CRYOGENIC EQUIPMENT

Static Vacuum Jacketed Piping for Cryogenic Applications

SPECIFICATION

Introduction (Fig.1)

Cryogenic liquids are very cold by nature: -150ºC or -238°F. The best way to bring a cryogenic liquid from a source to a point of use is by using a static vacuum jacketed piping system. We use the term "system" because there are much more components involved than the piping itself:

- Valves and check valves
- Hoses
- Vapor vent device and related heaters
- Thermal expansion pressure relief valves
- Manifolds
- Bayonets

... and much more.

Anatomy of a Static Vacuum Insulated Pipe (Fig. 2)

Heat transfer of cryogenic fluids can take place in numerous ways:

- by thermal convection
- by thermal radiation
- by thermal conduction
- by transfer of energy by phase changes

A vacuum insulated pipe is specifically designed to minimize heat transfer by any of the above mentioned ways.

<u>Vacuum & the Annular Space</u> - A vacuum jacketed pipe is basically a pipe in which the cryogenic liquid travels is contained within a second pipe. The space between the two is called the annular space. A vacuum is pulled in the annular space down to about 9 micron of vacuum pressure.

<u>Super Insulation</u> - The inner pipe is wrapped with several layers of a double sided "tape": one side of the tape is aluminum foil and the other side is fiberglass paper.

<u>Gas Getter</u> - There are always a few molecules remaining in the annular space despite the very high vacuum pressure. We add an absorbing material called "gas getter" or "gas trap" in the annular space to catch the molecules while bouncing around in the annular space.

<u>Pump Out Adaptor</u> - Each spool is delivered under high vacuum. The vacuum connection is often called a "pump out adaptor". This adaptor is the mechanical device that protrudes from the outer shell/pipe and it is always protected against mechanical impact and debris. It is of paramount importance not to tamper with this device.

Bayonets (Fig. 3)

Unlike other piping systems that can be fabricated on site, VJ piping systems are manufactured off site and are delivered in wooden crates to job sites. Unless the dimensions of the static vacuum jacketed piping are very short, very rarely you will see static vacuum insulated piping made out of one section. In general, VJ piping systems are delivered in multiple sections called "spools". The spools are connected together by inserting a male bayonet inside a female bayonet. This bayonet joint is secured by a V-band that is similar to a vacuum C-clamp.

Valves, Hoses and Other Accessories (Fig. 4 - Fig. 10)

Static vacuum jacketed piping systems are always composed of several pieces and parts. Those pieces and parts can be very simple like a relief valve or much more complex such as a fully automatic switchover manifold. Some of these components are available either vacuum insulated, not insulated at all, or both.

We are showing on page 5 the most popular non-vacuum jacketed components. It is important to note that non- vacuum insulated components have high heat loss values which greatly increases the cryogenic fluid consumption.

Measurements and Isometric Drawings (Page 7)

Static vacuum jacketed pipes are shop fabricated following measurements taken in the field. The measurements are laid out on an isometric drawing. The isometric drawing contains important information such as the different components, the location of each bayonet/tee/elbow, the flow direction and more. The isometric drawings contains all lengths and dimensions allowing us to fabricate/weld each spool.

Mandatory Signature

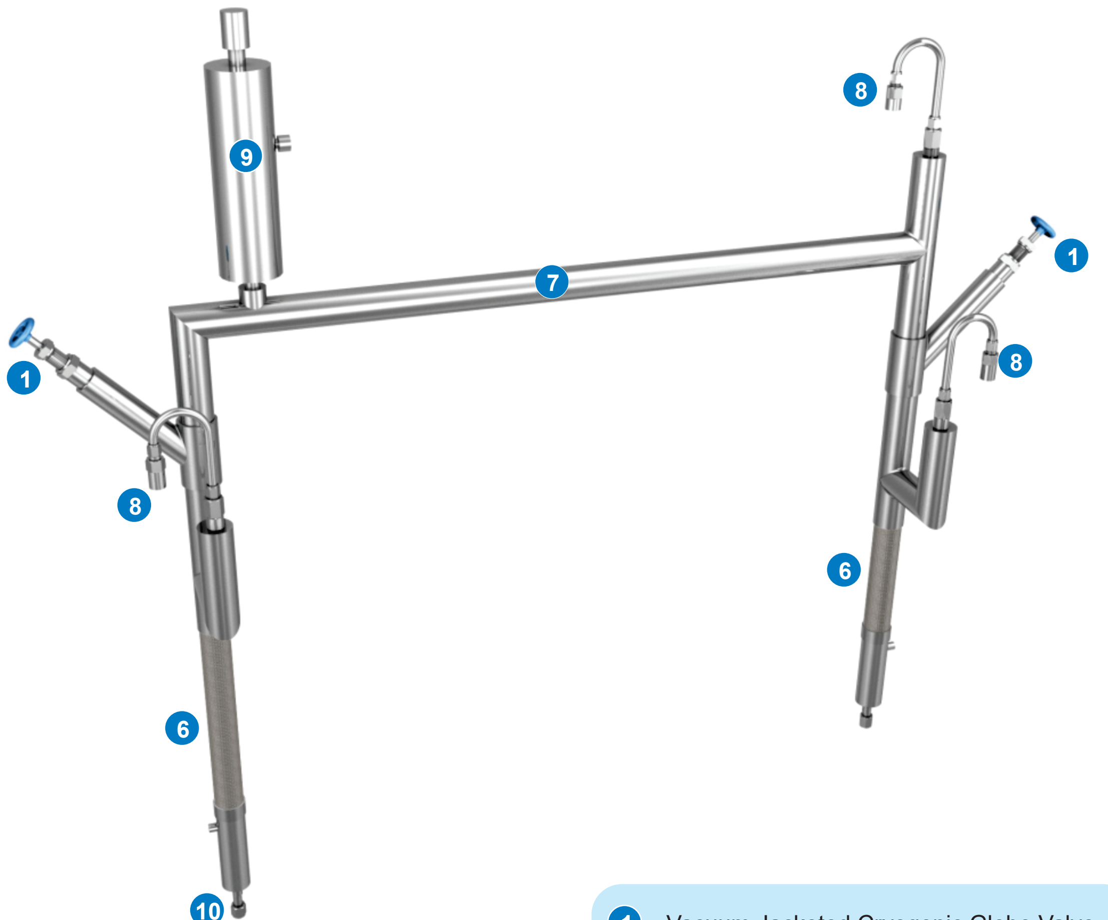
Fabrication of the static vacuum jacketed pipes begins when the installer confirms with a signature the measurements contained in the isometric drawings. It is important to highlight that:

- VJ piping are not modifiable in the field.

- There will be additional fees (which could be significant) with any modifications made to the spools once the isometric drawing is signed off and fabrication is started.

System Components

Fig. 1 - Vacuum Jacketed Components



1. Vacuum Jacketed Cryogenic Globe Valve [Angle Pattern]
2. Thermal Expansion Pressure Relief Valve
3. Male Pipe Port (inlet or Outlet)
4. Vacuum Jacketed Male Bayonet
5. Vacuum Jacketed Female Bayonet
6. Vacuum Jacketed Hose
7. Vacuum Jacketed Pipe
8. Thermal Expansion Pressure Relief Valve Installed at the End of a Candy Cane
9. Vacuum Jacketed Cryovent [to be Installed Only When the Source of Cryogenic Liquid is a Bulk Tank]
10. Flare Fitting

How to Join Spools Together

Fig. 2 - Anatomy of a Static Vacuum Insulated Pipe & Related Components

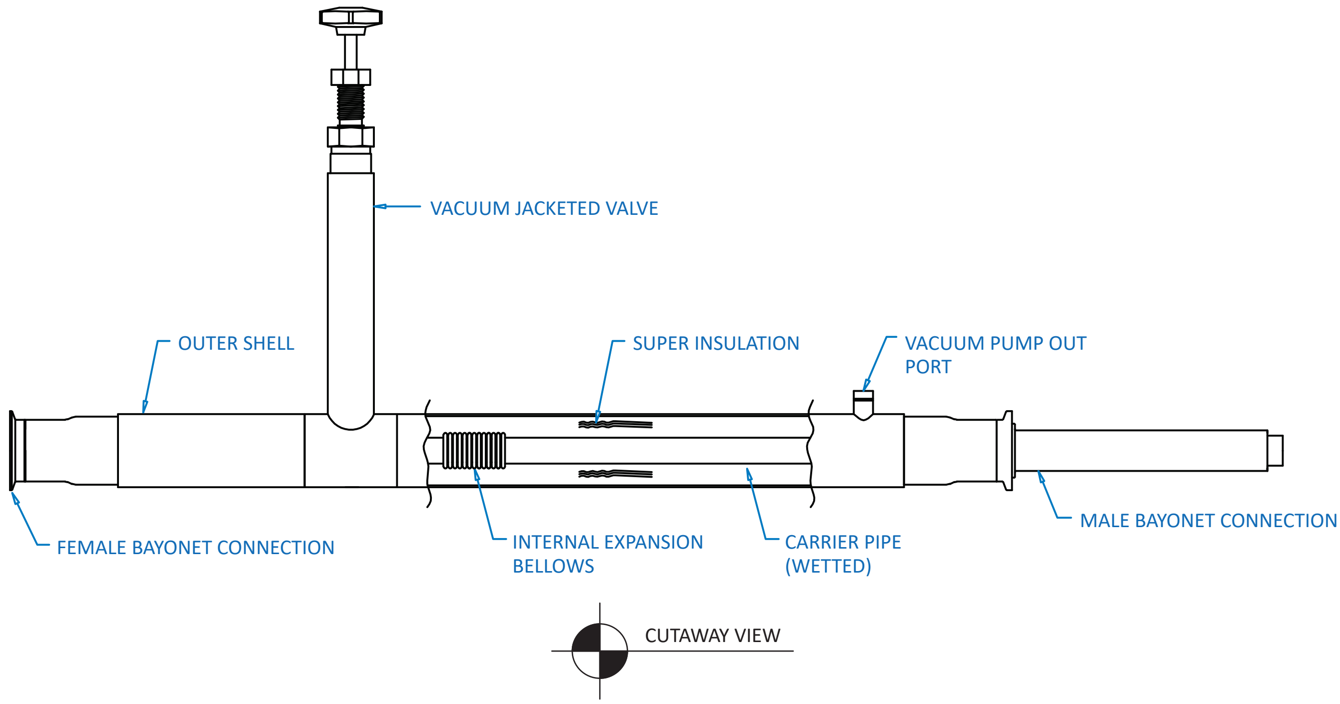
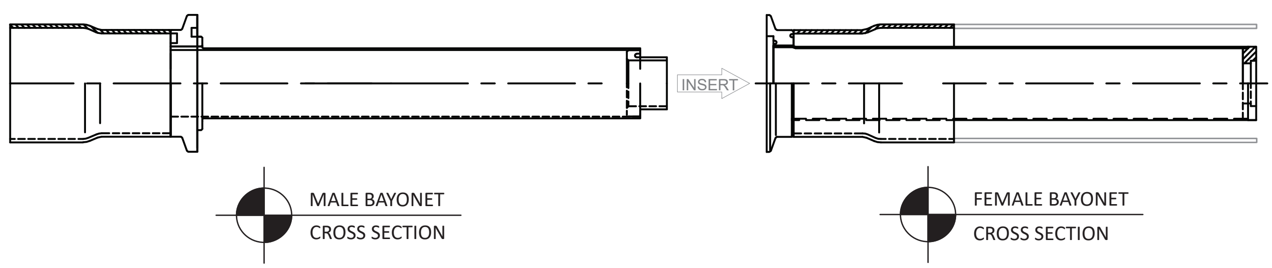
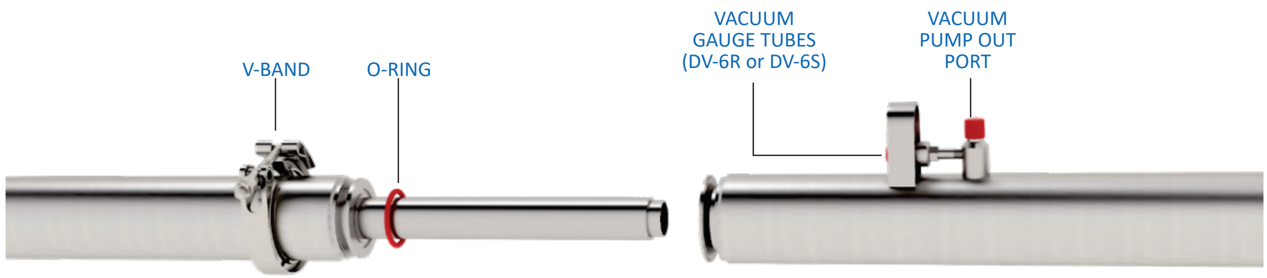


Fig. 3 - Typical Vacuum Insulated Bayonet

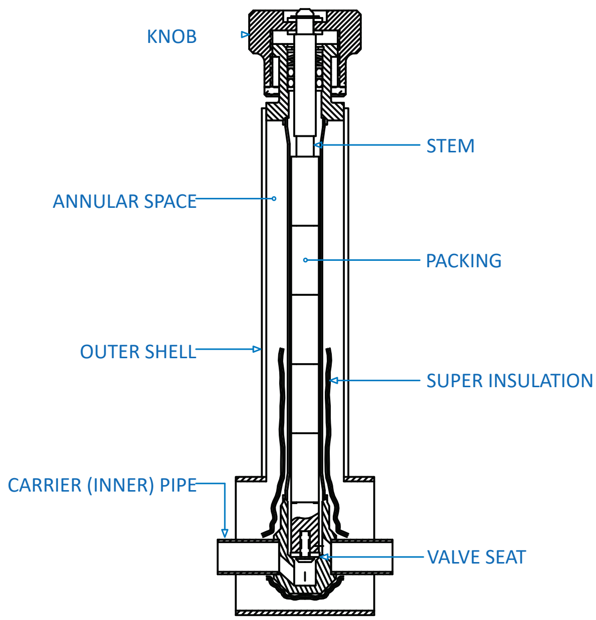




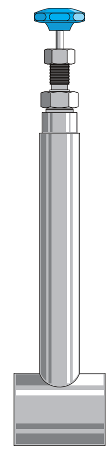
V-BANDS ARE USED TO SECURE THE MALE-FEMALE BAYONET CONNECTION TOGETHER

Vacuum Jacketed Piping - Typical Components

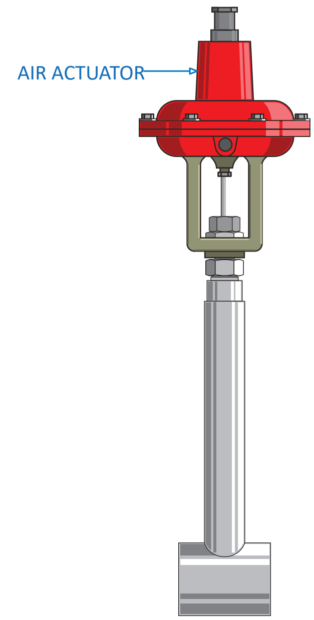
Fig. 4 - Typical Vacuum Insulated Valves



VACUUM INSULATED VALVE
CROSS SECTION

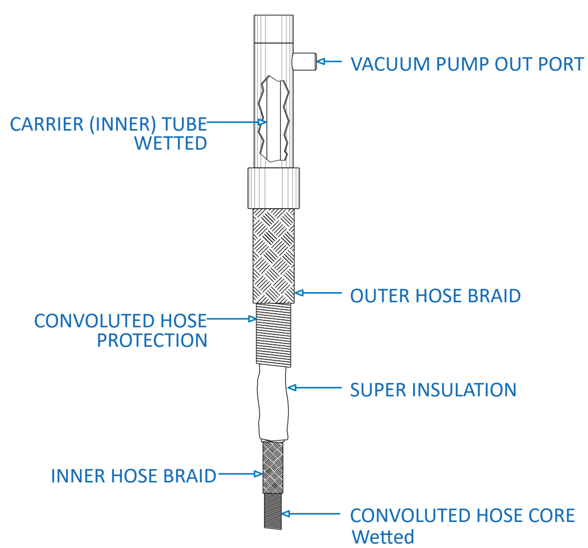


VJ GLOBE VALVE
MANUALLY OPERATED



VJ GLOBE VALVE
AIR OPERATED

Fig. 5 - Typical Vacuum Insulated Hose



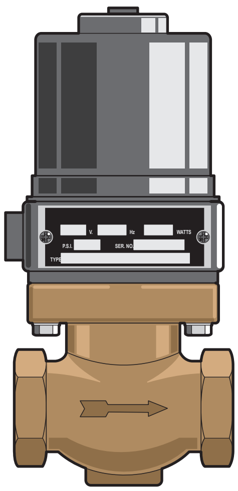
VACUUM INSULATED FLEXIBLE HOSE
CUTAWAY VIEW

VACUUM INSULATED FLEXIBLE HOSE
PICTURE

Non-Vacuum Jacketed Insulated Piping Typical Components

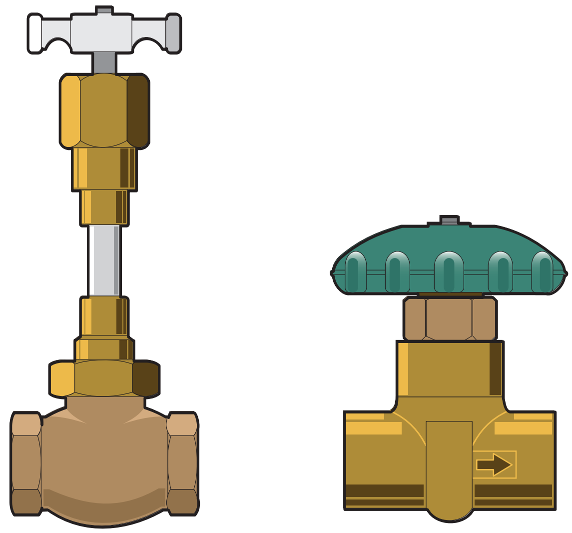
There are several cryogenic components that are not vacuum jacketed. Outside of their low cost compared to their vacuum jacketed counterparts, they all have one very specific thing in common: high heat loss/transfer (they freeze up and they are often smothered under ice). Hereunder are some of the non-vacuum jacketed piping components and their specifics.

Fig. 6 - Typical Cryogenic Solenoid Valve



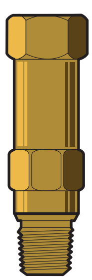
They are available in normally open or normally closed positions. They can be ordered with pretty much any coil wattage.

Fig. 7 - Typical Non-Vacuum Insulated Cryogenic Valves



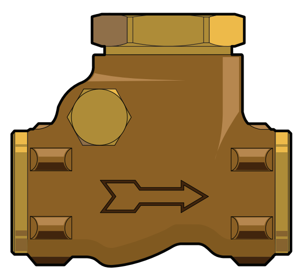
They are normally found under cryogenic bulk tanks. Their sizes, shapes and styles vary greatly upon manufacturers.

Fig. 8 - Typical Thermal Expansion Pressure Relief Valve



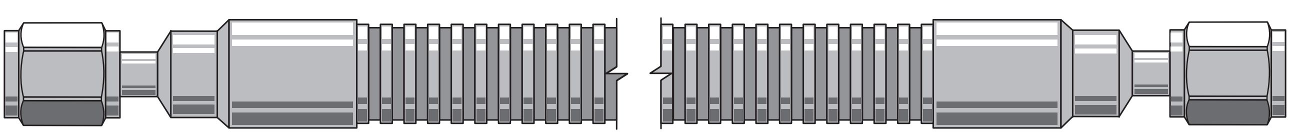
Also known as “pop safeties”, the thermal expansion pressure relief valves are extensively used on VJ piping systems. They are used everywhere there is a possibility to trap cryogenic liquids between two closed ends. These relief valves are not available in a vacuum insulated version.

Fig. 9 - Typical Cryogenic Swing Check Valve



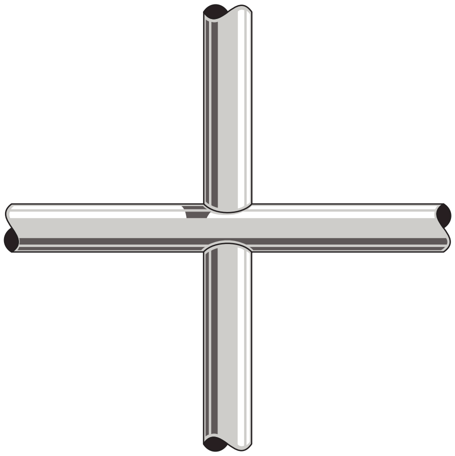
There is no such thing as a vacuum insulated cryogenic check valve. There are two (2) popular cryogenic check valves: the spring loaded check valve and the swing check valve (shown above).

Fig. 10 - Typical Non-Insulated Cryogenic Liquid Metal Hose

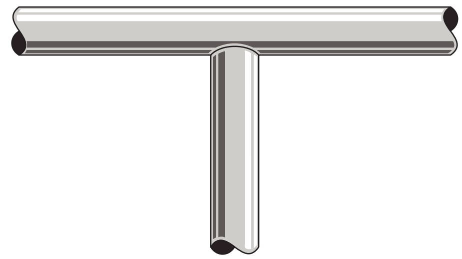


These cryogenic metal hoses are very popular due to their low cost compared to their vacuum jacketed version. The user shall understand though that these hoses are the most important source of heat leak into a cryogenic system (heat leak = cryogenic liquid evaporation).

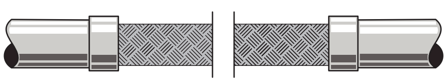
Vacuum Jacketed Piping Shapes



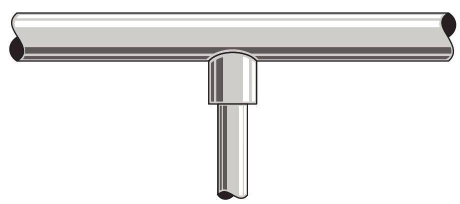
CROSS



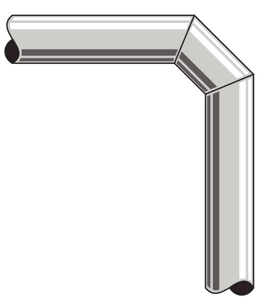
TEE



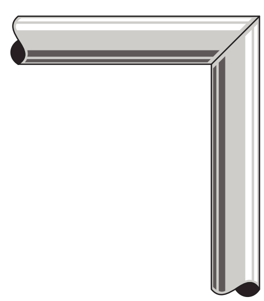
HOSE TRANSITION



REDUCER



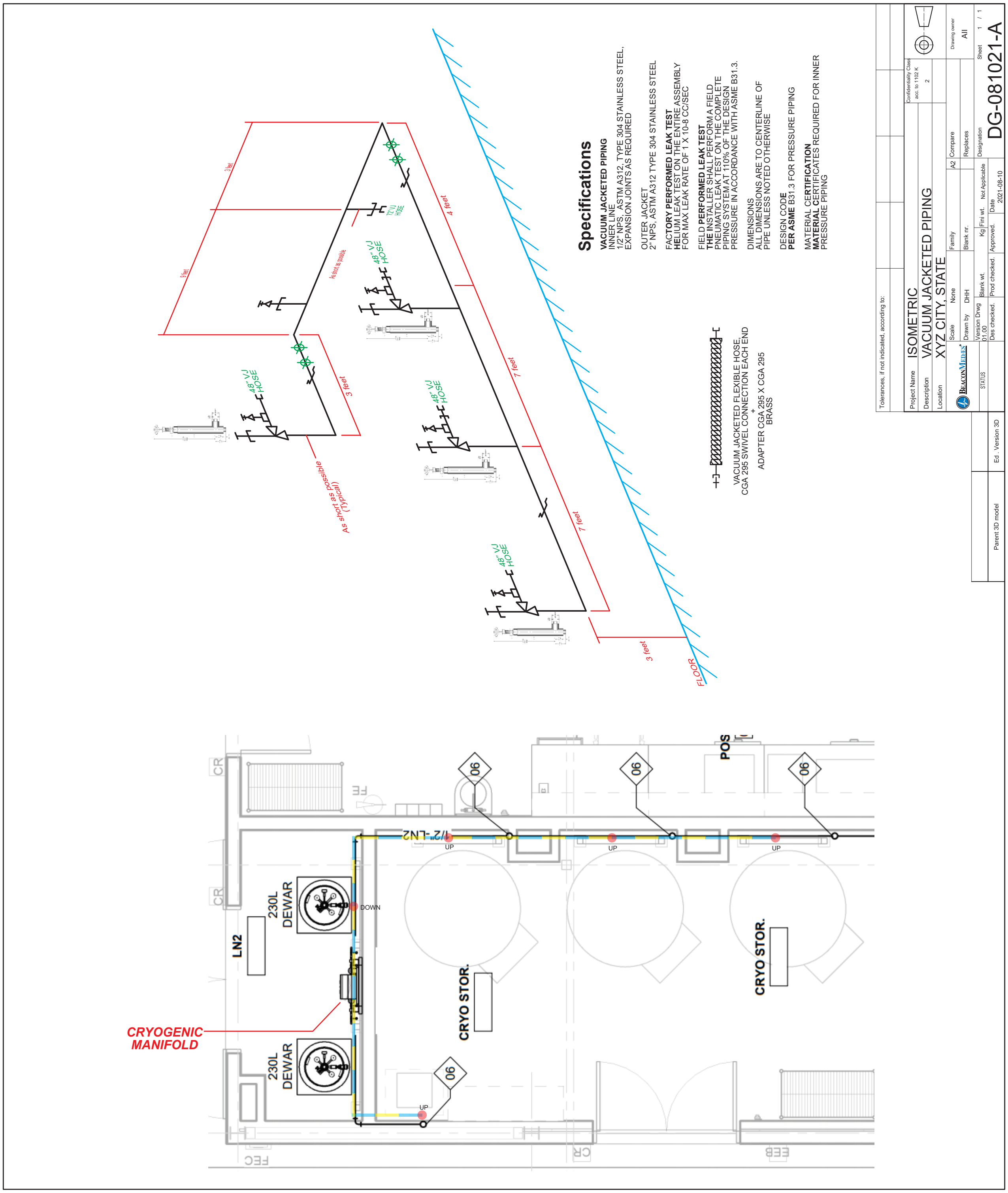
LONG ELBOW



SHORT ELBOW

Isometric Drawing

Goal: Three-dimensional P&ID representation of the liquid nitrogen system generally taken from a floor plan.
Contains: Dimensions, relief valves, valves, hoses, connection types, wall penetrations, and any important data.
Verification & Signature: The installer needs to verify dimensions and sign-off isometric drawings before construction starts.



Specifications & Performance

Table 1 - Liquid Nitrogen Flow

Carrier Pipe (Inner) NPS Schedule 5	Gallons per Minute (gpm)	Liters per Minute (lpm)	Pounds per Minute (lb/min)
1/2"	7.66	29	51.7
1"	29.6	112	199.7
1-1/2"	85.2	323	574.8
2"	159	602	1,072.8
3"	441	1,669	2,975.4
4"	890	3,369	6004.7

Data based on:
1. Maximum recommended flow rate.
2. 100 feet of rigid piping with a minimum of 5 psi pressure drop @ 60 psi operating pressure.

Table 2 - Available Sizes, Weight, Dimensions & Cooldown Requirement

Carrier Pipe (Inner) NPS Schedule 5	Outside Pipe (Shell/ Jacket) NPS Schedule 5	Outside Diameter (inch)	Dry Weight (lb/ft)	Cooldown (lb of LN_2/ft)
1/2"	2"	2.375	3.00	0.27
1"	3"	3.500	4.48	0.43
1-1/2"	3-1/2"	4.000	5.46	0.64
2"	4"	4.500	6.07	0.80
3"	5"	5.563	10.32	1.51
4"	6"	6.625	12.65	1.96

Table 3 - Heat Leak (Btu/hr*ft)

Nominal Pipe Size	Liquid Nitrogen (LN2) -320°F (20 MLI)	Liquid Oxygen (LOX) -297°F (20 MLI)	Liquid Helium (LHe) -452°F (24 MLI)
1/2"	0.236	0.222	0.272
1"	0.344	0.324	0.394
1-1/2"	0.445	0.419	0.507
2"	0.581	0.547	0.659
3"	0.834	0.785	0.942
4"	1.058	0.996	1.192

Data is provided for estimation only. Contact BeaconMedaes for a thorough system analysis.
Data is based on straight pipe only (no internal spacers, fittings, or bayonets).

Specifications & Performance

Table 4 - Static Vacuum Piping Specifications

Fluid Service	Liquid Nitrogen, Liquid Argon, Liquid Oxygen
Maximum Working Pressure	150 psig (Higher Pressure Rating Available Upon Demand)
Operating Temperature	-320°F to 150°F
Mechanical Thermal Barrier	Multiple Layers of Super Insulation Consisting of Aluminum Foil and Fiberglass Paper
Annular Space Vacuum Pressure	1 x 10^{-8} cc/second of Helium
Gas Getter	Zeolite
Design and Construction Code	Process Piping - ASME B31.3 - Latest Edition
Material Certification	Material Certification Available On Demand
Cleaning	Commercial Cleaning (Cleaning of Oxygen Service Available on Demand)
Material of Construction	Type 304 Stainless Steel

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