Specification for Vacuum Insulated Piping General Fabrication, Testing and Purchasing

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1.0 SCOPE

The ASME Code for Pressure Piping, ASME B31.3 latest edition, establishes the requirements for engineering, design, fabrication, and testing of piping used in liquid and gas cryogenic service. CryoWorks, Inc. specification number CDIENG-00118, is established as a base line to meet or exceed the intent of those requirements during the production of this class of piping with specific emphasis on areas which are not code-regulated, such as vacuum and thermal insulation, but are of prime importance in the fabrication of a quality vacuum insulated, or double-wall containment piping system.

2.0 ENGINEERING DESIGN

CryoWorks Engineering/Design staff will ensure that the following areas meet code requirements, contract specifications, and sound engineering practices.

2.1 COMPONENTS

2.1.1 All components will be reviewed for conformance to the design parameters required by ASME B31.3 code, latest edition.

2.2 FLEXIBILITY

2.2.1 The system will be analysed to ensure sufficient flexibility. This includes analysis of individual spool sections as well as the total system, while considering allowable stress levels of materials of fabrication as well as consideration for site conditions, anchors, supports, and interface connections.

2.3 COMPONENT LOCATION

2.3.1 All components including valves, relief valves, cryogenic couplings, and seal-off valves will be reviewed for system location while considering supports, anchors, site, safety, accessibility, and interference with existing equipment.

2.4 NON-DESTRUCTIVE EXAMINATION AND TESTING

2.4.1 All components and piping examination and testing will meet code requirements per customer specifications and contract documents. It is the responsibility of the owner/user of the piping system to ensure all local regulations are satisfied. ASME code is not required to be followed for all service fluids in all jurisdictions. When the code does not regulate testing, such as vacuum integrity, CryoWorks Engineering/Design staff will require NDT to meet quality standards set down by this specification/Customer specification and contract.

2.5 SAFEGUARDS (APPENDIX "G" ASME B31.3)

2.5.1 When required by the Customer's specifications, CryoWorks Engineering/Design will give appropriate consideration to safeguarding the system.

3.0 MATERIAL AND COMPONENT SELECTION

CryoWorks will use only code-qualified components and materials as defined in Chapter III and Chapter IV, Table 326.1 of the ASME B31.3 and/or as listed in Appendix "A," for use within the system and components temperature limits, unless specified/approved by the Customer. All CryoWorks material components will be of new, traceable origin. No used material or material of unknown origin will be permitted unless specified/approved by the Customer.

3.1 INNER (PROCESS)

Process pipe will be fabricated using Type 304/304L, ASTM A-312 stainless steel pipe, welded or seamless, or tubing per ASTM A-269.

3.2 VACUUM JACKET

Piping used for the vacuum jacket will meet the same material specifications as the inner pipe and will be schedule 5 or greater, the wall thickness will be in conformance to Section VIII, Division 1, of the Boiler and Pressure Vessel Code, paragraph UG- 28. Where heavier wall is required for pipe supports or anchors, CryoWorks Engineering will review and reinforcements will be added, or pipe schedule adjusted to meet design conditions.

3.3 FITTINGS

Inner-line butt weld fittings will conform to ASTM A-403 WP-W or A-403 WP-S, grade 304/304L stainless steel. ASTM A403 CR grade fittings will be acceptable when MAWP reduction for wall thinning is accounted for during system design. Flanges will conform to ASTM A-182, grade 304/304L stainless steel. No inner-line mitered elbows will be used. Branch connections will be designed and fabricated per ASME B31.3 code requirements. Inner line welded joints will be designed and fabricated per ASME B31.3 with consideration of specific fluid service requirements.

3.3.1 Valves

Vacuum jacketed (VJ) valves will conform to the pressure rating, material, and other design features required to meet specified service. VJ Valve component materials of construction will be 300-series stainless steel. Valve features to include: low handle torque for bubble tight shut-off, stainless steel body, stem and threads, redundant stem seal, cryogenic stem packing, brass bonnet, redundant cryogenic bonnet seal, bonnet purge port (possible thermal relief location), tight fit stem, MLI on jacketed valves, brass plug, plug to stem stabilizer and PCTFE M400H (KEL-F) seat seal w/ locked thread insert.

3.4 EXPANSION JOINTS

Unless otherwise specified on the drawings or customer requirements, the piping spools will be designed and fabricated using single-ply bellows to compensate for thermal cycling. Internal bellows will be used for 2"x 4" NPS and smaller piping rated at or below 200 PSIG. External bellows will be used on piping larger than 2"x 4" NPS and for pressure higher than

200 PSIG. Bellows material will be type 304, 316, or 321 stainless steel. Normal design cycle life of 5,000 complete cycles in accordance with ASME B31.3 Code.

3.4.1 Flexible Components

Flexible metal hose may be used on the inner line and vacuum jacket to compensate for system movement. Single layer braid will be installed on the jacket flex for protection. Multi/Single braid will be installed on the inner line when required by system design pressure.

3.5 VACUUM CLOSURES

Vacuum end closures may be required between the inner process line and the vacuum jacket. Engineering/Design will consider system heat leak, thermal stress, shipping loads, and system performance requirements while evaluating the type of vacuum closure to be used.

3.5.1 Cryogenic Couplings (Bayonets)

When bayonet connections are used, they will be either a close-tolerance design or dissimilar metal tip design. Close-tolerance designs utilize a 0.003” to 0.007” gap between the male and female matching parts to create a vapor gap along the bayonet to keep the O-ring seal warm. Dissimilar metal tip designs utilize a shrink tight fit to create the vapor gap. Coupling flange will be designed to accept V-band or flanged connection, as specified. Bayonets will be mass spectrometer leak-tight.

3.6 INNER PIPE SUPPORTS (SPACERS)

The inner (process) pipe will be centered within the vacuum jacket by a support system designed to transfer the loads between the two pipes during thermal cycles with the inner line filled with process fluid, as well as during shipment. In addition to thermal and shipping loads, the spacer configuration will be designed to minimize heat leak into process pipe.

3.6.1 Spacer design will withstand the following loading during shipment and after installation:

- 3 “g” load applied vertically downward
- 3 “g” load applied vertically upward
- 2 “g” load applied horizontally (longitudinally or laterally) combined with a 1 “g” load vertically downward
- Meet the Uniform Building Code for zone 4 seismic requirements with the inner line filled with process fluid

3.7 LAMINAR RADIATION SHIELDING (SUPERINSULATION)

The inner (process) pipe will be wrapped with a minimum of 20 alternating layers of aluminum and polyester insulation. All LOX, LH2 and LNG systems shall use Lydall CRS wrap with a minimum of 20 layers. All types of insulation will be affixed to the inner pipe using Kapton tape.

3.8 CHEMICAL GETTERING SYSTEM

Each spool assembly will have a chemical gettering system installed during fabrication. The system will consist of a calcium zeolite desiccant, (Linde Type 5A molecular sieve), and a hydrogen converter such as palladium oxide (or Silver Zeolite). The quantity of each material in the gettering system will be determined by CryoWorks based upon the diameter and length of the spool. In oxygen service, only use Ionex®-type Ag 400 Silver Zeolite which is acceptable for oxygen applications.

3.9 EVACUATION PORT

Each pipe spool assembly will be fabricated with CryoWorks Evacuation Port. To meet specific customer specification and contract requirements, optional bellows-sealed isolation valves and thermocouple vacuum gauge tubes will be added to the side of the evacuation port when required. Each evacuation port to be all-stainless-steel construction with a brass inner plug, equipped with a double O-ring seal to prevent vacuum loss from vibration or shock, and vinyl cover cap to prevent moisture and contamination from entering the evacuation port internals. The evacuation port assembly provides a combination pump-out opening, seal-off, and relief device. The evacuation port assembly will be positioned on each spool in an approved location considering safety, accessibility to pump-down devices, and non-interference with neighboring equipment. Each thermocouple gauge tube assembly will be covered to prevent damage while in service.

3.9.1 Vacuum Gauge Tubes

When required, each spool will be equipped with a thermocouple vacuum gauge tube to monitor the vacuum level without breaking into the vacuum annulus.

3.9.2 Isolation Valve

When required, a bellows seal isolation valve will be placed between the vacuum annulus and the thermocouple gauge tube to isolate the tube for maintenance.

4.0 FABRICATION

Piping will be fabricated in a clean, well-lit shop. Pipe ends will be cleaned and properly prepared to meet the code requirements for connection.

4.1 WELDING

All welding will be performed by welders who have been qualified to procedures and positions as required by ASME Section IX, Article II, of the Boiler and Pressure Vessel Code for the material, temperature, and application intended. CryoWorks shop welding standards will meet the requirements of ASME B31.3 Piping Code, Chapter V for full-penetration welds.

4.2 WELDING EQUIPMENT

Welding will be performed using GTAW, GMAW, or orbital welding. The shielding gas may be argon, helium, or any procedure-approved mixture. Filler metal will comply with the procedures.

4.3 CLEANLINESS

Work areas will be maintained in a clean orderly manner. Piping and components will be cleaned with an environmentally-approved cleaning solvent inside and out prior to welding and after all cutting, grinding, or filing. All burrs, grease, oil, and metal residue will be removed prior to welding. The outside of the inner line will be cleaned prior to the installation of laminar radiation shielding. The inside of the vacuum jacket will be cleaned prior to installation. Prior to final assembly and testing, the annular space of all vacuum jacketed piping will be thoroughly cleaned to remove contamination and hydrocarbon residue. In addition, each piece is individually inspected and air-dried prior to assembly.

4.3.1 All surfaces to be cleaned will be completely wetted by means of immersion, circulation, flushing, spraying, or swabbing and dried with dry GN2 or dry, oil-free air.

4.3.2 Cleaned surfaces will be visually inspected for contamination, scale, or rust. Discoloration due to welding will be acceptable. Any visual sign of contamination will be cause for re-cleaning the part.

4.3.3 White cloth, ultra violet, and special cleaning procedures will be dictated by the customer contract and specification requirements and will be addressed in separate specifications.

5.0 INSPECTION AND TESTING

All inspection and testing will be directed by the Quality Assurance Manager and will meet the requirements of the CryoWorks Quality Assurance Manual and contract-related specifications. Quality Assurance is a function and requirement of each employee. Final review of materials certification, welder's qualification, record and test examination, and maintenance of records falls under the direction of the Quality Assurance Manager.

5.1 REQUIRED EXAMINATION

Examinations required by the ASME B31.3 Piping Code are:

- Random Visual Examination
- Random Radiography
- Component and material certification records

5.1.1 Radiography - 5 percent of all inner line butt welds will be random radiographed. Radiographs will be read, and reader sheets will be prepared in accordance with the code by certified technicians.

5.1.2 Pressure Testing - All inner lines will be either pneumatically (not less than 110% of design pressure) or hydrostatically (not less than 150% of design pressure) pressure tested. Test pressure, medium, and time duration will be directed by Engineering/Design and customer requirements.

Pneumatic testing is preferred because of reduced chance of inner line contamination, and when performed with a combination of nitrogen and helium gas, while mass spectrometer leak testing, this method provides more accurate leak detection.

5.2 SUPPLEMENTARY EXAMINATION

Supplementary examination, beyond code requirements, will be detailed in separate specifications and performed as directed by Engineering/Design. Specifications will include type of inspection/tests, procedure or method, standard, and acceptance criteria.

5.3 DIMENSIONAL

Upon completion of fabrication, each spool assembly will be dimensionally inspected to verify that dimensions meet engineering design. At the same time, each assembly will be visually inspected for workmanship, material conditions, and completeness.

5.4 COMBINATION PRESSURE/MASS SPECTROMETER LEAK TEST

5.4.1 With the spool seal-off valve connected to a Mass Spectrometer Leak Detector with a sensitivity of 1×10^{-9} std cc/sec GHe, evacuate the annular vacuum space.

5.4.2 Blank off the inner line for pneumatic pressure test. The inner line will be pressurized with a mixture of 90% dry nitrogen gas and 10% helium gas. Proof pressure will be reached in 25% steps with each step pressure-held for 2 minutes and the vacuum

gauge monitored for increased pressure. The final proof pressure will be held for 10 minutes and the vacuum level monitored.

Any change in pressure indicates a leak.

5.4.3 Upon completion of the pressure test, the pressure will be reduced to maximum design working pressure and the vacuum space (inner line welds) will be tested using the mass spectrometer.

At the same time, the jacket welds will be sprayed or bagged with helium gas. Inner line welds not enclosed by the vacuum jacket will be soap bubble tested for leaks.

A measured leak rate by the mass spectrometer of 1 x 10^{-9} std cc/sec GHe or less constitutes a successful test.

5.4.4 Upon completion of the pressure/leak test the spool will continue over to the evacuation / bake-out processes – see section 6.0 below. Otherwise, the vacuum annulus will be brought back to atmospheric pressure by slowly backfilling with dry nitrogen gas.

6.0 EVACUATION

6.1 EVACUATION PROCESS

6.1.1 Upon the successful completion of the pressure and mass spectrometer leak test, each spool will undergo bake-out and evacuation. The bake-out procedures may be performed prior to the leak testing procedures.

6.1.2 Each line will be heated to between 212°F and 250°F by forcing filtered and heated air through the inner line. The vacuum jacket can be covered with insulating blankets if required. The inlet and exit temperature of the bake-out will be monitored. Each individual line temperature will be monitored to ensure proper exit temperature of the individual spool section.

6.1.3 Upon reaching the prescribed temperature (generally after 1 day), evacuation of the annular space is started using a mechanical fore pump (or dry pump) connected to the system through a diffusion pump and LN2 cold trap to prevent oil from back-streaming (or dry pump w/blower). Heating and pumping are continued until the spool vacuum is less than 5 microns. The time period is determined by the piping size (volume of the annular space) and the history of time/pressure reduction in reaching the 5 micron level. Total time for bake and evacuation is approximately 5 to 7 days.

6.2 VACUUM RETENTION TEST

The vacuum retention test will start after the vacuum seal-off valve has been closed and the spool has returned to ambient temperature. The pressure of each spool will be measured and recorded every 24 hours using the thermocouple gauge tube. Each vacuum reading will be recorded with date, time, and ambient temperature. The minimum test period will be 5 days, unless otherwise authorized by the customer/CryoWorks engineering.

This test will not be required on spools without a vacuum thermocouple gauge tube.

6.2.1 Test Acceptance

6.2.1.1 If daily readings remain unchanged, other than effects of temperature variations, the spool is acceptable.

6.2.1.2 If daily readings increase less than 2 microns per day, and the final maximum stabilized reading after 5 days is below 15 microns, the spool is considered acceptable. The increase in readings of less than 2 microns per day can be attributed to outgassing.

6.2.1.3 A continuous pressure increase throughout the retention period, not attributed to ambient temperature changes or outgassing, is indicative of a leak. The spool will then undergo additional mass spectrometer leak testing until the cause can be found and corrected. The spool will then be baked out and re-evacuated, as required, and subjected to an additional retention test

Note:
When the opportunity presents itself to gather additional vacuum retention data past the required 5 days, or that specified by the customer, readings should still be collected as they will only increase our confidence in the vacuum reliability. Those readings may increase over time due to outgassing. Using similar logic as stated above, the readings after 1 week should not be greater than 19 microns, 2 weeks- 33 microns, 3 weeks- 47 microns, but the overall cut-off should stop at 50 microns regardless of duration.

7.0 FINAL CLEANING

All process surfaces will be final cleaned as required, after final welding, machining, threading, pressure testing, and final evacuation. All components will be pre-cleaned and progressively cleaned during fabrication. Final cleaning applies only to areas and procedures which may be contaminated during fabrication.

7.1 EXAMINATION

All cleaned, exposed exterior surfaces, and interior surfaces to the physical extent possible, will be examined with a wipe technique. The surface will be rubbed in opposite directions with a clean, white paper or lint free cloth and examined. Any evidence of oil, dust rust or grime will be cause for rejection and re-cleaning.

7.2 REQUIRED RE-CLEANING

Parts or assemblies rejected for cleanliness will undergo complete or spot re-cleaning as required. Re-examination is required after re-cleaning.

8.0 PACKAGING AND SEALING

Pipe ends will be sealed with polyethylene sheets or bags to a minimum of 1 inch onto the jacket closure and sealed with water-proof tape. Ends will then be treated appropriate to the degree of protection required to prevent damage during shipment. This may be plywood backing flanges (flange connections), foam wrap (over the nose of bayonets), or other protection as necessary. An additional, polyethylene sheet will be taped into place as the outermost wrap. Threaded ends will be protected with "CAPlugs," or equal prior to applying the final seal. Additional packaging and sealing requirements may be specified by Engineering/Design and/or customer contract.

9.0 LABELING

Each spool will be labeled with a CryoWorks self-adhesive vinyl or tacked on stainless steel tag. The label will be placed near the vacuum seal-off valve and will contain the appropriate information to identify the spool part number, service, etc.

Spools cleaned for oxygen service will be labeled with an additional label indicating "cleaned for oxygen service."