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USACE / NAVFAC / AFCESA | **UFGS-15217N (September 1999)**

Preparing Activity: NAVFAC | **Replacing without revision NFGS of same number and date**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 23 June 2005
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SECTION TABLE OF CONTENTS

DIVISION 15 - MECHANICAL

SECTION 15217N

MEDICAL GAS AND VACUUM PIPING

09/99

-- End of Section Table of Contents --

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SECTION 15217N

MEDICAL GAS AND VACUUM PIPING
09/99

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NOTE: This guide specification covers the requirements for materials, performance, installation, and testing for medical gas and vacuum systems.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.
****

****
NOTE: Indicate the following information on the project drawings:

1. Pressure gage sizes, ranges, and case types.

2. Pressures, flow rates, and other conditions for valves, outlets, filters, piping (pipe and fittings), and equipment.

3. Alarm systems and controls details.

4. Motor sizes in kilowatt or horsepower, and power requirements.

5. Air compressor, compressor receiver, vacuum pumps, anaesthesia gas evacuation pumps, oral evacuation pumps, and accessories installation details, indicating sizes, identification numbers, capacities, and operating pressures, and other

operating conditions.

6. Medical gas cylinder manifold systems, including non-ferrous manifold, fittings, valves, parts, anchorage, and connections rated at 20,682 kPa (gage) 3,000 psig working pressure for each type of medical gas.

7. Do not locate medical air compressor near patient care areas that would be adversely affected by compressor noise or vibration. Provide medical air compressors with a water supply piped from the medical facility's potable water system. Provide reduced-pressure backflow preventer on potable water branch to compressor. Do not recirculate exchange water. An energy recovery heat exchanger may be used. Dust, dirt, and oil fume conditions at the project location may require the installation of air cleaners on the compressors.

8. Bulk liquid oxygen systems, including liquid oxygen storage tanks, evaporators, piping, and controls.

9. Vibration and noise isolators, seismic restraints, equipment bases, inertia bases, and foundations for equipment and piping.

10. Emergency liquid oxygen connection point details.

11. Sizes of pipe and fittings. Include purge vent valve "dirt leg" locations and details.

12. Electrical receptacle locations.
****

PART 1 GENERAL

1.1 REFERENCES

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NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI A13.1	(1996; R 2002) Scheme for Identification of Piping Systems

ANSI B16.18	(1984; R 1994) Cast Copper Alloy Solder Joint Pressure Fittings

AMERICAN WELDING SOCIETY (AWS)

AWS A5.28	(1996) Low Alloy Steel Electrodes for Gas Shielded Metal Arc Welding
AWS A5.8	(1992) Filler Metals for Brazing and Braze Welding
AWS B2.1	(2000) Welding Procedure and Performance Qualification
AWS B2.2	(1991) Brazing Procedure and Performance Qualification
AWS Z49.1	(1999) Safety in Welding, Cutting and Allied Processes

ASME INTERNATIONAL (ASME)

ASME B16.22	(2002) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B40.1	(1991) Gauges - Pressure Indicating Dial Type - Elastic Element
ASME BPVC SEC VIII D1	(2001) Boiler and Pressure Vessel Code; Section VIII, Pressure Vessels Division 1 - Basic Coverage

ASTM INTERNATIONAL (ASTM)

ASTM A 167	(2004) Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A 269	(2004) Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A 403/A 403M	(2004) Wrought Austenitic Stainless Steel Piping Fittings
ASTM B 280	(2003) Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
ASTM B 32	(2004) Solder Metal
ASTM B 43	(1998; R 2004) Seamless Red Brass Pipe, Standard Sizes
ASTM B 88	(2003) Seamless Copper Water Tube
ASTM B 88M	(2003) Seamless Copper Water Tube (Metric)
ASTM C 552	(2003) Cellular Glass Thermal Insulation

ASTM D 1785	(2004a) Poly(Vinyl Chloride)(PVC) Plastic Pipe, Schedules 40, 80, and 120
ASTM D 2466	(2002) Poly(Vinyl Chloride)(PVC) Plastic Pipe Fittings, Schedule 40
ASTM D 2467	(2004e1) Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
ASTM D 2564	(2004) Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
ASTM D 2855	(1996; R 2002) Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings

COMPRESSED GAS ASSOCIATION (CGA)

CGA G-10.1	(2004) Commodity Specification for Nitrogen
CGA G-7.1	(2004) Commodity Specification for Air
CGA G-8.1	(1990) Nitrous Oxide Systems at Consumer Sites
CGA P-2.1	(1983) Medical-Surgical Vacuum Systems in Health Care Facilities
CGA V-1	(2003) Compressed Gas Cylinder Valve Outlet and Inlet Connections
CGA V-5	(2000) Diameter-Index Safety System (Non-Interchangeable Low Pressure Connections for Medical Gas Applications)

COPPER DEVELOPMENT ASSOCIATION (CDA)

CDA A4015	(1994; R 1995) Copper Tube Handbook

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-110	(1996) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
MSS SP-58	(2002) Pipe Hangers and Supports - Materials, Design and Manufacture
MSS SP-69	(2002) Pipe Hangers and Supports - Selection and Application
MSS SP-72	(1999) Ball Valves with Flanged or Butt-Welding Ends for General Service
MSS SP-80	(2003) Bronze Gate, Globe, Angle and Check Valves
MSS SP-81	(2001) Stainless Steel, Bonnetless,

	Flanged, Knife Gate Valves
MSS SP-88	(1993; R 2001) Diaphragm Valves
MSS SP-89	(1998) Pipe Hangers and Supports - Fabrication and Installation Practices

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2004) Industrial Controls and Systems: Controllers, Contactors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC
NEMA ICS 6	(1993; R 2001) Industrial Control and Systems: Enclosures
NEMA MG 1	(2003; R 2004) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 50	(2001) Bulk Oxygen Systems at Consumer Sites
NFPA 70	(2005) National Electrical Code
NFPA 99	(2005) Health Care Facilities

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA Seismic Restraint Mnl	(1998, 2nd Ed) Seismic Restraint Manual: Guidelines for Mechanical Systems

THE SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC SP 6	(2000) Commercial Blast Cleaning

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS A-A-1689	(Rev B) Tape, Pressure-Sensitive Adhesive, (Plastic Film)

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.104	Oxygen

1.2 RELATED REQUIREMENTS

Section 15050N BASIC MECHANICAL MATERIALS ND METHODS, applies to this section with the additions and modifications specified herein.

1.3 SUBMITTALS

****

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item

should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Medical gas systems

Vacuum systems

Equipment foundations

SD-03 Product Data

Compressors

Liquid oxygen storage tank

Manifold

Station outlets and terminal units

Pipe and fittings

Pumps

Specialties

Valves

Vibration isolators

SD-06 Test Reports

Component tests

Cross-connection tests

Bulk liquid oxygen system tests

Final alarm tests

Final purging and testing

Gas source tests

Holding charges

Medical air compressor and vacuum pump tests

Positive pressure tests

System contaminant level tests

Vacuum systems tests

The testing agency shall prepare test reports for systems, equipment, and station outlets and terminals. The testing agency may either mobilize on the project site or test gas samples from sample bottles submitted by the Contractor. Upon completion of field tests, the Contractor shall provide documentation of the name of individuals performing tests and actual testing procedures. The Contractor shall provide a certification that test results were within limits permitted by these specifications.

SD-07 Certificates

Detail field testing procedures

Medical gas systems testing agency qualifications

Welder and brazer procedures and qualifications

SD-10 Operation and Maintenance Data

Bulk liquid oxygen systems, Data Package 4

Compressors, Data Package 4

Medical gas cylinder manifold systems, Data Package 4

Medical air systems, Data Package 4

Pumps, Data Package 4

Submit in accordance with Section 01781 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

Bulk liquid oxygen systems

Compressors

Medical air systems

Medical gas cylinder manifold systems

Piping systems diagrams

Pumps

1.4 DEFINITIONS

See NFPA 99, Chapter 2, Definitions, paragraph entitled "Definitions of Terms Used in the Standard."

1.5 QUALITY ASSURANCE

Materials, performance, installation, and testing shall comply with NFPA 99 with modifications and additions specified herein. The NFPA 99 recommendations shall be considered by the Government as mandatory requirements. Substitute the word "shall" for the word "should" in these manuals.

1.5.1 Procedures and Qualifications

Submit detail field testing procedures, medical gas systems testing agency qualifications, and welder and brazer procedures and qualifications. Include data on test methods, testing instruments and equipment, and instrument calibration sources and method references.

1.5.2 Qualifications of Testing Agency

Provide a testing agency for the approval of the Contracting Officer. The testing agency shall be independent of the medical gas equipment manufacturer and supplier. Provide names and locations of three projects where testing of gas systems has been performed by the testing agency. Include names and phones of owners and project supervisors for these projects. Provide a written statement that these projects are of similar scope of that stipulated in this specification.

1.5.3 Welder and Brazer Procedures and Performance Qualifications

Comply with AWS B2.1 and AWS B2.2.

1.5.4 Regulatory Requirements

AWS Z49.1 for brazing, soldering, and welding; 29 CFR 1910.104for oxygen; CGA G-8.1 for nitrous oxide; and Section 15050N BASIC MECHANICAL MATRIALS AND METHODS, paragraph entitled "Equipment Safety."

1.5.5 Design Requirements

1.5.5.1 Detail Drawings

Submit 610 by 910 mm 24 by 36 inch detail working drawings showing medical gas systems: oxygen (including oxygen and bulk liquid oxygen), nitrous oxide, nitrogen, and medical air; vacuum systems: vacuum, oral evacuation, and anesthesia gas evacuation systems; and equipment foundations: noise and vibration isolators, seismic restraints, equipment bases, inertia bases, and foundations for equipment and piping.

1.5.5.2 Piping Systems Diagrams

Submit texts and piping systems diagrams of oxygen, nitrous oxide, nitrogen, and medical air.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Pipe and Fittings

Sized and made for pressures and other design conditions as indicated.

2.1.1.1 Metal Pipe and Fittings

Oxygen, Nitrous Oxide, Nitrogen, Medical air, and Vacuum systems (include oral evacuation system and anesthesia gas evacuation system):

a. ASTM B 88M ASTM B 88 or ASTM B 280 ACR (air conditioning and refrigeration), seamless Type K or L hard-drawn copper tubing for above ground and inside buildings, and soft drawn (annealed) for underground. In lieu of copper tubing, standard weight (Schedule 40) brass pipe per ASTM B 43 may be used. Provide ANSI B16.18 cast copper, ASME B16.22 wrought copper, or brass fittings.

b. ASTM A 269 seamless stainless steel tubing, Type 304, 304L, or 316. Provide matching stainless steel fittings.

2.1.1.2 PVC Piping, Oral Evacuation System Only

ASTM D 1785, Type 1 (normal impact), Grade 1 (chemical resistance), Cell Classification 12454-B, Schedule [40] [80] pipe. Provide [ASTM D 2466] [ASTM D 2467] socket fittings and ASTM D 2564, PVC solvent cement with PVC primer recommended by pipe manufacturer. Provide wye cleanouts.

2.1.2 Valves

NFPA 99, sized and made for pressures and other design conditions as indicated. Valves of same type shall be the product of one manufacturer, uniform in pattern and appearance, color coded and labeled for the intended service. Identification plates may be used in lieu of labels. Submit calibration chart of the flow measuring device of each pressure reducing regulator.

2.1.2.1 Ball Valves (Oxygen and Nitrous Oxide)

For sizes 50 mm 2 inches or smaller, MSS SP-110, copper alloy valve design which permits inspection and repair of seats and seals without removing the

valve body, or valve ends, from the line. For sizes 65 mm 2 1/2 inches or greater, MSS SP-72, flanged connections, bronze or stainless steel body. Provide double-seal construction with replaceable Buna-N, neoprene, or polytetrafluoroethylene (TFE) seat seals. Provide valves suitable for at least 2068 kPa (gage) 300 pounds per square inch gage (psig), cold water, non-shock working pressure.

2.1.2.2 Diaphragm Valves (Oxygen, Nitrous Oxide, and Nitrogen)

MSS SP-88, brass-bodied, packless, diaphragm type with regrindable or renewable seats and disks capable of being disassembled in line for servicing o-ring and seating surfaces. Provide valves suitable for at least 2068 kPa (gage) 300 psig, cold water, non-shock working pressure.

2.1.2.3 Pressure Reducing Regulators

Hospital regulators with a calibrated flow measuring device and CGA V-1 valve connections. Minimum accuracy of flow measure device shall be plus or minus 3 percent for the intended use.

2.1.2.4 Gate Valves (Vacuum, Medical Air, and Anesthesia Gas Evacuation)

MSS SP-80 bronze, solder ends; or MSS SP-81, stainless steel, welded ends.

2.1.2.5 PVC Body Ball Valves (Oral Evacuation Systems Only)

PVC body double-seal ball valves with replaceable neoprene or TFE seat seals. Provide valves suitable for at least 690 kPa (gage) 100 psig, cold water, non-shock working pressure, designed especially for vacuum service. Operating parts of valve shall be removable without removing valve from line.

2.1.3 Specialties

2.1.3.1 Hangers and Supports

Steel adjustable type per MSS SP-58 and MSS SP-69. Provide hangers, supports, nuts, bolts, and washers with hot-dip galvanized finish after fabrication.

2.1.3.2 Piping Isolators

Commercial metal clad hair felt type for isolating pipe from hangers.

2.1.3.3 Pressure Gages

ASME B40.1 with restrictor, except that gages for oxygen and nitrous oxide systems shall be manufactured and labeled expressly for the intended service, and marked "DO NOT USE OIL." Provide gages with white dials and black lettering, and with sizes, ranges, and case type, as indicated.

2.1.3.4 Vacuum Bottle Brackets

Stainless steel, chrome-plated metal, or aluminum with finish matching adjacent station outlet.

2.1.3.5 Flexible Connectors

Manufactured expressly for operating conditions either annular and

helically corrugated flexible, single ply, seamless or seam-welded tubing with one or more layers of stainless steel or bronze wire braid, or reinforced TFE bellows or hose. Use manufacturer's recommended lengths and sizes for the intended service.

2.1.3.6 Sleeves

Provide plastic waterproof cement seal or mechanically adjustable segmented elastomeric seal. In Concrete and Masonry, use galvanized steel pipe, ductile-iron, or cast-iron. For partitions, floors and roofs, other than concrete or masonry, use 26-gage galvanized sheet steel.

2.1.3.7 Brazing Alloy

AWS A5.8, BCuP (Brazing-Copper-Phosphorus) series, greater than 538 degrees C 1,000 degrees F melting temperature. Use only cadmium free brazing filler. Do not use flux for copper-to-copper connections.

2.1.3.8 Soldering Alloys

ASTM B 32, Alloy Grade Sb5, Sn94, Sn95, or Sn96.

2.1.3.9 Welding Filler Metal

AWS A5.28 and compatible with the materials.

2.1.3.10 Threaded Joint Tape

TFE.

****
NOTE: Valve cabinets sometimes are called valve boxes.
****

2.1.3.11 Valve Cabinets

[Stainless] [galvanized sheet steel] [or] [extruded aluminum], flush-mounted, commercially available items with welded joints, and rigidly assembled. Provide boxes of proper size to accommodate valve and fittings. Punch or drill sides to receive tubing. Provide anchors to secure cabinets to wall construction.

a. Cover Plates: [Stainless steel] [aluminum] [or] [galvanized sheet steel]. Provide covers with replaceable plastic windows with a corrosion resistant device or lever, secured to cover for removal of window in an emergency.

b. Cabinet Labels: Each valve or valve cabinet shall be labeled for substance and color coded as follows: "CAUTION (intended service) TO (area served)." Color coding shall be the same as for the adjoining pipe.

2.1.3.12 Buried Piping

****
NOTE: In areas where ground temperatures stay below 16 degrees C 60 degrees F, insulate and provide heat trace for buried oxygen lines.

****

Encase in protective [cast-iron] [Schedule 40 PVC] pipe. [For oxygen piping, provide Factory Mutual (FM) listed heat trace, set for 27 degrees C 80 degrees F maximum, terminated at a junction box with terminal board, and mounted near the main oxygen supply shut-off valve just inside the building. Label the junction box "Underground Oxygen Piping Heat Trace." Do not permanently wire heat trace to electrical power. Provide buried lines with 25 mm one inch ASTM C 552 cellular glass and integral moisture barriers.]

2.1.3.13 Buried Pipe Warning and Identification Tape

Provide detectable aluminum foil plastic backed tape or detectable magnetic plastic tape manufactured for warning and identification of buried piping. Tape shall be detectable by an electronic detection instrument. Provide tape in rolls, 80 mm 3 inches minimum width, color coded for the service involved with warning and identification imprinted in bold black letters continuously and repeatedly over entire tape length. Use "CAUTION (intended service) LINE BURIED BELOW" or similar wording. Use permanent code and letter coloring unaffected by moisture and other substances contained in trench backfill material.

2.1.3.14 Piping Identification

FS A-A-1689, pressure sensitive adhesive tape and decals. Colors and labels must conform to ANSI A13.1.

2.1.3.15 Nitrogen

For cleaning, purging, and testing, use oil-free dry nitrogen as specified in paragraph entitled "Test Gases."

2.1.3.16 Equipment Foundations

Section 15070N MECHANICAL SOUND VIBRATION AND SEISMIC CONTROL, and as recommended by the equipment manufacturer.

2.1.4 Station Outlets and Vacuum Terminals (Inlets)

Sized and made for pressures and other design conditions, as indicated.

****

NOTE: For ceiling hose drops and nitrogen systems, use only Diameter-Index Safety System (DISS) connectors. Commercial connectors may be used for other systems.

****

2.1.4.1 Connectors

Permanently label and color code female connectors and include the warning "DO NOT USE OIL." Permanently label and color code male connectors. Provide labels with cast-in or engraved letters.

a. Diameter-Index Safety System (DISS) Connectors: CGA V-5 brass connections with color code, automatic valve, and secondary check valve. Provide each outlet connector with a positive acting metal or plastic cap secured with chain to the faceplate.

b. Commercial Connectors: Quick coupler with non-interchangeable code key on fitting with color code, automatic valve, and secondary check valve.

2.1.4.2 Ceiling Hoses

Provide conductive neoprene hoses with color code for appropriate service. Provide sufficient hose length capable of dropping to within 1.50 meters 4 feet and 8 inches from the floor. Provide chrome-plated, spring loaded, hose retractor kits to automatically withdraw hose assembly for a minimum of 508 mm 20 inch retraction from the fully extended position of the hoses. For the upper end of hoses, use female DISS connectors with nuts. For the lower end of hoses, use commercial connectors for all services except nitrogen service in which DISS connectors must be used.

****

NOTE: Color coding is secondary to labeling with DISS number to indicate pipe contents. Just color coding presents a problem for persons who are color blind.

****

2.1.4.3 Color Code and DISS Number Requirements

TABLE 1

COLOR CODED CONNECTORS WITH DISS NUMBER

Gas	Color Code	DISS Number	Automatic Valve	Secondary Check Valve
Oxygen	Green	1240	Yes	Yes
Nitrous Oxide	Blue	1040	Yes	Yes
Nitrogen	Black	1120	Yes	Yes
Medical Air	Yellow	1160	Yes	Yes
Vacuum	White	1220	Yes	Optional
Anesthesia Gas Evacuation	Purple	2220	Yes	No

2.1.4.4 Station Outlets and Terminal Units

Provide [DISS] [commercial] non-interchangeable connectors, automatic valves, secondary check valves (except evacuation outlets and optional for vacuum terminals), and capped 10 mm 3/8 inch tubing stubs for supply connections color coded and labeled for the intended services. Rigidly secure outlets in outlet boxes. Permanently label outlets and terminals with engraved faceplates or engraved laminated plastic plates color coded for the intended service.

****

NOTE: Use fixed column ceiling outlets or terminals

for surgical services. Use wall-mounted or flush-mounted ceiling outlets or terminals for patient units or locations.

****

a. Wall Type: Flush mount in [galvanized steel] [or] [cast aluminum] boxes with stainless steel or chrome-plated brass faceplates.

b. Fixed Column Ceiling Type: Mount on fixed columns fabricated of stainless steel with removable access panels and attachment provisions for adjustable auxiliary equipment hooks and slides.

c. Flush-Mounted Ceiling Type: Mount in [galvanized steel] [or] [cast aluminum] boxes with stainless steel or chrome-plated brass faceplates. Provide hose drops to a height of 2 meters 6 feet, 6 inches above floor. Provide color coded conductive hoses with connectors at top and bottom. In accordance with Table 1, provide valves at the hose outlet connector.

2.2 EQUIPMENT

****

NOTE: Edit alarm items to agree with appropriate system design.

****

2.2.1 Alarms

Provide enameled steel of minimum 16 gage, NEMA ICS 6, modular, master alarm panel for each appropriate medical and vacuum systems. Provide service indicator lights and alarm signal testers. Provide alarm signal testers with test buttons or switches to temporarily activate visual signals and audible signals to test the system status.

2.2.1.1 "Reserve In-Use" Switchover Alarm

For medical gas cylinder manifold systems, provide alarm which activates when any reserve medical gas supply goes into operation.

2.2.1.2 Pressure Alarms

For failure alarms for medical air compressors and vacuum pumps, provide low and high pressure switches, of either contact or mercury (Hg) type, to activate alarms when pressure either drops or rises. Set operating pressure differentials at 21 kPa (gage) 3 psig minimum.

2.2.1.3 Dew Point Alarm (Medical Air System)

Provide local non-cancellable visual and cancellable audible alarm. This alarm is activated by receiving signal from the dew point monitor, when the pressure dew point rises above 6 degrees C at 690 kPa (gage) 42 degrees F at 100 psig.

2.2.1.4 Air Filter Alarm (Medical Air Systems)

Provide differential pressure switch for the filter to activate an alarm when pressure drop across the filter exceeds 14 kPa 2 psi over that when the filter is new and clean.

2.2.1.5 High Temperature Shutdown Alarm (Medical Air Systems)

Provide temperature switch to activate an alarm and shutoff the compressor when the discharge-air temperature exceeds 177 degrees C 350 degrees F.

2.2.1.6 High Carbon Monoxide Level Alarm (Medical Air Systems)

For compressor with carbon monoxide monitor only, provide local non-cancellable visual and cancellable audible alarm to alarm when carbon monoxide levels rises above 15 milligram per kilogram parts per million.

2.2.1.7 Oil Filter Alarm (Vacuum Pumps)

Provide differential pressure switch for the discharge-oil filter to activate an alarm upon sensing backpressure or rising pressure drop beyond a set level.

2.2.1.8 Low Vacuum Alarm (Vacuum Pumps)

Provide vacuum switch to activate an alarm when the system vacuum upstream of shutoff valve drops below 41 kPa 12 inches Hg.

2.2.1.9 Bulk Liquid Oxygen Low Level Alarms (Bulk Liquid Oxygen System)

Provide the following alarms:

a. A "Reserve In-Use" alarm to function when liquid oxygen in converter tank reaches a predetermined minimum level or when "Reserve In-Use" switchover is activated.

b. A low level alarm for reserve tank.

c. A low pressure alarm in reserve tank.

d. A low level alarm for main tank.

2.2.2 Medical Gas Cylinder Manifold Systems

Provide non-ferrous manifold, fittings, valves, parts, and connections rated at 20,682 kPa (gage) 3000 psig working pressure for each type of medical gas as indicated. Non-ferrous materials include aluminum, brass, bronze, monel, and inconel.

2.2.2.1 Cylinder Banks

[Duplex] manifold arrangement with [_____] cylinder connections per bank. Provide each bank with a two-stage pressure regulator with built-in safety valves and pressure gages, check valves, cylinder connecting coils and handles, header valves, and all other required equipment. Pressure regulator shall reduce 20,682 kPa (gage) 3000 psig cylinder pressure to 379 kPa (gage) 55 psig for system delivery. For nitrogen cylinder banks, the system delivery pressure may be 1379 kPa (gage) 200 psig instead of 379 kPa (gage) 55 psig.

2.2.2.2 Bank Switch-Over

****

NOTE: Delete the bracketed sentence for systems with less than six cylinders.

****

Only one cylinder bank shall be used at one time. Switch-over from exhausted to full cylinders shall be automatic and without pressure fluctuation. Provide a pressure regulating valve down stream of switch-over valves. Resetting of manifold controls shall be automatic or manual after the replacement of empty cylinders. Pressure switch shall actuate switch-over controls and "Reserve In-Use" alarms. House manifold controls in a sheet steel cabinet. [Size the nitrous oxide regulators for a flow rate of 2625 milliter per second at 5515 kPa (gage) inlet and 345 kPa (gage) 2500 cubic feet per hour (cfh) at 800 psig inlet and 50 psig outlet pressures.]

2.2.3 Medical Air Systems

Provide medical compressed air with minimum air quality of CGA G-7.1, Grade D.

****

NOTE: Use piston (reciprocating) compressors for air flow up to 47 liter per second 100 cfmand power up to 19 kilowatt 25 horsepower. Use piston or rotary for air flow greater than 47 liter per second 100 cfm and power over 19 kilowatt 25 horsepower. The use of oil-free compressors is to exclude oil from the air stream and compression chambers.

****

2.2.3.1 Air Compressors

Submit manufacturer, model, operating speed (revolutions per second minute), capacity (liter per second (L/s) (cubic feet per minute (cfm), free air delivered at indicated pressure), bearings, lubrication, receiver capacity (liter) (gallon), electric motor (manufacture, frame, type, speed, current characteristics, and kilowatt horsepower), thermal cutoff switch (manufacturer, type, and model), starter (manufacturer, type, and model), air silencer (manufacturer, type, and model), air filter (manufacturer, type, and model), air cooler (manufacturer, type and model), and air dryer (manufacturer, type, and model. Oil-free [piston] [or] [rotary] compressors with steel body construction, capable of continuous operation at indicated discharge pressures and compatible with pneumatic surgical or medical handpieces. Provide filter-muffler intake for each compressor. Provide outlet filters.

[2.2.3.2 Aftercoolers

****

NOTE: Aftercoolers are generally required only for piston air compressors. Delete this paragraph if there is no aftercooler.

****

Steel body construction. Size aftercoolers for cooling the air to within 15 degrees of inlet water temperatures. Provide solenoid or automatic valve to shut off cooling water when compressor is not running.

]2.2.3.3 Drives

Provide direct drives with flexible couplings or V-belt drives.

2.2.3.4 Receivers

Welded steel tanks with ASME BPVC SEC VIII D1 code and label for pressure rating. Protect interior and exterior surfaces of receivers with a factory-applied 0.13 mm 5 mil minimum non-toxic enamel or galvanized coating. Provide necessary gages, switches, and automatic drains as recommended by manufacturer.

2.2.3.5 Medical Air Dryers

****
NOTE: If medical air dryers are for outdoor installation, indicate the local ambient conditions.
****

Self contained, refrigerated, hermetic compressors, moisture separator, heat exchanger, automatic controls, and automatic drains. At 38 degrees C 100 degrees F ambient, provide minimum drying capacity to produce a constant 2 degrees C 35 degree F dew point medical air. Provide an enameled steel housing[, weatherproofed for outside installation]. Provide cycling or non-cycling controls in accordance with manufacturer's recommendation. Provide dew point monitor with digital or gage display, carbon monoxide monitor with high carbon monoxide level alarm, and interface with the master alarm panels.

2.2.3.6 Intake Air Filter and Muffler

Dry-inlet filter and muffler with silencer tubes. Provide replaceable one micron filter elements.

2.2.3.7 Outlet Air Filters

Provide one micron filters of the indicated liter per second cfmcapacity and working pressure.

2.2.3.8 Failure Alarms

Provide pressure switch to activate audible and visual alarms when compressed air pressure falls below 20 percent of the predetermined setting. Provide high water level shutdown or alarm switches for the receivers.

2.2.3.9 Automatic Controls

Provide automatic controls for alternating the units on start-up and to prevent simultaneous start-up of two or more units when on emergency power.

2.2.4 Vacuum Pumps

Submit manufacturer, model, operating speed, capacity (liter per secondcfm, free air exhausted from rated vacuum), bearing, lubrication, adjustment of drive, capacity of tank (liter) (gallon), electric motor (manufacturer, frame, type, speed, current characteristics, and kilowatt horsepower), thermal cutout switch (manufacturer, type, and model), and motor starter (manufacturer, type, and model). Provide rotary or centrifugal pumps with stainless steel body construction. Provide pumps capable of continuous operation at indicated vacuum.

2.2.4.1 Outlet Mufflers and Vents

Provide pumps with outlet mufflers.

2.2.4.2 Drives

Electric motor driven with either flexible couplings or V-belt drives.

2.2.4.3 Vacuum Receivers

Welded steel tanks with ASME BPVC SEC VIII D1 code and label for the indicated vacuum pressures. Protect interior and exterior surfaces of receivers with factory-applied 0.13 mm 5 mil minimum non-toxic enamel or galvanized coating. Provide necessary gages, switches, and drains as recommended by the manufacturer.

2.2.4.4 Failure Alarms

Provide pressure switch to activate alarm when vacuum pressure falls 20 percent below predetermined setting.

2.2.4.5 Automatic Controls

Provide automatic controls for alternating the units on startup and prevent simultaneous start-up of two or more units when on emergency power.

2.2.4.6 Solenoid Valves

For vacuum pumps of the water seal or water displacement construction, provide brass, bronze, or steel body. Provide solenoid valve to cut off water supply when the pump is not running.

2.2.5 Anesthesia Gas Evacuation Pumps

Provide water-seal, positive-displacement, non-pulsating, vacuum pumps for handling flammable gases. Provide capability of a maximum vacuum level of 85 kPa 25 inch Hg. Ensure pump numbers, sizes, capacities, and operating pressures (vacuum) are as indicated.

2.2.5.1 Heat Exchanger

Provide minimum 90 percent water recirculation system with heat exchanger and controls. Provide a solenoid valve in the pump water supply to shut off the water when the pump is not running.

2.2.5.2 Motor Controls

Provide automatic, adjustable, vacuum-sensing, hand-off-automatic, electric switch; NEMA ICS 6, Type 12, UL Listed, dustproof control panel; circuit breakers for each control circuit; hour meter; magnetic starter; and heavy-duty alternator for the motors.

2.2.6 Oral Evacuation Pumps

Self-governing multi-stage turbine or rotary-vane pumps with direct connected electric motor drive capable of continuous operation under no flow conditions. Provide capability of a maximum vacuum level of 95 kPa 28 inch Hg. Provide air cooling and automatically lubricating provisions. Ensure pump number, sizes, capacities, and operating vacuum pressures are

as indicated.

2.2.6.1 Surge Control and Silencer for Turbine Pumps

Provide an automatic modulating surge control to bleed air into the turbine when system operates at less than 50 percent capacity. Mount the surge control device in the vertical pipe extending from the central separator to the turbine suction or inlet. For inlet part of the bleed valve, provide a baffled, sound-absorbent, lined muffler to silence air noise. Control the bleed valve by a motor current sensing device.

2.2.6.2 Motor Controls

Provide automatic, adjustable, vacuum-sensing, hand-off-automatic, electric switch; NEMA ICS 6, Type 12, UL-Listed, dustproof control panel; circuit breakers for each control circuit; hour meter; magnetic starter; and heavy-duty alternator for the motors.

2.2.6.3 Separators

****

NOTE: When the first or primary separators are to be incorporated in the factory-built dental equipment, provide secondary or final separators ahead of the evacuation pump.

****

Fabricate separators of welded steel hot-dip galvanized or with a factory applied corrosion preventative lining. Provide fittings and openings for the [central] [and] [individual station] separators as indicated. Provide float switches, drain pumps, sediment strainers, ball floats, quick opening springs, flushing water supply globe valves, disinfectant funnels and cocks, cleanout openings, and tangential intakes. Provide water flushing alarm and high-level cutout float switch.

2.2.7 Bulk Liquid Oxygen Systems

****

NOTE: Bulk liquid oxygen (LOX) tanks are normally purchased; however, they may be leased from the LOX supplier. In either case, the designer must coordinate the project design requirements with the supplier, Contacting Officer, and station accordingly.

****

NFPA 50 and NFPA 99. Provide liquid oxygen storage tanks, evaporators, piping, and controls.

2.2.7.1 Reserve Oxygen Back-Up

Provide an oxygen cylinder bank, as specified in the paragraph entitled "Medical Gas Cylinder Manifold Systems," to back-up the bulk liquid oxygen system. Provide automatic switchover switch with the "Reserve In-Use" switchover alarm.

2.2.7.2 Liquid Oxygen Storage Tank

Submit manufacturer's data for evaporative coil, liquid level gage, inner

container pressure gage, gage by-pass valve, gage vent valve, gage valves, thermocouple, thermocouple valve, thermocouple gage tube, inner container relief valve, inner container bursting disk, bottom fill valve, vent valve, inlet bleed valve, liquid fill connection, inlet relief valve, annular space evacuation valve and filter, pressurizer valve, liquid withdrawal valve, liquid to pump valve, pump vapor return valve, outer shell o-ring relief valve, and manway.

a. Inner Container: ASTM A 167, Type 304 stainless steel, welded tank with ASME label conforming to ASME BPVC SEC VIII D1.

b. Outer Shell: Welded carbon steel tank conforming to ASME BPVC SEC VIII D1 with an external collapsing kPa (gage) psig rating as indicated, but without ASME stamp.

2.2.7.3 Supports

Provide the supports for installed and loaded forces of 1 1/2-G vertical and 1/2-G horizontal.

2.2.7.4 Valves and Safety Devices

NFPA 50 and ASME BPVC SEC VIII D1.

2.2.7.5 Pipe and Fittings

ASTM A 269, Type 304, stainless steel pipe and ASTM A 403/A 403Mwelding fittings. Weld all pipe joints and fittings on inner container and outer shell.

2.2.7.6 Tank Finish

Provide SSPC SP 6 commercial blast cleaned tank. Paint tank with a primer coat and a manufacturer's standard exterior white with green color code finish.

2.2.8 Motors, Motor Starters, and Electrical Requirements

Provide NEMA MG 1 motors with continuous duty rating at service factor of minimum 1.15 and ambient temperature rise of maximum 40 degrees C. Provide NEMA ICS 2 motor starters with NEMA ICS 6 enclosures. For electrical requirements, see Section 16402 INTERIOR DISTRIBUTION SYSTEM.

PART 3 EXECUTION

3.1 INSTALLATION

****
NOTE: Seismic requirements are mandatory in seismic zones 3 and 4. Pipe and equipment vibration and noise isolation and seismic restraints must be designed and detailed on the drawings by the designer.
****

Comply with NFPA 50, NFPA 99, and CGA P-2.1. Provide vibration isolation, noise isolation, and [seismic restraints] for pipe and equipment in accordance with SMACNA Seismic Restraint Mnl and Section 15070N MECHANICAL SOUND VIBRATION AND SEISMIC CONTROL.

3.1.1 Piping

3.1.1.1 Pre-Installation Cleaning

Disassemble positive pressure pipe, fittings, valves, and other components. Provide only pipe and fittings which have been thoroughly washed. Use the following cleaning procedures:

a. Mix the solution of sodium carbonate or trisodium phosphate in the proportion of 454 gram one pound dry chemical in 11.40 liters 3 gallons of water.

b. Maintain the resulting solution at minimum 82 degrees C 180 degrees F.

c. Wash thoroughly, scrubbing as required. Rinse with clean water and blow dry with oil-free dry nitrogen.

Effectively cap ends of the pipe, fittings or valves, and label "CAUTION! CLEANED FOR MEDICAL GAS SERVICE." In lieu of cleaning by the installer at the job site, each pipe, fitting and valve may be supplied "CLEAN FOR OXYGEN SERVICE" by the manufacturer. Do not use carbon tetrachloride, hydrocarbon, or halogenated hydrocarbon solvents.

3.1.1.2 Piping Installation

Exercise care with cutting, brushing, and reaming tools and equipment to prevent oil, grease, and dirt from entering pipe and components. Rewash contaminated pipe and components. Cut pipe square and accurately to measurements and work into place without springing or forcing. Follow the general arrangement indicated. At the end of each work shift shut off valves, and cap or plug open ends. As work progresses, valve off each section to prevent moisture or dirt from entering piping.

3.1.1.3 Hangers and Supports Installation

Install hangers and supports in accordance with MSS SP-69 and MSS SP-89 except that spacing of the hangers and supports shall be in accordance with Table 2.

TABLE 2

MAXIMUM SPAN FOR PIPE HANGERS (mm)

Copper tube, Type K (Cu-K) and Type L (Cu-L); PVC Schedule 40 and 80 (PVC); brass and stainless steel (SS)

Pipe Size (mm)	Cu-K and Brass	Cu-L	PVC	SS
15	1140	1060	1060	1520
20	1290	1290	1060	1750
25	1520	1440	1210	1980
40	1750	1670	1370	2280
50	1980	1980	1370	2590
65	2210	2130	- - -	2810
80	2360	2280	1670	3120
90	2510	2510	- - -	3350

TABLE 2

MAXIMUM SPAN FOR PIPE HANGERS (mm)

Copper tube, Type K (Cu-K) and Type L (Cu-L); PVC Schedule 40 and 80 (PVC); brass and stainless steel (SS)

Pipe Size (mm)	Cu-K and Brass	Cu-L	PVC	SS
100	2740	2660	1900	3500
125	3040	2890	- - -	3800
150	3270	3200	2050	4190

TABLE 2

MAXIMUM SPAN FOR PIPE HANGERS (feet)

Copper tube, Type K (Cu-K) and Type L (Cu-L); PVC Schedule 40 and 80 (PVC); brass and stainless steel (SS)

Pipe Size (inches)	Cu-K and Brass	Cu-L	PVC	SS
1/2	3'-9"	3'-6"	3'-6"	5'-0"
3/4	4'-3"	4'-3"	3'-6"	5'-9"
1	5'-0"	4'-9"	4'-0"	6'-6"
1 1/2	5'-9"	5'-6"	4'-6"	7'-6"
2	6'-6"	6'-6"	4'-6"	8'-6"
2 1/2	7'-3"	7'-0"	- - -	9'-3"
3	7'-9"	7'-6"	5'-6"	10'-3"
3 1/2	8'-3"	8'-3"	- - -	11'-0"
4	9'-0"	8'-9"	6'-3"	11'-6"
5	10'-0"	9'-6"	- - -	12'-9"
6	10'-9"	10'-6"	6'-9"	13'-9"

3.1.1.4 Exposed Oxygen Piping

Install in wall-mounted sheet steel raceways and junction boxes.

3.1.1.5 Threaded Joints

Coat male threads of fittings used in shut off valves with TFE tape before assembly.

****

NOTE: Brazed joints exhibit a melting temperature in excess of 538 degrees C 1000 degrees F to retain the integrity of the piping system in the event of fire exposure.

****

3.1.1.6 Brazing and Soldering

Personnel qualification procedures shall conform with AWS B2.2. Metal preparation and joining procedures shall conform with CDA A4015 and NFPA 99. Use BCuP Series brazing alloys for joints, except for 50 mm 2 inch and smaller pipes, in nitrogen and vacuum systems only, solder joints may be used. Completely clean off excess after brazing and soldering.

3.1.1.7 Welding

Comply with AWS B2.1.

3.1.1.8 Cleaning of All Piping

During brazing, soldering, or welding operations, continuously purge with oil-free dry nitrogen. As each section is completed, blow lines clear of dirt and contamination with oil-free dry nitrogen in accordance with NFPA 99. Cap or plug open ends, when left unattended

3.1.1.9 PVC Solvent-Cemented Joints (Oral Evacuation Systems Only)

Install in accordance with ASTM D 2855 and additional written recommendations of the PVC pipe manufacturer.

3.1.1.10 Pitch

Pitch piping in the direction of flow. Do not trap [except where indicated].

3.1.1.11 Changes in Size

Effect changes in size with reducing fittings. Do not use bushings.

3.1.1.12 Pipe Sleeves

Provide where pipes and tubing pass through walls, floors, roofs, and partitions. Leave 6 mm 1/4 inch clearance around pipes. Secure sleeves in proper position and location before and during construction. Ensure sleeves of sufficient length to pass through entire thickness of walls, partitions, or slabs. Cut sleeves flush at both ends except that sleeves in floor slabs shall extend 50 mm 2 inches above the finished floor. Firmly pack space between pipe or tubing and sleeve with mineral wool insulation. [In lieu of pipe sleeves, core drilling of masonry and concrete may be provided when cavities in the core-drilled holes are completely grouted smooth.] Seal space at both ends of sleeve or core-drilled hole with plastic waterproof cement which will dry to a firm but pliable mass. In lieu of plastic cement seal, a mechanically adjustable segmented elastomeric seal may be used.

3.1.1.13 Identification of Piping

Identify piping in accordance with ANSI A13.1, except provide tape and decals conforming with FS A-A-1689 in lieu of stencils and paint. Provide copies of the piping identification code and piping layout schematic framed under glass [and install where indicated].

3.1.1.14 Excavation and Backfilling

Comply with Section 02300 EARTHWORK. Coordinate provision of utility warning and identification tape with backfill operation. Bury lines at a depth of minimum 305 mm one foot below finish grade.

3.1.2 Valves

****

NOTE: Controlling, pressure reducing, flow control

valves, etc. (not manual shut off), which are not redundant in the project design, require by-passes for maintenance operations on the valves.
****

Disassemble solder socket end valves before brazing, soldering, or welding to prevent damage to seats and seals. Except in flush wall mounted cabinets, install valves with stem vertical and with valves accessible for operation and maintenance. Install strainers on the inlet side of pressure reducing valves. Provide main gas valves, pressure reducing or flow control, with by-passes and isolation valves, to permit main valve maintenance and permit flow to patient care areas without interruption of gas.

3.1.2.1 Purge Vent Valves

Provide purge vent valves at the bottom of vertical risers 3 meters 10 feet or more in height. Up stream of the building entrance, also provide shut-off valves for buried lines and lines of 40 mm 1 1/2 inches and larger for above ground lines. Valves and connecting pipe shall be 25 mm one inch or line size if smaller than 25 mm one inch. After completion of tests, seal vent valve outlets with brazed caps.

3.1.3 Manifolds

Vent relief valves to the outside of the building.

3.1.4 Alarms

Install alarm systems in accordance with NFPA 99.

3.1.5 Equipment

3.1.5.1 Equipment Foundations

Provide equipment foundations of sufficient size, weight, and proper design to prevent shifting of equipment under operating conditions. [For projects in seismic zones 3 and 4, size the liquid oxygen tank's concrete foundation and tank anchoring for 3 times the tanks' fully loaded weight.]

3.1.5.2 Equipment Installation

Install equipment in accordance with manufacturer's written instructions and as indicated. Grout equipment mounted on concrete foundations before piping is installed.

3.1.5.3 Receivers

Provide a valved bypass around receivers.

3.1.5.4 Medical Air Systems

Make tie-in point for the compressor for medical air piping systems at a flange or union joint, following completion and approval of air quality testing of the compressor.

3.1.5.5 Bulk Liquid Oxygen Systems

Comply with NFPA 50 and install under the guidance of manufacturer's

erection superintendent. Provide bulk liquid oxygen systems with a shut-off valve, and a connection point with valve for portable emergency oxygen supply in accordance with NFPA 99. Connection fittings are to be sealed for maintaining cleanliness after testing.

3.1.6 Electrical Work

Comply with NFPA 70 and Section 16402 INTERIOR DISTRIBUTION SYSTEM. Ground metal piping systems. Provide electric motor driven equipment specified herein complete with motors, motor starters, and controls. Provide motor starters complete with thermal overload protection and other appurtenances necessary for the motor control specified. Provide manual or automatic control and protective devices required for the operation of equipment.

3.2 FIELD QUALITY CONTROL

The Contracting Officer will witness field tests. For field testing by testing agency, the Contractor shall provide a qualified testing agency as specified in Part 1, paragraph entitled "QUALITY ASSURANCE." The Contractor shall give the Contracting Officer 14 days prior notice for dates and times for acceptance tests.

3.2.1 Agency Testing

Tests for contaminants are required for new medical gas systems or existing systems which are modified, repaired, or replaced.

3.2.2 Sample Bottles

When gas sample bottles are to be used, the bottles are to be supplied by the testing agency, sealed and ready for use, and filled and labeled in accordance with the agency's written instructions.

3.2.3 Test Instruments

Provide vacuum gages with 2 kPa one inch Hg increments, readable to one kPa 1/2 inch Hg. Provide pressure gages with 2 kPa (gage) one psig increments, readable to one kPa (gage) 1/2 psig. Use only correct adapters for gages. Do not use universal adapters.

3.2.4 Pressure Test Gases

During initial purging, blowing out, and pressure testing, use only oil-free dry nitrogen conforming with CGA G-10.1, Grade F, except that hydrocarbons and halogenated hydrocarbons shall not exceed the limits in Table 4, "Test Gas Purity, Contaminate Levels, and Test Methods." Use no other gas, material, or liquid during purging and tests.

3.2.5 Outlet Adapters

Use only correct adapters for specified medical gas outlets. Do not use universal adapters.

3.2.6 Positive Pressure Tests

Test only one system at a time. Test each joint with soap solution, repair leaks found, and retest. In the systems not being tested, install pressure gages, bleed to zero pressure, and seal. Investigate the cause of significant pressure rise in the systems not being tested.

3.2.6.1 Leak Tests, Low Pressure Systems

Less than 4136 kPa (gage) 600 psig. Test each section of each system at 1034 to 1379 kPa (gage) 150 to 200 psig with oil-free dry nitrogen. When design pressure is greater than 1379 kPa (gage) 200 psig, pressurize each section in 350 kPa (gage) 50 psig increment until the design pressure is reached.

3.2.6.2 Leak Tests, High Pressure Systems

4136 - 20,682 kPa (gage)600 - 3000 psig. Before attaching service outlets, couplers or other equipment, pressurize each section in 1300 kPa (gage) 200 psig increments with oil-free dry nitrogen until the design pressure is reached. Leak test joints with soap solution at each 1300 kPa (gage) 200 psig increment.

3.2.6.3 Equipment Pressure Tests

Test joints with the system at 1034 kPa (gage) 150 psig with the equipment connected limited to the rough-in portion of service outlets. Do not connect equipment until after the test is completed. Carefully wipe off soapsuds and seal openings against contamination until tanks or equipment are connected.

3.2.6.4 Final Pressure Tests, Low Pressure Systems

Pressure test with nitrogen at 120 percent of design pressure for 24 hours. No pressure drop, except due to temperature change, will be accepted. Allow for ambient temperature change in accordance with the relationship PF + 101.32 = (P1 + 101.32) (T2 + 273) (T1 + 273) PF + 14.7 = (P1 + 14.7) (T2 + 460)/(T1 + 460), in which T and P represent Centigrade Fahrenheit temperature and gage pressure respectively, numbers 1 and 2 denote initial and final readings respectively, and PF is the calculated final pressure. When PF exceeds the measured final pressure, retest each section individually, and apply soap solution to all joints of each section for which a reduction in pressure occurs after allowing for ambient temperature change. Repair leaking joints and repeat test until no reduction in pressure occurs. Use a test gage calibrated in 2 kPa one psi increments and readable to one kPa (gage) 1/2 psig.

3.2.6.5 Final Pressure Tests, High Pressure Systems

Pressurize system with nitrogen in 1300 kPa (gage) 200 psigincrements. Hold design pressure for 24 hours. No pressure drop, except due to temperature change, will be accepted. Allow for ambient temperature change in accordance with the relationship PF + 101.32 = (P1 + 101.32) (T2 = 273)/(T1 + 273) PF + 14.7 = (P1 + 14.7) (T2 + 460)/(T1 + 460), in which T and P represent Centigrade Fahrenheit temperature and gage pressure respectively, numbers 1 and 2 denote initial and final readings respectively, and PF is the calculated final pressure. When PF exceeds the measured final pressure, retest each section individually, and apply soap solution to all joints of each section for which a reduction in pressure occurs after allowing for ambient temperature change. Repair leaking joints and repeat test until no reduction in pressure occurs. Use a test gage calibrated in 350 kPa (gage) 50 psig increments and readable to 175 kPa (gage) 25 psig in performing the tests.

3.2.7 Vacuum Systems Tests

Test vacuum, anesthesia gas evacuation, and oral evacuation systems.

3.2.7.1 Leak Tests

After installation of outlet valves but before installing vacuum pumps and alarm switches, pressurize each section of each system with oil-free dry nitrogen to 414 kPa 60 psig and test with soap solution. Repair leaks and retest.

3.2.7.2 Final Pressure Tests

Pressurize system with oil-free dry nitrogen to 173 kPa (gage) 25 psig for 24 hours. No pressure drop, except due to temperature change, will be accepted. Allow for ambient temperature change in accordance with the relationship PF + 101.32 = (P1 + 101.32) (T2 + 273)/(T1 + 273) PF + 14.7 = (P1 + 14.7) (T2 + 460)/(T1 + 460), in which T and P represent Centigrade Fahrenheit temperature and gage pressure respectively, numbers 1 and 2 denote initial and final readings respectively, and PF is the calculated final pressure. When PF exceeds the measured final pressure, retest each section individually, and apply a soap solution to all joints of each section in which a reduction in pressure occurs after allowing for ambient temperature change. Repair leaking joints and repeat test until no reduction in pressure occurs. Use a test gage calibrated in 2 kPa one psi increments and readable to one kPa (gage) 1/2 psig.

3.2.7.3 Vacuum Tests

After the installation of alarm switches, evacuate each system to 54 kPa 17 inches Hg, or to the indicated kPa inches Hg for oral evacuation system, and test each outlet's pressure (vacuum) with a test gage calibrated in 2 kPa one inch Hg increments and readable to one kPa 1/2 inch Hg.

3.2.7.4 Cleaning

Carefully wipe off soapsuds and seal openings against contamination until tanks or equipment are connected.

3.2.8 Cross-Connection Tests by Testing Agency

Comply with NFPA 99. Pressurize each system with nitrogen in accordance with Table 3. Check 100 percent of the outlets in each system. Include anesthesia gas evacuation in vacuum systems. Do not include the oral evacuation systems in these tests.

TABLE 3

CROSS-CONNECTION TEST PRESSURES

System	kPa (gage)
Vacuum	69
Nitrogen	207
Nitrous Oxide	276
Oxygen	345
Medical Air	414

TABLE 3

CROSS-CONNECTION TEST PRESSURES

System	psig
Vacuum	10
Nitrogen	30
Nitrous Oxide	40
Oxygen	50
Medical Air	60

3.2.9 Medical Air Compressor and Vacuum Pump Tests by Testing Agency

Operationally test each unit through their respective pressure and capacity ranges. Test control operations from start-up, low through high speeds, shut-down and emergency functions and safety limits. Check each unit for conformance with the indicated or specified performance requirements. Test medical air from compressor dryer/filter systems for contaminants in accordance with paragraph entitled "Medical Air Purity, Contaminate Levels, and Test Methods."

3.2.10 Bulk Liquid Oxygen System Tests by Testing Agency

Check and operate the systems for conformance with NFPA 50 and NFPA 99, the manufacturer's written performance specifications, and the indicated and specified requirements.

3.2.11 Component Tests by Testing Agency

Test system controls, alarms, pressure switches, and equipment operations. Verify the flow rate accuracy of each pressure reducing regulator.

3.2.12 Final Purging and Testing by Testing Agency

Use 414 to 448 kPa (gage) 60 to 65 psig, oil-free dry nitrogen to purge and clean medical air, oxygen, nitrogen, and nitrous oxide system 24 hours continuously for a minimum of 24 hours. Allow purge nitrogen to impinge upon a white cloth at a minimum flow rate of 100 liters per minute 3.50 cfm, until no evidence of discoloration is present and test gas used during the previous gas test has been removed from the piping systems. Bleed source gas for a minimum of one minute continuously through each terminal copper piping installed, as specified. After completion of purging and cleaning, completely remove temporary piping, adaptors, and connectors.

3.2.13 System Contaminant Level Tests by Testing Agency

3.2.13.1 Test Gases

After final purging and cleaning, use test gases as specified in paragraph entitled "Test Gas Purity, Contaminate Levels, and Test Methods," and provided by the Government, to test for contamination in medical air, oxygen, nitrogen, and nitrous oxide systems. For medical air system tests, use medical air as test gas specified in paragraph entitled "Medical Air Purity, Contaminate Levels, and Test Methods." Minimum flow rate of test gas shall be 100 liters per minute.

3.2.13.2 Test Gas Purity, Contaminate Levels, and Test Methods

Table 4 lists limits of contaminants or concentration minimums in the test gases used for purging and testing in oxygen, nitrogen, and nitrous oxide systems, and test methods to be used to determine levels of contaminants and concentration minimums.

TABLE 4

TEST GAS PURITY, CONTAMINATE LEVELS,
AND TEST METHODS

a. Test Gas: 99 percent by volume minimum; gas chromatography or equivalent.

b. Solid Particulate: 2 milligrams per cubic meter maximum; 0.8 micron pore size filter.

c. Hydrocarbon Compounds: One part per million, concentration volume per volume, maximum expressed as methane equivalents; gas chromatography or equivalent.

d. Halogenated Hydrocarbon Compounds: 2 parts per million, concentration volume per volume, maximum; mass spectrometry, infrared spectrometry, or gas chromatography.

e. Carbon Monoxide: 2 parts per million, concentration volume per volume, maximum; gas chromatography, electrochemical carbon monoxide analyzer, or equivalent.

f. Water (Moisture): Minus 50 degrees C 58 degrees F dew point; Pittsburg cup, dew point hygrometer, or electronic hygrometer.

3.2.13.3 Medical Air Purity, Contaminate Levels, and Test Methods

Determine medical air purity and contaminate levels by testing air quality at the compressor, but before air is allowed to enter piping system. Test air samples from each medical air system including air intake areas, filter/dryer equipment outlets, and specified system outlets. Limit solid particulate levels below the specified filter efficiency levels. Limit moisture levels below that of the specified dryer outlet dew point. Use test methods specified in paragraph entitled "Test Gas Purity, Contaminate Levels, and Test Methods."

3.2.13.4 Contamination Tests

Test gas sources, equipment outlets, and system outlets using test methods specified in paragraphs entitled "Test Gas Purity, Contaminate Levels, and Test Methods," and entitled "Medical Air Purity, Contaminate Levels, and Test Methods."

3.2.13.5 Gas Source Tests

Test gas and air sources for contamination and gas concentrations.Purge oxygen, medical gas, nitrous oxide, and nitrogen systems with an appropriate gas until gases reach specified concentrations, clean and free of contamination. Care must be taken to vent purged nitrous oxide and oxygen to the outside of the building and away from flames.

3.2.13.6 100 Percent Testing

Test 100 percent of the medical gas outlets in rooms which are supplied with nitrous oxide or nitrogen.

3.2.13.7 10 Percent Testing

Test 10 percent of the medical gas outlets in areas which are supplied only with oxygen or medical air. Test such outlets to ensure the gas traversed the greatest length of pipeline.

3.2.13.8 Contaminated Systems

Clean and retest contaminated sections with one or more contaminated outlets. In rooms or areas where only oxygen or medical air is supplied, retest 20 percent of the outlets including the original 10 percent first tested. Each time contamination is found, repeat cleaning operation and increase number of outlets tested by 10 percent until zero percent contamination is obtained. Take care to vent purged nitrous oxide and oxygen to outside of building, away from flames.

3.2.14 Holding Charges by Testing Agency

After successful completion of contamination and gas concentration tests, pressurize each system to the operating pressure with the appropriate gas, shutoff valves, and cap outlets to keep systems free of contamination.

3.2.15 Final Alarm Tests by Testing Agency

Test and operate switches, alarms, and controls in each system with appropriate medical gases.

-- End of Section --