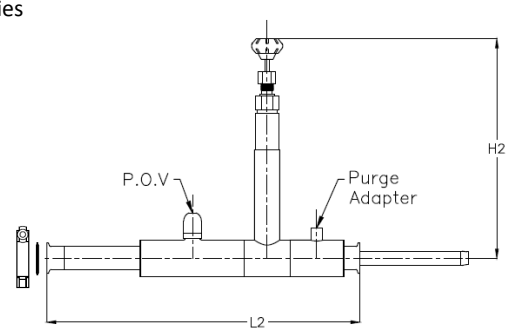
Modular Valves Dimension

Model	Valve Size	Y-Valve		T-Valve	
		H1 valve open	L1	H2 valve open	L2
C504	C2	-	-	8.4” (213mm)	13.8” (350mm)
C204	C5	10.2” (259mm)	21.7” (550mm)	14.4” (365mm)	21.7” (550mm)
C208	C10	13.4” (340mm)	28.1” (713mm)	17.4” (441mm)	29.5” (750mm)
C212	C15	17.2” (437mm)	-	22.5” (572mm)	-
C216	B20	17.2” (437mm)	-	22.5” (572mm)	-

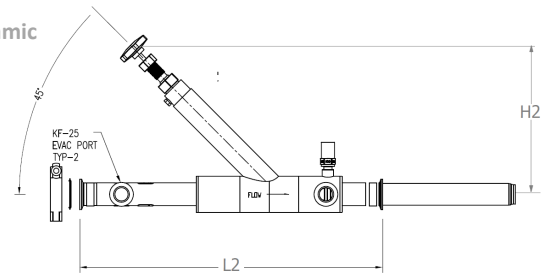
*Other configurations are available please contact us for more inquiries

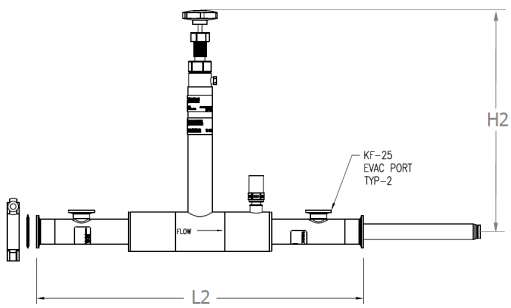
Static





Dynamic





Modular Fittings

Pre-engineered modular fittings has added advantage over the traditional rigid VJP, especially when use with Semi-Flex system. This option provide simplicity and cost saving as it reduces the necessity for precise system layout measurements. It also allows the fitting to be easily reused if use-point locations and plant layout are changed.

Modular fittings facilitate users to design and construct their own LN2 delivery system with minimum piping engineering experience or knowledge.

All Modular Fittings come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Vacuum Insulated Modular Fittings

CSM vacuum insulated fittings are recommended when system efficiency and elimination of frost, ice and moisture are essential. The initial cost is greater for the vacuum insulated option, but the savings outweigh the investment in less than a year.

The vacuum insulated Modular Fitting guarantees extremely low heat leak for minimum gas boil-off compared to foam-insulated fitting by at least 20 times. Thus, not only can liquid loss be reduced but the quality of liquid can be maintained at the same time.

Modular fittings are commonly used in both rigid and flexible types of vacuum jacketed piping systems, whether in Dynamic or Static vacuum technology.

Related Products:

Modular Valve

Features and Benefits

- Readily available in stock for immediate delivery
- Available in Tee, Elbow and other configurations for ease of selection
- Ease of installation, no welding or field cutting required
- Vacuum insulated modular fittings are maintenance free up to 10 years with no performance deterioration over that period
- 5 years vacuum warranty for static vacuum

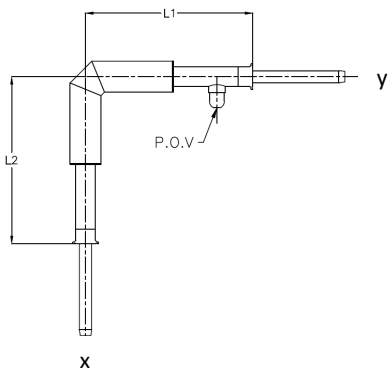
Modular Fitting Specifications

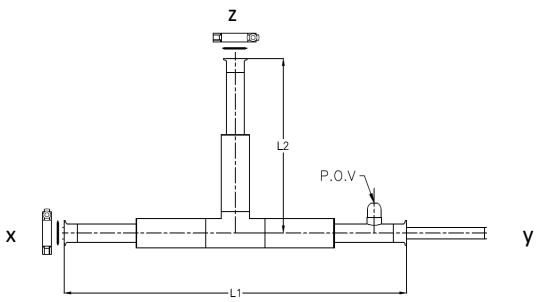
Model	C5	C10
Process Tube	0.75" ODT (19.05 mm OD)	1.125" ODT (29 mm OD)
Jacket Pipe	1.5" IPS (48.3 mm OD)	2.0" IPS (60.3 mm OD)
Steady State Heat Leak	0.32 btu/hr/ft (0.31 watts/m)	0.47 btu/hr/ft (0.45 watts/m)
Bayonet Heat Leak	4.0 btu/hr (1.2 watts)	8.1 btu/hr (2.4 watts)
Max. Operating Pressure	150 psig (10.3 bar)	150 psig (10.3 bar)
Vacuum Insulation Type	Static or Dynamic Vacuum	
Material Construction	Stainless Steel Series 300	
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s	
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services	

Modular Fitting Dimensions

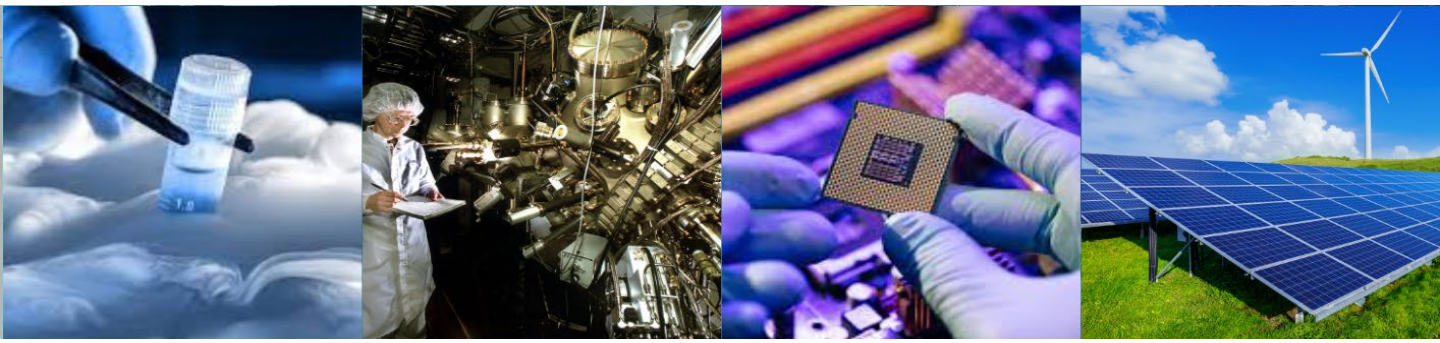
Configuration*		C5		C10	
Item	**x - y**	**L1**	**L2**	**L1**	**L2**
Elbow	F x F	12.8" (326mm)	12.8" (326mm)	13.4" (340mm)	13.4" (340mm)
	F x M	12.8" (326mm)	12.8" (326mm)	13.4" (340mm)	13.4" (340mm)
	M x M	12.8" (326mm)	12.8" (326mm)	13.4" (340mm)	13.4" (340mm)
Item	**x - y - z**	**L1**	**L2**	**L1**	**L2**
Tee	F x F x F	28.8" (732mm)	13.9" (353mm)	30.0" (764mm)	14.0" (355mm)
	F x F x M	28.8" (732mm)	13.9" (353mm)	30.0" (764mm)	14.0" (355mm)
	F x M x F	28.8" (732mm)	13.9" (353mm)	30.0" (764mm)	14.0" (355mm)
	F x M x M	28.8" (732mm)	13.9" (353mm)	30.0" (764mm)	14.0" (355mm)
	M x M x F	28.8" (732mm)	13.9" (353mm)	30.0" (764mm)	14.0" (355mm)
	M x M x M	28.8" (732mm)	13.9" (353mm)	30.0" (764mm)	14.0" (355mm)
	F x F x NPT	28.8" (732mm)	9.8" (250mm)	30.0" (764mm)	9.8" (250mm)
	F x M x NPT	28.8" (732mm)	9.8" (250mm)	30.0" (764mm)	9.8" (250mm)
	M x M x NPT	28.8" (732mm)	9.8" (250mm)	30.0" (764mm)	9.8" (250mm)

*Other configurations are available please contact us for more inquiries





Conditioning Equipment



Phase Separator

Atmospheric Pressure

Stainless steel, over-head horizontal type vacuum jacketed cryogenic conditioning system designed to store LN_2 at atmospheric pressure condition. Once the system has been set up, the liquid Level is controlled automatically by the controller.

Compatible with Triax piping system to transport pure LN2 from the Phase Separator, with no gaseous nitrogen will pass through your equipment

All Phase Separators comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

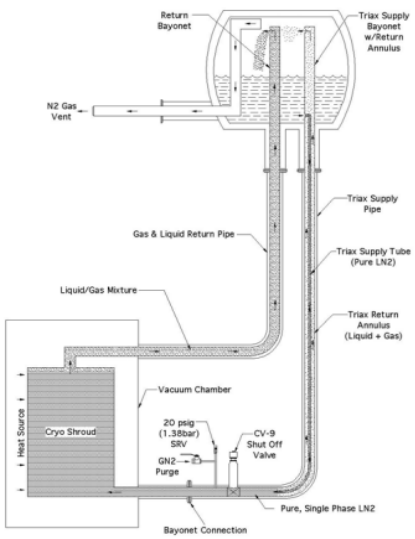
Phase Separator

A CSM atmospheric type of Phase Separator is mainly used in specialized applications that demand extremely high quality, low pressure liquid nitrogen. CSM Phase Separator is a vacuum insulated reservoir holding tank for liquid nitrogen with a differential pressure level control system that operates with a proportional inlet valve.

The Phase Separator is continuously full of liquid nitrogen under atmospheric conditions. Typical applications include direct feed to a LN2 doser or closed Loop liquid nitrogen circulation system typically found in MBE (Molecular Beam Epitaxy) system application.

Liquid nitrogen is fed from bulk storage tank to phase separator by StatiRigid or Semi-Flex piping system.

Phase Separator Closed Loop Application



Features and Benefits

- Differential pressure controls and a proportional inlet valve helps to maintain a constant liquid level at +/- 5%
- Provides a ready supply of vapor free pure liquid nitrogen to critical applications
- Available in 22 and 46 litre operating capacity with bottom outlets from 2 to 12 outlets. Higher capacity for custom application available
- It comes with special designed universal outlet connections, which allow either connections interchangeable with liquid feed Triax pipes or vapor return Triax pipes. This feature improve installation flexibility in a multiple pairs of closed loop piping system

Phase Separator Specifications

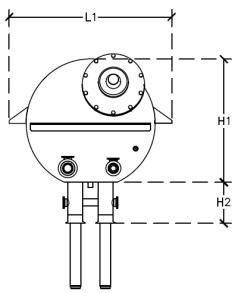
Model	C22.2	C22.4	C22.6	C46.8	C46.10	C46.12
Operating Capacity* Full capacity	6 gal (22L) 10 gal (36L)	6 gal (22L) 10 gal (36L)	6 gal (22L) 10 gal (36L)	12 gal (46L) 20 gal (78L)	12 gal (46L) 20 gal (78L)	12 gal (46L) 20 gal (78L)
Outlets (bottom)	2 (C10)	4 (C10)	6 (C10)	8 (C10)	10 (C10)	12 (C10)
Max. Inlet Pressure Max. Back Pressure	125 psig (9 bar) 22 psig (1.5 bar)	125 psig (9 bar) 22 psig (1.5 bar)	125 psig (9 bar) 22 psig (1.5 bar)	125 psig (9 bar) 22 psig (1.5 bar)	125 psig (9 bar) 22 psig (1.5 bar)	125 psig (9 bar) 22 psig (1.5 bar)
Vessel MAWP	150 psig (10 bar)	150 psig (10 bar)	150 psig (10 bar)	150 psig (10 bar)	150 psig (10 bar)	150 psig (10 bar)
Max. Withdrawal Rate	10 gal/min (38LPM)	10 gal/min (38LPM)	10 gal/min (38LPM)	20 gal/min (76LPM)	20 gal/min (76LPM)	20 gal/min (76LPM)
Weight – Empty	115 lbs (52 kg)	115 lbs (52 kg)	115 lbs (52 kg)	177 lbs (80 kg)	177 lbs (80 kg)	177 lbs (80 kg)
Weight – Full	154 lbs (70 kg)	154 lbs (70 kg)	154 lbs (70 kg)	259 lbs (117 kg)	259 lbs (117 kg)	259 lbs (117 kg)
Vacuum Insulation	Static	Static/Dynamic	Static/Dynamic	Static/Dynamic	Static/Dynamic	Static/Dynamic
Level Control	Differential Pressure with PID valve					
System Utilities	Electricity: 80 – 240 VAC, GN2 @40 psig (2.7 bar)					
Certifications	NEMA 4X, CE					
Materials	Stainless Steel Series 300					
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s					
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., CFOS cleaning for O2 services, X-ray, ASME coded pressure vessels BPVC Section VIII					

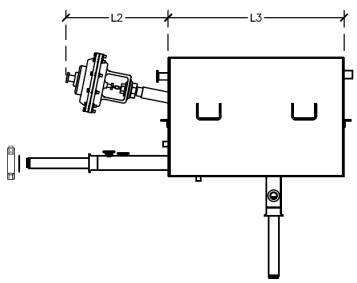
*Factory preset operating capacity, field adjustable by user depend on liquid flow output requirement and in-coming liquid saturation characteristic

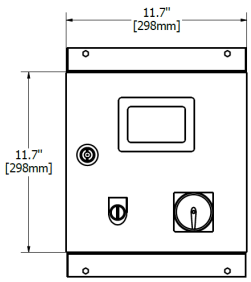
Phase Separator C22/C46 Dimensions

Model	H1	H2	L1	L2	L3
C22	16.4” (417mm)	5.5” (140mm)	21.6” (549mm)	14.2” (361mm)	24.4” (620mm)
C46	16.4” (417mm)	5.5” (140mm)	21.6” (549mm)	14.2” (361mm)	41.7” (1060mm)

C22

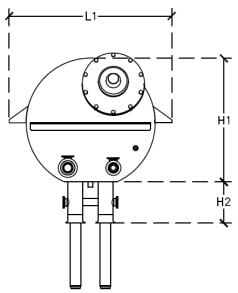


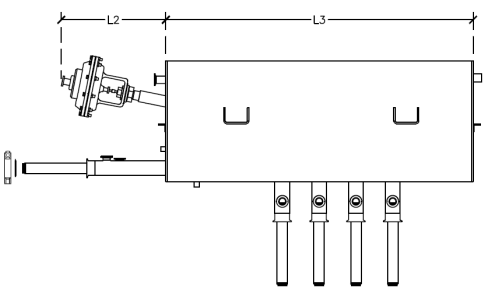




Controller Dimensions

C46





Phase Separator

Pressure Adjustable

Stainless steel, over-head horizontal type vacuum jacketed cryogenic conditioning system designed to store LN_2 at user required pressure setting. Once the system has been set up, the liquid Level and pressure is automatically control by the controller. The controller comes with a HMI to allow user to set their required pressure.

All Phase Separators comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Phase Separator - Pressure Adjustable

Pressure adjustable Phase Separator is used for stepping down the pressure of liquid nitrogen in the pipe line. This is done by venting out excessive vapor while maintaining a constant liquid supply capacity for downstream consumption. The result is a high quality, low pressure liquid nitrogen with precise temperature control at the user's point of use.

CSM Phase Separator is a vacuum insulated reservoir holding tank for liquid nitrogen with a pressure & level control system. The controller will operate its inlet proportional control valves to regulate the liquid level, and another vent proportional valve to regulate the user's required set pressure.

Typical Applications

- Test Handlers in semiconductor IC Assembly and Test
- Environmental Chambers
- Bottling Lines and Packaging
- Food Freezing

Features and Benefits

- Consistent liquid nitrogen delivery, dramatically improving process control and efficiency.
- User friendly operator controls with level & pressure alarm
- Vacuum jacketed vessel for frost-free operation.
- User adjustable output pressure for all models.
- HMI with digital display of liquid level and pressure readings
- Modbus output available

Related Products:

Vent Heater

Phase Separator Specifications

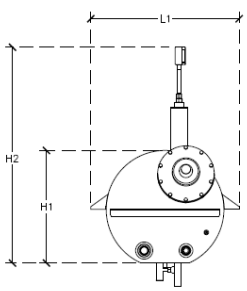
Model	C22P	C48P	C76P
Operational Capacity* / Full capacity	6 gallons (22L) 10 gal (36L)	12.6 gallons (48L) 20 gal (76L)	20 gallons (76L) 32 gal (120L)
Outlets (horizontal)	1 (C10)	2 (C10)	1 (C10 or C15)
Max. Inlet Pressure Max. Back Pressure	130 psig (8.6 bar) 58 psig (4 bar)	145 psig (10 bar) 87 psig (6 bar)	145 psig (10 bar) 87 psig (6 bar)
Vessel MAWP	130 psig (8.6 bar)	145 psig (10 bar)	145 psig (10 bar)
Max. Withdrawal Rate	5 gallons/minute (18LPM)	28 gallons/minute (106LPM)	40 gallons/minute (150LPM)
Weight – Empty – Full	108 lbs (49 kg) 146 lbs (66 kg)	132 lbs (60 kg) 225 lbs (102 kg)	Consult Factory
Level Control Sensor	Capacitance		
Vacuum Insulation	Static Vacuum only		
System Utilities	Electricity: 80 – 240 VAC, GN2 @40 psig (2.7 bar)		
Certifications	NEMA 4X, CE		
Materials	Stainless Steel Series 300		
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s		
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., CFOS cleaning for O2 services, X-ray, ASME coded pressure vessels BPVC Section VIII		

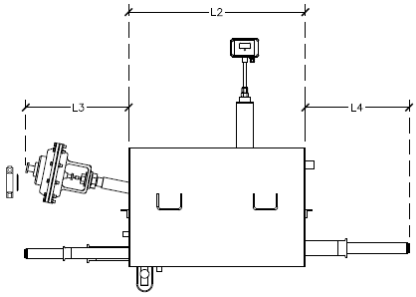
*Factory preset operating capacity, field adjustable by user depend on liquid flow output requirement and in-coming liquid saturation characteristic

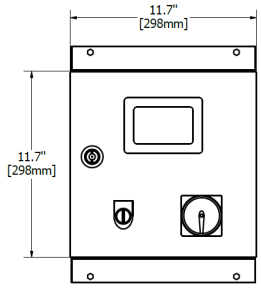
Phase Separator Dimensions

Model	H1	H2	L1	L2	L3	L4
C22	16.4" (417mm)	31.5" (799mm)	21.6" (549mm)	24.4" (620mm)	14.2" (361mm)	14.3" (364mm)
C48	21.7" (550mm)	33.5" (850mm)	25.8" (655mm)	33.9" (860mm)	23.1" (585mm)	14.3" (364mm)
C76	21.7" (550mm)	33.5" (850mm)	25.8" (655mm)	43.3" (1100mm)	29.1" (739mm)	14.3" (364mm)

C22

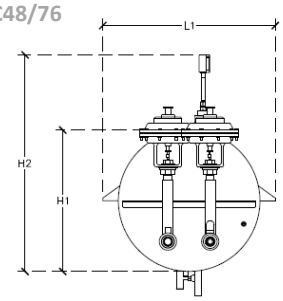


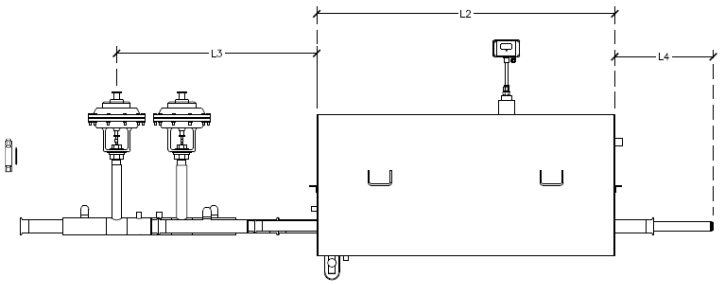




Controller Dimensions

C48/76





Degasser DG8

Degasser

Pipeline

The pipeline degasser removes gas by slowing down the liquid flow velocity, ensuring that the exit liquid supply is pure. It is typically installed either in-line or at the end of the pipeline before connecting to equipment. The degasser is modular and pre-engineered for easy installation and flexible arrangement within a piping system

All Degasser comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Degasser

Due to a constant heat leak and pressure drop between the storage tank and the consumer use points, a portion of the liquid nitrogen in the pipeline will evaporate into gas or vapor. As the liquid passes through the degasser, the gas is removed, ensuring high-quality liquid is delivered to the use points. This is done by mechanically separating the boil-off gas from the liquid.

The degasser is maintenance-free and does not require any field adjustments. Its operation requires no electrical power, sensors, pneumatics, or electronics. The pre-engineered degasser has a capacity of delivering liquid nitrogen flow consumptions up to 200 L/h, with higher capacities available upon request.

Related Products:

Vent Heater

Typical Applications

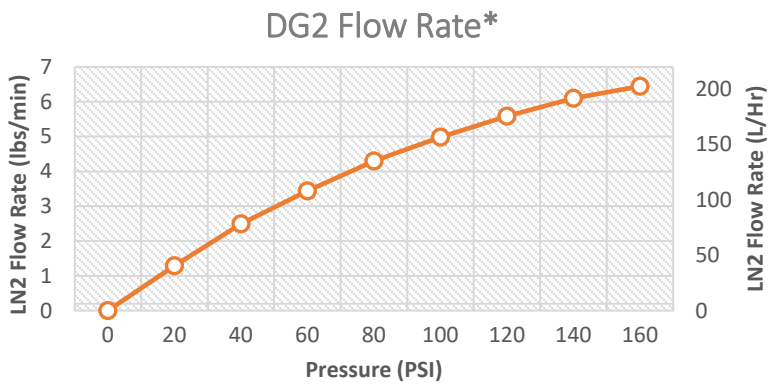
- This product is suitable for cooling down piping without venting gas through the equipment
- It can be used as phase separators in combination with a back-pressure valve when no electric power or pneumatics are available

Features and Benefits

- The degasser is available with either bayonet or pipe threaded termination
- It uses a bayonet connection to facilitate future expansion of the piping system
- The degasser ensures consistent and efficient liquid supply from bulk storage to the end application
- It maintains liquid in the piping system at all times

Pipeline Degasser Specifications

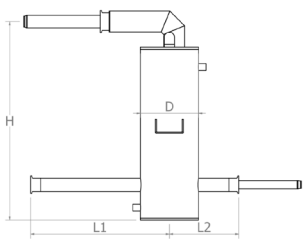
Degasser Model	DG2	DG8	DG22
Vessel Capacity	0.5 gal (2L)	2 gal (8L)	6 gal (22L)
Type	In-line / End of Line	In-line	In-line
Control Principle	Mechanical/Buoyancy Force		
Venting Capacity	1.5 Nm^3/hr Max (Fix Orifice)		
Insulation	Static vacuum with Multi-Layer Insulation		
Cleanliness Level	Cleaned oil and grease-free Oxygen clean on request		
Maximum Operating Pressure	200 psig (13.8 bar)		
Material Construction	Stainless Steel Series 300		
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s		
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services		



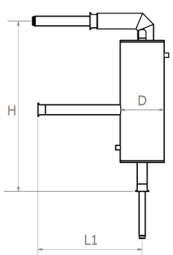
*Depending on liquid supply quality or liquid storage saturated pressure, i.e. gas & liquid mixture ratio. Larger saturation results in lesser liquid flow output

Dimensions

P/N	H	L1	L2	D
DG2-H-C5F/C5M-DD	22.5” (571mm)	15.7” (400mm)	7.9” (200mm)	6.6” (168mm)
DG8-H-C10F/C10M-DD	24.3” (617mm)	21.3” (540mm)	12.2” (310mm)	11.8” (300mm)
DG2-B-C5F/C5M-DD	25.6” (649mm)	15.7” (400mm)	-	6.6” (168mm)



In-line Degasser



End-of-line Degasser

Degasser

Point-of-use

The POU degasser removes gas by slowing down the liquid flow velocity, ensuring that the exit liquid supply is pure. It is typically installed to the dropper before connecting to equipment. The equipment degasser is modular and pre-engineered for easy installation.

All Degasser comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Degasser

Due to a constant heat leak and pressure drop between the storage tank and the consumer use points, a portion of the liquid nitrogen in the pipeline will evaporate into gas or vapor. As the liquid passes through the degasser, the gas is removed, ensuring high-quality liquid is delivered to the use points. This is done by mechanically separating the boil-off gas from the liquid.

The degasser is maintenance-free and does not require any field adjustments. Its operation requires no electrical power, sensors, pneumatics, or electronics. The pre-engineered degasser has a capacity of delivering liquid nitrogen flow consumptions up to 200 L/h, with higher capacities available upon request.

Typical Applications

- This product is suitable for cooling down piping without venting gas through the equipment
- This product can improve the consistency of the cooling mass of LN2, which is essential for stable test handler operations

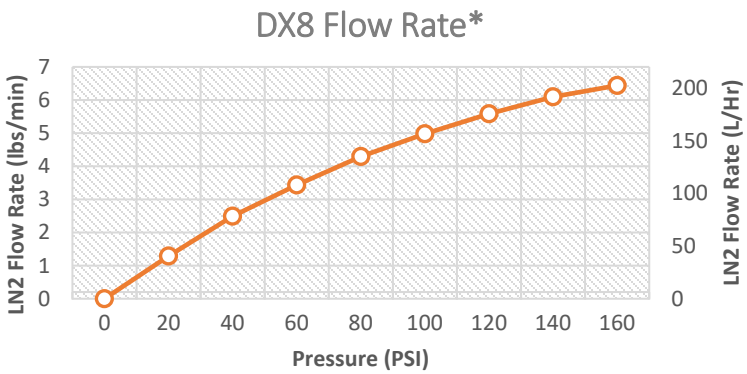
Features and Benefits

- The degasser is available with bayonet connection
- It uses a bayonet connection to reduce heat leaks from further deteriorating the LN2 cooling mass consistency
- The degasser ensures consistent and efficient liquid supply from bulk storage to the end application
- It maintains liquid in the piping system at all times

Installation Method

POU Degasser Specifications

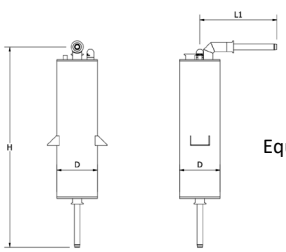
Degasser Model	DX2	DX8
Vessel Capacity	0.6 gal (2L)	2.2 gal (8L)
Liquid Outlets	1	1 or 2
Control Principle	Mechanical/Buoyancy	
Venting Capacity	1.5 Nm^3/hr (Theoretical Max)	
Orifice Size	Fixed Orifice	
Insulation	Static vacuum with Multi-Layer Insulation	
Cleanliness Level	Cleaned oil and grease-free Oxygen clean on request	
Maximum Operating Pressure	200 psig (13.8 bar)	
Material Construction	Stainless Steel Series 300	
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s	
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services	



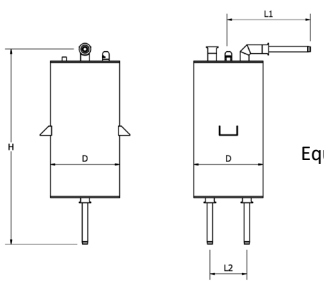
*Depending on liquid supply quality or liquid storage saturated pressure, i.e. gas & liquid mixture ratio. Larger saturation results in lesser liquid flow output

Dimensions

P/N	H	L1	L2	D
DX2	33.5” (850mm)	12.6” (320mm)	-	6.6” (168mm)
DX8	33.5” (850mm)	14.2” (360mm)	6.3” (160mm)	11.8” (300mm)



DX2
Equipment Degasser



DX8
Equipment Degasser

CryoVent

Mechanical

The Cryovent is designed to remove excess vapor from cryogenic piping systems when the liquid stops flowing, ensuring that your cryogenic system is always filled with liquid. It is modular and pre-engineered for easy installation and flexible arrangement in any piping system.

All Cryovents come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Cryovent

The cryovent is installed to enhance the liquid delivery performance of a piping system. Under normal operational circumstances, the liquid in the system is constantly vaporizing into gaseous nitrogen due to a constant heat leak. If the accumulated gas in the pipeline is not removed, it will block the liquid flow to the use points. The Cryovent plays an important role in removing the gas from the pipeline by automatically venting it to the atmosphere.

The Cryovent uses a mechanical (buoyancy) control principle. It allows only gas/vapor to vent while retaining the liquid medium in the pipeline. This ensures that quality liquid is readily available at all times in the pipeline, improving the liquid delivery efficiency. The Cryovent is maintenance-free and requires no field adjustments. Its operation requires no electrical power, sensors, pneumatics, or electronics.

Related Products:

Vent Heater

Typical Applications

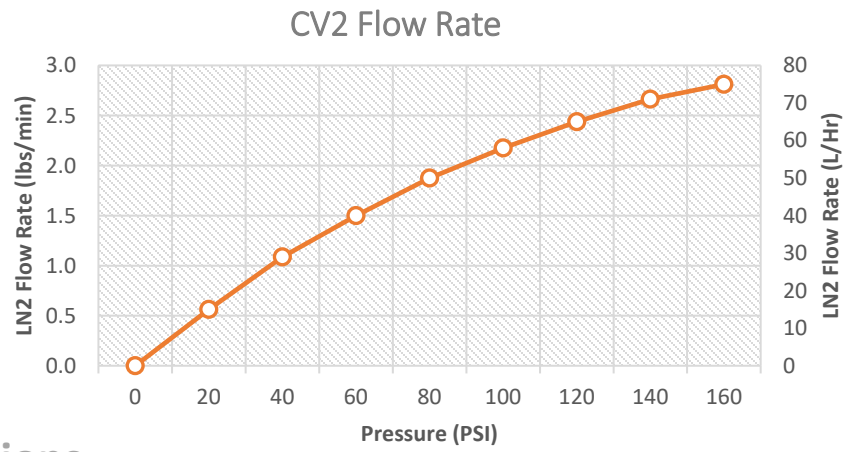
- This device functions as both a gas venting and pre-cooling device in a vacuum-jacketed piping system
- It is suitable for use with inert gases such as liquid nitrogen and argon. Optional CFOS cleaning is available for oxygen service

Features and Benefits

- The cryovent is available with either bayonet or pipe threaded termination
- It uses a bayonet connection to facilitate future expansion of the piping system
- The cryovent ensures consistent and efficient liquid supply from bulk storage to the end application
- It maintains the liquid level in the piping system at all times

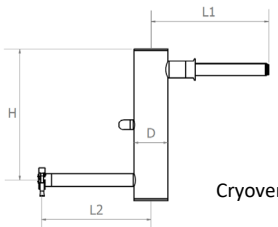
Cryovent Specifications

Cryovent Model	CV2	CV10
Capacity	0.6 gal (2L)	2.6gal (10L)
Control Principle	Mechanical/Buoyancy	
Venting Capacity	1.5 Nm^3/hr (Theoretical Max)	
Orifice Size	Fixed Orifice	
Insulation	Static vacuum with Multi-Layer Insulation; or Dynamic vacuum	
Cleanliness Level	Cleaned oil and grease-free Oxygen clean on request	
Maximum Operating Pressure MAWP	200 psig (13.8 bar)	
Material Construction	Stainless Steel Series 300	
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s	
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services	

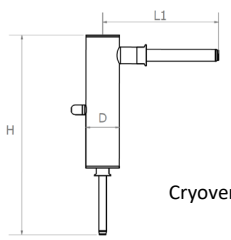


Dimensions

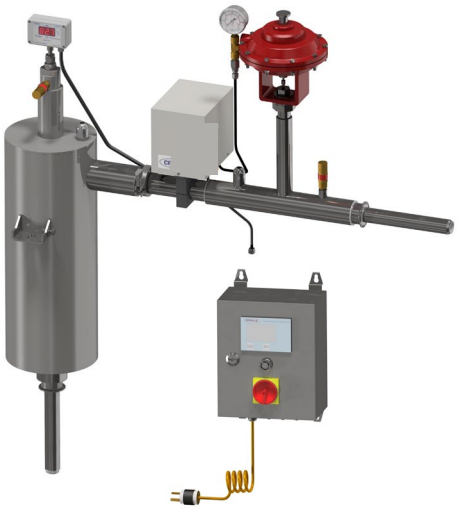
Model	H	L1	L2	D
CV2-H-C5F	18.1” (460.1mm)	11.9” (302mm)	12.8” (326mm)	4.0” (102mm)
CV2-H-C10F	16.9” (429.5mm)	11.9” (302mm)	12.6” (320mm)	4.0” (102mm)
CV2-B-C5M	24.2” (614mm)	11.9” (302mm)	-	4.0” (102mm)
CV2-B-C10M	25.7” (654mm)	11.9” (302mm)	-	4.0” (102mm)
CV10-H-C10F	22.3” (565mm)	16.5” (420mm)	20.2” (513mm)	12.0” (300mm)



Cryovent, Horizontal



Cryovent, Vertical



CryoVent

Electronic

The Electronic Cryovent is a high-capacity keepful device designed to remove excess vapor from cryogenic piping systems when the liquid stops flowing, ensuring that your cryogenic system is always filled with liquid. It is modular and pre-engineered for easy installation and flexible arrangement in any piping system.

All Cryovents come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Cryovent

The Electronic Cryovent is installed to enhance the liquid delivery performance of a piping system. Under normal operational circumstances, the liquid in the system is constantly vaporizing into gaseous nitrogen due to a constant heat leak. If the accumulated gas in the pipeline is not removed, it will block the liquid flow to the use points. The Electronic Cryovent plays an important role in removing the gas from the pipeline by automatically venting it to the atmosphere.

The Electronic Cryovent uses an electronic (Liquid Level) control principle. It allows only gas/vapor to vent while retaining the liquid medium in the pipeline. This ensures that quality liquid is readily available at all times in the pipeline, improving the liquid delivery efficiency. The Electronic Cryovent is maintenance-free and requires no field adjustments.

Typical Applications

- This device functions as both a gas venting and pre-cooling device in a vacuum-jacketed piping system
- It is suitable for use with inert gases such as liquid nitrogen and argon. Optional CFOS cleaning is available for oxygen service

Features and Benefits

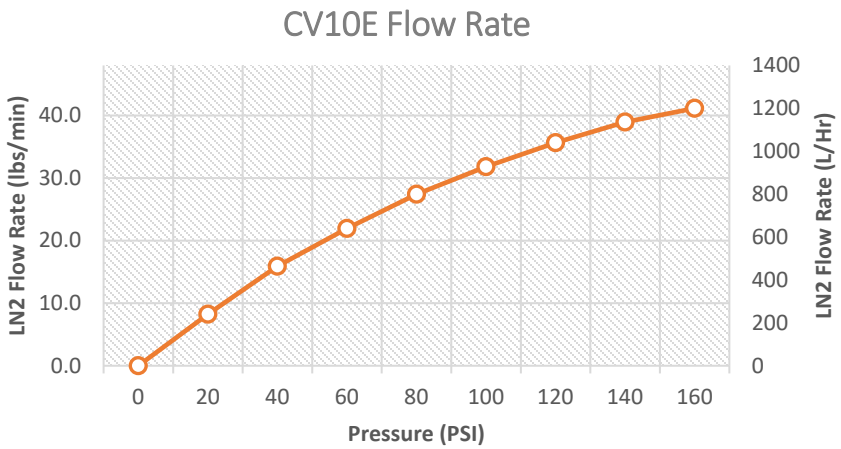
- The cryovent is available with either bayonet or pipe threaded termination
- It uses a bayonet connection to facilitate future expansion of the piping system
- The cryovent ensures consistent and efficient liquid supply from bulk storage to the end application
- It maintains the liquid level in the piping system at all times

Related Products:

Vent Heater

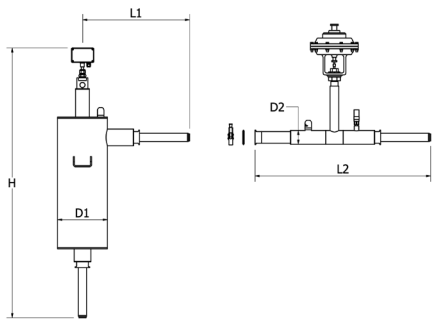
Electronic Cryovent Specifications

Cryovent Model	CV10E
Capacity	2.7 gal (10L)
Control Principle	Electronic/Liquid Level
Venting Capacity	150 Nm^3/hr (Theoretical Max)
Orifice Size	Variable Orifice
Insulation	Static vacuum with Multi-Layer Insulation; or Dynamic vacuum
Cleanliness Level	Cleaned oil and grease-free Oxygen clean on request
Maximum Operating Pressure MAWP	200 psig (13.8 bar)
Material Construction	Stainless Steel Series 300
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services



Dimensions

Model	H	L1	L2	D1	D2
CV10E-B-C10M	46.6" (1183mm)	18.4" (469mm)	30.3" (770mm)	8.6" (219mm)	2.3" (60mm)



Electronic Cryovent

VHA

Vent Heater

Vent-Heater is use for outdoor venting or indoor vent line termination in a large enclosed area with proper air exchange.

Provides ice-free termination, minimizing safety hazards such as falling ice, water drips, large ice accumulation, and roof damage. The protective outer mesh shields personnel from the high-temperature heater located inside

Vent Heater

Cryovent exhaust heater is designed to fit on the bayonet outlet of a CSM Cryovent and Phase Separator where the cold discharge gas needs to be warmed prior to venting. Typically used to eliminate long-distance vent lines, the need for insulation or venting into exhaust ducts.
When liquid in the piping system is constantly vaporizing, the vapor exiting the venting device outlet may cause condensation and eventually, frosting. This can be prevented by using a vent heater to provide a heated pathway for the cryogenic vapor exiting the vent outlet, as cold nitrogen vapor is warmed to halt the creation of ice and condensation. This creates a safe environment while minimizing potential pipe strain associated with a non-heated Cryovent.

All Vent Heaters come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Typical Applications

- Vent outlet for Cryovent and Degasser
- Vent outlet at Phase Separators
- End of venting pipe line

Features and Benefits

- Can be installed on the bayonet connection outlet of any liquid nitrogen keepful device
- Eliminates ice formation on vent piping
- Eliminates the need for foam insulation on vent piping
- Eliminates the need for a large free space for vent piping
- Provides ice-free termination, minimizing safety hazards such as falling ice, water drips, large ice accumulation, and roof damage
- The protective outer mesh shields personnel from the high-temperature heater located inside

Related Products:

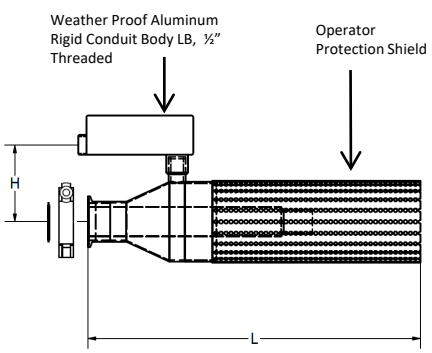
VH10A

Vent Heater Specifications

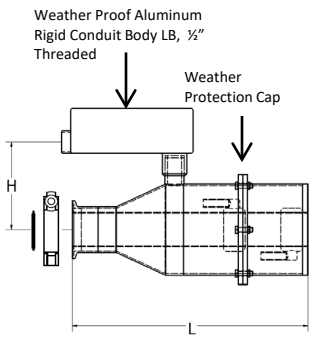
Vent heater Model	VH	VH10A
Material Construction	Stainless Steel Series 300	Aluminium
Application	Indoor / Outdoor	Indoor
Power	150Watt – 450Watt (subject to customer application)	20 W
Voltage/ Amp	24VDC / 110 VAC / 220 VAC (customer to define upon order)	24VDC
Power Connection	Standard Aluminum Rigid Conduit Body LB, ½" Threaded	M12
Standard Testing	Dimensional Check Heater functional test	

Vent Heater Dimensions

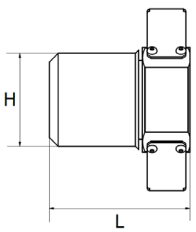
P/N	Application	H	L
VH10A-24DC	Indoor	2.1" (53mm)	3.1"(80mm)
VHA-C5F	Indoor	3.0" (80mm)	10.0" (250mm)
VHA-C10F	Indoor	3.9" (100mm)	15.0" (380mm)
VHA-C15F	Indoor	5.0" (127mm)	15.0" (380mm)
VHB-C5F	Outdoor	3.0" (80mm)	10.0" (250mm)
VHB-C10F	Outdoor	3.9" (100mm)	11.3" (286mm)
VHB-C15F	Outdoor	5.0" (127mm)	15.0" (380mm)



VHA series, 120/220VAC
Indoor

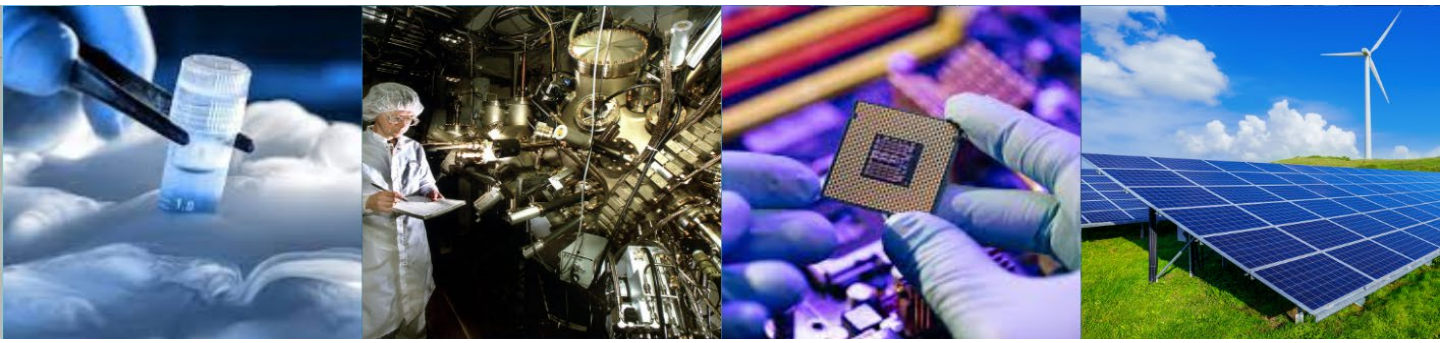


VHB series120/220VAC
Outdoor



VH10A, 24 VDC
Indoor

Accessories



Automated or Manual Changeover System

Dewar Changeover®

Pre-engineered, valve manifold station, easily expandable when the LGC demand increases. Vacuum insulated with lowest heat leak and lower liquid nitrogen losses compared to traditional foam insulated LGC manifold station. Also, its highest safety feature prevents operator from cold burns.

All Dewar Changeover System come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

How it Works

Uninterrupted liquid nitrogen supply with LGC is achievable with a dewar changeover system. The station consist of two sides, one active supply and one standby. When the active supply is depleted, the operator only need to manually switch over the supply to the standby tank. Automatic changeovers are available as option for unattended operation.

This dewar changeover system comes with necessary instruments to monitor liquid nitrogen pressure and level in the cylinder. This allows operator to verify the liquid nitrogen volume to avoid premature changeout and wastage.

CSM dewar changeover system is fully vacuum insulated, guarantees extremely low heat leak compared to foam-insulated station – at least 20 times reduction in liquid boil-off. This ensures consistent liquid supply quality to point-of-use. Lower boil-off translates to savings in LN2 consumption, equivalent to at least 6 months period of equipment capital payback.

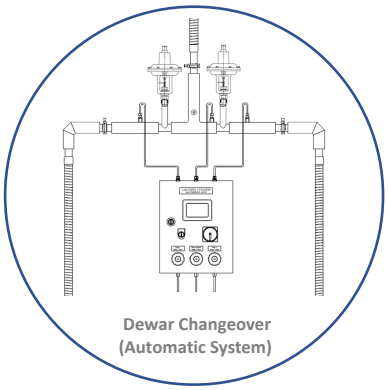
Typical Applications

- Liquid withdrawal applications using LGC, especially uninterrupted liquid supply is paramount to production need
- Suitable for of LIN, LAR or LOX

Features and Benefits

- Minimal liquid supply downtime for higher productivity
- Available in 1x1, 2x2, 4x4 liquid cylinder configurations
- Frost-free and condensation free operation with vacuum insulation system.
- Prevent premature liquid cylinder changeouts through proper monitoring
- Compact size enables ease of installation in limited spaces

Related Products:

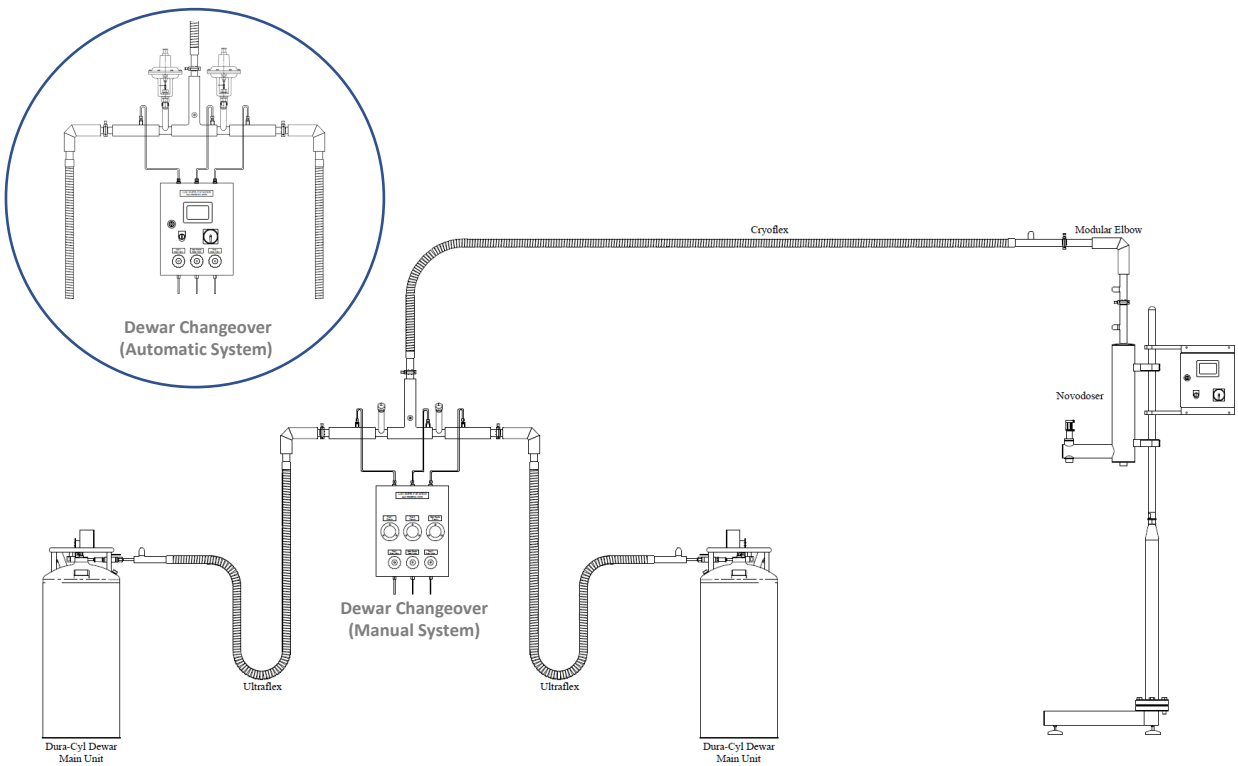


Dewar Changeover (Automatic System)

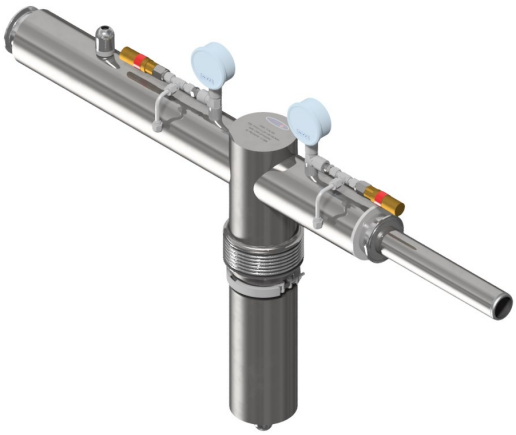
Dewar Changeover System® Specifications

Model	DC5	DC10
Inner Diameter	0.75” ODT (19.05 mm OD)	1.125” ODT (29 mm OD)
Outer Diameter	1.5” IPS (48.3 mm OD)	2.0” IPS (60.3 mm OD)
Steady State Heat Loss	1 btu/hr/ft (.96 watts/m)	2 btu/hr/ft (1.9 watts/m)
Bayonet Heat Loss	6.5 btu/hour (1.9 watts)	12 btu/hour (3.5 watts)
VJ Valve Heat Loss @20 K	2.4 btu/hour (0.7 watts)	4.5 btu/hour (1.4 watts)
Vacuum Insulation Type	Static Vacuum with MLI, Absorbent and Getters	
Maximum Operating Pressure	150 psig (10 bar)	
Material Construction	Stainless Steel Series 300	
Changeover Control Type	Manual or Automatic	
Monitoring System	Analog Gauge (Manual System) or Alarm Switch (Automatic System)	
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s	
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services	

Typical Dewar Changeover System® for LN2 Supply



Modular T-Filter®



Pre-engineered Modular T-filter, to filter incoming liquid nitrogen for pure liquid supply. Vacuum insulated with lowest heat leak and lower liquid nitrogen losses compared to traditional non-vacuum insulated Y-filter. Also, it has high safety feature to prevent operator from cold burns.

How it Works

Modular T-filter is available with bayonet connection and is easily integrated into existing vacuum jacketed piping system effortlessly.

T-filter is also available in a switch-over station (S.O.S) for uninterrupted liquid nitrogen supply during filter maintenance or element change-out. The S.O.S consist of two T-filter, one active and one standby. When the filter in active use is due for service, the operator can manually switch over the liquid flow to the standby filter.

This T-filter station is available in automatic switch-over function using pressure differential instruments to monitor the filter element working condition. A differential pressure more than 1.5 bar indicates a filter element blockage and needs cleaning or replacement. The fully vacuum insulated design guarantees low heat leak compared to foam-insulated type with 30 times lesser liquid boil-off. Besides ensuring better liquid flow and quality, it also helps to save LN2 losses, equivalent to less than 3 months of capital payback.

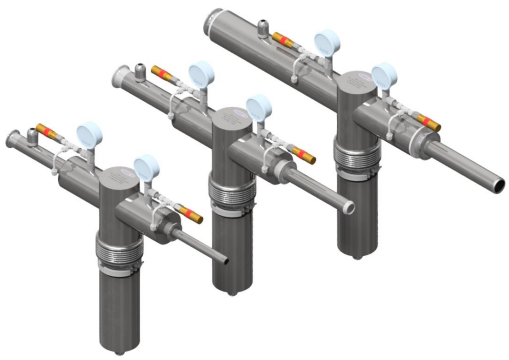
All Cryogenic T-Filter come with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Typical Applications

- To remove particle or debris from liquid stream that may pose problems to downstream piping, valves, instrumentation and production process.
- Suitable for of LIN, LAR or LOX

Features and Benefits

- Easy to replace filter element. There is no foam insulation to break & re-foam
- Installation is quick and easy. No costly on-site foam insulation work is needed
- Saving of liquid nitrogen usage between 300kg to 500kg per day, thanks to its vacuum jacketed feature compared to traditional non-vacuum insulated Y-filter
- Frost-free and condensation free operation, suitable for cleanroom & HACCP work area
- Requires less footprint due to top entry filter element design

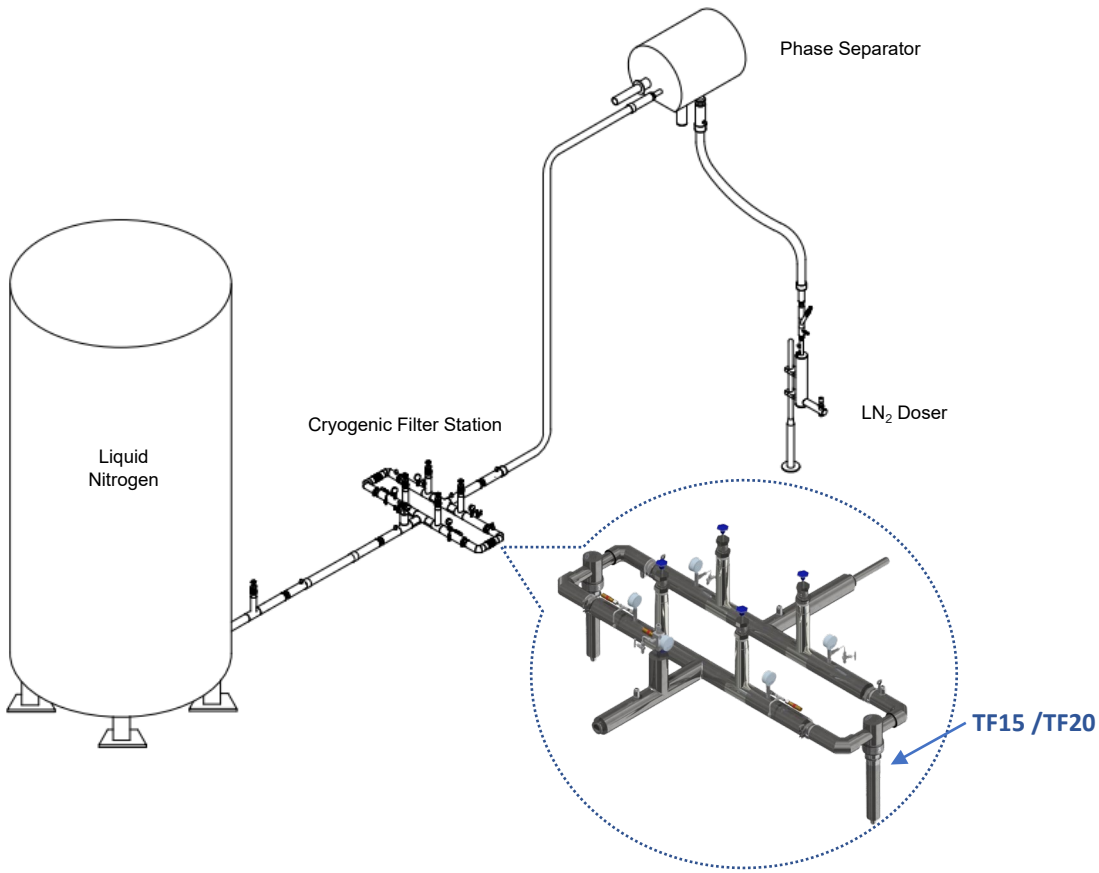


Cryogenic T-Filter - Available Connection Types

Modular T-Filter® Specifications

Model	TF10	TF15	TF20
Pipe size	½", 1"	1.5"	2"
Pore size, micrometre (um)	10um, 40um, 100um		
Filter Element Material Grade	SS316L (1.4404)		
Max Flow Capacity	1600LPH	3200LPH	4500LPH
Connection size	Bayonet C5, C10	Bayonet C15, B15, W15	Bayonet B20, W20
Steady State Heat Loss	2 btu/hr/ft (1.8 watts)	4 btu/hr/ft (3.8 watts)	8 btu/hr/ft (7.2 watts)
Vacuum Insulation Type	Static Vacuum with MLI, Absorbent and Getters; Dynamic Vacuum as option		
Maximum Operating Pressure	150 psig (10 bar)		
Housing Material	Stainless Steel Series 300		
Switch Over	Manual or Automatic Control		
Monitoring System	Analog Gauge (Manual System) or Alarm Switch (Automatic System)		
Standard Testing	Dimensional Check He leak checked 1 x 1 0 - 9 cc/s		
Optional	Pneumatic pressure test, Vacuum retention testing, LN2 cold shock, pre-material certs., X-ray, ASME B31.3 certification, CFOS cleaning for O2 services		

Typical Cryogenic Switch-Over Filter Station® for LN2 Supply



ADF10 Dewar Auto-Filling®

Dewar Auto-Filling System

Pre-engineered Dewar Auto-Filling System is to allow unattended filling of LN2 dewar. The system comes with all the necessary safety features to prevent liquid nitrogen safety hazard like asphyxiation and cold burn, normally associated with manual filling process.

How it Works

CSM Dewar Automatic Fast Filling System ADF10 Model comes with automatic control to allow unattended filling of liquid cylinders. This is an extremely fast filling system in the market today.

It operates by two high pressure & high flow cryogenic solenoid valve for liquid supply & vapor venting. A thermistor sensor is used to detect liquid nitrogen overflow to prompt an superfast automatic shut-off the moment liquid cylinder is full. Built in post-filling pressure venting.

Beside thermistor signal Input, ADF10 could also receive optional signal from other instruments such as weighing scale, oxygen level monitoring sensor, emergency over-ride signal to shut-off the LN2 flow.

The ADF10 comes with 2 lengths of flexible hoses for easy connection between the ADF and dewar. If there is any leakage detected due to poor fitting connection between the hose and dewar, the ADF will not start the filling process.

Option is available for premium quality vacuum insulated hose to minimize heat leak and avoid cold burn incidence to the operator.

Dewar Auto-Filling System comes with CSM renowned customer service, from conceptual design to implementation, and are backed by a one year warranty

Typical Applications

- Unattended dewar filling of cryogenic fluids
- Suitable for LIN and LAR

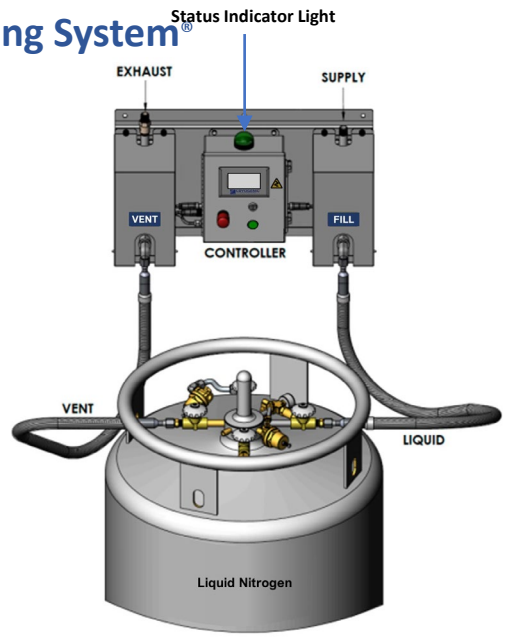
Features and Benefits

- Accurate cryogenic sensing for faster, safer, and reliable fill sensing technology to automatically shut off the fill cycle.
- Easy, single button operation for convenient filling operation.
- Vent safety interlock ensure filling & vent lines are properly installed before system starts filling
- Higher filling output and higher operation safety
- Compact size enables ease of installation in limited spaces

Dewar Auto-Filling® Specifications

Model	ADF10
Min / Max Operating Pressure	22-300 psig (1.5 – 20.0 bar)
Max Filling Time	10 LPM (Less than 20 min for 160L dewar)
Solenoid Valve, Size (Cv)	½" (3.5)
Safety Shut down Signal input 1	Liquid Nitrogen Overflow
Safety Shut down Signal input 2	Pipe connection leakage detection
Safety Shut down Signal input 3	Emergency shut down override button
Safety Shut down Signal input 4	Oxygen level monitoring sensor
Alarm dry output, 24VDC	2 nos
Case Material Construction	Stainless Steel Series 304L
Electrical Enclosure	Weather Tight
Filling Control Type	Automatic, Weight, and timer Post-fill Pressure Venting
Utilities	Electrical 110 ~230VAC, Single Phase
Dimension (mm)	381(H) x 660(L) x 254(D)
Weight (kg)	25
Standard Testing	Pressure Leak Test 10 Bar
Optional	LN2 functional test Vacuum insulated flexible hose

Typical Dewar Filling System®



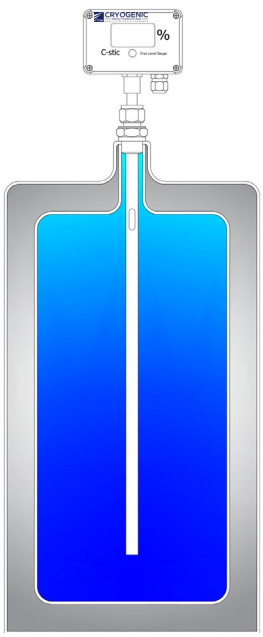
Cryo-Stic

Cryo-Stic is used as a direct replacement for mechanical float gauges. Provides continuous and accurate measurement than mechanical or pressure devices within +/-1% (over full scale). The thermal barrier helps prevent influence of cold temperatures on electronics.

Cryo-Stic

The C-Stic is a very robust level meter specially for storage of liquified gases, like nitrogen, oxygen, argon, carbon dioxide and nitrous oxide. It provides an easy to mount, accurate and reliable liquid level digital reading. Cryo-Stic measures the capacitance of the sensor. i.e dielectric properties of the liquified gas between two stainless steel electrodes. These electrodes produces signal to sensor head, which in turn converts level signal to digital data. Level data is communicated to a gauge mounted directly on sensor, or remotely attached via cable. Designs also available for LNG, cryofreezer, LPG. Also, containers can be transported without gauge in place. This reduces chances of damage which prolongs life of product.

All Cryo-Stics come with CSM renowned customer service, from conceptual design to implementation



Typical Applications

- For cryogenic liquid storage tanks
- For liquid petroleum gas
- Cryofreezer

Features and Benefits

- Accurate measurements improves overall system efficiency.
- Higher flexibility than a thermal device, enables continuous measurement of liquid level
- Remote monitoring options for data acquisition
- No moving parts enhances reliability and durability, thus preventing unnecessary damage to Cryo-Stic device.
- Flexible gauge mounting options, can be mounted directly on sensor or remotely attached via cable.

Cryo-Stic Specifications

Cryo-Stic Model	CLG-2
Material Construction	Aluminium Enclosure
Components	Level Gauge
Display	3-digit LCD (in % full)
Power	2 x AA type battery or external 24 VDC
Voltage/ Amp	4 – 20mA / 0 – 5V output
Power Connection	9 pin connector
Communication	Continuous Reading Optical and Acoustic Alarms LED Status Indicators
Gauge Temperature	Operating gauge: -20 to 60 Deg. Celsius
Mounting	Directly on sensor or wall mount by cable
Standard Testing	Functional Test

Cryo-Stic Application

All Cryogenic components come with CSM renowned after sales service, from maintenance, repair and warranty support. Backed by Just-In-Time local stock and a one year manufacturer warranty

Cryogenic Components

Besides vacuum jacketed products, we stock & supply extensive non-vacuum jacketed cryogenic fluid components to support your cryogenic system need. Every item in our stock has been preselected and validated through years of usage, experience and knowledge in Cryogenic system. This will save you time, money and associated safety hazard in doing your own test & evaluation.

Pressure Regulator: There are two types of pressure regulators commonly used in cryogenic application, pressure reducing or back pressure control.

Pressure reducing regulator is suitable for use at point of use to reduce liquid nitrogen supply pressure to the desired inlet pressure of equipment or tool. It is often needed in a piping system with multiple point of use and with different supply pressure requirement. it provides the users with flexibility to set the required usage pressure.

Back pressure regulator is often used together with pressure reducing regulator to control the pressure build-up in a cryogenic system due to heat leaks by regulating the venting pressure.

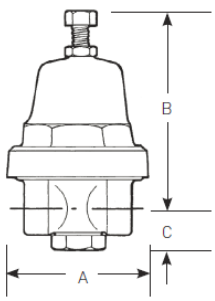
Thermal Relief Valves: Critical component to prevent over pressure due to system heat leak. Liquid nitrogen will vaporized and expand 700X in volume due to heat leaks into the system. Over pressurization hazard is eliminated with strategic use of TRV, especially at locations where LN2 could potentially trapped due to the system operation. It is usually set at a pressure higher than the typical line operating pressure but lower than the line maximum allowable pressure (MAWP).

Valves: CSM stocks a variety of cryogenic valves. To qualify its usage in a Cryogenic system, the valves design and material of construction must fulfill requirement for low temperature, thermal compensation in expansion & contraction, thermal-relief and operator safety. Example valves we stock are ball valve with downstream vent hole, check valve, globe valve, solenoid valve.

Cryogenic Regulators

Model		Max. Inlet Pressure	Outlet Pressure Range	Size (inch)	Maximum Capacity
A-32 Bronze		600 psig (41.4 bar)	2 – 600 psig (0.1 – 41.4 bar)	¼" – ⅜"	2027 SCFH (54 Nm^3h)
A-36 Brass		600 psig (41.4 bar)	10 – 400 psig (0.7 – 27.6 bar)	⅜"	2027 SCFH (54 Nm^3h)
B Bronze		720 psig (49.6 bar)	5 – 250 psig (0.3 – 17.2 bar)	¼" –2"	282 – 341940 SCFH (8 – 9164 Nm^3h)

Model	Size" (mm)	Dimensions		
		A" (mm)	B" (mm)	C" (mm)
A32	¼"(8)	2 ¼" (57.15)	3 $^3/_{16}$" (80.96)	⅝" (15.88)
A32	⅜" (10)	2 ¼" (57.15)	3 $^3/_{16}$" (80.96)	⅝" (15.88)
A36	⅜" (10)	2 $^7/_{16}$" (61.91)	4 ½" (114.30)	1" (25.40)
B	⅜" (10)	3 ⅞" (98.43)	4 ⅛" (104.78)	1 ¾" (44.45)
B	½" (15)	4 ½" (114.30)	4 ½" (114.30)	2 ⅛" (53.98)



Construction

Bronze forged body and spring chamber; bronze trim and diaphragms; Teflon seat disc and diaphragm gasket; stainless steel pressure spring; All parts commercially cleaned for cryogenic service. Available in 1/4", 3/8", 1/2" FPT inlet/outlets.

Caution!

Cryogenic regulators allow LN2 to flow in only one direction. Therefore, the system should be evaluated to determine if an additional safety relief valve is required.

Temperature Rating

70 to -196 deg C (+150°F to -320°F)

Pressure Setting

Factory set upon request

Spring range available:

1 to 50 psi

35 to 75 psi

55 to 120psi

Safety Relief Valves

Model	Inlet Size (A)	Seat Material	Set Pressure (Colour code)	PRV flow at 110% set pressure.	Dimension (height B)
PRV-4-22-B	¼"	F	22 psig (yellow)	0.783 SCFM	2.6"
PRV-4-35-B	¼"	F	35 psig (purple)	0.783 SCFM	2.6"
PRV-4-50-B	¼"	F	50 psig (white)	0.783 SCFM	2.6"
PRV-4-100-B	¼"	F	100 psig (gray)	0.783 SCFM	2.6"
PRV-4-150-B	¼"	T	150 psig (red)	0.783 SCFM	2.6"
PRV-4-230-B	¼"	T	230 psig (blue)	0.783 SCFM	2.6"
PRV-4-350-B	¼"	T	350 psig (orange)	0.783 SCFM	2.6"
CRVD-8-18-B	½"	T	18 psig (red)	0.783 SCFM	3.5"

Remarks (Seat Material):
F for Fluorosilicone for PRV and SS styles for 15-139psi;
T for PTFE for PRV and SS styles for 140-600psi

Construction

Fully constructed with brass material from the body, seat retainer, adjusting screw to pipe away adapter; and stainless steel spring.

Warning!

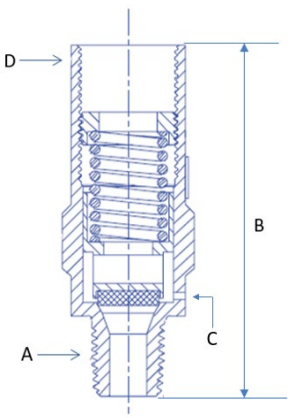
Inspection and maintenance of pressure relief valves is very important. Failure to properly inspect and maintain pressure relief valves could result in personal injuries or property damage. The useful safe service life of a pressure relief valve may be significantly affected by the service environment.
Always ensure sufficient thermal barrier during installation to avoid PRV from freezing and causing failure. Contact us for appropriate candy stick.

Pipe Away Option, D

P- Pipeaway included and attached, D. No drain hole in relief valve.

Drain Hole Option, C

Relief valves without pipeaway typically provided with drain holes, C.
Part Number Example: PRV-4-22C-B

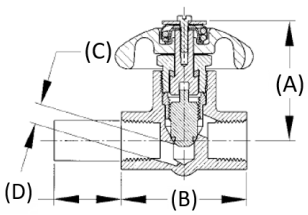


Features

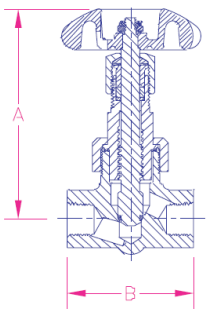
- All valves are cleaned and packaged for oxygen service per CGA G-4.1.
- Bubble tight at 95% of set pressure.
- Easy to read color coded psig / bar labels.
- Unique tamper resistant adjusting screw.
- Adapters provide standard pipe thread connections for venting gas to the outdoors.
- Repeatable performance.
- 100% factory tested.
- Temperatures Range -320° to +165° F.

Cryogenic Globe Valves

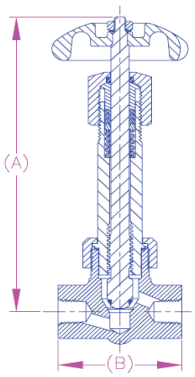
Model	Inlet/Outlet Connection	Height (A)	Body Width (B)	Material	Cv Factor
SS-4	¼" F.NPT	2 ¾"	2.5"	Brass	0.72
ES-6	⅜" F.NPT	4"	2.5"	Brass	1.10
BK-6	⅜" F.NPT	6.5"	2.5"	Brass	1.10
BK-8	½" F.NPT	6.5"	2.5"	Brass	1.10



SS



ES



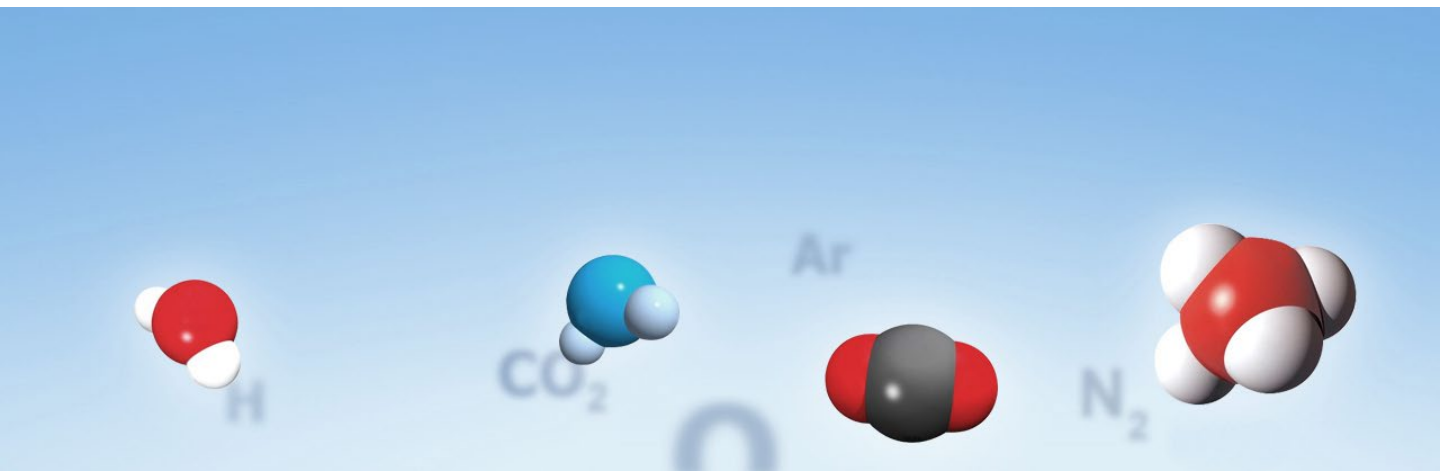
BK

Construction
Body & Bonnet: Brass
Stem: Stainless Steel
Seat Disc: CTFE
Handwheel: Aluminium
Packing & Bonnet Gasket: PTFE

Warning!
Always install thermal relief valve between two isolation valve!
Always wear glove and appropriate PPE to protect against cold burn hazard.
If the valve is frozen shut or frozen open, do not attempt to force open by wrench. Allow the valve to defrost completely before operate.

Features & Benefits:
- Spring loaded stem seal automatically adjusts for any gasket wear, eliminate constant need to retighten packing nut.
- Non-rising stem and low profile allow the valve to fit into tight areas and still provide easy access.
- Unique pressure-sealed moisture barrier helps prevent freeze up at cryogenic temperatures.
- Conical swivel seal design helps prevent seat galling from over-torquing.
- Cleaned for oxygen service per CGA G-4.1.
- Maximum working pressure is 600 PSIG.
- Working temperature range is -196 to 75 °C (-320°F to +165°F).

Technical Data



Liquid Gases Physical Properties

Name of Gas Chemical Symbol Molecular Weight Color Odor Taste	Oxygen O_2 31.9988 None None None	Nitrogen N_2 28.0134 None None None	Argon Ar 39.948 None None None	Helium He 4.0026 None None None	Methane CH_4 16.043 None None None	Hydrogen H_2 2.01594 None None None
Spec. Gravity (Air=1) 70°F. 1 Atm.	1.105	0.9669	1.395	0.13796	.5539	0.0695
Density lb Per cu ft 70°F 1 Atm.	0.08281	0.07245	0.1034	0.01034	0.0415	0.005209
Spec Vol. cu ft per lb 70°F 1 Atm.	12.076	13.803	9.671	96.71	24.096	192.0
Density Sat'd Vapor, lb per cu ft 1 Atm.	0.27876	0.2874	0.35976	1.0434	.1134	0.083133
Normal Boiling Point °F	-297.33	-320.36	-302.55	-452.1	-258.7	-423.0
Heat of Vaporization BTU per Pound	91.7	85.6	70.1	9	223.3	191.7
Critical Pressure Atmospheres, Abs. lb per sq in, Abs.	50.14 736.9	33.54 492.9	48.34 710.4	2.26 33.2	666.88	12.98
Critical Temp. °F	-181.08	-232.40	-188.12	-450.31	-116.67	190.8
Triple Point Pressure Atmosphere, Abs.	0.00145	0.1238	0.68005	None		-399.96
lb per sq in, Abs.	0.0213	1.189	9.994		1.7032	0.071
Triple Point Temp. °F	-361.83	-346.01	-308.8	None	-296.45	-434.56
Specific Heat Const. Press	0.2199 @77°F	0.2488 @77°F	0.1244 @77°F	1.2404 @77°F	0.5339 @80°F	3.4202 @77°F
Ratio Specific Heats	1.396 @80.3°F	1.4014 @70°F	1.6665 @86°F	1.6671 @77°F	1.305 @80°F	1.405 @77°F
Coeff. Viscosity, Micropoises @77°F	206.39	177.96	226.38	198.5	112	89.37
Thermal Conductivity, 32°F BTU/(sq ft)(Hr.)(°F/ft)	0.0142	0.0139	0.00980	0.08266 @40°F	0.0193 @70°F	0.0973
Ionization Potential, Volts	13.6	14.5	15.7	24.5		13.5
Exitation Potentials: First Resonance Potential, Volts	9.1	6.3	11.56	20.91		10.2
Metastable Potentials, Volts			11.66 11.49	19.77		

Unit Conversion Table

Oxygen						
	Weight		Gas		Liquid	
	Pounds (lbs.)	Kilograms (kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	12.076	0.3174	0.1050	0.3977
1 Kilogram	2.205	1	26.62	0.6998	0.2316	0.8767
1 SCF Gas	0.08281	0.03756	1	0.02628	0.008691	0.0329
1 Nm3 Gas	3.151	1.4291	38.04	1	0.3310	1.2528
1 Gal Liquid	9.527	4.322	115.1	3.025	1	3.785
1 L Liquid	2.517	1.1417	30.38	0.7983	0.2642	1

Nitrogen						
	Weight		Gas		Liquid	
	Pounds (lbs.)	Kilograms (kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	13.803	0.2657	0.1481	0.5606
1 Kilogram	2.205	1	30.42	0.7796	0.3262	1.2349
1 SCF Gas	0.07245	0.03286	1	0.02628	0.01074	0.04065
1 Nm3 Gas	2.757	1.2506	38.04	1	0.408	1.5443
1 Gal Liquid	6.745	3.06	93.11	2.447	1	3.785
1 L Liquid	1.782	0.8083	24.6	0.6464	0.2642	1

Argon						
	Weight		Gas		Liquid	
	Pounds (lbs.)	Kilograms (kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	9.671	0.2543	0.08600	0.3255
1 Kilogram	2.205	1	21.32	0.5605	0.18957	0.7176
1 SCF Gas	0.1034	0.04690	1	0.02628	0.008893	0.03366
1 Nm3 Gas	3.933	1.7840	38.04	1	0.3382	1.2802
1 Gal Liquid	11.630	5.276	112.5	2.957	1	3.785
1 L Liquid	3.072	1.393	29.71	0.7812	0.2642	1

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F. Liquid measured at 1 atmosphere and boiling temperature. Nm 3 (normal cubic meter) measured at 1 atmosphere and 0°C. All values rounded to nearest 4/5 significant numbers.

Unit Conversion Table

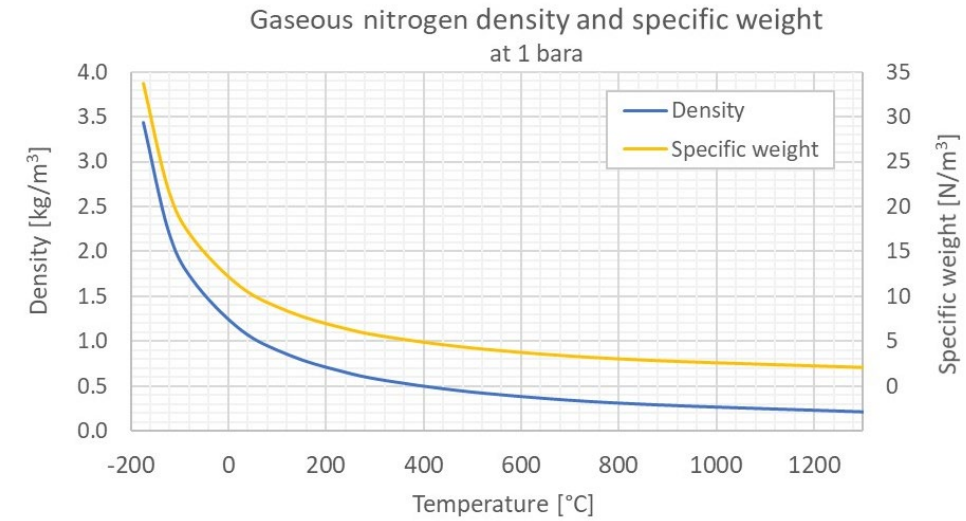
Helium						
	Weight		Gas		Liquid	
	Pounds (lbs.)	Kilograms (kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	96.71	2.542	0.9593	3.631
1 Kilogram	2.205	1	213.2	5.603	2.115	8.006
1 SCF Gas	0.01034	0.004690	1	0.02628	0.009919	0.03754
1 Nm3 Gas	0.3935	0.17847	38.04	1	0.3775	1.4289
1 Gal Liquid	1.0423	0.4728	100.80	2.649	1	3.785
1 L Liquid	0.2754	0.1249	26.63	0.6998	0.2642	1

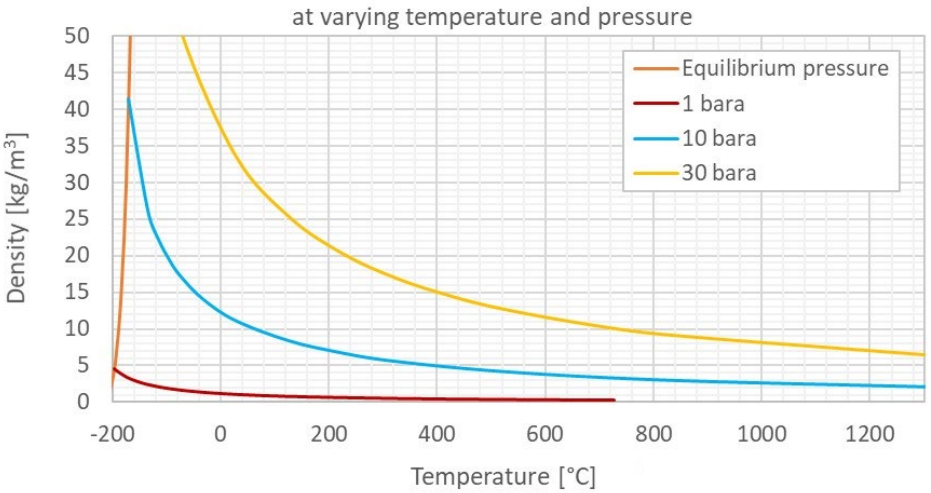
Methane						
	Weight		Gas		Liquid	
	Pounds (lbs.)	Kilograms (kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	24.058	0.67986	0.28366	1.0734
1 Kilogram	2.205	1	53.048	1.4991	0.62548	2.3667
1 SCF Gas	0.0414	0.0188	1	0.028259	0.011744	0.044437
1 Nm3 Gas	1.465	0.6645	35.386	1	0.41557	1.5725
1 Gal Liquid	3.53	1.6	84.925	2.3999	1	3.7839
1 L Liquid	0.9329	0.4231	22.444	0.63425	0.26463	1

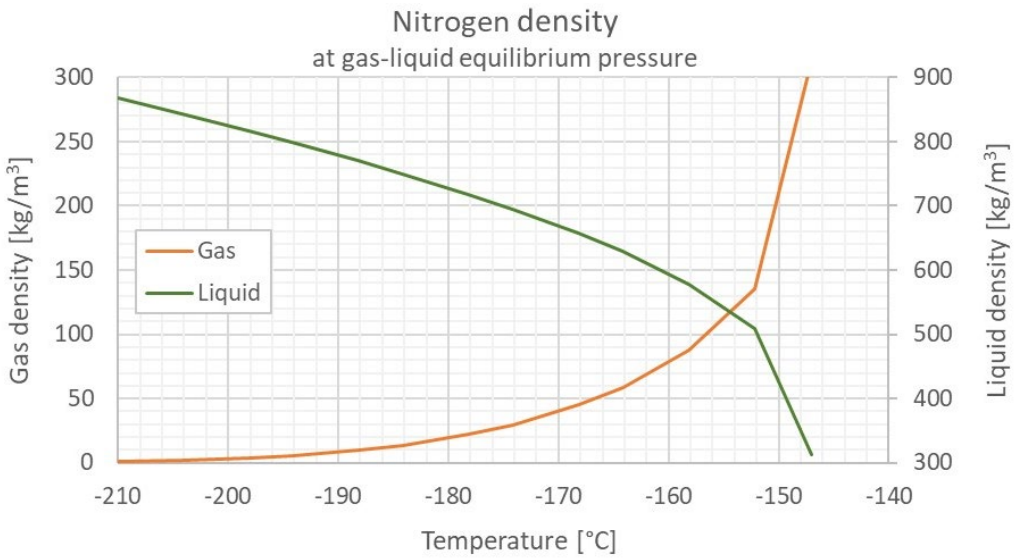
Hydrogen						
	Weight		Gas		Liquid	
	Pounds (lbs.)	Kilograms (kg)	Cubic Feet (SCF)	Cubic Meters (Nm3)	Gallons (Gal)	Liters (L)
1 Pound	1	0.4536	192.00	5.047	1.6928	6.408
1 Kilogram	2.205	1	423.3	11.126	3.733	14.128
1 SCF Gas	0.005209	0.002363	1	0.02628	0.008820	0.03339
1 Nm3 Gas	0.19815	0.08988	38.04	1	0.3355	1.2699
1 Gal Liquid	0.5906	0.2676	113.41	2.981	1	3.785
1 L Liquid	0.15604	0.07078	29.999	0.7881	0.2642	1

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F. Liquid measured at 1 atmosphere and boiling temperature. Nm 3 (normal cubic meter) measured at 1 atmosphere and 0°C. All values rounded to nearest 4/5 significant numbers.

Nitrogen Density







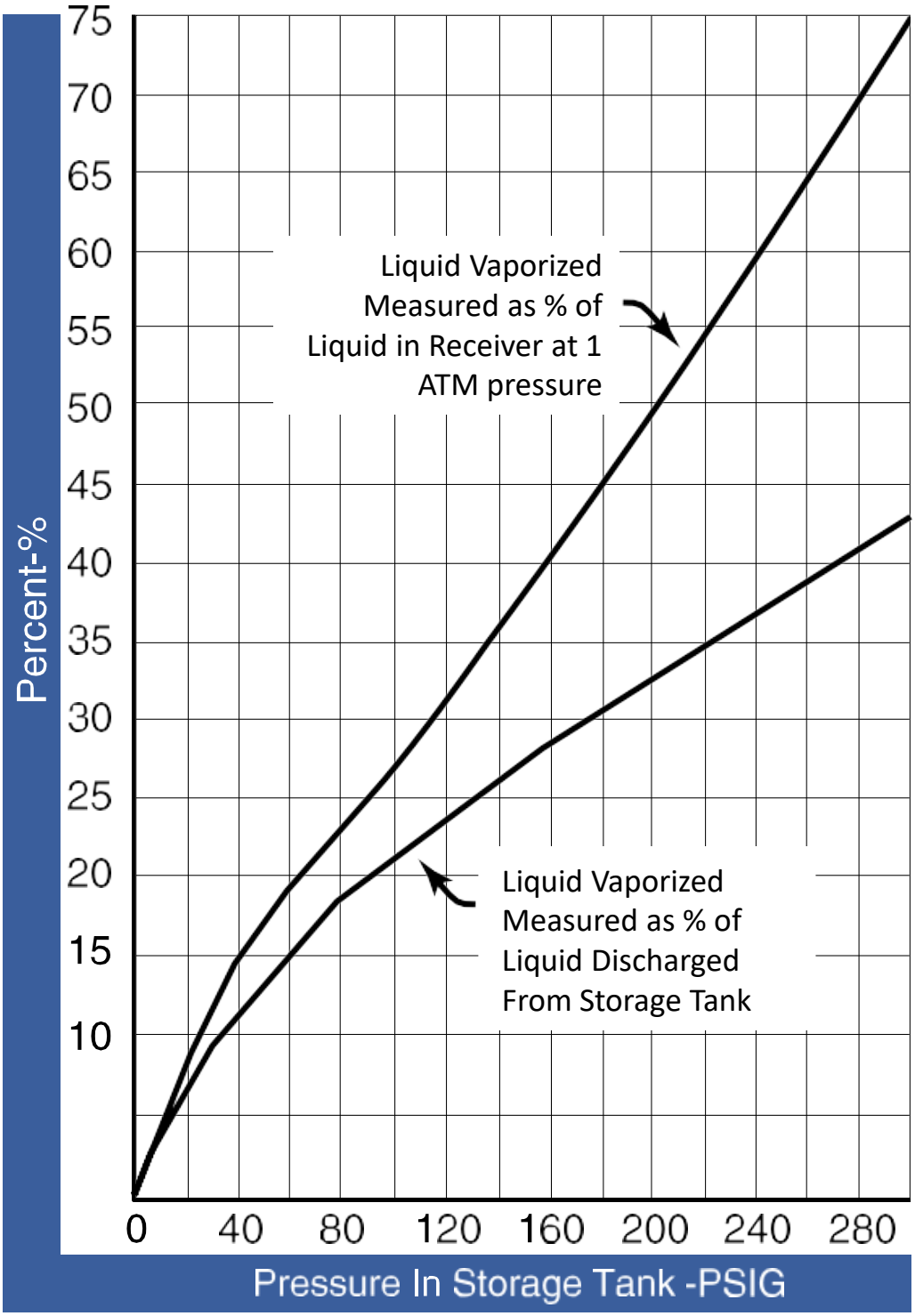
Nitrogen Viscosity (Equilibrium Stage)

State	Temperature			Pressure		Dynamic (Absolute) Viscosity					Kinematic Viscosity	
	[K]	[°C]	[°F]	[MPa]	[bara]	[µPa s]	[cP]	[lbf s/ft^2 *10^{-6}]	[lbm/ft s*10^{-6}]	[lbm /ft h]	[cSt], [m2/s*10-6]	[ft2/s*10-6]
Liquid at equilibrium	63.15	-210	-346	0.013	0.125	311.6	0.3116	6.508	209.4	0.7538	0.3593	3.867
	69	-204	-335	0.033	0.332	230.9	0.2309	4.821	155.1	0.5584	0.2739	2.948
	75	-198	-325	0.076	0.76	176.8	0.1768	3.692	118.8	0.4276	0.2164	2.33
	79	-194	-317	0.122	1.22	150.7	0.1507	3.148	101.3	0.3646	0.1887	2.031
	85	-188	-307	0.229	2.29	121.3	0.1213	2.534	81.52	0.2935	0.1575	1.695
	89	-184	-299	0.331	3.31	106.2	0.1062	2.218	71.35	0.2569	0.1415	1.524
	95	-178	-289	0.541	5.41	88	0.088	1.838	59.14	0.2129	0.1225	1.319
	99	-174	-281	0.726	7.26	78.42	0.07842	1.638	52.7	0.1897	0.1128	1.214
	105	-168	-271	1.08	10.8	65.29	0.06529	1.364	43.87	0.1579	0.0993	1.069
	109	-164	-263	1.38	13.8	57.79	0.05779	1.207	38.83	0.1398	0.09185	0.9887
	115	-158	-253	1.94	19.4	47.29	0.04729	0.9877	31.78	0.1144	0.08172	0.8796
	121	-152	-242	2.64	26.4	36.51	0.03651	0.7625	24.53	0.08832	0.07166	0.7713

Nitrogen Viscosity (Supercritical Phase)

State	Temperature			Pressure		Dynamic (Absolute) Viscosity					Kinematic Viscosity	
	[K]	[°C]	[°F]	[MPa]	[bara]	[µPa s]	[cP]	[lbf s/ft^2 *10^{-6}]	[lbm/ft s*10^{-6}]	[lbm /ft h]	[cSt], [m2/s*10-6]	[ft2/s*10-6]
Liquid	100	-173	-280	5	50	84.51	0.08451	1.765	56.79	0.2044	0.1186	1.277
Supercritical Phase	600	327	620	5	50	29.88	0.02988	0.6241	20.08	0.07229	1.088	11.71
	1100	827	1520	5	50	44.33	0.04433	0.9259	29.79	0.1072	2.941	31.66
	1600	1327	2420	5	50	56.48	0.05648	1.18	37.95	0.1366	5.427	58.42
Liquid	200	-73.2	-99.7	10	100	17.7	0.0177	0.3697	11.89	0.04282	0.09	0.9555
	300	26.9	80.3	10	100	19.96	0.01996	0.4169	13.41	0.04829	0.1787	1.923
	400	127	260	10	100	23.51	0.02351	0.491	15.8	0.05687	0.2896	3.117
Supercritical Phase	500	227	440	10	100	26.99	0.02699	0.5637	18.14	0.06529	0.4184	4.504
	600	327	620	10	100	30.28	0.03028	0.6325	20.35	0.07326	0.5635	6.066
	1100	827	1520	10	100	44.49	0.04449	0.9293	29.9	0.1076	1.5	16.14
	1600	1327	2420	10	100	56.48	0.05648	1.18	37.95	0.1366	2.745	29.55

Nitrogen Vapor Release Chart



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