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Part 7: Healthcare facilities and medical gas and medical vacuum systems

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In order to match with technological development and to keep continuous progress in industries, standards are subject to periodic review. Users shall ascertain that they are in possession of the latest edition

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Foreword

Rwanda Standards are prepared by Technical Committees and approved by Rwanda Standards Board (RSB) through Board of Directors in accordance with the procedures of RSB, in compliance with Annex 3 of the WTO/TBT agreement on the preparation, adoption and application of standards.

The main task of technical committees is to prepare national standards. Final Draft Rwanda Standards adopted by Technical committees are ratified by members of RSB Board of Directors for publication and gazettment as Rwanda Standards.

DRS 644-7 was prepared by Technical Committee RSB/TC 17, *Urban planning.*

In the preparation of this standard, reference was made to the following standard:

IAPMO, *2024 Uniform plumbing code*

The assistance derived from the above source is hereby acknowledged with thanks.

DRS 644 consists of the following parts, under the general title *Plumbing works — Code of practice*:

— *Part 1: General*

— *Part 2: Plumbing fixtures and fixture fittings*

— *Part 3: Water supply and distribution*

— *Part 4: Sanitary and drainage system installation*

— *Part 5: Water heaters*

— *Part 6: Fuel gas piping and firestop protection*

— *Part 7: Healthcare facilities and medical gas and medical vacuum systems*

— *Part 8: Alternate water sources for non-potable applications and non-potable rainwater catchment systems*

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Committee membership

The following organizations were represented on the Technical Committee on *Urban planning* (RSB/TC 17) in the preparation of this standard.

City of Kigali

Institute of Engineering Rwanda (IER)

Ministry of Infrastructure (MININFRA)

Rwanda Housing Authority (RHA)

Rwanda Inspectorate, Competition and Consumer Protection Authority (RICA)

Rwanda Plumbers Organization (RPO)

Rwanda Polytechnic – Kigali College

Rwanda Polytechnic – Musanze College

Rwanda Transport Development Agency (RTDA)

Rwanda Utility Regulatory Authority (RURA)

Rwanda Water Resources Board (RWB)

University of Rwanda – College of Science and Technology (UR-CST)

Water and Sanitation Corporation (WASAC)

Water for People

Rwanda Standards Board (RSB) – Secretariat

Introduction

Many healthcare facilities use pipeline systems to deliver medical gases and to provide vacuum to areas where they are used in patient care or to power equipment such special fixtures and systems in health care facilities. This document specifies technical requirements from the central supply system to the station outlets or inlets in hospitals, clinics and other health care facilities.

Plumbing works — Code of practice — Part 7: Healthcare facilities and medical gas and medical vacuum systems

1 Scope

This Draft Rwanda Standard provides recommendations and guidelines for special fixtures and systems in health care facilities, special plumbing for such facilities, installation, testing, and verification of medical gas and medical vacuum piping systems, except as otherwise indicated in this standard, from the central supply system to the station outlets or inlets in hospitals, clinics, and other health care facilities.

Other plumbing in such facilities conforms to other applicable clauses of this standard.

This Standard does not apply to the following, except as otherwise addressed:

a) cylinder and container management, storage, and reserve requirements;

b) bulk supply systems;

c) electrical connections and requirements;

d) motor requirements and controls;

e) systems having nonstandard operating pressures;

f) waste anaesthetic gas disposal (WAGD) systems;

g) surface-mounted medical gas rail systems;

h) breathing air replenishment (BAR) systems;

i) portable compressed gas systems;

j) medical support gas systems;

k) gas-powered device supply systems;

l) scavenging systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7396-1, *Medical gas pipeline systems — Part 1: Pipeline systems for compressed medical gases and vacuum*

ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*

ASTM B88, *Standard Specification for Seamless Copper Water Tube (Metric)*

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless -Steel Tubing for General Service*

ASTM A312, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless-Steel Pipes*

ASTM A403, *Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings*

ASTM D3212, *Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals*

RS 273: 2022, *Sanitary appliances — Selection, installation and maintenance — Code of practice*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in DRS 644-1 apply.

4 Symbols and Abbreviated terms

WAGD: Waste anesthetic gas disposal

BAR: Breathing air replenishment

psi: Pound per square inch

HgV: mercury vacuum

Med Vac: Medical–surgical vacuum

CO_2: Carbon dioxide

He: Helium

N_2: Nitrogen

N_2O: Nitrous oxide

O_2: Oxygen

Med Air: Medical air

CFM: Cubic feet per minute

L/s: Litre per second

MAWP: Maximum allowable working pressure

STP: Standard temperature and pressure

NPS: Nominal pipe size

Hp: Horse power

kW: kilowatt

DN: Nominal diameter

ppm: parts per million

HEPA: High efficiency particulate air

Cv: Valve flow coefficient

CMT: corrugated medical tubing

D.I.S.S: Diameter index safety system

GTAW: Gas tungsten arc welding

Nl/min: Normal litres per minute

Nitrogen NF: Nitrogen, National formulary grade

SCFM: standard cubic foot per minute

O.D: Outside dimeter

5 Conflict of requirements

The requirements of this standard shall not be interpreted to conflict with the requirements of NFPA 99. For requirements of portions of medical gas and vacuum systems not addressed in this chapter or medical gas and vacuum systems beyond the scope of this chapter refer to NFPA 99.

5.1 Where required

Construction and equipment requirements shall be applied only to new construction and new equipment, except as modified in individual clauses of this standard. {NFPA 99:1.3.2}

5.2 Existing systems.

Only the altered, renovated, or modernized portion of an existing system or individual component shall be required to meet the installation and equipment requirements stated in this standard. If the alteration, renovation, or modernization adversely impacts the existing performance requirements of a system or component, additional upgrading shall be required. An existing system that is not in strict compliance with the provisions of this standard shall be permitted to be continued in use, unless the Competent Authority has determined that such use constitutes a distinct hazard to life. [NFPA 99:1.3.2.1 – 1.3.2.3]

6 Design requirements

6.1 Risk categories

All activities, as well as systems or equipment that are new or altered, shall be designed to meet Category 1 through Category 4 requirements as detailed in this standard. {NFPA 99:4.1}

6.1.1 Processes and operations

The health care facility's governing body shall establish the processes and operations that are planned for the health care facility. [NFPA 99:4.2.1]

6.1.2 Risk assessment

The governing body shall conduct risk assessments and shall determine risk categories based on the character of the processes and operations conducted in the health care facility. [NFPA 99:4.2.1.1]

Risk categories shall be classified by the health care facility's governing body by following and documenting a defined risk assessment procedure. [NFPA 99:4.2.2]

6.1.2.1 Documents to the Competent Authority

Where required by the Competent Authority, the risk assessment shall be provided to the Competent Authority for review based on the character of the processes and operations conducted in the health care facility. [NFPA 99:4.2.2.1]

6.2 Anaesthesia

It shall be the responsibility of the health care facility's governing body to designate anesthetizing locations. [NFPA 99:1.3.4.2]

6.3 Wet procedure locations

It shall be the responsibility of the health care facility's governing body to designate wet procedure locations. [NFPA 99:1.3.4.3]

7 Health care facilities

7.1 Drinking fountain control valves

Drinking fountain control valves shall be flush-mounted or fully recessed where installed in corridors or other areas where patients are transported on a gurney, bed, or wheelchair.

7.2 Psychiatric patient rooms

Piping and drain traps in psychiatric patient rooms shall be concealed. Fixtures and fittings shall be resistant to vandalism

7.3 Locations for ice storage

Ice makers or ice storage containers shall be located in nursing stations or similarly supervised areas to minimize potential contamination.

7.4 Sterilizers and bedpan steamers

Sterilizers and bedpan steamers shall be installed in accordance with the manufacturer's installation instructions and shall confirm with Section 7.4.1 and Section 7.4.2.

7.4.1 Drainage connections

Sterilizers and bedpan steamers shall be connected to the sanitary drainage system through an air gap in accordance with WDRS-4. The size of indirect waste piping shall be not less than the size of the drain connection on the fixture. Each such indirect waste pipe shall not exceed 15 feet (4572 mm) in length and shall be separately piped to a receptor. Such receptors shall be located in the same room as the equipment served. Except for bedpan steamers, such indirect waste pipes shall not require traps. A trap having a seal of not less than 3 inches (76 mm) shall be provided in the indirect waste pipe for a bedpan steamer.

7.4.2 Vapor vents and stacks

Where a sterilizer or bedpan steamer has provision for a vapor vent and such a vent is required by the manufacturer, the vent shall be extended to the outdoors above the roof. Sterilizer and bedpan steamer vapor vents shall be installed in accordance with the manufacturer's installation instructions and shall not be connected to a drainage system vent.

7.5 Aspirators

Provisions for aspirators or other water-supplied suction devices shall be installed with the specific approval of the Competent Authority. Where aspirators are used for removing body fluids, they shall include a collection container to collect liquids and solid particles. Aspirators shall indirectly discharge to the sanitary drainage system through an air gap in accordance with WDRS-4. The potable water supply to an aspirator shall be protected by a vacuum breaker or equivalent backflow protection device in accordance with WDRS-3.

7.6 Drains

Drains shall be installed on dryers, aftercoolers, separators, and receivers.

7.7 Clinical sinks

Clinical sinks shall be installed in accordance with the manufacturer's installation instructions and shall conform with this section.

Clinical sinks shall be directly connected to the sanitary drainage system and shall be provided with approved flushing devices installed in accordance with WDRS-2.

7.8 Water supply for hospitals

Hospitals should be provided with not less than two approved potable water sources that are installed in such a manner as to prevent the interruption of water service.

7.9 Work performed in occupied healthcare facilities

In existing, occupied, inpatient healthcare facilities, all plumbing systems installation and remodel work shall be performed by personnel certified in accordance with ASSE/IAPMO/ANSI 12010.

8 Medical gas and medical vacuum piping systems

8.1 General

The installation of medical gas and medical vacuum piping systems shall comply with the requirements of this standard.

8.2 Certification of systems

Certification of medical gas and vacuum systems shall comply with the requirements of Section 10 of this standard.

8.3 Construction documents

Before a medical gas or medical vacuum system is installed or altered in a hospital, medical facility, or clinic, duplicate construction documents shall be filed with Competent Authority. Approval of the plans shall be obtained before issuance of a permit by the Competent Authority.

8.3.1 **Requirements**

Construction documents shall show the following:

(i) Plot plan of the site, drawn to scale, indicating the location of existing or new cylinder storage areas, property lines, driveways, and existing or proposed buildings

(ii) Piping layout of the proposed piping system or alteration, including alarms, valves, the origin of gases, user outlets, and user inlets. The demand and loading of piping, existing or future, shall also be indicated

(iii) Complete specification of materials.

8.4 Extent of work

Construction documents submitted to the Competent Authority shall clearly indicate the nature and extent of the work proposed and shall show in detail that such work will be in accordance with the provisions of this standard.

8.5 Record

A record of as-built plans and valve identification records shall remain on the site.

9 System performance

9.1 Required operating pressures

Medical gas and vacuum systems shall be capable of delivering service in the pressure ranges listed in Table 1.

9.2 Minimum flow rates

Medical gas and vacuum systems shall be capable of supplying the flow rates listed in Table 2.

9.3 Minimum station outlets and inlets

Station outlets and inlets for medical gas and vacuum systems shall be provided as listed in Table 3.

10 System certification

10.1 Certification

Prior to a medical gas or vacuum system being placed in service, such system shall be certified in accordance with Section 10.2.

10.2 Certification tests

Certification tests, verified and attested to by the certification body, shall include the following:

(i) Verifying in accordance with the installation requirements

(ii) Testing and checking for leakage, correct zoning, and identification of control valves

(iii) Checking for identification and labelling of pipelines, station outlets, and control valves

(iv) Testing for cross-connection, flow rate, system pressure drop, and system performance

(v) Functional testing of pressure relief valves and safety valves

(vi) Functional testing of sources of supply

(vii) Functional testing of alarm systems, including accuracy of system components

(viii) Purge flushing of system and filling with specific source gases

(ix) Testing for purity and cleanliness of source gases

(x) Testing for specific gas identity at each station outlet

Table 1 — Standard designation colours and operating pressures for gas and vacuum systems

[NFPA 99: TABLE 5.1.11]

Gas service	Abbreviated name	Colours (background/ text)	Standard gauge pressure
Medical air	Med Air	Yellow/black	50–55 psi
Carbon dioxide	CO_2	Gray/black or gray/white	50–55 psi
Helium	He	Brown/white	50–55 psi
Nitrogen	N_2	Black/white	55–185 psi
Nitrous oxide	N_2O	Blue/white	50–55 psi
Oxygen	O_2	Green/white or white/green	50–55 psi
Oxygen/carbon dioxide mixtures	O_2/CO_2 n % (n = % of CO_2)	Green/white	50–55 psi
Medical–surgical vacuum	Med Vac	White/black	15 inch to 30 inch HgV
Waste anesthetic gas disposal	WAGD	Violet/white	Varies with system type
Medical-surgical vacuum/ WAGD combination	Med-surg/WAGD	White/black and violet/white	15 inch to 30 inch HgV

Other mixtures	Gas A% / Gas B%	Colors as above; major gas for background/minor gas for text	None
Nonmedical air and dental air	—	Yellow and white diagonal stripe/black	None
Nonmedical vacuum and dental vacuum	—	White and black diagonal stripe/black boxed	None
Laboratory air	—	Yellow and white checkerboard/black	None
Laboratory vacuum	—	White and black checkerboard/black boxed	None
Instrument air	—	Red/white	50–185 psi
NOTE For SI units: 1 pound-force per square inch = 6.8947 kPa, 1 inch of mercury vacuum (HgV) = 3.386 kPa			

10.3 Report items

A report that includes the specific items addressed in Section 10.2, and other information required by this document, shall be delivered to the Competent Authority prior to acceptance of the system.

10.4 Components

Functioning of alarm components shall be verified in accordance with the testing and monitoring requirements of the manufacturer and the Competent Authority.

Table 2 — Minimum flow rates (cubic feet per minute)

Medical system	Flow rate
Oxygen	0.71 CFM per outlet[1]
Nitrous Oxide	0.71 CFM per outlet[1]
Medical Compressed Air	0.71 CFM per outlet[1]
Nitrogen	15 CFM free air per outlet
Vacuum	1 SCFM per inlet[2]
Carbon Dioxide	0.71 CFM per outlet[1]
Helium	0.71 CFM per outlet
For SI units: 1 cubic foot per minute (CFM) = 0.7L/S NOTE 1 A room designed for a permanently located respiratory ventilator or anaesthesia machine shall have an outlet capable of a flow rate of 6.36 CFM (3.0 L/s) at the station outlet NOTE 2For testing and certification purposes, individual station inlets shall be capable of a flow rate of 3 SCFM (1.4 L/s), while maintaining a system pressure of not less than 12 inches of mercury (41 kPa) at the nearest adjacent vacuum inlet	

Table 3 — Minimum outlets and inlets per station

Location	Oxygen	Medical vacuum	Medical air	Nitrous oxide	Nitrogen	Helium	Carbon dioxide
Patient rooms for medical/surgical, obstetrics, and pediatrics	1/bed	1/bed	1/bed	-	-	-	-
Examination/treatment for nursing units	1/bed	1/bed	-	-	-	-	-
Intensive care (all)	3/bed	3/bed	2/bed	-	-	-	-
Nursery[1]	2/bed	2/bed	1/bed	-	-	-	-
General operating rooms	2/room	3/room[4]	2/room	1/room	1/room	-	-
Cystoscopic and special invasive procedures	2/room	3/room[4]	2/room	-	-	-	-
Recovery delivery and labor/delivery/recovery rooms[2]	2/bed 2/room	2/bed 3/room[4]	1/bed 1/room	-	-	-	-
Labor rooms	1/bed	1/bed	1/bed	-	-	-	-
First aid and emergency treatment[3]	1/bed	1/bed[4]	1/bed	-	-	-	-
Autopsy	-	1/station	1/station	-	-	-	-
Anesthesia workroom	1/station	-	1/station	-	-	-	-

[1] Includes pediatric nursery.

[2] Includes obstetric recovery.

[3] Emergency trauma rooms used for surgical procedures shall be classified as general operating rooms.

[4] Vacuum inlets required are in addition to inlets used as part of a scavenging system for removal of anesthetizing gases.

11 Piped gas and vacuum systems

11.1 Central supply systems

11.2 Terms

Where the terms medical gas or medical support gas occur, the provisions shall apply to all piped systems for oxygen, nitrous oxide, medical air, carbon dioxide, helium, nitrogen, instrument air, and mixtures thereof. Wherever the name of a specific gas service occurs, the provision shall apply only to that gas. [NFPA 99:5.1.1.3]

11.3 Nature of hazards of gas and vacuum systems

Potential fire and explosion hazards associated with positive pressure gas central piping systems and medical–surgical vacuum systems shall be considered in the design, installation, testing, operation, and maintenance of these systems. [NFPA 99:5.1.2]

11.4 Permitted locations for medical gases

Central supply systems for oxygen, medical air, nitrous oxide, carbon dioxide, and all other patient medical gases shall be piped only to medical gas outlets conforming with Section 19, into areas where the gases will be used under the direction of licensed medical professionals for purposes congruent with the following:

(i) Direct respiration by patients

(ii) Clinical application of the gas to a patient, such as the use of an insufflator to inject carbon dioxide into patient body cavities during laparoscopic surgery and carbon dioxide used to purge heart-lung machine blood flow ways

(iii) Medical device applications directly related to respiration

(iv) Power for medical devices used directly on patients

(v) Calibration of medical devices intended for Section 11.4(1) through Section 11.4(4)

(vi) Simulation centers for the education, training, and assessment of health care professionals [NFPA 99:5.1.3.5.2]

11.5 Materials

Materials used in central supply systems shall meet the following requirements:

(i) In those portions of systems intended to handle oxygen at gauge pressures greater than 350 pounds-force per square inch (psi) (2413 kPa), interconnecting hose shall contain no polymeric materials

(ii) In those portions of systems intended to handle oxygen or nitrous oxide material, construction shall be compatible with oxygen under the temperatures and pressures to which the components can be exposed in the containment and use of oxygen, nitrous oxide, mixtures of these gases, or mixtures containing more than 23.5% oxygen

(iii) If potentially exposed to cryogenic temperatures, materials shall be designed for low-temperature service

(iv) If intended for outdoor installation, materials shall be installed per the manufacturer's requirements [NFPA 99:5.1.3.5.4]

12 Pressure-regulating equipment

12.1 Where required

Pressure-regulating equipment shall be installed in the supply main upstream of the final line-pressure valve. Where multiple piping systems for the same gas at different operating pressures are required, separate pressure-regulating equipment, relief valves, and source shutoff valves shall be provided for each pressure.

12.2 Pressure relief valves

All pressure relief valves shall meet the following requirements:

(i) They shall be of brass, bronze, or stainless-steel construction

(ii) They shall be designed for the specific gas service

(iii) They shall have a relief pressure setting not higher than the maximum allowable working pressure (MAWP) of the component with the lowest working pressure rating in the portion of the system being protected

(iv) They shall be vented to the outside of the building, except that relief valves for compressed air systems having less than 3000 cubic feet (84 950 L) at STP shall be permitted to be diffused locally by means that will not restrict the flow

(v) They shall have a vent discharge line that is not smaller than the size of the relief valve outlet or ¾ NPS (20 mm), whichever is larger

(vi) Where two or more relief valves discharge into a common vent line, the internal cross-sectional area of the common line shall be not less than the aggregate cross-sectional area of all relief valve vent discharge lines served

(vii) They shall not discharge into locations creating potential hazards

(viii) They shall have the discharge terminal turned down and screened to prevent the entry of rain, snow, or vermin

(ix) They shall be designed in accordance with ASME B31.3 [NFPA 99:5.1.3.5.6.1]

12.3 Pressure-relief valve requirements

Central supply systems for positive pressure gases shall include one or more relief valves, all meeting the following requirements:

(i) They shall be located between each final line regulator and the source valve

(ii) They shall have a relief setting that is 50% above the normal system operating pressure, as indicated in Table 1 [NFPA 99:5.1.3.5.6.4

13 Oxygen concentrator supply units

13.1 Oxygen requirements

Oxygen concentrator supply units for use with medical gas pipelines shall produce oxygen meeting the requirements of Oxygen 93 USP or Oxygen USP. [NFPA 99:5.1.3.9.1.1]

13.2 Particulate size

Output shall have less than or equal to 1.686×10^{-6} pounds per cubic yard (1 mg/m^3) of permanent particulates sized 1 micron or larger at normal atmospheric pressure. [NFPA 99:5.1.3.9.1.2]

13.3 Suitability

Materials of construction on the air side of the oxygen concentrator unit shall be suitable for the service as determined by the manufacturer. [NFPA 99:5.1.3.9.1.3]

13.4 Compatible Materials.

Materials of construction on the oxygen side of the oxygen concentrator unit shall comply with Section 11.5. [NFPA 99:5.1.3.9.1.4]

13.5 Oxygen concentrator components

The components that make up the oxygen concentrator unit shall be as follows:

(i) The manufacturer of the concentrator unit shall be permitted to use such components and arrangement of such components as needed to produce oxygen conforming with Section 13.1 in the quantity as required by the facility, except where otherwise specifically defined in this document

(ii) Air receivers and oxygen accumulators, where used, shall conform with Section VIII.1, “Unfired Pressure Vessels,” of the ASME Boiler and Pressure Vessels Code and be provided with overpressure relief valves. [NFPA 99:5.1.3.9.1.5]

13.6 Supply air quality

The supply air to the concentrator(s) shall be of a quality to ensure the oxygen concentrator unit can produce oxygen complying withSection 13.1 and shall not be subject to normally anticipated contamination (e.g., vehicle or other exhausts, gas leakage, discharge from vents, flooding). [NFPA 99:5.1.3.9.1.6]

13.7 Electrical components

The oxygen concentrator supply unit and any associated electrical equipment shall be provided with, at a minimum, the following electrical components:

(i) Either a disconnect switch for each major electrical component or a single disconnect that deactivates all electrical components in the concentrator unit

(ii) Motor starting devices with overload protection for any component with an electrical motor over 2 hp (1.5 kW) [NFPA 99:5.1.3.9.1.7]

13.8 Vent valve

A vent valve shall be provided as follows:

(i) Located on the source side of the concentrator outlet isolation valve to permit the operation of the oxygen concentrator unit for validation, calibration, and testing while the unit is isolated from the pipeline system

(ii) Sized to allow for at least 25% of the oxygen concentrator unit flow

(iii) Vented to a location compliant with Section 13.8.1 [NFPA 99:5.1.3.9.1.8]

13.8.1 **Venting of relief valves**

Indoor supply systems shall have all relief valves vented per Section 12.2(ii) through Section 12.2(ix). [NFPA 99:5.1.3.3.3.2]

13.9 Valved sample port

A DN8 (NPS 1/4) valved sample port shall be provided near the oxygen concentration monitor sensor connection for sampling of the gas from the oxygen concentrator unit. [NFPA 99:5.1.3.9.1.9]

13.10 Suitable filter

At least 0.1micron filter suitable for oxygen service shall be provided at the outlet of the oxygen concentrator supply unit. [NFPA 99:5.1.3.9.1.10]

13.11 Check valve.

A check valve shall be provided at the outlet of the oxygen concentrator supply unit to prevent backflow into the oxygen concentrator supply unit and to allow service to the unit. [NFPA 99:5.1.3.9.1.11]

13.12 Outlet valve

An outlet valve shall be provided to isolate all components of the oxygen concentrator from the pipeline with the following characteristics:

(i) The valve shall have both manual and automatic actuation with visual indication of open or closed

(ii) The valve shall close automatically whenever the oxygen concentrator unit is not producing oxygen of a concentration equal to that in Section 13.1

(iii) Continuing operation of the oxygen concentrator supply unit through the vent mode shall be permitted with the isolating valve closed

(iv) The isolating valve, when automatically closed due to low concentration, shall require manual reset to ensure the oxygen concentrator supply unit is examined prior to return to service

(v) Closing the isolating valve, whether automatically or manually, shall activate an alarm signal at the master alarms (see Section 21.2.1) indicating that the oxygen concentrator supply unit is disconnected. [NFPA 99:5.1.3.9.1.12]

13.13 Oxygen concentration monitor

The oxygen concentrator supply unit shall be provided with an oxygen concentration monitor with the following characteristics:

(i) The monitor shall be capable of monitoring 99% of oxygen concentration with 1% accuracy

(ii) The monitor shall continuously display the oxygen concentration and shall activate local alarm and master alarms per NFPA 99 when a concentration lower than 91% percent is observed

(iii) The monitor shall continuously display the oxygen concentration

(iv) It shall be permitted to insert the monitor into the pipeline without a demand check [NFPA 99:5.1.3.9.1.13]

14 Category 1 Medical air central supply systems

14.1 Quality of medical air

Medical air shall be required to have the following characteristics:

(i) It shall be supplied from cylinders, bulk containers, or medical air compressor sources, or it shall be reconstituted from oxygen USP and oil-free, dry nitrogen NF.

(ii) It shall meet the requirements of medical air USP

(iii) It shall have no detectable liquid hydrocarbons

(iv) It shall have less than 25 ppm gaseous hydrocarbons

(v) It shall have equal to or less than 1.686 x 10^{-6} pounds per cubic yard (1 mg/m3) of permanent particulates sized 1 micron or larger in the air at normal atmospheric pressure. [NFPA 99:5.1.3.6.1]

14.2 Medical air compressors

Medical air compressors shall be installed in a well-lit, ventilated, and clean location and shall be accessible. The location shall be provided with drainage facilities in accordance with this standard. The medical air compressor area shall be located separately from medical gas cylinder system sources, and shall be readily accessible for maintenance.

14.2.1 **Medical air compressor**

Medical air compressors shall be sufficient to serve the peak calculated demand with the largest single compressor out of service. In no case shall there be fewer than two compressors. [NFPA 99:5.1.3.6.3.9(B)]

14.2.2 **Required components**

Medical air compressor systems shall consist of the following:

(i) Components shall be arranged to allow service and a continuous supply of medical air in the event of a single fault failure.

Component arrangement shall be permitted to vary as required by the technology(ies) employed, provided that an equal level of operating redundancy and medical air quality is maintained. [NFPA 99:5.1.3.6.3.9(A)(1), 5.1.3.6.3.9(A)(2)

(ii) Automatic means to prevent backflow from all on-cycle compressors through all off-cycle compressors

(iii) Manual shutoff valve to isolate each compressor from the centrally piped system and from other compressors for maintenance or repair without loss of pressure in the system

(iv) Intake filter-muffler(s) of the dry type

(v) Pressure relief valve(s) set at 50% above line pressure

(vi) Piping and components between the compressor and the source shutoff valve that do not contribute to contaminant levels

(vii) Except as defined in Section 14.2.2(1) through Section 14.2.2(6) , materials and devices used between the medical air intake and the medical air source valve that are of any design or construction appropriate for the service as determined by the manufacturer. [NFPA 99:5.1.3.6.3.2 (2-7)]

14.3 Medical air receivers

Receivers for medical air shall meet the following requirements:

(i) They shall be made of corrosion-resistant materials or otherwise be made corrosion resistant.

(ii) They shall conform with Section VIII.1, “Unfired Pressure Vessels,” of the ASME Boiler and Pressure Vessel Code

(iii) They shall be equipped with a pressure relief valve, automatic drain, manual drain, sight glass, and pressure indicator

(iv) They shall be of a capacity sufficient to prevent the compressors from short-cycling. [NFPA 99:5.1.3.6.3.6]

14.4 Valves

A medical air receiver(s) shall be provided with proper valves to allow the flow of compressed air to enter and exit out of separate receiver ports during normal operation and allow the receiver to be bypassed during service without shutting down the supply of medical air. [NFPA 99:5.1.3.6.3.9(D)]

15 Compressor intake

15.1 Air sources

Air sources for medical air compressors shall conform with Section 4.5.2 through Section 4.5.6.

15.2 Medical air compressor source

The medical air compressors shall draw their air from a source of clean air. [NFPA 99:5.1.3.6.3.11(A)]

If an air source equal to or better than outside air (e.g., air already filtered for use in operating room ventilating systems) is available, it shall be permitted to be used for the medical air compressors with the following provisions:

(ii) This alternate source of supply air shall be available on a continuous 24 hours-per-day, 7 day-per-week basis

(ii) Ventilating systems having fans with motors or drive belts located in the airstream shall not be used as a source of medical air intake. [NFPA 99:5.1.3.6.3.11(E)]

15.3 Air intakes

Compressor intake piping shall be permitted to be made of materials and use a joining technique as permitted under Section 23 and Section 24. [NFPA 99:5.1.3.6.3.11(F)]

15.4 Location

Medical air intakes shall be located as follows:

(i) The medical air intake shall be located a minimum of 25 feet (7620 mm) from ventilating system exhausts, fuel storage vents, combustion vents, plumbing vents, vacuum and WAGD discharges, or areas that can collect vehicular exhausts or other noxious fumes

(ii) The medical air intake shall be located a minimum of 20 feet (6096 mm) above ground level

(iii) The medical air intake shall be located a minimum of 10 feet (3048 mm) from any door, window, or other opening in the building. [NFPA 99:5.1.3.6.3.11(B-D)]

15.5 Separate compressors

Air intakes for separate compressors shall be permitted to be joined together to one common intake where the following conditions are met:

(i) The common intake is sized to minimize backpressure in accordance with the manufacturer's recommendations

(ii) Each compressor can be isolated by manual or check valve, blind flange, or tube cap to prevent open inlet piping when the compressor(s) is removed for service from the consequent backflow of room air into the other compressor(s). [NFPA 99:5.1.3.6.3.11(G)]

15.6 Screening

The end of the intake shall be turned down and screened or otherwise be protected against the entry of vermin, debris, or precipitation by screening fabricated or composed of a noncorroding material. [NFPA 99:5.1.3.6.3.11(H)]

16 Medical surgical vacuum central supply systems

16.1 General

The vacuum plant shall be installed in a well-lit, ventilated, and clean location with accessibility. The location shall be provided with drainage facilities in accordance with this standard. The vacuum plant, where installed as a source, shall be located separately from other medical vacuum system sources and shall be readily accessible for maintenance.

16.2 Medical-surgical vacuum sources

Medical-surgical vacuum central supply systems shall consist of the following:

(i) Two or more vacuum pumps sufficient to serve the peak calculated demand with the largest single vacuum pump out of service

(ii) Automatic means to prevent backflow from any on-cycle vacuum pumps through any off-cycle vacuum pumps

(iii) Shutoff valve or other isolation means to isolate each vacuum pump from the centrally piped system, and other vacuum pumps for maintenance or repair without loss of vacuum in the system

(iv) Vacuum receiver

(v) Piping between the vacuum pump(s), discharge(s), receiver(s), and vacuum source shutoff valve in accordance with Section 23, except brass, galvanized, or black steel pipe, which is permitted to be used as recommended by the manufacturer

(vi) Except as defined in tSection 16.2(1) through Section 16.2(5), materials and devices used between the medical vacuum exhaust and the medical vacuum source that are permitted to be of any design or construction appropriate for the service as determined by the manufacturer

(vii) Vacuum filtration per Section 16.4 [NFPA 99:5.1.3.7.1.1]

16.3 Vacuum receivers

Receivers for vacuum shall meet the following requirements:

(i) They shall be made of materials deemed suitable by the manufacturer

(ii) They shall comply with Section VIII.1, “Unfired Pressure Vessels,” of the ASME Boiler and Pressure Vessel Code

(iii) They shall be capable of withstanding a gauge pressure of 60 psi (414 kPa) and 30 inch (762 mm) gauge HgV

(iv) They shall be equipped with a manual drain

(v) They shall be of a capacity based on the technology of the pumps. [NFPA 99:5.1.3.7.3]

16.4 Vacuum filtration

Central supply systems for vacuum other than liquid ring pumps shall be provided with inlet filtration with the following characteristics:

(i) Filtration shall be at least duplex to allow one filter to be exchanged without impairing the vacuum system

(ii) Filtration shall be located on the patient side of the vacuum producer

(iii) Filters shall be efficient to 0.3 µ and 99.97% HEPA

(iv) Filtration shall be sized for 100% of the peak calculated demand while one filter or filter bundle is isolated

(v) It shall be permitted to group multiple filters into bundles to achieve the required capacities

(vi) The system shall be provided with isolation valves on the source side of each filter or filter bundle and isolation valves on the patient side of each filter or filter bundle, permitting the filters to be isolated without shutting off flow to the central supply system

(vii) A means shall be available to allow the user to observe any accumulations of liquids

(viii) A vacuum relief petcock shall be provided to allow vacuum to be relieved in the filter canister during filter replacement

(ix) Filter elements and canisters shall be permitted to be constructed of materials as deemed suitable by the manufacturer

(x) In normal operation, one filter or filter bundle shall be isolated from the system to be available for service should a blockage in the operating filter occur or rotation of the filters be desired after filter element exchange. [NFPA 99:5.1.3.7.4]

16.5 Piping arrangement and redundancies

Piping arrangement shall be as follows:

(i) Piping shall be arranged to allow service and a continuous supply of medical-surgical vacuum in the event of a single fault failure

(ii) Piping arrangement shall be permitted to vary based on the technology(ies) employed, provided that an equal level of operating redundancy is maintained

(iii) Where only one set of vacuum pumps is available for a combined medical-surgical vacuum system and an analysis, a research, or a teaching laboratory vacuum system, such laboratories shall be connected separately from the medical-surgical system directly to the receiver tank through its own isolation valve and fluid trap located at the

receiver, and between the isolation valve and fluid trap, a scrubber shall be permitted to be installed. [NFPA 99:5.1.3.7.5, 5.1.3.7.5.1]

16.6 Piping serviceability

The medical-surgical vacuum receiver(s) shall be serviceable without shutting down the medical-surgical vacuum system by any method to ensure continuation of service to the facility's medical-surgical pipeline distribution system. [NFPA 99:5.1.3.7.5.2]

16.7 Shutoff valve

Medical-surgical vacuum central supply systems shall be provided with a source shutoff valve per Section 18.6. [NFPA 99:5.1.3.7.5.3]

17 Medical-surgical vacuum exhaust

17.1 Vacuum source exhausts

The medical-surgical vacuum pumps shall exhaust in a manner and location that minimizes the hazards of noise and contamination to the facility and its environment. [NFPA 99:5.1.3.7.7.1]

17.2 Location

The exhaust shall be located as follows:

(i) Outdoors

(ii) At least 25 feet (7620 mm) from any door, window, air intake, or other openings in buildings or places of public assembly

(iii) At a level different from air intakes

(iv) Where prevailing winds, adjacent buildings, topography, or other influences will not divert the exhaust into occupied areas or prevent dispersion of the exhaust. [NFPA 99: 5.1.3.7.7.2]

17.3 Screening

The end of the exhaust shall be turned down and screened or otherwise be protected against the entry of vermin, debris, or precipitation by screening fabricated or composed of a noncorroding material. [NFPA 99:5.1.3.7.7.3]

17.4 Dips and loops

The exhaust shall be free of dips and loops that might trap condensate or oil or provided with a drip leg and valved drain at the bottom of the low point. [NFPA 99:5.1.3.7.7.5]

17.5 Multiple pumps

Vacuum exhausts from multiple pumps shall be permitted to be joined together to one common exhaust where the following conditions are met:

(i) The common exhaust is sized to minimize back pressure in accordance with the pump manufacturer's recommendations.

(ii) Each pump can be isolated by manual or check valve, blind flange, or tube cap to prevent open exhaust piping when the pump(s) is removed for service from consequent flow of exhaust air into the room. [NFPA 99:5.1.3.7.7.6]

18 Valves

18.1 Gas and vacuum shutoff valves

Shutoff valves shall be provided to isolate sections or portions of the piped distribution system for maintenance, repair, or planned future expansion need and to facilitate periodic testing. [NFPA 99:5.1.4.1.1]

18.2 Security

All valves, except valves in zone valve box assemblies, shall be secured by any of the following means:

(i) Located in secured areas.

(ii) Locked or latched in their operating position

(iii) Located above ceilings, but remaining accessible and not obstructed. [NFPA 99:5.1.4.1.2]

18.3 Labelled

All valves shall be labeled as to gas supplied and the area(s) controlled, in accordance with Section 27.14. [NFPA 99:5.1.4.1.3]

18.4 Accessibility

Zone valves shall be installed in valve boxes with removable covers large enough to allow manual operation of valves. Zone valves for use in certain areas, such as psychiatric or paediatric areas, shall be permitted to be secured with the approval of the Competent Authority to prevent inappropriate access. [NFPA 99:5.1.4.1.4]

18.4.1 Flammable gases

Valves for nonflammable medical gases shall not be installed with valves for flammable gases in the same zone valve box assembly with flammable gases. [NFPA 99:5.1.4.1.5]

18.5 Valve types

New or replacement valves shall be permitted to be of any type as long as they meet the following conditions:

(i) They have a minimum Cv factor in accordance with Table 4 or 5

(ii) They use a quarter turn to off

(iii) They are constructed of materials suitable for the service

(iv) They are provided with copper tube extensions by the manufacturer for brazing or with corrugated medical tubing (CMT) fittings

(v) They indicate to the operator if the valve is open or closed

(vi) They permit in-line serviceability

(vii) They are cleaned for oxygen service by the manufacturer if used for any positive-pressure service

(viii) They have threaded purge ports on the patient side and the source side

(ix) They have a minimum working pressure equal to or greater than the relief valve protecting the piping system on which the valve is installed for any positive-pressure service. [NFPA 99:5.1.4.1.6]

Table 4 — Positive gases pressure

[NFPA 99: TABLE 5.1.4.1.6(a)]

Valve size inch	**Minimum Cv** full open
1/2	17
3/4	31
1	60
1 1/4	110
1 1/2	169
2	357
2 1/2	390
3	912
4	1837
NOTE For SI units: 1 inch = 25.4 mm	

18.6 Source valves

A shutoff valve shall be placed at the immediate connection of each central supply system to the piped distribution system to allow the entire central supply system, including all accessory devices (e.g., air dryers, final line regulators), to be isolated from the facility. [NFPA 99:5.1.4.2.1]

18.6.1 **Location**

The source valve shall be located in the immediate vicinity of the central supply system. [NFPA 99:5.1.4.2.2]

18.7 Main Line valve

A shutoff valve shall be provided in the main supply line inside of the buildings being served, except where one or more of the following conditions exist:

(i) The source and source valve are located inside the building served

(ii) The source system is physically mounted to the wall of the building served, and the pipeline enters the building in the immediate vicinity of the source valve. [NFPA 99:5.1.4.3.1]

18.7.1 **Location**

The main line valve shall be located on the facility side of the source valve and outside of the source room, the enclosure, or where the main line first enters the building. [NFPA 99:5.1.4.3.2]

18.8 Riser valves

Each riser supplied from the main line shall be provided with a shutoff valve in the riser adjacent to the main line. [NFPA 99:5.1.4.4]

18.9 Service valves.

Service valves shall be installed to allow servicing or modification of lateral branch piping from a main or riser without shutting down the entire main, riser, or facility. [NFPA 99:5.1.4.5.1]

18.9.1 **Branch Piping**

Only one service valve shall be required for each branch off of a riser, regardless of how many zone valve boxes are installed on that lateral. Service valves shall be placed in the branch piping prior to any zone valve box assembly on that branch. [NFPA 99:5.1.4.5.2, 5.1.4.5.3]

18.10 Zone valves

All station outlets/inlets shall be supplied through a zone valve, which shall be placed as follows:

(i) It is installed so that a wall intervenes between the valve and the outlets/inlets that it controls

(ii) It is readily operable from a standing position

(iii) It is installed where it is visible and accessible at all times

(iv) It is not installed where it can be hidden from plain view, such as behind normally open or normally closed doors.

(v) It is not installed in a room with the station outlets/inlets that it controls

(vi) It is not installed in rooms, areas, or closets that can be closed or locked. [NFPA 99:5.1.4.6.1]

18.10.1 **Readily accessible**

A zone valve in each medical gas or vacuum line shall be provided for each Category 1 space and anesthetizing location for moderate sedation, deep sedation, or general anesthesia specific for the occupancy, and shall be located as follows:

(i) They are installed immediately outside the area controlled

(ii) They are installed where they are visible and accessible at all times [NFPA 99:5.1.4.6.2]

18.10.2 **Arrangement**

Piping on the patient side of zone valves shall be arranged to provide the following:

(i) Shutting off the supply of medical gas or vacuum to one zone will not affect the supply of medical gas or vacuum to another zone or the rest of the system

(ii) Service will only be to outlets/inlets located on that same story

(iii) All gas delivery columns, hose reels, ceiling tracks, control panels, pendants, booms, or other special installations are located on the patient side of the zone valve. [NFPA 99:5.1.4.6.3]

18.10.3 **Indicators**

A pressure/vacuum indicator shall be provided on the station outlet/inlet side of each zone valve. [NFPA 99:5.1.4.6.4]

18.11 In-line shutoff valves

Optional in-line valves shall be permitted to be installed to isolate or shut off piping for servicing of individual rooms or areas. [NFPA 99:5.1.4.7]

18.12 Valves for future connections

Future connection valves shall be labeled as to gas content. [NFPA 99:5.1.4.8.1]

18.12.1 **Downstream piping**

Downstream piping shall be closed with a brazed cap with tubing allowance for cutting and rebrazing. [NFPA 99:5.1.4.8.2]

19 Station outlets and inlets

19.1 General

Each station outlet/inlet for medical gases or vacuums shall be gas-specific, whether the outlet/inlet is threaded or is a noninterchangeable quick coupler. [NFPA 99:5.1.5.1]

19.2 Required valves

Each station outlet shall consist of a primary and a secondary valve (or assembly).

Each station inlet shall consist of a primary valve (or assembly) and shall be permitted to include a secondary valve (or assembly). [NFPA 99:5.1.5.2, 5.1.5.3]

19.2.1 Secondary valve

The secondary valve (or assembly) shall close automatically to stop the flow of gas (or vacuum, if provided) when the primary valve (or assembly) is removed. [NFPA 99:5.1.5.4]

19.3 Identification

Each outlet/inlet shall be legibly identified in accordance with Section 27.15. [NFPA 99:5.1.5.5]

19.4 Threaded outlets/fittings

Threaded outlets/inlets shall be noninterchangeable connections complying with the mandatory requirements of CGA V-5. [NFPA 99:5.1.5.6]

19.5 Gas-specific station outlet/inlet

Each station outlet/inlet, including those mounted in columns, hose reels, ceiling tracks, or other special installations, shall be designed so that parts or components that are required to be gas-specific for compliance with Section 19.1 and Section 19.7 cannot be interchanged between the station outlet/inlet for different gases. [NFPA 99:5.1.5.7]

19.6 Common parts

The use of common parts in outlets/inlets, such as springs, O-rings, fasteners, seals, and shutoff poppets, shall be permitted. [NFPA 99:5.1.5.8]

19.7 Marking of components

Components of a vacuum station inlet necessary for the maintenance of vacuum specificity shall be legibly marked to identify them as components or parts of a vacuum or suction system. [NFPA 99:5.1.5.9]

19.8 Components not specific to a vacuum

Components of inlets not specific to a vacuum shall not be required to be marked. [NFPA 99:5.1.5.10]

19.9 Factory-installed copper inlet tubes

Factory-installed copper inlet tubes on station outlets extending no further than 8 inches (203 mm) from the body of the terminal shall be not less than DN8 (NPS 1/4) (3/8 inch O.D.) size, with 0.3 inch (7.6 mm) minimum inside diameter. [NFPA 99:5.1.5.11]

19.10 Factory-installed copper outlet tubes

Factory-installed copper outlet tubes on station inlets extending no further than 8 inches (203 mm) from the body of the terminal shall be not less than DN10 (NPS 3/8) (1/2 in O.D.) size, with 0.4 inch (10.2 mm) minimum inside diameter. [NFPA 99:5.1.5.12]

19.11 Protection from damage

Station outlets/inlets shall be permitted to be recessed or otherwise protected from damage. [NFPA 99:5.1.5.13]

19.12 Multiple wall outlets/inlets

When multiple wall outlets/inlets are installed, they shall be spaced to allow the simultaneous use of adjacent outlets/inlets with any of the various types of therapy equipment. [NFPA 99:5.1.5.14]

19.13 Nonstandard operation pressures

Station outlets in systems having nonstandard operating pressures shall meet the following additional requirements:

(i) They shall be gas-specific

(ii) They shall be pressure-specific where a single gas is piped at more than one operating pressure [e.g., a station outlet for oxygen at 80 psi (552 kPa) shall not accept an adapter for oxygen at 50 psi (345 kPa)]

(iii) If operated at a pressure in excess of 80 psi (552 kPa), they shall be either D.I.S.S connectors or comply with Section 19.13(4)

(iv) If operated at a gauge pressure between 200 psi and 300 psi (1379 kPa and 2068 kPa), the station outlet shall be designed so as to prevent the removal of the adapter until the pressure has been relieved to prevent the adapter injuring the user or others when removed from the outlet. [NFPA 99:5.1.5.15]

19.14 Post installation

After installation of the piping, but before installation of the station outlets and inlets and other medical gas and medical gas system components (e.g., pressure-actuating switches for alarms, manifolds, pressure gauges, or pressure relief valves), the line shall be blown clear using oil-free, dry nitrogen NF.

20 Pressure and vacuum indicator locations

20.1 Isolation

A pressure-relief valve shall not be isolated from its intended use by a valve

20.2 Pressure and vacuum indicator locations

XXXX **Category** **1.**

Pressure/vacuum indicators shall be readable from a standing position. Pressure/vacuum indicators shall be provided at the following locations, as a minimum:

(i) Adjacent to the alarm-initiating device for source main line pressure and vacuum alarms in the master alarm system

(ii) At or in area alarm panels to indicate the pressure/vacuum at the alarm activating device for each system that is monitored by the panel

(iii) On the station outlet/inlet side of zone valves. [NFPA 99:5.1.8.2.1, 5.1.8.2.2]

21 Warning systems

All master, area, and local alarm systems used for medical gas and vacuum systems shall include the following:

(i) Separate visual indicators for each condition monitored, except as permitted in Section 21.2.2 for local alarms that are displayed on master alarm panels

(ii) Visual indicators that remain in alarm until the situation that has caused the alarm is resolved.

(iii) Cancellable audible indication of each alarm condition that produces a sound with a minimum level of 80 dBA at 3 feet (914 mm)

(iv) Means to indicate a lamp or LED failure and audible failure

(v) Visual and audible indication that the communication with an alarm-initiating device is disconnected

(vi) Labelling of each indicator, indicating the condition monitored

(vii) Labelling of each alarm panel for its area of surveillance

(viii) Reinitiating of the audible signal if another alarm condition occurs while the audible alarm is silenced

(ix) Power for master alarms, area alarms, sensors, and switches from the life safety branch of the essential electrical system s described in NFPA 99

(x) Power for local alarms, dew point sensors, and carbon monoxide sensors permitted to be from the same essential electrical branch as is used to power the air compressor system

(xi) Where used for communications, wiring from switches or sensors that is supervised or protected as required by NFPA 70 for life safety and critical branches circuits in which protection is any of the following types:

(a) Conduit

(b) Free air

(c) Wire

(d) Cable tray

(e) Raceways

(xii) Communication devices that do not use electrical wiring for signal transmission and are supervised such that failure of communication initiates an alarm

(xiii) Assurance by the responsible authority of the facility that the labelling of alarms, where room numbers or designations are used, is accurate and up-to-date

(xiv) Provisions for automatic restart after a power loss of 10 seconds (e.g., during generator start-up) without giving false signals or requiring manual reset

(xv) Alarm switches/sensors installed so as to be removable and accessible for service and testing. [NFPA 99:5.1.9.1]

21.1.1 **Master alarms**

A master alarm system shall be provided to monitor the operation and condition of the source of supply, the reserve source (if any), and the pressure in the main lines of each medical gas and vacuum piping system. [NFPA 99:5.1.9.2]

21.1.2 **Master alarm signal**

The master alarm shall include at least one signal from the source equipment to indicate a problem with the source equipment at this location. This master alarm signal shall activate when any of the required local alarm signals for this source equipment activates. [NFPA 99:5.1.9.5.2]

22 Piping materials for field-installed positive pressure medical gas systems

22.1 General

The provisions of this clause apply to field-installed piping for the distribution of medical gas systems.

22.2 Cleaning

Tubes, valves, fittings, station outlets, and other piping components in medical gas systems shall have been cleaned for oxygen service by the manufacturer prior to installation in accordance with the mandatory requirements of CGA G-4.1, except that fittings shall be permitted to be cleaned by a supplier or agency other than the manufacturer. [NFPA 99:5.1.10.1.1]

Where tube ends, fittings or other components become contaminated before installation they shall be recleaned in accordance with Section 25.8.7 and Section 25.8.8.

22.3 Delivery

Each length of tube shall be delivered plugged or capped by the manufacturer and kept sealed until prepared for installation. Fittings, valves, and other components shall be delivered sealed and labeled and kept sealed until prepared for installation. [NFPA 99:5.1.10.1.2, 5.1.10.1.3]

22.4 Tubes for medical gas systems

Tubes shall be hard-drawn seamless copper in accordance with ASTM B819, medical gas tube, Type L, except Type K shall be used where operating pressures are above a gauge pressure of 185 psi (1276 kPa) and the pipe sizes are larger than DN80 [(NPS 3) (31/8 inchesO.D.)]. {NFPA 99:5.1.10.1.4}

22.5 Manufacturer markings

ASTM B819, medical gas tube shall be identified by the manufacturer's markings "OXY," "MED," "OXY/MED," "OXY/ACR," or "ACR/MED" in blue (Type L) or green (Type K). [NFPA 99:5.1.10.1.7]

22.6 Documentation

The installer shall furnish documentation certifying that all installed piping materials comply with the requirements of Section 22.2. [NFPA 99:5.1.10.1.8]

23 Piping materials for field-installed medical-surgical vacuum systems

23.1 Tubes for medical vacuum systems

Piping for vacuum systems shall be constructed of any of the following:

(1) Hard-drawn seamless copper tube in accordance with the following:

(i) ASTM B88, copper tube (Type K, Type L, or Type M)

(ii) ASTM B280, copper ACR tube

(iii) ASTM B819, copper medical gas tubing (Type K or Type L)

(2) Stainless steel tube in accordance with the following:

(i) ASTM A269 TP304L or 316L

(ii) ASTM A312 TP304L or 316L

(iii) ASTM A312 TP 304L/316L, Schedule 5S pipe, and ASTM A403 WP304L/316L, Schedule 5S fittings {NFPA 99:5.1.10.2.1}

23.2 Where not required

If medical gas tube in accordance with ASTM B819, Standard Specification for Seamless Copper Tube for Medical Gas Systems, is used for vacuum piping, such special marking shall not be required. [NFPA 99:5.1.10.2.2.2]

24 Joints and connections

24.1 General

This Clause sets forth the requirements for pipe joint installations for a medical gas or vacuum system.

24.2 Changes in direction

Positive pressure patient gas systems, medical support gas systems, and vacuum systems constructed of hard-drawn seamless copper or stainless-steel tubing shall have all turns, offsets, and other changes in direction made using fittings or techniques appropriate to any of the following acceptable joining methods:

(i) Brazing, as described in Section 25

(ii) Welding, as described in Section 26.1 through Section 26.2.1

(iii) Memory metal fittings, as described in Section 26.3

(iv) Axially swaged, elastic preload fittings, as described in Section 26.4

(v) Threaded, as described in Section 26.5 [NFPA 99:5.1.10.3.1]

24.3 Medical vacuum systems

Vacuum systems and WAGD systems fabricated from copper tubing shall be permitted to have branch connections made using mechanically formed, drilled, and extruded tee-branch connections that are formed in accordance with the tool manufacturer's instructions. Such branch connections shall be joined by brazing, as described in Section 25. [NFPA 99:5.1.10.3.3]

25 Brazed joints

25.1 Brazed joints and fittings

Fittings shall be wrought-copper capillary fittings conforming with ASME B16.22, or brazed fittings complying with ASME B16.50. Cast copper alloy fittings shall not be permitted.

Brazed joints shall be made using a brazing alloy that exhibits a melting temperature in excess of 1000 °F (538 °C) to retain the integrity of the piping system in the event of fire exposure. [NFPA 99:5.1.10.4.1.1 – 5.1.10.4.1.3]

25.2 Tube joints

Brazed tube joints shall be the socket type. [NFPA 99:5.1.10.4.1.4

25.3 Filler metals

Filler metals shall bond with and be metallurgically compatible with the base metals being joined Filler metals shall comply with AWS A5.8. [NFPA 99:5.1.10.4.1.5, 5.1.10.4.1.6]

25.4 Copper-to-copper joints

Copper-to-copper joints shall be brazed using a copper–phosphorus or copper-phosphorus-silver brazing filler metal (BCuP series) without flux. [NFPA 99:5.1.10.4.1.7]

25.5 Accessible

Joints to be brazed in place shall be accessible for necessary preparation, assembly, heating, filler application, cooling, cleaning, and inspection. [NFPA 99:5.1.10.4.1.9]

25.6 Purging

Braze joints shall be continuously purged with nitrogen NF. [NFPA 99:5.1.10.4.1.10]

25.7 Tube ends

Tube ends shall be cut square using a sharp tubing cutter to avoid deforming the tube. [NFPA 99:5.1.10.4.2.1]

25.7.1 Cutting wheels

The cutting wheels on tubing cutters shall be free from grease, oil, or other lubricant not suitable for oxygen service. [NFPA 99:5.1.10.4.2.2]

25.7.2 **Cut ends**

The cut ends of the tube shall be rolled smooth or deburred with a sharp, clean deburring tool, taking care to prevent chips from entering the tube. [NFPA 99:5.1.10.4.2.3]

25.8 Cleaning procedures

The interior surfaces of tubes, fittings, and other components that are cleaned for oxygen service shall be stored and handled to avoid contamination prior to assembly and brazing. [NFPA 99:5.1.10.4.3.1]

25.8.1 **Exterior surfaces**

The exterior surfaces of tube ends shall be cleaned prior to brazing to remove any surface oxides. When cleaning the exterior surfaces of tube ends, no matter shall be allowed to enter the tube. [NFPA 99:5.1.10.4.3.2, 5.1.10.4.3.3]

25.8.2 **Interior surfaces**

If the interior surfaces of fitting sockets become contaminated prior to brazing, they shall be recleaned for oxygen in accordance with Section 25.8.7 and be cleaned for brazing with a clean, oil-free, stainless steel or brass wire brush. [NFPA 99:5.1.10.4.3.4]

25.8.3 **Abrasive pads**

Clean, nonshedding, abrasive pads shall be used to clean the exterior surfaces of the tube ends. [NFPA 99:5.1.10.4.3.5]

25.8.4 **Prohibited**

The use of steel wool or sand cloth shall be prohibited. The cleaning process shall not result in grooving of the surfaces to be joined. [NFPA 99:5.1.10.4.3.6, 5.1.10.4.3.7]

25.8.5 **Wiped**

After being abraded, the surfaces shall be wiped using a clean, lint-free white cloth. [NFPA 99:5.1.10.4.3.8]

25.8.6 **Examination**

Tubes, fittings, valves, and other components shall be visually examined internally before being joined to verify that they have not become contaminated for oxygen service and that they are free of obstructions or debris. [NFPA 99:5.1.10.4.3.9]

25.8.7 **On-site recleaning**

The interior surfaces of tube ends, fittings, and other components that were cleaned for oxygen service by the manufacturer, but that became contaminated prior to being installed, shall be permitted to be recleaned on-site by the installer by thoroughly scrubbing the interior surfaces with a clean, hot water–alkaline solution, such as sodium carbonate or trisodium phosphate, using a solution of 1 pound (0.5 kg) of sodium carbonate or trisodium phosphate to 3 gallons (11 L) of potable water, and thoroughly rinsing them with clean, hot, potable water

Other aqueous cleaning solutions shall be permitted to be used for on-site recleaning permitted in this Clause, provided that they are in accordance with the mandatory requirements of CGA G-4.1. [NFPA 99:5.1.10.4.3.10, 5.1.10.4.3.11]

25.8.8 **Contaminated materials**

Material that has become contaminated internally and is not clean for oxygen service shall not be installed. [NFPA 99:5.1.10.4.3.12]

25.8.9 **Timeframe for brazing**

Joints shall be brazed within 8 hours after the surfaces are cleaned for brazing. [NFPA 99:5.1.10.4.3.13]

25.9 Brazing dissimilar metals

Flux shall only be used when brazing dissimilar metals, such as copper and bronze or brass, using a silver (BAg series) brazing filler metal. [NFPA 99:5.1.10.4.4.1]

25.9.1 **Surface cleaning.**

Surfaces shall be cleaned for brazing in accordance with Section 25.8. [NFPA 99:5.1.10.4.4.2]

25.9.2 **Flux**

Flux shall be applied sparingly to minimize contamination of the inside of the tube with flux. The flux shall be applied and worked over the cleaned surfaces to be brazed using a stiff bristle brush to ensure complete coverage and wetting of the surfaces with flux. [NFPA 99:5.1.10.4.4.3, 5.1.10.4.4.4]

25.9.3 **Short sections of copper**

Where possible, short sections of copper tube shall be brazed onto the non-copper component, and the interior of the subassembly shall be cleaned of flux prior to installation in the piping system. [NFPA 99:5.1.10.4.4.5]

25.9.4 **Flux-coated brazing rods**

On joints DN20 (NPS 3⁄4) (7⁄8-inch O.D.) size and smaller, flux-coated brazing rods shall be permitted to be used in lieu of applying flux to the surfaces being joined. [NFPA 99:5.1.10.4.4.6]

25.10 Nitrogen purge

When brazing, joints shall be continuously purged with oil-free, dry nitrogen NF to prevent the formation of copper oxide on the inside surfaces of the joint. [NFPA 99:5.1.10.4.5.1]

25.10.1 **Source**

The source of the purge gas shall be monitored, and the installer shall be audibly alerted when the source content is low. [NFPA 99:5.1.10.4.5.2]

25.10.2 **Flow rate control**

The purge gas flow rate shall be controlled by the use of a pressure regulator and flowmeter, or combination thereof.

Pressure regulators alone shall not be used to control purge gas flow rates. [NFPA 99:5.1.10.4.5.3, 5.1.10.4.5.4]

25.10.3 **Oxygen analyzer**

In order to ensure that all ambient air has been removed from the pipeline prior to brazing, an oxygen analyzer shall be used to verify the effectiveness of the purge. The oxygen analyzer shall read below 1% oxygen concentration before brazing begins. [NFPA 99:5.1.10.4.5.5]

25.10.4 **During installation**

During and after installation, openings in the piping system shall be kept sealed to maintain a nitrogen atmosphere within the piping to prevent debris or other contaminants from entering the system. [NFPA 99:5.1.10.4.5.6]

25.10.5 **Discharge opening**

While a joint is being brazed, a discharge opening shall be provided on the opposite side of the joint from where the purge gas is being introduced. [NFPA 99:5.1.10.4.5.7]

25.10.6 **Temperature of joint.**

The flow of purge gas shall be maintained until the joint is cool to the touch. [NFPA 99:5.1.10.4.5.8]

25.10.7 **Opening to be sealed**

After the joint has cooled, the purge discharge opening shall be sealed to prevent contamination of the inside of the tube and maintain the nitrogen atmosphere within the piping system. [NFPA 99:5.1.10.4.5.9]

25.10.8 **Final brazed connection**

The final brazed connection of new piping to an existing pipeline containing the system gas shall be permitted to be made without the use of a nitrogen purge. [NFPA 99:5.1.10.4.5.10]

25.10.9 **Final tie-in test**

After a final brazed connection in a positive pressure medical gas pipeline is made without a nitrogen purge, an outlet in the immediate downstream zone of the affected portion(s) of both the new and existing piping shall be tested in accordance with the final tie-in test in Section 28.9 through Section 28.9.4. [NFPA 99:5.1.10.4.5.11]

25.10.10 **Autogenous orbital welding process**

When using the autogenous orbital welding process, joints shall be continuously purged inside and outside with inert gas(es) in accordance with the qualified welding procedure. [NFPA 99:5.1.10.4.5.12]

25.11 Assembling and heating brazed joints

Tube ends shall be inserted into the socket, either fully or to a mechanically limited depth that is not less than the minimum cup depth (overlap) specified by ASME B16.50. [NFPA 99:5.1.10.4.6.1]

25.11.1 **Heating of joint**

Where flux is permitted, the joint shall be heated slowly until the flux has liquefied. After flux is liquefied, or where flux is not permitted to be used, the joint shall be heated quickly to the brazing temperature, taking care not to overheat the joint. [NFPA 99:5.1.10.4.6.2, 5.1.10.4.6.3]

25.12 Inspection of brazed joints

After brazing, the outside of all joints shall be cleaned by washing with water and a wire brush to remove any residue and allow clear visual inspection of the joint. [NFPA 99:5.1.10.4.7.1]

25.12.1 **Where flux is used**

Where flux has been used, the wash water shall be hot. [NFPA 99:5.1.10.4.7.2]

25.12.2 **Visually inspected**

Each brazed joint shall be visually inspected after cleaning the outside surfaces. [NFPA 99:5.1.10.4.7.3]

25.12.3 **Prohibited brazed joints**

Joints exhibiting the following conditions shall not be permitted:

(i) Flux or flux residue (when flux or flux-coated series rods are used with dissimilar metals)

(ii) Base metal melting or erosion

(iii) Unmelted filler metal

(iv) Failure of the filler metal to be clearly visible all the way around the joint at the interface between the socket and the tube

(v) Cracks in the tube or component

(vi) Cracks in the braze filler metal

(vii) Failure of the joint to hold the test pressure under the installer-performed initial pressure test (see Section 28.5 through Section 28.6) and standing pressure test (see Section 28.6.12 or Section 28.6.20). [NFPA 99:5.1.10.4.7.4]

25.12.4 **Defective brazed joints**

Brazed joints that are identified as defective under the conditions of Section 25.12.3(2) or Section 25.12.3 (5) shall be replaced. [NFPA 99:5.1.10.4.7.5]

Brazed joints that are identified as defective under the conditions of Section 25.12.3 (1), Section 25.12.3 (3), Section 25.12.3 (4), Section 25.12.3 (6) or Section 25.12.3 (7) shall be shall be permitted to be repaired, except that no joint shall be reheated more than once before being replaced. [NFPA 99:5.1.10.4.7.6]

26 Welded joints

26.1 Welded joints procedure

Welded joints for medical gas and medical-surgical vacuum systems shall be permitted to be made using a gas tungsten arc welding (GTAW) autogenous orbital procedure. [NFPA 99:5.1.10.5.1.1]

26.1.1 **Welder qualification procedure**

The GTAW autogenous orbital procedure and the welder qualification procedure shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. Welder qualification procedures shall include a bend test and a tensile test in accordance with Section IX of the ASME Boiler and Pressure Vessel Code on each tube size diameter. [NFPA 99:5.1.10.5.1.2, 5.1.10.5.1.3]

26.1.2 **Welding procedure specification**

Each welder shall qualify to a welding procedure specification (WPS) for each tube diameter. [NFPA 99:5.1.10.5.1.4]

26.1.3 **Purging of joints**

GTAW autogenous orbital welded joints shall be purged during welding with a commercially available mixture of 75% helium (+/- 5 %) and 25 % argon (+/- 5%). [NFPA 99:5.1.10.5.1.5]

26.1.4 **Shield gas**

The shield gas shall be as required in Section 1322.1.3. [NFPA 99:5.1.10.5.1.6]

26.1.5 **Test coupons**

Test coupons shall be welded and inspected, as a minimum, at the start of work and every 4 hours thereafter, or when the machine is idle for more than 30 minutes, and at the end of the work period. Test coupons shall be inspected on the I.D. and O.D. by a qualified quality control inspector. Test coupons shall also be welded at change of operator, weld head, welding power supply, or gas source. [NFPA 99:5.1.10.5.1.7 – 5.1.10.5.1.9]

26.2 Welding for stainless tube

Stainless tube shall be welded using metal inert gas (MIG) welding, tungsten inert gas (TIG) welding, or other welding techniques suited to joining stainless tube. [NFPA 99:5.1.10.5.2.1]

26.2.1 Qualifications

Welders shall be qualified to Section IX of the ASME Boiler and Pressure Vessel Code. [NFPA 99:5.1.10.5.2.2]

26.3 Memory metal fittings

Memory metal fittings having a temperature rating not less than 1000 °F (538 °C) and a pressure rating not less than 300 psi (2068 kPa) shall be permitted to be used to join copper or stainless steel tube. Memory metal fittings shall be installed by qualified technicians in accordance with the manufacturer's instructions . [NFPA 99:5.1.10.6.1, 5.1.10.6.2]

26.4 Axially swaged fittings

Axially swaged fittings providing metal-to-metal seals, suitable for service at 300 psig (2070 kPa) and able to withstand a temperature of 1000 °F (538 °C) and that, when complete, are permanent and nonseparable shall be permitted to be used to join copper or stainless steel tube. Axially swaged fittings shall be installed by qualified technicians in accordance with the manufacturer's instructions. [NFPA 99:5.1.10.7.1, 5.1.10.7.2]

26.5 Threaded fittings

Threaded fittings shall meet the following criteria:

(i) They shall be limited to connections for pressure and vacuum indicators, alarm devices, gas-specific demand check fittings, and source equipment on the source side of the source valve

(ii) They shall be tapered pipe threads complying with ASME B1.20.1.

(iii) They shall be made up with polytetrafluoroethylene (PTFE) tape or other thread sealant recommended for oxygen service, with sealant applied to the male threads only and care taken to ensure sealant does not enter the pipe. [NFPA 99:5.1.10.8]

26.6 Other types of fittings

Listed or approved metallic gas tube fittings that, when made up, provide a permanent joint having the mechanical, thermal, and sealing integrity of a brazed joint shall be permitted to be used. [NFPA 99:5.1.10.9.1]

26.6.1 Dielectric fittings

Dielectric fittings that comply with the following shall be permitted only where required by the manufacturer of special medical equipment to electrically isolate the equipment from the system distribution piping:

(i) They shall be of brass or copper construction with an approved dielectric

(ii) They shall be permitted to be a union

(iii) They shall be clean for oxygen where used for medical gases and medical support gases. [NFPA 99:5.1.10.9.2]

26.7 Prohibited joints

The following joints shall be prohibited throughout medical gas and vacuum distribution pipeline systems:

(i) Flared and compression-type connections, including connections to station outlets and inlets, alarm devices, and other components

(ii) Other straight-threaded connections, including unions

(iii) Pipe-crimping tools used to permanently stop the flow of medical gas and vacuum piping

(iv) Removable and nonremovable push-fit fittings that employ a quick assembly push fit connector. [NFPA 99:5.1.10.10]

27 Installation of piping and equipment

27.1 Required pipe sizing

Piping systems shall be designed and sized to deliver the required flow rates at the utilization pressures. [NFPA 99:5.1.10.11.1.1]

27.1.1 **Mains and branches**

Mains and branches in medical gas piping systems shall be not less than DN15 (NPS 1⁄2) (5⁄8 inch O.D.) size. Mains and branches in medical-surgical vacuum systems shall be not less than DN20 (NPS 3⁄4) (7⁄8 inch O.D) size. [NFPA 99:5.1.10.11.1.2, 5.1.10.11.1.3]

27.1.2 **Drops to Individual stations**

Drops to individual station outlets and inlets shall be not less than DN15 (NPS 1⁄2) (5⁄8 inch O.D.) size. [NFPA 99:5.1.10.11.1.4]

27.1.3 **Runouts and connecting tubing**

Runouts to alarm panels and connecting tubing for gauges and alarm devices shall be permitted to be DN8 (NPS 1⁄4) (3⁄8 inch O.D.) size. [NFPA 99:5.1.10.11.1.5]

27.1.4 **Maximum demand**

Where the maximum demand for each medical gas or vacuum system does not exceed the values in Table 1323.1.4(1) through Table 1324.1.4(6), the size of pipe of each section of the system shall be determined in accordance with Section 27.1.5. The size for systems beyond the range of Table 1323.1.4(1) through Table 1324.1.4(6) shall be determined in accordance with Section 27.1.6.

27.1.5 **Sizing procedures (refer to Table 7-12)**

The size of each section of pipe in a system within the range of Table 1323.1.4(1) through Table 1324.1.4(6) shall be determined in accordance with the following:

(i) Determine the total flow rate and number of outlets or inlets for each section of pipe in accordance with Table 2 & 3.(ii) Measure the length of the section of pipe to each station outlet or inlet on the system. Multiply the measured pipe length by 1.5 (150%), to account for the number of fittings in the system, to determine the pipe equivalent length.

(iii) Beginning with the most remote outlet or inlet, multiply the total flow rate by the diversity factor specified in Table 5 for each section of pipe to determine the sizing flow rate for the piping.

(iv) Select Table 1323.1.4(1) through Table 1324.1.4(6) based on the medical gas or vacuum being transported through the piping.

(v) Select an estimated pipe size for determining the system pressure loss. Multiply the pipe equivalent length, for a given section of pipe, by the pressure loss for the sizing flow rate in the applicable table. Divide that number by 100 to determine the system pressure loss for the section of pipe.

(vi) Add the pressure loss for each section of piping, from the source equipment location to the outlet or inlet, to determine the total system pressure loss to each outlet or inlet. The total system pressure loss in the piping to each outlet or inlet shall not exceed the values specified in Table 6.

Table 5 — SYSTEM SIZING – FLOW REQUIREMENTS FOR STATION OUTLETS AND INLETS

Number of outlets and inlets terminal units per facility	Diversity percentage of average flow per outlets and inlets terminal units	Minimum permissible system flow of all pressurized medical gas systems[2] (standard cubic feet per minute)
1 - 10	100 %	Actual demand
11 - 25	75 %	7.0
26 - 50	50 %	13.1
51 - 100	50 %	17.5

[1]Flow rates of station outlets and inlets in accordance with Table 2.

[2]The minimum system flow is the average outlets and inlets flow times the number of station outlets and inlets times the diversity percentage.

Table 6 — Maximum permitted pressure loss in medical gas and medical vacuum systems

Type of system	Maximum allowable system pressure loss psi
Medical air	5
Nitrogen	15
Nitrous Oxide	5
Carbon Dioxide	5
Oxygen	5
Medical Vacuum	4 inches of mercury
NOTE For SI units: 1 pound-force per square inch = 6.8947 kPa, 1 inch of mercury = 3.386 kPa	

27.1.6 **Engineering methods**

For conditions other than those covered by Section 27.1.4, such as longer runs of greater gas or vacuum demands, the size of each medical gas or vacuum piping system shall be determined by standard engineering methods acceptable to the Competent Authority, and each system shall be so designed that the total pressure drop or gain between the source equipment and an outlet or inlet shall not exceed the allowable pressures shown in Table 1.

27.2 Pipe protection

Piping shall be protected against freezing, corrosion, and physical damage. [NFPA 99:5.1.10.11.2]

27.2.1 **Exposed piping**

Piping exposed in corridors and other areas where subject to physical damage from the movement of carts, stretchers, portable equipment, or vehicles shall be protected. [NFPA 99:5.1.10.11.2.1]

27.2.2 Underground piping

Piping underground within buildings or embedded in concrete floors or walls shall be installed in a continuous conduit. [NFPA 99:5.1.10.11.2.2]

Table 7 — Pressure loss for medical air

Flow rate scfm[1]	Pressure drop (psi) per 100 feet[2]		
	1/2-inch pipe	3/4-inch pipe	1 inch pipe
0.35	0.004	0.001	–
0.71	0.012	0.003	–
1.06	0.023	0.005	–
1.41	0.037	0.007	–
1.77	0.055	0.011	–
2.12	0.075	0.015	–
2.47	0.097	0.019	–
2.82	0.123	0.024	–
3.18	0.151	0.029	–
3.53	0.181	0.035	–
4.24	0.249	0.048	–
4.94	0.326	0.063	–
5.65	0.413	0.080	–
6.36	0.507	0.098	–
7.06	0.611	0.118	0.030
7.77	0.723	0.139	0.035
8.47	0.843	0.162	0.041
9.18	0.969	0.187	0.047
9.89	1.108	0.212	0.053
10.59	1.252	0.240	0.060
12.36	1.647	0.315	0.079
14.12	2.090	0.398	0.100
15.89	2.580	0.490	0.123
17.66	3.116	0.591	0.148
19.42	–	0.701	0.176
21.19	–	0.818	0.205
22.95	–	0.944	0.236
24.72	–	1.078	0.268
28.25	–	1.369	0.341
31.78	–	1.690	0.421
35.31	–	2.043	0.509
38.84	–	2.425	0.603
42.37	–	2.838	0.705
45.90	–	3.280	0.814

49.43	–	3.751	0.929
52.97	–	4.249	1.052
56.50	–	–	1.181
60.03	–	–	1.318
63.56	–	–	1.461
67.09	–	–	1.611
70.62	–	–	1.768
81.21	–	–	2.276
88.28	–	–	2.647
95.34	–	–	3.044

[1] Based on the pressure of 14.7 psig (101 kPa) at 68°F (20 °C).
[2] Based on the pressure of 55 psig (379 kPa) at 68°F (20 °C)
NOTE For SI units: 1 standard cubic foot per minute = 28.32 sstandard litre per minute (SLPM), 1 inch = 25 mm, 1 foot = 304.8 mm, 1 pound-force per square inch = 6.8947 kPa

Table 8 — Pressure loss for nitrogen

Flow rate scfm[1]	Pressure drop (psi) per 100 feet[2]		
	1⁄2-inch pipe	3⁄4-inch pipe	1 inch pipe
5.30	0.126	0.024	–
10.59	0.430	0.082	–
15.89	0.886	0.168	–
21.19	1.485	0.281	–
26.48	2.220	0.419	–
31.78	3.089	0.581	–
37.08	4.087	0.766	–
42.37	–	0.975	–
47.67	–	1.206	–
52.97	–	1.460	0.361
58.26	–	1.736	0.429
63.56	–	2.033	0.502
68.85	–	2.352	0.580
74.15	–	2.692	0.663
79.45	–	3.054	0.752
84.74	–	3.436	0.845
90.04	–	3.840	0.943
95.34	–	4.264	1.046
100.63	–	4.709	1.154
105.93	–	–	1.267
116.52	–	–	1.508
127.12	–	–	1.768
137.71	–	–	2.046
148.30	–	–	2.344
158.90	–	–	2.660
169.49	–	–	2.994

180.08	–	–	3.347
190.67	–	–	3.719
201.27	–	–	4.108
211.86	–	–	4.516
222.45	–	–	4.942
233.05	–	–	–
243.64	–	–	–
254.23	–	–	–
264.83	–	–	–
275.42	–	–	–
286.01	–	–	–
296.60	–	–	–
307.20	–	–	–
317.79	–	–	–

[1] Based on the pressure of 14.7 psig (101 kPa) at 68°F (20°C).
[2] Based on the pressure of 55 psig (379 kPa) at 68°F (20°C).
NOTE For SI units: 1 standard cubic foot per minute (scfm)= 28.32 SLPM, 1 inch = 25 mm, 1 foot = 304.8 mm, 1 pound-force per square inch = 6.8947kPa

Table 9 — Pressure loss for nitrous oxide and carbon dioxide

Flow rate scfm[1]	Pressure drop (psi) per 100 feet[2]		
	1/2-inch pipe	3/4-inch pipe	1 inch pipe
0.35	0.004	–	–
0.71	0.014	–	–
1.06	0.029	–	–
1.41	0.047	–	–
1.77	0.070	–	–
2.12	0.096	–	–
2.47	0.125	–	–
2.82	0.159	–	–
3.18	0.195	–	–
3.53	0.235	0.045	–
4.24	0.324	0.062	–
4.94	0.425	0.081	–
5.65	0.539	0.103	–
6.36	0.664	0.127	–
7.06	0.802	0.153	0.038
7.77	0.950	0.181	0.045
8.47	1.110	0.211	0.053
9.18	1.281	0.243	0.061
9.89	1.463	0.278	0.070
10.59	1.656	0.314	0.079
12.36	2.186	0.413	0.103

14.12	2.752	0.525	0.131
15.89	3.442	0.648	0.162
17.66	4.166	0.783	0.195
19.42	–	0.929	0.231
21.19	–	0.744	0.270
22.95	–	0.858	0.312
24.72	–	0.980	0.356
28.25	–	1.244	0.453
31.78	–	1.537	0.560
35.31	–	1.858	0.677
38.84	–	2.205	0.804
42.37	–	2.581	0.941
45.90	–	2.982	1.088
49.43	–	3.411	1.245
52.97	–	4.249	1.411
56.50	–	–	1.587
60.03	–	–	1.772
63.56	–	–	1.967
67.09	–	–	2.174
70.62	–	–	2.385
79.45	–	–	2.959
88.28	–	–	3.589

[1] Based on the pressure of 14.7 psig (101 kPa) at 68°F (20°C).
[2] Based on the pressure of 55 psig (379 kPa) at 68°F (20°C)
NOTE For SI units: 1 standard cubic foot per minute = 28.32 SLPM, 1 inch = 25 mm, 1 foot = 304.8 mm, 1 pound-force per square inch = 6.8947 kPa

Table 10 — Pressure loss for oxygen

Flow rate SCFM[1]	Pressure drop (psi) per 100 feet[2]		
	1⁄2 inch pipe	3⁄4 inch pipe	1 inch pipe
0.35	0.004	–	–
0.71	0.013	0.003	–
1.06	0.025	0.005	–
1.41	0.041	0.008	–
1.77	0.060	0.012	–
2.12	0.082	0.016	–
2.47	0.107	0.021	–
2.82	0.135	0.026	–
3.18	0.166	0.032	–
3.53	0.199	0.038	–
4.24	0.274	0.053	–
4.94	0.359	0.069	–
5.65	0.454	0.087	–

6.36	0.558	0.107	–
7.06	0.672	0.129	0.033
7.77	0.795	0.153	0.039
8.47	0.927	0.179	0.045
9.18	1.066	0.205	0.052
9.89	1.218	0.233	0.059
10.59	1.377	0.263	0.066
12.36	1.811	0.346	0.087
14.12	2.298	0.438	0.110
15.89	2.837	0.539	0.135
17.66	3.456	0.650	0.163
19.42	–	0.771	0.193
21.19	–	0.900	0.225
22.95	–	1.038	0.260
24.72	–	1.185	0.295
28.25	–	1.505	0.375
31.78	–	1.859	0.463
35.31	–	2.247	0.559
38.84	–	2.667	0.663
42.37	–	3.121	0.775
45.90	–	3.607	0.895
49.43	–	4.125	1.022
52.97	–	–	1.157
56.50	–	–	1.299
60.03	–	–	1.449
63.56	–	–	1.607
67.09	–	–	1.772
70.62	–	–	1.944
81.21	–	–	2.503
91.81	–	–	3.127
102.40	–	–	3.813

[1] Based on pressure of 14.7 psig (101 kPa) at 68°F (20°C).
[2] Based on pressure of 55 psig (379 kPa) at 68°F (20 °C).
NOTE For SI units: 1 standard cubic foot per minute = 28.32 SLPM, 1 inch = 25 mm, 1 foot = 304.8 mm, 1 pound-force per square inch = 6.8947 kPa

Table 11 — Pressure loss for vacuum

Table 11 — Pressure loss for vacuum

Table 11 — Pressure loss for vacuum (continued)

27.3 Location of piping

Piping risers shall be permitted to be installed in pipe shafts if protected from physical damage, effects of excessive heat, corrosion, or contact with oil. [NFPA 99:5.1.10.11.3.1]

27.3.1 **Prohibited locations**

Piping shall not be installed in kitchens, stairwells, elevator shafts, elevator machine rooms, areas with open flames, electrical service equipment over 600 volts, and areas prohibited under NFPA 70 except for the following locations:

(i) Room locations for medical air compressor supply systems and medical-surgical vacuum pump supply systems

(ii) Room locations for secondary distribution circuit panels and breakers having a maximum voltage rating of 600 volts. [NFPA 99:5.1.10.11.3.2]

27.3.2 **Approved locations**

Medical gas piping shall be permitted to be installed in the same service trench or tunnel with fuel gas lines, fuel oil lines, electrical lines, steam lines, and similar utilities, provided that the space is ventilated (naturally or mechanically) and the ambient temperature around the medical gas piping is limited to 130 °F (54 °C) maximum. [NFPA 99:5.1.10.11.3.3]

27.3.3 Prohibited contact with oil

Medical gas piping shall not be located where subject to contact with oil, including a possible flooding area in the case of a major oil leak. [NFPA 99:5.1.10.11.3.4]

27.4 Pipe support

Piping shall be supported from the building structure. [NFPA 99:5.1.10.11.4.1]

27.4.1 Hangers and supports

Hangers and supports shall comply with and be installed in accordance with MSS SP-58. [NFPA 99:5.1.10.11.4.2]

27.4.2 Copper tube

Supports for copper tube shall be sized for copper tube. [NFPA 99:5.1.10.11.4.3]

27.4.3 Damp locations

In potentially damp locations, copper tube hangers or supports that are in contact with the tube shall be plastic-coated or otherwise be electrically insulated from the tube by a material that will not absorb moisture. [NFPA 99:5.1.10.11.4.5]

27.4.4 Maximum spacing

Maximum support spacing shall be in accordance with Table 13. [NFPA 99:5.1.10.11.4.6]

Table 13 — Maximum pipe support spacing [NFPA 99: TABLE 5.1.10.11.4.6]

Pipe size			Hanger spacing (feet)
DN8	(NPS 1⁄4)	(3⁄8 of an inch O.D.)	5
DN10	(NPS 3⁄8)	(1⁄2 of an inch O.D.)	6
DN15	(NPS 1⁄2)	(5⁄8 of an inch O.D.)	6
DN20	(NPS 3⁄4)	(7⁄8 of an inch O.D.)	7
DN25	(NPS 1)	(1 1⁄8 of an inch O.D.)	8
DN32	(NPS 1 1⁄4)	(1 3⁄8 of an inch O.D.)	9
DN40 and larger	(NPS 1 1⁄2)	(1 5⁄8 of an inch O.D.)	10
Vertical risers, all sizes, every floor, but not to exceed			15
For SI units: 1 inch=25.4mm, 1 foot=304.8mm			

27.4.5 **Seismic provisions**

Where required, medical gas and vacuum piping shall be seismically restrained against earthquakes in accordance with the applicable building code. [NFPA 99:5.1.10.11.4.7]

27.5 Frost protection

Buried piping outside of buildings shall be installed below the local level of frost penetration. [NFPA 99:5.1.10.11.5.1]

27.5.1 **Backfilling and trenching**

The installation procedure for underground piping shall protect the piping from physical damage while being backfilled. [NFPA 99:5.1.10.11.5.2]

27.5.2 **Conduit, cover, or enclosure**

If underground piping is protected by a conduit, cover, or other enclosure, the following requirements shall be met:

(i) Access shall be provided at the joints for visual inspection and leak testing

(ii) The conduit, cover, or enclosure shall be self-draining and not retain groundwater in prolonged contact with the pipe. [NFPA 99:5.1.10.11.5.3]

27.5.3 **Excessive stresses**

Buried piping that will be subject to surface loads shall be buried at a depth that will protect the piping or its enclosure from excessive stresses. [NFPA 99:5.1.10.11.5.4]

27.5.4 **Minimum backfill**

The minimum backfilled cover above the top of the pipe or its enclosure for buried piping outside of buildings shall be 36 inches (914 mm), except that the minimum cover shall be permitted to be reduced to 18 inches (457 mm) where there is no potential for damage from surface loads or surface conditions. [NFPA 99:5.1.10.11.5.5]

27.5.5 **Trenches**

Trenches shall be excavated so that the pipe or its enclosure has firm, substantially continuous bearing on the bottom of the trench. [NFPA 99:5.1.10.11.5.6]

27.5.6 **Composition of backfill**

Backfill shall be clean, free from material that can damage the pipe, and compacted. [NFPA 99:5.1.10.11.5.7]

27.5.7 Marker

A continuous tape or marker placed immediately above the pipe or its enclosure shall clearly identify the pipeline by specific name. [NFPA 99:5.1.10.11.5.8]

27.5.8 Warning

A continuous warning means shall also be provided above the pipeline at approximately one-half the depth of burial. [NFPA 99:5.1.10.11.5.9]

27.5.9 Wall sleeve

Where underground piping is installed through a wall sleeve, the outdoor end of the sleeve shall be sealed to prevent the entrance of groundwater into the building. [NFPA 99:5.1.10.11.5.10]

27.6 Connectors

Hose and flexible connectors, both metallic and nonmetallic, shall be no longer than necessary and shall not penetrate or be concealed in walls, floors, ceilings, or partitions. [NFPA 99:5.1.10.11.6.1]

27.6.1 Flexible connectors

Flexible connectors, metallic or nonmetallic, shall have a minimum burst pressure, with a gauge pressure of 1000 psi (6895 kPa). [NFPA 99:5.1.10.11.6.2]

27.6.2 Metallic flexible joints

Metallic flexible joints shall be permitted in the pipeline where required for expansion joints, seismic protection, thermal expansion, or vibration control and shall be as follows:

(i) For all wetted surfaces, made of bronze, copper, or stainless steel.

(ii) Cleaned at the factory for oxygen service and received on the job site with certification of cleanliness.

(iii) Suitable for service at 300 psi (2068 kPa) or above and able to withstand temperatures of 1000 °F (538 °C).

(iv) Provided with brazing extensions to allow brazing into the pipeline per Section 25

(v) Supported with pipe hangers and supports as required for their additional weight. [NFPA 99:5.1.10.11.6.3]

27.7 Prohibited system interconnections

Two or more medical gas or vacuum piping systems shall not be interconnected for installation, testing, or any other reason except as permitted by Section 27.7.1. [NFPA 99:5.1.10.11.7.1]

27.7.1 Medical gas and medical vacuum

Medical gas and vacuum systems with the same contents shall be permitted to be interconnected with an inline valve installed between the systems. **[NFPA 99:5.1.10.11.7.2]**

27.7.2 Leak Testing

Leak testing shall be accomplished by separately charging and testing each individual piping system. [NFPA 99:5.1.10.11.7.3]

27.8 Manufacturer's instructions

The installation of individual components shall be made in accordance with the instructions of the manufacturer. Manufacturer's instructions shall include directions and information deemed by the manufacturer to be adequate for attaining proper operation, testing, and maintenance of the medical gas and vacuum systems. Copies of the manufacturer's instructions shall be left with the system owner. [NFPA 99:5.1.10.11.8.1 – 5.1.10.11.8.3]

27.9 Changes in system use

Where a positive-pressure medical gas piping distribution system originally used or constructed for use at one pressure and for one gas is converted for operation at another pressure or for another gas, all provisions of Section 22 through Section 27.12 shall apply as if the system were new. [NFPA 99:5.1.10.11.9.1]

27.9.1 Medical vacuum system

A vacuum system shall not be permitted to be converted for use as a gas system. [NFPA 99:5.1.10.11.9.2]

27.10 Qualifications of installers

The installation of medical gas and vacuum systems shall be made by qualified, competent technicians who are experienced in performing such installations, including all personnel who actually install the piping system. Installers of medical gas and vacuum piped distribution systems, all appurtenant piping supporting pump and compressor source systems, and appurtenant piping supporting source gas manifold systems not including permanently installed

bulk source systems, shall be certified in accordance with ASSE/IAPMO/ANSI 6010. [NFPA 99:5.1.10.11.10.1, 5.1.10.11.10.2]

27.10.1 Brazing

Brazing shall be performed by individuals who are qualified in accordance with Section 27.11. [NFPA 99:5.1.10.11.10.5]

27.10.2 Documentation

Prior to any installation work, the installer of medical gas and vacuum piping shall provide and maintain documentation on the job site for the qualification of brazing procedures and individual brazers that is required under Section 27.11. [NFPA 99:5.1.10.11.10.6]

27.10.3 Health care organization personnel

Health care organization personnel shall be permitted to install piping systems if all of the requirements of Section 27.10 are met during the installation. [NFPA 99:5.1.10.11.10.7]

27.11 Qualification of brazing procedures and brazing

Brazing procedures and brazer performance for the installation of medical gas and vacuum piping shall be qualified in accordance with either Section IX, "Welding and Brazing Qualifications," of the ASME Boiler and Pressure Vessel Code, or AWS B2.2, both as modified by Section 27.11.1 through Section 27.11.4. [NFPA 99:5.1.10.11.11.1]

27.11.1 Examination

Brazers shall be qualified by visual examination of the test coupon followed by sectioning. [NFPA 99:5.1.10.11.11.2

27.11.2 Brazing procedure specification

The brazing procedure specification shall address cleaning, joint clearance, overlap, internal purge gas, purge gas flow rate, and filler metal. [NFPA 99:5.1.10.11.11.3]

27.11.3 Documentation

The brazing procedure qualification record and the record of brazer performance qualification shall document filler metal used, base metals, cleaning, joint clearance, overlap, internal purge gas and flow rate during brazing of coupon, and absence of internal oxidation in the completed coupon. [NFPA 99:5.1.10.11.11.4]

27.11.4 Procedures

Brazing procedures qualified by a technically competent group or agency shall be permitted under the following conditions:

(i) The brazing procedure specification and the procedure qualification records meet the requirements of this code

(ii) The employer obtains a copy of both the brazing procedure specification and the supporting qualification records from the group or agency and signs and dates these records, thereby accepting responsibility for the qualifications that were performed by the group or agency

(iii) The employer qualifies at least one brazer following each brazing procedure specification used. [NFPA 99:5.1.10.11.11.5]

27.11.5 Conditions of acceptance

An employer shall be permitted to accept brazer qualification records of a previous employer under the following conditions:

(i) The brazer has been qualified following the same or an equivalent procedure that the new employer uses

(ii) The new employer obtains a copy of the record of brazer performance qualification tests from the previous employer and signs and dates these records, thereby accepting responsibility for the qualifications performed by the previous employer. [NFPA 99:5.1.10.11.11.6]

27.11.6 Qualifications

Performance qualifications of brazers shall remain in effect indefinitely, unless the brazer does not braze with the qualified procedure for a period exceeding 6 months or there is a specific reason to question the ability of the brazer. [NFPA 99:5.1.10.11.11.7]

27.12 Breaching or penetrating medical gas piping

Positive pressure patient medical gas piping and medical support gas piping shall not be breached or penetrated by any means or process that will result in residual copper particles or other debris remaining in the piping or affect the oxygen-clean interior of the piping. The breaching or penetrating process shall ensure that any debris created by the process remains contained within the work area. [NFPA 99:5.1.10.11.12.1, 5.1.10.11.12.2]

27.13 Labelling, identification and operating pressure

Colour and pressure requirements shall be in accordance with Table 1. [NFPA 99:5.1.11]

27.13.1 Pipe labelling

Piping shall be labeled by stenciling or adhesive markers that identify the patient medical gas, the medical support gas, or the vacuum system and include the following:

(i) Name of the gas or vacuum system or the chemical symbol (per Table 1)

(ii) Gas or vacuum system color code per Table 1. [NFPA 99:5.1.11.1.1]

27.13.2 Pipe pressure labeling

Where positive pressure gas piping systems operate at pressures other than the standard gauge pressure in Table 1 the operating pressure in addition to the name of the gas shall be labeled. [NFPA 99:5.1.11.1.2]

27.13.3 Location of pipe labeling

Pipe labels shall be located as follows:

(i) At intervals of not more than 20 feet (6096 mm)

(ii) At least once in or above every room

(iii) On both sides of walls or partitions penetrated by the piping

(iv) At least once in every story height traversed by risers. [NFPA 99:5.1.11.1.4]

27.13.4 Paint

Medical gas piping shall not be painted. [NFPA 99:5.1.11.1.5]

27.14 Identification of shutoff valves

Shutoff valves shall be identified with the following:

(i) Name or chemical symbol for the specific medical gas or vacuum system

(ii) Gas or vacuum system color code in accordance with Table 1

(iii) Room or areas served

(iv) Caution to not close or open the valve except in emergency [NFPA 99:5.1.11.2.1]

27.14.1 Nonstandard operating pressures

Where positive pressure gas piping systems operate at pressures other than the standard gauge pressure of 50 psi (345 kPa) to 55 psi (379 kPa) or a gauge pressure of 160 psi (1103 kPa) to 185 psi (1276 kPa) for nitrogen or instrument air, the valve identification shall also include the nonstandard operating pressure. [NFPA 99:5.1.11.2.2]

27.14.2 Source valves

Source valves shall be labeled in substance as follows:

Source valve for the (source name) [NFPA 99:5.1.11.2.4]

27.14.3 Main line valves

Main line valves shall be labeled in substance as follows:

Main line valve for the (gas/vacuum name) serving (name of the building) [NFPA 99:5.1.11.2.5]

27.14.4 Riser valves

The riser valve(s) shall be labeled in substance as follows:

Riser for the (gas/vacuum name) serving (name of the area/building served by the particular riser) [NFPA 99:5.1.11.2.6]

27.14.5 Service valves

The service valve(s) shall be labeled in substance as follows:

Service valve for the (gas/vacuum name) serving (name of the area/building served by the particular valve) [NFPA 99:5.1.11.2.7]

27.14.6 Zone valve box

Zone valve box assemblies shall be labeled with the rooms, areas, or spaces that they control as follows:

Zone valves for the (gas/vacuum name) serving (name of rooms or spaces served by the particular valve)

Labeling shall either be visible from outside the zone valve box assembly through the cover or be replicated on the outside, but not affixed to the removable cover. [NFPA 99:5.1.11.2.8

27.15 Identification

Station outlets and inlets shall be identified as to the name or chemical symbol for the specific medical gas or vacuum provided and shall include the following:

(i) Name of the gas or vacuum system or the chemical symbol in accordance with Table 1

(ii) Gas or vacuum system color code in accordance with Table 1

In sleep labs, where the outlet is downstream of a flow control device, the station outlet identification shall include a warning not to use the outlet for ventilating patients

Where medical gas systems operate at pressures other than the standard gauge pressure of 50 psi to 55 psi (345 kPa to 380 kPa) or a gauge pressure of 160 psi to 185 psi (1103 kPa to 1275 kPa) for nitrogen, the station outlet identification shall include the nonstandard operating pressure in addition to the name of the gas. [NFPA 99:5.1.11.3.1 – 5.1.11.3.2]

28 Performance Criteria and Testing Category 1 (Gases, Medical Surgical Vacuum).

28.1 Where required

Inspection and testing shall be performed on components, or portions thereof, of new, piped medical gas or vacuum systems, additions, renovations, temporary installations, or repaired systems in accordance with Section 28.2 through Section 28.10, and certified in accordance with Section 10.

28.2 Breached systems

All systems that are breached and components that are subject to additions, renovations, or replacement (e.g., new gas sources: bulk, manifolds, compressors, dryers, alarms) shall be inspected and tested. Systems shall be deemed breached at the point of pipeline intrusion by physical separation or by system component removal, replacement, or addition. Breached portions of the systems subject to inspection and testing shall be confined to only the specific altered zone and components in the immediate zone or area that is located upstream for vacuum systems and downstream for pressure gases at the point or area of intrusion. [NFPA 99:5.1.12.1.3 – 5.1.12.1.5]

28.2.1 **Reports**

The inspection and testing reports shall be submitted directly to the party that contracted for the testing, who shall submit the report through channels to the responsible facility authority and any others that are required. Reports shall contain detailed listings of all findings and results. [NFPA 99:5.1.12.1.6, 5.1.12.1.7]

28.3 Test Gas

The test gas shall be oil-free, dry nitrogen NF. [NFPA 99:5.1.12.2.1.2]

28.4 Initial piping blowdown

Piping in medical gas and vacuum distribution systems shall be blown clear by means of oil-free, dry nitrogen NF after installation of the distribution piping but before installation of station outlet/inlet rough-in assemblies and other system components (e.g., pressure/vacuum alarm devices, pressure/vacuum indicators, pressure relief valves, manifolds, source equipment). [NFPA 99:5.1.12.2.2]

28.5 Initial pressure tests – medical gas and vacuum systems

Each section of the piping in medical gas and vacuum systems shall be pressure tested. Initial pressure tests shall be conducted as follows:

(i) After blowdown of the distribution piping

(ii) After installation of station outlet/inlet rough-in assemblies

(iii) Prior to the installation of components of the distribution piping system that would be damaged by the test pressure (e.g., pressure/vacuum alarm devices, pressure/vacuum indicators, line pressure relief valves). [NFPA 99:5.1.12.2.3.1, 5.1.12.2.3.2]

28.6 Shutoff valve

The source shutoff valve shall remain closed during tests specified in Section 28.5 through Section 28.6.2.

28.6.1 **Required test pressure**

The test pressure for pressure gases and vacuum systems shall be 1.5 times the system operating pressure but not less than a gauge pressure of 150 psi (1034 kPa). The test pressure shall be maintained until each joint has been examined for leakage by means of a leak detectant that is safe for use with oxygen and does not contain ammonia. [NFPA 99:5.1.12.2.3.4, 5.1.12.2.3.5]

28.6.2 **Leaks**

Leaks, if any, shall be located, repaired (if permitted), replaced (if required), and retested. [NFPA 99:5.1.12.2.3.6]

28.6.3 **Initial cross-connection test**

It shall be determined that no cross-connections exist between the various medical gas and vacuum piping systems. [NFPA 99:5.1.12.2.4]

28.6.4 **Atmospheric pressure**

All piping systems shall be reduced to atmospheric pressure. [NFPA 99:5.1.12.2.4.1]

28.6.5 **Sources of test gas**

Sources of test gas shall be disconnected from all piping systems, except for the one system being tested. [NFPA 99:5.1.12.2.4.2]

28.6.6 **System to be charged**

The system under test shall be charged with oil-free, dry nitrogen NF to a gauge pressure of 50 psi (345 kPa). [NFPA 99:5.1.12.2.4.3]

28.6.7 **Check outlets and inlets**

After the installation of the individual faceplates with appropriate adapters matching outlet/inlet labels, each individual outlet/inlet in each installed medical gas and vacuum piping system shall be checked to determine that the test gas is being dispensed only from the piping system being tested. [NFPA 99:5.1.12.2.4.4]

28.6.8 **Repeat test**

The cross-connection test referenced in Section 28.6.3 shall be repeated for each installed medical gas and vacuum piping system.

28.6.9 **Identification of system**

The proper labeling and identification of system outlets/inlets shall be confirmed during these tests. [NFPA 99:5.1.12.2.4.6]

28.6.10 **Initial piping purge tests**

The outlets in each medical gas piping system shall be purged to remove any particulate matter from the distribution piping. [NFPA 99:5.1.12.2.5]

28.6.11 **Procedure**

Using appropriate adapters, each outlet shall be purged with an intermittent high-volume flow of test gas until the purge produces no discoloration in a clean white cloth. [NFPA 99:5.1.12.2.5.1]

28.6.11.1 Location

The purging required in Section 28.6.11 shall be started at the closest outlet/inlet to the zone valve and continue to the furthest outlet/inlet within the zone. [NFPA 99:5.1.12.2.5.2]

28.6.12 **Standing pressure tests – for positive pressure medical gas piping systems**

After successful completion of the initial pressure tests under Section 28.5 through Section 28.6.2, medical gas distribution piping shall be subjected to a standing pressure test. NFPA 99:5.1.12.2.6]

28.6.13 **Time frame for testing**

Tests shall be conducted after the final installation of station outlet valve bodies, faceplates, and all other distribution system components. [NFPA 99:5.1.12.2.6.1]

28.6.14 **Source valve**

The source valve shall be closed during this test. [NFPA 99:5.1.12.2.6.2]

28.6.15 **Length of testing**

The piping systems shall be subjected to a 24-hour standing pressure test using oil-free, dry nitrogen NF. [NFPA 99:5.1.12.2.6.3]

28.6.16 **Test pressure**

Test pressures shall be 20 percent above the normal system operating line pressure. [NFPA 99:5.1.12.2.6.4]

28.6.17 **Conclusion of test**

The leakage over the 24-hour test shall not exceed 0.5 percent of the starting pressure [e.g., 0.3 psig (2 kPa) starting at 60 psi (414 kPa)] except that attributed to specific changes in ambient temperature. [NFPA 99:5.1.12.2.6.5]

28.6.18 **Leaks**

Leaks, if any, shall be located, repaired (if permitted) or replaced (if required), and retested. [NFPA 99:5.1.12.2.6.6]

28.6.19 **Proof of testing**

The 24-hour standing pressure test of the positive pressure system shall be witnessed by an ASSE/IAPMO/ANSI 602 inspector, an ASSE/IAPMO/ANSI 6030 verifier, or the Competent Authority or its designee. A form indicating that this test has been performed and witnessed shall be provided to the verifier at the start of the tests required in Section 28.8 through Section 28.10. [NFPA 99:5.1.12.2.6.7]

28.6.20 **Standing pressure tests – medical vacuum piping systems**

After successful completion of the initial pressure tests under Section 28.5 through Section 28.6.2, vacuum distribution piping shall be subjected to a standing vacuum test. [NFPA 99:5.1.12.2.7]

28.6.21 **Timeframe for testing**

Tests shall be conducted after installation of all components of the vacuum system. [NFPA 99:5.1.12.2.7.1]

28.6.22 **Length of testing**

The piping systems shall be subjected to a 24-hour standing vacuum test. [NFPA 99:5.1.12.2.7.2]

28.6.23 **Test pressure**

Test pressure shall be between 12 inches (305 mm) HgV and full vacuum. [NFPA 99:5.1.12.2.7.3]

28.6.24 **Disconnection of testing source**

During the test, the source of test vacuum shall be disconnected from the piping system. [NFPA 99:5.1.12.2.7.4]

28.6.25 **Conclusion of test**

The leakage over the 24-hour test shall not exceed 0.5 percent of the starting pressure [e.g., 0.125 inch (0.3 mm) HgV starting at 25 inches (635 mm) HgV] except that attributed to specific changes in ambient temperature. [NFPA 99:5.1.12.2.7.5]

28.6.26 **Proof of testing**

The 24-hour standing pressure test of the vacuum system shall be witnessed by the Competent Authority or its designee. A form indicating that this test has been performed and witnessed shall be provided to the verifier at the start of the tests required in Section 28.8 through Section 28.10. [NFPA 99:5.1.12.2.7.6]

28.6.27 **Leaks**

Leaks, if any, shall be located, repaired (if permitted) or replaced (if required), and retested. [NFPA 99:5.1.12.2.7.7]

28.7 System inspection

System inspections shall be performed prior to concealing piping distribution systems in walls, ceilings, chases, trenches, underground, or otherwise hidden from view. [NFPA 99:5.1.12.3.1.1]

28.7.1 **Test gas**

The test gas shall be nitrogen NF. [NFPA 99:5.1.12.3.1.2]

28.7.2 **Inspection qualification**

Inspections shall be conducted by a party technically competent and experienced in the field of medical gas and vacuum pipeline inspections and testing and meeting the requirements of ASSE/IAPMO/ANSI 6020, or ASSE/IAPMO/ANSI 6030. [NFPA 99:5.1.12.3.1.3]

28.7.3 **Inspection personnel**

Inspections shall be performed by a party other than the installing contractor. [NFPA 99:5.1.12.3.1.4]

28.7.4 **Qualifications**

Where systems have not been installed by inhouse personnel, inspections shall be permitted by personnel of the organization who meet the requirements of Section 28.7.2. [NFPA 99:5.1.12.3.1.5]

28.7.5 **Inspections**

The initial pressure tests performed by the installing contractor shall be witnessed by an ASSE/IAPMO/ANSI 6020 inspector, an ASSE/IAPMO/ANSI 6030 verifier, or the Competent Authority or its designee. A form indicating that this test has been performed and witnessed shall be provided to the verifier at the start of the tests required in Section 28.8 through Section 28.10. The presence and correctness of labeling and valve tagging required by this code for all concealed components and piping distribution systems shall be inspected. [NFPA 99:5.1.12.3.2 – 5.1.12.3.2.2]

28.8 System verification

Verification tests shall be performed only after all tests required in Section 28.3 through Section 28.6.27, Installer Performed Tests, have been completed.

28.8.1 **Test gas**

The test gas shall be oil-free, dry nitrogen NF or the system gas where permitted. [NFPA 5.1.12.4.1.2]

28.8.2 **Approved tester**

Testing shall be conducted by a party technically competent and experienced in the field of medical gas and vacuum pipeline testing and meeting the requirements of ASSE/IAPMO/ANSI 6030, except as required by Section 28.8.3. [NFPA 99:5.1.12.4.1.3]

Testing shall be performed by a party other than the installing contractor. [NFPA 99:5.1.12.4.1.5]

Where systems have not been installed by in-house personnel, testing shall be permitted by personnel of that organization who meet the requirements of Section 28.8.2. [NFPA 99:5.1.12.4.1.3]

28.8.3 **Cryogenic fluid testing**

Testing of the cryogenic fluid central supply system shall be conducted by a party technically competent and experienced in the field of cryogenic fluid systems and meeting the requirements of ASSE/IAPMO/ANSI 6035, in accordance with the mandatory requirements in CGA M-1. [NFPA 99:5.1.12.4.1.4]

28.8.4 **Particulate matter**

In order to remove any traces of particulate matter deposited in the pipelines as a result of construction, a heavy, intermittent purging of the pipeline shall be done. [NFPA 99:5.1.12.4.6]

28.9 Final tie-in test

Each joint in the final connection between the new work and the existing system shall be leak-tested with the gas of system designation at the normal operating pressure by means of a leak detectant that is safe for use with oxygen and does not contain ammonia. [NFPA 99:5.1.12.4.9.2]

28.9.1 **Vacuum joints**

Vacuum joints shall be tested using an ultrasonic leak detector or other means that will allow detection of leaks in an active vacuum system. [NFPA 99:5.1.12.4.9.3]

28.9.2 **Pressure gases**

For pressure gases, immediately after the final brazed connection is made and leak-tested, an outlet in the new piping and an outlet in the existing piping that are immediately downstream from the point or area of intrusion shall be purged in accordance with the applicable requirements of Section 28.8.4. [NFPA 99:5.1.12.4.9.4]

28.9.3 **Positive pressure gases**

Before the new work is used for patient care, positive pressure gases shall be tested for operational pressure and gas concentration in accordance with Section 28.9.5 and Section 28.10. [NFPA 99:5.1.12.4.9.5]

28.9.4 **Permanent records**

Permanent records of these tests shall be maintained in accordance with NFPA 99. [NFPA 99:5.1.12.4.9.6]

28.9.5 **Operational flow pressure drop test**

Operational flow pressure drop tests shall be performed at each station outlet/inlet or terminal where the user makes connections and disconnections. [NFPA 99: 5.1.12.4.10]

28.9.6 **Medical-surgical vacuum inlets**

Medical-surgical vacuum inlets shall draw 3 SCFM (85 Nl/min) without reducing the vacuum pressure below 12 inch (305 mm) gauge HgV at any adjacent station inlet. [NFPA 99:5.1.12.4.10.4]

28.9.7 **Oxygen and Medical Air outlets**

Oxygen and medical air outlets serving Category 1 space shall allow a transient flow rate of 6 SCFM (170 SLPM) for 3 seconds. [NFPA 99:5.1.12.4.10.5]

28.10 Medical gas concentration test

After purging each system with the gas of system designation, the following shall be performed:

(i) Each pressure gas source and outlet shall be analyzed for concentration of gas, by volume.

(ii) Analysis shall be conducted with instruments designed to measure the specific gas dispensed.

(iii) Allowable concentrations shall be as indicated in Table 14 [NFPA 99:5.1.12.4.11]

Table 14 — Gas concentrations

Medical gas	Concentration
Oxygen USP	≥99% oxygen
Oxygen 93 USP	≥90% oxygen ≤96%
Nitrous oxide USP	≥99% nitrous oxide
Nitrogen NF	≤1% oxygen or ≥99% nitrogen
Medical air USP Other gases	19.5% - 23.5% oxygen Named gases by ±1%, or per specification

29 Piped gas and vacuum systems

29.1 General

Category 2 piped gas or piped vacuum system requirements shall be permitted when all of the following criteria are met:

(i) Only moderate sedation, minimal sedation or no sedation is performed. Deep sedation and general anesthesia shall not be permitted.

(ii) The loss of the piped gas or piped vacuum systems is likely to cause minor injury to patients, staff, or visitors.

(iii) The facility piped gas or piped vacuum systems are intended for Category 2 patient care space. [NFPA 99:5.2.1.2]

29.2 Nature of hazards of gas and vacuum systems

The requirement of Section 11.3 shall apply to the nature of hazards of gas and vacuum systems. [NFPA 99:5.2.2]

29.3 Central supply systems

Category 2 systems shall conform to Section 11.4 through Section 13.13. [NFPA 99:5.2.3.4]

29.4 Category 2 medical air supply systems

Systems shall comply with Section 14 through Section 15.6, except as follows:

(i) Medical air compressors, dryers, aftercoolers, filters, and regulators shall be permitted to be simplex

(ii) The facility staff shall develop their emergency plan to deal with the loss of medical air. [NFPA 99:5.2.3.5]

29.5 Oxygen concentrators

Oxygen supply systems using concentrators shall be permitted to consist of two sources, one of which shall be a cylinder header with sufficient cylinder connections for one average day's supply. [NFPA 99:5.2.3.6]

29.6 Category 2 Medical-surgical vacuum

Category 2 systems shall comply with Section 16 through Section17.5, except as follows:

(i) Medical-surgical vacuum systems shall be permitted to be simplex

(ii) The facility staff shall develop their emergency plan to deal with the loss of medical-surgical vacuum. [NFPA 99:5.2.3.7]

29.7 Valves

Systems shall comply with Section 18 through Section 18.12.1. [NFPA 99:5.2.4]

29.8 Pressure and vacuum indicators

Category 2 systems shall comply with Section 20.2. [NFPA 99:5.2.8]

29.9 Warning systems

Warning systems associated with Category 2 systems shall provide the master, area, and local alarm functions of a Category 1 system as required in Section 21, except as follows:

(i) Warning systems shall be permitted to be a single alarm panel

(ii) The alarm panel shall be located in an area of continuous surveillance while the facility is in operation

(iii) Pressure and vacuum switches/sensors shall be mounted at the source equipment with a pressure indicator at the master alarm panel. [NFPA 99:5.2.9]

29.10 Category 2 Distribution

Category 2 systems shall comply with Section 23 through Section 27.12. [NFPA 99:5.2.10]

29.11 Labelling and identification

Category 2 systems shall comply with Section 27.13 through Section 27.15. [NFPA 99:5.2.11]

29.12 Performance criteria and testing — gas, medical–surgical vacuum and WAGD

Category 2 systems shall comply with Section 28. [NFPA 99:5.2.12]

30 Category 3 Piped gas and vacuum systems

30.1 General

Category 3 piped gas and vacuum systems shall be permitted when all of the following criteria are met:

(i) Only minimal sedation; or no sedation is performed. Deep sedation, moderate sedation, and general anesthesia are not performed

(ii) The loss of the piped gas and vacuum systems is not likely to cause injury to patients, staff, or visitors, but can cause discomfort

(iii) The facility piped gas and vacuum systems are intended for Category 3 patient care rooms. [NFPA 99:5.3.1.2]

30.2 Nature of hazards of gas and vacuum systems

The requirement of Section 11.3 shall apply to the nature of hazards of gas and vacuum systems. [NFPA 99:5.3.2]

30.3 Medical air supply systems

Category 3 central supply systems shall be permitted to consist of the following:

(i) Gas cylinder or cryogenic liquid container headers in accordance with NFPA 99

(ii) Oxygen concentrator supply units in accordance with NFPA 99

(iii) Cylinder manifolds for gas cylinders in accordance with NFPA 99

(iv) Manifolds for cryogenic liquid containers in accordance with NFPA 99

(v) Cryogenic fluid central supply systems in accordance with NFPA 99

(vi) Medical air compressor systems in accordance with NFPA 99

(vii) Proportioning air systems in accordance with NFPA 99

(viii) Medical-surgical vacuum systems in accordance with NFPA 99

(ix) Waste anesthetic gas disposal systems (WAGDs) in accordance with NFPA 99

(x) Instrument air compressor systems in accordance with NFPA 99 {NFPA 99:5.3.3.5}

30.4 Medical–surgical vacuum systems

Category 3 systems shall comply with Section 11.4 through Section 13.13 and Section 16 through Section 17.5, except as follows:

(i) Medical–surgical vacuum systems shall be permitted to be simplex

(ii) The facility staff shall develop an emergency plan to deal with the loss of medical–surgical vacuum

(iii) Emergency electrical service shall conform to the requirements of Section 6.6 of NFPA 99 and NFPA 70. [NFPA 99:5.3.3.7]

30.5 Valves

Category 3 systems shall comply with Section 18 [NFPA 99:5.3.4]

30.6 Pressure and vacuum indicators

Category 3 systems shall comply with Section 20.2 [NFPA 99:5.3.8]

30.7 Warning systems

Warning systems associated with Category 3 systems shall provide the master, area, and local alarm functions of a Category 1 system as required in Section 21, except as follows:

(i) Warning systems shall be permitted to be a single alarm panel (i.e., a combination master/area alarm panel)

(ii) The alarm panel shall be located in an area of continuous surveillance while the facility is in operation

(iii) Pressure and vacuum switches/sensors shall be mounted at the source equipment with a pressure indicator at the master alarm panel

(iv) Electrical power for warning systems shall be in accordance with Section 6.6 of NFPA 99 for Category 3 and Category 4 spaces [NFPA 99:5.3.9]

30.8 Distribution

Category 3 systems shall comply with Section 23 through Section 27.12 [NFPA 99:5.3.10]

30.9 Labeling and identification

Category 3 systems shall comply with Section 27.13 through Section 27.15. [NFPA 99:5.3.11]

31 Dental gas and vacuum systems

31.1 General

Dental gas and vacuum systems shall comply with this code and NFPA 99

31.2 Emergency shutoff valves (oxygen and nitrous oxide)

(i) edical gas systems shall have an emergency shutoff valve accessible from all use-point locations in an emergency

(ii) Where a central medical gas supply system supplies two treatment facilities, each facility shall be provided with an emergency shutoff valve located in that treatment facility so as to be accessible from all use-point locations in an emergency

(iii) Emergency shutoff valves shall be labelled to indicate the gas controlled by the shutoff valve and shall shut off only the gas to the treatment facility that they serve.

(iv) A remotely activated shutoff valve at a gas supply manifold shall not be used for emergency shutoff. For clinical purposes, such a remote valve actuator shall not fail-close in the event of loss of electric power. Where remote actuators are the type that fail-open, it shall be mandatory that cylinder shutoff valves be closed whenever the system is not in use. [NFPA 99:15.4.2.6.1 – 15.4.2.6.4.2]

31.3 Warning systems (Oxygen and Nitrous Oxide)

a) Category 2 warning systems shall comply with Section 29.9 except as follows:

(i) Warning systems shall be permitted to be a single alarm panel

(ii) The alarm panel shall be located in an area of continuous surveillance while the facility is in operation

(iii) Pressure and vacuum switches/sensors shall be mounted at the source equipment with a pressure indicator at the master alarm panel

b) Warning systems for medical gas systems shall provide the following alarms:

(i) Oxygen main line pressure low

(ii) Oxygen main line pressure high

(iii) Oxygen changeover to secondary bank or about to changeover (if automatic)

(iv) Nitrous oxide main line pressure low

(v) Nitrous oxide main line pressure high

(vi) Nitrous oxide changeover to secondary bank or about to changeover (if automatic)

c) Audible and noncancelable alarm visual signals shall indicate if the pressure in the main line increases or decreases 20% from the normal operating pressure.

d) Visual indications shall remain until the situation that caused the alarm is resolved.

e) Pressure switches/sensors shall be installed downstream of any emergency shutoff valves and any other shutoff valves in the system and shall cause an alarm for the medical gas if the pressure decreases or increases 20% from the normal operating pressure.

f) A cancellable audible indication of each alarm condition that produces a sound at the alarm panel shall reinitiate the audible signal if another alarm condition occurs while the audible signal is silenced. [NFPA 99:15.4.2.10]

31.4 Initial pressure test

Each section of the piping in positive-pressure gas systems and copper vacuum systems shall be pressure tested. Plastic vacuum and plastic scavenging piping shall not be pressure tested. [NFPA 99:15.4.7.4.4.1]

31.4.1 **Pressure test, initial pressure tests shall be conducted as follows:**

(i) After blowdown of the distribution piping

(ii) After installation of station outlet/inlet rough-in assemblies

(iii) Prior to the installation of components of the distribution piping system that would be damaged by the test pressure (e.g., pressure/vacuum alarm devices, pressure/vacuum indicators, and line pressure relief valves). [NFPA 99:15.4.7.4.4.2]

31.4.2 **Source shutoff valve**

The source shutoff valve shall remain closed during the pressure tests. [NFPA 99:15.4.7.4.4.3]

31.4.3 **Test pressure**

The test pressure for oxygen and nitrous oxide piping shall be 1.5 times the system operating pressure but not less than a gauge pressure of 150 psi (1035 kPa). [NFPA 99:15.4.7.4.4.4]

31.4.4 **Examine for leaks**

The test pressure shall be maintained until each joint has been examined for leakage by means of a leak detectant that is safe for use with oxygen and does not contain ammonia. [NFPA 99:15.4.7.4.4.5]

31.4.5 **Leaks located**

Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested. [NFPA 99:15.4.7.4.4.6]

31.5 Maximum copper tube support spacing

The maximum support spacing for copper tube shall be in accordance with Table 15 [NFPA 99:15.4.5.6.5]

Table 15 — Maximum copper tube support spacing

[NFPA 99: TABLE 15.4.5.6.5]

Pipe size			Hanger spacing feet
DN8	(NPS 1/4)	(3/8 of an inch O.D.)	5
DN10	(NPS 3/8)	(1/2 of an inch O.D.)	6
DN15	(NPS 1/2)	(5/8 of an inch O.D.)	6
DN20	(NPS 3/4)	(7/8 of an inch O.D.)	7
DN25	(NPS 1)	(1 1/8 of an inch O.D.)	8
DN32	(NPS 1 1/4)	(1 3/8 of an inch O.D.)	9
DN40 and larger	(NPS 1 1/2)	(1 5/8 of an inch O.D.)	10
Vertical risers, all sizes, every floor, but not to exceed			15
For SI units: 1 inch =25 mm, 1 foot = 304.8mm			

31.6 Maximum plastic pipe support spacing

The maximum support spacing for plastic pipe shall be in accordance with Table 16. [NFPA 99:15.4.5.6.6]

Table 16 — Maximum plastic pipe support spacing

[NFPA 99: TABLE 15.4.5.6.6]

Pipe size	Hanger spacing Feet

DN15	(NPS ½)	(⅝ of an inch O.D.)	4
DN20	(NPS ¾)	(⅞ of an inch O.D.)	4
DN25	(NPS 1)	(1⅛ of an inch O.D.)	4.33
DN32	(NPS 1¼)	(1⅜ of an inch O.D.)	4.33
DN40	(NPS 1⅛)	(1⅝ of an inch O.D.)	4.66
DN50	(NPS 2)	(2⅜ of an inch O.D.)	4.66
DN65 and larger	(NPS 2½)	(2⅞ of an inch O.D.)	5
Vertical risers, all sizes, every floor, but not to exceed			10
For SI units: 1 inch = 25 mm, 1foot = 304.8 mm			

31.7 Standing pressure tests for oxygen and nitrous oxide piping

After successful completion of the initial pressure tests in Section 1327.4, the gas distribution piping shall be subject to a standing pressure test. [NFPA 99:15.4.7.4.6.1]

31.7.1 **Tests required**

Tests shall be conducted after the final installation of station outlet valve bodies, faceplates, and other distribution system components (e.g., pressure alarm devices, pressure indicators, line pressure relief valves, manufactured assemblies, and hoses). [NFPA 99:15.4.7.4.6.2]

31.7.2 **Source valve**

The source valve shall be closed during this test. [NFPA 99:15.4.7.4.6.3]

31.7.3 **Piping systems**

The piping systems shall be subjected to 24-hour standing pressure tests using oil-free, dry nitrogen NF. [NFPA 99:15.4.7.4.6.4]

31.7.4 **Test pressure**

Test pressures shall be 20 % above the normal system operating line pressure. [NFPA 99:15.4.7.4.6.5]

31.7.5 **Change in test pressure**

At the conclusion of the tests, there shall be no change in the test pressure except that attributed to specific changes in ambient temperature. [NFPA 99:15.4.7.4.6.6]

31.7.6 **Leaks**

Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested. [NFPA 99:15.4.7.4.6.7]

31.8 Verifier operational pressure test

Operational pressure tests shall be performed at each station outlet or terminal where the user makes connections and disconnections. [NFPA 99:15.4.7.5.8.1]

31.9 Test gas

Tests shall be performed with the gas of system designation. [NFPA 99:15.4.7.5.8.2]

31.10 Medical gas outlets

All medical gas outlets with a gauge pressure of 50 psi (345 kPa), including oxygen and nitrous oxide, shall deliver 1.8 standard cubic feet per minute (SCFM) (50 SLPM) with a pressure drop of not more than 5 psi (34 kPa) and static pressure of 50 psi (345 kPa) to 55 psi (379 kPa). [NFPA 99:15.4.7.5.8.3]

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