SECTION 40 10 00

GAS AND VAPOR PROCESS PIPING AND DUCTWORK

GENERAL

1.1 INTRODUCTION

A. This section provides guidelines for the development of laboratory compressed, laboratory vacuum, and specialty compressed gas systems. The section includes pipe, pipe fittings, valves, accessories, vacuum pumps, air compressors, and air dryers. Bulk carbon dioxide, nitrogen and oxygen that will not be used for breathing air systems may use this specification for pipe, fittings systems, valves, and accessories.

B. Specialty piping systems are designed to serve specific program requirements independent of general building mechanical systems. Throughout this section references to specialty piping systems shall include all of the systems listed below. When a requirement is only applicable to a specific service that service will be named in the paragraph with the specific requirement. Specialty piping systems may include:

1. Process and equipment vacuum systems
2. Compressed air
3. Nitrogen, standard and ultra-high purity
4. Research grade oxygen
5. Hydrogen, standard and ultra-high purity
6. Argon
7. Liquid nitrogen

1.2 RELATED SECTIONS

A. Section 31 23 00 – Excavation and Fill: Execution requirements for pipe trenches and backfill specified by this section.

B. Section 26 05 83 – Equipment Wiring Connections: Execution requirements for electric connections specified by this section.

1.3 QUALITY ASSURANCE

A. Designer Qualifications: All specialty piping design work shall be signed and stamped by a mechanical engineer licensed in the State of California. Requests for exceptions to this requirement shall be evaluated by the Facilities Department Manager of Engineering Services Division.

B. Installer Qualifications: List of bidders for installation of process piping systems shall be reviewed by the Project Manager to ensure that bidders are qualified.

C. Testing:

1. Process piping installers shall provide testing services as set forth in the Contract Documents.
2. All testing shall be performed in the presence of the Project Manager's representative.
3. Deviations from the cleaning, testing, and certification requirements set forth in the Contract Documents shall be subject to written approval of the Project Manager.

1.4 REFERENCES

A. ASTM International:
1. ASTM B 32 Solder Metal.
2. ASTM B 75 Seamless Copper Tube.
3. ASTM B 88 Seamless Copper Water Tube.
4. ASTM B 280 Seamless Copper Tube for Air Conditioning and Refrigeration Field Service.
5. ASTM B 306 Copper Drainage Tube (DWV).
6. ASTM B 584 Copper Alloy Sand Castings for General Applications.
7. ASTM B 813 Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Alloy Tube.
8. ASTM B 819 Seamless Copper Tube for Medical Gas Systems.
11. ASTM A 47 Ferritic Malleable Iron Castings.
12. ASTM A 536 Ductile Iron Castings.

B. American National Standards Institute/American Welding Society:
1. ANSI/AWS A5.8 Specification for Filler Metals for Brazing.
2. ANSI/AWS A5.31 Specification for Fluxes for Brazing and Braze Welding.

C. ASME International:
1. ASME B1.20.1 Pipe Threads, General Purpose (Inch).
2. ASME B16.18 Cast Copper Alloy Solder Joint Pressure Fittings.
3. ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges.
4. ASME B16.22 Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings.
5. ASME B16.23 Cast Copper Alloy Solder-Joint Drainage Fittings - DWV.
6. ASME B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500, and 2500.
7. ASME B16.26 Cast Copper Alloy fittings for Flared Copper Tubes.
8. ASME B16.29 Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings - DWV.
10. ASME B16.50 Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
11. ASME B16.51 Cast and Wrought Copper and Copper Alloy Press-Connect Pressure Fittings
12. ASME B31.1 Power Piping.
13. ASME B31.5 Refrigeration Piping.
14. ASME B31.9 Building Services Piping.
15. ASME Section IX Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualification.

D. National Fire Protection Association:

E. Manufacturers’ Standardization Society:
   1. MSS-SP-58 Pipe Hangers and Supports - Materials, Design and Manufacture.
   2. MSS-SP-69 Pipe Hangers and Supports - Selection and Application.
   4. MSS-SP-89 Pipe Hangers and Supports - Fabrication and Installation Practices.

F. Compressed Gas Association:

1.5 SUBMITTALS

A. General:
   1. In the absence of specific requirements in the design contract the following submission requirements shall be followed. Confirm the submission requirements with Stanford University Project Manager.
   2. Design drawings, data and calculations at various stages of completion shall be submitted for each phase of the University's plan review process. The specific submission requirements for each phase are outlined below.
   3. Refer also to Section 01 33 00: Submittal Requirements.

B. 100% Schematic Design Submissions:
   1. Selection of types of specialty piping systems.
   2. Preliminary system cost estimate in terms of unit cost (dollars per square foot gross building floor space, dollars per system or component, or similar).
   3. Location of major specialty piping equipment such as compressors, vacuum pumps, or compressed gas cylinders.
   4. Schematic diagrams of major specialty piping systems.

C. 100% Design Development Submissions:
1. Location of all specialty piping equipment.
2. Routing plans for all piping mains.
3. Major riser diagrams.
4. Preliminary design calculations, including selection of major equipment.
5. Preliminary cost estimate for all systems.
6. Outline specifications.

D. 50% Construction Documents Submissions:
1. 50% complete specialty piping plans, sections, and details.
2. Final selection of equipment and systems options considered under Design Development Phase.
3. Design calculations.
4. Revised system cost estimate based on 50% design documents.
5. 50% complete specifications.

E. 95% Construction Documents Submissions:
1. 95% complete design drawings.
2. 100% design calculations.
3. Revised system cost estimate based on 90% design documents.
4. 95% complete specifications.

F. 100% Construction Documents Submissions:
1. Final contract drawings and specifications.
2. Final cost estimate.

G. Contract Closeout:
1. As-Built Drawings: All changes to Contract Drawings and Specifications, including schedules, control diagrams, etc., shall be incorporated into As-Built Drawings in accordance with Section 01 33 00: Submittal Requirements.
2. Operations and Maintenance Manuals shall include complete specialty piping systems operating and service descriptions written by the Consulting Engineer. The descriptions shall supplement any operating instructions provided as part of vendor-furnished equipment. Refer to Section 01 33 00: Submittal Requirements.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Pre-purchased Equipment: The Consultant responsible for the pre-purchase specification of equipment or materials shall consult the Project Manager regarding delivery, inspection and acceptance, storage, and handling of the products.

B. Equipment Furnished by the Contractor: Specific provisions for delivery and storage locations as well as handling, protection, and security measures shall be included in the Contract Documents.
C. Pipe and tube required by the applicable standard to be cleaned and capped shall be delivered to the job site with factory-applied end-caps. Maintain end-caps through shipping, storage, and handling to prevent pipe-end damage and prevent entrance of dirt, debris, and moisture.

D. Protect stored pipe and tube from moisture and dirt. Elevate above grade. When stored inside, do not exceed the structural capacity of the floor.

E. Protect fittings, flanges, and piping specialties from moisture and dirt.

1.7 GENERAL DESIGN CONSIDERATIONS

A. General:

1. Design shall be in accordance with applicable ASHRAE and ASPE handbooks.
2. Maintenance shall be an important design consideration for all systems. Sectional valves are required. Shutdown of parts of systems should not unnecessarily disrupt operation of entire building systems.
3. Energy conservation shall be an important design consideration for all systems.

B. Coordination: The University expects careful design coordination between plumbing, specialty piping, HVAC, and fire protection disciplines.

PART 2 -SPECIALTY PIPING SYSTEM REQUIREMENTS

2.1 PIPE AND PIPE FITTINGS

A. Steel pipe is for use only on industrial compressed air systems. It may not be used in laboratories or after the air compressor. Steel pipe may be used for vacuum pump exhaust line. All piping must be metal for any system that operates over 5 PSIG. Piping between the compressor and the first isolation valve shall schedule 80 steel or Type L annealed copper.

B. Solder and brazing filler materials shall not contain lead (max 0.1%) or antimony (max 0.05%).


1. Fittings: ASME B16.3, malleable iron, or ASTM A234, forged steel welding type.
2. Joints: Threaded or welded to ANSI B31.1.

D. Copper Tubing: ASTM B88 (ASTM B88M), Type L drawn.

1. Fittings: ASME B16.18 cast copper alloy or ASME B16.22, wrought copper and bronze.
2. Joints: ASTM B32, solder, Alloy Grade E (Silvabrite-100 or equal).

E. Copper Tubing: ASTM B819, Type L annealed, Type ACR-OXY.
2. Joints: AWS A5.8 Classification BCUP-3 or BCUP-4 Silver Braze (Silvaloy 15 or equal).

F. Stainless Steel Tubing

1. ASTM SA312 Type 316L seamless stainless steel
2. Joints: butt-welded fittings and joints or orbital welding fittings and joints.
3. With the approval of Stanford Facilities and the Stanford Project Manager flared metal gasket face seal fittings (VCR) may be used.
4. Order pipe, tubing and fittings from manufacturer as pre-cleaned and factory sealed for oxygen use.
5. Up to one inch use tubing, 1-1/4 inch and above use schedule 10 pipes, on exterior H2 use schedule 40 pipes, on all other exterior use schedule 10 pipes.

G. Soldering and Brazing Fluxes: Soldering and brazing fluxes having greater than 0.20-percent Lead (Pb) content are prohibited from use in potable water systems and shall not be used.

1. Soldering Fluxes: ASTM B 813, liquid or paste type.
2. Brazing Fluxes: ANSI/AWS A5.31, Type FB3-A or FB3-C.
   a. The use of brazing flux is not necessary if the components being joined are wrought copper tube, wrought copper fittings and the filler metal being used is of the BCuP series.

2.2 COMPRESSED AIR VALVES

A. Ball Valves: MSS SP-110, Class 150, 400 psi CWP, bronze, two piece body, chrome plated brass ball, regular port, teflon seats and stuffing box ring, blow-out proof stem, lever handle, threaded or brazed ends.

B. Air Outlets: Quick Connector: 3/8 inch brass, snap on connector with self-closing valve, Style A.

2.3 AIR PRESSURE REDUCING VALVE

A. Pressure Reducing Station: Consisting of automatic reducing valve and bypass, and low pressure side relief valve and gage. Provide oil separator where indicated.

B. Valve Capacity: Reduce pressure from 200 psi to 30 psi, adjustable upward from reduced pressure.

2.4 COMPRESSED AIR CHECK VALVE

A. Tubing check valve: brass body, brass seat, 316 stainless steel spring, 1/2 psi cracking pressure. Oxygen cleaned by manufacturer. TCV series valve, Check-All Valve Manufacturing or equal (no known equal).
2.5 COMPRESSED AIR PRESSURE REGULATOR

A. At service point to laboratories provide an ASME rated pressure regulator. Regulator shall accept inlet pressures up to 500 PSI and shall reduce outlet pressure between 1 and 60 PSI. Outlet pressure shall be easily adjusted with hand operated valve configured for setting pressure between 1 and 60 PSI in 2 PSI increments. Manufacturer: Fairchild Model 10 or Model 100, Fischer-Rosemount, or equal.

2.6 ACCESSORIES

A. Piping Identification: Pressure sensitive adhesive tape and decals, color and labeling to conform to 23 05 53 – Identification of HVAC Piping and Equipment.

2.7 GAS OUTLETS

A. Outlet Units: CGA V-5, Diameter Index Safety System (DISS), NFPA 99 non-interchangeable connectors, automatic valves, secondary check valves (except vacuum and evacuation outlets), and capped 3/8 inch (8 mm) tubing stubs for supply connections, color coded and labeled for intended service.

B. Faceplates:
   1. Flush Outlets: Mount in galvanized steel boxes with stainless steel faceplate with Lexan cover, color coded with embossed labeling.
   2. Surface Outlets: Surface mount with color-coded plastic cover and stainless steel faceplate with Lexan cover, color-coded with embossed labeling.

2.8 AIR COMPRESSORS AC-1

A. Sizes, type and capacity as shown on schedule.

B. Complete packaged triplex assembly. Three motor-driven common base skid-mounted oil-less compressors with UL listed triplex electrical control in a NEMA Type 12 control cabinet, AMSE receiver, aftercooler, refrigeration type air dryer and inline air intake filter/muffler. Assemble on heavy-duty fabricated steel sub-base frame completely pre-wired and pre-piped to a single-point service connections including air dryer. Factory test prior to shipment.

C. Cycling Refrigeration Air Dryer: Automatic drain trap and a three valve bypass system. Provide a pressure dew point of 35ºF at 100 PSIG. Dryer will be mounted and piped on compressor skid and wired to the compressor control panel. A separate disconnect switch shall be furnished as standard on the dryer instrument panel.

D. Receiver: Construct in accordance with appropriate ASME standards with National Board label affixed. Include pressure gage with dial graduated to double the operating pressure, pressure relief valve, gage glass, liquid sensing switch and automatic drain trap. Tank shall be galvanized steel.

E. Motors: Standard open frame, drip-proof, ball bearing, 40ºC rise, NEMA standard Design B induction type. Voltage as listed and required.
F. UL Listed Triplex Electrical Control System: Mount in NEMA Type 12 cabinet. Include panel main disconnect switch, fusible disconnect switches, magnetic starters, hand-off-automatic (H-O-A) selector switches. 115-volt control transformers, timed unloader controls and automatic lead pump alternator. The external display shall include indicator lights to show each compressor “on” warning lights with horn and reset buttons to show thermal overload. All compressors over 5 HP shall be equipped with a run time meter. Trouble alarm dry contacts connection to BMS.

G. Factory-trained service representative to review per manufacturer's recommendations, the assembly prior to initial start-up and operation instructions

H. Provide all necessary inter-connections between compressors, controls and sensors.

I. Provide high/low pressure switch for connection to BMS.

2.9 VACUUM PUMPS VP-I

A. Sizes, type and capacity as scheduled on drawings.

B. Complete factory-assembled packaged expandable vacuum system mounted on a common skid. Two motor-driven pump units with ASME code receiver and UL listed automatic alternating control system in a NEMA 12 control cabinet. Assembly is pre-piped and pre-wired to a single-point service connections. Factory test prior to shipment.

C. Each pump shall be equipped with an automatic purge system to flush any gases from the pump to prevent condensation as the pump cools. Purge system shall include isolation valve and actuator, solenoid bleed valve, and controls to operate a 15-minute shutdown purge. If the supply of air or power is discontinued, the isolation valve will go to the closed position and the purge valve will go to the open position. The lead pump shall be time alternated and shall operate on a pressure-activated basis. Each pump shall be supplied with the initial charge of oil. Each pump shall be supplied with a threaded exhaust adapter to permit piping of the exhaust gases to a remote point.

D. Pump Assembly: Two rotary vane, continuous duty, oil sealed, air cooled vacuum pumps, each with two needle bearings, two shaft seals and two fans to ensure cool operation. Pumps shall be skid mounted in a vertical arrangement which allows for future expansion to a triplex system.

E. Appurtenances: Provide for each vacuum pump, check valves, isolation valves, oil filter and bypass, conical inlet screen, inlet particulate filter and vacuum gage.

F. 200 gal. Receiver: Construct in accordance with ASME standards with National Board Label affixed and in steel construction. Furnish with gage glass assembly and drain valve.

G. Motors: Totally enclosed, fan cooled motors, ball-bearing. 40ºC rise, NEMA standard Design B, induction type. Voltage as listed and required.

H. UL Listed Duplex Electrical Control System: Mount in NEMA 12 cabinet. Include panel main disconnect switch, fusible disconnect switches, magnetic motor starters with
overload relays and reset switches, 110-volt control circuit transformers, vacuum control switches, can timer for automatically switching the operating sequence of the pumps, hand-off automatic selector switches and running lights. The entire control system shall be configured for future expansion to an automatic alternating triplex and a quadruplex unit. Trouble alarm dry contacts for connection to BMS.

I. Include a factory-trained service representative to review, per manufacturer’s recommendations, assembly prior to its initial start-up and operation instruction.

J. Provide pressure switch for connection to BMS.

2.10 NITROGEN

A. Nitrogen piping shall be piped in ACR Type L copper with brazed fittings and to the requirements in Facilities Design Guide section on Compressed Air and Vacuum Systems.

2.11 OXYGEN, ARGON, ULTRA HIGH PURITY NITROGEN AND HYDROGEN:

A. Piping: ASTM SA312 Type 316L seamless stainless steel with butt-welded fittings and joints. With the approval of Stanford Facilities and the Stanford Project Manager flared metal gasket face seal fittings (VCR) may be used. Order pipe, tubing and fittings from manufacturer as pre-cleaned and factory sealed for oxygen use. Up to one inch use tubing, 1-1/4 inch and above use schedule 10 pipes, on exterior H2 use schedule 40 pipes, on all other exterior use schedule 10 pipes.

B. Valves:

1. ½” point of use valves: Nupro series stainless steel UW bellows valve with tube extensions for butt-welding.
2. ½” and ¾” line valves: “Carten Systems” stainless steel diaphragm valve with tube extension and purge ports for butt-welding.
3. 1” and larger: Copper stainless steel ball valves with tube extension for butt-welding.

2.12 LIQUID NITROGEN:

A. MVE or CVI vacuum jacketed cryogenic pipe with Bayonet type fittings. Inner pipe to be constructed out of Invar or 304SS. Jacket shall be 304 stainless steel. Vacuum jacket shall be 304 stainless steel. Vacuum jacket must have provisions for re-evaluation and shall be included as in integral part of the system. Rigid and flexible sections of the system shall be designed for easy adaptation for the dislocation and stresses caused by temperature differentials. Piping shall be designed to withstand a maximum working pressure of 100 PSIG.
2.13 GAS MANIFOLD SYSTEMS

A. Gas Manifold: Consist of wall mounted controls cabinet and necessary header connection and pigtails for multiple cylinders. Arrange controls to have half of cylinders in service and half in reserve.

B. Manifold Delivery: Provide automatic changeover from primary to secondary bank and allow replacing depleted cylinders with no change in line pressure. Provide bank regulators to reduce cylinder pressure for line regulator with adjustable set point. Provide manifold relief valve with and adjustable set point.

C. By-pass System: Between regulators to service regulator or switch over system without interrupting supply of gas. Bleed valves allow adjustment of pressure reducing regulators.

D. Cabinet: House components in lockable cabinet with baked enamel finish.
   1. Three front mounted gages indicate bank and hospital line pressures.
   2. Green indicator light indicates service bank in use.
   3. Red indicator light indicates reserve bank in use.
   4. Provide terminal block connections for remote alarm.

PART 3 -EXECUTION

3.1 PREPARATION

A. Requirements for high purity compressed air systems.
   1. Pre-Installation Cleaning: Disassemble positive pressure gas systems pipe, fittings, valves, and components, except those supplied cleaned and prepared for intended service, and thoroughly wash in hot solution of sodium carbonate or trisodium phosphate mixed 1 lb to 3 gal of water. After washing, rinse with water, dry and cap until installation.

3.2 PIPING SCHEDULE

A. Laboratory Compressed air
   1. Copper Tube ASTM B88 (ASTM B88M), Type L drawn

B. Laboratory Vacuum
   1. Copper Tube (ASTM B88M), Type L drawn
   2. Vacuum exhaust may be Steel Pipe: ASTM A53, Schedule 40 black

C. Compressed specialty gases
   1. ASTM B819, Type L annealed, Type ACR-OXY
D. ASTM SA312 Type 316L seamless stainless steel with butt-welded or orbital welded fittings and joints. With the approval of Stanford Facilities and the Stanford Project Manager flared metal gasket face seal fittings (VCR) may be used. Order pipe, tubing and fittings from manufacturer as pre-cleaned and factory sealed for oxygen use. Up to one inch use tubing, 1-1/4 inch and above use schedule 10 pipes, on exterior H2 use schedule 40 pipes, on all other exterior use schedule 10 pipes.

E. Cryogenic Liquids

1. MVE or CVI vacuum jacketed cryogenic pipe with Bayonet type fittings. Inner pipe to be constructed out of Invar or 304SS. Jacket shall be 304 stainless steel. Vacuum jacket shall be 304 stainless steel.

3.3 PIPING INSTALLATION

A. General:

1. Piping shall be protected from damage and contamination during transport and construction. Exposed ends of piping shall be kept sealed prior to and during erection and at the end of each working day.
2. Specialty gas and copper tubing and piping shall be cut with dedicated wheel cutter. Cut ends shall be square to form proper seating in socket fittings. All cut ends shall be reamed and deburred.
3. Tools used for copper pipe cutting and installation may only be used on copper piping systems. Copper fragments may contaminate other systems if the tools are used on other piping systems.

B. Plastic Piping: All plastic piping systems shall be installed in strict accordance with pipe manufacturer's recommendations, including preparation of pipe fittings for joining, selection of solvent and primer, curing, and installation.

C. Piping Supports:

1. Spring vibration isolation pipe hangers shall be installed in mechanical rooms and areas sensitive to vibration. The drawings shall indicate specific areas where this requirement applies.
2. Polypropylene piping shall be supported on continuous trough supports, with hanger spacing and rod sizes same as specified for metallic piping. Troughs shall be galvanized steel V or U shape, or semi-circular shape. V or U shape troughs shall have blocking at hangers to prevent rotation. Troughs shall be sized for a maximum deflection of 1/360th of span under actual loads, with "S" equal to 25,000 psi, and "E" equal to 29,000 psi.

3.4 WELDING AND BRAZING

A. Welder Qualification: All welders must be qualified to pass ASME, Section IX Code, pipe weld in 6-G position, where the root pass will be evaluated for cleanliness (the root
B. Specialty Piping Welding (Steel Piping):

1. Base Metal: This procedure outlines the method of joining Austenitic stainless steel to Austenitic stainless steel.
   a. Grade: The materials used in production shall meet the requirement of the applicable ASTM specification, depending on its form (i.e., pipe, tubing, etc.).
   b. Alternate materials: Changes in alloy must be made within the ASME P-number alloy group. When substitutions are made within this alloy group, care shall be taken to also change the filler metal alloy within the filler metal composition group.
   c. Weld on VCR metal gasket face seal fittings may be used on piping for non-toxic, non-flammable gases and liquids.

2. Filler Material: Filler wire shall conform to ASME SFA-5 or ASTM A371. It shall be stored and handled in such a manner that it remains clean and dry. Wire that has been contaminated with oil or grease, or has lost its identity shall be discarded.

3. Preparation of Base Metal: Edges or surfaces of the parts to be welded shall be prepared by machining, cutting, or a combination of these methods. All piping material shall be cleaned as previously described. All surfaces shall be thoroughly dry (moisture free) before welding commences. Purge weld shall be gassed back for three to five (3 to 5) minutes at appropriate flow rate.

4. Electrical Characteristics: Welding shall be done with direct current, straight polarity (electrode negative, work positive). High frequency arc starting shall be used.

5. Welding Techniques:
   a. Welding shall be from outside only on pipe configurations.
   b. Tack welds shall be of the same quality as required in the completed weld and shall be visually examined for defects before applying any complete passes. The ends (starts and stops) of the tacks shall blend in smoothly with the base metal so that subsequent passes can be applied without interruption.
   c. All excessive oxidation remaining on any weld bead shall be removed by stainless steel wire brushing only before depositing subsequent beads. Iridescent discoloration is not considered "excessive oxidation" and does not need removal. Wire brushes shall have stainless steel bristles only, and shall not have been used previously on carbon steel or oily surfaces.
   d. Backup shielding (Argon) shall be provided to the backside of the material in the local area of the weld. The area shall be purged to replace
atmospheric gases with argon. A flow rate of five to fifteen (5 to 15) CFH shall be maintained to ensure a slight positive pressure.

e. Inspection: Visual inspection shall be done by the welder and the Project Manager's representative after each pass.

f. Inspection Criteria: Cracks, cold laps, open porosity and tungsten inclusions shall not be allowed. If the above occurs, the weldment shall be removed and rewelded per this specification. Weld beads shall be applied in such a manner that they are smooth into adjacent beads and the base metal with no areas, such as crevices, undercuts, or overlaps, that would weaken the structure or prevent adequate penetration of subsequent weld passes. Undercut of the final pass which reduces the initial material thickness shall be repaired by additional welding.

6. Repair: All materials welded using this procedure or which fall within the requirements of this procedure may also be repair welded using this procedure.

7. Interpass Temperature: Interpass temperature shall not exceed 350oF, which shall be checked with temp stick or surface pyrometer. The temp stick shall not be applied in such a manner that the melted wax could flow or spread into the weld.

C. Specialty Piping Brazing:

1. All brazing operators shall be qualified in accordance with the tests described below. The Contractor shall be responsible for qualifying the brazing operation as follows:

a. Test samples of each operator's work shall be made according to the procedure set forth below.

b. These samples shall be sawed in half and torn apart to reveal the soundness of the joint.

c. These samples shall also be examined for cleanliness, oxides, and other contaminants. Test samples will be inspected for weld penetration. Minimum penetration shall be eighty-five percent (85%), and maximum penetration shall be one-hundred-ten percent (110%).

d. These tests to qualify brazing operators shall be witnessed by the Project Manager's representative.

e. The Contractor shall notify the operators whose work is judged to be below standard and they shall not be permitted to continue this type of work.

2. Copper lines shall be brazed using an oxygen-acetylene system with the torch slightly on the carbonizing side.

3. Braze Alloy: For all copper lines, all joints shall be brazed with a fluxless brazing alloy such as copper-phos or sil-floss (15% silver).

4. During brazing, all gas lines shall be continuously purged with nitrogen gas, which shall be allowed to escape into the atmosphere through a purge restrictor.
No brazed joint shall be less than twelve inches (12”) away from the end of the purge, which will require in many instances that an extension be used. For each purge restrictor used, a minimum flow of ten to fifteen (10 to 15) SCFH of nitrogen purge gas shall be used, but in all cases sufficient purge gas shall be used to prevent oxidation. This shall be checked by welder and the Project Manager's representative prior to welding.

5. All joints that show evidence of overheating, cracking, poor penetration, or other defects of fit-up or workmanship shall be replaced as directed by the Project Manager at Contractor's expense.

6. If the system becomes contaminated prior to acceptance, the Contractor must replace the entire system at no expense to the University if so required by the University.

D. Welding of Stainless Steel Tubing

1. Stainless steel tubing shall be butt welded or orbital welded when used in high purity applications.

2. Welds shall conform the criteria established in ASME B31.3.

3. Any discoloration of the weld or HAZ as a result of oxidation during welding must be held to a minimum. A light discoloration may be permissible if it is tight to the surface, but the amount allowed (if any) for a particular installation is subject to agreement between the owner/user and the contractor. Discoloration has been shown to be proportional to the amount of oxygen (and moisture) in the ID purge gas which is usually argon. A cryogenic source (dewar or bulk gas supply) is recommended for urging during welding of high purity laboratory systems.

3.5 FIELD QUALITY CONTROL

A. General:

1. Any deviation from the cleaning, installation testing, and certification requirements herein shall be approved in writing by the Project Manager.

2. All materials and workmanship shall be subject to inspection and examination by the Project Manager's representative at any place where fabrication or erection is carried on.

3. The Owner reserves the right to reject all or any part of the system that does not conform to the requirements herein. Rejected materials or equipment shall be returned at the Contractor's expense.

4. The University reserves the right to remove random samples of the installed work sufficient to establish the quality of materials and workmanship. If such samples indicate materials or workmanship do not meet the contract specification, the Contractor shall be required to replace or re-clean the installed work at no expense to the University. The University shall reimburse the Contractor on a time and materials basis for such work if the system proves to be installed to specification.

5. All testing shall be done in the presence of the Project Manager's representative.

6. Only high-purity cryogenic nitrogen and argon shall be used for purging and leak pressure testing of high purity piping systems.
7. The purity of the gases shall be maintained throughout the entire installation of gas delivery systems. A certified gas analysis will be required by the Owner to guarantee that the final purity of the gases at points of use is the same as that of the cryogenic purging supply at the completion of construction. Analytical purity testing shall be performed at one-hundred percent (100%) completion of construction. The Project Manager's representative shall approve the sampling procedure, analytical test methods, and analytical laboratory used.

8. Upon completion of this work, all systems shall be adjusted for use. Should any piece of apparatus or any material or work fail in any of these tests, it shall be immediately removed and replaced by new materials. The defective portion of the work shall be replaced by the Contractor in the presence of the Project Manager's representative at no expense to the University.

9. Test gauges shall be installed and test medium source connections shall be made to convenient specialty connections. After completion of testing, the gauges and source connection shall be removed and the specified specialty attachments replaced.

10. Only gauges cleaned for O2 service shall be used.

11. After each system is accepted by the University, Contractor shall leave system with a "block purge" of forty to fifty (40-50) PSIG.

12. Any leaks found shall be repaired in the following manner:
   a. Welded joint - Reweld
   b. Brazed joint - Rebrazed
   c. Plastic joint - Remove/Reweld
   d. Screw joint - Tighten (do not use compound) or replace as directed by the Project Manager's representative.

B. Pipe Testing:

1. All piping shall be tested as noted below. Test pressures shall be maintained until all leaks have been identified.

2. Defective piping shall be repaired or replaced until tests are accomplished successfully.

3. The use of oil-pumped air or nitrogen is expressly forbidden. All air and nitrogen used for testing and purging operations must be from a cryogenic source.

<table>
<thead>
<tr>
<th>System</th>
<th>Testing Pressure</th>
<th>Testing Media</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen, Compressed air</td>
<td>150 PSIG</td>
<td>Nitrogen</td>
<td>24 hours</td>
</tr>
<tr>
<td>Vacuum</td>
<td>50 PSIG</td>
<td>Water</td>
<td>4 hours</td>
</tr>
<tr>
<td>Hydrogen, Argon and other Ultra-high purity gases</td>
<td>200 PSIG</td>
<td>Nitrogen</td>
<td>24 hours</td>
</tr>
<tr>
<td>Liquid Nitrogen</td>
<td>150 PSIG</td>
<td>Nitrogen</td>
<td>24 hours</td>
</tr>
</tbody>
</table>
C. Welding Tests: Pressure testing shall be at 1-1/2 times the operation pressure (not to exceed any design pressure), or as specified above, for a period of twenty-four (24) hours without any variations of pressure that cannot be accounted for other than a change in temperature.

1. The pressure shall be reduced to operation pressure and held at that pressure for a period of twenty-four (24) hours without any loss.
2. Visual inspection shall be made for undercutting, porosity, inclusions, and cracking.
3. Helium leak testing shall be required for all high purity systems.

3.6 INSTALLATION

A. Install line size isolation valve and check valve on compressor discharge.
B. Place shut off valve on water inlet to Aftercooler. Pipe drain to floor drain.
C. Connect condensate drains to nearest floor drain with copper DWV piping.
D. Install drip connections with valves at low points of piping system.
E. Install take-off to outlets from top of main, with shut off valve after take-off. Slope take-off piping to outlets.
F. Install compressed air couplings, female quick connectors, and pressure gages where outlets are indicated.
G. Install tees instead of elbows at changes in direction of piping. Fit open end of each tee with plug.
H. Identify piping system and components.
I. Braze joints in pipe and tubing. Avoid leaving excess flux inside of pipe and fittings. During brazing of pipe connections, purge interior of pipe continuously with nitrogen.
J. Effect changes in size with reducing fittings. Make changes in direction of required turns or offsets with fittings or tubing shaped by bending tools. Make bends free of flattening, buckling or thinning of tube wall.
K. Cut pipe and tubing accurately and install without springing or forcing.
L. Install pipe level or grade piping down in direction of flow.
M. Provide pipe sleeves where pipes and tubing pass through walls, floors, roofs, and partitions.
N. Finish flush at both ends. Extend 2 inches above finished floors. Pack space between pipe or tubing and sleeve, and caulk.
O. Identify piping with tape and decals. Provide piping identification code and schematic. Install labeling on pipe at intervals of not more than 20 feet and at least once in each room and each story traversed by pipeline.

P. Coordinate provision of utility warning and identification tape with backfill operation. Provide above all buried lines at a depth of 8 to 12 inches below finish grade.

Q. Install underground piping in trench minimum 42 inches deep adequately protected against physical damage and corrosion, or in ducts and tunnels, which are not occupied by fuel oil lines and are vented.

R. Except where indicated or in flush wall mounted cabinets, install manual shut off valves with stem vertical and accessible for operation and maintenance.

S. Install strainers on inlet side of main pressure reducing valves. Provide main gas valves (pressure reducing or flow control) with bypasses and isolation valves to permit maintenance without interruption of gas.

T. Provide a by-pass with valves, around receivers.

3.7 FIELD QUALITY CONTROL

A. 01 77 00 – Closeout Procedures: Testing, adjusting, and balancing.

B. Test for Compressed Air Piping Leak Test: Prior to initial operation, clean and test compressed air piping in accordance with ANSI B31.1.

C. Independent testing agency to certify system is complete, zone valves installed, alarm systems functional, and tests performed. Document tests and submit.

D. Ensure that there is atmospheric pressure in piping systems, other than the system under test.

E. Test system with dry compressed air or dry nitrogen with test pressure in piping system at 3 times system operating pressure.

F. Check each station outlet of every piping system to determine test gas is dispensed only from outlet of system under investigation. Measure pressure with gage attached to specific adapter. Do not use a universal adapter.

G. Disconnect test gas and connect proper gas to each system. Purge entire system to remove test gas. Check with analyzer suitable for gas installed.

3.8 CLEANING

A. Section 01 77 00 – Closeout Procedures: Final cleaning.

B. After erection of pipe and tubing but prior to installation of service outlet valves, blow systems clear of free moisture and foreign matter with nitrogen gas.
C. Install service outlet valves, subject system to test pressure equal to 150% of operating pressure with nitrogen or dry compressed air. Check with soapy water. Provide 24-hour standing pressure test.