Medical Gas and Vacuum Systems Handbook

THIRD EDITION

Edited by

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With extracts from Chapters 1 through 5, Chapter 15, and Annexes A and B of the 2018 edition of NFPA® 99, *Health Care Facilities Code*

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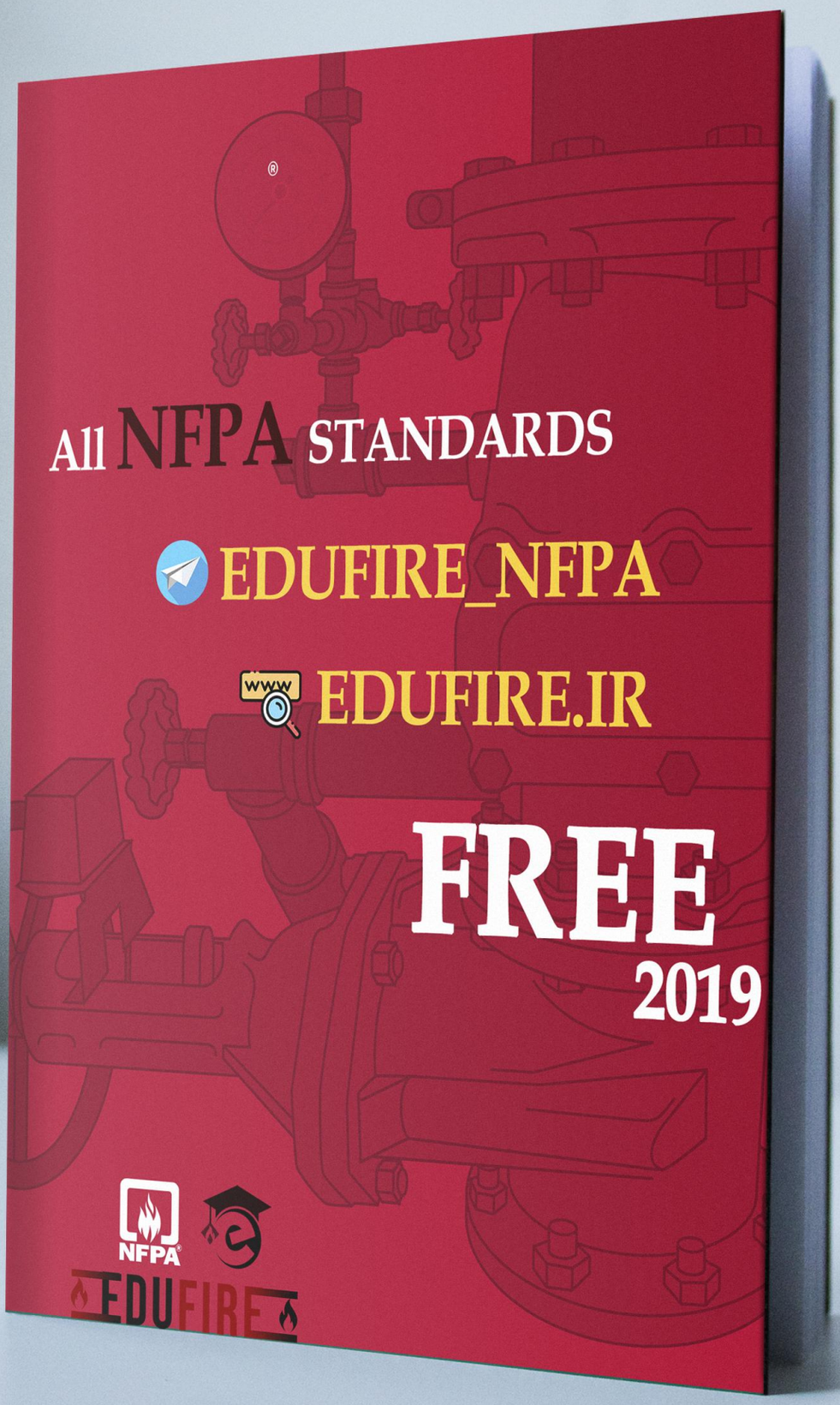

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This handbook contains extracted portions of the 2018 edition of NFPA 99, *Health Care Facilities Code* ("NFPA 99"). These extracts are assembled here along with the other information in this handbook to provide a convenient reference on medical gas and vacuum systems. These extracts, however, are not intended to be a substitute for the full text of NFPA 99, which should always be consulted to ensure full code compliance.

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Preface

This third edition of the *Medical Gas and Vacuum Systems Handbook* gives readers specific information about the medical gas and vacuum requirements of NFPA 99, *Health Care Facilities Code*, along with accompanying explanatory material. The handbook is developed to provide a convenient reference for persons responsible for installing, designing, verifying, or maintaining medical gas and vacuum systems.

As health care delivery continues to change, it is no longer useful to look at the occupancies in which health care is delivered to determine the types of medical gas and vacuum systems that are applicable. Many procedures that were once performed only in hospitals are now performed in doctor's offices, clinics, nursing homes, and other types of occupancies. Because of this, the 2012 edition of NFPA 99 transformed the document from occupancy-based to a risk-based code and the 2018 edition continues to build on that approach. To determine the type of protection needed for a medical gas system, one must first determine the risk to the patient, regardless of occupancy. This handbook provides information from NFPA 99 to those in the field as they navigate these and other issues.

NFPA 99 is generally accepted as one of the most widely used standards on best-practice requirements for the installation and use of equipment and on the daily operation of medical gas and vacuum systems in health care facilities. The *Medical Gas and Vacuum Systems Handbook* extracts pertinent information from NFPA 99 on medical gases and vacuum systems and consolidates it in a concise handy reference. While these extracts should prove highly useful, they are not intended to be a substitute for the full text of NFPA 99, which should always be consulted to ensure full understanding of and compliance with the code.

In addition to the extracted provisions of NFPA 99, this handbook provides ancillary artwork and explanation in the form of commentary. The explanatory material, which represents the views of the editor and contributors, is not intended to change or modify the code. In any dispute between the commentary and the code, the code prevails.

For the reader's convenience, this handbook contains two parts: Part One covers important code material from the first five chapters and Chapter 15 of NFPA 99, and Part Two contains three supplements that provide additional information, but are not part of NFPA 99. Supplement 1 provides information on qualifications for personnel and general brazing procedures. Supplement 2 provides information on cleaning for oxygen service and preparing joints for brazing. Supplement 3 covers installation testing and documentation.

The gas and vacuum system portions of NFPA 99 were previously collected in a separate publication, NFPA 99C, *Gas and Vacuum Systems*, which is no longer published. NFPA sought to recognize NFPA 99C's unique audience by creating a handbook that provides relevant portions of NFPA 99 and other useful information for professionals concerned with medical gas and vacuum systems. Hopefully users will find this handbook to be a valuable reference tool.

The purpose of this handbook is to provide the user with insight as to why the code requirements are included and how compliance with them can be achieved. NFPA 99 is developed by experts representing the many varying interest categories involved with medical gas and vacuum systems. The better the requirements of the code are understood, applied, and enforced, the better protected patients, caregivers, and visitors will be in health care facilities.

Acknowledgments

Producing this handbook required a substantial amount of time on the part of many dedicated individuals outside of NFPA and NFPA staff as well. For their substantial work of contributing new commentary, revising older commentary, and providing new features and exhibits, I would like to acknowledge Mark Allen, Neil Gagne, and Jonathan Willard. I would also like to thank Keith Ferrari, who contributed much of the material found in this handbook through his work on the previous edition of the handbook, the impact of which is still found throughout the commentary.

Of the numerous staff who play a vital role in producing great finished products that enhance the mission of the NFPA, there were several fantastic individuals involved in the production of this handbook. Specifically, I must thank: Debra Rose, the book's product manager; Irene Herlihy, developmental and production editor; Barbara Ingalls, copy editor; Cheryl Langway, art coordinator; and Josiane Domenici, permissions editor, for their assistance, professionalism, and dedication to this project.

Jonathan Hart

About the Editor

Jonathan R. Hart, PE

Jon Hart is a Principal Fire Protection Engineer for NFPA. In this role he serves as staff liaison to NFPA 99, *Health Care Facilities Code*, working with the technical committees and the correlating committee responsible for the development of the document. He is a developer and instructor of the two-day NFPA 99 Seminar and is the technical editor of the *Health Care Facilities Code Handbook*. Jon has also worked with codes and standards involving the fire protection of IT equipment, the fire protection of telecommunications facilities, the ventilation control and fire protection of commercial cooking operations, and explosion protection. He has a Bachelor of Science in Mechanical Engineering and a Master of Science in Fire Protection Engineering, both from Worcester Polytechnic Institute. Jon is a registered professional engineer in the discipline of fire protection.

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NFPA 99 Summary of Technical Changes: 2015 to 2018

This table provides an overview of major code changes related to medical gas and vacuum systems from the 2015 to the 2018 edition of NFPA 99, *Health Care Facilities Code*. Purely editorial and formatting changes are not included. For more information about the reasons for each change, visit www.nfpa.org/99. The first revision (FR), first correlating revision (FCR), second revision (SR), and second correlating revision (SCR) numbers are given in the third column of this table for reference to the official documentation of the technical committee's actions.

Section Number	Comments	FR/FCR/ SR/SCR Reference
Chapter 1		
1.1.12	Revised to specify that the hyperbaric facilities chapter is used for facility design, chamber design, and facility operation.	**FR 103**
1.1.13	Added to include a scope statement for the new chapter on dental gas and vacuum systems.	**SR 109**
1.3.4 **1.3.4.1** **1.3.4.2** **1.3.4.3**	The defined term *governing body* has been changed to *health care facility's governing body* for consistency throughout the document.	**FR 113, FCR 2**
Chapter 3		
3.3.22 **A.3.3.22**	Definition of *central supply system* was added in combination with ensuring consistency to terminology throughout Chapter 5. This allows for better differentiation between the complete source of supply and references to just the supply source.	**FR 601**
3.3.37 **3.3.38** **3.3.39**	Definitions of *dental air, dental office, and dental vacuum/scavenging were* added to define terms widely used in new Chapter 15 on dental gas and vacuum systems.	**SR 642, SR 643**
3.3.72 **A.3.3.72**	Definition of health care facility's governing body was added as the term is now used in multiple chapters in NFPA 99.	**FR 112**
3.3.127	Definition of *oxygen concentrator unit* was added because these units are now permitted by Chapter 5 as central supply sources.	**FR 106, SR 602**
3.3.131	Definition of *oxygen 93 USP* was added to delineate between oxygen USP and oxygen 93 USP, two different and distinct medical gases.	**SR 604**
3.3.138 **A.3.3.138**	Definition of *producer* was added because it is used for WAGD and for plume.	**FR 603**
3.3.171	The definition of *supply source* and the subdefinitions that fall under 3.3.171 have been revised to clarify that supply source is only one component of the central supply system.	**FR 601**

Section Number	Comments	FR/FCR/ SR/SCR Reference
Chapter 4		
4.2.1 4.2.1.1	Revised to clearly identify that the health care facility's governing body is the party responsible for determining risk categories.	FR 108, SR 105
4.2.2 A.4.2.2 4.2.2.1	Revised to clarify that the facility always has the responsibility for determining the risk categories and the AHJ always has the oversight to require that risk assessments be submitted for review.	SR 106
4.2.3	Revised to clarify that risk assessments are not needed if the user selects to meet Category 1 requirements.	FR 108
4.3	Revised to reflect the applicability of risk categories to Chapter 14 and the new Chapter 15.	SR 110
Chapter 5		
5.1.3.3.1.6 5.1.3.3.1.7 5.1.3.3.1.8 5.1.3.3.1.9 5.1.3.3.1.10	Terminology has been revised to correlate with the definition changes made in Chapter 3.	FR 903
5.1.3.3.2	Item (3) was modified and item (4) was added to specify that outdoor central supply locations only need to be provided a minimum of two entry/exits where the location is greater than 200 ft^2. Item (9) was modified and item (10) was added to clarify the requirement for heating these locations. The previous language referencing heating by indirect means was not clear. Now, fuel fired equipment is clearly prohibited, which was the original intent.	FR 610, SR 607
5.1.3.3.3.1	Added language requiring central supply locations to reference ventilation requirements.	FR 611
5.1.3.3.4.1	Revised to correlate with changes made to Chapter 11. The language added matches the application statement in Chapter 1 by not requiring construction requirements to be applied retroactively to previously approved installations.	SCR 6
5.1.3.5.2(6)	Added item (6) to allow the use of medical gases in the training and assessment of health care professionals in simulation centers.	FR 613
5.1.3.5.5 5.1.3.5.5.1 A.5.1.3.5.5.1	Revised to allow all effective methods to be used for controlling line pressure.	FR 614
5.1.3.5.7	Revised to require auxiliary connections only for liquid cryogenic sources.	SR 641
5.1.3.5.11	Added to define the requirements for oxygen concentrator supplies.	FR 609, SCR 16
5.1.3.5.12.3	Revised to improve safety by prohibiting an installation where the cylinder headers are not in the same room as the manifold control cabinet.	FR 616
Table 5.1.3.5.13.1	Extracts the table for Minimum Separation Distance Between Portable Cryogenic Containers and Exposures in NFPA 55.	FR 617
5.1.3.5.13.4	Revised to add requirement for flow capacity to also be addressed in the design and construction of the system.	FR 618

Section Number	Comments	FR/FCR/ SR/SCR Reference
5.1.3.5.14	Deleted section on microbulk. The requirements for stationary microbulk and bulk are identical and there is no need for two separate sections. This will provide guidance for the AHJ. Also see the revised definitions in Chapter 3.	FR 627
5.1.3.5.14	This section has been renamed Cryogenic Fluid Supply Systems, in order to apply to what were previously separated bulk and micro-bulk systems. Throughout the section, "bulk cryogenic" was replaced with "cryogenic fluid supply." Items (2), (3), and (4) were deleted from 5.1.3.5.14.2 because they are included in 5.1.3.3, Central Supply Systems	FR 626
5.1.3.6.3.10	Revised to account for new developments in control methods for compressors and pumps, while preserving the performance characteristics inherent in the original text. Previously the language of Item (C) potentially allowed the installation of equipment that did not comply with NFPA 70E. The language of (C) has been revised to prevent this.	FR 620
5.1.3.6.3.12(F)	Revised to account for new developments in control methods for compressors and pumps, while preserving the performance characteristics inherent in the original text.	FR 621
5.1.3.7.1.1(7)	New item (7) requires vacuum filtration as now specified in 5.1.3.7.4	FR 652
5.1.3.7.4	Added requirement for inlet filtration of vacuums to align with normal international practice.	FR 651
5.1.3.7.6	Revised to account for new developments in control methods for compressors and pumps, while preserving the performance characteristics inherent in the original text.	FR 622
5.1.3.7.8	Revised to account for new developments in control methods for pumps, while preserving the performance characteristics inherent in the original text.	FR 623
5.1.3.8.3.2	Revised to account for new developments in control methods for compressors and pumps, while preserving the performance characteristics inherent in the original text.	FR 624
5.1.3.8.4	Revised to account for new developments in control methods for compressors and pumps, while preserving the performance characteristics inherent in the original text.	FR 625
5.1.3.9	Added to provide details for a central supply system that uses an oxygen concentrator as one of the supply sources.	FR 640, SCR 5
5.1.4.1.6 Table 5.1.4.1.6(a) Table 5.1.4.1.6(b)	Added new Tables 5.1.4.1.6(a) and 5.1.4.1.6(b) to prevent the possibility of ball valves using smaller internal components inside larger valve bodies.	FR 650
5.1.4.6	Revised for clarity and to delete redundant clauses and remove an unnecessary requirement.	SR 633
A.5.1.4.6.1(2)	Added to better define standing position and that it is not meant to be standing on a ladder or anything other than the floor.	FR 649
A.5.1.5	Added to include reference to the FGI guidelines for the minimum number of outlets/ inlets required	FR 628
5.1.5.17	Added to prevent instances of hose assemblies occasionally disconnecting from quick connect outlets. DISS outlets provide a much safer / secure connection.	FR 628
5.1.6.1(5)	Added to require that the operational pressure test be done by the assembly manufacturer prior to installation.	FR 647, SR 634
5.1.6.2	Revised to update leakage requirements.	FR 642

Section Number	Comments	FR/FCR/ SR/SCR Reference
5.1.6.5	Revised to require the manufacturer of the assembly to provide verification documentation certifying that the assembly meets the requirement.	FR 644
5.1.6.6	Requirement has been changed to require that components meet this criterion rather than the manufactured assembly itself. ANSI/UL 723 has been added as an alternate test method to ASTM E84.	FR 676
5.1.6.9	Added labeling requirement to help those providing care and maintenance better identify what gas they are dealing with on a given hose.	FR 645, SR 635
5.1.9.2.4(14)	Added requirements for alarms needed to support the concentrator supply system.	FR 641, SR 616
5.1.9.4.5	Added to clarify 5.1.9.4.4(2) to show that the use of one area alarm panel for an operating room suite is permissible.	FR 629
5.1.9.5.4	Added new alarm requirements to support the new oxygen concentrator supplies	FR 630, SCR 20
5.1.10.1.4	Added to allow for the use of corrugated medical tubing for positive-pressure medical gas systems.	SR 620
5.1.10.1.5	Added to provide a minimum flame spread index and smoke developed index for the plastic jacket of medical tubing using ASTM E84, which is widely used for these measurements.	SR 624
5.1.10.1.6	Added to provide the requirement for marking CMT, similar to the other types of tubing currently allowed in the Code. Distance between marking has been included to make sure that the marking is not spread out over too great of a distance.	SR 625
5.1.10.2.1	New allowance for the use of corrugated medical tubing for vacuum systems.	SR 621
5.1.10.3.2	Added to recognize that CMT is an inherently flexible tube product that can be safely bent up to the minimum bend radius with no reduction in cross sectional area or damage to the tubing. The minimum bend radius is verified for each tube size as part of the listing process.	SR 627
5.1.10.3.4	Added to prohibit mechanically formed, drilled, and extruded tee-branch connections as they are not appropriate for corrugated metal tubing.	SR 628
5.1.10.4.3.4	Revised to require stainless steel or brass brush, which should help prevent the potential for degreasing a steel wire brush, which could cause it to rust.	FR 633
5.1.10.11.3.2	Revised to clearly prohibit locating unprotected medical gas piping in stairwells.	FR 634
5.1.10.11.4.4	Added requirements for the support of CMT.	SR 630
5.1.10.11.6.4	Clarified that it is not the intent that the prohibition of concealing hose and flexible connectors be applied to the joints detailed in 5.1.10.11.6.3.	FR 902
5.1.10.11.10.3	Added installer qualifications for systems using CMT.	SR 622
5.1.10.11.11.4	Added base metal as an item to be documented because it is an essential variable and is critical to the brazing procedure.	FR 635
5.1.11.2.7	Revised to require more specific labeling for zone valve box assemblies.	FR 677
5.1.11.5	Added to require source equipment to be labeled with minimum information to allow those responding to an issue to be able to understand the potential impact on patient care as quickly as possible.	FR 636
5.1.12.1.1	Revised to clarify application is to both gas and vacuum and that both the process as well as the procedure need to be documented.	FR 679

Section Number	Comments	FR/FCR/ SR/SCR Reference
5.1.12.1.11	Revised to clarify that only the verifier final report is sufficient to meet this requirement.	**FR 680**
5.1.12.2.6.5	Revised to update leakage requirements.	**FR 643**
5.1.12.2.6.7	Added requirement for ASSE 6020 Inspector certification for the standing pressure test of the positive pressure system.	**FR 637**
5.1.12.3	Added to require that the concealed piping distribution system and associated components be inspected prior to being concealed.	**FR 631**
5.1.12.4.1.4	Added to require qualifications to new standard ASSE 6035, *Professional Qualifications Standard for Bulk Medical Gas Systems Verifiers.*	**FR 638**
5.1.12.4.8.2	Added to clarify that halogenated hydrocarbons is a comparative test.	**FR 653**
5.1.12.4.10	Revised title to more accurately reflect what the test is evaluating.	**FR 659**
5.1.12.4.14.3(H)	Revised to match item (E), which states the compressor system shall operate for at least 12 hours prior to testing.	**FR 663**
5.1.12.4.14.4	Tests have been added to support the addition of concentrator sources and to verify that they are operating properly prior to use.	**FR 661, SCR 21**
5.1.13.3.4.3	Revised item (1) to no longer specify a gauge pressure of 1380 kPa (200 psi) at the compressor but now to require pressure adequate for the intended line pressure.	**FR 665**
5.1.13.3.4.5	Revised to no longer specify a compressor capable of gauge pressure of 1380 kPa (200 psi) but now to require they are a capable of providing pressure adequate for the intended line pressure.	**FR 668**
5.1.13.3.4.12	Revised to account for new developments in control methods for compressors and pumps, while preserving the performance characteristics inherent in the original text.	**FR 683**
5.1.13.8	Revised to no longer specify a compressor capable of gauge pressure of 1380 kPa (200 psi) but now to require they are a capable of providing pressure adequate for the intended line pressure.	**FR 670**
5.1.14.4	Added a reference to the new requirement for labeling in 5.1.11.5.	**FR 678**
5.1.14.5.7(5) and (6)	Added new (5) and (6) to support the use of oxygen concentrators by including maintenance requirements to ensure their continued safe use once in service.	**FR 671**
5.1.14.5.10	Revised to support concentrators when cylinders are used as reserves by adding important maintenance requirements.	**FR 672, SR 619**
5.2.3.6	Added to allow oxygen concentrator supply systems in a Category 2 system.	**FR 673**
5.3	Deleted majority of Category 3 requirements. Requirements for dental gas and vacuum systems are now located in Chapter 15.	**SR 632**
Chapter 15	Added new chapter specific to dental gas and vacuum systems to properly address their unique needs.	

Medical Gas and Vacuum Systems Handbook

Extracts from NFPA 99, *Health Care Facilities Code*, 2018 edition, with Commentary

Part 1

The *Medical Gas and Vacuum Systems Handbook* is presented in two parts. Part 1 extracts code requirements, annexes, and associated commentary from the 2018 edition of the *Health Care Facilities Code Handbook*. Chapters 1, 2, 4, and 5 and portions of Chapter 3 of NFPA 99, *Health Care Facilities Code* , are included in this book together with the companion expert commentary from the handbook for those chapters. This handbook also includes the text of Annex A, inserted immediately following the code text it discusses. Annex A is not part of the enforceable requirements but is provided as information and guidance. This annex text is added in place for the readers' convenience. Annex B of NFPA 99, which provides the reader with additional explanatory material, is found at the end of the five chapters. For the entire text of NFPA 99, see www.nfpa.org/99.

Special Features

Existing Facilities
Identifies the code requirements that apply to existing facilities.

FAQs
Identifies specific code questions that are commonly received by NFPA staff and that are answered within the commentary.

Test Procedure
Provides specific procedures for the installation tests and verification tests for medical gas systems.

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Discusses topics more in depth at the end of various chapters.

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Text revisions are shaded. A Δ before a section number indicates that words within that section were deleted and a Δ to the left of a table or figure number indicates a revision to an existing table or figure. When a chapter was heavily revised, the entire chapter is marked throughout with the Δ symbol. Where one or more sections were deleted, a • is placed between the remaining sections. Chapters, annexes, sections, figures, and tables that are new are indicated with an ***N***.

Note that these indicators are a guide. Rearrangement of sections may not be captured in the markup, but users can view complete revision details in the First and Second Draft Reports located in the archived revision information section of each code at www.nfpa.org/docinfo. Any subsequent changes from the NFPA Technical Meeting, Tentative Interim Amendments, and Errata are also located there.

Shaded text = Revisions Δ = Text deletions and figure/table revisions • = Section deletions ***N*** = New material

1

Administration

Editor's Note: *The following chapter is extracted in its entirety from Chapter 1 of the 2018 edition of NFPA 99,* Health Care Facilities Code. *Commentary is also provided to explain the code and assist the user and is not part of the code. NFPA 99 can be viewed in full at: www.nfpa.org/99.*

The Medical Gas and Vacuum Systems Handbook is an extract from NFPA 99, *Health Care Facilities Code*. Medical gas and vacuum systems are an important portion of the complete content of NFPA 99, which includes other subjects such as electrical systems, electrical equipment, gas equipment, emergency and security management, and other health care facility specific subjects. Chapters 1 through 5 and 15 are extracted from NFPA 99 into this handbook to provide those interested exclusively in medical gas and vacuum system requirements a complete document without the extraneous material.

The 2018 edition is very similar in application and structure to the two previous editions with the exception of large modification to Category 3 systems and the new addition of Chapter 15 specifically for dental gas and vacuum systems. Numerous technical changes have been made to many of the subjects addressed. This handbook is designed to help the users of the code become familiar with these changes as well as with other provisions of the code.

1.1 Scope.

Section 1.1 includes the scope of each of the individual chapters within NFPA 99. NFPA 99 is intended to cover facilities that treat humans. Freestanding veterinary facilities present many of the same hazards as hospitals, but they are not addressed in NFPA 99. However, hyperbaric chambers used for animals located within health care facilities are addressed in Chapter 14. NFPA 150, *Standard on Fire and Life Safety in Animal Housing Facilities,* addresses the hazards to animals and staff. Note that because Chapter 1 is extracted from NFPA 99 there are references to chapters not included in this handbook.

1.1.1 The scope of this code is to establish minimum criteria as follows in 1.1.2 through 1.1.14.

1.1.2 Fundamentals. Chapter 4 establishes criteria for levels of health care services or systems based on risk to the patients, staff, or visitors in health care facilities.

1.1.3 Gas and Vacuum Systems.

1.1.3.1 Chapter 5 covers the performance, maintenance, installation, and testing of the following:

(1) Nonflammable medical gas systems with operating pressures below a gauge pressure of 2068 kPa (300 psi)
(2) Vacuum systems in health care facilities
(3) Waste anesthetic gas disposal (WAGD) systems, also referred to as scavenging
(4) Manufactured assemblies that are intended for connection to the medical gas, vacuum, or WAGD systems (also referred to as scavenging)

1.1.3.2 Requirements for portable compressed gas systems are covered in Chapter 11.

1.1.4 Electrical Systems.

1.1.4.1 Chapter 6 covers the performance, maintenance, and testing of electrical systems (both normal and essential) in health care facilities.

Chapter 6, Electrical Systems, does not apply to all health care facilities or all situations. Those responsible for a particular health care facility, or for an individual patient care function within a health care facility, are urged to evaluate the application of this chapter in relation to their particular situation. See Sections 6.4 through 6.6 for how the chapter is meant to apply. If additional electrical supply features are installed, installation must be done in a manner consistent with the details and philosophy of Chapter 6.

Chapter 6 is to be used in conjunction with *NFPA 70*, *National Electrical Code*, particularly Article 517, which addresses health care facilities.

Δ **1.1.4.2** The following areas are not addressed in this code, but are addressed in other NFPA documents:

(1) Specific requirements for wiring and installation of equipment are covered in *NFPA 70*.

While NFPA 99 covers the requirements for the performance of the electrical systems and certain features that are required, *NFPA 70* contains the requirements for the installation of the electrical systems to protect against hazards from electrical shock and fire. Perhaps the best way to distinguish between the jurisdictions of each is that NFPA 99 provides requirements to ensure that loss of power does not result in injury to patients or staff, and *NFPA 70* ensures that there is limited risk of fire or shock from the installation. To help clarify, an NFPA Inter-committee Task Group provided the following definitions to help differentiate performance requirements (such as are found in Chapter 6 of NFPA 99) from installation requirements (such as those in Article 517 of the *NEC*):

Performance requirement. A specification of the manner in which equipment or a system is intended to function or operate.

Installation requirement. A specification of the material and process associated with putting equipment in place and making it ready for use in accordance with the performance requirements.

(2) Requirements for illumination and identification of means of egress in health care facilities are covered in NFPA *101*.
(3) Requirements for installation, testing, and maintenance of fire protection signaling systems are covered in *NFPA 72*.

For requirements specifically for signaling system locations and types of initiating devices, also see NFPA *101*, *Life Safety Code*.

(4) Requirements for installation of fire pumps are covered in NFPA 20, except that the alternate source of power are permitted to be the essential electrical system.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, requires alternate sources of power for electrically operated fire pumps, and all of the requirements for such installations are located in NFPA 20, except that NFPA 99 permits the alternate power to come from the EES. While NFPA 99 does not specifically name the branch on which the fire pump is permitted to be located, by process of elimination it can only be placed on the equipment branch. This could allow for delayed connection to the alternate power source, which would not meet the 10-second restore requirement of NFPA 20. Delayed connection of the fire pump electrical load should not be done.

(5) Requirements for installation of stationary engines and gas turbines are covered in NFPA 37.

1.1.5 Information Technology and Communications Systems. Chapter 7 covers the performance, maintenance, and testing of information technology and communications systems in health care facilities.

1.1.6 Plumbing. Chapter 8 covers the performance, maintenance, and testing of plumbing systems in health care facilities.

1.1.7 HVAC Systems. Chapter 9 covers the performance, maintenance, and testing of heating, cooling, and ventilating in health care facilities.

1.1.8 Electrical Equipment. Chapter 10 covers the performance, maintenance, and testing of electrical equipment in health care facilities.

1.1.9 Gas Equipment. Chapter 11 covers the performance, maintenance, and testing of gas equipment in health care facilities.

1.1.10* Emergency Management. Chapter 12 establishes criteria for emergency management in the development of a program for effective disaster preparedness, response, mitigation, and recovery in health care facilities.

A.1.1.10 Because no single model of an emergency management plan is feasible for every health care facility, this chapter is intended to provide criteria for the preparation and implementation of an individual plan. The principles involved are universally applicable; the implementation needs to be tailored to the specific facility.

The Centers for Medicare and Medicaid Services (CMS) has specific emergency management and planning criteria for complying with their Conditions of Participation (COP). The final rule, published in September 2016, is titled "Emergency Preparedness Requirements for Medicare and Medicaid Participating Providers and Suppliers." Chapter 12 can be used as a guide. However, for compliance with the COP, the CMS criteria must be followed.

1.1.11 Security Management. Chapter 13 establishes criteria for security management, including management controls, mitigation practices, staff training, and program evaluation in health care facilities.

Δ **1.1.12* Hyperbaric Facilities.** Chapter 14 establishes criteria for design and operation of hyperbaric chambers and facilities. Chapter 14 covers electrical, fire, pressure, and gas hazards associated with hyperbaric facilities that are used, or intended to be used, for medical and experimental procedures at gauge pressures from 0 kPa to 690 kPa (0 psi to 100 psi).

A.1.1.12 Hyperbaric chambers are found in a variety of settings, including but not limited to hospitals, doctor's offices, private clinics, and business occupancies. Not all hyperbaric facilities are designed or equipped the same. Hyperbaric treatment and facilities are used for a variety of emergent and nonemergent conditions, and the acuity of patients ranges from stable to critical. These variations lead to differences in hyperbaric equipment, ancillary support equipment, and facility location. This chapter is intended to provide minimum safeguards for hyperbaric patients and personnel regardless of the location of the facility.

N **1.1.13 Dental Gas and Vacuum System.** Chapter 15 covers the performance, maintenance, and testing of dental gas and vacuum systems in health care facilities.

Chapter 15 is new to the 2018 edition. It addresses the unique concerns of dental functions in health care facilities in response to a request from the industry to provide requirements tailored to dental use.

1.1.14 Features of Fire Protection. Chapter 16 covers the performance, maintenance, and testing of fire protection equipment in health care facilities.

Chapter 16 makes extensive use of extracts from NFPA *101* in addition to other material. Although the chapter includes requirements for fire protection, much of it is nonspecific and refers the user to installation standards.

1.2 Purpose.

The purpose of this code is to provide minimum requirements for the installation, inspection, testing, maintenance, performance, and safe practices for facilities, material, equipment, and appliances, including other hazards associated with the primary hazards.

As with all NFPA documents, NFPA 99 is intended to provide only minimum requirements to protect occupants of health care facilities against the hazards it addresses. There are many options available to facility owners, designers, and other stakeholders that go above and beyond the minimum levels prescribed in this code. Providing this higher level might be the preference for some facilities but could be unnecessary or overly burdensome for other facilities and is therefore not required for all health care facilities. The minimum requirements are by no means a limitation to the level that can be provided, and the code should not be applied that way.

1.3 Application.

1.3.1 This code shall apply to all health care facilities other than home care and veterinary care.

There is much useful information available from other sources on how to apply safety in the home health care environment and with the equipment found there. One such source is the NFPA pamphlet, "Fires and Burns Involving Home Medical Oxygen," available at www.nfpa.org/safety-information/for-consumers/causes/medical-oxygen. The requirements of NFPA 99, however, are not intended to be applied to the home health care environment. See also Supplement 2 of this handbook.

1.3.1.1 This document is intended for use by those persons involved in the design, construction, inspection, and operation of health care facilities and in the design, manufacture, and testing of appliances and equipment used in patient care rooms of health care facilities.

How NFPA 99 is used will depend on whether the document is adopted for use and who adopts the document for use, whether governmental or nongovernmental agencies or companies. This paragraph also highlights the variety of people who can and will be involved in the application of NFPA 99. There are many different stakeholders in these projects, and coordination is vital to ensure proper application on the end product. Coordination among the stakeholders should be a priority of any health care organization for both future and newly constructed buildings as well as existing facilities. Commissioning is an effective means to provide this coordination from the beginning of a project. Documents are available that provide guidelines on the commissioning process, including NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems*, and the ASHE *Health Facility Commissioning Guidelines*.

1.3.2 Construction and equipment requirements shall be applied only to new construction and new equipment, except as modified in individual chapters.

This subsection applies throughout the document and is as important as any other provision within NFPA 99. Each individual chapter includes requirements — requirements for the administration of systems and equipment, for maintaining storage and equipment rooms properly and safely, or for general maintenance and testing — for existing installations. Subsection 1.3.2 clarifies that, in all the chapters to follow, unless otherwise specified, the requirements of the code are only intended to apply to new construction and new equipment.

1.3.2.1 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 code.

1.3.2.2 If the alteration, renovation, or modernization adversely impacts the existing performance requirements of a system or component, additional upgrading shall be required.

The two previous paragraphs state that, where an existing system undergoes a renovation or modernization, the requirements of NFPA 99 are meant to apply only to those portions of the system. It is recognized that sometimes these changes have the potential to dramatically impact the existing system or component. Where this occurs, it is necessary to complete additional upgrading in order to meet the requirements.

1.3.2.3 An existing system that is not in strict compliance with the provisions of this code shall be permitted to be continued in use, unless the authority having jurisdiction has determined that such use constitutes a distinct hazard to life.

Although this paragraph repeats the intent of 1.3.2 that the requirements are not meant to be applied to existing systems, it also provides permission for the authority having jurisdiction to require compliance where existing conditions are a distinct hazard to life.

1.3.3 Policies.

1.3.3.1 The health care organization shall ensure that policies are established and maintained that permit the attending physician to satisfy the emergency needs of any patient that supersede the requirements of this code.

1.3.3.2 Each such special use shall be clearly documented and reviewed to attempt to have future similar needs met within the requirements of this code.

While NFPA 99 is intended to provide a minimum level of safety to patients and caregivers, it is recognized that there are special situations and types of care that may not have been anticipated in the writing of this code. It is also not the intent of NFPA 99 to make medical care decisions for any patient; these can only be properly addressed by a physician. This paragraph allows for those decisions to be made, and in fact requires health care facilities to provide for special case policies, as long as the special cases are documented.

1.3.4 Patient Care Spaces.

Δ **1.3.4.1** The health care facility's governing body or its designee shall establish the following areas in accordance with the type of patient care anticipated *(see 3.3.136 Patient Care Space)*:

(1) Category 1 spaces
(2) Category 2 spaces
(3) Category 3 spaces
(4) Category 4 spaces

There are two important concepts that can be identified in the wording of this paragraph. The first is that the word "spaces" is used instead of "room" in all instances. This reflects a change made in Chapter 6 to correlate with *NFPA 70, National Electrical Code*. In a large room, many different services may be provided in different spaces, and this language assesses the risk in individual spaces within a room, rather than treating the room as a single risk factor.

Second, what in past editions were called patient care spaces are now referred to by a certain category (for instance, from a "critical care room" to a "Category 1 space"), which further establishes the risk-based approach used in NFPA 99. The health care organization must designate a category for the spaces based on the anticipated level of patient care that will be provided therein. Rather than labeling a room "critical care" or "general care," this approach examines the risk to the patient based on the procedures that will be performed. The designation of these spaces will determine the type of essential electrical system that will need to be provided in the application of Chapter 6.

The definitions for these spaces are shown in Exhibit 1.1.

EXHIBIT 1.1

Categories for Spaces.

Category 1 Space	Space in which failure of equipment or a system is likely to cause major injury or death of patients, staff, or visitors.
Category 2 Space	Space in which failure of equipment or a system is likely to cause minor injury to patients, staff, or visitors.
Category 3 Space	Space in which the failure of equipment or a system is not likely to cause injury to patients, staff, or visitors but can cause discomfort.
Category 4 Space	Space in which failure of equipment or a system is not likely to have a physical impact on patient care.

1.3.4.2 Anesthesia. It shall be the responsibility of the health care facility's governing body to designate anesthetizing locations.

The administration of anesthesia provides a greater level of risk to the patient and so requires greater protection, as outlined in Chapter 6. Beyond simply designating rooms as anesthetizing locations, it

is important to identify the level of sedation that patients will be provided in these locations. The different levels are defined in 3.3.66, and understanding these levels will play a role in the application of Chapter 5, as well as in conducting a risk assessment. The different definitions for general anesthesia and the levels of sedation are shown in Exhibit 1.2.

EXHIBIT 1.2

Anesthesia Definitions.

General Anesthesia	A drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.
Deep Sedation/Analgesia	A drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.
Moderate Sedation/Analgesia (Conscious Sedation)	A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patient airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.
Minimal Sedation (Anxiolysis)	A drug-induced state during which patients respond normally to verbal commands. Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected.

1.3.4.3 Wet Procedure Locations. It shall be the responsibility of the health care facility's governing body to designate wet procedure locations.

In 2010, the Fire Protection Research Foundation published "Evaluation of Health Care Operating Rooms as Wet/Dry Locations." In creating this report, the Foundation conducted a literature search and evaluated the risk of shock in these locations. The report discussed a risk analysis method for evaluating the operating room (OR) as a wet or dry location. NFPA 99 will continue to define ORs as wet locations unless a risk analysis can demonstrate that ORs do not pose a wet location hazard. A 2012 follow-up report from the Foundation provided sample risk assessments that might be performed to meet this requirement. Wet procedure locations are defined in 3.3.183 as follows:

> **Wet procedure location:** The area in a patient care space where a procedure is performed that is normally subject to wet conditions while patients are present, including standing fluids on the floor or drenching of the work area, either of which condition is intimate to the patient or staff.

1.4 Equivalency.

1.4.1 Nothing in this code is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this code. Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency. The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.4.2 Alternative systems, methods, or devices approved as equivalent by the authority having jurisdiction shall be recognized as being in compliance with this code.

An equivalency statement is included in many NFPA documents to allow for products, designs, and system arrangements that are not specifically covered by the standard being used. However, the products, designs, or arrangements must demonstrate that they do not lower the level of safety provided by the standard or alter the standard's intent.

1.4.3 The authority having jurisdiction shall be permitted to grant exceptions to this code.

Although authorities having jurisdiction can adopt and enforce voluntary standards that they consider appropriate (that is, they can adopt and enforce requirements as written, issue waivers to specific facilities not meeting certain requirements, or adopt a document but change certain requirements), 1.4.3 is a reminder to authorities that, while they enforce the entire code, they can grant exceptions.

1.5* Units. Primary units will be trade units, and secondary units will be the conversion.

A.1.5 Although it is common practice for medical appliances to use metric units on their dials, gauges, and controls, many components of systems within the scope of this document are manufactured and used in the United States and employ nonmetric dimensions. Since these dimensions (such as nominal pipe sizes) are not established by the National Fire Protection Association, the Technical Correlating Committee on Health Care Facilities cannot independently change them. Accordingly, this document uses dimensions that are presently in common use by the building trades in the United States. Trade units vary from SI to U.S. customary units, depending on the equipment devices or material.

1.6 Code Adoption Requirements.

Section 1.6 stipulates that NFPA does not determine effective dates for documents and that enforcement is the responsibility of the authority having jurisdiction. This reflects the fact that NFPA is a codes and standards organization and that adoption, application, and enforcement are the responsibility of other bodies.

1.6.1 The effective date of application of any provision of this document is not determined by the National Fire Protection Association. All questions related to applicability shall be directed to the authority having jurisdiction.

1.6.2 Enforcement. This code shall be administered and enforced by the authority having jurisdiction. *(See Annex C for a sample wording for enabling legislation.)*

References Cited in Commentary

1. "Evaluation of Health Care Operating Rooms as Wet/Dry Locations," October 2010, Fire Protection Research Foundation, Quincy, MA.
2. "Fires and Burns Involving Home Medical Oxygen," August 2008, Fire Analysis and Research Division, National Fire Protection Association, Quincy, MA.

3. *Health Facility Commissioning Guidelines*, 2010 edition, American Society for Healthcare Engineering (ASHE), Chicago, IL.
4. *Manual of Style for NFPA Technical Committee Documents,* July 2004 edition, National Fire Protection Association, Quincy, MA.
5. NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems,* 2018 edition, National Fire Protection Association, Quincy, MA.
6. NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2016 edition, National Fire Protection Association, Quincy, MA.
7. *NFPA 70®*, *National Electrical Code®*, 2017 edition, National Fire Protection Association, Quincy, MA.
8. NFPA *101®*, *Life Safety Code®*, 2018 edition, National Fire Protection Association, Quincy, MA.
9. NFPA 150, *Standard on Fire and Life Safety in Animal Housing Facilities,* 2016 edition.

2

Referenced Publications

Editor's Note: *The following chapter is extracted in its entirety from Chapter 2 of the 2018 edition of NFPA 99,* Health Care Facilities Code. *Commentary is also provided to explain the code and assist the user and is not part of the code. NFPA 99 can be viewed in full at: www.nfpa.org/99.*

Chapter 2 lists all the publications that are referenced in the mandatory code sections of NFPA 99. Annex D lists all the publications that are referenced in the nonmandatory annexes. The purpose of Chapter 2 is to provide the user with a complete list of publications that are needed for the effective use of this code and to achieve compliance with all of its requirements. These publications are compiled in one location for ease of use and to simplify the process of updating the references for adopting agencies or jurisdictions. The editions of the referenced publications listed are required per this code, unless the adopting agency or jurisdiction updates the list of codes and standards.

2.1* General. The documents referenced in this chapter, or portions of such documents, are referenced within this code and shall be considered part of the requirements of this code, and the following shall also apply:

(1) Documents referenced in this chapter, or portion of such documents, shall only be applicable to the extent called for within other chapters of this code.
(2) Where the requirements of a referenced code or standard differ from the requirements of this code, the requirements of this code shall govern.
(3) Existing buildings or installations that do not comply with the provisions of the codes or standards referenced in this chapter shall be permitted to be continued in service, provided that the lack of conformity with these documents does not present a serious hazard to the occupants as determined by the authority having jurisdiction. [***101:***2.1]

While all the documents listed are in mandatory sections of NFPA 99, they are only to be applied to the extent called for in this code. For example, if an NFPA 99 section states that means of egress must comply with NFPA *101®*, *Life Safety Code®*, then only the means of egress requirements from NFPA *101* would need to be met in order to be in compliance with that section of NFPA 99. Even though NFPA *101* appears in this Chapter 2 list, it is not assumed to be required in its entirety.

Further, it is important to understand that even though NFPA 13, *Standard for the Installation of Sprinkler Systems*, is referenced, this does not mean all facilities must be protected by automatic sprinklers. However, if facilities are required by NFPA 99 or another code to be protected by sprinklers, that sprinkler protection must comply with NFPA 13.

While the correlating committee for NFPA 99 attempts to ensure that this code does not conflict with other codes and standards, Section 2.1(2) does specify that, where a conflict exists between NFPA 99 and another document listed in this chapter, the requirements of this code apply.

A.2.1 The documents referenced in this chapter or portions of such documents are referenced within this code and are considered part of the requirements of this document.

Documents referenced in this chapter or portions of such documents are only applicable to the extent called for within other chapters of this code.

Where the requirements of a referenced code or standard differ from the requirements of this code, the requirements of this code govern.

Δ 2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2017 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2016 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2016 edition.
NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2016 edition.
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2017 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2018 edition.
NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2016 edition.
NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines,* 2018 edition.
NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 2015 edition.
NFPA 54, *National Fuel Gas Code,* 2018 edition.
NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2016 edition.
NFPA 58, *Liquefied Petroleum Gas Code,* 2017 edition.
NFPA 70®, National Electrical Code®, 2017 edition.
NFPA 72®, National Fire Alarm and Signaling Code, 2016 edition.
NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment,* 2014 edition.
NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2018 edition.
NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2015 edition.
NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,* 2017 edition.
NFPA *101®, Life Safety Code®,* 2018 edition.
NFPA 110, *Standard for Emergency and Standby Power Systems,* 2016 edition.
NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems,* 2016 edition.
NFPA 170 *Standard for Fire Safety and Emergency Symbols,* 2015 edition.
NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel–Burning Appliances,* 2016 edition.
NFPA 259, *Standard Test Method for Potential Heat of Building Materials,* 2013 edition.
NFPA 260, *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture,* 2013 edition.

NFPA 261, *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes,* 2013 edition.
NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth,* 2015 edition.
NFPA 701, *Standard Methods of Fire Tests for Flame Propagation of Textiles and Films,* 2015 edition.
NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2015 edition.
NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems,* 2015 edition.
NFPA 1600®, Standard on Disaster/Emergency Management and Business Continuity/ Continuity of Operations Programs, 2016 edition.
NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2015 edition.
NFPA 5000®, Building Construction and Safety Code®, 2018 edition.

2.3 Other Publications.

Each document that is published by an organization other than NFPA carries an edition date that was specifically adopted by the health care facilities technical committees, through NFPA's revisions process, and was open to public input and comment and public review in the First Draft Report and Second Draft Report. This means that the technical committees have reviewed each referenced document and have specifically decided through deliberate action to adopt a specific edition. As noted in the commentary to Section 2.1, the extent to which they are mandatory is detailed within the code.

2.3.1 ANSI Publications. American National Standards Institute, Inc., 22 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI B57.1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections*, 1965.
ANSI Z136.3, *American National Standard for Safe Use of Lasers in Health Care*, 2011.
ANSI/AAMI ES 60601–1, *Medical Electrical Equipment*, 2012.

2.3.2 ASHRAE Publications. ASHRAE Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329-2305.

ASHRAE 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, 2010.
ASHRAE 170, *Ventilation of Health Care Facilities*, 2013, including Addenda a, b, d, e, g, ae.

2.3.3 ASME Publications. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME A.17.1, *Safety Code for Elevators and Escalators*, 2013.
ASME A.17.3, *Safety Code for Existing Elevators and Escalators*, 2011.
ASME B1.20.1, *Pipe Threads, General Purpose, Inch*, 2013.
ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*, 2013.
ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*, 2013.
ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*, 2013.
ASME B31.3, *Pressure Process Piping*, 2014.
ASME B40.100, *Pressure Gauges and Gauge Attachments*, 2013.
ASME *Boiler and Pressure Vessel Code*, Sections VIII and IX, 2014.
ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, 2012.

2.3.4 ASSE Publications. ASSE International, 18927 Hickory Creek Drive, Suite 220, Mokena, IL 60448.

ASSE 6010, *Professional Qualifications Standard for Medical Gas Systems Installers*, 2015.
ASSE 6020, *Professional Qualifications Standard for Medical Gas Systems Inspectors*, 2015.
ASSE 6030, *Professional Qualifications Standard for Medical Gas Systems Verifiers*, 2015.
ASSE 6035, *Professional Qualifications Standard for Bulk Medical Gas Systems Verifiers*, 2015.
ASSE 6040, *Professional Qualifications Standard for Medical Gas Maintenance Personnel*, 2015.

Δ **2.3.5 ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM A240/A240M, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*, 2015b.
ASTM A269/A269M, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 2015a.
ASTM A312/A312M, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*, 2016.
ASTM B32, *Standard Specification for Solder Metal*, 2008, reapproved 2014.
ASTM B88, *Standard Specification for Seamless Copper Water Tube*, 2014.
ASTM B103, *Standard Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar*, 2015.
ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, 2016.
ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*, 2000, reapproved 2011.
ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, 2002, reapproved 2010.
ASTM D5/D5M, *Standard Test Method for Penetration of Bituminous Materials*, 2013.
ASTM D1785, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120*, 2015.
ASTM D2466, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40*, 2015.
ASTM D2467, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*, 2015.
ASTM D2672, *Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement*, 2014.
ASTM D2846/D2846M, *Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems*, 2014.
ASTM D4359, *Standard Test Method for Determining Whether a Material Is a Liquid or a Solid*, 1990, reapproved 2012.
ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2015b.
ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2016.
ASTM E1537, *Standard Test Method for Fire Testing of Upholstered Furniture*, 2015.
ASTM E1590, *Standard Test Method for the Fire Testing of Mattresses*, 2013.
ASTM E2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer at 750°C*, 2016.
ASTM F438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 40*, 2015.

ASTM F439, *Standard Specification for Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 80*, 2013.
ASTM F441/F441M, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80*, 2015.
ASTM F493, *Solvent Cements for CPVC Pipe and Fittings*, 2014.

2.3.6 AWS Publications. American Welding Society, 8669 NW 36 Street, #130, Miami, FL 33166-6672.

ANSI/AWS A5.8M/A5.8, *Specification for Filler Metals for Brazing and Braze Welding*, 2011, Addendum 1, 2014.
AWS B2.2/B2.2M, *Standard for Brazing Procedure and Performance Qualification*, 2010.

2.3.7 BICSI Publications. BICSI, 8610 Hidden River Parkway, Tampa, FL 33637-1000.

The BICSI Information Transport Systems (ITS) Dictionary, 3rd edition.

2.3.8 CDA Publications. Copper Development Association Inc., 260 Madison Avenue, New York, NY 10016.

Copper Tube Handbook, 2010.

Δ **2.3.9 CGA Publications.** Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

CGA C-7, *Guide to Classification and Labeling of Compressed Gases*, 2014.
CGA G-4, *Oxygen*, 2015.
CGA G-4.1, *Cleaning Equipment for Oxygen Service*, 2009.
CGA G-6.1, *Standard for Insulated Carbon Dioxide Systems at Consumer Sites*, 2013.
CGA G-6.5, *Standard for Small, Stationary, Insulated Carbon Dioxide Supply Systems*, 2013.
CGA G-8.1, *Standard for Nitrous Oxide Systems at Customer Sites*, 2013.
CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*, 2013.
CGA O2-DIR, *Directory of Cleaning Agents for Oxygen Service*, edition 4.
CGA P-2.5, *Transfilling of High Pressure Gaseous Oxygen Used for Respiration*, 2011.
CGA P-2.6, *Transfilling of Liquid Oxygen Used for Respiration*, 2011.
CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites*, 2013.
CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1), 2013.
CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*, 2008, reaffirmed 2013.

2.3.10 CSA Publications. Canadian Standards Association, 178 Rexdale Blvd., Toronto, M9W 1R3, Canada.

CSA C22.2 No. 0.3, *Test Methods for Electrical Wires and Cables*, 2009, reaffirmed 2014.

2.3.11 FGI Publications. Facility Guidelines Institute, 1919 McKinney Avenue, Dallas, TX 75201.

Guidelines for Design and Construction of Hospitals and Outpatient Facilities, 2014.

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2.3.12 ISA Publications. International Society of Automation, 67 T.W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709.

ANSI/ISA S-7.0.01, *Quality Standard for Instrument Air*, 1996.

2.3.13 MSS Publications. Manufacturer's Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street NE, Vienna, VA 22180-4602.

SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application and Installation*, 2009.

N **2.3.14 State of California Publications.** State of California, Department of Consumer Affairs, 3485 Orange Grove Avenue, North Highlands, CA 95660-5595.

California Technical Bulletin 117, *Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture,* 2000.
California Technical Bulletin 129, *Flammability Test Procedure for Mattresses for Use in Public Buildings,* 1992.
California Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, 1991.

2.3.15 TC Publications. Transport Canada, 330 Sparks Street, Ottawa, ON, K1A ON5, Canada.

Transportation of Dangerous Goods Regulations.

2.3.16 TIA Publications. Telecommunications Industry Association, 1320 North Courthouse Road, Suite 200, Arlington, VA 22201.

TIA/EIA 568-B, *Commercial Building Telecommunications Cabling Standard*, 2012.
TIA/EIA 606-B, *Administration Standard for Commercial Telecommunications Infrastructure*, 2009.

N **2.3.17 USP–NF Publications.** U.S. Pharmacopeial Convention, 12601 Twinbrook Parkway, Rockville, MD 20852-1790.

Monograph: Oxygen USP 93.
Monograph: Oxygen USP.

2.3.18 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, 2008, 2013.
ANSI/UL 1069, *Safety Standard for Hospital Signaling and Nurse Call Equipment*, 2007, revised 2015.
UL 1685, *Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*, 2015.

Δ **2.3.19 U.S. Government Publications.** U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Department of Energy STD-3020, *Specification for HEPA Filters Used by DOE Contractors*, 2005.
Title 16, Code of Federal Regulations, Part 1632, "Standard for the Flammability of Mattresses and Mattress Pads (FF 4-72)."
21 USC 9, United States Food, Drug, and Cosmetic Act.

2.3.20 Other Publications. *Merriam-Webster's Collegiate Dictionary,* 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2018 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2016 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2018 edition.
NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2016 edition.
NFPA 70®, *National Electrical Code®,* 2017 edition.
NFPA 99B, *Standard for Hypobaric Facilities,* 2018 edition.
NFPA *101®*, *Life Safety Code®,* 2018 edition.
NFPA 110, *Standard for Emergency and Standby Power Systems,* 2016 edition.
NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents,* 2017 edition.
NFPA 5000®, *Building Construction and Safety Code®,* 2018 edition.

References Cited in Commentary

1. NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2016 edition, National Fire Protection Association, Quincy, MA.
2. NFPA *101®*, *Life Safety Code®,* 2018 edition, National Fire Protection Association, Quincy, MA.

3

Definitions

***Editor's Note**: The following chapter includes selected definitions extracted from Chapter 3 of the 2018 edition of NFPA 99,* Health Care Facilities Code. *Commentary is also provided to explain the code and assist the user and is not part of the code. NFPA 99 can be viewed in full at: www.nfpa.org/99.*

Chapter 3 lists the definitions of terms used in NFPA 99, *Health Care Facilities Code*. Each definition in Section 3.3, General Definitions, is the responsibility of a technical committee. The appropriate committee abbreviation follows the definition in brackets.

The committees responsible for most of the definitions listed in this chapter are as follows: the Technical Committee on Piping Systems (PIP), the Technical Committee on Medical Equipment (MED), the Technical Committee on Fundamentals (FUN), the Technical Committee on Electrical Systems (ELS), and the Technical Committee on Hyperbaric and Hypobaric Facilities (HYP).

3.1 General. The definitions contained in this chapter shall apply to the terms used in this code. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

Official definitions are under the purview of the NFPA Standards Council, not the committees that write NFPA 99. They are the same in all NFPA documents. Any proposals to change these definitions must be addressed to the NFPA Standards Council.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require

evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

As pointed out in A.3.2.2, a health care facility can be the enforcing authority. Such authority, however, is possible only in the absence of any governmental regulations. To be sure, a facility can enforce more stringent requirements than the government, but this authority might not always be successful. Most health care facilities have numerous authorities having jurisdiction at local, state, and federal levels. Examples include fire marshals, building officials, state or local health officials, the U.S. Occupational Safety and Health Administration (OSHA), the Centers for Medicare and Medicaid Services (CMS), and Accrediting Organizations (AO). The Joint Commission, HFAP, and DNV are examples of AOs.

3.2.3* Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

A.3.2.3 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

3.2.4 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

3.2.5 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.6* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

A.3.2.6 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

3.2.7 Shall. Indicates a mandatory requirement.

Where used, the term *shall* indicates a requirement of this code that is mandatory. Most sections of code specify the way something must be done. There are sections, however, where the requirement is a permission; it often relaxes a requirement that preceded it under certain conditions, or it provides a list of limitations. These allowances typically take a form similar to the following example from Chapter 5. Paragraph 5.1.3.3.1.1 reads, "Any of the following central supply systems shall be permitted to be located together in the same outdoor enclosure: …" This paragraph then lists several systems that can be in the same room, but it is not requiring that all of these systems must be located in the same room.

Another example is 5.1.3.3.3.4(1), which reads, "Outdoor locations surrounded by impermeable walls, except fire barrier walls, shall have protected ventilation openings located at the base of each wall…" This section is immediately followed by 5.1.3.3.3.4(2), which, while it uses "shall," is more of an exception to the rule than a requirement in all instances; it reads, "Walls that are shared with other enclosures or with buildings shall be permitted to not have openings."

3.2.8 Should. Indicates a recommendation or that which is advised but not required.

The term *should* indicates a recommendation, not a requirement, of this code. A provision of this code associated with *should* is informational, and its use is limited to the annexes of this code. Sections with a letter preceding their numbering are annex sections. *Should* identifies a good idea or a better practice, but if the recommendation is not followed, then an acceptable level of safety is still expected to be provided. The terms *should* and *recommend* are commonly found in the annexes.

3.2.9 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Adiabatic Heating. The heating of a gas caused by its compression. (HYP)

In general thermodynamic terms, adiabatic heating refers to an energy exchange process in which there is no external gain or loss of heat energy. As used in this code, it refers to the special case of the rapid compression of a gas in which the mechanical energy input serves to raise the temperature of the gas, as in a compressor. An example of adiabatic heating is the rise in temperature of the environment within a hyperbaric chamber during rapid compression.

3.3.3 Alarm System.

NFPA 99 recognizes three distinct types of alarms in medical gas and vacuum systems: master alarms, area alarms, and local alarms. The actual operation of all alarms is very similar; all include an audible component that can be canceled, a visual component that is continuous when the alarm is active, and a test function. Requirements are found in 5.1.9 for Category 1 alarms, in 5.2.9 for Category 2 alarms, and in 5.3.9 for Category 3 alarms.

3.3.3.1 Area Alarm System. A warning system within an area of use that provides continuous visible and audible surveillance of Category 1 and Category 2 medical gas and vacuum systems. (PIP)

Area alarms are typically those located in treatment areas at or near the nurses' station. They monitor and report on conditions for the benefit of the staff in that area. They are sometimes called "zone alarms," but this usage is incorrect. See 5.1.9.4 for requirements for area alarms. Area alarms are commonly found on the control panel of air or vacuum equipment. Exhibit 3.1 shows a typical area alarm.

3.3.3.2 Category 3 Alarm System. A warning system within an area of use that provides continuous visible and audible surveillance of Category 3 medical gas systems. (PIP)

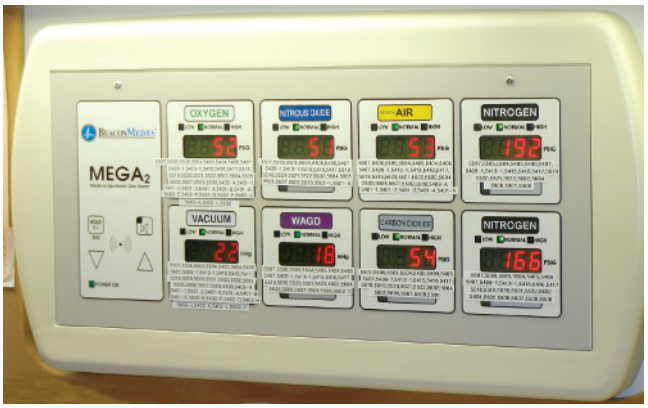
The definition of *Category 3 alarm system* refers to a specific type of alarm commonly used in a medical gas system where there is low risk to the patient. Category 3 alarms reflect the lower complexity of a Category 3 system and the facilities in which they are typically installed. It is worth noting that these types of alarms are now detailed in Chapter 15. This definition will likely need to be revisited during the next revision of the code to account for the move of dental gas and vacuum systems from Category 3 of Chapter 5, to their own Chapter 15.

3.3.3.3 Local Alarm System. A warning system that provides continuous visible and audible surveillance of medical gas and vacuum system source equipment at the equipment site. (PIP)

Local alarms are placed on or very near the source equipment they monitor and are "local" to that equipment. They are sometimes referred to as "source alarms," which is perhaps more descriptive but can be confusing because local alarms do monitor more than just the source itself. See 5.1.9.5 for requirements for local alarms. Exhibit 3.2 shows a local alarm.

EXHIBIT 3.1

Typical Area Alarm.



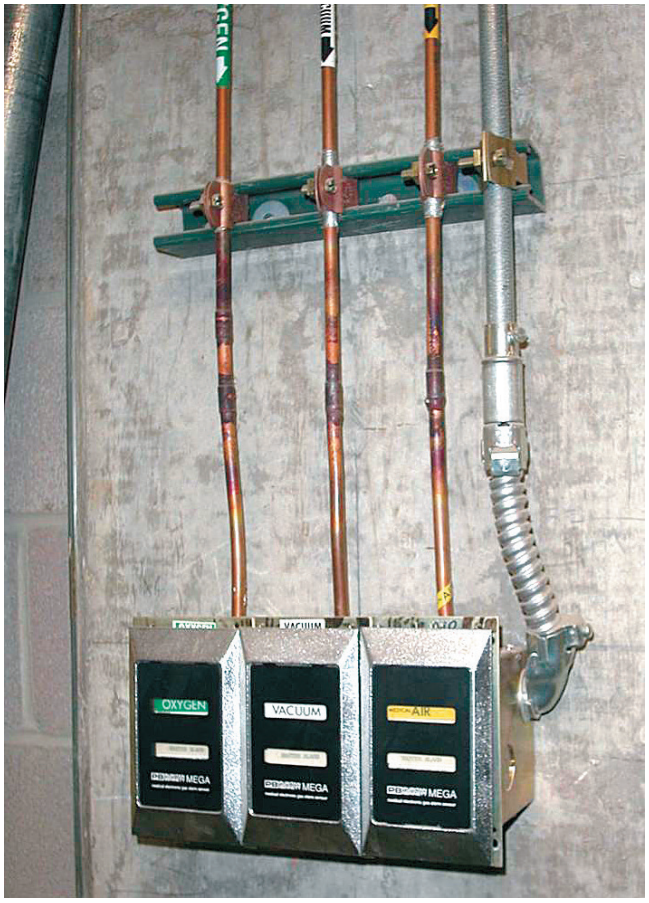


EXHIBIT 3.2

Local Alarm.

3.3.3.4 Master Alarm System. A warning system that monitors 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. (PIP)

The definitions of area, local, and master alarm systems are included here because the terms are frequently misinterpreted. The master alarm is the alarm used to indicate the condition of the sources of supply (which may be remote). Master alarms are found at locations that are attended whenever the building is occupied and where they can be seen by staff who will act to correct any failures. In practice, these are also occasionally called "source alarms," but the term *master alarm* is more conventional and is used in NFPA 99. Exhibit 3.3 shows a master alarm.

3.3.4 Alternate Power Source. One or more generator sets, or battery systems where permitted, intended to provide power during the interruption of the normal electrical service; or the public utility electrical service intended to provide power during interruption of service normally provided by the generating facilities on the premises. (ELS)

3.3.5 Ambulatory Health Care Occupancy. An occupancy used to provide services or treatment simultaneously to four or more patients that provides, on an outpatient basis, one or more of the following: (1) treatment for patients that renders the patients incapable of taking action for self-preservation under emergency conditions without the assistance of others; (2) anesthesia that renders the patients incapable of taking action for self-preservation under

EXHIBIT 3.3

Master Alarm in Facilities Engineering.

emergency conditions without the assistance of others; (3) treatment for patients who, due to the nature of their injury or illness, are incapable of taking action for self-preservation under emergency conditions without the assistance of others. [***101***, 2018] (FUN)

3.3.7 Anesthetic. As used in this code, applies to any inhalational agent used to produce sedation, analgesia, or general anesthesia. (MED)

Note that the reference to "inhalation" is part of the definition of the term *anesthetic*. This is specified so that pills and other methods of administering medication are not considered in determining which areas are anesthetizing locations.

3.3.12* Atmosphere. The pressure exerted by, and gaseous composition of, an environment. (HYP)

A.3.3.12 Atmosphere. As employed in this code, the term *atmosphere* can refer to the environment within or outside of a hyperbaric facility. When used as a measure of pressure, atmosphere is expressed as a fraction of standard air pressure [101.4 kPa (14.7 psi)]. *(See the first column of Table D.1 in NFPA 99B.)*

The term *atmosphere* has two distinct meanings. Its general meaning is the space occupied by gases surrounding a particular region, usually air at a particular pressure and temperature. The term also has a technical meaning as a unit of pressure, which is used extensively in Chapter 14, Hyperbaric Facilities. The context of the requirement determines which meaning is pertinent. It is important to be precise in describing the various atmospheres associated with hyperbaric operation (i.e., ambient and chamber).

3.3.12.1 Atmosphere Absolute (ATA). The pressure of the earth's atmosphere, 760.0 mmHg, 101.325 kPa, or 14.7 psia. Two ATA = two atmospheres. *(See also 3.3.12, Atmosphere.)* (HYP)

Understanding the concept of atmosphere absolute (ATA) is important in hyperbaric chamber operations. An atmosphere of pressure is equal to 33 ft of seawater (FSW), 101.4 kilopascals (kPa), or 14.7 pounds per square inch (psi). Although a chamber can be pressurized to an internal pressure of two atmospheres (66 FSW, or 202.8 kPa, or 29.4 psi), a person exposed to that pressure environment responds physiologically to a pressure equivalent of three ATA. Normal atmospheric pressure of 1 atmosphere or 101.4 kPa (14.7 psi) must be taken into account and added to the actual chamber atmosphere.

3.3.12.2* Atmosphere of Increased Burning Rate. Any atmosphere containing a percentage of oxygen or oxygen and nitrous oxide greater than the quotient of 23.45 divided by the square root of the total pressure in atmospheres. (HYP)

Δ **A.3.3.12.2 Atmosphere of Increased Burning Rate.** The degree of fire hazard of an oxygen-enriched atmosphere varies with the concentration of oxygen and diluent gas and the total pressure. The definition contained in the current edition of NFPA 53 and in editions of NFPA 56D prior to 1982 did not necessarily reflect the increased fire hazard of hyperbaric and hypobaric atmospheres.

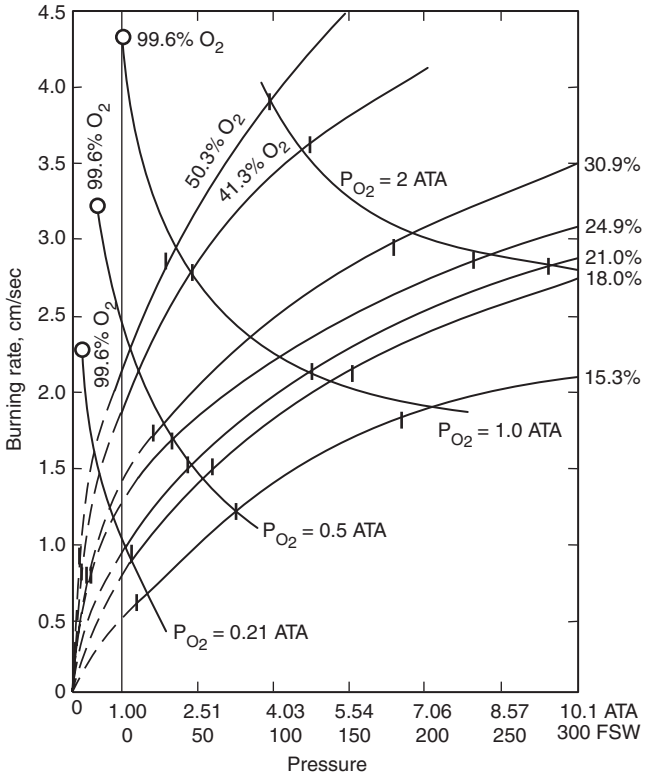
The definition of *atmosphere of increased burning rate* used in Chapter 14 and in NFPA 99B defines an oxygen-enriched atmosphere with an increased fire hazard as it relates to the increased burning rate of material in the atmosphere. It is based on a 1.2 cm/sec (0.47 in./sec) burning rate (at 23.5 percent oxygen at 1 atmosphere absolute) as described in Figure A.3.3.12.2.

This rate can be determined as follows:

$$\frac{23.45}{\sqrt{TP_{atmos}}} \qquad \textbf{[A.3.3.12.2]}$$

where:

TP_{atmos} = total pressure in atmospheres



ATA = Atmospheres absolute
FSW = Feet of sea water

FIGURE A.3.3.12.2 *Burning Rates of Filter Paper Strips at an Angle of 45 Degrees in N_2–O_2 Mixtures. (Adapted from Figure 4 of "Technical Memorandum UCRI-721, Chamber Fire Safety.")*

The definition of *atmosphere of increased burning rate* accounts for the special atmospheres now in use by military, nonmilitary, and private sector operators of hyperbaric and hypobaric chambers. It is based on actual test data under hyperbaric and hypobaric conditions.

The definition reflects the adherence to oxygen concentrations at levels below 23.5 percent. Virtually all modern hyperbaric chamber operations routinely monitor interior chamber oxygen levels and increase chamber ventilation rates as levels approach 23.5 percent. If oxygen levels cannot be maintained below this maximum, all hyperbaric chamber operations should be terminated. The definition of *atmosphere of increased burning rate* reflects the fact that, if a fire should occur in a hyperbaric chamber, the rate of burning will be faster due to the increased partial pressure of oxygen found in the hyperbaric environment.

3.3.12.3 Chamber Atmosphere. The environment inside a chamber. (HYP)

3.3.13 Automatic. Providing a function without the necessity of human intervention. (ELS)

3.3.18 Branch Line. See 3.3.144, Piping.

3.3.19 Bulk System. An assembly of equipment for supplying compressed gas (consisting of, but not limited to, storage containers, pressure regulators, pressure relief devices, vaporizers, manifolds, and interconnecting piping) that terminates where the gas, at service pressure, first enters the main line. The storage containers are either stationary or movable and include unconnected reserves on hand at the site, and the source gas is stored as a compressed gas or cryogenic fluid.

The term *bulk system* is derived from historic usage. The term itself is a poor description of what the system typically is and does. More descriptive is the U.K. term *V.I.E.* for *vacuum insulated evaporator.* In essence, the bulk system (which is the term used in the United States) is a system of vessels and heat exchangers for storing gas in large quantities. This gas has typically been converted into a cryogenic liquid and is transported and stored in an extremely cold, liquid state. The V.I.E. or bulk system acts to gasify the liquid under controlled conditions and to deliver that gas to the facility.

However, NFPA 99's definition does not limit a bulk system to one that contains cryogenic liquid, but instead encompasses any system above a given total capacity. Although it is unlikely that a facility would attempt to keep this much gas in cylinders simply because of the acreage required to store it, NFPA 99 requires any system of this capacity — whether cylinder or liquid — to be treated according to the rules for a bulk system. See Exhibit 3.4 for an example of bulk medical gas storage at a large state university hospital.

3.3.19.1 Bulk Inert Gas System. A bulk system with a storage capacity of more than 566 m^3 [20,000 ft^3 (scf)] of inert gas.

3.3.19.2 Bulk Nitrous Oxide System. A bulk system with a storage capacity of more than 1452 kg (3200 lb) [approximately 793 m^3 (28,000 ft^3) at normal temperature and pressure] of nitrous oxide (PIP).

3.3.19.3* Bulk Oxygen System. A bulk system with a storage capacity of more than 566 m^3 (20,000 ft^3) at normal temperature and pressure of oxygen.

A.3.3.19.3 Bulk Oxygen System. The oxygen containers can be stationary or movable, and the oxygen can be stored as gas or liquid. The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line.

3.3.19.4 Micro-Bulk Cryogenic System. An assembly of equipment including a container that is permanently installed through anchoring to a foundation, pressure regulators, pressure

EXHIBIT 3.4

Bulk Medical Gas Systems Including O_2, N_2O, and CO_2.

relief devices, vaporizers, manifolds, and interconnecting piping that is designed to be filled at the health care facility with a cryogenic gas, that has a storage capacity of less than or equal to 566 m^3 [20,000 ft^3 (scf)] of oxygen, including unconnected reserves on hand at the site, and that terminates at the source valve.

Micro-bulk systems were introduced in the 2015 edition of the code and had their own dedicated section. For the 2018 edition, the requirements for cryogenic systems of that size have been incorporated into 5.1.3.5.14.

3.3.20 Category 3 Drive Gas System. An assembly of component parts including, but not limited to, the source, pressure and operating controls, filters and purification equipment, valves, alarm warning systems, alarm wiring, gauges, and a network of piping and suitable outlets that produces and distributes compressed air from cylinders, compressed air from compressors, or nitrogen from cylinders less than 1100 kPa gauge (less than 160 psi gauge) to power devices (hand pieces, syringes, cleaning devices, delivery system chairs, and so forth) as a power source. The system includes the compressor intakes and ends with the service outlet where the user connects their clinical equipment. (PIP)

3.3.21 Category 3 Vacuum System. A Category 3 vacuum distribution system that can be either a wet system designed to remove liquids, air–gas, or solids from the treated area; or a dry system designed to trap liquid and solids before the service inlet and to accommodate air–gas only through the service inlet. (PIP)

This definition is a leftover from the Category 3 definition of *vacuum* when it included dental applications. As medical and dental applications are now separate, this definition will require reconsideration, because a medical vacuum is never "wet" as described here.

N **3.3.22* Central Supply System.** The complete source of supply for a medical gas or vacuum system or a medical support gas system.

This definition and the definition of *supply source* (3.3.171) are related. NFPA 99 deals with the risk of loss of supply primarily by requiring at least two sources. So, in a two-source system, a *supply source*

is one-half of a *central supply system*. These two terms will be used when it is necessary to distinguish between the part and the whole.

N **A.3.3.22 Central Supply System.** Central supply systems comprise the equipment necessary to produce, condition, control, and monitor the gases or vacuum. They include all equipment from the atmospheric intake on air compressors, exhaust on vacuum pumps, and cylinders or containers for pressurized gases through to the source valve *(see 5.1.4.2)*. Examples of central supply systems include air compressor sources, vacuum pump sources, cylinder and container headers and manifolds, liquid bulk gas systems proportioning systems and combinations thereof.

This definition was added to the 2018 edition in an effort to ensure consistent terminology throughout Chapter 5. Defining *central supply system* allows for better differentiation between the complete source of supply and references to just the supply source.

3.3.25 Combustible. Capable of undergoing combustion. (MED)

3.3.26* Combustible Liquid. Any liquid that was a closed-cup flash point at or above 37.8°C (100°F). Combustible liquids are classified as follows: (a) Class II liquid. Any liquid that has a flash point at or above 37.8°C (100°F) and below 60°C (140°F); (b) Class IIIA liquid. Any liquid that has a flash point at or above 60°C (140°F) and below 93°C (200°F); (c) Class IIIB liquid. Any liquid that has a flash point at or above 93°C (200°F).

This definition uses the NFPA 30, *Flammable and Combustible Liquids Code*, criteria to describe combustible liquids.

Δ **A.3.3.26 Combustible Liquid.** See NFPA 30 for further information on flash point test procedures.

3.3.27* Combustion. A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form of either a glow or flame. [**5000,** 2018] (HYP)

Exhibit 3.5 shows three zones of a chemical reaction in an oxygen/nitrogen mixture, which is similar to air. At approximately the 6 percent mark, oxygen paper strips will not burn due to lack of oxygen in the chemical reaction.

A.3.3.27 Combustion. Combustion is not limited to a chemical reaction always involving oxygen. Certain metals, such as calcium and aluminum, will burn in nitrogen; nitrous oxide will support the combustion of phosphorus and carbon; and so on. However, this document deals with the more common process of fuels burning in air.

3.3.29 Container. A low-pressure, vacuum-insulated vessel containing gases in liquid form. (MED)

The term *container* is used in Chapter 11 to refer specifically to oxygen containers and is now widely accepted for this type of application. The term *cylinder* is reserved for high-pressure applications.

3.3.29.1 Liquid Oxygen Ambulatory Container. A container used for liquid oxygen not exceeding 1.5 L (0.396 gal) specifically designed for use as a medical device as defined by 21

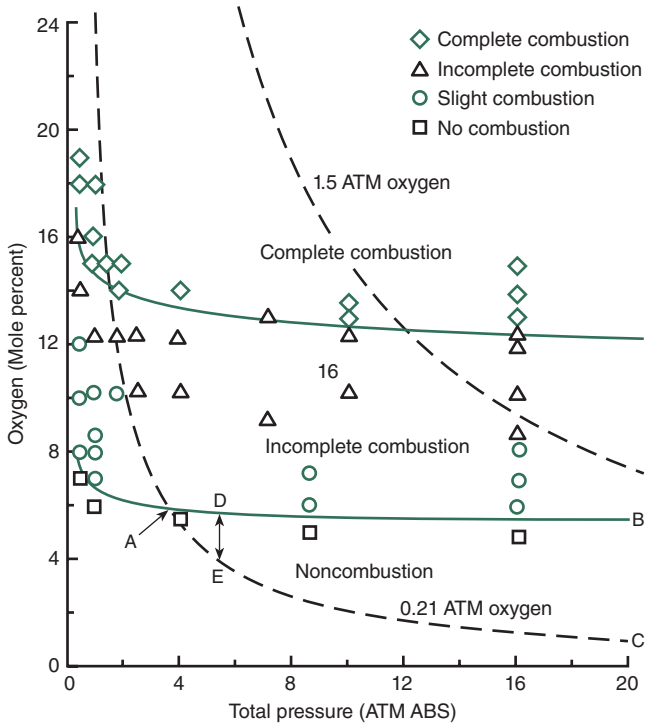


EXHIBIT 3.5

Three Combustion Zones for Vertical Paper Strips in N_2–O_2 Mixtures. (Source: "Technical Memorandum UCRI-721, Chamber Fire Safety")

USC Chapter 9, the United States Food, Drug and Cosmetic Act, that is intended for portable therapeutic use and to be filled from its companion base unit, which is a liquid oxygen home care container. (MED)

The term *liquid oxygen ambulatory container* addresses a type of liquid oxygen container encountered in a home environment. Another type of container found in the home environment is the liquid oxygen home care container. While not included in NFPA 99, this type is defined by federal standards.

3.3.29.2 Liquid Oxygen Base Reservoir Container. A container used for liquid oxygen not exceeding 60 L (15.8 gal) specifically designed for use as a medical device as defined by 21 USC Chapter 9, the United States Food, Drug and Cosmetic Act, that is intended to deliver gaseous oxygen for therapeutic use, transfilling, or both. (MED)

3.3.29.3 Liquid Oxygen Portable Container. A container used for liquid oxygen not exceeding 1.5 L (0.396 gal) specifically designed for use as a medical device as defined by 21 USC Chapter 9, the United States Food, Drug and Cosmetic Act, that is intended for portable therapeutic use and to be filled from its companion base unit, which is a liquid oxygen base reservoir container. (MED)

3.3.30 Critical Branch. A system of feeders and branch circuits supplying power for task illumination, fixed equipment, select receptacles, and select power circuits serving areas and functions related to patient care that are automatically connected to alternate power sources by one or more transfer switches during interruption of the normal power source. (ELS)

Judgment should be used when choosing loads to be connected to the critical branch, because this branch provides electric power to areas and equipment involved in the most critical patient care functions. Paragraph 6.7.5.1.3 provides requirements as to what is permitted to be connected to the critical branch.

N **3.3.32 Cryogenic Fluid Central Supply System.** An assembly of equipment for supplying compressed gas, including, but not limited to, a stationary tank(s) that is permanently installed through anchoring to a foundation, pressure regulators, pressure relief devices, vaporizers, manifolds, and interconnecting piping that is designed to be filled at the health care facility with a cryogenic fluid and that terminates at the source valve.

N **3.3.32.1 Bulk Cryogenic Fluid Central Supply System.** A cryogenic fluid central supply system with a storage capacity of more than 566 m^3 [20,000 ft^3 (scf)].

N **3.3.32.2 Bulk Nitrous Oxide Central Supply System.** A central supply system with a storage capacity of more than 1452 kg (3200 lb) [i.e., approximately 793 m^3 (28,000 ft^3) at normal temperature and pressure] of nitrous oxide (PIP).

N **3.3.32.3 Micro-Bulk Cryogenic Fluid Central Supply System.** A cryogenic fluid central supply system with a storage capacity of less than or equal to 566 m^3 [20,000 ft^3 (scf)].

3.3.33 Cylinder. A supply tank containing high-pressure gases or gas mixtures at pressures that can be in excess of 13.8 kPa gauge (2000 psi gauge). (MED)

See the commentary following 3.3.29, Container.

3.3.36 Demand Check. A paired set of fittings that permit gas flow when correctly mated but interrupt flow when separated. (PIP)

Demand check is a term commonly used in the industry. This check valve allows gas to flow only when the fittings are properly mated and will not allow gas to flow when they are pulled apart or separated.

N **3.3.37 Dental Air.** Compressed gas to drive dental devices, supplied by compressed air systems, pressurized cylinders of air, nitrogen, or CO_2.

N **3.3.38 Dental Office.** A building or part thereof in which the following occur: (1) examinations and minor treatments/procedures performed under the continuous supervision of a dental professional; (2) use of limited to minimal sedation and treatment or procedures that do not render the patient incapable of self-preservation under emergency conditions; and (3) no overnight stays for patients or 24-hour operations.

N **3.3.39 Dental Vacuum/Scavenging.** A system used in dentistry for oral evacuation and nitrous oxide/oxygen scavenging.

In the 2018 edition, the definitions of *dental air, dental office*, and *dental vacuum/scavenging* have been added for use in the new Chapter 15 on dental facilities.

3.3.43 D.I.S.S. Connector. A system of noninterchangeable medical gas and vacuum connectors complying with CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*. (PIP)

CGA V-5, *Diameter-Index Safety System* (*Noninterchangeable Low Pressure Connections for Medical Gas Applications*), also known as the V-5 D.I.S.S. standard, is an internationally accepted standard for noninterchangeable, threaded, gas-specific connections, such as the one shown in Exhibit 3.6. The standard is limited to applications under 1380 kPa (200 psi). (See also 11.2.3.) The higher-pressure applications use a pin-index safety system. (See 11.2.2 and A.11.4.1.2.)

EXHIBIT 3.6

D.I.S.S. Connector. (Courtesy of Tri-Tech Medical Inc.)

3.3.48 Emergency Oxygen Supply Connection (EOSC). An assembly of equipment that permits a gas supplier to make a temporary connection to supply oxygen to a building that has had its normal source of oxygen interrupted. (PIP)

The last word of this definition was changed from "disconnected" to "'interrupted'" in the previous edition to better reflect the intent of providing an emergency oxygen supply connection (EOSC). As the name implies, the EOSC should be for emergency use when the system is interrupted, rather than to provide backup supply while the system is intentionally disconnected for maintenance or any other purpose. Exhibit 3.7 shows an EOSC.

3.3.49 Equipment Branch. A system of feeders and branch circuits arranged for delayed, automatic, or manual connection to the alternate power source and that serves primarily 3-phase power equipment. (ELS)

Often, the equipment branch serves heavy equipment that is 3-phase powered, such as pumps and fans. This type of equipment is necessary for the operation of the facility, but a brief interruption in service can be tolerated without serious consequences. Rapid transfer of these heavy loads to the alternate power source could cause large surges and further disrupt the system. Delayed connection to certain equipment branch loads is allowed. This will reduce the sizing of the alternate power supply by reducing the initial startup load.

EXHIBIT 3.7

Emergency Oxygen Supply Connection (EOSC).

3.3.51* Essential Electrical System. A system comprised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to ensure continuity of electrical power to designated areas and functions of a health care facility during disruption of normal power sources, and also to minimize disruption within the internal wiring system. (ELS)

Chapter 6 of NFPA 99 details the type of essential electrical system required for a health care facility and which loads are permitted to be included on each of the three branches.

A.3.3.51 Essential Electrical System. The essential electrical system can be comprised of three branches: life safety branch, critical branch, and equipment branch.

3.3.52 Evacuation — Waste Gas. See 3.3.181, Waste Anesthetic Gas Disposal.

Evacuation is a term still often used in practice for what is now officially *waste anesthetic gas disposal* or *WAGD*. Although the term *WAGD* is perhaps not the clearest abbreviation, the term *evacuation* has too many other medical meanings and is close in connotation to the term *suction*. See 3.3.181, Waste Anesthetic Gas Disposal (WAGD).

3.3.57* Flammable. A combustible that is capable of easily being ignited and rapidly consumed by fire.

A.3.3.57 Flammable. Flammables can be solids, liquids, or gases exhibiting these qualities. Many substances that are nonflammable in air become flammable if the oxygen content of the gaseous medium is increased above 0.235 ATA.

3.3.58 Flammable Gas. Any substance that exists in the gaseous state at normal atmospheric temperature and pressure and is capable of being ignited and burned when mixed with proper proportion of air, oxygen, or other oxidizers. (HYP)

3.3.59 Flammable Liquid. A liquid that has a closed-cup flash point that is below 37.8°C (100°F) and a maximum vapor pressure of 2068 mmHg (40 psi absolute) at 37.8°C (100°F).

This definition of *flammable liquid* is from NFPA 30.

3.3.60* Flash Point. The minimum temperature at which a liquid or a solid emits vapor sufficient to form an ignitable mixture with air near the surface of the liquid or the solid. (FUN)

A.3.3.60 Flash Point. Note that the flash point temperature is heavily dependent on the test used to determine it.

3.3.61 Flow-Control Valve. A valve, usually a needle valve, that precisely controls flow of gas. (MED)

3.3.62* Flowmeter. A device for measuring volumetric flow rates of gases and liquids. (MED)

Some flowmeters, such as the one shown in Exhibit 3.8, can indicate the mean flow rate, in addition to the volumetric flow rate, of a substance being measured.

A.3.3.62 Flowmeter. A pressure compensated flowmeter should be used to indicate an accurate flow of gas whether the gas is discharged into ambient pressure or into a system at nonambient pressure.

3.3.65 Gas-Powered System. A Level 3 gas distribution system comprised of component parts including but not limited to cylinders, manifolds, air compressor, motor, receivers, controls, filters, dryers, valves, and piping that delivers compressed air or nitrogen at pressures less than 1100 kPa (less than 160 psi) gauge to power devices (e.g., hand pieces, syringes, cleaning devices) as a power source. (PIP)

The term *gas-powered system* applies to a system that is used primarily by dentists to drive pneumatic tools. It is related to, but different from, instrument air as used in Category 1 or Category 2 systems. See 3.3.84, Instrument Air. Note that gas-powered systems are never used where the gas might be breathed, because the gas in fact might not even be air — it could be nitrogen. See Chapter 15 for requirements for gas-powered systems.

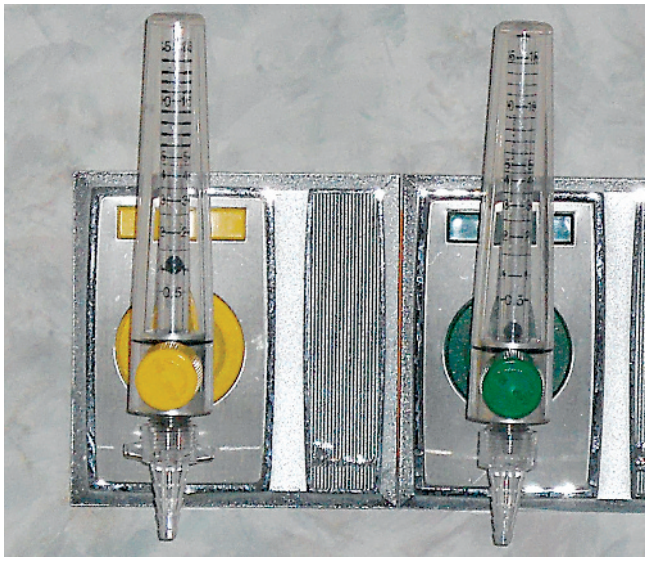


EXHIBIT 3.8

Flowmeter.

3.3.66* General Anesthesia and Levels of Sedation/Analgesia.

A.3.3.66 General Anesthesia and Levels of Sedation/Analgesia. It should be noted that these are not static conditions. Minimal sedation can easily become moderate sedation, and moderate sedation can progress to deep sedation or general anesthesia.

3.3.66.1 General Anesthesia. A drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired. (MED)

3.3.66.2 Deep Sedation/Analgesia. A drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained. (MED)

3.3.66.3 Moderate Sedation/Analgesia (Conscious Sedation). A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patient airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained. (MED)

3.3.66.4 Minimal Sedation (Anxiolysis). A drug-induced state during which patients respond normally to verbal commands. Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected. (MED)

3.3.71* Health Care Facilities. Buildings, portions of buildings, or mobile enclosures in which human medical, dental, psychiatric, nursing, obstetrical, or surgical care is provided. (FUN)

Δ **A.3.3.71 Health Care Facilities.** Health care facilities include, but are not limited to, hospitals, nursing homes, limited care facilities, clinics, medical and dental offices, and ambulatory health care centers, whether permanent or movable. This definition applies to normal, regular operations and does not pertain to facilities during declared local or national disasters. A health care facility is not a type of occupancy classification as defined by NFPA *101*. Therefore, the term *health care facility* should not be confused with the term *health care occupancy*. All health care occupancies (and ambulatory health care occupancies) are considered health care facilities; however, not all health care facilities are considered health care occupancies, as health care facilities also include ambulatory health care occupancies and business occupancies.

As the annex note points out, a health care occupancy is a subset of a health care facility. A medical office building can be a health care facility, but under NFPA *101®*, *Life Safety Code®*, it would typically be a business occupancy. A hospital is a health care facility, but it can be several different occupancies (health care, assembly, business, ambulatory health care, etc.). Note that, for the purposes of NFPA 99, a portion of a building can be considered a health care facility. In the application of this code, only that portion is considered a health care facility, not the entire building.

3.3.72* Health Care Facility's Governing Body. The person or persons who have the overall legal responsibility for the operation of a health care facility. (FUN)

N **A.3.3.72 Health Care Facility's Governing Body.** This definition excludes political governmental agencies, such as authorities having jurisdiction, that exercise local, regional, or

national legal jurisdiction over the design, construction, inspection, and operation of a particular health care facility.

The term *health care facility's governing body* is now being used instead of *governing body* in multiple chapters in NFPA 99. See 4.2.1, 4.2.1.1, and associated commentary for additional information regarding this change.

3.3.73 Home Care. Medical services (equipment) provided in residential occupancies. (FUN)

Home health care is an important part of the health care system. It is not the intention of NFPA 99 to apply to the home health care setting.

3.3.74 Hospital. A building or portion thereof used on a 24-hour basis for the medical, psychiatric, obstetrical, or surgical care of four or more inpatients. [***101***, 2018] (FUN)

The definition of *hospital* is consistent with that in other NFPA documents, such as NFPA *101*.

3.3.76 Hyperbaric Facility. Building, structure, or space used to house hyperbaric chambers and auxiliary service equipment for medical applications and procedures at pressures above normal atmospheric pressure. (HYP)

This definition states that a hyperbaric facility can be a space within a facility or structure and that, when applying NFPA 99, the requirements of Chapter 14 should be applied to only that part of the facility. See also 3.3.79, Hypobaric Facility.

N **3.3.77* Hyperbaric Operations.** Procedures conducted on the patient receiving hyperbaric treatment.

N **A.3.3.77 Hyperbaric Operations.** Such procedures include but are not limited to (a) therapy inside a hyperbaric chamber, (b) changing clothes, (c) vital signs assessments, (d) noninvasive transcutaneous oxygen monitoring, (e) clinical and medical assessments, and (f) minor dressing changes. Debridement or other surgical procedures, application of casting material, application of skin substitutes, and application of bioengineered grafts are not recommended in the chamber room. (HYP)

This newly added definition of *hyperbaric operations* affords the authorities having jurisdiction and end users an understanding of the activities allowed in the hyperbaric room when used in conjunction with Chapter 14.

3.3.78 Hyperbaric Stand-Alone Oxygen System. The oxygen system is entirely separate from the hospital's Category 1 Oxygen System or is a freestanding hyperbaric facility. (HYP)

3.3.84* Instrument Air. A medical support gas that falls under the general requirements for medical gases. Medical air and instrument air are distinct systems for mutually exclusive applications. (PIP)

FAQ What is the difference between instrument air and medical air?

Instrument air is an alternative for nitrogen that is used to drive tools, power columns, dry glassware, and similar tasks. Instrument air should not be confused with medical air, which is a pharmaceutical used for life support. See also 3.3.102, Medical Air, and 3.3.65, Gas-Powered System.

A.3.3.84 Instrument Air. Instrument air is intended for the powering of medical devices unrelated to human respiration (e.g., to remove excess moisture from instruments before further processing, or to operate medical–surgical tools, air-driven booms, pendants, or similar applications).

3.3.85 Intermittent Positive-Pressure Breathing (IPPB). Ventilation of the lungs by application of intermittent positive pressure to the airway. (MED)

3.3.87 Invasive Procedure. Any procedure that penetrates the protective surfaces of a patient's body (i.e., skin, mucous membrane, cornea) and that is performed with an aseptic field (procedural site). [Not included in this category are placement of peripheral intravenous needles or catheters used to administer fluids and/or medications, gastrointestinal endoscopies (i.e., sigmoidoscopies), insertion of urethral catheters, and other similar procedures.] (ELS)

3.3.91* Laboratory. A building, space, room, or group of rooms intended to serve activities involving procedures for investigation, diagnosis, or treatment in which flammable, combustible, or oxidizing materials are to be used.

Diagnostic and/or therapeutic areas of health care facilities are often referred to as laboratories. For the purposes of this document, however, only those areas with the hazards indicated in the definition are considered laboratories. Note that a laboratory is not facility dependent. NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* contains the application of requirements for laboratories.

Isolated frozen section laboratories are included in this definition if they use flammable liquids. They are not included if they do not use flammable liquids.

NFPA 45 is the primary reference document for construction requirements, and it applies to all health care laboratories that store or use flammable or combustible liquids in quantity. NFPA 45 should be consulted for details concerning those volumes that determine applicability.

A.3.3.91 Laboratory. These laboratories are not intended to include isolated frozen section laboratories; areas in which oxygen is administered; blood donor rooms in which flammable, combustible, or otherwise hazardous materials normally used in laboratory procedures are not present; and clinical service areas not using hazardous materials.

3.3.92 Leak Detectant. For purposes of this standard, a reagent, a solution, or an electronic or mechanical device suitable for the detection or visualization of escaping gas. (PIP)

3.3.93 Life Safety Branch. A system of feeders and branch circuits supplying power for lighting, receptacles, and equipment essential for life safety that is automatically connected to alternate power sources by one or more transfer switches during interruption of the normal power source. (ELS)

3.3.94* Limited-Combustible (Material). See 4.4.2.

Δ **A.3.3.94 Limited-Combustible (Material).** Material subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition is considered combustible.

See NFPA 259 and NFPA 220.

3.3.96* Liquid. Any material that (1) has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Standard Test Method for Penetration of Bituminous Materials*, or (2) is a viscous substance for which a specific melting point cannot be determined but that is determined to be a liquid in accordance with ASTM D4359, *Standard Test for Determining Whether a Material is a Liquid or a Solid*. [**30,** 2018] (LAB)

A.3.3.96 Liquid. When not otherwise identified, the term *liquid* includes both flammable and combustible liquids. *(See also B.11.1.1.)*

3.3.97* Local Signal. A visible indication of the operating status of equipment. (PIP)

Local signals are not alarms but rather are a kind of aid to the operator. The requirements for local signals are found in 5.1.3.5.9.

A.3.3.97 Local Signal. Examples would include a gauge, a flag, a light, or some other possible manifestation that allows a maintenance person to stand at the equipment and know what conditions are present (e.g., which header of cylinders is in service). The elements to be displayed are typically those that will also be monitored at the master alarm, but the local signal is visible at the equipment rather than remotely.

3.3.99 Manifold. A device for connecting the outlets of one or more gas cylinders to the central piping system for that specific gas. (PIP)

3.3.100* Manufactured Assembly. A factory-assembled product designed for aesthetics or convenience that contains medical gas or vacuum outlets, piping, or other devices related to medical gases. (PIP)

These potentially large and complex subcomponents of a medical gas system are assembled in a factory and integrated into the medical gas system on site.

The quantity and complexity of the piping that manufactured assemblies might contain can significantly affect the final testing, operation, and integrity of the complete system. The requirements in NFPA 99 (see 5.1.6) are intended to ensure that the integrity of the piping does not diminish between the wall and the appliance interface, because the use of a manufactured assembly creates a similar wall-like interface.

A.3.3.100 Manufactured Assembly. Examples are headwalls, columns, ceiling columns, ceiling-hung pendants, movable track systems, and so on.

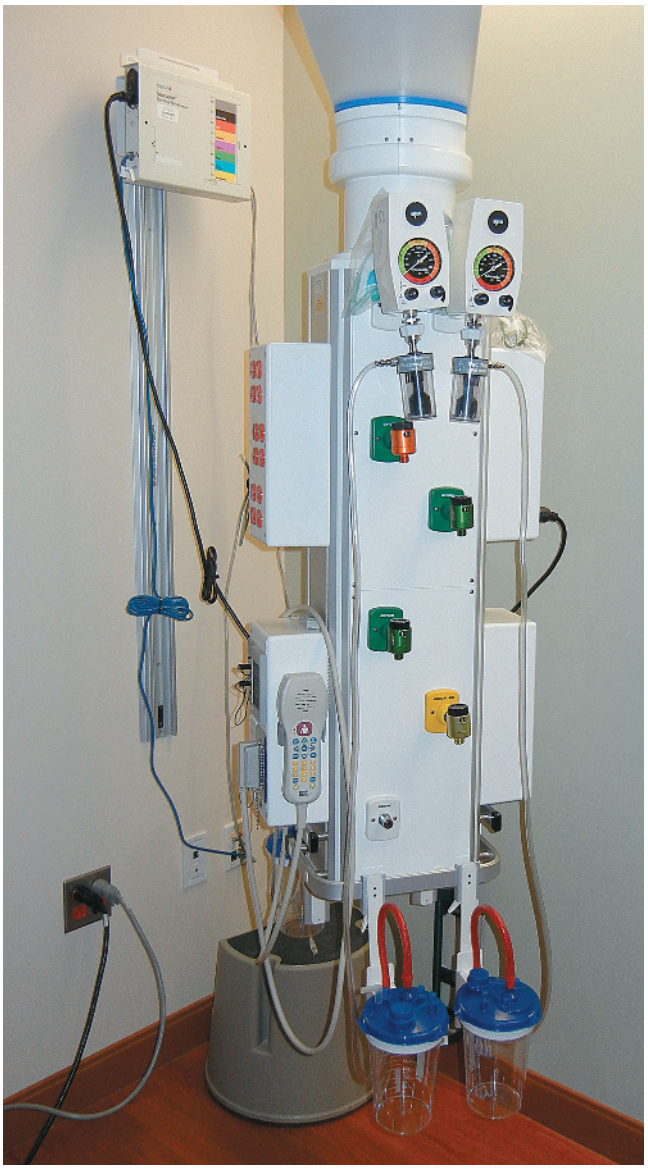
Manufactured assemblies might include ceiling columns, booms, pendants, headwalls, horizontal trunking systems, movable columns, power columns, prepiped benches, cabinetry with medical gases installed, preassembled wall sections, portable treatment rooms, modular operating rooms (ORs), modular patient rooms, and a plethora of other manifestations of prepiped and more or less "movable" equipment. Exhibit 3.9 shows an example of a manufactured assembly.

3.3.102* Medical Air. For purposes of this code, medical air is air supplied from cylinders, bulk containers, or medical air compressors or reconstituted from oxygen USP and oil-free, dry nitrogen NF. (PIP)

While this appears to be a simple definition, many of the requirements for medical air — specifically concerning the quality and allowed use — are defining characteristics of the gas. Note that instrument air is

EXHIBIT 3.9

Example of a Manufactured Assembly.



used to drive tools, power columns, dry glassware, and so forth. Medical air, by contrast, is a pharmaceutical used for life support. See 5.1.3.6.

A.3.3.102 Medical Air. Air supplied from on-site compressors and associated air treatment systems (as opposed to medical air USP supplied in cylinders) that complies with the specified limits is considered medical air. Hydrocarbon carryover from the compressor into the pipeline distribution system could be detrimental to the safety of the end user and to the integrity of the piping system. Mixing of air and oxygen is a common clinical practice, and the hazards of fire are increased if the air is thus contaminated. Compliance with these limits is thus considered important to fire and patient safety. The quality of local ambient air should be determined prior to its selection for compressors and air treatment equipment.

3.3.102.1 Proportioning System for Medical Air USP. A central supply that produces medical air (USP) reconstituted from oxygen USP and nitrogen NF by means of a mixer or blender. (PIP)

A proportioning system is used to blend oxygen USP and oil-free, dry nitrogen NF (see 3.3.115.1, Nitrogen NF) to form medical air. This system proportions the correct amount of both gases to be defined as medical air.

3.3.103 Medical Air Compressor. A compressor that is designed to exclude oil from the air stream and compression chamber and that does not under normal operating conditions or any single fault add any toxic or flammable contaminants to the compressed air. (PIP)

This definition reflects the critical importance of excluding toxic and potentially damaging elements from the medical air both for the safety of equipment, where pure oxygen is commonly added to the air, and for the safety of patients, who will often breathe the air without other filtration or purification. (See 3.3.102, Medical Air.) Appropriate limitations and safety devices are listed in Chapter 5 for each accepted technology.

Compressors can be designed to deliver the quality of air required for medical compressed air purposes. Factors such as the inherent design of the compressor and the way it is maintained will influence the extent to which oil or other contaminants are injected into the medical compressed air line during a compressor failure. Exhibit 3.10 shows a medical air compressor.

3.3.104 Medical Gas. A patient medical gas or medical support gas. *(See also 3.3.142, Patient Medical Gas and 3.3.107, Medical Support Gas.)* (PIP)

The term *medical gas* correlates with the use of the term by the American Society of Anesthesiologists.

3.3.105 Medical Gas System. An assembly of equipment and piping for the distribution of nonflammable medical gases such as oxygen, nitrous oxide, compressed air, carbon dioxide, and helium. (PIP)

3.3.106* Medical Office. A building or part thereof in which the following occur: (1) examinations and minor treatments/procedures performed under the continuous supervision of a medical professional; (2) the use of limited to minimal sedation and treatment or procedures that do not render the patient incapable of self-preservation under emergency conditions; and (3) no overnight stays for patients or 24-hour operations. (FUN)

A.3.3.106 Medical Office. Examples include a dental office/clinic, a medical office/clinic, an immediate care facility, and a podiatry office.

EXHIBIT 3.10

Medical Air Compressor.

3.3.107 Medical Support Gas. Nitrogen or instrument air used for any medical support purpose (e.g., to remove excess moisture from instruments before further processing, or to operate medical–surgical tools, air-driven booms, pendants, or similar applications) and, if appropriate to the procedures, used in laboratories and are not respired as part of any treatment. Medical support gas falls under the general requirements for medical gases. (PIP)

3.3.108 Medical–Surgical Vacuum. A method used to provide a source of drainage, aspiration, and suction in order to remove body fluids from patients. (PIP)

3.3.109 Medical–Surgical Vacuum System. An assembly of central vacuum–producing equipment and a network of piping for patient suction in medical, medical–surgical, and waste anesthetic gas disposal (WAGD) applications. (PIP)

3.3.110 Multiple Treatment Facility. A diagnostic or treatment complex under a single management comprising a number of single treatment facilities, which can be accessed one from the other without exiting the facility (i.e., does not involve widely separated locations or separate distinct practices). (FUN)

The definition of *multiple treatment facility* is applied only in Chapter 15. (See also 3.3.165, Single Treatment Facility.)

3.3.115 Nitrogen. An element that, at atmospheric temperatures and pressures, exists as a clear, colorless, and tasteless gas; it comprises approximately four-fifths of the earth's atmosphere. (MED)

3.3.115.1 Nitrogen NF. Nitrogen complying as a minimum with nitrogen NF. (PIP)

Nitrogen is used for pipe joining and pressure-testing purposes. Grade NF is the nitrogen acceptable for use in pipes intended for medical application. Nitrogen is required to be oil-free because it is used in piped oxygen lines where particles of oil can be a fire hazard, as well as a hazard to patients.

Nitrogen NF is nitrogen as defined by the U.S. Pharmacopeia (USP) and National Formulary (NF). Because the USP is the standard for pharmaceutical purity in the United States and much of the world, it has been argued that nitrogen NF is a drug and should not be available without a doctor's prescription. However, this controversy appears to have subsided, and the gas is now widely available for nitrogen purging and testing, as detailed in Chapter 5 of this code.

3.3.117 Nitrous Oxide. An inorganic compound, one of the oxides of nitrogen. It exists as a gas at atmospheric pressure and temperature, possesses a sweetish smell, and is used for inducing anesthesia when inhaled. The oxygen in the compound will be released under conditions of combustion, creating an oxygen-enriched atmosphere. (MED)

3.3.118 Noncombustible (Material). See 4.4.1.

3.3.119 Nonflammable. Not readily capable of burning with a flame and not liable to ignite and burn when exposed to flame.

3.3.120 Nonflammable Anesthetic Agent. Refers to those inhalation agents that, because of their vapor pressure at 37°C (98.6°F) and at atmospheric pressure, cannot attain flammable concentrations when mixed with air, oxygen, or mixtures of oxygen and nitrous oxide. (MED)

3.3.121* Nonflammable Medical Gas System. See 3.3.105, Medical Gas System, and Chapter 5.

A.3.3.121 Nonflammable Medical Gas System. See Chapter 5, Gas and Vacuum Systems.

3.3.122 Nonmedical Compressed Air. Air that is used for purposes other than patient care or medical devices that provide direct patient care. (MEC)

3.3.123 Nursing Home. A building or portion of a building used on a 24-hour basis for the housing and nursing care of four or more persons who, because of mental or physical incapacity, might be unable to provide for their own needs and safety without the assistance of another person. [***101***, 2018] (FUN)

3.3.125* Oxidizing Gas. A gas that supports combustion. (HYP)

A.3.3.125 Oxidizing Gas. Oxygen and nitrous oxide are examples of oxidizing gases. There are many others, including halogens.

3.3.126* Oxygen. A chemical element that, at normal atmospheric temperatures and pressures, exists as a colorless, odorless, and tasteless gas and comprises about 21 percent by volume of the earth's atmosphere. (MED)

A.3.3.126 Oxygen. Oxygen's outstanding property is its ability to sustain life and to support combustion. Although oxygen is nonflammable, materials that burn in air will burn much more vigorously and create higher temperatures in oxygen or in oxygen-enriched atmospheres.

3.3.126.1 Gaseous Oxygen. A colorless, odorless, tasteless, and nontoxic gas, comprising about 21 percent of normal air by volume, that is about 10 percent heavier than air; also the physical state of the element at atmospheric temperature and pressure. (MED)

3.3.126.2* Liquid Oxygen. Exists at cryogenic temperature, approximately −184.4°C (−300°F) at atmospheric pressure. It retains all of the properties of gaseous oxygen, but, in addition, when allowed to warm to room temperature at atmospheric pressure, it will evaporate and expand to fill a volume 860 times its liquid volume. (MED)

A.3.3.126.2 Liquid Oxygen. If spilled, the liquid can cause frostbite on contact with skin.

N **3.3.127 Oxygen Concentrator Unit.** An engineered assembly of components that operate to raise the concentration of oxygen, providing oxygen as a drug product.

This definition is new to the 2018 edition and is added to define the active element of the oxygen supply source using concentrators (see 5.1.3.5.11). Concentrators are available for oxygen 93 USP (see 3.3.131) and for oxygen USP (see 3.3.133), with the vast preponderance being the 93 percent type (mainly for economic reasons). Most operate using a molecular sieve in a pressure swing mode that allows them to separate the nitrogen from the oxygen in the feed air, which concentrates the oxygen. There are also membrane-type concentrators, but these are rare in hospital-size applications. The technology is evolving, and concentrators as a supply source option have gradually become more economical and reliable and have begun to displace traditional cylinder supplies in some locations.

3.3.128* Oxygen Delivery Equipment. Any device used to transport and deliver an oxygen-enriched atmosphere to a patient. (MED)

A.3.3.128 Oxygen Delivery Equipment. If an enclosure such as a mask, hood, incubator, canopy, or tent is used to contain the oxygen-enriched atmosphere, that enclosure is considered to be oxygen-delivery equipment.

3.3.129 Oxygen-Enriched Atmosphere (OEA). For the purposes of this code, an atmosphere in which the concentration of oxygen exceeds 23.5 percent by volume. (HYP)

The normal percentage of oxygen in air is 20.9 percent, commonly expressed as 21 percent. The value of 23.5 percent reflects an error factor of ±2.5 percent. Such a margin of error is necessary because of the imprecision of gas measurement devices and the practicality of reconstituting air from gaseous nitrogen and oxygen. Hyperbaric chambers located in areas of potential atmospheric pollution cannot be pressurized with air drawn from the ambient atmosphere. Such chambers are supplied by "air" that is prepared by mixing one volume of oxygen with four volumes of nitrogen. It is impractical to reconstitute large volumes of air with tolerances closer than 21 percent ± 2.5 percent.

The code does not intend to imply that the use of compressed air cylinders in normal atmospheric areas (such as areas outside hyperbaric chambers) would create an oxygen-enriched atmosphere. The compressed air expands as it leaves the cylinder, drops to normal atmospheric pressure, and is not oxygen-enriched.

This definition of *oxygen-enriched atmosphere* varies slightly from the one in NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, which states that the concentration of oxygen in the atmosphere exceeds 21 percent by volume or its partial pressure exceeds 21.3 kPa (160 torr). The scope of the definition is limited to the way the term is used throughout NFPA 99. The definition is independent of the atmospheric pressure of the area and is based solely on the percentage of oxygen. In defining the term, the issue of environments — such as a hyperbaric chamber, where the atmospheric pressure can vary — was taken into consideration. Under normal atmospheric conditions, oxygen concentrations above 23.5 percent will increase the fire hazard level. Different atmospheric conditions (such as pressure) or the presence of gaseous diluents, however, can actually increase or decrease the fire hazard level even if an oxygen-enriched atmosphere exists. An oxygen-enriched atmosphere, in and of itself, does not always signify that an increased fire hazard exists.

3.3.130* Oxygen Hood. A device encapsulating a patient's head and used for a purpose similar to that of a mask. *(See also 3.3.101, Mask.)* (HYP)

The oxygen hood was developed for those patients unable to breathe oxygen in a hyperbaric chamber through a traditional mask. For example, patients who are undergoing mandibular reconstruction surgery and are unable to be fitted with an oronasal mask might use an oxygen hood. The clear, flexible hood is either attached to a rubber neck dam/ring assembly or taped to the patient's skin to help prevent oxygen leaks into the chamber environment. Hood inflation is maintained with a delicate balance of supply (100 percent oxygen) and exhaust. The hood assembly is the most commonly used oxygen delivery device in Class A clinical hyperbaric medicine chambers. Exhibit 3.11 shows a patient using an oxygen hood.

A.3.3.130 Oxygen Hood. For additional information, see A.3.3.12.2 and Figure A.3.3.12.2.

N **3.3.131 Oxygen 93 USP.** Oxygen complying with Oxygen 93 USP Monograph.

This definition was added to the 2018 edition to delineate between oxygen USP and oxygen 93 USP, two different and distinct medical gases with two different USP Monographs. Oxygen USP has an assay specification of "not less than 99.0% Oxygen" where oxygen 93 USP has an assay specification of "93% ± 3% Oxygen."

3.3.132* Oxygen Toxicity (Hyperbaric). Physical impairment resulting from breathing gaseous mixtures containing oxygen-enriched atmospheres at elevated partial pressures for extended periods of time. (HYP)

There are two types of oxygen toxicity: pulmonary (called the Lorrain Smith effect) and central nervous system (called the Paul Bert effect). Prolonged breathing of 60 percent to 100 percent oxygen

EXHIBIT 3.11

Oxygen Hood. (Courtesy of Sea-Long Medical Systems)

for long periods of time can produce serious lung damage. Effects range from minor lung irritation to a pneumonia-like condition. Central nervous system oxygen toxicity occurs more rapidly than pulmonary toxicity and produces seizure activity similar to epileptic convulsions. Breathing 100 percent oxygen at 60 ft of seawater (FSW) for 30 continuous minutes will produce seizure activity in approximately 2 percent of the population.

Neither pulmonary nor central nervous system oxygen toxicity is a problem in routine hyperbaric chamber operations due to well-established safety practices.

A.3.3.132 Oxygen Toxicity (Hyperbaric). Under the pressures and times of exposure normally encountered in hyperbaric treatments, toxicity is a direct function of concentration and time of exposure.

3.3.133 Oxygen USP. Oxygen complying with oxygen USP monograph.

3.3.136* Patient Care Space. Any space of a health care facility wherein patients are intended to be examined or treated. (FUN)

The terminology in these definitions has been changed in two distinct ways in previous editions. The first is that the word *room* was changed to *space* in all instances. This reflects a change that was made in Chapter 6 to correlate with *NFPA 70* and to reflect that, in a large room, there can be many different services being provided in different spaces. The idea of this change is to look at the risk in individual spaces within a room, rather than in the room as a whole.

Second, the treatment of patient care spaces as certain categories of space ("Category 1 space," as opposed to "critical care room") further establishes the risk-based approach to NFPA 99. The health care organization must identify a space based on the anticipated level of patient care in each. Doing so reflects a move away from simply labeling a room "critical care" or "general care" and toward more closely examining what the risk is to the patient based on the actual procedures that will be performed. The designation of these spaces will determine the type of essential electrical system to

which an area needs to be connected in the application of Chapter 6. The annex material following each category of space provides what that space was previously referred to as, and it also gives some examples of what type of rooms might fall under each category.

A.3.3.136 Patient Care Space. Business offices, corridors, lounges, day rooms, dining rooms, or similar areas typically are not classified as patient care spaces.

3.3.136.1* Category 1 Space. Space in which failure of equipment or a system is likely to cause major injury or death of patients, staff, or visitors. (FUN)

A.3.3.136.1 Category 1 Space. These spaces, formerly known as critical care rooms, are typically where patients are intended to be subjected to invasive procedures and connected to line-operated, patient care–related appliances. Examples include, but are not limited to, special care patient rooms used for critical care, intensive care, and special care treatment rooms such as angiography laboratories, cardiac catheterization laboratories, delivery rooms, operating rooms, post-anesthesia care units, trauma rooms, and other similar rooms.

3.3.136.2* Category 2 Space. Space in which failure of equipment or a system is likely to cause minor injury to patients, staff, or visitors. (FUN)

A.3.3.136.2 Category 2 Space. These spaces were formerly known as general care rooms. Examples include, but are not limited to, inpatient bedrooms, dialysis rooms, in vitro fertilization rooms, procedural rooms, and similar rooms.

3.3.136.3* Category 3 Space. Space in which the failure of equipment or a system is not likely to cause injury to patients, staff, or visitors but can cause discomfort. (FUN)

A.3.3.136.3 Category 3 Space. These spaces, formerly known as basic care rooms, are typically where basic medical or dental care, treatment, or examinations are performed. Examples include, but are not limited to, examination or treatment rooms in clinics, medical and dental offices, nursing homes, and limited care facilities.

3.3.136.4* Category 4 Space. Space in which failure of equipment or a system is not likely to have a physical impact on patient care. (FUN)

A.3.3.136.4 Category 4 Space. These spaces were formerly known as support rooms. Examples of support spaces include, but are not limited to, anesthesia work rooms, sterile supply, laboratories, morgues, waiting rooms, utility rooms, and lounges. (FUN)

N **3.3.138* Producer.** The machine(s) or device(s) that generate the flow and suction required for vacuum, WAGD, and plume evacuation systems to operate.

N **A.3.3.138 Producer.** Examples of these producers include vacuum pumps, fans, blowers, and venturis.

3.3.142 Patient Medical Gas. Piped gases such as oxygen, nitrous oxide, helium, carbon dioxide, and medical air that are used in the application of human respiration and the calibration of medical devices used for human respiration. (PIP)

3.3.143 Piped Distribution System. A pipeline network assembly of equipment that starts at and includes the source valve, warning systems (master, area, local alarms), bulk gas system signal actuating switch wiring, interconnecting piping, and all other components up to and including the station outlets/inlets. (PIP)

The term *piped distribution system* is also applied to a vacuum system, even though a vacuum system flows to, rather than away from, the source.

3.3.144 Piping. The tubing or conduit of the system. The three general classes of piping are main lines, risers, and branch (lateral) lines. (PIP)

3.3.144.1 Branch (Lateral) Lines. Those sections or portions of the piping system that serve a room or group of rooms on the same story of the facility. (PIP)

3.3.144.2 Main Lines. The piping that connects the source (pumps, receivers, etc.) to the risers or branches, or both. (PIP)

3.3.144.3 Risers. The vertical pipes connecting the system main line(s) with the branch lines on the various levels of the facility. (PIP)

The definitions in 3.3.144.1 through 3.3.144.3 apply to both positive-pressure gas systems and negative-pressure vacuum systems, because the layouts of the distribution systems of each are similar.

3.3.146 Pressure.

3.3.146.1 Absolute Pressure. The total pressure in a system with reference to zero pressure. (HYP)

3.3.146.2 Ambient Pressure. Refers to total pressure of the environment referenced. (HYP)

3.3.146.3 Gauge Pressure. Refers to total pressure above (or below) atmospheric. (HYP)

3.3.146.4 High Pressure. A pressure exceeding 1.38 kPa (200 psi) gauge (215 psia). (MED)

3.3.146.5* Operating Pressure. The pressure that a particular piping system is set to operate at. (PIP)

A.3.3.146.5 Operating Pressure. The operating pressure for patient medical gases is typically 345 kPA to 380 kPa (50 psig to 55 psig). The operating pressure for medical support gases is typically 1100 kPa to 1275 kPA (160 psig to 185 psig).

3.3.146.6* Partial Pressure. The pressure, in absolute units, exerted by a particular gas in a gas mixture. (HYP)

A.3.3.146.6 Partial Pressure. The pressure contributed by other gases in the mixture is ignored. For example, oxygen is one of the constituents of air; the partial pressure of oxygen in standard air, at a standard air pressure of 14.7 psia, is 3.06 psia or 0.208 ATA or 158 mm Hg.

The effect of a component gas (such as carbon dioxide) could be insignificant at normal ambient pressure but extremely hazardous under hyperbaric conditions. Dalton's law states, "In a mixture of gases the pressure exerted by each gas is the same as it would exert if it alone occupied the same volume; and the total pressure is the sum of the partial pressures of the component gases." For example, if 2 percent carbon dioxide exists at a chamber pressure of 5 ATA [132 ft of seawater (FSW)], it would have the same physiological effect as 10 percent CO_2 breathed at sea level. Elevated partial pressures of carbon dioxide are thought to reduce one's tolerance to central nervous system oxygen toxicity.

3.3.146.7 Positive Pressure. Pressure greater than ambient atmospheric. (MED)

3.3.146.8 Working Pressure (Rated). The maximum rated operating pressure for a pipe, tube, or vessel based on its material, its allowable stress in tension, its outside diameter and wall thickness, the operating temperature, the joining method, and industry safety factors. (PIP)

3.3.147* Pressure-Reducing Regulator. A device that automatically reduces gas under high pressure to a usable lower working pressure. (MED)

A.3.3.147 Pressure-Reducing Regulator. In hospitals, the term *regulator* is frequently used to describe a regulator that incorporates a flow-measuring device.

3.3.149 psia. Pounds per square inch absolute, a unit of pressure measurement with zero pressure as the base or reference pressure. (HYP)

3.3.150* psig. Pounds per square inch gauge, a unit of pressure measurement with atmospheric pressure as the base or reference pressure. (HYP)

See the commentary following 3.3.12.1 for a discussion of the term *atmosphere absolute (ATA)*.

A.3.3.150 psig. Under standard conditions, 0 psig is equivalent to 14.7 psia.

3.3.156* Remote. A Level 3 source of supply that is accessed by exiting the single or multiple treatment facility. (PIP)

Note that "remoteness" is not a matter of distance; rather, it is based on whether one must use an exit to go from the use point to the storage area.

A.3.3.156 Remote. A gas storage supply system can be remote from the single treatment facility, but all use points must be contiguous within the facility.

3.3.157 Reserve Supply. Where existing, that portion of the supply equipment that automatically supplies the system in the event of failure of the operating supply. The reserve supply only functions in an emergency and not as a normal operating procedure. (PIP)

Reserve supply should not be confused with secondary supply. (See 3.3.171.4, Secondary Supply.)

3.3.158 Risk Categories.

3.3.158.1 Category 1. Activities, systems, or equipment whose failure is likely to cause major injury or death to patients, staff, or visitors.

3.3.158.2 Category 2. Activities, systems, or equipment whose failure is likely to cause minor injury to patients, staff, or visitors.

3.3.158.3 Category 3. Activities, systems, or equipment whose failure is not likely to cause injury to patients, staff, or visitors but can cause discomfort.

3.3.158.4 Category 4. Activities, systems, or equipment whose failure would have no impact on patient care.

3.3.159 Scavenging. Evacuation of exhaled mixtures of oxygen and nitrous oxide. (PIP)

3.3.162 Semipermanent Connection. A noninterchangeable connection, usually a D.I.S.S. connector, which is the termination of the pipeline and that is intended to be detached only for service. It is not the point at which the user makes connections or disconnections. (PIP)

This definition for *semipermanent connection* is applied only to the manufactured assembly. This is the point at which the assembly is connected to the physical pipeline. In a manufactured assembly, the

semipermanent connection is not used except when the assembly requires service, and thus it has its own requirements and allowances. See 5.1.6 for these requirements.

The copper pipelines to these assemblies are commonly terminated with an outlet (typically a D.I.S.S. connector) that is hidden behind or within the manufactured assembly. The connection between this pipeline outlet and the outlets at which the user makes connections (known as the *terminal*) is commonly made using flexible tubing (typically rubber hoses). Because these hoses and outlets are hidden, the flexible connections and outlets are accessible to maintenance personnel only when the manufactured assembly is disassembled.

This practice has created two distinct hazards. First, manufacturers are encouraging the installation of multiple station outlets to allow for convenient future connections. These station outlets are frequently not tested and certified, increasing the possibility of a latent cross-connection that would be discovered only after the outlet is activated, which could be long after the system is in service. The second hazard results from the flexible assembly and connection hidden in the manufactured assembly. A leak or rupture would allow the development of an oxygen-enriched atmosphere that could have very serious consequences in a fire incident. (See 5.1.6 for requirements designed to mitigate these hazards.)

3.3.163 Service Inlet. The pneumatic terminus of a Level 3 piped vacuum system. (PIP)

The definition of *service inlet* helps to distinguish between an inlet for a Category 3 vacuum system and an inlet for a more critical level of patients, such as for a Category 1 vacuum system. The equivalent to a service inlet in Category 1 and Category 2 vacuum systems is a station inlet.

3.3.164 Service Outlet. The pneumatic terminus of a piped gas system for other than critical, continuous duty, nonflammable medical life support–type gases such as oxygen, nitrous oxide, or medical air. (PIP)

The equivalent to a service outlet in Category 1 and Category 2 medical gases is a station outlet.

3.3.165* Single Treatment Facility. A diagnostic or treatment complex under a single management comprising a number of use points, but confined to a single contiguous group of use points (i.e., does not involve widely separated locations or separate distinct practices). (PIP)

The definition of *single treatment facility* is applied only in Category 3 medical gas systems. See also 3.3.110, Multiple Treatment Facility.

A.3.3.165 Single Treatment Facility. The definition of single treatment facility was established to take into consideration principally single-level installations or those of a practice that could be two-level, but are reached by open stairs within the confines of the single treatment facility. *(See Figure A.3.3.165.)*

3.3.167 Space. A portion of the health care facility designated by the health care facility's governing body that serves a specific purpose.

Instead of requiring a facility to determine how a room should be classified, the code now permits a facility to designate different spaces to a risk category. This can allow for larger rooms in which there are different categories of patient care spaces that can be protected with well-defined limitations as to what can be performed where within that room. For more on this terminology change, see the commentary following 3.3.136, Patient Care Space.

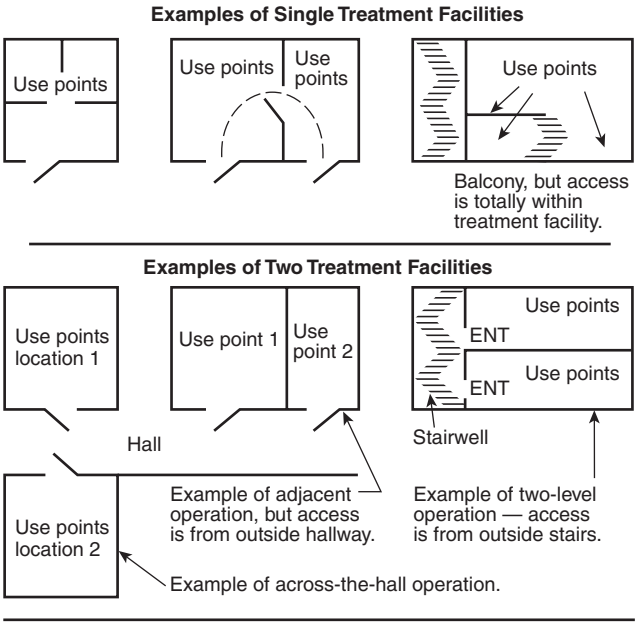


FIGURE A.3.3.165 *Examples of Treatment Facilities.*

3.3.168 Standard Cubic Feet per Minute (SCFM). Volumetric flow rate of gas in units of standard cubic feet per minute. (PIP)

Standard cubic feet per minute (SCFM) is a standard reference unit. In an actual gas flow situation, gas flow rate will be different as pressure and temperature change.

With regard to patient suction therapy and Category 1 vacuum systems, SCFM is the volume of air drawn into the vacuum system through patient drainage and aspiration equipment or the ambient room air, or both.

3.3.169 Station Inlet. An inlet point in a piped medical/surgical vacuum distribution system at which the user makes connections and disconnections. (PIP)

This term *station inlet* distinguishes between the end connector of Category 1 piped vacuum systems and the end connector of Category 1 piped gas systems.

The equivalent to a station inlet in Category 1 and Category 2 medical gases is a station outlet. Exhibit 3.12 shows two station outlets and a station inlet.

3.3.170 Station Outlet. An outlet point in a piped medical gas distribution system at which the user makes connections and disconnections. (PIP)

3.3.171 Supply Source. Those portions of the central supply system that act as a self-contained supply.

The definition for *supply source* and the subdefinitions that fall beneath 3.3.171 have been revised for the 2018 edition to clarify that supply sources are only one component of the central supply system. This improves consistency and clarity with the use of Chapter 5.

3.3.171.1 Operating Supply. The portion of the central supply system that is supplying the piping system at the time of observation. (PIP)

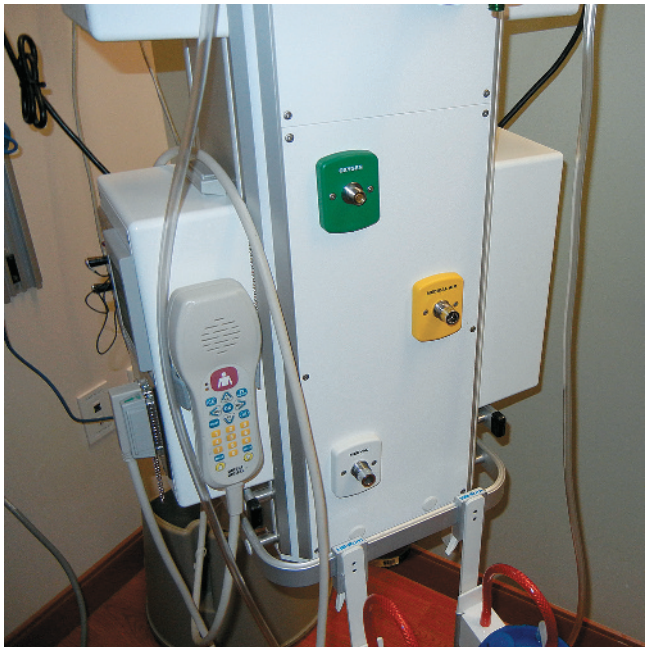


EXHIBIT 3.12

Station Outlet for Oxygen (top), Medical Air (middle), Station Inlet for Medical Vacuum (bottom).

3.3.171.2 Primary Supply. The portion of the central supply system that is the default supply for the piping system. (PIP)

3.3.171.3 Reserve Supply. Where provided, the portion of the central supply system that will supply the piping system when the primary and secondary supplies are exhausted or are not operative. (PIP)

3.3.171.4 Secondary Supply. Where provided, the portion of the central supply system that will supply the piping system when the primary supply is exhausted or is not operative. (PIP)

FAQ Is a secondary supply the same as a reserve supply?

The term *secondary supply* should not be confused with the term *reserve supply*. A secondary supply will, in the course of normal operation, be brought online once the primary supply has dropped below the amount or pressure required for normal operation. A reserve supply is used only in the event of the failure of both the primary and secondary supplies.

3.3.172* Surface-Mounted Medical Gas Rail Systems. A surface-mounted gas delivery system intended to provide ready access for two or more gases through a common delivery system to provide multiple gas station outlet locations within a single patient room or Category 1 Space. (PIP)

A surface-mounted medical gas rail system is intended to service one given patient care area without penetrating any of the room's normal wall enclosures. For example, two adjoining rooms could have rail systems connected in series from one source. The interconnection between the rooms is intended to be a section of the piping distribution system, not the rail itself.

EXHIBIT 3.13

A Surface-Mounted Medical Gas Rail System.

Where two adjoining areas in a room are separated with a partition that is not floor to ceiling, the surface-mounted medical gas rail system could be continuous within the room enclosure. Exhibit 3.13 shows a surface-mounted medical gas rail system.

A.3.3.172 Surface-Mounted Medical Gas Rail Systems. It is the intent that surface-mounted medical gas rail systems would be permitted in individual patient rooms but would not be permitted to go directly through room walls to adjacent patient rooms. However, it is the intent to permit surface-mounted medical gas rails to be used in a given Category 1 space where there can be a partition separating certain patient care functions, essentially leaving the system within the given Category 1 space. As an example, two adjacent patient rooms outside of a Category 1 space care unit would not be permitted to have a surface-mounted medical gas rail interconnect between the two rooms through the wall. However, in a nursery where there might be one or two segregated areas for isolation, a medical gas rail system supplying more than one isolation room, but within the nursery area, would be permitted to be interconnected with the nursery system.

3.3.174 Terminal. The end of a flexible hose or tubing used in a manufactured assembly where the user is intended to make connection and disconnection. (PIP)

3.3.176 Transfilling. The process of transferring a medical gas in gaseous or liquid state from one container or cylinder to another container or cylinder. (MED)

3.3.178 Use Point. A location with any number of station outlets and inlets arranged for access by a practitioner during treatment of a patient. (PIP)

3.3.179 Vaporizer. A heat exchange unit designed to convert cryogenic liquid into the gaseous state. (PIP)

3.3.180 Ventilation. The mechanical or natural movement of air. (MEC)

3.3.181 Waste Anesthetic Gas Disposal (WAGD). The process of capturing and carrying away gases vented from the patient breathing circuit during the normal operation of gas anesthesia or analgesia equipment. (PIP)

This definition and the definition for *scavenging* (3.3.159) are two terms for the same thing, but scavenging is the term applied in dental applications, and WAGD is the term in medical application. The piping systems are similar, but the connection and interface to the patient are very different.

The WAGD system has formerly been referred to as *evacuation, scavenging,* and *exhaust,* and, in Europe, it is known as an anesthetic gas scavenging system (AGSS). The 2008 edition of the CGA V-5 D.I.S.S. standard still denotes the connector as "evacuation" or "evac," proof that the old name persists. The term *WAGD*, however, is technically correct, more descriptive, and less susceptible to

misinterpretation. Scavenging and evacuation have other medical uses, though they are sometimes confused with WAGD.

For further information on WAGD, see the commentary following 5.1.3.8.

References Cited in Commentary

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3. NFPA 30, *Flammable and Combustible Liquids Code*, 2018 edition, National Fire Protection Association, Quincy, MA.
4. NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 2015 edition, National Fire Protection Association, Quincy, MA.
5. NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, 2016 edition, National Fire Protection Association, Quincy, MA.
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7. NFPA *101®*, *Life Safety Code®*, 2018 edition, National Fire Protection Association, Quincy, MA.
8. Schmidt, T. C., Dorr, V. A., and Hamilton, Jr., R. W., "Technical Memorandum UCRI-721, Chamber Fire Safety," Ocean Systems, Inc., Research and Development Laboratory, Tarrytown, NY. September 25, 1973.

4

Fundamentals

Editor's Note: *The following chapter is extracted in its entirety from Chapter 4 of the 2018 edition of NFPA 99,* Health Care Facilities Code. *Commentary is also provided to explain the code and assist the user and is not part of the code. NFPA 99 can be viewed in full at: www.nfpa.org/99.*

Chapter 4 provides valuable guidance in how to apply the code to health care facilities. Prior to 2012, occupancy chapters at the end of NFPA 99 determined which systems were required in various locations. With changes in the health care delivery system, many procedures that 15 years ago occurred only in hospitals are now being done in an office setting. Yet, the risks to the patients from such procedures have not necessarily diminished.

If the treatment or the procedure is the same, the protection level provided to both the patient and the caregiver should be at the same level, regardless of whether the procedure takes place in a hospital or an office location. However, historically the level of life safety and types of systems in use in an office setting are considerably different from those seen in a hospital. The addition of Chapter 4 to the 2012 edition of the code was an attempt to level these requirements to protect both the patient who is undergoing a procedure or treatment as well as the caregiver.

The application of NFPA 99 starts here in Chapter 4. Systems and equipment must be evaluated for the potential impact of a system failure on both the patients and the caregivers. Based on the worst-outcome scenario of a failure, a system is assigned a category. The NFPA 99 chapter on that system or equipment then describes the requirements for the assigned risk category. Note that intervention by the caregiver is not considered in this evaluation. Extensive annex notes are provided to help the user of the code understand the considerations that should be made when applying a risk category through the use of a risk assessment.

The following example helps to illustrate this approach to patient and caregiver safety: An outpatient surgery center plans to perform procedures that require use of a ventilator for the patient. The failure of the piped oxygen system to supply the ventilator during a procedure would cause major injury or death. This piped system will need to comply with the NFPA 99 requirements in Chapter 5, Gas and Vacuum Systems, for a Category 1 system. This applies even if the caregiver could provide manual ventilation.

4.1* Risk Categories. Activities, systems, or equipment shall be designed to meet Category 1 through Category 4 requirements, as detailed in this code.

A.4.1 Four levels of systems categories are defined in this code, based on the risks to patients and caregivers in the facilities. The categories are as follows:

(1) Category 1: Systems are expected to work or be available at all times to support patient needs.

(2) Category 2: Systems are expected to provide a high level of reliability; however, limited short durations of equipment downtime can be tolerated without significant impact on patient care. Category 2 systems support patient needs but are not critical for life support.
(3) Category 3: Normal building system reliabilities are expected. Such systems support patient needs, but failure of such equipment would not immediately affect patient care. Such equipment is not critical for life support.
(4) Category 4: Such systems have no impact on patient care and would not be noticeable to patients in the event of failure.

The category definitions apply to equipment operations and are not intended to consider intervention by caregivers or others. Potential examples of areas/systems and their categories of risk follow. A risk assessment should be conducted to evaluate the risk to the patients, staff, and visitors.

(1) Ambulatory surgical center, two patients with full OR services, Category 1
(2) Reconstructive surgeon's office with general anesthesia, Category 1
(3) Procedural sedation site for outpatient services, Category 2
(4) Cooling Towers in Houston, TX, Category 2
(5) Cooling Towers in Seattle, WA, Category 3
(6) Dental office, no general anesthesia, Category 3
(7) Typical doctor's office/exam room, Category 4
(8) Lawn sprinkler system, Category 4

Systems that are critical for life support of a patient must be highly reliable or have a backup system. Less critical systems, such as automated delivery systems, do not require redundancy because failure of the system would have minimum impact on patient care or caregivers.

The committee's initial review of this topic of risk involved a very complex matrix addressing reliability, levels of sedation, and complexity of the procedure or treatment. The following four-category model was determined to be the best way to address the major issues in protecting patients and caregivers:

1. Category 1 systems are available at all times for life-support systems.
2. Category 2 systems are highly reliable systems with system failure impact limited to minor injury to the patient or staff.
3. Category 3 system failures may cause discomfort to the patient or caregiver.
4. Category 4 systems have no impact on the patient or caregivers.

Specific requirements for different categories are addressed to some degree in Chapters 5 through 7. Chapters 8 through 11 do not have levels for systems or equipment identified. Chapter 12 has two levels of risk identified based on the level of operation during an emergency. Some technical committees addressed risk in different ways than others, since the basis for the risk assessment is more suitable to systems at this point rather than to equipment or processes (such as emergency and security management). Chapter 16, Features of Fire Protection, addresses fire protection, storage, and special hazards found in health care facilities.

A.4.1.1 and A.4.1.2 list examples of the definitions for major injury and minor injury to give the code user some guidance in determining the category for a system.

4.1.1* **Category 1.** Activities, systems, or equipment whose failure is likely to cause major injury or death of patients, staff, or visitors shall be designed to meet Category 1 requirements, as detailed in this code.

A.4.1.1 Major injury can include the following:

(1) Any amputation
(2) Loss of the sight of an eye (whether temporary or permanent)

(3) Chemical or hot metal burn to the eye or any penetrating injury to the eye
(4) Any injury that results in electric shock and electric burns leading to unconsciousness and that requires resuscitation or admittance to a hospital for 24 hours or more
(5) Any other injury leading to hypothermia, heat induced illness, or unconsciousness requiring resuscitation or admittance to a hospital for 24 hours or more
(6) Loss of consciousness caused by asphyxia or lack of oxygen or exposure to a biological agent or harmful substance
(7) Absorption of any substance by inhalation, skin, or ingestion causing loss of consciousness or acute illness requiring medical treatment
(8) Acute illness requiring medical treatment where there is reason to believe the exposure was to biological agents, its toxins, or infected materials

Failure of a Category 1 system has very serious consequences. Major injury or death can be caused by the failure of any of the following:

- Emergency power for the operating rooms
- Medical gas system in the ICU
- Ventilator-assisted procedure in a medical office operating suite
- Cardiac catheterization imaging equipment

4.1.2* Category 2. Activities, systems, or equipment whose failure is likely to cause minor injury of patients, staff, or visitors shall be designed to meet Category 2 requirements, as detailed in this code.

A.4.1.2 A minor injury means *not serious* or *involving risk of life*.

Failure of a Category 2 system can cause minor injury. Examples of such systems include those that would support the following:

- Task or procedure lighting in patient rooms
- Procedures that can be completed without medical gases with a potential for minor injury

4.1.3 Category 3. Activities, systems, or equipment whose failure is not likely to cause injury to patients, staff, or visitors, but can cause discomfort, shall be designed to meet Category 3 requirements, as detailed in this code.

If the following Category 3 systems were not functioning, the patient or caregiver might experience minor discomfort:

- Heating system in the southern United States
- Humidity control in nonoperating areas
- Dental drill
- Motorized bed adjustments
- Vacuum in a dental office (no oral surgery)

4.1.4 Category 4. Activities, systems, or equipment whose failure would have no impact on patient care shall be designed to meet Category 4 requirements, as detailed in this code.

Category 4 systems do not affect the patient or caregivers. Category 4 systems include the following:

- Gray water lawn sprinkler systems
- Seasonal lighting systems
- Public address systems

- Pneumatic tube systems
- Vacuum system in the research portion of a facility

4.2* Risk Assessment.

A.4.2 Risk assessment should follow procedures such as those outlined in ISO/IEC 31010, *Risk Management — Risk Assessment Techniques*; NFPA 551; SEMI S10-0307E, *Safety Guideline for Risk Assessment and Risk Evaluation Process*; or other formal process. The results of the assessment procedure should be documented and records retained. Figure A.4.2 is a sample risk assessment model that can be used to evaluate the categories.

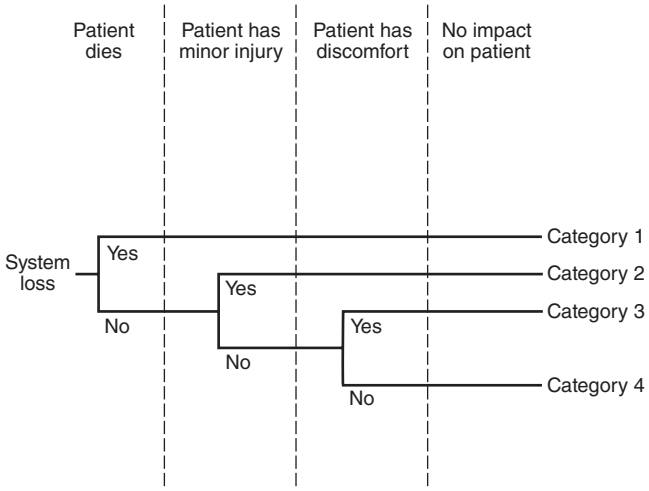


FIGURE A.4.2 *Examples of Treatment Facilities.*

There are many different risk assessment techniques and procedures available. These can include fault tree analyses, risk matrices (see Exhibit 4.1), event trees (see Exhibit 4.2), and several other tools. Different types of risk assessments can include qualitative, semi-quantitative, and quantitative methods. These can range from very complex analyses to more simple thought processes such as that shown in Figure A.4.2. This chapter does not specify the type of assessment that must be done, only that it be a defined procedure and that it be documented.

EXHIBIT 4.1

Example of a Simplified Risk Matrix.

Frequency of occurrence				
Frequent	Med	High	High	High
Probable	Med	Med	High	High
Occasional	Low	Med	Med	High
Remote	Low	Low	Med	High
Improbable	Low	Low	Low	Med
	No Effect	Discomfort	Minor Injury	Death

Severity of occurrence

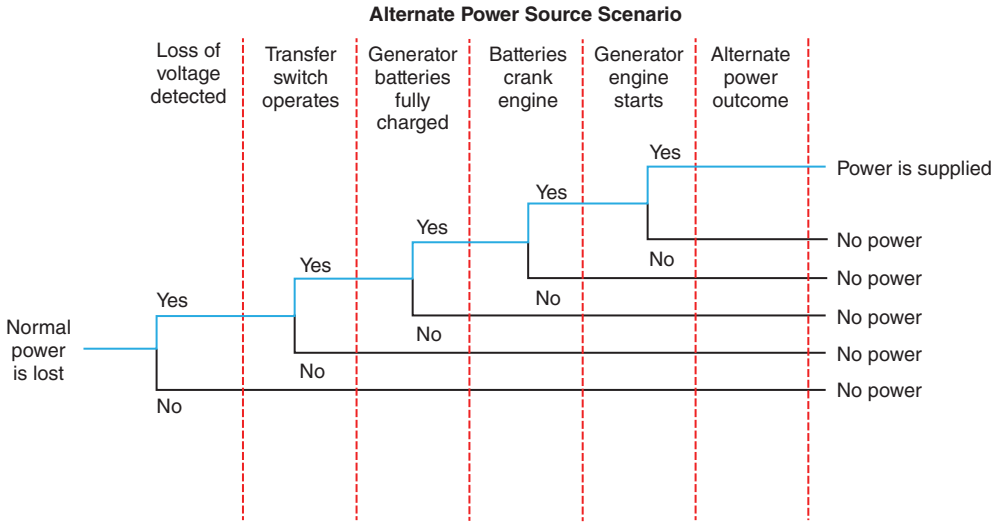


EXHIBIT 4.2

Example of a Simplified Event Tree Analysis.

Important considerations that might be included in a risk assessment and the associated documentation include but are certainly not limited to the following:

- Who participated or provided insight in the development of the risk assessment?
- What level of anesthesia/sedation is being provided in the space(s) being evaluated or the space(s) that the system in question serves?
- What procedure will be performed in the space(s) being evaluated or the space(s) that the system in question serves?
- Will patients be rendered incapable of self-preservation?
- Are patients independently able to maintain ventilatory function?
- Is assistance in maintaining a patient airway required?
- Will cardiovascular function of the patient be impaired?

N **4.2.1** The health care facility's governing body shall establish the processes and operations that are planned for the health care facility.

N **4.2.1.1** 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.

Paragraphs 4.2.1 and 4.2.1.1 were revised to eliminate the possibility of extreme interpretations about risk categories — whether from the facility or from the authority having jurisdiction. An appropriate risk assessment must include the establishment of the processes and operations that are planned for a facility, and no entity should have a better understanding of that than the health care facility's governing body. With that information, it is the responsibility of that governing body to then determine risk categories. The term *governing body* has been revised to be *health care facility's governing body* here and elsewhere in the code in order to clarify the intent.

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

N **A.4.2.2** Classification of risk categories requires a collaborative effort between the health care facility's governing body and the authority having jurisdiction.

N **4.2.2.1** Where required by the authority having jurisdiction, the risk assessment shall be provided to the authority having jurisdiction for review based on the character of the processes and operations conducted in the health care facility.

All of 4.2.2 is new to the 2018 edition and is meant to clarify the requirement and give direction as to what is expected. The facility always has the responsibility for determining the risk categories, and the authority having jurisdiction always has the oversight to require that risk assessments be submitted for review. While code language cannot force the two parties to collaborate to achieve the right end, the requirement and associated annex language can certainly improve the chances for a successful risk assessment review and improve both parties' understanding of the facility's operations.

4.2.3 A documented risk assessment shall not be required where Category 1 is selected.

This provision, first incorporated in the 2015 edition of the code, allows a facility to bypass conducting a risk assessment where a Category 1 system is installed. The reasoning is that if the highest level of safety prescribed by this code is provided in a facility, then there is no need to conduct the risk assessment there. It has been further revised for the 2018 edition to clarify that this is the case when a Category 1 risk is selected voluntarily during the planning and design stages. Even where this provision is applied, however, it would be best practice for a facility to conduct an assessment for a better understanding of the risks involved in different spaces.

4.3 Application.

The Category definitions in Chapter 4 shall apply to Chapters 5 through 11, 14, and 15, except as modified in those chapters.

While this provision requires an evaluation to determine risk categories for items in Chapters 5 through 11, 14, and 15, not all chapters have different levels of service or equipment identified. There is only one set of criteria in Chapter 10 because electrical equipment does not have a Category 1, 2, or 3. Therefore, all electrical equipment must comply with the requirements as noted for new and existing in Chapter 10. It is not the intent of this section to require risk assessments and the determination of risk categories unless those chapters utilize the risk-based approach.

4.4 Materials.

4.4.1* Noncombustible Material.

A.4.4.1 The provisions of 4.4.1 do not require inherently noncombustible materials to be tested in order to be classified as noncombustible materials.

4.4.1.1 A material that complies with any of the following shall be considered a noncombustible material:

(1) A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat
(2) A material that is reported as passing ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*
(3) A material that is reported as complying with the pass/fail criteria of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750 Degrees C*

4.4.1.2 Where the term *limited-combustible* is used in this code, it shall also include the term *noncombustible*. [***101***:4.6.13]

Δ **4.4.2* Limited-Combustible Material.** A material shall be considered a limited-combustible material where one of the following is met:

(1) The conditions of 4.4.2.1 and 4.4.2.2, and the conditions of either 4.4.2.3 or 4.4.2.4, shall be met.
(2) The conditions of 4.4.2.6 shall be met.

Δ **A.4.4.2** Materials subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition are considered combustible. (*See NFPA 259 and NFPA 220.*) [***101*:**A.4.6.14]

4.4.2.1 The material shall not comply with the requirements for noncombustible material in accordance with 4.4.1.

4.4.2.2 The material, in the form in which it is used, shall exhibit a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) where tested in accordance with NFPA 259.

4.4.2.3 The material shall have the structural base of a noncombustible material with a surfacing not exceeding a thickness of ⅛ in. (3.2 mm) where the surfacing exhibits a flame spread index not greater than 50 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*.

4.4.2.4 The material shall be composed of materials that, in the form and thickness used, exhibit neither a flame spread index greater than 25 nor evidence of continued progressive combustion when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, and shall be of such composition that all surfaces that would be exposed by cutting through the material on any plane would exhibit neither a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E84 or ANSI/UL 723.

N **4.4.2.5** Materials shall be considered limited-combustible materials where tested in accordance with ASTM E2965, *Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter*, at an incident heat flux of 75 kW/m^2 for a 20-minute exposure and both of the following conditions are met:

(1) The peak heat release rate shall not exceed 150 kW/m^2 for longer than 10 seconds.
(2) The total heat released shall not exceed 8 MJ/m^2.

4.4.2.6 Where the term *limited-combustible* is used in this *Code*, it shall also include the term *noncombustible*. [***101***:4.6.14]

5

Gas and Vacuum Systems

Editor's Note: *The following chapter is extracted in its entirety from Chapter 5 of the 2018 edition of NFPA 99,* Health Care Facilities Code. *Commentary is also provided to explain the code and assist the user and is not part of the code. NFPA 99 can be viewed in full at: www.nfpa.org/99.*

Chapter 5 covers the equipment, installation, performance, testing, and maintenance of medical gas, medical vacuum systems (MGVS), waste anesthetic gas disposal (WAGD), and medical support gases (MSG). The requirements of this chapter assign risk categories for MGVS and MSG based on the building system categories and by using risk assessments. The rules for the risk assessment are defined in Chapter 4, Fundamentals. Once the risk category for the MGVS and MSG has been determined, the user can refer to the Chapter 5 section for that category. Note that for the 2018 edition, dental gas and vacuum requirements were moved to a separate chapter, Chapter 15. Chapter 5 should be used only for medical applications for piped gases and vacuum systems.

History of Piped Medical Gas and Vacuum Systems

The subject of piped gas systems and their accompanying hazards was first brought before what was then the NFPA Committee on Gases in 1932. The concerns raised then remain relevant today. These include the ability of piped oxygen and nitrous oxide to violently exacerbate fires; patient safety concerns that arise from pressurized gas, simple debris in the pipe, and restrictions to flow; the significance of vacuum in medical treatments; and a host of other challenges arising from the increasing complexity and variety of applications for gases in medicine.

The widespread presence and inherent reliability of piped gas and vacuum systems in health care facilities has crowded out alternatives, such as portable medical gas cylinders and portable suction machines placed in each patient care room. The medical facilities of today are less able to do without these systems or to deal with their sudden loss than were health care facilities of 1932. This elevates concerns over system reliability, and so the code has become more complex and prescriptive over the years.

Chapter Organization

Chapter 5 is organized by Category 1 requirements (Section 5.1), Category 2 requirements (Section 5.2), and Category 3 requirements (Section 5.3). Similar requirements are numbered in parallel. For instance, requirements for labeling are numbered 5.X.11; so these labeling criteria can be found under 5.1.11 for Category 1, 5.2.11 for Category 2, and 5.3.11 for Category 3. The category can be determined by using the risk category procedures in Chapter 4. Commentary Table 5.1 provides general information

on the location of topics addressed for Category 1, Category 2, and Category 3 systems in NFPA 99. The information in this table can be used to focus the search for specific provisions for Category 1 systems, Category 2 systems, and Category 3 systems.

COMMENTARY TABLE 5.1 *Quick Locator for Category 1, Category 2, and Category 3 Systems Requirements*

Topic	*Category 1 Systems*	*Category 2 Systems*	*Category 3 Systems*
Applicability	5.1.1	5.2.1	5.3.1
Nature of Hazards of Gas and Vacuum Systems	5.1.2	5.2.2	5.3.2
Sources	5.1.3	5.2.3	5.3.3
Valves	5.1.4	5.2.4	5.3.4
Station Outlets/Inlets	5.1.5	5.2.5	5.3.5
Manufactured Assemblies	5.1.6	5.2.6	5.3.6
Surface-Mounted Medical Gas Rails (MGR)	5.1.7	5.2.7	5.3.7
Pressure and Vacuum Indicators	5.1.8	5.2.8	5.3.8
Warning Systems	5.1.9	5.2.9	5.3.9
Distribution	5.1.10	5.2.10	5.3.10
Labeling, Identification, and Operating Pressure	5.1.11	5.2.11	5.3.11
Performance Criteria and Testing (Gases, Medical–Surgical Vacuum, and WAGD)	5.1.12	5.2.12	5.3.12
Support Gases	5.1.13	5.2.13	5.3.13
Operation and Management	5.1.14	5.2.14	5.3.14
Dental requirements	See Chapter 15		

The requirements for an MGVS are categorized primarily on the basis of the level of risk to patients from a failure of the supply system. A Category 1 MGVS is intended to be the most reliable and redundant of the three MGVS risk categories, because patients being served by this system would be at the greatest risk of a major injury or death if the system fails. A Category 2 MGVS meets the same criteria as the Category 1 MGVS with a few exceptions — such as medical air supply systems and medical–surgical vacuum systems, which are permitted to be simplex, and warning systems, which are permitted to be a single alarm. (To find all exceptions, see Section 5.2, Category 2 Piped Gas and Vacuum Systems.) The exceptions in Section 5.2 for Category 2 systems are permitted because patients depending on these systems are *not* at risk of major injury or death in the event of MGVS failure.

Category 3 has a specific derivation and history, which has made it particularly problematic through the last editions of the code and resulted in much rewriting and reorganization. Initially appearing as "Type 2 systems" in the earlier NFPA 56F, then moving to become "Level 3" in the 1996 version, the requirements made sense when applied to equipment and practices used by the dentist practicing alone or with one or two others. While the application of the standard was controlled by levels and the occupancy chapters (Chapters 11–20 in the 2005 edition of NFPA 99), some users would attempt to apply these rules in a medical setting. Naturally, the fit was poor and the confusion great. When "levels" became "categories," the occupancy chapters disappeared, and the risk-based approach to defining category via the fundamentals chapter debuted. The changes made the dilemma even more unmanageable. In an attempt to reconcile the two applications, Category 3 requirements underwent major overhauls in the 2002, 2005, 2012, and 2015 editions, but none of these rewrites solved the dilemmas for either the medical or the dental user. In the 2018 edition, dentistry has acquired its own chapter (Chapter 15), and medical and dental requirements are completely separated.

At the moment, Category 3 MGVS has the same requirements as a Category 2 system. This can be expected to change as users have the opportunity to consider the MGVS needs of low acuity medical settings. A Category 3 MGVS is intended for use by patients for whom the interruption of the supply of gas would not be life threatening and would not cause major or minor injuries but may cause patient discomfort.

The Technical Committee on Medical Gases found no need for a Category 4 system, and none has been provided for in the chapter. The reason there is no Category 4 MGVS is simply that in all situations where MGVS are used for patient care the failure would have some impact on the patient.

Figures in the annexes are drawn not for engineering precision but, rather, are intended to broadly depict the installation components to provide broad comprehension and guidance. The location of the figures in Annex A is intentional; they are not and never have been required parts of the code but are only a means of illustrating the text. There is nothing in NFPA 99 requiring that an MGVS be installed. However, if an MGVS is installed within a health care facility then Chapter 4 will help determine the category of systems, and Chapter 5 can be referenced for the specific details.

5.1 Category 1 Piped Gas and Vacuum Systems.

5.1.1* Applicability.

A.5.1.1 Section 5.1 covers requirements for Category 1 piped gas and vacuum systems; Section 5.2 covers Category 2 piped gas and vacuum systems; and Section 5.3 covers Category 3 piped gas and vacuum systems. Laboratory systems are no longer covered by Chapter 5 (2002 edition).

5.1.1.1 These requirements shall apply to health care facilities that require Category 1 systems as referenced in Chapter 4.

5.1.1.2 Category 1 piped gas or piped vacuum system requirements shall be applied where any of the following criteria is met:

(1) General anesthesia or deep sedation is performed as defined in 3.3.65.1 and 3.3.65.2.
(2) The loss of the piped gas or piped vacuum systems is likely to cause major injury or death of patients, staff, or visitors.
(3) The facility piped gas or piped vacuum systems are intended for Category 1 patient care space per 3.3.135.1.

In addition to the risk assessment approach, 5.1.1.2 requires further specifics as to when a Category 1 system must be installed. Its parallel requirements 5.2.1.2 and 5.3.1.2, for Category 2 and 3 respectively, will likely play a larger role than this one in the application of the code. These paragraphs were added to guard against a risk assessment being used to lower the level of safety. For instance, as a result of a risk assessment a system might rank as a Category 2 risk, but the extra provisions in these new paragraphs could cause it to require a Category 1 system, regardless. See 5.2.1.2 and the associated annex material for more discussion on this.

5.1.1.3* 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.

The terms *medical gas* or *medical support gas* are used throughout most of the code. The sections where specific gases are identified are related to source equipment, labeling, storage, alarm tables, gas purity tables, and other gas-specific parts of the code such as 5.1.3.6, which is specific to medical air.

A.5.1.1.3 These requirements do not restrict the distribution of other inert gases through piping systems.

FAQ Are flammable gases covered by this chapter?

Natural gas, hydrogen, and acetylene are flammable gases, so they are not included under the requirements for piped nonflammable medical gases for Category 1, 2, or 3. Typically, requirements for those gases are found in NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* and in laboratory-specific requirements.

5.1.1.4 An existing system that is not in strict compliance with the provisions of this code shall be permitted to be continued in use as long as the authority having jurisdiction has determined that such use does not constitute a distinct hazard to life.

A risk analysis conducted on the MGVS with reference to the specific requirement in question can determine whether the system or components of the system are a distinct hazard to the life of patients, caregivers, or visitors.

5.1.1.5 The following sections of this chapter shall apply to the operation, management, and maintenance of Category 1 medical gas and vacuum systems in both new and existing facilities:

(1) 5.1.2
(2) 5.1.3.1
(3) 5.1.3.2
(4) 5.1.3.3.4
(5) 5.1.3.6.2
(6) 5.1.3.6.3.10(A)(2)
(7) 5.1.3.7.6(A)(2)
(8) 5.1.3.8.4.3(A)(2)
(9) 5.1.14

As stated in Section 1.3 of this code, NFPA 99 is intended to largely apply to new construction or altered, renovated, or modernized portions of facilities. The nine paragraphs listed are specific exceptions and are intended to apply to both new and existing health care facilities. A quick reading of them will show why this is true, as they all deal with ongoing operations.

Other exceptions do exist: (1) The general rule may be modified by individual chapters, and (2) the general rule never applies where systems not in strict compliance pose a distinct hazard to life. It is the role of the authority having jurisdiction (sometimes the owner in this case) to evaluate the new provisions of the code and determine whether this is true in their circumstances.

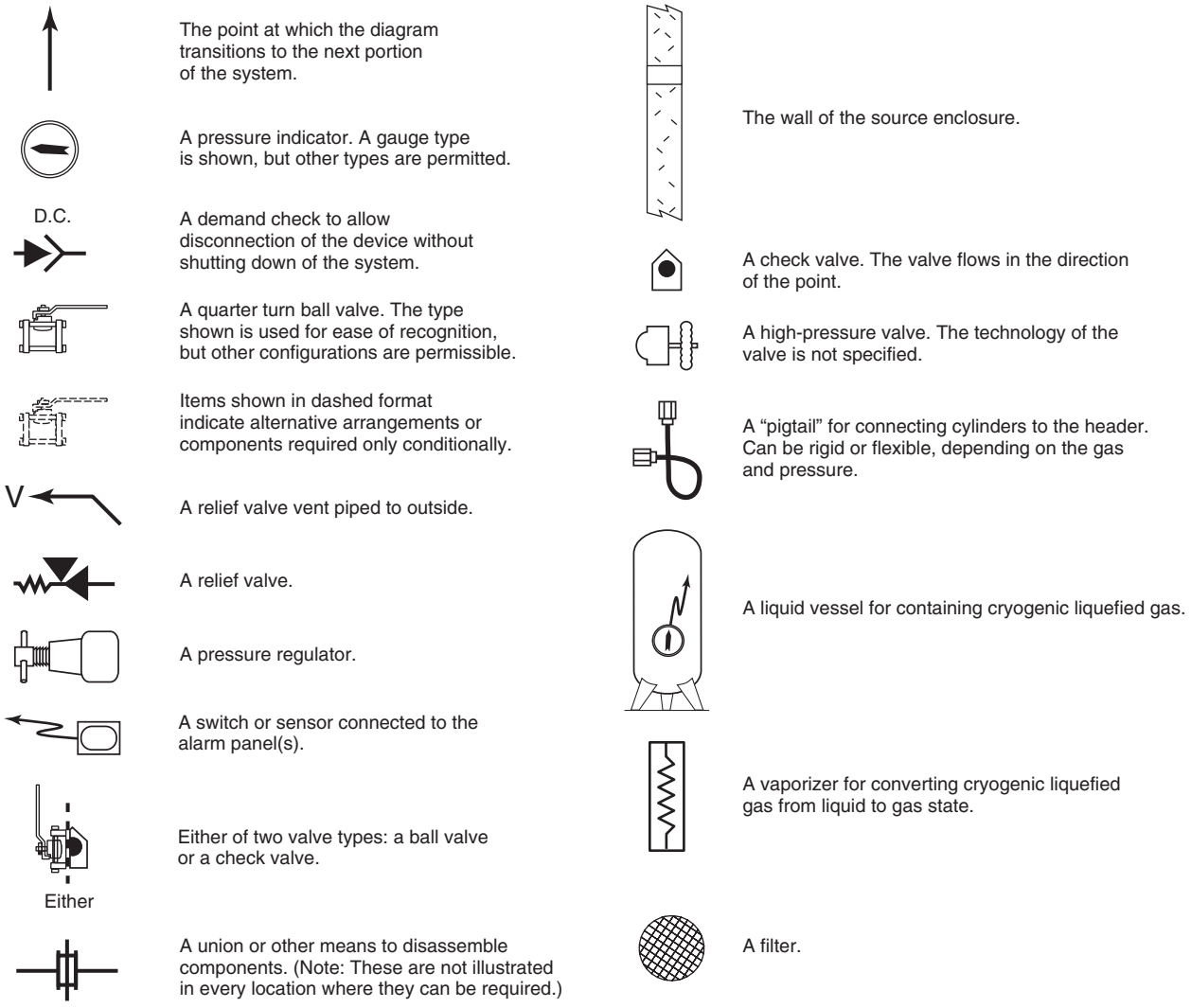
5.1.2 Nature of Hazards of Gas and Vacuum Systems. Potential fire and explosion hazards associated with positive pressure gas central piping systems and medical–surgical vacuum systems shall be considered in the design, installation, testing, operation, and maintenance of these systems.

The hazards associated with MGVS are the same whether dealing with new or existing construction. In dealing with medical gases, standards seem to be successfully mitigating construction-related hazards, and now most of the reported MGVS problems often relate to the operation and maintenance of the systems. As a result, NFPA 99 now provides more extensive guidance on maintenance (see 5.1.14).

See Chapter 11, Gas Equipment, for requirements for freestanding cylinders not associated with piped gas systems, including their storage and transfilling.

5.1.3* Category 1 Sources.

A.5.1.3 See Figure A.5.1.3. Category 1 source drawings in this annex are representational, demonstrating a possible arrangement of components required by the text. The diagrams are not intended to imply method, materials of construction, or more than one of many possible and equally compliant arrangements. Alternative arrangements are permitted if they meet the intent of the text. Listed paragraphs might not be the only paragraphs that apply.



△ ***FIGURE A.5.1.3*** *Legend for Typical Category 1 Source Drawings.*

5.1.3.1 Central Supply System Identification and Labeling.

All of 5.1.3.1 is identified as applying to both new and existing facilities by 5.1.1.5. Provisions for central supplies to be appropriately identified and labeled ensure that the contents of containers and cylinders are easily identifiable, and they are also required to be provided with gas-specific outlet connections that further prevent the use of the wrong gas for an application. The locations of the central supply are required to be labeled so as to ensure that staff are aware of the contents of the room and take appropriate precautions in those areas.

5.1.3.1.1* Cylinders, containers, and tanks shall be designed, fabricated, tested, and marked (stamped) in accordance with regulations of DOT, Transport Canada (TC) *Transportation of Dangerous Goods Regulations*, or the ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," Section VIII. [**55:**7.1.5.1]

A.5.1.3.1.1 Regulations of the U.S. Department of Transportation (formerly U.S. Interstate Commerce Commission) outline specifications for transportation of explosives and dangerous articles (49 CFR 171–190). In Canada, the regulations of the Canadian Transport Commission, Union Station, Ottawa, Ontario, apply.

The U.S. Department of Transportation (DOT) Regulations, 49 CFR 171–190, "Specifications for Transportation of Explosives and Dangerous Articles," is the standard for the manufacture and requalification of compressed gas cylinders. This standard provides for reasonably safe and economical cylinders and is thus referenced to avoid redundancy. Cylinders complying with DOT regulations are also considered safe for the storage of gases in health care facilities.

5.1.3.1.2* Cylinder contents shall be identified by attached labels or stencils naming the contents in accordance with the mandatory requirements of CGA C-7, *Guide to Classification and Labeling of Compressed Gases*.

The exchanging of cylinders on a manifold is the most common interface that facility staff have with the medical gas pipelines. It was lack of attention — to the labeling and verifying that the correct contents were in a labeled cylinder — that caused a multiple-death incident and prompted the U.S. Food and Drug Administration (FDA) to issue its only medical gas–related alert in recent memory.

Although cylinders are mechanically "keyed" for the gas contained therein, and the manifolds are fitted with the matching "key" in the form of the gas-specific connector (in the United States, this is defined in CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*), it is always possible for someone unaware of the system to use a wrench to defeat these measures. In addition, mislabeled and miskeyed gases are known to have been delivered. Although it is not practical in most facilities to test the contents of each gas cylinder, it is easy to confirm that the labels (see Exhibit 5.1) are in place, are legible, and match the gas-specific connector. A simple go/no-go tester can be made of a known Compressed Gas Association (CGA) connector from an old cylinder lead — or from a lead purchased from a gas equipment supplier. Cylinders that are missing their labels, or that have cylinder connections not matching their labels, should be assumed to contain something other than the gas they are expected to contain. Such cylinders should not be used and should be quarantined and returned to the supplier immediately.

A.5.1.3.1.2 CGA documents contain both mandatory and nonmandatory language. Enforceable language uses the word "shall"; nonmandatory language uses the word "should." This section indicates that NFPA 99 is making reference only to the mandatory requirements in the CGA document.

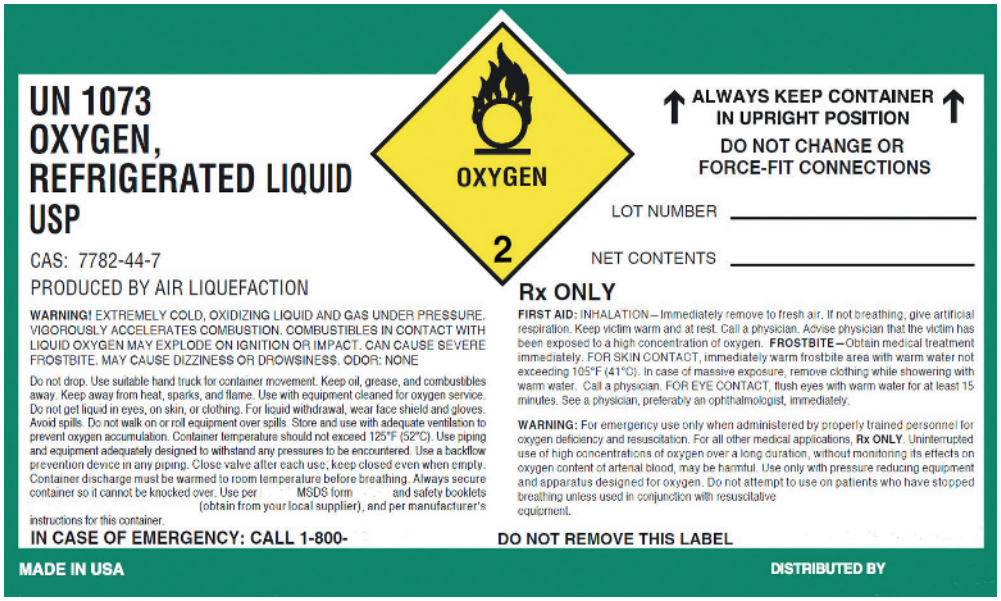


EXHIBIT 5.1

Liquid Container Identification. (Courtesy of Praxair)

In all instances where this code references a CGA document, the phrase "mandatory requirements of" now appears in front of the document title. This was done to be in accordance with the *Manual of Style for NFPA Technical Committee Documents,* which does not permit mandatory references to nonmandatory documents or requirements. Paragraph A.5.1.3.1.2 clarifies how this reference to the mandatory requirements is intended to be applied.

5.1.3.1.3 Liquid containers shall have additional product identification visible from all directions with a minimum of 51 mm (2 in.) high letters such as a 360-degree wraparound tape for medical liquid containers.

Δ **5.1.3.1.4** Cryogenic liquid containers shall be provided with gas-specific outlet connections in accordance with the mandatory requirements of CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*, or CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

5.1.3.1.5 Cylinder and cryogenic liquid container outlet connections shall be affixed in such a manner as to be integral to the valve(s), unremovable with ordinary tools, or so designed as to render the attachment point unusable when removed.

To reduce the number of incidents caused by mix-ups and contamination of medical gases, manufacturers have gone to great lengths to refit containers that had easily removable valves and outlet connections. Under this requirement and other regulations for manufacturers, any health care facility in the United States that buys its gases from a medical gas supplier should find the outlet connections "unremovable with ordinary tools."

5.1.3.1.6 The contents of cylinders and cryogenic liquid containers shall be verified prior to use.

One way to verify the contents of cylinders or cryogenic liquid containers is to receive a Certificate of Analysis (COA) from the medical gas supplier. Another way is to test the gas content on site with a gas-specific analyzer.

5.1.3.1.7 Labels shall not be defaced, altered, or removed, and connecting fittings shall not be modified.

5.1.3.1.8 Locations containing positive pressure gases other than oxygen and medical air shall have their door(s) labeled as follows:

Positive Pressure Gases
NO Smoking or Open Flame
Room May Have Insufficient Oxygen
Open Door and Allow Room to Ventilate Before Entering

FAQ Are leaks very common with source equipment?

As with any gas source, large-scale discharges from an MGVS are very rare, but little leaks are almost universal. Although the greatest hazard arises with a massive discharge of gas (e.g., after a relief valve failure) — which, as mentioned, is extremely rare — the more commonplace problems include the cylinder lead that was not tightened properly, the connector that was nicked and does not quite seal, the pigtail that has a small break, or the connector that has lost its sealing O-ring.

Three hazards exist whereby gases might accumulate in a closed space. One is fire, since oxygen and nitrous oxide are both strong oxidizers; a second is simple displacement of breathable air, such as from a decrease in oxygen content in the air to below 19.5 percent from a nitrogen leak); and the third is the presence of nonflammable gases that can themselves be hazardous, such as cryogenic gases and nitrous oxide and carbon dioxide.

The requirements for ventilation for manifold rooms (found in 5.1.3.3.3 and in Chapter 9) and the confined space regulations of OSHA 29 CFR 1910.146, "Permit-Required Confined Spaces," both have their origins in the simple reality that the majority of systems will have leaks. Signage should clearly state that a hazard exists because gas can build up.

5.1.3.1.9 Locations containing central supply systems or cylinders containing only oxygen or medical air shall have their door(s) labeled as follows:

Medical Gases
NO Smoking or Open Flame

See Checklist 5.1 for a sample checklist that can be used to verify that the requirements of 5.1.3.1 have been met. An interactive PDF version of this checklist is also available as an "eForm" in the Purchase Products & Training tab at www.nfpa.org/99.

5.1.3.2 Central Supply System Operations.

The requirements of 5.1.3.2 address the safe use and storage of cylinders and containers that make up the central supply system and that need to be continually observed in the day-to-day operations of a facility to maintain safety. For this reason, all of 5.1.3.2 is identified as applying to both new and existing facilities in 5.1.1.5.

5.1.3.2.1 The use of adapters or conversion fittings to adapt one gas-specific fitting to another shall be prohibited.

The fittings prohibited by 5.1.3.2.1, often called "cheater" fittings, present a number of patient risks, including the mix-up of gases (cross-connections) or the contamination or overpressurization of

Checklist

Checklist 5.1 Central Supply Location Identification and Labeling (New and Existing)

System: _____

Location: _____

Y = Satisfactory **N** = Unsatisfactory (explain below) **N/A** = Not applicable

Date _____ Inspector _____

	Y	*N*	*N/A*	*Comments*
Cylinders, containers, and tanks are designed, fabricated, tested, and marked (stamped) in accordance with regulations of DOT, Transport Canada (TC) *Transportation of Dangerous Goods Regulations*, or the ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," Section VIII.	☐	☐	☐	
Cylinder contents are identified by attached labels or stencils naming the contents in accordance with the mandatory requirements of CGA C-7, *Guide to the Classification and Labeling of Compressed Gases.*	☐	☐	☐	
Liquid containers have additional product identification visible from all directions with a minimum of 51 mm (2 in.) high letters such as a 360-degree wraparound tape for medical liquid containers.	☐	☐	☐	
Cryogenic liquid containers are provided with gas-specific outlet connections in accordance with the mandatory requirements of CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*, or CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections.*	☐	☐	☐	
Cylinder and cryogenic liquid container outlet connections are affixed in such a manner as to be integral to the valve(s), unremovable with ordinary tools, or so designed as to render the attachment point unusable when removed.	☐	☐	☐	
The contents of cylinders and cryogenic liquid containers are verified prior to use.	☐	☐	☐	
Labels are not defaced, altered, or removed, and connecting fittings are not modified.	☐	☐	☐	
Locations containing positive pressure gases other than oxygen and medical air have their door(s) labeled as follows: **Positive Pressure Gases** **NO Smoking or Open Flame** **Room May Have Insufficient Oxygen** **Open Door and Allow Room to Ventilate Before Entering**	☐	☐	☐	
Locations containing central supply systems or cylinders containing only oxygen or medical air have their door(s) labeled as follows: **Medical Gases** **NO Smoking or Open Flame**	☐	☐	☐	

ancillary equipment that could result if, for example, a nitrogen line and medical air line using a conversion fitting are mixed up.

5.1.3.2.2 Cylinders and containers shall be handled in strict accordance with 11.6.2.

5.1.3.2.3 Only gas cylinders, reusable shipping containers, and their accessories shall be permitted to be stored in rooms containing central supply systems or gas cylinders.

Exhibit 5.2 shows medical gas cylinders stored in the manner described in 5.1.3.2.3.

EXHIBIT 5.2

Medical Gas Cylinders in a Room Without Other Unrelated Items.

5.1.3.2.4 No flammable materials, cylinders containing flammable gases, or containers containing flammable liquids shall be stored in rooms with gas cylinders.

5.1.3.2.5 If cylinders are wrapped when received, the wrappers shall be removed prior to storage.

Paragraph 5.1.3.2.5 is intended to prohibit wrappers that will either significantly add to the quantities of combustible material in the room and/or cover the cylinder labels so that the contents of the cylinder might not be readily apparent. Examples of this might be cardboard or shrink-wrap. This is not intended to apply to the plastic mesh material that is often on cylinders when delivered by suppliers. The mesh material is meant to protect the cylinders and their labels while they are being transported and should not be considered a "wrapper" as this section is referencing.

See Exhibit 5.3 for an example of a carbon dioxide cylinder protected with a plastic mesh. While mesh is normally open enough to not overly obscure the label, consideration should be given to the obscuration of the cylinder labeling and how readily someone might be able to confirm the contents.

5.1.3.2.6 Cylinders without correct markings or whose markings and gas-specific fittings do not match shall not be used.

See the commentary following 5.1.3.1.2.

EXHIBIT 5.3

Cylinder with Plastic Mesh Protective Material. (Courtesy of Apex Medical Gas Systems)

5.1.3.2.7 Cryogenic liquid storage units intended to supply gas to the facility shall not be used to transfill other liquid storage vessels.

FAQ What are the hazards of transfilling liquid oxygen?

There have been several incidents of property damage and personal injury associated with the improper transfilling of liquid oxygen (LOX) from the hospital primary bulk oxygen supply. Transfilling is a drug manufacturing step subject to U.S. Food and Drug Administration registration and inspection and subject to full compliance with regulatory-mandated current Good Manufacturing Practices (cGMP) found in 21 CFR Parts 210 and 211. The transfilling of LOX from the health care facility's bulk vessels into any other type of container can result in commingling of the bulk LOX with residues in the other vessel, thereby destroying the USP compliance and certification of the bulk LOX remaining in the vessel. The health care facility's central piping system from the bulk LOX is directly connected to the facility's patients. Any such product commingling in the bulk LOX system requires immediate requalification, including product testing to re-establish conformance to cGMP. Failure to do so can create an adulterated and misbranded drug.

5.1.3.2.8 Care shall be exercised when handling cylinders that have been exposed to freezing temperatures or containers that contain cryogenic liquids to prevent injury to the skin.

Cryogens are extremely cold and can cause instant, severe frostbite. Direct contact with cryogenic liquids, or with uninsulated cryogenic pipes or equipment, can cause freeze burns and tissue damage.

5.1.3.2.9 Cylinders containing compressed gases and containers for volatile liquids shall be kept away from radiators, steam piping, and like sources of heat.

5.1.3.2.10 When cylinder valve protection caps are supplied, they shall be secured tightly in place unless the cylinder is connected for use.

If a cylinder that does not have a cylinder valve protection cap as referenced by 5.1.3.2.10 falls over, the cylinder valve could snap off. Depending on the cylinder size, the quantity of gas within the cylinder, and the orifice size at the break, the resulting expulsion of gas could propel the cylinder rapidly and/or violently about.

5.1.3.2.11 Containers shall not be stored in a tightly closed space.

See the commentary following 5.1.3.1.8. Cylinders should always be kept in ventilated spaces so any gas that leaks can disperse safely.

5.1.3.2.12 Cylinders in use and in storage shall be prevented from reaching temperatures in excess of 52°C (125°F).

The maximum temperature of 52°C (125°F) matches the CGA recommendations that are applied to several other sections in the chapter. The temperature at which a full cylinder might approach the "pop off" pressure — or the amount of gas pressure that will cause the burst disk to rupture on the cylinder — is 52°C (125°F). Some authorities consider even this temperature too high, and certainly it is advisable never to allow cylinders to reach elevated temperatures. A common way that cylinders can reach these temperatures is if they were placed in full sun on a hot summer day.

5.1.3.2.13 Central supply systems for nitrous oxide and carbon dioxide using cylinders or portable containers shall be prevented from reaching temperatures lower than the recommendations of the central supply system's manufacturer, but shall never be lower than –7°C (20°F) or greater than 52°C (125°F).

The minimum temperatures for nitrous oxide and carbon dioxide result from the fact that these gases are actually above their triple point [the temperature and pressure at which the three phases (gas, liquid, and solid) of a substance coexist] in a standard cylinder and are thus in liquid form. Their pressure–temperature curves are steep, so they lose pressure rapidly as temperatures fall and reach a point where the liquid simply cannot vaporize and the gas cannot be drawn off. The exact location of this point will vary with the equipment installed, since some manifolds are more susceptible to low inlet pressures than others.

See Checklist 5.2 for a sample checklist that can be used to verify that the requirements of 5.1.3.2 have been met. An interactive PDF version of this checklist is also available as an "eForm" in the Purchase Products & Training tab at www.nfpa.org/99.

5.1.3.3* Central Supply System Locations.

Paragraphs 5.1.3.3.1.1 through 5.1.3.3.1.4 clarify the allowable locations for various sources and are intended to minimize the potentially dangerous practice of placing various medical gas sources together in the same room or enclosure. Understanding the "Fire Triangle" is the most basic concept of fire prevention and control. For a fire to occur, the three critical elements that follow must be present:

1. A fuel (such as oil or gas) or combustible material (such as paper or wood)
2. An ignition or heat source (such as a compressor or pumps)
3. Oxygen (oxidizers such as oxygen and nitrous oxide) in sufficient quantities to support combustion

When all three of these elements come together, combustion is the result. However, if only one of these elements is removed from contact with the other two, the threat of fire can be minimized. Thus if oxygen, heat, or the fuel supply is removed, risk of fire is minimized. Exhibit 5.4 shows a central supply location with minimal additional storage other than what is permitted in 5.1.3.3.1. (See also 5.1.3.3.4.2.)

Δ **A.5.1.3.3** The bulk supply system should be installed on a site that has been prepared to meet the requirements of NFPA 55 or CGA G-8.1, *Standard for Nitrous Oxide Systems at Customer Sites*. A storage unit(s), reserve, pressure regulation, and a signal actuating switch(es) are components of the supply system. Shutoff valves, piping from the site, and electric wiring from a signal switch(es) to the master signal panels are components of the piping system.

The bulk supply system is normally installed on the site by the owner of this equipment. The owner or the organization responsible for the operation and maintenance of the bulk supply system is responsible for ensuring that all components of the supply system — main supply, reserve supply, supply system signal-actuating switch(es), and delivery pressure regulation equipment — function properly before the system is put in service.

In the locating of central supply systems, consideration should be given to ensuring the resilience of the facility under reasonably anticipated adverse conditions. Examples have included the following:

(1) Flooding of systems located in basements from extraordinary weather, water main breaks, and sprinkler head failures
(2) Seismic events that rendered the supply system inoperative
(3) Degradation of the quality of air at the intake due to a nearby fire and chemical release
(4) Electrical problems, including failure of motor control centers and failure of switchgear to properly connect

Many of these risks can be ameliorated by care when siting the central supply systems and their utility connections.

5.1.3.3.1 General. Central supply systems shall be located to meet the criteria in 5.1.3.3.1 through 5.1.3.3.1.10.

5.1.3.3.1.1 Any of the following central supply systems shall be permitted to be located together in the same outdoor enclosure:

(1) Manifolds for gas cylinders *(see 5.1.3.5.12)*
(2) Manifolds for cryogenic liquid containers *(see 5.1.3.5.13)*
(3) Bulk cryogenic liquid systems *(see 5.1.3.5.14)*
(4)* Individual components on the oxygen side of concentrator sources *(see 5.1.3.9)*

Checklist

Checklist 5.2 Central Supply System Operations (New and Existing)

System: _____

Location: _____

Y = Satisfactory **N** = Unsatisfactory (explain below) **N/A** = Not applicable

Date _____ Inspector _____

	Y	*N*	*N/A*	*Comments*
Adapters or conversion fittings to adapt one gas-specific fitting to another are prohibited.	☐	☐	☐	
Cylinders and containers are handled in strict accordance with 11.6.2 of NFPA 99.	☐	☐	☐	
Only gas cylinders, reusable shipping containers, and their accessories are stored in rooms containing central supply systems or gas cylinders.	☐	☐	☐	
No flammable materials, cylinders containing flammable gases, or containers containing flammable liquids are stored in rooms with gas cylinders.	☐	☐	☐	
If cylinders are wrapped when received, the wrappers are removed prior to storage.	☐	☐	☐	
Cylinders without correct markings or whose markings and gas-specific fittings do not match are not used.	☐	☐	☐	
Cryogenic liquid storage units intended to supply gas to the facility are not used to transfill other liquid storage vessels.	☐	☐	☐	
Care is exercised when handling cylinders that have been exposed to freezing temperatures or containers that contain cryogenic liquids to prevent injury to the skin.	☐	☐	☐	
Cylinders containing compressed gases and containers for volatile liquids are kept away from radiators, steam piping, and like sources of heat.	☐	☐	☐	
When cylinder valve protection caps are supplied, they are secured tightly in place unless the cylinder is connected for use.	☐	☐	☐	
Containers are not stored in a tightly closed space.	☐	☐	☐	
Cylinders in use and in storage are prevented from reaching temperatures in excess of 52°C (125°F).	☐	☐	☐	
Central supply systems for nitrous oxide and carbon dioxide using cylinders or portable containers are prevented from reaching temperatures lower than the recommendations of the central supply system's manufacturer, but are never lower than −7°C (20°F) or greater than 52°C (125°F).	☐	☐	☐	

EXHIBIT 5.4

Central Supply Location for Gas Cylinders.

N **A.5.1.3.3.1.1(4)** Examples include the concentrator unit, the oxygen reservoir, and regulating devices.

5.1.3.3.1.2 Any of the following systems shall be permitted to be located together in the same indoor enclosure:

(1) Manifolds for gas cylinders *(see 5.1.3.5.12)*
(2) Manifolds for cryogenic liquid containers *(see 5.1.3.5.13)*
(3) In-building emergency reserves *(see 5.1.3.5.16)*
(4) Instrument air standby headers *(see 5.1.13.3.4.6)*
(5)* Individual components on the oxygen side of concentrator sources *(see 5.1.3.9)*

Indoor locations, as stated in this paragraph and elsewhere, should not be interpreted as necessarily meaning that it is a location within the confines of the building. The requirement is meant to ensure that this kind of equipment will not be located where it is exposed to the elements. This equipment is often located, for instance, in a remote power plant or boiler plant building, which could satisfy this requirement. A shed or outbuilding could fulfill this requirement equally well, provided that the interior conditions and ventilation are suitable.

The inclusions of item (5) recognizes that concentrator supply sources in a typical pressure swing adsorption system are composed of many components. In rough outline there is an air supply, the concentrator unit itself, and the oxygen storage tank. On the air side, there is a compressor, dryers, filters, charcoal adsorbers, and other elements related to the production of the feed air. These are analogs to the medical air compressor system and are subject to the same hazards and concerns as the other rotating equipment. Once through the concentrator unit, the gas is now essentially oxygen, and the analog is the oxygen cylinder manifold. Thus, it is important that, although these are all part of one system, they be treated based on the hazards involved.

FAQ Can rooms for manifolds be used for other purposes, such as storage rooms or workshops?

There are two distinct reasons why rooms for manifolds cannot be used for other purposes: fire safety and worker safety. Medical gases are generally oxidizers and will greatly accelerate the progress of a fire. Were items to be stored in the manifold or cylinder room, there is the possibility of literally "adding fuel to the fire." Were the manifold to leak, or in the case of cryogenic gases where venting from the containers is considered normal to prevent overpressurization of the container, the workers in the room could be exposed to the gases, which could have toxic effects. Manifold rooms and cylinder storage rooms should be reserved for that purpose only.

N **A.5.1.3.3.1.2(5)** Examples include the concentrator unit, the oxygen reservoir, and regulating devices.

5.1.3.3.1.3 Any of the following central supply systems shall be permitted to be located together in the same room:

(1) Medical air central supply compressor supply sources *(see 5.1.3.6.3)*
(2) Medical–surgical vacuum central supply sources *(see 5.1.3.7)*
(3) Waste anesthetic gas disposal (WAGD) central supply sources *(see 5.1.3.8)*
(4) Instrument air compressor central supply sources *(see 5.1.13.3.4)*
(5) Any other compressor, vacuum pump, or electrically powered machinery
(6)* Compressors, dryers, and air receivers used to supply oxygen concentrators *(see 5.1.3.9)*

N **A.5.1.3.3.1.3(6)** This includes individual components on the air side of concentrators.

(7) Concentrator units with air and oxygen sides in an integral unit *(see 5.1.3.9)*

FAQ Can air compressors and vacuum pumps be in the same room as other equipment?

NFPA 99 does not prohibit medical air compressors and vacuum pumps from being in the same room as air handlers, chillers, or gas hot water heaters. This arrangement is acceptable in part because air compressor intakes and vacuum pump exhausts are required by NFPA 99 to be located outdoors. However, it is not permitted to place these items in with manifolds of other gas supplies. (See 5.1.3.3.1.4.)

The inclusion of item (6) recognizes that concentrator supply sources in a typical pressure swing adsorption system are composed of many components.

Paragraph 5.1.3.3.1.3(7) is essentially an exception to 5.1.3.3.1.3(6). Some concentrators are built as single units (not merely on a single base but as an integrated operating unit) and are intended to operate as one unit. It would be impractical or impossible to separate the two "halves," but it should also be unnecessary since the integral systems must also be built in recognition of the hazard involved.

5.1.3.3.1.4 Any central supply system listed under 5.1.3.3.1.3 shall not be located in the same room with any central supply system listed under 5.1.3.3.1.1 or 5.1.3.3.1.2, except instrument

air reserve headers complying with 5.1.3.2.12 and 5.1.13.3.4.6 shall be permitted to be in the same room as an instrument air compressor.

5.1.3.3.1.5 Indoor locations for oxygen, nitrous oxide, and mixtures of these gases shall not communicate with the following:

(1) Areas involved in critical patient care
(2) Anesthetizing locations where moderate sedation, deep sedation, or general anesthesia is administered
(3) Locations storing flammables
(4) Rooms containing open electrical contacts or transformers
(5) Storage tanks for flammable or combustible liquids
(6) Engines
(7) Kitchens
(8) Areas with open flames

The statement that storage rooms "shall not communicate" means that the central supply system and storage locations for oxygen, nitrous oxide, and mixtures of these gases shall not be located in, or immediately adjacent to, the areas listed under 5.1.3.3.1.5.

This list of areas includes locations where fuel, combustibles, and/or ignition sources are present. Introducing oxidizers such as oxygen and nitrous oxide would bring all three elements of the "fire triangle" together, which could result in combustion. By keeping one of these elements removed from contact with the other two, the threat of fire can be minimized.

A simple test would be to determine which areas, if the gas escaped, could be affected. If any of these areas are on the prohibited list, they should be separated.

Δ **5.1.3.3.1.6** Cryogenic fluid central supply systems for oxygen shall comply with NFPA 55.

This section has been revised to no longer reference specific volumes of gas in order for the cryogenic oxygen system to comply with NFPA 55. Previously, this reference only applied where the volume exceeded 566,355 L (20,000 ft^3), which is still defined as the volume for a bulk oxygen system. Terminology here and in the following several paragraphs has been revised to correlate with the definition changes made in Chapter 3.

A cryogenic fluid is a liquefied gas that is held in liquid state by being kept at cryogenic temperatures (below 150°C [238°F]). Typical cryogenic liquids in medical gas are oxygen (183°C), nitrogen (196°C), and possibly helium (268°C). Noncryogenic liquids (nitrous oxide and carbon dioxide) are held in their liquid state by pressure.

In the code, the term *bulk* and *cyrogenic fluid* may seem to be interchangeable, because in fact most bulk installations are cryogenic liquid installations. However, bulk installations can include cryogenic, high-pressure storage, or a mixture of both.

NFPA 55 requires that bulk systems be located either outdoors or in a building used only for the purpose. Because 5.1.3.3.1.6 requires compliance with NFPA 55, the maximum amount of oxygen that can be stored in one room inside a health care facility is limited to 566,335 L (20,000 ft^3).

There is a tendency to use this number as the sole test of a bulk gas installation, which is not really the intent. To protect the operator, any installation provided with a stationary tank of liquefied gases should be installed following these rules insofar as possible. The hazards are common to any stationary liquid installation.

FAQ Is there a limit on the total amount of gas that can be placed in an indoor storage room or indoor central supply room?

There are limitations on the volume of gases other than oxygen and nitrous oxide that can be placed in an indoor storage room or indoor central supply room. Any bulk inert gas, such as nitrogen and helium, installation with more than 566,335 L (20,000 ft^3) of gas or gas equivalent will now be subject to the rules under CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites*. Exhibit 5.5 shows an example of an outdoor bulk gas installation.

The limits on gas storage described in 5.1.3.3.1.6 through 5.1.3.3.1.10 are specific to the type of gas. The maximum allowable quantities of multiple gases stored together per storage area are not listed in NFPA 99. However, it would be prudent not to store more than 566,335 L (20,000 ft^3) of oxidizing gas, such as oxygen or nitrous oxide, in a single storage room.

EXHIBIT 5.5

Bulk Central Supply System Requiring Compliance with NFPA 55.

5.1.3.3.1.7 Bulk nitrous oxide central supply systems shall comply with the mandatory requirements of CGA G-8.1, *Standard for Nitrous Oxide Systems at Customer Sites*.

5.1.3.3.1.8 Central supply systems for carbon dioxide using permanently installed containers with product capacities greater than 454 kg (1000 lb) shall comply with the mandatory requirements of CGA G-6.1, *Standard for Insulated Carbon Dioxide Systems at Consumer Sites*.

5.1.3.3.1.9 Central supply systems for carbon dioxide using permanently installed containers with product capacities of 454 kg (1000 lb) or less shall comply with the mandatory requirements of CGA G-6.5, *Standard for Small, Stationary, Insulated Carbon Dioxide Supply Systems*.

Δ **5.1.3.3.1.10*** Cryogenic fluid central supply systems for inert gases shall comply with the mandatory requirements of CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites*.

The CGA documents referenced in 5.1.3.3.1.7 through 5.1.3.3.1.10 — as well as NFPA 55, referenced in 5.1.3.3.1.6 — list installation requirements for central supply systems considered bulk gas installations. When a bulk gas system is installed at a health care facility, additional requirements beyond these documents for patient safety must be followed. NFPA 99 defines all the additional requirements (such as alarms, backup reserves, and labeling) that are needed for a health care facility's central supply bulk system.

To help the user identify and understand the scopes and content of the various CGA documents referenced by NFPA 99, Commentary Table 5.2 provides the name, full title, and abstract of each of those referenced within the code.

COMMENTARY TABLE 5.2 *CGA Referenced Document Overview*

Publication	*Updates/Abstract*
CGA C-7, *Guide to Classification and Labeling of Compressed Gases*, 10th edition (2014)	**Abstract:** This publication has been prepared to state the general principles for labels and markings and give recommended minimum requirements for many hazardous gases and selected liquids. The methods of preparing label information established by GHS as required by Title 29 of the U.S. Code of Federal Regulations (29 CFR) Part 1910.1200 (OSHA's Hazard Communication Standard) have been followed to meet the specific labeling and marking needs of the compressed gas industry. This publication is not intended to address state, provincial, territorial, or local regulatory label and marking requirements such as the "Proposition 65" warnings required by the state of California.
CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*, 2008	**Abstract:** Provides dimensions and other data to produce or use medical designed fittings for various gas connections used in hospital or patient care applications. The fittings are gas specific and noninterchangeable. This will avoid cross-connection of medical gases.
CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*, 13th edition (2013)	**Abstract:** Detailed dimension drawings of 115 valve outlet connections for nearly 270 different products. Covers threaded connections, yoke outlets, and the Pin Index Safety System for flush outlet valves of the yoke type used for medical gases. The scope of this standard is to provide connections that minimize the possibility of hazardous misconnections. This standard is based on a coordinated plan for the inclusion of future connections as they are required on cylinders that are not permanently manifolded during transport and use. Standard outlet connections for respective gases are fully defined and complete in themselves. The outlet connections are designed to minimize the possibility of hazardous misconnections.
CGA G-8.1, *Standard for Nitrous Oxide Systems at Customer Sites*, 5th edition (2013)	**Abstract:** This standard covers the general design principles recommended for the installation of nitrous oxide central supply systems (either cylinders connected to a common manifold or systems fed by bulk liquid containers) at medical or industrial consumer sites. Special reference to protecting the system, patients, personnel, and property from fire originating from sources other than the system itself. Previous edition cited in 29 CFR.
CGA G-6.1, *Standard for Insulated Liquid Carbon Dioxide Systems at Consumer Sites*, 7th edition (2013)	**Abstract:** This publication covers the design, location, installation, operation, and maintenance of insulated liquid carbon dioxide supply systems located at user sites. The system covered is from the container fill connections to the user's process piping. NOTE — Small, stationary, insulated carbon dioxide systems with containers having individual capacities of 1000 lb or less and designed, manufactured, and certified in accordance with American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section VIII, Division 1 requirements are not covered by this publication. Refer to CGA G-6.5, *Standard for Small, Stationary Insulated Carbon Dioxide Supply Systems* [1, 2]. NOTE — Many of the provisions and design philosophies in this publication apply to storage units in production and depot service. However, the operation, operating conditions, and control systems of those units may require further engineering, controls, and safety equipment than required by storage units at a user site. It also contains minimum requirements and recommended practices for the design, construction, installation, operation, and maintenance of such systems. This publication is intended to serve as a guide for regulatory authorities in writing regulations and to assist designers, inspectors, and other interested parties.
CGA G-6.5, *Standard for Small Stationary Insulated Carbon Dioxide Supply Systems*, 4th edition (2013)	**Abstract:** This standard contains minimum requirements and recommended practice for the design, construction, installation, operation, and maintenance of small stationary insulated carbon dioxide systems from the fill connection to the carbon dioxide container gas outlet regulator. These systems are primarily used for supplying carbon dioxide gas at beverage dispensing sites and can also be used in greenhouses, by welding fabricators, and for other applications.

CGA P-18, *Standard for Bulk Inert Gas Systems* (an American National Standard), 4th edition (2013)	**Abstract:** The purpose of this standard is to provide information on installation of bulk inert gas systems for argon, nitrogen, and helium service. This standard does not apply to carbon dioxide systems. For additional requirements on bulk inert gas systems at health care facilities, see CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*, NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, and NFPA 99, *Health Care Facilities Code*. Bulk carbon dioxide system requirements are found in NFPA 55 and CGA G-6.1, *Standard for Insulated Liquid Carbon Dioxide Systems at Consumer Sites*.
CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*, 3rd edition (2013)	**Updated title:** CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*, 3rd edition (2013) **Abstract:** This standard provides the minimum requirements for the installation, maintenance, and removal of CMG supply systems at health care facilities. This standard applies to all new or upgraded CMG supply systems at health care facilities. It provides direction for compliance with the following national regulations and model codes: • Federal Food, Drug, and Cosmetic Act [1]; • Title 21 of the U.S. Code of Federal Regulations (21 CFR) Parts 210-211 [2]; • NFPA 55, Compressed Gases and Cryogenic Fluids Code [3]; and • NFPA 99, Health Care Facilities Code [4]. Section 5 covers the scope of these regulations and their applicability to CMG supply systems. CGA M-1 captures the requirements from these codes along with best practices to provide a comprehensive document for the process of designing, locating, installing, starting up, maintaining, testing, removing, and documenting work on a medical gas supply system. This standard does not apply to: • the piped distribution system; • manufacturing plants or other establishments operated by the supplier or the supplier's agent for the purpose of storing and refilling portable containers, trailers, mobile supply trucks, or tank cars with medical gases; or • nonhealth care facilities such as laboratories, pharmaceutical, or biotechnology facilities.
CGA G-4.1, *Cleaning Equipment for Oxygen Service*, 2009	**Abstract:** Describes cleaning methods intended for equipment used in the production, storage, distribution and use of liquid and gaseous oxygen. Improperly cleaned equipment used in oxygen service could result in a combustion reaction causing damage to equipment and injury to personnel. This standard presents methods for cleaning that, when properly used, will result in the degree of cleanliness required for safe operation of oxygen service equipment. Consideration is also given to environmental issues including the ozone depletion potential of solvents. Previous edition cited in 49 CFR.
CGA 02-DIR, *Directory of Cleaning Agents for Oxygen Service*, Edition 4	**Withdrawn in 2008**

A.5.1.3.3.1.10 Examples of inert gases include but are not limited to helium and nitrogen.

Although NFPA 99 does not require that storage rooms for gases be locked, it does require that they be "secured" if the public has access. In light of reported thefts of nitrous oxide and helium cylinders for substance-abuse purposes, some means of limiting access to storage rooms is prudent to prevent unauthorized persons from creating a hazard or harming themselves.

Δ **5.1.3.3.2* Design and Construction.** Locations for central supply systems and the storage of positive-pressure gases shall meet the following requirements:

(1) They shall be constructed with access to move cylinders, equipment, and so forth, in and out of the location on hand trucks complying with 11.4.3.1.1.
(2) They shall be provided with lockable doors or gates or otherwise able to be secured.

(3) If outdoors, they shall be provided with an enclosure (e.g., wall or fencing) constructed of noncombustible materials.

(4) If outdoors and greater than 18.6 m² (200 ft²), they shall be provided with a minimum of two entry/exits.

If a person was in the enclosure and an event occurred (such as a bulk tank valve rupture or fill line leak) that resulted in the escape of gases that prevented egress via one opening, the person could exit via the other opening. This general provision has been changed in the 2018 edition to include this exception for small enclosures. The measurement is of the enclosed area overall. Note the exception in 5.1.3.3.2(5).

(5) If outdoors, bulk cryogenic liquid systems shall be provided with a minimum of two entry/exits.

Outdoor bulk liquid systems must always have two gates, while a manifold enclosure is permitted to have only one if the enclosure is less than 18.6 m² (200 ft²). See also 5.1.3.3.1.6.

(6) If indoors, they shall have interior finishes of noncombustible or limited-combustible materials.

(7)* If indoors, the room shall be separated from the rest of the building by walls and floors having a 1-hour fire resistance rating with doors and other opening protectives having a ¾-hour fire protection rating.

Δ **A.5.1.3.3.2(7)** The test for walls and floors is ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*; or UL 263, *Fire Resistance Ratings*. The test for doors is NFPA 252.

Items (6) and (7) were revised for the 2015 edition in order to correlate the language used here with terminology found in NFPA *101®*, *Life Safety Code®*, *NFPA 5000®*, *Building Construction and Safety Code®*, and commonly used building codes. The intent is that the room be separated from the rest of building by 1-hour fire resistance–rated barriers. Most building codes and, in particular, NFPA *101*, require such doors to have a ¾-hour fire protection rating. Doors do not have a fire resistance rating. Under the NFPA system, gypsum board is a limited-combustible material. Fire-retardant–treated wood (FRT) wood is not.

(8)* They shall comply with *NFPA 70* for ordinary locations.

A.5.1.3.3.2(8) Electrical devices should be physically protected, such as by use of a protective barrier around the electrical devices, or by location of the electrical device such that it will avoid causing physical damage to the cylinders or containers. For example, the device could be located at or above 1.5 m (5 ft) above finished floor or other location that will not allow the possibility of the cylinders or containers to come into contact with the electrical device as required by this section.

(9)* Fuel-fired equipment shall not be located in the room.

N **A.5.1.3.3.2(9)** Examples of indirect heating include steam, hot water, and electric heating.

(10) If heat is required the maximum allowable temperature of the in-room heating element shall be 130°C (266°F).

The provision of heat for a manifold room is a consistent challenge for designers. The room should not communicate with the occupied areas of the building in any way that escaped gas could reach staff or

patients, which restrains use of the building's central system. Small room heaters present challenges when they have open heater elements or use fuel (e.g., a kerosene heater), but otherwise they should be suitable.

Items (9) and (10) represent these limits and are an improvement over the prior rule, which simply stipulated "indirect" heat (written with the steam radiator in mind).

(11) They shall be provided with racks, chains, or other fastenings to secure all cylinders from falling, whether connected, unconnected, full, or empty.

FAQ Does "secure all cylinders" mean a single chain can be used to secure multiple cylinders?

A restraint system of chains, metal straps, or storage racks provides a reliable method of securing gas cylinders. Chains or metal straps at the bottom and top third of the cylinders provides protection against tipping, falling, or being knocked over. This does not mean that each cylinder needs to be individually restrained. See Exhibit 5.6 for examples of properly secured and improperly secured cylinders. Note that in seismic areas, additional requirements may apply.

(12)* They shall be supplied with electrical power compliant with the requirements for essential electrical systems as described in Chapter 6.

A.5.1.3.3.2(12) Chapter 6 specifies medical gas equipment that should be powered by the essential electrical systems. Electrical equipment that is not essential for the operation of the supply system can be powered by nonessential power (e.g., telemetry, site lighting).

(13) They shall have racks, shelves, and supports, where provided, constructed of noncombustible materials or limited-combustible materials.

A wooden rack is considered a combustible material and cannot be used for securing cylinders.

(14) They shall protect electrical devices from physical damage.

The protection for electrical devices described here could be a protective barrier around the electrical devices, or the actual location of the electrical device so as to avoid physical damage with the cylinders or containers [e.g., locating the device at 1.5 m (5 ft) or above the finished floor or other location], which will not allow cylinders or containers to come in contact with the electrical device.

There is a belief in some circles that manifold rooms must be built to explosionproof requirements or at least to standards suitable for flammable gases. To support this idea, some would cite that electrical devices are required to be located at 1.5 m (5 ft) above the finished floor, as is required for explosionproof locations, but this 1.5 m (5 ft) requirement was always intended only to prevent cylinders from damaging the devices. To remove confusion, the requirement was changed from specifying that electrical devices need to be located 1.5 m (5 ft) above the floor to simply stating they must be protected from physical damage. Locating devices at this height would still achieve this requirement.

(15)* They shall allow access by delivery vehicles and management of cylinders.

N **A.5.1.3.3.2(15)** Considerations for this access include proximity to loading docks, access to elevators, and passage of cylinders through public areas.

EXHIBIT 5.6

Two Different Arrangements: (left) Properly Secured Cylinders and (right) Improperly Secured Cylinders.

A storage location for a central supply system that contains cylinders (such as a manifold system) requires periodic management of cylinders, including removing empty gas cylinders from service and replacing them with full ones. Some of the factors in determining the route to and from the loading docks include proximity to loading docks, access to elevators (if needed), and passage through public areas.

(16) They shall be designed to meet the operational requirements of 5.1.3.2 with regard to room temperature.

See Checklist 5.3 for a sample checklist that can be used to verify that the requirements of 5.1.3.3.2 have been met. An interactive PDF version of this checklist is also available as an "eForm" in the Purchase Products & Training tab at www.nfpa.org/99.

A.5.1.3.3.2 Electric wiring and equipment in storage rooms for oxygen and nitrous oxide are not required to be explosionproof.

5.1.3.3.3 Ventilation.

Ventilation requirements for central supply systems locations, cylinder and container storage, and locations for transfilling of gases can be found in Chapter 9. As with any gas source, large-scale discharges from an MGVS are very rare, but little leaks are almost universal. Although the greatest hazard

Checklist

Checklist 5.3 Central Supply Location

System: _____

Location: _____

Y = Satisfactory **N** = Unsatisfactory (explain below) **N/A** = Not applicable

Date _____ Inspector _____

	Y	*N*	*N/A*	*Comments*
Constructed with access to move cylinders, equipment, and so forth, in and out of the location on hand trucks	☐	☐	☐	
Provided with lockable doors or gates or otherwise able to be secured	☐	☐	☐	
Provided with an enclosure (e.g., wall or fencing) constructed of noncombustible materials (if outdoors)	☐	☐	☐	
Provided with a minimum of two entry/exits [If outdoors and greater than 18.6 m^2 (200 ft^2)]	☐	☐	☐	
Bulk cryogenic liquid systems provided with a minimum of two entry/exits (if outdoors)	☐	☐	☐	
Interior finishes are of noncombustible or limited-combustible materials.	☐	☐	☐	
Cryogenic liquid storage units intended to supply gas to the facility are not used to transfill other liquid storage vessels.	☐	☐	☐	
If indoors, the room is separated from the rest of the building by walls and floors having a 1-hour fire resistance rating with doors and other opening protectives having a 3/4-hour fire protection rating.	☐	☐	☐	
Complies with *NFPA 70* for ordinary locations	☐	☐	☐	
Fuel-fired equipment is not located in the room.	☐	☐	☐	
If heat is required the maximum allowable temperature of the in-room heating element is 130°C (266°F).	☐	☐	☐	
Provided with racks, chains, or other fastenings to secure all cylinders from falling, whether connected, unconnected, full, or empty	☐	☐	☐	
Supplied with electrical power compliant with the requirements for essential electrical systems as described in Chapter 6 of NFPA 99	☐	☐	☐	
Racks, shelves, and supports, where provided, are constructed of noncombustible materials or limited-combustible materials.	☐	☐	☐	
Electrical devices are protected from physical damage.	☐	☐	☐	
Access by delivery vehicles and management of cylinders allowed	☐	☐	☐	
Designed to meet the operational requirements of 5.1.3.2 of NFPA 99 with regard to room temperature	☐	☐	☐	

arises with a massive discharge of gas (such as after a relief valve failure) — which, as mentioned, is extremely rare — the more commonplace problems include the cylinder lead that was not tightened properly, the connector that was nicked and does not quite seal, the pigtail that has a small break, or the connector that has lost its sealing O-ring.

With containers holding cryogenic gases, venting from the containers must be considered normal, although good design will attempt to minimize venting. These containers are designed to vent the overpressure created by heat leakage through the container wall.

Because manifold rooms can meet the OSHA definition of a confined space, it is advisable to assess the room for the installation of oxygen depletion monitors.

5.1.3.3.3.1 Ventilation for Indoor Locations. Central supply system locations, medical gas storage rooms, and transfilling room ventilation shall comply with 9.3.6.

The requirements for the ventilation of indoor storage and transfilling rooms were first removed from this chapter and placed in Chapter 9 for the 2012 edition of the code. Paragraph 5.1.3.3.3.1 acts as a reference to direct the user back to that location for these requirements. The 2018 edition has included central supply system locations in the list of rooms required to be ventilated. It has always been the intent that these rooms be provided with ventilation, but the previous language could have been read as not requiring it there.

9.3.6 Medical Gas Storage or Transfilling.

Δ **9.3.6.1** All gases, other than medical gases, shall be provided with ventilation per NFPA 55.

Δ **9.3.6.2** Outdoor storage/installations for medical gases and cryogenic fluids shall be provided with ventilation per NFPA 55.

9.3.6.3* Medical gases and cryogenic fluids that are in use per Chapter 11 shall not require special ventilation.

Refer to Chapter 11 for details and safety requirements for medical gases and cryogenic fluids that do not require ventilation. Examples of medical gases that do not require ventilation include the following:

- Up to 8.5 m^3 (300 ft^3) of nonflammable medical gas located outside an enclosure (such as a smoke compartment) at locations open to the corridor, such as at a nurses' station or in a corridor of a health care facility
- Cylinders contained in "crash carts" and in use on wheelchairs or gurneys
- An individual cylinder placed in a patient room for immediate use by a patient, which is not required to be stored in an enclosure and is considered in use

A.9.3.6.3 Paragraph 9.3.6.3 only covers fluids that are stored in enclosed spaces.

Δ **9.3.6.4** Transfilling area shall be provided with ventilation in accordance with NFPA 55.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* covers ventilation requirements for gas storage used for transfilling stations located outdoors.

9.3.6.5 Indoor storage or manifold areas and storage or manifold buildings for medical gases and cryogenic fluids shall be provided with natural ventilation or mechanical exhaust ventilation in accordance with 9.3.6.5.1 through 9.3.6.8.

Exhibit 9.2 shows a ventilation opening in the wall of a manifold room.

9.3.6.5.1* For the purposes of this section the volume of fluid (gas and liquid) to be used in determining the ventilation requirements shall be the volume of the stored fluid when expanded to standard temperature and pressure (STP) of either the largest single vessel in the enclosed space or of the entire volume of the connected vessels that are on a common manifold in the enclosed space, whichever is larger.

EXHIBIT 9.2

Ventilation for Manifold Room.

A.9.3.6.5.1 See Table A.11.3.4.

Prior to the 2012 edition of NFPA 99, the dividing line between mechanical and natural ventilation requirements for medical gas storage and manifold areas was 85 m^3 (3000 ft^3). Beginning with the 2012 edition, the ventilation requirements have been based on the ventilation rate needed in the event of potential escape of the particular gas or fluid, as described in the natural ventilation and mechanical ventilation requirements in 9.3.6.5.2.

With any gas source, leaks can occur. Common problems can include the following:

- A cylinder lead that is not tightened properly
- A connector that does not seal
- A pigtail that breaks
- A connector that loses its sealing O-ring

The greatest hazard arises in the case of a mass discharge of gas, which is most commonly due to a relief valve failure. Venting from containers holding cryogenic liquid is normal. These containers are designed to vent the overpressure created by the heat leakage through the container wall.

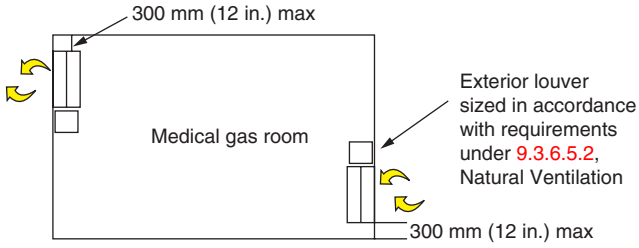
Medical gases are supplied in standard cylinder styles having the typical dimensions and capacities. Table A.11.3.4, Typical Medical Gas Cylinders' Volume and Weight of Available Contents, should be used to assist in calculating ventilation rates.

9.3.6.5.2 Natural Ventilation.

9.3.6.5.2.1 Natural ventilation shall consist of two nonclosable louvered openings, each having an aggregate free opening area of at least 155 cm^2/35 L (24 $in.^2$/1000 ft^3) of the fluid designed to be stored in the space and in no case less than 465 cm^2 (72 $in.^2$).

Prior to the 2012 edition of NFPA 99, where the total volume of medical gases that were connected and in storage was less than 85 m^3 (3000 ft^3) at standard temperature and pressure (STP), natural ventilation was permitted; and where storage was greater than or equal to 85 m^3 (3000 ft^3) at STP, mechanical ventilation was required. Beginning with the 2012 edition, natural ventilation has been allowed to be used for storage greater than 85 m^3 (3000 ft^3) when the natural ventilation openings, such as the louvered openings shown in Exhibit 9.3, are designed in accordance with the requirements of 9.3.6.5.2.

For example, if 141 m^3 (5000 ft^3) of oxygen at STP is stored in a room, the natural ventilation openings would need to be 774 cm^2 (120 $in.^2$). Mechanical ventilation can be used in lieu of natural ventilation.



Note: Motorized dampers and mechanical ventilation should be used when climate is hot or cold to prevent overheating/cooling. Design engineer should provide verification with stored gas manufacturer for upper/lower parameters of room temperature and provide supplemental heating/cooling as needed.

EXHIBIT 9.3

Louvered Openings Providing Natural Ventilation.

9.3.6.5.2.2 One opening shall be located within 30 cm (1 ft) of the floor, and one shall be located within 30 cm (1 ft) of the ceiling.

9.3.6.5.2.3 The openings shall be located to ensure cross ventilation.

The location of the two vents, one at the floor and one at the ceiling, ensures cross ventilation, rather than simple diffusion. See Exhibit 9.3.

9.3.6.5.2.4 Natural ventilation openings shall be directly to the outside atmosphere without ductwork.

It could be dangerous to have excess nonflammable gases dumping into an exit access corridor when it is being used as an exit from a fire or other emergency. Louvered natural ventilation openings vent directly to the outside and are not to be located in an exit access corridor. If natural ventilation openings cannot vent directly to the outside atmosphere, use of mechanical ventilation is required.

9.3.6.5.2.5 Mechanical ventilation shall be provided if natural ventilation requirements cannot be met.

9.3.6.5.3 Mechanical Ventilation.

9.3.6.5.3.1 Mechanical exhaust to maintain a negative pressure in the space shall be provided continuously, unless an alternative design is approved by the authority having jurisdiction.

9.3.6.5.3.2 Mechanical exhaust shall be at a rate of 1 L/sec of airflow for each 300 L (1 cfm per 5 ft^3 of fluid) designed to be stored in the space and not less than 24 L/sec (50 cfm) nor more than 235 L/sec (500 cfm).

9.3.6.5.3.3 Mechanical exhaust inlets shall be unobstructed and shall draw air from within 300 mm (1 ft) of the floor and adjacent to the cylinder or containers.

The requirement for ventilation to be located at the floor recognizes that the most common medical gases (oxygen and nitrous oxide) in use and storage are heavier than air. In the stillness of a closed storage room, these gases tend to settle at the floor level.

9.3.6.5.3.4 Mechanical exhaust air fans shall be supplied with electrical power from the essential electrical system. Where an essential electrical system is not provided, a risk assessment shall be conducted to determine if continuous ventilation shall be provided by alternate means.

This section has been revised to recognize that not all facilities have essential electrical systems. The added language provides a strategy for addressing ventilation in such spaces.

9.3.6.5.3.5 Dedicated exhaust systems shall not be required, provided that the system does not connect to spaces that contain combustible or flammable materials.

Although in these cases the exhaust systems do not need to be dedicated, the exhaust of medical gases cannot interconnect with other facility air-handling systems that serve locations containing combustible or flammable materials. Best practice is to locate medical gas storage space on an exterior wall and provide dedicated exhaust.

9.3.6.5.3.6 The exhaust duct material shall be noncombustible.

Δ **9.3.6.5.3.7** A means of make-up air shall be provided according to one of the following:

(1) Air shall be permitted via noncombustible ductwork to be transferred from adjacent spaces, from outside the building, or from spaces that do not contain combustible or flammable materials.
(2) Air shall be permitted to be transferred from a corridor under the door up to the greater of 24 L/sec (50 cfm) or 15 percent of the room exhaust in accordance with NFPA 90A.
(3) Supply air shall be permitted to be provided from any building ventilation system that does not contain flammable or combustible vapors.

An example of a mechanically ventilated storage room would provide exhaust at a minimum of 1 L/sec for each 300 L of gas (1 cfm per 5 ft^3 of fluid) with exhaust capture at 152 mm (6 in.) above the finished floor. Make-up air would be provided directly from outdoors or from the building ventilation

supply. The room should be designed for neutral or negative pressure in adjacent spaces to prevent gas migration in case of system failure and gas leakage. Make-up air should not be provided directly from outdoors if summer or winter temperatures can cause excessive temperature in the space. The medical gas provider should be consulted as needed to provide proper operating minimum and maximum temperatures.

Δ **9.3.6.6** Discharge from the natural and mechanical ventilation systems shall be sited by a minimum separation distance in accordance with NFPA 55.

9.3.6.7 A storage room shall maintain a temperature not greater than 52°C (125°F).

9.3.6.8 A transfer or manifold room shall maintain a temperature not greater than 52°C (125°F) and not less than −7°C (20°F).

5.1.3.3.3.2 Venting of Relief Valves. Indoor supply systems shall have all relief valves vented per 5.1.3.5.6.1(4) through 5.1.3.5.6.1(9).

Since the 2002 edition, all relief valves are required to be vented to the outside. The code permits the vents to be tied together to allow for a single penetration of the wall.

Δ **5.1.3.3.3.3 Ventilation for Motor-Driven Equipment.** The following source locations shall be ventilated to prevent accumulation of heat:

(1) Medical air central supply systems sources *(see 5.1.3.6)*
(2) Medical–surgical vacuum central supply systems sources *(see 5.1.3.7)*
(3) Waste anesthetic gas disposal (WAGD) central supply systems sources *(see 5.1.3.8.1)*
(4) Instrument air central supply systems sources *(see 5.1.13.3.4)*

All motor-driven equipment will unavoidably create heat, and the equipment is designed to discharge this excess heat into the environment. Such heat is unlikely to create a fire hazard, but if the equipment recirculates its own hot air, temperatures can become extreme. These temperatures may cause the tripping of motor overloads or thermal malfunction devices, premature failure of variable speed inverters, and so on. The stress on the equipment is greatly increased and the life shortened when it is not held within the temperature limits recommended by its manufacturer.

There are two elements to ventilation as it applies here: first, the ambient temperature, which may itself become higher than the manufacturer recommends; and second, prevention of air recirculation, which can raise the room temperature above the recommended maximum. In climates with low ambient temperatures year-round, simple natural ventilation might be sufficient. In warmer climates, mechanical ventilation up to or including air-conditioning of mechanical spaces might be required. Because it is essential to the reliability of the equipment, this ventilation is a life safety concern.

5.1.3.3.3.4 Ventilation for Outdoor Locations.

(1) Outdoor locations surrounded by impermeable walls, except fire barrier walls, shall have protected ventilation openings located at the base of each wall to allow free circulation of air within the enclosure.

This requirement is aimed at preventing a cryogenic liquid system from being placed in a vault or surrounded by a solid wall, such as a wall of concrete blocks or brick. In such situations, the gate might be

the only opening where vented gas can escape. It has also been demonstrated that enclosures with inadequate ventilation tend to accumulate ice. The requirement in 5.1.3.3.3.4 is intended to ensure a minimal cross-ventilation. The size of these openings will have to be determined by consultation with the bulk system supplier, because it will vary with the system size and configuration. Because the air might contain elevated levels of the gas in the enclosure, it is inappropriate to allow the system to vent into a building, which would be the result of opening a common wall. Where fires walls are installed, any penetration to a fire wall is required to follow NFPA 55.

(2) Walls that are shared with other enclosures or with buildings shall be permitted to not have openings.
(3) The fire barrier wall shall not have openings or penetrations, except conduit or piping shall be permitted, provided that the penetration is protected with a firestop system in accordance with the building code.

5.1.3.3.4 Storage.

5.1.3.3.4.1 Full or empty medical gas cylinders, when not connected, shall be stored in locations complying with 5.1.3.3.2 through 5.1.3.3.3 and shall be permitted to be in the same rooms or enclosures as their respective central supply systems. Approved existing installations shall be permitted to be continued in service.

The last sentence of 5.1.3.3.4.1 is new to the 2018 edition. While this section is for storage and should therefore logically apply to new and existing facilities, the cross references in the section send the user back to 5.1.3.3.2, which is for design and construction. Most NFPA codes and standards, NFPA 99 included, do not retroactively require compliance with the newest requirements for design and construction requirements. The inclusion of the new sentence is meant to indicate that approved existing installations can be permitted unless an authority having jurisdiction were to determine that it represents a distinct hazard to life. This aligns with the applicability statements found in Chapter 1.

5.1.3.3.4.2 Cylinders, whether full or empty, shall not be stored in enclosures containing motor-driven machinery, with the exception of cylinders intended for instrument air reserve headers complying with 5.1.13.3.4.6, which shall be permitted to be placed in the same location containing an instrument air compressor when it is the only motor-driven machinery located within the room. Only cylinders intended for instrument air reserve headers complying with 5.1.13.3.4.6 shall be permitted to be stored in enclosures containing instrument air compressors.

The storage requirements of 5.1.3.3.4 are identified in 5.1.1.5 as applying to both new and existing facilities. Indoor storage rooms used for cylinders are meant to be designed the same way as rooms used to store central supply systems, whether those cylinders are connected to their respective manifolds or not. All the hazards associated with cylinders exist whether connected to a central supply system or freestanding, and thus all the requirements in 5.1.3.3, Central Supply System Locations, apply to freestanding cylinders in storage as well. One item in 5.1.3.3 identifies that cylinders cannot be placed in rooms with mechanical equipment, such as compressors, boilers, or air handlers. There are some exceptions, such as in the case of air cylinders connected to an instrument air supply system where the air cylinders are set up as a secondary supply to the instrument air compressor. This exception is permitted only because of the limited oxidizing characteristics of air and the provisions for venting both the cylinder header and the enclosure contained in this code.

Δ **5.1.3.4 Control Equipment.** For control equipment, as specified in 5.1.3.5.5, 5.1.3.5.6, and 5.1.3.5.8, that is physically remote from the supply system, the control equipment shall be

installed within a secure enclosure to prevent unauthorized access in accordance with 5.1.3.3.2(2).

5.1.3.4.1 The enclosure shall provide enough space to perform maintenance and repair.

5.1.3.4.2 The location of the enclosure for control equipment other than for medical air shall not communicate with combustible or flammable materials.

Remote line control equipment would include shutoff valves, pressure regulators, relief valves, and gauges that are not within the same storage location as the central supply system. This remote line equipment needs to be handled with the same care as any other manifold location. The location of the remote line control equipment needs to be free from combustibles and flammable materials and allow for enough space to perform maintenance and repairs.

5.1.3.5* Central Supply Systems. Central supply systems shall be permitted to consist of the following:

(1) Cylinder manifolds for gas cylinders per 5.1.3.5.12
(2) Manifolds for cryogenic liquid containers per 5.1.3.5.13
(3) Cryogenic fluid central supply systems per 5.1.3.5.14
(4) Medical air compressor systems per 5.1.3.6
(5) Medical–surgical vacuum producers per 5.1.3.7
(6) WAGD producers per 5.1.3.8
(7) Instrument air compressor systems per 5.1.13.3.4
(8) Proportioning systems for medical air USP per 5.1.3.6.3.14

With the introduction of oxygen concentrator supply systems to this edition of the code, there should be a ninth item to the list of 5.1.3.5 that includes those as an allowable supply system. This was an oversight by the committee, and their criteria and specifications in the code should be seen as acceptable for their use as central supply systems in health care facilities.

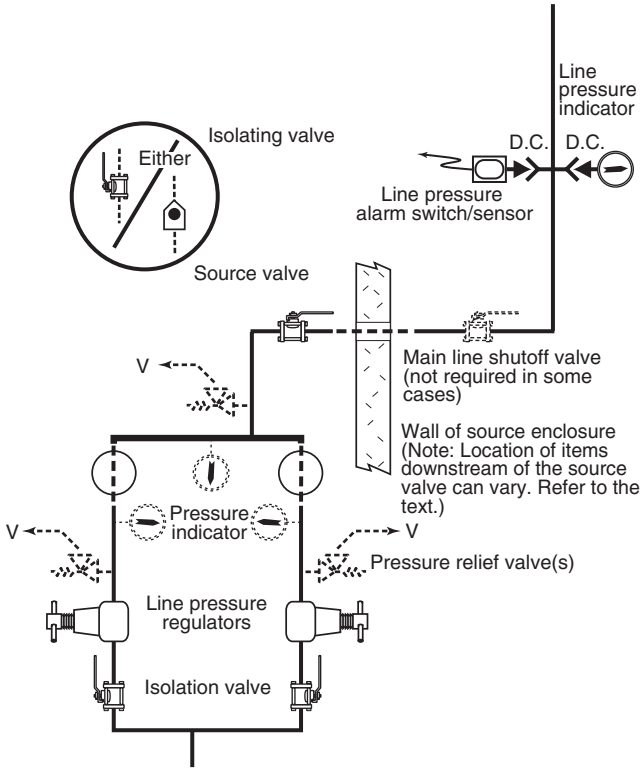
A.5.1.3.5 See Figure A.5.1.3.5. A four-valve bypass arrangement is illustrated. Three-way valves are permitted in lieu of the four valves shown.

The subsystem illustrated in Figure A.5.1.3.5 is critical to any medical gas supply source, and the same or very similar arrangements of components will be seen in any medical gas system. A relief valve is required downstream of any pressure regulator and where gas may become trapped. The two alternative locations indicated in the figure reflect the code and the options available for valving. Good engineering practice should be observed in all designs when determining the valving. The text would also permit use of a three-way valve under some circumstances, but this is not illustrated in the figure.

5.1.3.5.1 General. Central supply systems shall be obtained from a supplier or manufacturer familiar with their proper construction and use and installed in accordance with the manufacturer's instructions.

Δ **5.1.3.5.2 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 complying with 5.1.5, into areas where the gases will be used under the direction of licensed medical professionals for purposes congruent with the following:

(1) Direct respiration by patients
(2) 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



Δ ***FIGURE A.5.1.3.5*** *Typical Arrangement for Line Controls at Pressure Sources.*

(3) Medical device applications directly related to respiration
(4) Power for medical devices used directly on patients
(5) Calibration of medical devices intended for (1) through (4)
(6) Simulation centers for the education, training, and assessment of health care professionals

FAQ Can medical gases be used for other purposes?

This requirement reflects a long-term concern that medical gases are piped to areas that are outside the control of medical personnel and where the gas is intended for uses other than patient care. Common examples of this misuse include piping medical oxygen into a laboratory for instrumentation, piping medical air into central supply to run sterilizers or to blow down tools, or using medical nitrogen to operate door openers.

The intent of this requirement is to prevent misuse so the systems do not fail and are not contaminated as a result of inappropriate use. Medical gas systems are meant to be treated with the respect due to the pharmaceuticals they convey and are not to be thought of or treated as simple utilities.

Item (6) was added to the 2018 edition of the code. Many hospitals and health care facilities have added simulation centers in parts of their facilities. It is necessary to use medical gases in the training and assessment of health care professionals in these simulation centers. There is no danger to patients, staff, or the public in using theses piped medical gases in the simulation centers. The addition of item (6) allows this use.

5.1.3.5.3 Support Gases. Central supply systems for support gases shall not be piped to, or used for, any purpose except medical support application.

Instrument air and nitrogen are medical support gases. Medical support gases are intended to be used for any medical support purpose, such as removing excess moisture from an instrument before further processing or to operate medical–surgical tools, air-driven booms, pendants, or similar equipment or for similar applications. Medical support gases are not medical gases and should not be used for patient respiration.

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

(1) In those portions of systems intended to handle oxygen at gauge pressures greater than 2413 kPa (350 psi), interconnecting hose shall contain no polymeric materials.

Under some circumstances (including the presence of pure oxygen at cylinder pressures), the linings of interconnecting hose can ignite and blow out or explode. Although there are always potential issues when placing polymeric materials in pure oxygen, these flexible pigtails made from polymeric materials have accumulated a particularly problematic history and thus were prohibited in the 2002 edition of NFPA 99. Both the risk of ignition and the rate of combustion increase with higher concentrations of the oxidizing gas. Higher pressure usually results in a lower ignition temperature and increased combustion rate. Furthermore, in the case of adiabatic compression, a higher pressure will create a higher temperature. Increased temperature will also increase the risk of ignition, as the amount of energy that must be added to start a fire decreases. The ignition temperatures of polymeric materials are lower than those of metals, and they become significantly lower with increasing pressure. Since this prohibition on polymers is limited to environments of oxygen at high pressures, these pigtails are not prohibited when used with other gases or with oxygen at gauge pressures less than 2413 kPa (350 psi).

(2) 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 percent oxygen.
(3) If potentially exposed to cryogenic temperatures, materials shall be designed for low temperature service.
(4) If intended for outdoor installation, materials shall be installed per the manufacturer's requirements.

A.5.1.3.5.4 Components include, but are not limited to, containers, valves, valve seats, lubricants, fittings, gaskets, and interconnecting equipment, including hose. Easily ignitable materials should be avoided.

Compatibility involves both combustibility and ease of ignition. Materials that burn in air will burn violently in pure oxygen at normal pressure and explosively in pressurized oxygen. Also, many materials that do not burn in air will do so in pure oxygen, particularly under pressure. Metals for containers and piping have to be carefully selected, depending on service conditions. The various steels are acceptable for many applications, but some service conditions can call for other materials (usually copper or its alloys) because of their greater resistance to ignition and lower rate of combustion.

Similarly, materials that can be ignited in air have lower ignition energies in oxygen. Many such materials can be ignited by friction at a valve seat or stem packing or by adiabatic compression produced when oxygen at high pressure is rapidly introduced into a system initially at low pressure.

5.1.3.5.5 Controls for Line Pressure.

5.1.3.5.5.1* All positive-pressure supply systems shall be provided with means to control the final line pressure at the source with all the following characteristics:

(1) Able to maintain stable pressures within the limits of Table 5.1.11
(2) Each control mechanism able to flow 100 percent of the peak calculated demand.
(3) Redundant, such that each component of the control mechanism can be isolated for service or replacement while maintaining normal operation.
(4) Protected against overpressure *(see 5.1.3.5.6)*.
(5) Be constructed of materials deemed suitable by the manufacturer.

This is an example of a trend that will be manifest elsewhere in the 2018 edition of NFPA 99 and in many other standards as well. The language here has been changed from *prescriptive* ("do this") to *performance* ("achieve this"). The reason for writing standards this way is to allow for any alternative solutions or technologies as long as they can achieve the required results. Performance language is harder to draft and more difficult to enforce, because it requires an understanding of the intention and one cannot simply "check the box" during inspection.

In this case, what was required previously was two pressure regulators in a four-valve bypass arrangement, with some exceptions. There was only one allowed solution. The regulator in a bypass solution will still meet the requirements here but so could a solution like output pressure control on a compressor, which the old language would have prohibited.

N **A.5.1.3.5.5.1** The intent of 5.1.3.5.5.1 is to ensure that the pressure at the station outlet is steady and maintained safely within the limits of Table 5.1.11. Traditionally, line pressure regulators were required here as the only allowed control-of-pressure devices. Other methods of control are becoming possible (e.g., variable speed controlled on pressure). The present wording is intended to achieve the performance requirement *(see Table 5.1.11)* and to allow not only traditional pressure regulators but other control methods as well.

5.1.3.5.5.2 The line pressure regulators required under 5.1.3.5.5.1, where used for bulk cryogenic liquid systems, shall be of a balanced design.

5.1.3.5.6 Relief Valves.

5.1.3.5.6.1 All pressure relief valves shall meet the following requirements:

(1) They shall be of brass, bronze, or stainless steel construction.
(2) They shall be designed for the specific gas service.
(3) 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.
(4) They shall be vented to the outside of the building, except that relief valves for compressed air systems having less than 84,950 L (3000 ft^3) at STP shall be permitted to be diffused locally by means that will not restrict the flow.
(5) They shall have a vent discharge line that is not smaller than the size of the relief valve outlet.
(6) Where two or more relief valves discharge into a common vent line, its internal cross-sectional area shall be not less than the aggregate cross-sectional area of all relief valve vent discharge lines served.
(7) They shall not discharge into locations creating potential hazards.
(8) They shall have the discharge terminal turned down and screened to prevent the entry of rain, snow, or vermin.
(9) They shall be designed in accordance with ASME B31.3, *Pressure Process Piping.*

No shutoff valve should be positioned in a location that would allow pressure to build up in the supply portion of a system if the shutoff valve were closed. Therefore, the location of the shutoff valve is very important. Exhibit 5.7 shows a pressure relief valve.

Although the hazards vary, any release of gas(es) in an enclosed area could be hazardous to persons inside or around the immediate area. All gases, except medical air, should be vented to the outside and into a safe location, as required by 5.1.3.5.6.1(4) and (7).

Vent lines are intended to be short, to discharge outdoors, and to discharge where the gases will not be a hazard either to the building or to anyone who might be nearby. Specific hazards of concern include the following:

- The gas itself (nitrous oxide could be hazardous if discharged into any occupied space or drawn into the building)
- The aggravation of a fire hazard (oxygen could cause a severe fire if discharged anywhere near an ignition source)
- The pressure (a sudden discharge of high-pressure gas could be noisy and frightening to passersby and might physically eject dirt, stones, or other items)

Relief valve vent lines are permitted to be tied together to allow a single penetration of the wall. In this case, line size is determined by calculating the area of each of the individual vent connections. As an example, a design calls for the tying together of four valves to a single vent line. Each valve has a 1.3 cm (½ in.) NPT outlet, which equates to an area of 1.265 cm^2 (0.196 $in.^2$). Adding together the four 1.3 cm (½ in.) valves results in an aggregate area of 5.065 cm^2 (0.785 $in.^2$), indicating a line size of 2.6 cm (1 in.).

Relief valve lines (the actual piping) need to be labeled (see 5.1.3.5.6.4). There has been at least one report of a person tying into a relief line under the assumption that it was the system pipeline, which is an easy mistake to make since the pipe material is the same (see 5.1.3.5.6.2) and it connects to the same equipment.

5.1.3.5.6.2 When vented to outdoors, materials and construction for relief valve discharge lines shall be the same as required for positive pressure gas distribution. *(See 5.1.10.1.)*

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

(1) They shall be located between each final line regulator and the source valve.
(2) They shall have a relief setting that is 50 percent above the normal system operating pressure, as indicated in Table 5.1.11.

5.1.3.5.6.4 When vented outside, relief valve vent lines shall be labeled in accordance with 5.1.11.1 in any manner that will distinguish them from the medical gas pipeline.

5.1.3.5.7 Auxiliary Source Connection. All cryogenic fluid central supply systems shall be provided with an auxiliary source connection point of the same size as the main line, which shall be located immediately on the patient side of the source valve.

The 2015 version of the code required these auxiliary connections for all central supply systems. In the 2018 edition, the provision has been rolled back to encompass only liquid cryogenic sources (bulk liquid systems and liquid manifold systems) and is no longer required for others.

5.1.3.5.7.1 The connection shall consist of a tee, a valve, and a removable plug or cap.

5.1.3.5.7.2 The auxiliary source connection valve shall be normally closed and secured.

EXHIBIT 5.7

Pressure Relief Valve. (Courtesy of Tri-Tech Medical, Inc.)

Δ **5.1.3.5.8 Multiple Pressures.** Where a single central supply system supplies separate piped distribution networks operating at different pressures, each piped distribution network shall comply with the following:

(1) Medical air compressor systems: 5.1.3.5.5 (pressure regulators) and 5.1.9.2.4(7) (master alarm)
(2) All central supply systems: 5.1.3.5.5 (pressure regulators), 5.1.3.5.6 (relief valves), 5.1.4.2 (source valve), and 5.1.9.2.4(7) (master alarm)

Some piped gas systems use the same gas sources or manifolds but distribute the gas at more than one pressure. Overall safety of a system operating at several different pressures should be equal to that of a system at a single operating pressure. A degree of redundancy in the components is therefore required.

5.1.3.5.9 Local Signals.

Local signal requirements arise from the simple need of a maintenance person to know what is going on with any given piece of source equipment. A local signal is not an alarm like a local or master alarm. It is simply an indicator — it might be a gauge, a flag, a light, or some other possible manifestation — that allows a maintenance person to stand at the equipment and know what conditions are present (which header of cylinders is in service, for instance, or whether the reserve is full or whether the main or secondary tank on the bulk system is in service). The elements to be displayed are typically, but are not required to be, those that are also monitored at the master alarm, but the local signal is visible at the equipment rather than remotely.

5.1.3.5.9.1 The following central supply systems shall have local signals located at the source equipment:

(1) Manifolds for gas cylinders without reserve supply *(see 5.1.3.5.12)*
(2) Manifolds for gas cylinders with reserve supply

(3) Manifolds for cryogenic liquid containers *(see 5.1.3.5.13)*
(4) Bulk cryogenic liquid systems *(see 5.1.3.5.14)*
(5) In-building emergency reserves *(see 5.1.3.5.16)*
(6) Instrument air headers *(see 5.1.13.3.4.6)*

5.1.3.5.9.2 The local signals shall meet the following requirements:

(1) Provision of visual indication only
(2) Labeling for the service and condition being monitored
(3) If intended for outdoor installation, be installed per manufacturer's requirements

Δ **5.1.3.5.10* Headers.** In central supply systems using cylinders containing either gas or liquid, each header shall include the following:

(1)* Cylinder connections in the number required for the header's application

A.5.1.3.5.10(1) The appropriate number of cylinders should be determined after consideration of delivery schedules, proximity of the facility to alternate supplies, and the emergency plan.

(2) Cylinder lead for each cylinder constructed of materials complying with 5.1.3.5.4 and provided with end fittings permanently attached to the cylinder lead complying with the mandatory requirements of CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1)
(3) Filter of a material complying with 5.1.3.5.4 to prevent the intrusion of debris into the manifold controls
(4) Header shutoff valve downstream of the nearest cylinder connection, but upstream of the point at which the header connects to the central supply system
(5) Pressure indicator indicating the pressure of header contents
(6) Check valve to prevent backflow into the header and to allow service to the header
(7) If intended for gas cylinder service, a check valve at each connection for the cylinder lead in 5.1.3.5.10(2) to prevent loss of gas in the event of damage to the cylinder lead or operation of an individual cylinder relief valve
(8) If intended for gas cylinder service, a pressure regulator to reduce the cylinder pressure to an intermediate pressure to allow the proper operation of the primary and secondary headers
(9) If intended for service with cryogenic liquid containers, a pressure relief valve
(10) Vent valves, if fitted on a header, vented outside of the building per 5.1.3.5.6.1(5) through 5.1.3.5.6.1(9) and 5.1.3.5.6.2

A.5.1.3.5.10 See Figure A.5.1.3.5.10(a) and Figure A.5.1.3.5.10(b). Connection to the gas outlet connection is illustrated. If the liquid outlet connection were used, an external vaporizer could be required.

A header is an element of a source system that can be applied in various ways as appropriate to the configuration of the source desired. There are two variants — a header with cylinders and a header with containers — that are identical in most requirements. Exhibit 5.8 shows a cylinder manifold source.

An in-line filter upstream of the main line regulator is required per 5.1.3.5.10(3). This helps prevent debris from entering the regulator itself, which is one of the more common reasons for regulator failure. The filter is typically inside the regulator and might not be visible. It ordinarily requires no maintenance and, therefore, does not need to be accessible.

Figure A.5.1.3.5.10(a) shows a high-pressure cylinder header configuration and Figure A.5.1.3.5.10(b) shows a liquid container header configuration. Both are primarily subcomponents used in central supply systems, as shown in Figure A.5.1.3.5.12, Figure A.5.1.3.5.13, and Figure A.5.1.3.5.14(b). However, a high-pressure cylinder header configuration as illustrated in Figure A.5.1.3.5.10(a) might also be used

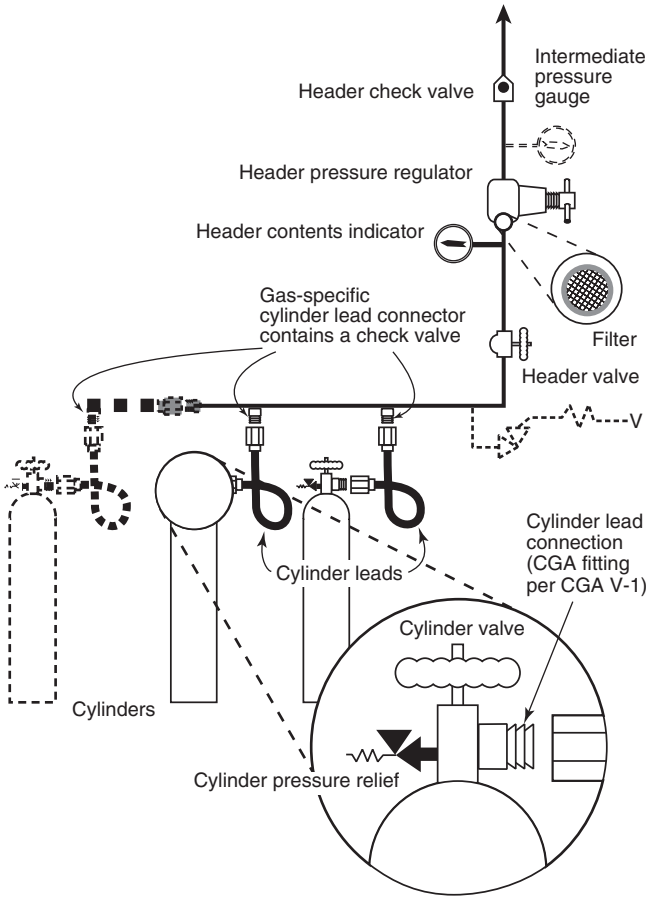


FIGURE A.5.1.3.5.10(a) *Header for Gas in Cylinders.*

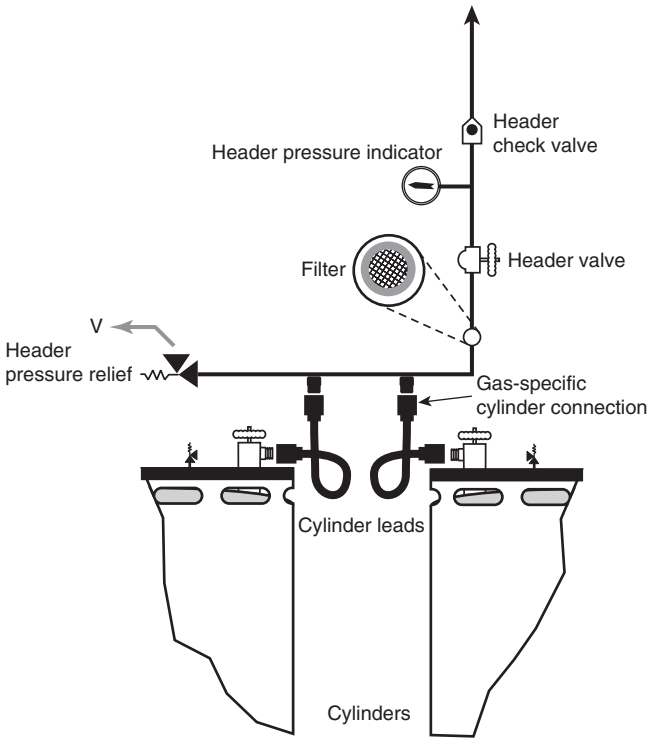


FIGURE A.5.1.3.5.10(b) *Header for Cryogenic Gas in Containers.*

by itself, such as in the case of an in-building emergency reserve (refer to 5.1.3.5.16). A liquid container header configuration similar to the one shown in Figure A.5.1.3.5.10(b) should never be used by itself, except perhaps in some temporary application under close and continuous supervision.

In Figure A.5.1.3.5.10(a) and Figure A.5.1.3.5.10(b), both headers are intended to be used as elements of the complete source systems as described in Figure A.5.1.3.5.12, Figure A.5.1.3.5.13, and Figure A.5.1.3.5.14(b). Thus, a manifold as shown in Figure A.5.1.3.5.12 will be composed of two headers as described in Figure A.5.1.3.5.10(a). A manifold as shown in Figure A.5.1.3.5.13 will be composed of two headers as described in Figure A.5.1.3.5.10(b). The intent is to allow the "mixing and matching" of the basic components to allow a variety of different manifold configurations to be created.

EXHIBIT 5.8

Cylinder Manifold Source for a Nitrous Oxide Piped Gas System.

N 5.1.3.5.11* Oxygen Concentrator Supply Units.

Requirements for an oxygen concentrator–based supply source have been added in the 2018 edition. These requirements should be read in conjunction with the requirements for the central supply system for oxygen-using concentrators, which can be found in 5.1.3.9. The central supply system will consist of at least two supply sources, one of which will be of the type described here.

While a detailed description of oxygen concentrators is outside the scope of this handbook, a basic description will help the user understand why these requirements have been drafted in this manner.

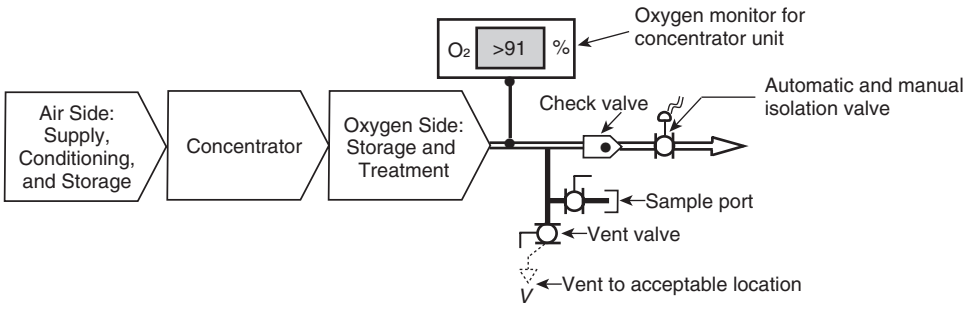
Normal air is 20.9 percent oxygen and 79 percent nitrogen. The concentration process removes the nitrogen thereby concentrating the oxygen. This is done by passing air through a molecular sieve, which retards the passage of nitrogen and outputs concentrated oxygen. Much like a sponge, the sieve bed can only hold so much nitrogen before the output gas becomes air again. So it is necessary to regenerate the sieve bed by venting or pulling the nitrogen off the sieve.

The air source is typically a compressor or blower, which pushes the air onto the sieve. A vent, blower, or pump is used to remove the nitrogen and recycle the sieve.

On the inlet to the sieve bed is standard air, but on the output side, the gas is now concentrated oxygen, sometimes at pressure.

The concerns addressed here deal with the safety aspects and limitations of this process. The language is intentionally performance based, as there are multiple ways to achieve the desired result with these systems.

N A.5.1.3.5.11 See Figure A.5.1.3.5.11.



Δ ***FIGURE A.5.1.3.5.11*** *Elements of an Oxygen Concentrator Supply Source.*

N 5.1.3.5.11.1 Oxygen concentrator supply units for use with medical gas pipelines shall produce oxygen meeting the requirements of Oxygen 93 USP or Oxygen USP.

Two different technologies for concentrators exist as of this writing. One will produce oxygen with a normal concentration of 90 to 96 percent; the other, which employs an additional sieve, can produce oxygen of 99+ percent.

N 5.1.3.5.11.2 Output shall have less than or equal to 1 mg/m^3 (6.85×10^{-7} lb/yd^3) of permanent particulates sized 1 micron or larger at normal atmospheric pressure.

The sieve bed is known to shed particulate matter, and therefore it is essential to ensure this does not pass downstream. A filter at the inlet of the air source is often provided, but this is the decision of the manufacturer and user and does not impact the quality of the oxygen directly.

Note that there is a requirement for a filter at the supply source outlet (see 5.1.3.5.11.10). It will need to be suitable for use with oxygen (see 5.1.3.5.11.5).

N **5.1.3.5.11.3** Materials of construction on the air side of the oxygen concentrator unit shall be suitable for the service as determined by the manufacturer.

N **5.1.3.5.11.4** Materials of construction on the oxygen side of the oxygen concentrator unit shall comply with 5.1.3.5.4

N **5.1.3.5.11.5** The components that make up the oxygen concentrator unit shall be as follows:

(1) The manufacturer of the concentrator unit shall be permitted to use such components and arrangement of such components as needed to produce oxygen complying with 5.1.3.5.11.1 in the quantity as required by the facility, except where otherwise specifically defined in this code.
(2) Air receivers and oxygen accumulators, where used, shall comply with Section VIII, "Unfired Pressure Vessels," of the ASME *Boiler and Pressure Vessels Code* and be provided with overpressure relief valves.

When oxygen is stored after being concentrated (quite a common practice with pressure swing adsorber concentrators), the vessel will be storing oxygen at pressure, which means that these vessels will need to be made of materials suitable for oxygen at these pressures and cleaned internally (see 5.1.3.5.11.5). They are often made of stainless steel, although this is not a requirement. Exhibit 5.9 shows an oxygen concentrator supply system, including the control panel and receiver tanks.

N **5.1.3.5.11.6** The supply air to the concentrators shall be of a quality to ensure the oxygen concentrator unit can produce oxygen complying with 5.1.3.5.11.1 and shall not be subject to normally anticipated contamination (e.g., vehicle or other exhausts, gas leakage, discharge from vents, flooding, and so forth).

This is a reference to the fact that, unlike medical air, intakes for the air sources in concentrators do not need to be piped to a clean source nor do they need to be fed with oil-free or oil-less air compressors (although doing so is a very good idea to extend the life of the sieve, it is not necessary to achieve the desired purity). Molecular sieve is very effective at removing contaminants as well.

EXHIBIT 5.9

Oxygen Concentrator System. (Courtesy of PCI Gases)

N **5.1.3.5.11.7** The oxygen concentrator supply unit and any associated electrical equipment shall be provided, a minimum, with the following electrical components:

(1) Either a disconnect switch for each major electrical component or a single disconnect that deactivates all electrical components in the concentrator unit.
(2) Motor starting devices with overload protection for any component with an electrical motor over 2 hp.

N **5.1.3.5.11.8** A vent valve shall be provided as follows:

The vent valve exists because the initial starting concentration of a concentrator supply source will not be up to the desired specification of oxygen (99 percent or 90 to 96 percent), and the concentrator will need to run for a time to flush all the air and other contaminants from the system before it is placed in operation. This valve allows that to occur while the supply source is isolated from the patient pipeline.

(1) 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
(2) Sized to allow for at least 25 percent of the oxygen concentrator unit flow
(3) Vented to a location compliant with 5.1.3.3.3.2

The valve will be venting very high concentrations of oxygen.

N **5.1.3.5.11.9** 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.

N **5.1.3.5.11.10** At least one 0.1 micron filter suitable for oxygen service shall be provided at the outlet of the oxygen concentrator supply unit.

N **5.1.3.5.11.11** 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.

N **5.1.3.5.11.12** An outlet valve shall be provided to isolate all components of the oxygen concentrator from the pipeline with the following characteristics:

This valve is unusual in that it is required to be both manual and automatic. On other supply sources, the valve required here would be manual only. In this case, the valve has two important functions. First, it allows the operator to isolate the supply source if needed for maintenance — a manual operation. Second, it isolates the supply source when the supply source cannot maintain the minimum concentration of oxygen. This might happen with a contaminated sieve bed and can occur rapidly. In that case, the valve must be shut immediately, otherwise the supply source would send low concentration oxygen into the pipeline. Because of this, the valve must be automatic, closing immediately when substandard oxygen concentration is detected and sending an alarm to the master panels.

Standard practice might then be to determine why the supply source was not operating correctly, correct the problem and calibrate the oxygen monitor, open the vent valve to purge any oxygen storage vessel, and then return the supply source to service.

(1) The valve shall have both manual and automatic actuation with visual indication of open or closed.
(2) The valve shall close automatically whenever the oxygen concentrator unit is not producing oxygen of a concentration equal to that in 5.1.3.5.11.1.
(3) Continuing operation of the oxygen concentrator supply unit through the vent mode shall be permitted with the isolating valve closed.

(4) 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.
(5) Closing the isolating valve, whether automatically or manually, shall activate an alarm signal at the master alarms *(see 5.1.9.2)* indicating that the oxygen concentrator supply unit is disconnected.

N **5.1.3.5.11.13** The oxygen concentrator supply unit shall be provided with an oxygen concentration monitor with the following characteristics:

The oxygen monitor is the most critical piece of instrumentation on the supply source. It needs to be accurate and durable, because the entire product stream depends on its accuracy and reliability. These monitors need to be checked often and calibrated with care.

(1) The monitor shall be capable of monitoring 99 percent oxygen concentration with 1 percent accuracy,
(2) The monitor shall continuously display the oxygen concentration and shall activate local alarm and master alarms per 5.1.3.9.4 when a concentration lower than 91 percent is observed.
(3) The monitor shall continuously display the oxygen concentration.
(4) It shall be permitted to insert the monitor into the pipeline without a demand check.

This is in contradiction to 5.1.8.2.4, which requires all monitors to be on demand checks. The exception is because the supply source cannot be operated without this monitor in correct operation (see 5.1.3.5.11.12).

5.1.3.5.12* Manifolds for Gas Cylinders.

A.5.1.3.5.12 See Figure A.5.1.3.5.12.

The use of a "black box" to illustrate the controls in Figure A.5.1.3.5.12 reflects the fact that many alternative control sequences are possible and could all equally meet the intent of NFPA 99. It is not the intent of the code to define how this mechanism must work, only that it define what the mechanism must achieve.

5.1.3.5.12.1 The manifolds in this category shall be located in accordance with 5.1.3.3.1 and shall meet the following:

(1) If located outdoors, they shall be installed in an enclosure used only for this purpose and sited to comply with minimum distance requirements in Table 5.1.3.5.13.1.
(2) If located indoors, they shall be installed within a room used only for enclosure of such manifolds.

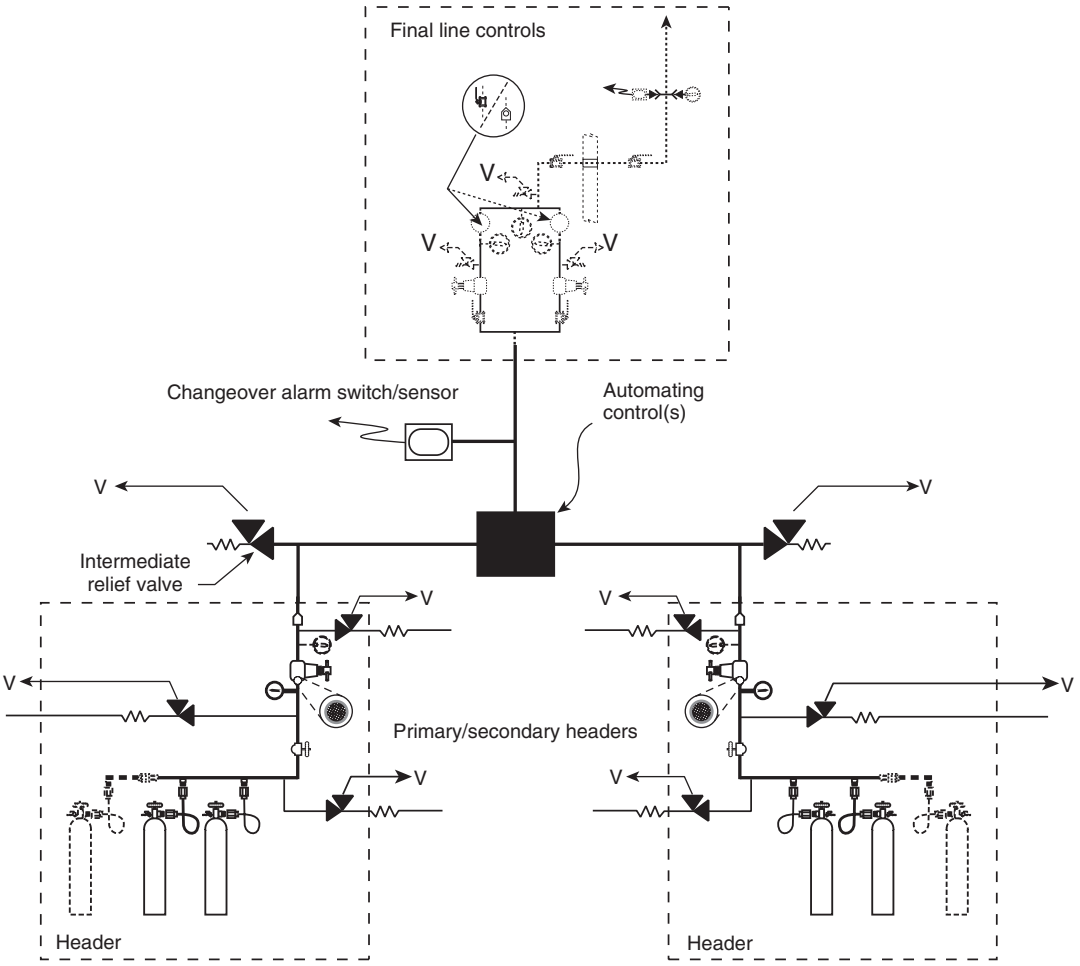
5.1.3.5.12.2 The manifold locations for this category shall be constructed in accordance with 5.1.3.3.2.

5.1.3.5.12.3 The manifolds in this category shall have their primary and secondary headers located in the same enclosure.

This was not stated as a requirement in the previous edition for cylinder manifolds. It was stated in the previous edition for cryogenic manifolds. Adding the requirements here improves safety by prohibiting an installation where the cylinder headers are not in the same room as the manifold control cabinet.

5.1.3.5.12.4 The manifolds in this category shall consist of the following:

(1) Two equal headers in accordance with 5.1.3.5.10, each with a sufficient number of gas cylinder connections for one average day's supply, but not fewer than two connections,



Δ ***FIGURE A.5.1.3.5.12*** *Manifold for Gas Cylinders.*

and with the headers connected to the final line pressure regulator assembly in such a manner that either header can supply the system

Manifolds are designed with two equal headers, each with an average day's supply of cylinders. By design, if each header has a minimum of an average day's supply, then you have a minimum of two days of gas supply until the medical gas manifold supply is empty. Gas cylinders are normally transported to consumers by the gas supplier on a weekly, biweekly, or monthly basis. When cylinders become empty and need to be replaced or in the case of an emergency cylinder delivery, the facility's supplier may not be located in the same town as the health care facility, and the supplier may require up to 24 hours to deliver additional cylinders to the facility site. Keeping additional cylinders on site can mitigate this concern, but it does not allow for the manifold supply to be sized for less than an average day's supply.

To reduce the risk of disruption of the medical gas supply, equal headers with automatic means of alternating the two headers are required. The manifold will automatically transfer gas supply demand from the primary supply to the secondary supply when the primary supply reaches a low-contents changeover setting. At this point, the secondary supply becomes the primary supply; and when the empty cylinders are replaced, the original primary supply becomes the secondary supply. As part of this process, the operational changes are indicated at the local signal and master alarms. This design allows the person who is replacing the empty cylinders with full cylinders to do so with little or no disruption to the operation of the medical gas supply system.

(2) Vent valves, if fitted on a header, vented outside of the building per 5.1.3.5.6.1(5) through 5.1.3.5.6.1(9) and 5.1.3.5.6.2

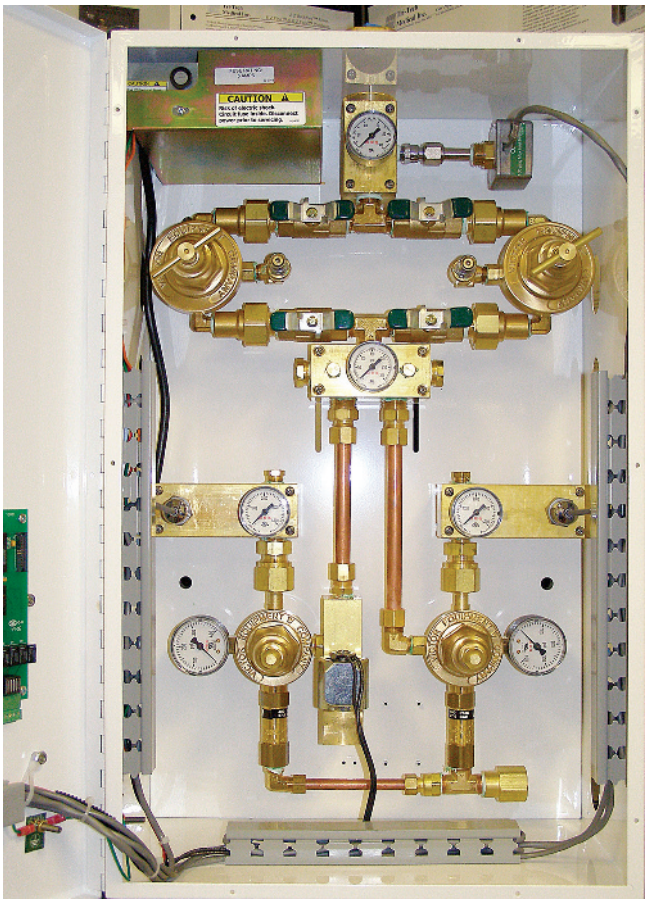
Vent valves are quite unusual on medical manifolds but are often seen on manifolds for laboratories.

(3) Intermediate relief valve(s), piped to the outside in accordance with 5.1.3.5.6.1(5) through 5.1.3.5.6.1(9), that protects the piping between the header pressure regulator and the line pressure regulator assembly, and protects the line pressure regulators from overpressure in the event of a header regulator failure

See Exhibit 5.10 for an example of a typical manifold.

EXHIBIT 5.10

Typical Manifold for Cylinder Gases. (Courtesy of Tri-Tech Medical, Inc.)



5.1.3.5.12.5 The manifolds in this category shall include an automatic means of alternating the two headers to accomplish the following in normal operation:

(1) One header is the primary and the other is the secondary, with either being capable of either role.
(2) When the primary header is supplying the system, the secondary header is prevented from supplying the system.
(3) When the primary header is depleted, the secondary header automatically begins to supply the system.

FAQ What is the purpose of the secondary source?

The intent behind the construction requirements for all medical gas sources is most clearly visible in 5.1.3.5.12.5 and can be described as follows:

1. To provide redundancy so that one source of gas is always backed up by another
2. To provide cascade, so that the system secondary can become the source of supply when the one in service is emptied or in the event of failure of the first source. Where there is a reserve source, it automatically feeds the system in the event of failure of the primary and secondary sources.

5.1.3.5.12.6 The manifolds in this category shall have a local signal that visibly indicates the operating status of the equipment and shall activate an indicator at all master alarm panels when or at a predetermined set point before the secondary header begins to supply the system, indicating changeover has occurred or is about to occur.

The changeover to a secondary supply alarm indicates that the primary medical gas cylinder supply has reached a low-pressure setting point (for instance, when there are empty cylinders), and the cylinders need to be exchanged for full cylinders. At this point, there is only one side (the secondary supply side) of the manifold supplying medical gases to the medical gas distribution system. When a changeover alarm is indicated on the local and master alarm panels, the person in charge of exchanging cylinders needs to be alerted immediately. As soon as this person is alerted, he or she should remove the empty tanks — following the manufacturer's cylinder changing procedures — and replace them with full tanks. Then the manifold is required to automatically reset the indicators and primary and secondary operations.

5.1.3.5.12.7 If manifolds are located out of doors, they shall be installed per the manufacturer's requirements.

Not all manifolds are suitable for outdoor use. Many have electrical components that, if they get wet, can present a hazard to persons nearby. Some manifolds are not designed for the thermal stresses encountered outdoors.

FAQ Is a cylinder manifold with reserve cylinder still allowed in NFPA 99?

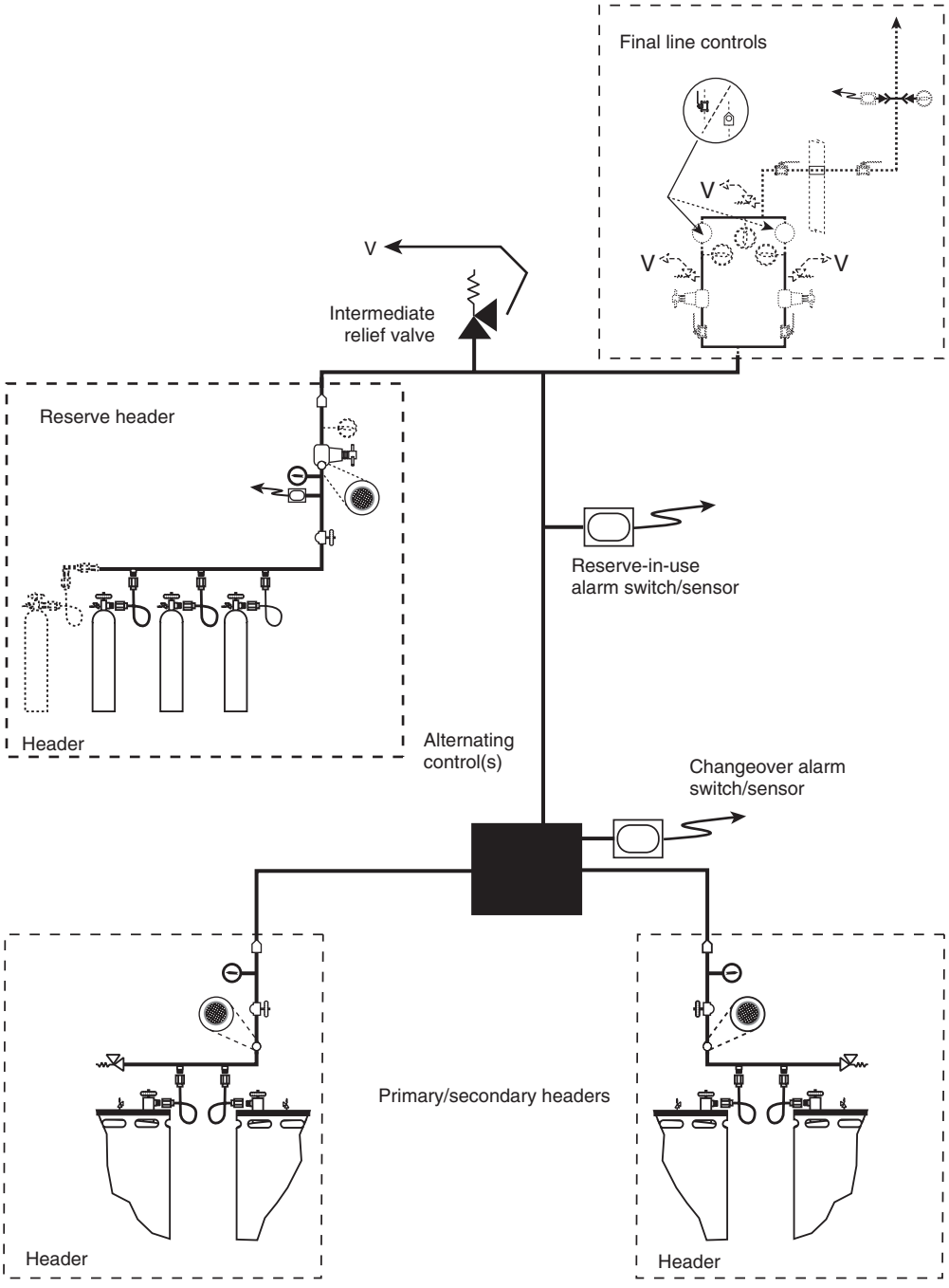
The cylinder manifold with cylinder reserve is no longer addressed directly by the code. This is not because it is no longer permitted, however, but because the code is intended to reflect minimum safe practice and not to cover every possible form. The provision of reserves above the minimum stipulated here is and has always been permitted.

5.1.3.5.13* Manifolds for Cryogenic Liquid Containers.

This paragraph allows two configurations for manifolds for cryogenic liquid containers. The first configuration includes a manifold with an equal number of liquid containers on the primary and secondary supply and an average day's supply of high-pressure cylinders for the reserve supply. The second configuration includes a primary supply of liquid containers and a secondary supply of high-pressure cylinders equal in capacity to the primary supply of liquid containers, along with an average day's supply of high-pressure cylinders for the reserve supply.

This configuration is the one exception to the "two source rule" followed throughout the code. It is necessary because of the unusual operating characteristics of liquid containers, which create scenarios where under quite normal operation it is possible to draw the containers on the primary and the reserve down simultaneously or to have them fall empty at the same time.

A.5.1.3.5.13 See Figure A.5.1.3.5.13.



Δ ***FIGURE A.5.1.3.5.13*** *Typical Source of Supply for Cryogenic Gas in Containers.*

Δ **5.1.3.5.13.1** Manifolds for cryogenic liquid containers shall be located in accordance with 5.1.3.3.1 and shall meet the following:

(1) If located outdoors, they shall be installed in an enclosure used only for the enclosure of such containers and sited to comply with minimum distance requirements in Table 5.1.3.5.13.1.
(2) If located indoors, they shall be installed within a room used only for the enclosure of such containers.

N ***TABLE 5.1.3.5.13.1*** *Minimum Separation Distance Between Portable Cryogenic Containers and Exposures*

	Minimum Distance	
Exposure	***ft***	***m***
(1) Building exits	10	3.1
(2) Wall openings	1	0.3
(3) Air intakes	10	3.1
(4) Property lines	5	1.5
(5) Room or area exits	3	0.9
(6) Combustible materials, (e.g., paper, leaves, weeds, dry grass, debris)	15	4.5
(7) Incompatible hazardous materials	20	6.1

[**55:**Table 8.7.3]

This table or the charts that preceded it in NFPA 55 have always been a requirement in NFPA 99. NFPA 55 has replaced the traditional figure with this table, and NFPA 99 has followed suit by extracting it for ease of use for the 2018 edition.

5.1.3.5.13.2 The manifolds in this category shall have their primary and secondary headers located in the same enclosure.

The primary and secondary headers for manifolds for cryogenic liquid containers are located in the same enclosure to better maintain and monitor the operations of the containers and of the manifolds.

Unlike gas cylinders, which have a consistent pressure during operations, the pressure in a liquid container will fluctuate during normal operations. Cryogenic liquid containers convert liquid to gas produced by evaporation and build pressure with pressure builders. During low-usage periods the container will build pressure, and during high-usage periods the container will have low pressure. The cryogenic liquid container also has a normal evaporation rate (NER) that averages between 1–3 percent per day.

5.1.3.5.13.3 The reserve header shall be permitted to be located in the same enclosure as the primary and secondary headers or in another enclosure compliant with 5.1.3.5.13.1.

5.1.3.5.13.4 The manifolds in this category shall consist of the following:

(1) Two equal headers per 5.1.3.5.10, each having sufficient internal or external vaporization capacity to meet the required peak flow rate and each having sufficient number of liquid container connections for one average day's supply, and with the headers connected to the final line pressure regulator assembly in such a manner that either header can supply the system

Previously, this section addressed volume but ignored flow capacity. It has been revised for the 2018 edition to add the needed requirement for flow capacity to also be addressed in the design and construction of the system.

(2) Reserve header per 5.1.3.5.10 having sufficient number of gas cylinder connections for one average day's supply, but not fewer than three connections, and connected downstream of the primary/secondary headers and upstream of the final line pressure regulators

FAQ Why can't a cryogenic container be used as the reserve supply?

The reserve header required here consists of high-pressure gas cylinders, as opposed to low-pressure cryogenic containers. Containers are not used as reserve supplies in these types of systems, because they can lose a percentage of their contents per day in boil-off (the normal evaporative rate, or NER, of the container), and therefore, they might not contain enough gas when needed, such as when the main or primary supply is depleted.

(3) Pressure relief installed downstream of the connection of the reserve header and upstream of the final line pressure regulating assembly and set at 50 percent above the nominal inlet pressure

5.1.3.5.13.5 The manifolds in this category shall include an automatic means of controlling the three headers to accomplish the following during normal operation:

(1) If provided with two liquid container headers, one cryogenic liquid header shall be the primary and the other shall be the secondary, with either being capable of either role.
(2) If provided with one liquid container header and one gas cylinder header (a hybrid arrangement), the liquid container header is the primary and the gas cylinder header is the secondary.
(3) When the primary header is supplying the system, the secondary header is prevented from supplying the system.
(4) When the primary header is depleted, the secondary header automatically begins to supply the system.

5.1.3.5.13.6 The manifolds in this category shall be equipped with a means to conserve the gas produced by evaporation of the cryogenic liquid in the secondary header (when so provided). This mechanism shall discharge the conserved gas into the system upstream of the final line regulator assembly.

A liquid container filled with oxygen has a typical NER in the range of 1–3 percent per day. If this container remains unused, the pressure will gradually build up until the safety valve begins to bleed off the excess gas pressure. The liquid container manifold in this category requires a means to capture gas that would otherwise be lost in venting. In this configuration, a liquid manifold includes an economizer, which captures a majority of the vented gas. The manifold first draws from the container that has the highest pressure in the primary headers or secondary headers. The manifold is designed to draw from the primary header only after the gas in excess of the NER is drawn away from both the primary and the secondary headers.

5.1.3.5.13.7 The manifolds in this category shall include a manual or automatic means to place either header into the role of primary header and the other into the role of secondary header, except where a liquid/gas hybrid manifold is employed.

5.1.3.5.13.8 The manifolds in this category shall include a means to automatically activate the reserve header if for any reason the primary and secondary headers cannot supply the system.

Δ **5.1.3.5.13.9** The manifolds in this category shall have a local signal that visibly indicates the operating status of the equipment and activates an indicator at all master alarms under the following conditions:

(1) When or at a predetermined set point before the secondary header begins to supply the system, indicating changeover
(2) Where a hybrid arrangement is employed, when or at a predetermined set point before the secondary (cylinder) header contents fall to one average day's supply, indicating secondary low
(3) When or at a predetermined set point before the reserve header begins to supply the system, indicating reserve is in use
(4) When or at a predetermined set point before the reserve header contents fall to one average day's supply, indicating reserve low

5.1.3.5.14* Cryogenic Fluid Central Supply Systems.

The title of this section has been changed in the 2018 edition to reflect the usage of NFPA 55. The language will not be familiar to all users of NFPA 99.

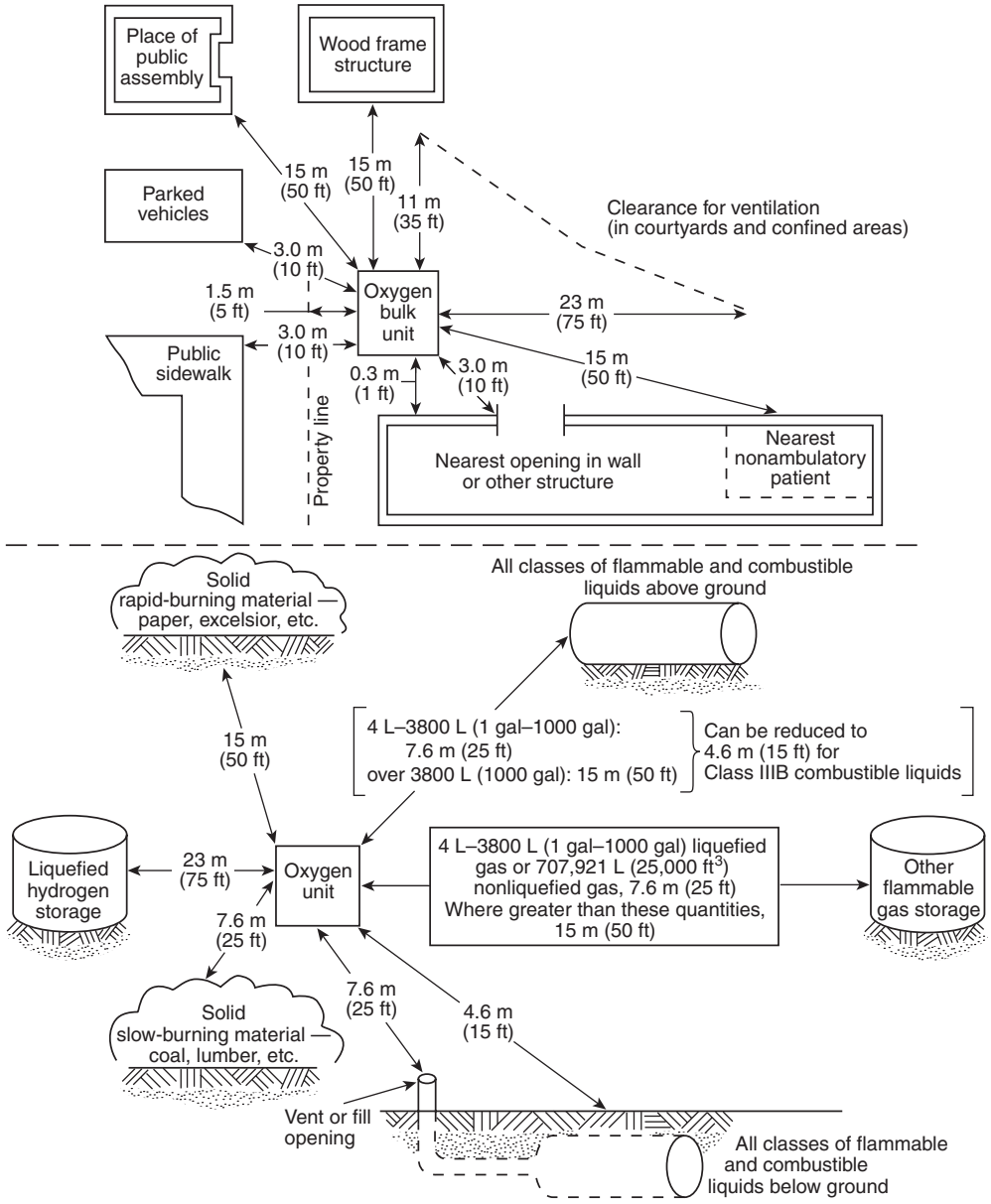
This change makes it convenient to merge the former sections on micro and small bulk liquid systems and the section on bulk liquid systems. Many requirements may appear to have been removed. However, they are still in force and can be found in NFPA 55. The rule is that general requirements that are common to all installations of cryogenic liquid systems (industrial or medical) will appear in NFPA 55, and only medically specific requirements will appear in NFPA 99. These include the dimensional requirement for maintenance [5.1.3.5.14.2(3)], the prescribed operating cascade (5.1.3.5.14.3), and the local alarms (5.1.3.5.14.4). Requirements common to any bulk cryogenic system can be found in NFPA 55. See Exhibit 5.11 for an example of storage tanks. The smaller tank in the photo acts as a reserve supply. Note the security fencing and the sign prohibiting smoking.

The supplier of bulk gas is a crucial partner in complying with these requirements. When suppliers are changed, it is vital that the facility re-examine the sizing of bulk cryogenic liquid sources. The greatest issue with planning a bulk gas source is the time required to get a tanker to the site to refill the vessel(s) once the low-level alarm is triggered. When planning, one should consider not only the time required under normal circumstances but also the time required when predictable emergencies arise. For example, where a facility is located in an active seismic zone or in the likely path of violent storms, it might be necessary to consider how much oxygen the facility will use during a period when a tanker cannot be dispatched from the usual gas production facility and another tanker must travel from a more distant facility over roads compromised by some disaster. This planning will influence and be influenced by the facility's disaster plan, which may not yet be drafted when design and construction is underway. See also Chapter 12, Emergency Management.

Δ **A.5.1.3.5.14** For bulk oxygen systems, see NFPA 55. See Figure A.5.1.3.5.14(a) and Figure A.5.1.3.5.14(b). Two possible choices of reserves are illustrated. Both are not required.

Δ **5.1.3.5.14.1** Cryogenic fluid central supply systems shall be in accordance with NFPA 55.

Cryogenic liquid systems located outdoors require compliance with NFPA 55 for sighting distance. These systems must also comply with NFPA 99 for design and construction; they must have a minimum of two entries/exits, have electrical power compliant with the essential electrical system (EES) as described in Chapter 6, and provide protection from physical damage for electrical devices.

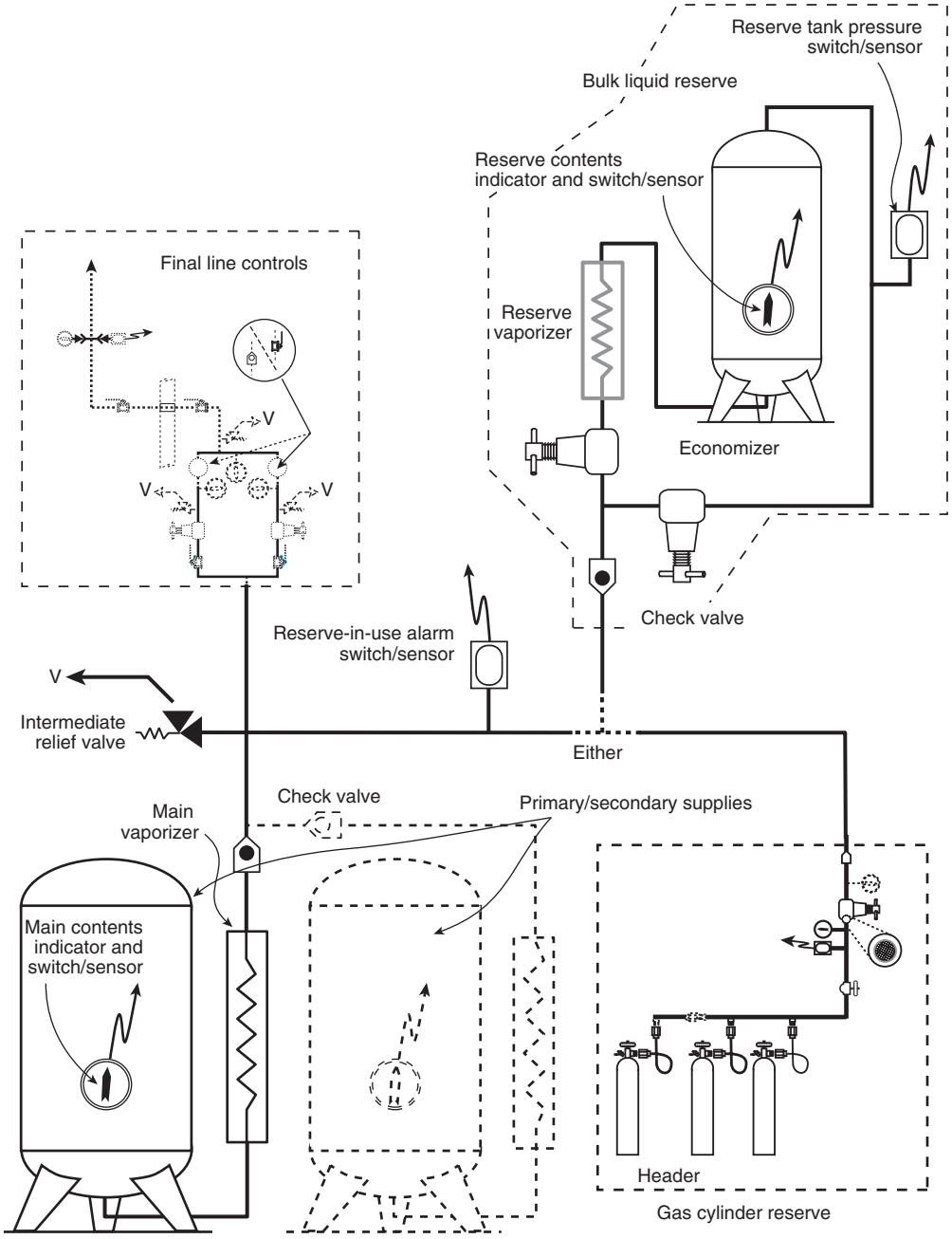


Δ ***FIGURE A.5.1.3.5.14(a)*** *Distance Between Bulk Oxygen Systems and Exposures.*

Minimum clearance is required around the equipment to allow for maintenance and repair of the system components.

Δ **5.1.3.5.14.2** Bulk cryogenic liquid systems shall have the following protections:

(1) Be installed in accordance with NFPA 55
(2) Be installed in accordance with the mandatory requirements in CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*
(3) Have a minimum work space clearance of 3 ft (1 m) around the storage container, vaporizer(s), and the cabinet opening or front side of the pressure regulating manifold for system maintenance and operation.



Δ ***FIGURE A.5.1.3.5.14(b)*** *Typical Source of Supply for Cryogenic Gas in Bulk.*

For bulk cryogenic liquid sources, compliance with this paragraph will require a reserve in the form of another cryogenic liquid vessel or gas cylinders. These reserves are to be connected before the final line controls.

5.1.3.5.14.3 Cryogenic fluid central supply sources shall include automatic means to provide the following functions:

EXHIBIT 5.11

Storage Tanks Holding Bulk Supplies of Liquid Oxygen Usually Found in Health Care Facilities.

(1) When the main supply is supplying the system, the reserve supply shall be prevented from supplying the system until the main supply is reduced to a level at or below the reserve activation pressure.
(2) When the main supply cannot supply the system, the reserve supply shall automatically begin to supply the system.
(3) Where there is more than one main supply vessel, the system shall operate as described in 5.1.3.5.13 for primary, secondary, and reserve operation.
(4) Where there are two or more cryogenic vessels, they shall be permitted to alternate (e.g., on a timed basis) in the roles of primary, secondary, and reserve, provided that an operating cascade (primary–secondary–reserve) as required in 5.1.3.5.13.5 is maintained at all times.
(5) Where a cryogenic vessel is used as the reserve, the reserve vessel shall include a means to conserve the gas produced by evaporation of the cryogenic liquid in the reserve vessel and to discharge the gas into the line upstream of the final line regulator assembly as required by 5.1.3.5.13.6.

The typical bulk cryogenic liquid central supply source is designed with a primary supply and a reserve supply. The reserve supply provides an automatic backup supply for the primary supply if the primary supply is being refilled or is down for maintenance or repairs (in this specific case, there is no provision for a secondary supply).

Where a bulk cryogenic liquid primary supply, secondary supply, and reserve supply are installed, the gas supply will follow the same operating cascade as listed for manifolds for cryogenic liquid containers (5.1.3.5.13.5). If the primary supply and secondary supply are both bulk cryogenic liquid

supplies, alternating of the primary supply and secondary supply is permitted, to provide the most economical means to conserve the gas in both supplies. Where a cryogenic vessel is used for the reserve supply, to conserve gas the reserve vessel is permitted to discharge the gas produced by evaporation of the cryogenic liquid into the medical gas line upstream of the final line regulator assembly.

Δ **5.1.3.5.14.4*** The cryogenic fluid central supply shall have a local signal that visibly indicates the operating status of the equipment and an indicator at all master alarms under the following conditions:

(1) When or at a predetermined set point before the main supply reaches one average day's supply, indicating low contents
(2) When or at a predetermined set point before the reserve supply begins to supply the system, indicating reserve is in use
(3) When or at a predetermined set point before the reserve supply contents fall to one average day's supply, indicating reserve low
(4) If the reserve is a cryogenic vessel, when or at a predetermined set point before the reserve internal pressure falls too low for the reserve to operate properly, indicating reserve failure
(5) Where there is more than one main supply vessel, when or at a predetermined set point before the secondary vessel begins to supply the system, indicating changeover

A.5.1.3.5.14.4 The local signal arose from the simple need of a maintenance person to know what is going on with any given piece of source equipment. Note that it is not an alarm in the sense of a local or master alarm. It is simply an indicator, which might be a gauge, a flag, a light, or some other possible manifestation that allows a maintenance person to stand at the equipment and know what conditions are present (e.g., which header of cylinders is in service). The elements to be displayed are typically those that will also be monitored at the master alarm, but the local signal is visible at the equipment rather than remotely.

5.1.3.5.15* Emergency Oxygen Supply Connection (EOSC). Emergency oxygen supply connections (EOSCs) shall be installed to allow connection of a temporary auxiliary source of supply for emergency or maintenance situations where either of the following conditions exist:

A.5.1.3.5.15 See Figure A.5.1.3.5.15.

If the relief valve on the emergency oxygen supply connection is moved downstream from the check valve in the emergency oxygen line, it should be connected to the system with a demand check fitting.

The emergency oxygen supply connection (EOSC) can be used as a part of the emergency operation plan (EOP) for an unplanned loss of oxygen supply. However, a risk assessment should be conducted by the facility to determine the contingency plan for vital life support and Category 1 Space. There might need to be interim measures for dealing with the loss of oxygen (e.g., high-pressure oxygen cylinders available for back feeding Category 1 Space).

FAQ What is the purpose of the emergency oxygen supply connection?

The purpose of the emergency oxygen supply connection (EOSC) required by 5.1.3.5.15 is to allow the facility to be supplied from a temporary source of oxygen while repairs to, or the replacement of, an outdoor remote oxygen supply source is being completed. The connection should be sufficiently

EXHIBIT 5.12

Emergency Oxygen Supply Inlet Used in Case of Failure of Normal Source.

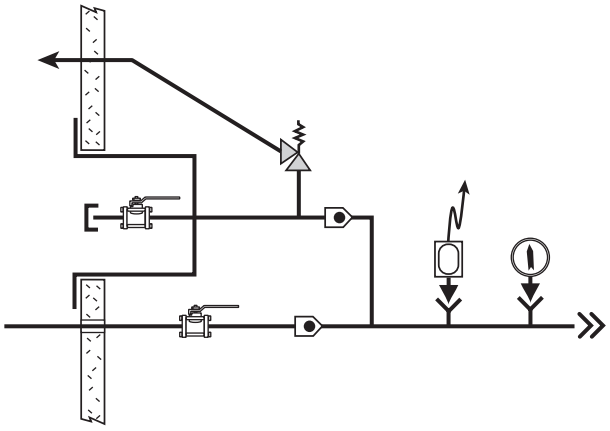


FIGURE A.5.1.3.5.15 *Emergency Oxygen Supply Connection.*

remote from the supply source to allow this temporary connection without impeding the work that is being done on the source. The connection cannot be located within the enclosure or in any area where access to the supply source would be compromised while using the connection. Exhibit 5.12 shows an example of an EOSC. Note that the EOSC and the auxiliary supply connection are similar in function.

(1) The bulk cryogenic liquid central supply system or micro-bulk cryogenic liquid system is outside of and remote from the building that the oxygen supply serves, and there is no connected in-building oxygen reserve sufficient for one average day's supply. *(See 5.1.3.5.16 for requirements for such reserves.)*

(2) Multiple freestanding buildings are served from a single oxygen source such that damage to the interconnecting oxygen line could result in one or more buildings losing oxygen supply, in which case each building is required to be provided with a separate emergency connection.

Item (2) exists to eliminate an issue unique to multi-building campuses served from a single source. If there is a danger to the main line from the source to the first building, there is an equal danger to the line from the first to the second building, from the second to the third, and so on.

5.1.3.5.15.1 EOSCs shall be located as follows:

(1) Located on the exterior of the building being served in a location accessible by emergency supply vehicles at all times in all weather conditions
(2) Connected to the main supply line immediately downstream of the main shutoff valve

The location of an EOSC on the exterior of the building being served and in an area that will remain accessible in any weather and at any time is required to allow temporary supplies, such as an 18-wheel temporary oxygen trailer or other temporary auxiliary supply of oxygen, and the needed space to access the EOSC. If work is being done on the main oxygen bulk supply, large vehicles such as cranes, trailers, or work vehicles might be parked near the bulk oxygen supply, causing the area to be very congested. Having the EOSC remote from the bulk supply and attached to the building being served allows temporary oxygen supply vehicles access to the EOSC without restrictions.

5.1.3.5.15.2 EOSCs shall consist of the following:

(1) Physical protection to prevent unauthorized tampering
(2) Female DN (NPS) inlet for connection of the emergency oxygen source that is sized for 100 percent of the system demand at the emergency source gas pressure
(3) Manual shutoff valve to isolate the EOSC when not in use
(4) Two check valves, one downstream of the EOSC and one downstream of the main line shutoff valve, with both upstream from the tee connection for the two pipelines
(5) Relief valve sized to protect the downstream piping system and related equipment from exposure to pressures in excess of 50 percent higher than normal line pressure

Placing the relief valve downstream instead of upstream of the check valve on the emergency fill line better protects the patient if someone overpressurizes the emergency low-pressure oxygen connection. If the relief valve is placed upstream and someone realizes the error of overpressurizing the patient side of the check valve, this pressure would be greater than the pressure between the emergency connection at the box and the check valve located on the emergency low-pressure oxygen connection. The relief valve would no longer protect the patient.

(6) Any valves necessary to allow connection of an emergency supply of oxygen and isolation of the piping to the normal source of supply
(7) Minimum of 1 m (3 ft) of clearance around the EOSC for connection of temporary auxiliary source

The EOSC is typically used for temporary supply connections during construction, replacement of bulk central supply sources, and in some cases emergencies, such as when a main oxygen line is accidentally dug up or broken. The 1 m (3 ft) clearance allows hospital personnel and gas suppliers the clearance necessary to connect temporary oxygen lines and supplies to the EOSC and remain safe from hazardous conditions such as natural gas manifolds, combustible solids, parked vehicles, inlets to sewers or drains, or electrical hazards.

5.1.3.5.16 In-Building Emergency Reserves (IBERs).

NFPA 99 recognizes and permits a rare but useful variation on the basic theme of providing supply for gases whose source is located remotely and is therefore subject to damage or inadvertent disconnection (such as from digging up the pipe with a backhoe during construction). Although the typical method for covering this event is the EOSC described in 5.1.3.5.15, an alternative method is a permanent small source inside the building. This concept as seen in the field and under these

provisions might be implemented either as an emergency source for an entire building or as a local source for specific areas of very high criticality such as neonatal intensive care units (NICUs), ICUs, and so on.

5.1.3.5.16.1 IBERs shall not be used as substitutes for the bulk gas reserve system that is required in 5.1.3.5.14.3.

5.1.3.5.16.2 When an IBER is provided inside the building as a substitute for the EOSC or for other purposes, it shall be located in accordance with 5.1.3.3 as follows:

(1) In a room or enclosure constructed per 5.1.3.3.2
(2) In a room or enclosure ventilated per 5.1.3.3.3

5.1.3.5.16.3 IBERs shall consist of either of the following:

(1) Gas cylinder header per 5.1.3.5.10 with sufficient cylinder connections to provide for at least one average day's supply with the appropriate number of connections being determined after consideration of the delivery schedule, the proximity of the facility to alternate supplies, and the facility's emergency plan
(2) Manifold for gas cylinders complying with 5.1.3.5.12

5.1.3.5.16.4 IBERs shall include a check valve in the main line placed on the distribution system side of the ordinary source's main line valve to prevent flow of gas from the emergency reserve to the ordinary source.

5.1.3.5.16.5 IBERs shall have a local signal that visibly indicates the operating status of the equipment and an alarm at all master alarms when or just before the reserve begins to serve the system.

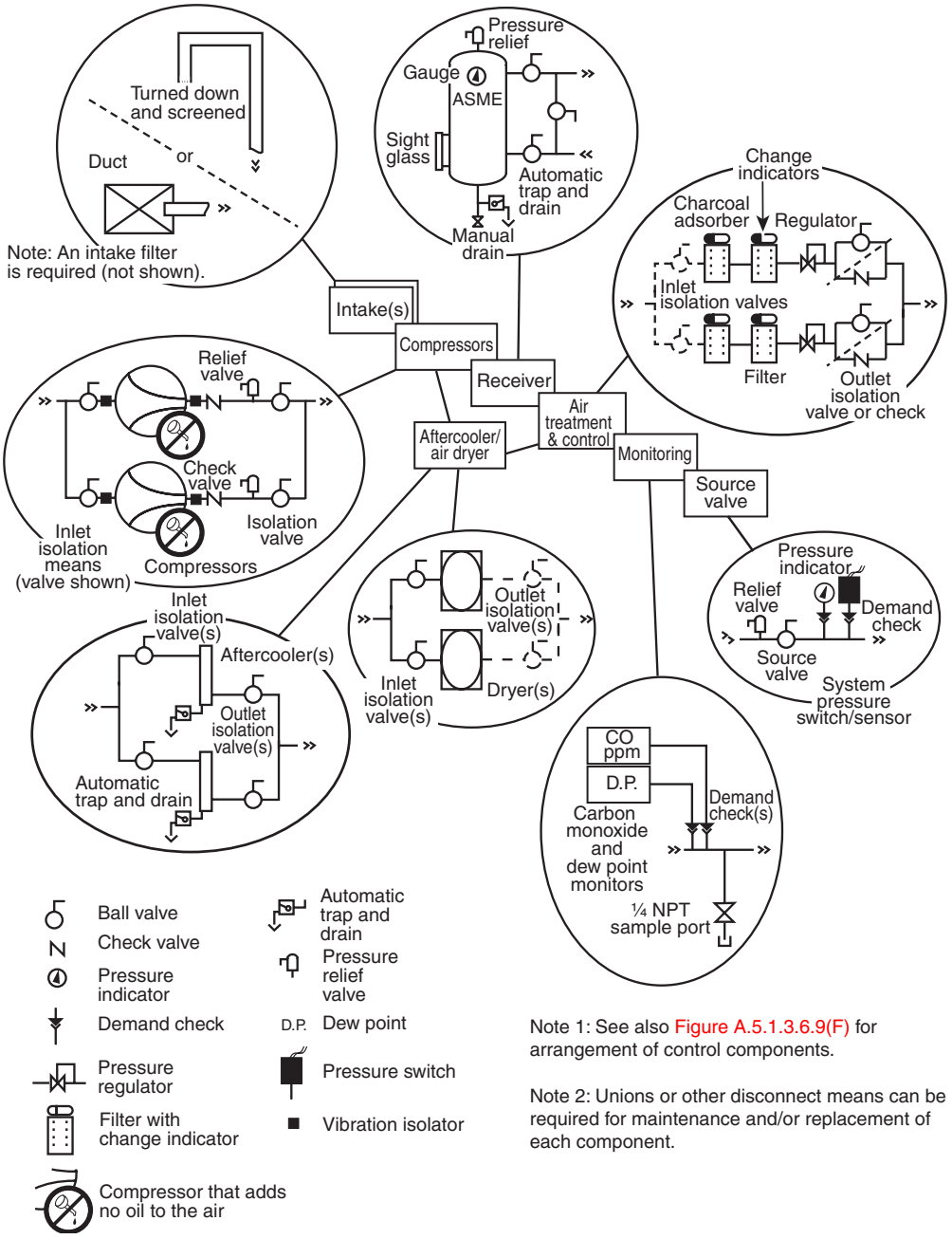
5.1.3.6* Category 1 Medical Air Central Supply Systems.

There are three types of medical air supply systems that meet NFPA 99 requirements. The first type is a medical air compressor source system, the second is a medical air cylinder source system, and the third is a medical air proportioning source system. A medical air cylinder source system is described in 5.1.3.5.12, Manifolds for Gas Cylinders. A medical air proportioning source system is described in 5.1.3.6.3.14, Category 1 Medical Air Proportioning Supply Sources.

Medical air compressor source systems are described in the paragraphs within 5.1.3.6. Due to the large volume of air that most hospitals consume, on-site production is usually the most practical and economical method of supply.

Medical air is used for a variety of patient applications. The equipment required to produce medical air suitable for patient use is quite complex. Therefore it must be carefully installed and maintained to minimize the risk of contamination or breakdown.

A.5.1.3.6 Air supplied from on-site compressor and associated air treatment systems (as opposed to medical air USP supplied in cylinders) that complies with the specified limits is considered medical air. Hydrocarbon carryover from the compressor into the pipeline distribution system could be detrimental to the safety of the end user and to the integrity of the piping system. Mixing of air and oxygen is a common clinical practice, and the hazards of fire are increased if the air is contaminated. Compliance with these limits is thus considered important to fire and patient safety. The quality of local ambient air should be determined prior to its selection for compressors and air treatment equipment. See Figure A.5.1.3.6.



Note 1: See also Figure A.5.1.3.6.9(F) for arrangement of control components.

Note 2: Unions or other disconnect means can be required for maintenance and/or replacement of each component.

Δ ***FIGURE A.5.1.3.6*** *Elements of a Typical Duplex Medical Air Compressor Source System (Category 1 Gas Systems).*

5.1.3.6.1* Quality of Medical Air. Medical air shall be required to have the following characteristics:

(1) 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.
(2) It shall meet the requirements of medical air USP.
(3) It shall have no detectable liquid hydrocarbons.

(4) It shall have less than 25 ppm gaseous hydrocarbons.
(5) It shall have equal to or less than 1 mg/m^3 (6.85 × 10^{-7} lb/yd^3) of permanent particulates sized 1 micron or larger in the air at normal atmospheric pressure.

The derivation of these requirements should be clarified. Medical air is considered by the U.S. Food and Drug Administration (FDA) and United States Pharmacopoeia to be a manufactured drug, as it is directly administered to patients for internal use. Thus, the requirements of the USP monograph for medical air are included here but not listed. They are as follows:

Oxygen % by volume: 19.5% to 23.5%
Carbon dioxide: ≤500 parts per million
Carbon monoxide: ≤10 parts per million
Nitrogen dioxide: ≤2.5 parts per million
Nitric oxide: ≤2.5 parts per million
Sulfur dioxide: ≤5 parts per million

It is interesting to note that for most of the world, most of the time, clean outdoor air easily meets these limits.

In the pharmacopeia, the implicit assumption is that medical air comes from a high-pressure cylinder. The FDA naturally follows this logic and regulates the bottling of medical air into cylinders under cGMP regulations. However, most medical air is actually produced using a compressor on site, so the other requirements in NFPA 99 are the result of experience with the compressors and the environment. Because an elevated dew point is the natural consequence of compressing air, but can lead to liquid water in the piping, it is monitored. Hydrocarbons in gaseous and liquid form can be the consequence of some compressor types and compressor failure modes, so they are controlled. Particulates are unavoidable from the inlet, from the operation of the mechanical equipment itself, and from many air dryer types, so they are also constrained.

A.5.1.3.6.1 Supply systems for medical air using compressors draw air of the best available quality from a source of clean local ambient air; add no contaminants in the form of particulate matter, odor, or other gases; and dry, filter, regulate, and supply that air only via the medical air piping distribution system for use exclusively in the application of human respiration.

The utilization of an air treatment system is the joint responsibility of the system designer, the hospital clinical and engineering staffs, and the authority having jurisdiction. Different types of compressors have characteristics that affect the selection of the type of air treatment system. Some air treatment systems impose an additional load upon the compressors that has to be accounted for in the sizing of the system (usable capacity). The compressor duty cycle has to be chosen in accordance with the manufacturer's recommendation.

The type of air compressor and air condition at the intake will govern the type of filter provided for the air compressor supply system. All filters should be examined quarterly for the presence of liquids or excessive particulates and replaced according to the manufacturer's instructions.

One procedure for reaching a decision on the quality of the medical air is the following:

(1) Test at the intake and at the sample connection valve.
(2) If the two purities agree within the limits of accuracy of the test, the compressor system can be accepted.
(3) If the air is found to exceed the values for medical compressed air as defined in 5.1.3.6.1, the facility can elect to install purification apparatus for the contaminants in question.

5.1.3.6.2* Uses of Medical Air. Medical air sources shall be connected to the medical air distribution system only and shall be used only for air in the application of human respiration and calibration of medical devices for respiratory application.

FAQ Can medical air be used for nonpatient applications?

Although medical air is now permitted for use by medical staff through supplied air respirators, the medical air compressor is not to be used for other air-driven patient therapy devices such as air cushion mattresses, for cleaning or blowing down scopes either before or after use of sterilizers, for laboratory or pneumatic temperature controllers, or for other nonpatient functions. The use of the medical air compressor to power pneumatically driven arms, booms, pendants, or columns is also inappropriate (for these applications, see 5.1.13.3.4, Instrument Air Supply Systems).

Because 5.1.3.6.2 is a requirement relating to the permitted use of medical air from an operational perspective, it is a provision that needs to be observed on an ongoing basis throughout the life of the system. Therefore, this requirement is identified in 5.1.1.5 as applying to both new and existing facilities.

Exhibit 5.13 illustrates a typical medical air compressor source system located in a health care facility's mechanical room. Exhibit 5.14 illustrates a twin-tower desiccant dryer, such as that used in compressed medical air systems to remove moisture from compressed air lines. Exhibit 5.15 illustrates duplexed medical air filters, regulators, and valving. The duplexed filters, regulators, and valving are part of the medical air controls for cleaning and pressure regulating equipment.

EXHIBIT 5.13

Medical Compressed Air Source.

A.5.1.3.6.2 It is the intent that the medical air piping distribution system support only the intended need for breathable air for such items as intermittent positive pressure breathing (IPPB) and long-term respiratory assistance needs, anesthesia machines, and so forth. The system is not intended to be used to provide engineering, maintenance, and equipment needs for general hospital support use. It is the intent that the life safety nature of the medical air be protected by a system dedicated solely for its specific use.

As a compressed air supply source, a medical air compressor should not be used to supply air for other purposes, because such use could increase service interruptions, reduce service life, and introduce additional opportunities for contamination.

5.1.3.6.3* Medical Air Compressor Supply Sources.

A.5.1.3.6.3 See Figure A.5.1.3.6.

EXHIBIT 5.14

Twin-Tower Desiccant Dryer.

EXHIBIT 5.15

Medical Air Filters and Valving.

5.1.3.6.3.1 Location. Medical air compressor systems shall be located per 5.1.3.3 as follows:

(1) Indoors in a dedicated mechanical equipment area, adequately ventilated and with any required utilities (e.g., electricity, drains, lighting)
(2) In a room ventilated per 5.1.3.3.3.3
(3) For air-cooled equipment, in a room designed to maintain the ambient temperature range as recommended by the manufacturer

The ambient temperature of the area where a medical air compressor is located is critical to the operation of the system. Compressed medical air systems subjected to low temperatures might be slow to start, encounter control line freeze problems, or condensate freeze problems. To remedy these issues,

maintenance personnel can apply heaters to key elements or simply relocate the unit to a warmer area of the plant.

On the other end of the spectrum, compressed medical air systems exposed to extremely high temperatures can experience unscheduled shutdowns, increased maintenance, and decreased lubricant life. These factors can be reduced by adjusting ventilation, using a higher performance lubricant, or relocating the compressor to a cooler location.

Δ **5.1.3.6.3.2 Required Components.** Medical air compressor systems shall consist of the following:

(1) Components complying with 5.1.3.6.3.4 through 5.1.3.6.3.8, arranged per 5.1.3.6.3.9
(2) Automatic means to prevent backflow from all on-cycle compressors through all off-cycle compressors
(3) 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
(4) Intake filter–muffler(s) of the dry type
(5) Pressure relief valve(s) set at 50 percent above line pressure
(6) Piping and components between the compressor and the source shutoff valve that do not contribute to contaminant levels
(7) Except as defined in 5.1.3.6.3.2(1) through (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

The materials for individual components and the interconnecting piping of the medical air compressor system are permitted to be of materials the manufacturer considers suitable. The exception allows for considerable variation in materials and methods of construction, however. This recognizes that making components from the same materials as the pipeline can be prohibitively expensive and in some cases impractical. Therefore, the manufacturer is allowed to select any appropriate materials for components, such as the compressor, aftercoolers, the receiver, regulators, filters, and dryers. See the Closer Look at the end of this chapter for more information on medical components.

5.1.3.6.3.3 Air Drying Equipment. Medical air compressor systems shall preclude the condensation of water vapor in the piping distribution system by air drying equipment.

Maximum and design dew points are specified elsewhere in this code. However, because there are circumstances where the stipulated dew points are not low enough to preclude the condensation of water vapor in the piping system, this provision remains in NFPA 99. See Exhibit 5.16 for a medical air compressor system showing the control panel and receiver tank. The importance of knowing the dew point in a compressed medical air line can be critical for some applications. For example, patient ventilators, blenders, and anesthesia machines rely on sufficiently dried and filtered air in order to function properly and prevent product contamination. Continuous monitoring and control of dew point is required for medical air. The risks associated with unchecked dew point levels can include equipment failure, condensation in process lines and on finished product, and the potential for bacterial formation.

5.1.3.6.3.4 Compressors for Medical Air.

The requirements for compressors are carefully written to apply broadly to any technology. These provisions have been successfully applied to a number of technologies over the years.

EXHIBIT 5.16

Medical Air Compressor System. (Courtesy of BeaconMedaes)

Before applying compressor technologies, one must first determine the basic character of the compressor. Three basic types of compressors (reciprocating, rotating, and liquid ring) are specifically recognized here, but others may be applied if they meet the requirements of this section of the code. Other types existing and yet to be invented (such as scroll, vane, diaphragm, and acoustic) can also be evaluated against the following rules: If the machine contains no free oil or grease at all, it would be appropriate to evaluate the compressor against 5.1.3.6.3.4(A)(1); if the compressor contains oil in the running gear but not in the compression chamber or air end, it must be analyzed against the requirements of 5.1.3.6.3.4(A)(2) or 5.1.3.6.3.4(A)(3).

Only one rule applies universally: If the compressor contains oil or grease in the compression chamber or air end, it fits none of the categories and is excluded.

(A)* Compressors for medical air shall be designed to prevent the introduction of contaminants or liquid into the pipeline by any of the following methods:

Δ **A.5.1.3.6.3.4(A)** Examples of 5.1.3.6.3.4(A)(1) are liquid ring and permanently sealed bearing compressors.

An example of 5.1.3.6.3.4(A)(2) is an extended head reciprocating compressor with an atmospheric vent between the compression chamber and the crankcase.

An example of 5.1.3.6.3.4(A)(3) is a rotating element compressor with the compression chamber being nonlubricated and separated from the lubricated gears by at least one shaft

seal with an atmospheric vent on both sides. The vent on the lubricated side is provided with a gravity drain to atmosphere.

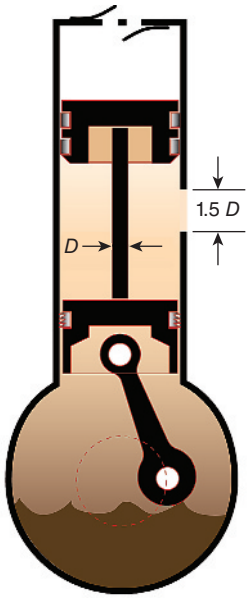
(1) Elimination of oil anywhere in the compressor (e.g., liquid ring and permanently sealed bearing compressors)
(2) Reciprocating compressors provided with a separation of the oil-containing section from the compression chamber by at least two seals creating an area open to atmosphere that allows the following:
   (a) Direct and unobstructed visual inspection of the interconnecting shaft through vent and inspection openings no smaller than 1.5 shaft diameters in size

FAQ What is the purpose of having an inspection hole sized at 1.5 times the size of the shaft diameter?

Reciprocating compressors can provide a visual indication of the failure of the critical seals between the oil-lubricated crankcase and the compression chamber, but the seal must be easily seen. The provision for an opening of 1.5 times the shaft diameter is intended to ensure that the visual inspection required can be effectively performed. Exhibit 5.17 shows an illustration of the 1.5 shaft diameter rule. The vent opening is 1.5 times the diameter of the distance piece.

EXHIBIT 5.17

Illustration of 1.5 Shaft Diameter Rule in Oil-Free Reciprocating Compressor.



   (b) Confirmation by the facility operators of proper seal operation by direct visual inspection through the above-shaft opening, without disassembly of the compressor (e.g., extended head compressors with an atmospheric vent between the compression chamber and the crankcase)

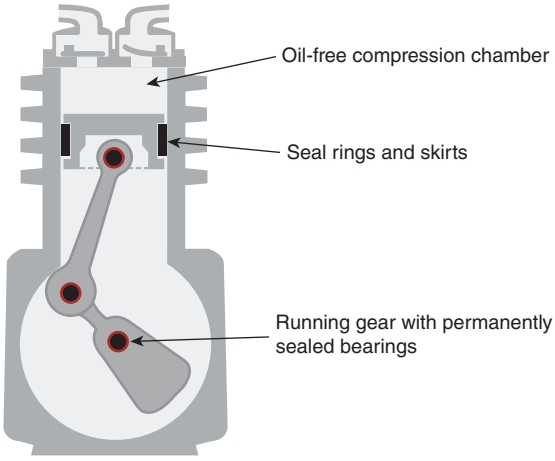
See Exhibit 5.18 through Exhibit 5.20 for examples of the different types of compressors that are discussed in 5.1.3.6.3.4(A).

(3) Rotating element compressors provided with a compression chamber free of oil that provide the following:
   (a) Separation of each oil-containing section from the compression chamber by at least one seal having atmospheric vents on each side with the vent closest to the oil-containing section supplied with a gravity drain to atmosphere
   (b) Unobstructed visualization of the atmospheric vent(s), closest to each oil-containing section, that is accessible for inspection without disassembling the compressor
   (c) Entry of the rotating shaft into each compression chamber at a point that is above atmospheric pressure
   (d) Confirmation by the facility operators of proper seal operation by direct visual inspection of the atmospheric vents

FAQ Is oil allowed in a rotating element compressor?

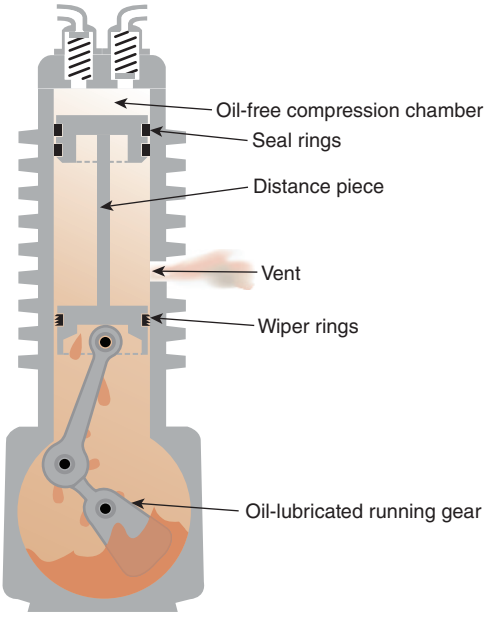
Rotating element compressors must be designed to exclude oil from the compression chamber; be provided with a method to directly check, without disassembly of the compressor, for oil migration from failure of the seals; and be provided with the same safeguards (such as filters and oil indicators) required of any oil-containing compressor.

EXHIBIT 5.18



Oil-Less Compressor.

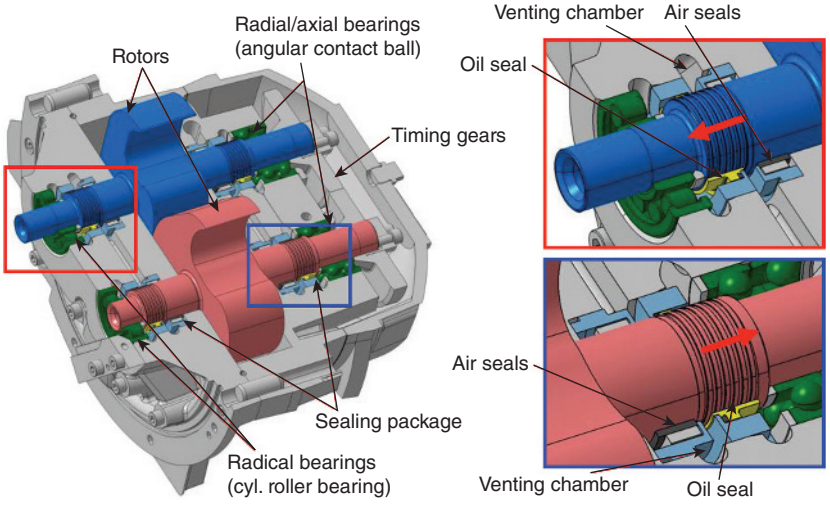
EXHIBIT 5.19



Oil-Free Compressor.

EXHIBIT 5.20

Rotary-Type Compressor. (Courtesy of Atlas Copco)



The primary difference between a compressor under 5.1.3.6.3.4(A)(2) and one under 5.1.3.6.3.4(A)(3) is the technical method permitted for inspection of the seals. Under (2) it is a physical hole, 1.5 times the shaft diameter. Under (3) it is probably a physical hole through which oil will emerge by the action of gravity or air flow. Essential in both cases is the provision for not requiring disassembly to visualize the hole, which is intended to ensure that the inspection, being easy, will be performed often.

(B) For liquid ring compressors, service water and seal water shall be treated to control waterborne pathogens and chlorine from hyperchlorination from entering the medical air.

There have been reports of chlorine and chlorine by-products appearing in medical air when liquid ring compressors have been employed. These chemical compounds are suspected as the cause of the deterioration of engineered plastic parts in ventilators, outlets, and other apparatus. It is probable, although not proven, that these compounds are appearing as a result of hyperchlorination for Legionella control and increased chlorine levels in public water supplies. Since liquid ring compressors are a favorite technology for many engineers, it is important to call attention to this possibility and thereby to preserve the quality of the medical air.

(C) Liquid ring compressors shall comply with the following:

(1) Service water and seal water of a quality recommended by the compressor manufacturer shall be used.
(2) Reserve medical air standby headers or a backup compressor shall be installed.
(3) When installed, the header shall comply with 5.1.3.5.10.
(4) When installed, the number of attached cylinders shall be sufficient for 1 hour normal operation.

(D) Compressors shall be constructed of materials deemed suitable by the manufacturer.

(E) Antivibration mountings shall be installed for compressors as required by equipment dynamics or location and in accordance with the manufacturer's recommendations.

(F) Flexible connectors shall connect the air compressors with their intake and outlet piping.

Antivibration mountings and flex connectors are important not only to the operation of the equipment but also to prevent noise transmission into the building. Consideration needs to be given to seismic requirements as well.

5.1.3.6.3.5 Aftercoolers.

Provision for and proper design of an aftercooler are crucial to assuring that medical air remains dry. It is in an aftercooler, and not in the dryer, that the overwhelming bulk of water will be removed. In addition, dryers are designed to accept a certain maximum inlet temperature [typically 37.8°C (100°F)], and for most compressor types, an aftercooler is the only reliable way to ensure that the inlet air does not exceed this temperature.

(A) Aftercoolers, where required, shall be provided with individual condensate traps.

(B) The receiver shall not be used as an aftercooler or aftercooler trap.

Provision for traps and drains for an aftercooler is good engineering practice, based on the fact that water will re-evaporate into the air if allowed to stand in the system. Immediate removal of any liquid is vital.

(C) Aftercoolers shall be constructed of materials deemed suitable by the manufacturer.

(D) Antivibration mountings shall be installed for aftercoolers as required by equipment dynamics or location and in accordance with the manufacturer's recommendations.

5.1.3.6.3.6 Medical Air Receivers. Receivers for medical air shall meet the following requirements:

(1) They shall be made of corrosion-resistant materials or otherwise be made corrosion resistant.
(2) They shall comply with Section VIII, "Unfired Pressure Vessels," of the ASME *Boiler and Pressure Vessel Code.*
(3) They shall be equipped with a pressure relief valve, automatic drain, manual drain, sight glass, and pressure indicator.

A pressure relief valve is used to control or limit the pressure in a receiver that can build up by a process upset, component or equipment failure, or fire. An automatic drain removes water and debris from the receiver; a manual drain is another means of removing water and debris from the receiver. A sight glass enables visual inspection of automatic drains to see whether they are operating properly, and a pressure indicator indicates the air pressure in a receiver.

(4) They shall be of a capacity sufficient to prevent the compressors from short-cycling.

5.1.3.6.3.7 Medical Air Dryers. Medical air dryers, where required, shall meet the following requirements:

(1) Be designed to provide air at a maximum dew point that is below the frost point [0°C (32°F)] at 345 kPa to 380 kPa (50 psi to 55 psi) at any level of demand
(2) Be sized for 100 percent of the system peak calculated demand at design conditions
(3) Be constructed of materials deemed suitable by the manufacturer
(4) Be provided with antivibration mountings installed as required by equipment dynamics or location and in accordance with the manufacturer's recommendations

The most common problem with medical air compressor systems is water accumulation. An elevated dew point is a natural consequence of compressing air with water vapor already in it. To remove this liquid, dryers are installed. Medical air dryers need to produce a maximum dew point of 0°C (32°F). The maximum dew point alarm setting of 0°C (32°F) is not set because of a medical need but, rather, because a properly operating dryer (whether refrigerant, membrane, or desiccant) should be able to maintain this dew point or lower to remove liquid accumulation in the process lines.

Each dryer is sized for 100 percent of system peak calculated demand to successfully eliminate water during times of maximum capacity demand or less. There are a number of dryers and types of dryers on the market today. The designs and materials used in a dryer to achieve the maximum dew point may be unique to each manufacturer.

5.1.3.6.3.8 Medical Air Filters. Medical air filters shall meet the following requirements:

(1) Be appropriate for the intake air conditions
(2) Be located upstream (source side) of the final line regulators
(3) Be sized for 100 percent of the system peak calculated demand at design conditions and be rated for a minimum of 98 percent efficiency at 1 micron or greater
(4) Be equipped with a continuous visual indicator showing the status of the filter element life
(5) Be constructed of materials deemed suitable by the manufacturer

Filters of any type require periodic replacement or maintenance, or both. To facilitate these tasks, filters must be duplexed. Duplexed air filters (98 percent efficient at 1 micron or greater) are required in 5.1.3.6.3.9(E) as part of the piped air system. Filters of this and even greater quality are readily available. They must achieve the criteria in 5.1.3.6.1. Selection of filters should be based on the characteristics of

the compressor, probable intake conditions, and other considerations that affect the quality of the air leaving the source equipment. Final line filters, such as those in Exhibit 5.21, require a visual indicator to ensure proper maintenance of these filters.

EXHIBIT 5.21

Medical Air Filters with Visual Indicators Showing the Status of the Filter Element Life. (Courtesy of Koffel Associates, Inc.)

5.1.3.6.3.9 Piping Arrangement and Redundancies.

Redundancy of critical components to compensate for potential failure has always been an important underlying principle in MGVS designed to comply with NFPA 99. Successive revisions have expanded the principle of redundancy to include components that could require service in the ordinary course of operation and would require shutting down the system. Through all these revisions, a single principle has emerged — single fault. The single fault principle provides that no single failure should be able to render the system inoperable.

FAQ Does NFPA 99 consider multiple fault failures?

The single fault principle is significant. Without it, the code would require consideration of multiple fault failures, and NFPA 99 could quickly begin to stack redundancy on top of redundancy, attempting to compensate for any combination of failures (if A fails and B fails, and so on), which is beyond the intent of a minimum safe standard.

(A) Component arrangement shall be as follows:

(1) Components shall be arranged to allow service and a continuous supply of medical air in the event of a single fault failure.
(2) 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.

Components are generally duplexed — or in the case of the receiver, bypassed — to allow for the medical compressed air source to continuously supply medical air to the piping distribution system

if a single fault failure occurs. The medical compressed air source needs to provide an equal level of operating reliability and air quality when any one of the redundant components is out of service.

(B) 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.

There is no upper limit on the number of compressors. There can be any number, as long as there are at least two.

(C) When aftercoolers are provided, they shall be arranged to meet either one of the following:

(1) Arranged as a duplex or multiplex set, sized to serve the peak calculated demand with the largest single aftercooler out of service, and provided with valves adequate, to isolate any single aftercooler from the system without shutting down supply of medical air
(2) Arranged one per compressor, sized to handle the output of that compressor, and valved as appropriate to allow repair or replacement with that compressor out of service but without shutting down supply of medical air

(D)* 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.

A.5.1.3.6.3.9(D) A typical example of valving the receiver is shown in Figure A.5.1.3.6.3.9(D).

(E) Dryers, filters, and regulators shall be at least duplexed, with each component sized to serve the peak calculated demand with the largest of each component out of service.

As with compressors, while two is the typical number of dryers, filters, and regulators, more than two would be allowed.

(F)* Dryers, filters, and regulators shall be provided with manual valves upstream and manual valves or check valves downstream to allow service to the components without shutting down the system in either one of the following ways:

(1) They shall be installed for each component, upstream and downstream of each component, allowing each to be individually isolated.
(2) They shall be installed upstream (source side) and downstream of components in series so as to create redundant parallel branches of components.

In addition to the valves around dryers, regulators, and filters required by 5.1.3.6.3.9 to permit their servicing, piping unions or other means should also be used to permit easier removal of these items should they need replacement.

A.5.1.3.6.3.9(F) The two configurations are equally acceptable. The components can be arranged in either of the arrangements shown in Figure A.5.1.3.6.3.9(F).

(G) A three-way valve (three-port), indexed to flow, full port shall be permitted to be used to isolate one branch or component for the purposes of 5.1.3.6.3.9(C), 5.1.3.6.3.9(D), 5.1.3.6.3.9(E), and 5.1.3.6.3.9(F).

Generally, where there are duplex sets of components, only one set will be in operation and the other will be in standby. In this situation, a three-way valve is an acceptable choice.

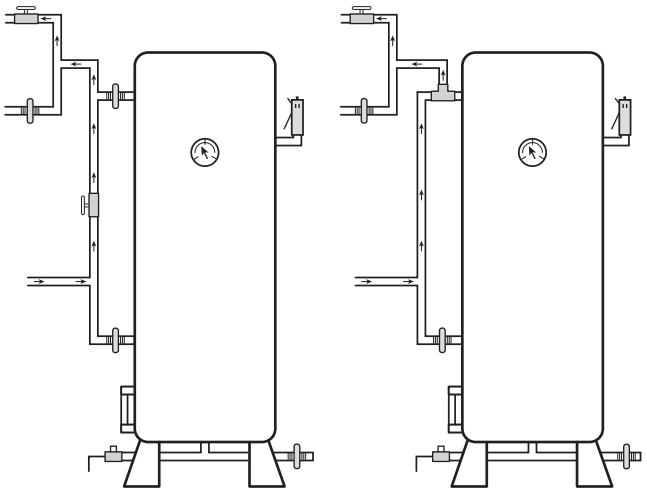


FIGURE A.5.1.3.6.3.9(D) *Receiver Valving Arrangement.*

(H) Under normal operation, only one aftercooler shall be open to airflow with the other aftercooler valved off.

(I) Under normal operation, only one dryer–filter(s)–regulator sequence shall be open to airflow with the other sequence valved off.

Δ **(J)** If the relief valve required in 5.1.3.6.3.2(5) and 5.1.3.6.3.6(3) can be isolated from the system by the valve arrangement used to comply with 5.1.3.6.3.9(F), then a redundant relief valve(s) shall be installed in the parallel sequence.

(K) A DN8 (NPS **1⁄4**) valved sample port shall be provided downstream of the final line pressure regulators, dew point monitor, and carbon monoxide monitor and upstream of the source shutoff valve to allow for sampling of the medical air.

(L) Medical air source systems shall be provided with a source valve per 5.1.4.2.

(M) Where medical air piping systems at different operating pressures are required, the piping shall separate after the filters but shall be provided with separate line regulators, dew point monitors, relief valves, and source shutoff valves.

The practice of operating the pipeline system at higher pressures with remote air line regulators (distributed pressure systems) is not permitted for any medical gas pipeline. The medical air is to be piped throughout the facility at a gauge pressure of 345 kPa to 380 kPa (50 psi to 55 psi). The piping network needs to be designed adequately to accommodate this pressure at the far reaches of the facility.

5.1.3.6.3.10* Electrical Power and Control.

N **A.5.1.3.6.3.10** The intent of 5.1.3.6.3.10 is to ensure that the pressure at the station outlet is steady and maintained safely within the limits of Table 5.1.11. Traditionally, line pressure regulators were required here as the only allowed control-of-pressure devices. Other methods of control are becoming possible (e.g., variable speed controlled on pressure). The present wording is intended to achieve the performance requirement *(see Table 5.1.11)* and to allow not only traditional pressure regulators but other control methods as well.

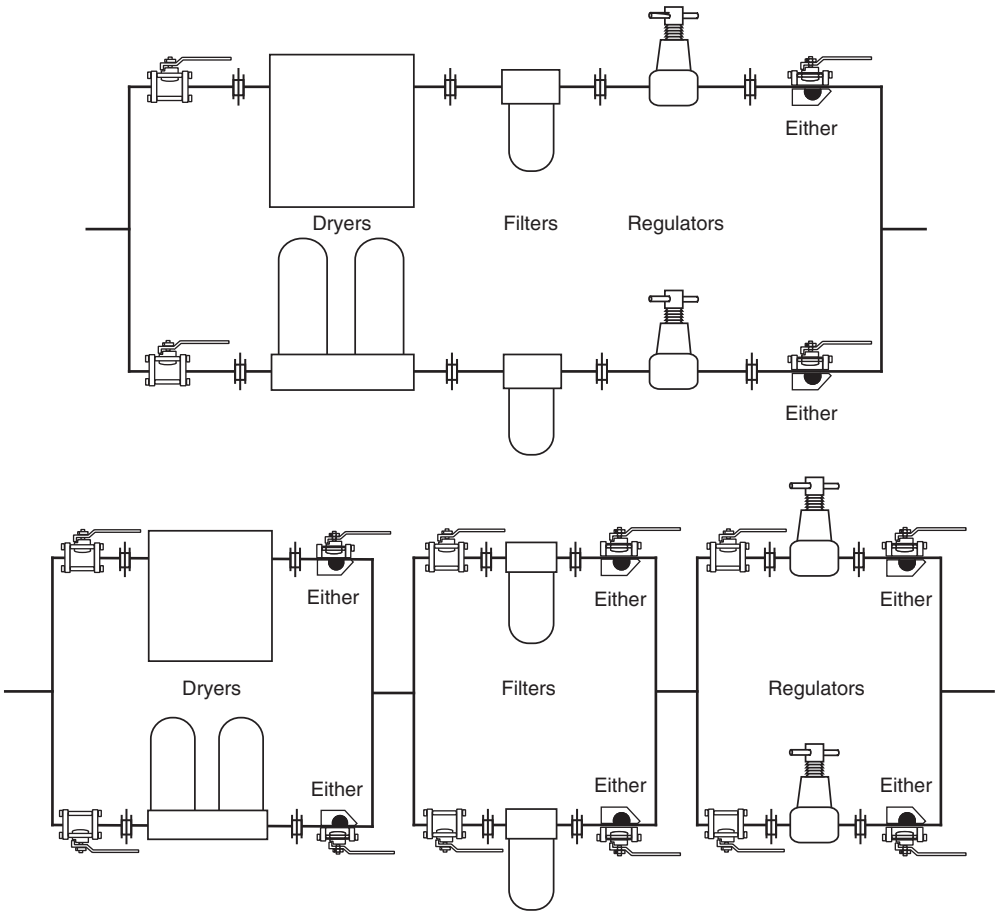


FIGURE A.5.1.3.6.3.9(F) *Alternate Valving Sequences for Line Controls in Medical Air.*

Δ **(A)** Medical air source systems shall be controlled to ensure continuous supply of medical air at pressures consistent with Table 5.1.11 under all conditions of system use as follows:

(1) Automatic activation of compressor(s) as necessary to supply the demand.
(2) Managing the operation to equalize wear on all compressors. Where this equalization is achieved manually, the facility staff shall arrange a schedule for manual alternation.

Alternation of compressors (automatically or manually) is required because it allows even wear on both compressors, thereby extending the life of the compressors and reducing the probability of system failure at any given time. Whether compressor alternation is automatic or manual, activation of the nonoperating compressor must be automatic in the event of operating compressor failure or overload. This alteration is identified by 5.1.1.5 as applying to both new and existing facilities.

(B) Controls shall provide the following functions:

(1) Where medical air source systems having two or more compressors employ any electrical circuit device that upon failure could prevent supply of medical air, the controls shall be provided with an automatically activated alternative method for ensuring supply (e.g., redundant component(s), an alternate electrical supply path, or other equivalent method).

(2) Control circuits shall be arranged in such a manner that isolation of one compressor or component from the system (e.g., for maintenance or repair) does not interrupt the operation of other compressor(s) or component(s).
(3) Automatic restart function shall be included, such that the supply of medical air will resume normally after power interruption without manual intervention.

FAQ Why is it important to have the compressors restart after a power interruption?

Medical air compressor sources are life-support systems that must provide an uninterrupted supply of medical air for the piped distribution system serving patients. The source of electrical power must be provided from the critical equipment branch of the emergency power system and function to automatically restart the medical air compressors upon interruption of primary power.

(C) Each compressor motor shall be provided with electrical components including, but not limited to, the following:

(1) Dedicated disconnect switch installed in the electrical circuit ahead of each motor starter
(2) Motor starting device
(3) Overload protection

(D) Medical air compressor system controls shall be provided with electrical systems including, at a minimum:

(1) Built-in disconnect means shall be included to allow appropriate operation of multiple compressor systems and protect service personnel from exposure to live voltages.
(2) Control circuits shall be arranged so that failure of any component of the control circuit, or shutdown of one compressor (e.g., for service), does not interrupt automatic operation of the standby compressor.
(3) An automatic restart function shall be included, such that the compressor(s) will restart after power interruption without manual intervention.
(4) Where components are common to more than one control circuit (e.g., autodrains) the common device shall be provided with electrical protection to prevent loss of the control circuits(s) in the event of short circuit in the device.

Two new provisions are included here. Item (1) deals with electrical safety for the worker, a subject generally not detailed in NFPA 99. This particular provision is related to *NFPA 70E®, Standard for Electrical Safety in the Workplace®*, and is included due to the specific hazard of arc flash, which has occurred with high-voltage medical gas equipment. Item (4) deals with a rare but serious kind of failure that is intrinsic in the required design of the controls as outlined in (B) and (C). Under those clauses, it is necessary for the controls to have redundant electrical supply pathways in the controls (but note: not necessarily redundant supplies). In implementing this rule, there sometimes will occur single devices that bridge both pathways. Thus, when one pathway fails, the requirement is to switch to the redundant pathway [5.1.3.6.3.10 (B)(1)]. The device can then continue to be powered from the alternate path. However, if the device *itself* is the cause of the electrical failure, then switching can also take down the other pathway. The new item (4) is a reminder to consider this possibility and guard against it.

Δ **(E)** Electrical installation and wiring shall conform to the requirements of *NFPA 70*.

N **(F)** Emergency electrical service for the compressors shall conform to the requirements of the essential electrical system as described in Chapter 6.

5.1.3.6.3.11 Compressor Intake.

No decision will have greater impact on the continued quality of medical air than the location of the intake. Location is a decision unique to each site, and the dimensions cited should be considered as the starting point in a detailed site investigation. Occurrences of contaminated air are frequently found to be associated with intake placement close to or downwind of vacuum exhausts, WAGD exhausts, laboratory or sanitary vents, HVAC exhausts, loading docks, or other sources of polluted air.

In recent editions, the dimensions have changed to reflect different risks associated with different forms of opening. This increases the distance from sources likely to discharge contaminants from 3 m to 7.6 m (10 ft to 25 ft), but it leaves the distance to doors and windows (from where noxious contamination is not likely) unchanged.

If a building has a series of stepped (staggered) roofs, the best location for the intake becomes more complicated to determine. Meeting all the requirements of this section does not necessarily mean locating the intake above the highest roof. Factors such as the size of each roof, the distance to the nearest doors and windows, and the location of other equipment on the roof all influence the final location(s).

(A) The medical air compressors shall draw their air from a source of clean air.

(B) The medical air intake shall be located a minimum of 7.6 m (25 ft) 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.

(C) The medical air intake shall be located a minimum of 6 m (20 ft) above ground level.

(D) The medical air intake shall be located a minimum of 3.0 m (10 ft) from any door, window, or other opening in the building.

(E) 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:

(1) This alternate source of supply air shall be available on a continuous 24-hour-per-day, 7-day-per-week basis.
(2) Ventilating systems having fans with motors or drive belts located in the airstream shall not be used as a source of medical air intake.

Periodic tests should be conducted to verify that the alternative source is equal to or better than the ambient source and that it remains that way. Conditions can change, causing the source of air to become unacceptable for medical air use. The air characteristics to be tested can be determined by reference to 5.1.3.6.1.

NFPA 99 requires that alternative sources of air be available 24 hours per day. This means such sources need to be maintained at all times. Many air-handling systems that might be used as a source of air are shut off during nonpeak times, thus lowering the quality and quantity of air within the system.

Concerns exist about air taken from air ventilating systems that have motors and bearing systems in the air duct. On failure, these systems can generate noxious vapors that would be taken in by the compressor, and thus they are prohibited to be used as air sources.

(F) Compressor intake piping shall be permitted to be made of materials and use a joining technique as permitted under 5.1.10.2 and 5.1.10.3.

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

(1) The common intake is sized to minimize back pressure in accordance with the manufacturer's recommendations.
(2) 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).

Intake sizing is particularly critical when joining intake lines together. Running a common intake for several compressors is often done when intakes would have to be piped considerable distances. When joining several air intakes, care must be taken to size the intake piping and intake filter(s) appropriately. In addition, isolation means are necessary to prevent room air from being drawn into the operating compressor(s) when other compressors are removed from service. Without proper isolation or valving at compressors, equipment can be damaged and pipelines contaminated.

For example, air compressors are designed to pull (or force) air into the compressor from atmospheric air. If two medical air compressors are commonly joined together to one air intake without proper isolation or valving of the individual compressors, air will be pulled from the air intake and the standby air compressor. This suction of air on a standby air compressor's inlet components could damage the air compressor, preventing it from operating properly.

The fundamental design principle for medical air compressors is that any single compressor must be able to be removed from service for maintenance or replacement without compromising the ability of the remaining compressor(s) to meet the demand. The actual sizing of the medical compressed air system requires a detailed engineering review, along with knowledge of NFPA 99.

Because repair and maintenance are a normal part of system operation, each compressor must be provided with a shutoff valve. Typically these are manual valves.

(H) 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.

FAQ What kind of materials can be used for the screening of the intake?

Suitable noncorroding materials that can be used for the screening of the intake might include galvanized steel, plastic, stainless steel, or other similar materials.

5.1.3.6.3.12 Operating Alarms and Local Signals. Medical air systems shall be monitored for conditions that can affect air quality during use or in the event of failure, based on the type of compressor(s) used in the system.

Paragraphs 5.1.3.6.3.12(A) through (E) define different types of air compressor technologies used to produce medical air. Each type of air compressor requires monitoring of its conditions to function appropriately to produce medical air. Continual monitoring of these conditions is critical to achieve proper operation and maintenance of the air compressors.

Required local alarms must be individually displayed locally, such as at the compressor site, but they can be drawn to the master alarms as a group. Typically, this grouped signal might read

"medical air system fault" and would cause a technician to examine the compressor to determine which of the several advisory alarms had been activated. Only certain signals, such as a dew point signal, require their own signal connected to each master alarm panel. See also the requirements for local alarms in 5.1.9.5.

(A) A local alarm complying with 5.1.9.5 shall be provided for the medical air compressor source.

Δ **(B)** Where liquid ring air compressors, compressors having water-cooled heads, or water-cooled aftercoolers are used, air receivers shall be equipped with a high water level sensor that shuts down the compressor system and activates a local alarm indicator. *[See 5.1.9.5.4(8).]*

Liquid ring compressors introduce several unique hazards, the first being water contamination, such as the chlorine and chlorine by-products found in the treatment of water that is supplied to a liquid ring air compressor. Chlorine can deteriorate plastic parts that come into contact with the air stream. Failure of the water/air separation mechanism(s) on a liquid ring compressor can cause "freeze up" or seize the unit from operating. Also, if too much water is run through the liquid ring compressor, such as when a water supply solenoid valve fails, the air compressor system or components may "push" water into the medical air stream and the patient's pipeline distribution network, possibly sending water to the medical air outlets and flooding ventilators and blenders. Any compressor system using water as a cooling medium (such as in the compressor head, an aftercooler, or the dryers) could also suffer infiltration of water into the system, which is the origin of the requirement for a high-water switch in the receiver.

A more subtle hazard exists with any compressor if the receiver simply fails to drain. In such a case, water can accumulate over time and ultimately fill the receiver, causing water to travel alongside the medical air throughout the pipeline distribution network.

Δ **(C)** Where liquid ring compressors are used, each compressor shall have a liquid level sensor in each air–water separator that, when the liquid level is above the design level, shuts down its compressor and activates a local alarm indicator. *[See 5.1.9.5.4(9).]*

Each compressor cylinder must have an individual switch/sensor; for example, if the compressor has three cylinders, three switches are to be provided. Even if the entire machine is monitored, a contamination hazard can result from failure of a single cylinder where there is more than one. That hazard is not adequately addressed by a single switch, which could detect only the combined output of the many cylinders.

Δ **(D)** Where nonliquid ring compressors compliant with 5.1.3.6.3.4(A)(1) are used, the air temperature at the immediate outlet of each compressor cylinder shall be monitored by a high-temperature sensor that shuts down that compressor and activates a local alarm indicator *[see 5.1.9.5.4(10)]*. The temperature setting shall be as recommended by the compressor manufacturer.

(E) Where compressors compliant with 5.1.3.6.3.4(A)(2) and 5.1.3.6.3.4(A)(3) are used, the following requirements shall apply:

(1) The air temperature at the immediate outlet of each compressor chamber shall be monitored by a high-temperature sensor that shuts down that compressor and activates a local alarm indicator *(see 5.1.9.5.4)*, the temperature setting shall be as recommended by the compressor manufacturer.
(2) Coalescing filters with element change indicator shall be provided.

(3) Charcoal absorber shall be provided.
(4) Gaseous hydrocarbons shall be monitored on a quarterly basis.

The requirement for coalescing filters recognizes that, even with all other safety provisions in place, oil vapor is a possibility in these machines and could pass unnoticed into the system. Coalescing filters provide a last defense against the oil vapors entering the pipeline.

(F) When the capacity of the medical air system not in use is less than the equivalent capacity of one compressor, a local alarm shall activate *[see 5.1.9.5.4(1)]*. This signal shall require manual reset.

The code was originally written around one type of control — on/off operation defined by pressure. Control methods for compressors and pumps are becoming more sophisticated and now can control for other conditions (e.g., flow) and in a variety of modes (e.g., continuous run with VSD). The revised text accounts for these developments while preserving the performance characteristics inherent in the original text.

Conditions that this alarm might indicate are all important and need to be checked. However, they can be checked only at the compressor site, which is why this alarm is not mandated to signal at the master alarms.

Δ **5.1.3.6.3.13 Medical Air Quality Monitoring.** Medical air quality shall be monitored downstream of the medical air regulators and upstream of the piping system as follows:

(1) Dew point shall be monitored and shall activate a local alarm and all master alarms when the dew point at system delivery pressure exceeds +2°C (+35°F).

The local alarm will apply to the dew point monitor for all systems and to any air treatment system where installed. This alarm must be echoed at the master alarm panel. (See 5.1.9.2.)

Where a facility uses desiccant-type dryers, some of which provide dew points in the –40°C to –73°C (–40°F to –100°F) range, it is important to remember that the dew point alarm system provided with these systems will need to be capable of monitoring a value that low. Dew point monitors that read out "below range" are not appropriate.

The dew point alarm set point represents the nominal performance of a refrigerated dryer [1.7°C (35°F)], with 4°F added to allow for individual variation in systems. NFPA 99 recognizes that to consistently attain this dew point, the system should be designed for better performance. Therefore, the design dew point [see 5.1.3.6.3.7(1)] is "below the frost point."

The question of the pressure at which dew point is to be expressed is decided by reference to the preferred location of the sensor, which is immediately downstream of the pressure regulators and filters. This location should experience only system pressure, so dew point is expressed at system gauge pressure [3.9°C (39°F) at 345 kPa (50 psi) is equivalent to –15.6°C (4°F) at 0 kPa (0 psi)].

The term *pressure dew point* provides one criterion for dew point readings. Although it is relatively easy to convert Celsius to Fahrenheit, it is more difficult to convert atmospheric dew point readings to pressure dew point readings. It is the intent of the code to set a maximum for the dew point of the medical air within the pipeline at pressure, not after it expands and is expelled into the room (i.e., at atmospheric dew point). The pressure dew point at compressor operating pressures will rise and fall with operation of the compressor. For instance, some compressors energize at a gauge pressure as low as 517 kPa (75 psi) and turn off at 695 kPa (95 psi). Pressure dew points at these gauge pressures would be higher than the dew point of the medical air downstream of the regulator at 345 kPa (50 psi). The designer of an air system must consider this phenomenon. Incidentally, this is how a refrigerant dryer can be brought to comply with NFPA 99, and it is how the "below frost point" criteria were chosen.

Closer Look

Dew Point

The basic intent of setting a dew point is the preclusion of liquid water forming in the pipes. Users are advised that the minimum dew point that will prevent water from forming in pipes varies from system to system. Under some conditions, the dew points set in this here might not be sufficiently low.

Chapter 5 uses the term *dew point* frequently. The following is offered for those readers not familiar with the term.

In a compressed air system, the temperature at which water vapor begins to condense into liquid is called the dew point. As an example, air with a dew point of 1°C (33°F) will form dew on the outside of a glass of ice [freezing point is 0°C (32°F)]. The dew point of the air does not necessarily have any relationship to the actual temperature of the air [e.g., air at a temperature of 37.8°C (100°F) can still have a dew point of –17.8°C (0°F)].

Whether water forms, however, is very closely related to the temperature of the air. Air cooled below its dew point will form water; air cooled below its frost point will form ice. For example, if air dried to a dew point of 1.6°C (35°F) pressure dew point (PDP) is blown into a room where the temperature of the ambient air is 21°C (70°F), the expelled air will not give up any moisture. However, if the same treated air is expelled into a room where the ambient air is only –6.6°C (20°F), water will be formed because the ambient temperature is below the dew point to which the air has been treated.

For another example, consider a dryer drying the air only to a dew point of 15.5°C (60°F) PDP. The pipeline distributing this air has been installed inside the facility but on an exterior wall that has not been adequately insulated. The pipeline is exposed to temperatures of 1.6°C to 4.4°C (35°F to 40°F). It is quite possible that water will form as the air passes through this colder area. That water will eventually be expelled out from the patient outlets as liquid.

Refrigerated dryers are common in many health care facilities in the United States. These dryers are subject to re-entrainment of water after it leaves the refrigerated portion of the dryer, and thus, it often cannot perform as required under low-flow conditions. For this reason, the code states "under all conditions of flow."

Regenerative dryers employ an adsorptive desiccant that attracts and holds moisture on its surface. These units have two towers: one that collects moisture, while the other is dried of moisture that it has collected. A circuit reverses the roles of the towers after a pre-set time, and dry air is used to drive collected moisture off of the desiccant.

These regenerative dryers are capable of discharging air at much lower dew points than the code requires [as low as –73.3°C (–100°F)] and are not subject to a low-flow performance penalty, but they do use air for internal regeneration, which can be objectionable, particularly on systems with highly variable usage.

Technologies exist to reduce the objectionable aspects of both types of dryers. There are other dryer technologies in use, but they are rare enough not to merit further consideration at this time.

(2) Carbon monoxide shall be monitored and shall activate a local alarm when the CO level exceeds 10 ppm. *[See 5.1.9.5.4(2).]*

Although other gases of concern are listed in 5.1.3.6.1, carbon monoxide (CO) is the only one that is continuously monitored, for two reasons: monitors are widely available and not excessively expensive or complex, and CO is a good indicator gas, meaning that its presence often is the best indicator of air quality problems in general. Air quality can vary from place to place and day to day. Local air quality can be determined only through knowledge of local conditions and testing at the intake. Testing could be necessary on a regular basis. Where the quality of the intake air is unreliable, specific air treatment devices can be desirable. Where installed, these devices should be monitored and alarmed. Such devices do increase the frequency and complexity of maintenance.

(3) Dew point and carbon monoxide monitors shall activate their individual monitor's signal at the alarm panels where their signals are required when their power is lost.

5.1.3.6.3.14 Category 1 Medical Air Proportioning Supply Sources.

Essentially, medical air proportioning systems take oxygen USP and nitrogen NF, typically sourced from two bulk systems, and blend them into a 20 percent to 80 percent mixture, creating "synthetic air." The resulting mixture is very dry and very pure and will pass as medical air USP. Thus it can be used as an alternative to air from cylinders or from a compressor system.

This technology has been understood for decades and is commonly used to produce various gas mixtures. The economics of utilizing such a system may generally be less favorable than a compressed air source, but exceptions might include situations where precise control of purity is needed and trace gases are entirely unacceptable. Then the additional purification apparatus, monitoring, and maintenance required to achieve the same result from compressor-generated air, as well as the failure risk that the additional elements involve, might make a proportioned air system worth consideration. The facility should conduct an analysis to determine the most effective system to meet their particular needs.

Δ (A) General.

These paragraphs of the code provide details of the process and systems required to generate medical air from mixing gaseous oxygen USP and nitrogen NF. Similar to medical compressed air produced from compressors on site, medical synthetic air is manufactured on site. Both medical synthetic air and medical air produced from air compressors must meet the quality of medical air characteristics listed in 5.1.3.6.1.

Medical synthetic air is generated by mixing gaseous oxygen USP and nitrogen NF in a proportioning system or mixing panel at pre-set pressures to ensure that the final result mixture is always correct. The mixture is continuously analyzed and monitored to check the mixture; the system shuts down automatically if the mixture deviates from its specification, and the reserve supply must be activated automatically.

(1) Medical air reconstituted from oxygen USP and nitrogen NF, produced using proportioning system(s), shall be required to meet the following:
   (a) The quality of medical air shall be in accordance with 5.1.3.6.1.
   (b) The system shall be capable of supplying this quality of medical air, per 5.1.3.6.1, over the entire range of flow.
   (c) The system shall produce medical air with an oxygen content of 19.5 percent to 23.5 percent.
   (d) The medical air shall be cleared for marketing by the FDA or approved by the FDA.
(2) The medical air proportioning system shall operate automatically.
(3) The mixture shall be analyzed continuously, and a recording capability shall be provided (e.g., via data port).
(4) The analyzing system specified in 5.1.3.6.3.14(A)(3) shall be a dedicated and an independent analyzer used to control the medical air proportioning system.
(5) If the mixture goes out of specification, an alarm shall be activated automatically, the primary medical air proportioning system shall be disconnected, and the reserve supply shall be activated.
(6) The system shall be arranged such that manual intervention is necessary to correct the composition of the mixture before reconnecting the medical air proportioning system to the health care facility pipeline system.
(7) If dedicated sources of oxygen USP and nitrogen NF supply the medical air proportioning system, reserve sources for the oxygen and nitrogen shall not be required.

(8) If dedicated sources of oxygen USP and nitrogen NF supply the medical air proportioning system, they shall not be used as the reserves for oxygen and nitrogen systems supplying the pipelines of the health care facility.

(9)* If the sources of oxygen USP and nitrogen NF that supply the medical air proportioning system are the same sources that supply the health care facility, engineering controls shall be provided to prevent cross contamination of oxygen and nitrogen supply lines, as provided in 5.1.3.5.8.

(10) A risk analysis and approval from the authority having jurisdiction shall be required.

Δ **A.5.1.3.6.3.14(A)(9)** The proportioning system should be monitored for conditions that can affect air quality during use or in the event of failure, based on the type of proportioning system design used in the system, including monitoring for the following systems and conditions:

(1) Where proportioning systems used are configured with a primary proportioning system and a reserve medical air manifold per 5.1.3.5.12

(2) Where proportioning systems used are configured with a primary proportioning system and a reserve proportioning system

(3) Where proportioning systems used are configured with a primary proportioning system and a reserve medical air compressor per 5.1.3.5.3

(4) Alarm at a predetermined set point, before the reserve supply begins to supply the system, indicating reserve supply in use

(5) Alarm at a predetermined set point, before the reserve supply contents fall to one average day's supply, indicating reserve low

Water-in-receiver alarms are not required for a proportioning system.
The engineering controls should include, as a minimum, the following:

(1) Engineering controls should be in place when the sources of oxygen USP or nitrogen NF, or both, are the same sources as those supplying the oxygen USP or nitrogen NF pipelines, or both, for other uses within the health care facility, and the following should apply:

(a) In cases where a new supply system is installed, or in cases where one or more bulk supplies are used to supply the mixer, bulk systems and vaporizers should be sized for total peak demand flow, including peak demand flow to the mixer and any other areas of utilization.

(b) Operating limits should be established, at a minimum, for the oxygen and nitrogen source pressures, both high and low, and for the medical air oxygen concentration, both high and low, based upon USP specifications. A process upset can be defined as an excursion in the process windows established for oxygen and nitrogen source pressures or medical air oxygen concentration, or both. A means to detect excursion from these process limits and power failure should be provided.

(c) At least one dedicated valve or other control should be installed in the proportioning system and/or the line(s) between the oxygen and/or nitrogen supply system(s) and proportioning system. The purpose of the dedicated control(s) is to prevent the cross contamination of the oxygen and nitrogen lines due to product backflow as follows:

i. The control(s) should be separate from the valve(s) or other device(s) used to control oxygen flow and nitrogen flow in normal operation.

ii. The control(s) should not cycle in normal operation.

iii. If installed in the line(s) between the oxygen or nitrogen supply system(s), or both, and proportioning system, upon activation of the control(s), an alarm should be sent to the facility. The control(s) cannot exist exclusively via the use of check valves.

(d) In the event of a process upset, the dedicated control(s) should either positively isolate the supply of oxygen or nitrogen, or both, from the mixer, or the dedicated control(s) should reduce the mixer pressure to less than half of the minimum final line pressure values, each, for the oxygen and nitrogen lines. In the event of a process upset, the control(s) should operate. Manual reset should be required to restart the proportioning system.

(B) Location. The medical air proportioning system shall be located per 5.1.3.3 as follows:

(1) The medical air proportioning system's supply of oxygen USP and nitrogen NF shall be located per 5.1.3.3 and NFPA 55, as applicable.
(2) The mixing device and controls, analyzers, and receivers shall be located indoors within a room or area per 5.1.3.3.1.
(3) The indoor location shall include atmospheric monitoring for oxygen concentration.
(4) The indoor location shall be constructed with all required utilities (e.g., electricity, drains, lighting) per *NFPA 5000*.
(5) The indoor location shall be ventilated and heated per Chapter 9 and the manufacturer's recommendations.

The primary source of supply for medical synthetic air is oxygen USP and nitrogen NF. The typical supplies are bulk cryogenic liquid sources. The bulk oxygen and bulk nitrogen will normally be installed outside and follow NFPA 55 and NFPA 99 location and installation requirements for bulk gas installations. The proportioning system mixing device, controls, analyzers, and receivers are installed in an enclosure following the requirements of 5.1.3.3.1.

(C) Required Components. The medical air proportioning system shall consist of the following:

(1) Supply of oxygen USP and supply of nitrogen NF as follows:
   (a) The supply lines shall be filtered to remove particulate entering the proportioning system.
   (b) The minimum safe supply gas temperature and recommended local signal shall be specified by the medical air proportioning system manufacturer.
(2) Mixing device with analyzers and engineering controls per manufacturer's recommendations to include, as a minimum, the following:
   (a) At least two oxygen analyzers capable of independently monitoring oxygen concentration
   (b) Mechanism where each analyzer based upon nonconforming oxygen concentration is capable, directly or via other medical air proportioning system controls, of automatically shutting off the supply from the medical air proportioning system to the medical air piped distribution system and activating the reserve supply
   (c) Mechanism where each analyzer, based upon nonconforming oxygen concentration, is capable, directly or via other proportioning system controls, of automatically shutting off the supply of oxygen and nitrogen to the proportioning system and activating the reserve supply
   (d) Provision for manual resetting of the proportioning system after detection of nonconforming oxygen concentration and subsequent shutdown once conforming oxygen concentration is established, in order to re-establish flow to the medical air piping system
   (e) Means of verifying the performance of the analyzers by reference to an air standard, with known traceable oxygen content
(3) Minimum of one recorder for recording the medical air proportioning system performance and air quality for a period of not less than 24 hours

(4) Continuous analysis of the mixture and a recording capability provided (e.g., via a data port)
(5) Mechanism for isolating the primary medical air proportioning system from the reserve supply and the medical air piping distribution system by employing sequential valves for redundancy
(6) Capability of the reserve supply to automatically activate if the primary supply is isolated
(7) Reserve supply of medical air USP sized, at minimum, for one average day's supply and consisting of one of the following:
  (a) Additional medical air proportioning unit with a dedicated supply of oxygen USP and nitrogen NF
  (b) Medical air compressor system per 5.1.3.6.3, with the exception of the allowance of a simplex medical air compressor system
  (c) Medical air cylinder manifold per 5.1.3.5.12
(8) Receiver fitted with a pressure relief valve and pressure gauge as follows:
  (a) The receiver shall be constructed of corrosion-resistant materials.
  (b) The receiver, relief valves, and pressure gauges shall comply with ASME *Boiler and Pressure Vessel Code* and manufacturer's recommendations.
(9)* Warning systems per 5.1.9, including a local signal and master alarm that indicates non-conforming oxygen concentration per manufacturer's recommendations

Δ **A.5.1.3.6.3.14(C)(9)** The proportioning system should be monitored for conditions that can affect air quality during use or in the event of failure, based on the type of proportioning system design used in the system, including the following situations:

(1) Where proportioning systems that are configured with a primary proportioning system and a reserve medical air manifold per 5.1.3.5.12 are used
(2) Where proportioning systems that are configured with a primary proportioning system and a reserve proportioning system are used
(3) Where proportioning systems that are configured with a primary proportioning system and a reserve medical air compressor per 5.1.3.5.12 are used
(4) When proportioning systems are configured to alarm at a predetermined set point before the reserve supply begins to supply the system, indicating reserve supply in use
(5) When proportioning systems are configured to alarm at a predetermined set point before the reserve supply contents fall to one average day's supply, indicating reserve low

Water-in-receiver alarms are not required for proportioning systems.

(10) Final line pressure regulators complying with 5.1.3.5.5
(11) Pressure relief complying with 5.1.3.5.6
(12) Local signals complying with 5.1.3.5.9.2

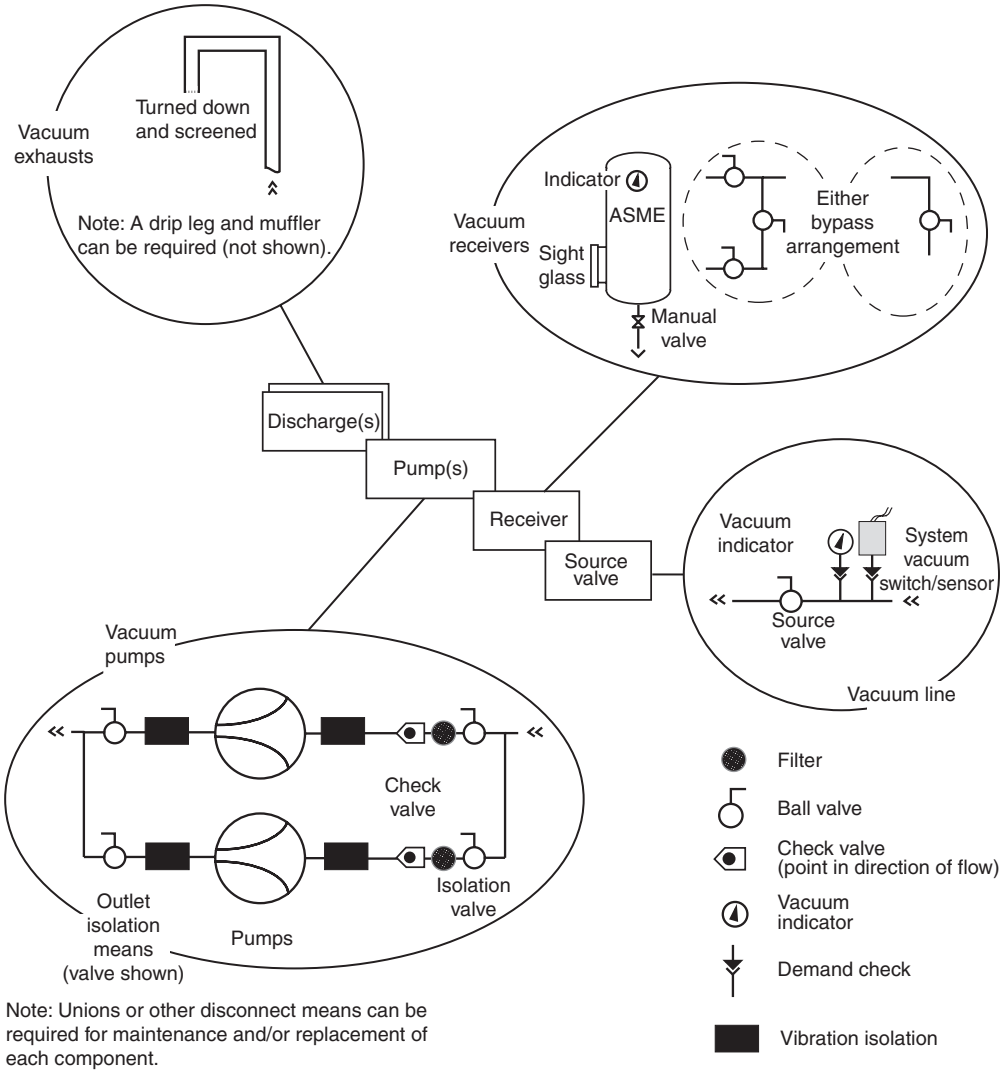
5.1.3.7* Medical–Surgical Vacuum Central Supply Systems.

A.5.1.3.7 See Figure A.5.1.3.7.

See Exhibit 5.22 and Exhibit 5.23, which illustrate the different types of vacuum pumps and their controllers.

5.1.3.7.1 Medical–Surgical Vacuum Central Sources. Medical–surgical vacuum central supply systems shall be located per 5.1.3.3 as follows:

(1) Indoors in a dedicated mechanical equipment area, adequately ventilated and with any required utilities
(2) In a room ventilated per 5.1.3.3.3.3



Δ ***FIGURE A.5.1.3.7*** *Elements of Typical Duplex Vacuum Source System (Category 1 Vacuum Systems).*

(3) For air-cooled equipment, in a room designed to maintain the ambient temperature range as recommended by the equipment manufacturer

FAQ Is medical–surgical vacuum treated to the same high standards as a medical gas?

In NFPA 99, vacuum is treated to the same high standards as medical gases. Medical–surgical vacuum systems, as well as medical gas systems, in health care facilities (in particular, those systems that are used in surgery and for respiratory therapy) are true life-saving, life-support systems. Exhibit 5.24 shows a typical medical vacuum system source and its components. Therefore, failure or shutdown of a vacuum pump(s) — causing reduction or loss of vacuum — can be injurious or fatal to patients. Vacuum is a true "medical gas" in that sense. Medical gases are generally thought of as a positive pressure gas, but a negative pressure gas (vacuum) is also a "medical gas."

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

(1) Two or more vacuum pumps sufficient to serve the peak calculated demand with the largest single vacuum pump out of service
(2) Automatic means to prevent backflow from any on-cycle vacuum pumps through any off-cycle vacuum pumps
(3) 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
(4) Vacuum receiver
(5) Piping between the vacuum pump(s), discharge(s), receiver(s), and vacuum source shutoff valve in accordance with 5.1.10.2, except brass, galvanized, or black steel pipe, which is permitted to be used as recommended by the manufacturer
(6) Except as defined in 5.1.3.7.1.1(1) through 5.1.3.7.1.1(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

EXHIBIT 5.22

Triplex Vacuum Pump Setup for Piped Medical Vacuum System, Including Control Panel. (Courtesy of BeaconMedaes)

EXHIBIT 5.23

Vertical-Mount Duplex Vacuum Pump System with Control Panel and Receiver. Pump Is Oil-Flooded Rotary Vane Unit. (Courtesy of BeaconMedaes)

The allowance described in 5.1.3.7.1.1(6) is for any design, materials, construction, and devices appropriate for medical–surgical vacuum service as determined by the manufacturer. The part of the medical–surgical vacuum source where this variance applies is between the vacuum pump and the source shutoff valve.

FAQ What is the difference between "vacuum discharge" and "vacuum exhaust"?

A vacuum discharge is the location on a vacuum pump that discharges the air from the pump into the vacuum exhaust line. The vacuum exhaust line is piped from the vacuum pump discharge to the outside atmosphere. The vacuum exhaust line pipes away the air that is discharged from the vacuum pump and releases it to the outside atmosphere.

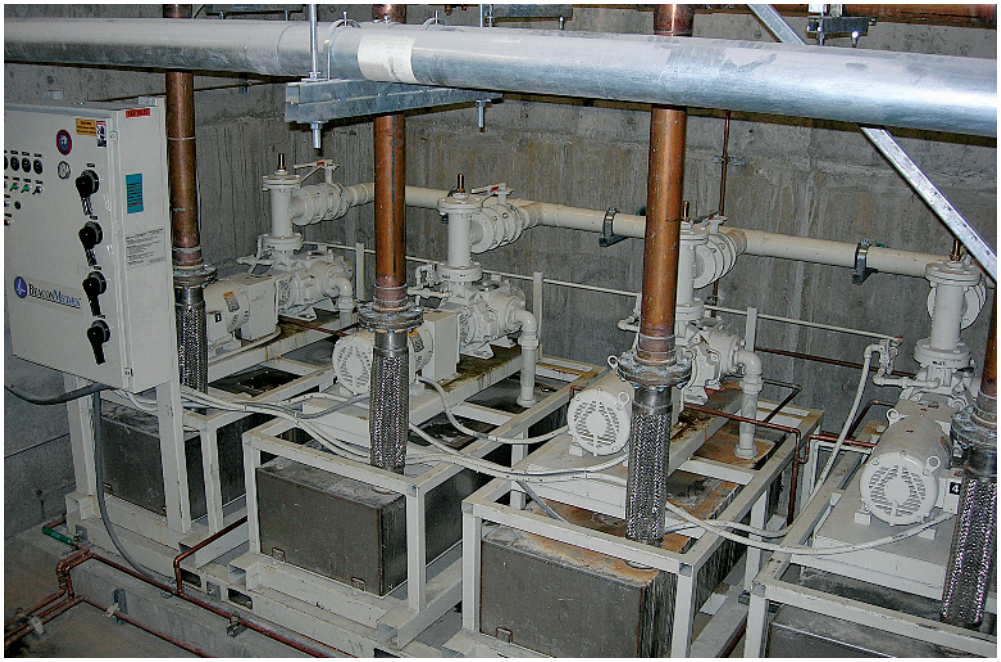


EXHIBIT 5.24

Typical Medical Vacuum System Source and Components.

(7) Vacuum filtration per 5.1.3.7.4

Vacuum filtration is required for the first time in the 2018 edition. This brings NFPA 99 in line with what has been a long-standing standard practice all over the world.

The requirement is for a filter meeting the high efficiency particulate air (HEPA) requirements of 99.97 percent efficient at 0.03 microns to be installed between the pump and the pipeline. Such a filter will prevent most bacteria and viruses from passing through to the pump. Thus, the filter is intended to protect workers who service the pump, their associates, and ultimately the community who would be exposed if these organisms were dispersed out the vacuum system exhaust (see also commentary for 5.1.3.7.4).

5.1.3.7.2 Vacuum Pumps.

5.1.3.7.2.1 Vacuum pumps shall be constructed of materials deemed suitable by the manufacturer.

5.1.3.7.2.2 Antivibration mountings shall be installed for vacuum pumps as required by equipment dynamics or location and in accordance with the manufacturer's recommendations.

The vibration in most modern vacuum pumps is at a high frequency and transmits easily along the pipes. Seismic requirements of the local building code should also be considered when selecting any antivibration system.

5.1.3.7.2.3 Flexible connectors shall connect the vacuum pumps with their intake and outlet piping.

5.1.3.7.2.4 For liquid ring vacuum pumps, seal water shall be of a quality recommended by the vacuum pump manufacturer.

5.1.3.7.3 Vacuum Receivers. Receivers for vacuum shall meet the following requirements:

(1) They shall be made of materials deemed suitable by the manufacturer.
(2) They shall comply with Section VIII, "Unfired Pressure Vessels," of the ASME *Boiler and Pressure Vessel Code.*
(3) They shall be capable of withstanding a gauge pressure of 415 kPa (60 psi) and 760 mm (30 in.) gauge HgV.
(4) They shall be equipped with a manual drain.
(5) They shall be of a capacity based on the technology of the pumps.

Vacuum can be stored as readily as compressed air. The primary function of the receiver is to act as a vacuum reservoir to accommodate sudden or unusually high system demands. The receiver also prevents possible overloading of the pump.

A receiver is a common system element for vacuum pumps that operate intermittently. In vacuum applications requiring high flow for short periods with long intervals between, even a small vacuum pump that runs continuously can store the necessary vacuum capacity. Check valves and isolation valves are normally used on the pump side of the tank, and appropriate bypass valves are used on the downstream side as a means to service the receiver without shutting down the medical–surgical vacuum system.

N **5.1.3.7.4 Vacuum Filtration.** Central supply systems for vacuum shall be provided with inlet filtration with the following characteristics:

(1) Filtration shall be at least duplex to allow one filter to be exchanged without impairing vacuum system
(2) Filtration shall be located on the patient side of the vacuum producer.
(3) Filters shall be efficient to 0.03 μ and 99.97 percent HEPA or better, per DOE-STD-3020.
(4) Filtration shall be sized for 100 percent of the peak calculated demand while one filter or filter bundle is isolated.
(5) It shall be permitted to group multiple filters into bundles to achieve the required capacities.
(6) 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.

(7) A means shall be available to allow the user to observe any accumulations of liquids.
(8) A vacuum relief petcock shall be provided to allow vacuum to be relieved in the filter canister during filter replacement.
(9) Filter elements and canisters shall be permitted to be constructed of materials as deemed suitable by the manufacturer.
(10) 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.

There are two primary layouts that will meet the intent of this requirement. One is to place a filter with each pump, sizing the filter capacity to the pump capacity. The other is to place the filters into valved pairs in a duplex arrangement, sizing the filters to the system capacity. Since these filters can be quite large, it is sometimes convenient to obtain the same capacity with two filters, which is the "bundle" arrangement described here. With bundles, it would be perfectly suitable to have three (or more) filters, each with an inlet and outlet valve, and to manage the needed 100 percent system capacity with any two in service and one in reserve, three in service and one in reserve, and so on.

Which arrangement is best will depend on the cost of the installation, space available, and convenience in accessing the filters for service.

Service is a major consideration, as the filter should be treated as a biohazard and appropriate personal protective equipment (PPE) and handling precautions should be used when changing them.

5.1.3.7.5 Piping Arrangement and Redundancies.

5.1.3.7.5.1 Piping arrangement shall be as follows:

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

The medical–surgical vacuum system is a life-support system; failure or unplanned shutdowns can cause serious injury or be fatal to patients. The critical nature of a medical–surgical vacuum system requires redundancy in piping and valve placement that allows continuous service in the event of a single fault failure.

A single fault failure is a part of a system that, if it fails, will stop the entire system from working. It is undesirable in any medical gas or medical vacuum system with a goal of high availability or reliability.

(2) Piping arrangement shall be permitted to vary based on the technology(ies) employed, provided that an equal level of operating redundancy is maintained.
(3) 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.

5.1.3.7.5.2 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.

5.1.3.7.5.3 Medical–surgical vacuum central supply systems shall be provided with a source shutoff valve per 5.1.4.2.

5.1.3.7.6 Electrical Power and Control.

N **(A)** Medical vacuum source systems shall be controlled to ensure continuous supply of suction at pressures consistent with Table 5.1.11 under all conditions of system use as follows:

(1) Automatic activation of pump(s) as necessary to supply the demand.
(2) Managing the operation to equalize wear on all pumps. Where this equalization is achieved manually, the facility staff shall arrange a schedule for manual alternation.

Alternation of pumps (automatically or manually) is desirable because it allows even wear on both pumps, thereby extending the life of the pumps and reducing the probability of system failure. Whether pump alternation is automatic or manual, activation of the nonoperating pump must be automatic in the event of operating pump failure or overload. Where pumps that require off-time for proper operation are used, the pumps should be sized at the top of the operating range so the stop setting can be reached on intermittent operation. This alternation of pumps is identified in 5.1.1.5 as applying to both new and existing facilities.

N **(B)** Controls shall provide the following functions:

(1) Where medical vacuum source systems having two or more pumps employ any electrical circuit device that upon failure could prevent supply of medical vacuum, the controls shall be provided with an automatically activated alternative method for ensuring supply (e.g., redundant component(s), an alternate electrical supply path, or other equivalent method).
(2) Control circuits shall be arranged in such a manner that isolation of one pump or component from the system (e.g. for maintenance or repair) does not interrupt the operation of other pump(s) or component(s).
(3) An automatic restart function shall be included, such that the supply of medical vacuum will resume normally after power interruption without manual intervention.

N **(C)** Each pump motor shall be provided with electrical components including, but not limited to:

(1) Dedicated disconnect switch installed in the electrical circuit ahead of each motor starter
(2) Motor starting device
(3) Overload protection

N **(D)** Vacuum source system controls shall be provided with electrical systems including, at a minimum:

(1) Control circuits shall be arranged so that failure of any component of the control circuit, or shutdown of one pump (e.g., for service), does not interrupt automatic operation of the standby pump.
(2) Controls shall be provided with built-in disconnect means to allow appropriate operation of multiple pump systems and protect service personnel from exposure to live voltages.
(3) Where components are common to more than one control circuit, the common device shall be provided with electrical protection to prevent loss of the control circuits(s) in the event of short circuit in the device.
(4) An automatic restart function shall be included, such that the pump(s) will restart after power interruption without manual intervention.

See the commentary for 5.1.3.6.3.10(D)(4).

N **(E)** Electrical installation and wiring shall conform to the requirements of *NFPA 70*.

N **(F)** Emergency electrical service for the pumps shall conform to the requirements of the essential electrical system as described in Chapter 6.

5.1.3.7.7 Medical–Surgical Vacuum Exhaust.

5.1.3.7.7.1 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.

FAQ Is vacuum discharge dangerous?

The discharge from patients, which is pulled into the vacuum piping, can carry infectious material. Therefore vacuum discharge is considered hazardous, and thus vacuum exhausts must be discharged outside and away from passersby and others. In the 2018 edition this concern has been directly addressed with the addition of vacuum filtration, but responsible location of the exhaust is still wise.

5.1.3.7.7.2 The exhaust shall be located as follows:

(1) Outdoors
(2) At least 7.5 m (25 ft) from any door, window, air intake, or other openings in buildings or places of public assembly
(3) At a level different from air intakes
(4) Where prevailing winds, adjacent buildings, topography, or other influences will not divert the exhaust into occupied areas or prevent dispersion of the exhaust

The medical vacuum exhaust needs to terminate outdoors above roof level, at least 7.5 m (25 ft) horizontally — it may be more, depending on prevailing wind direction and velocity — from all air intakes, doors, windows, louvers, or any other building openings. The vacuum discharge will be located at a different level than the medical air intake. If the exhausts are to be combined from each medical vacuum pump into one discharge pipe, the exhaust must be sized so there are no restrictions while flowing at a maximum discharge rate, and an isolation valve must be provided at the header for each pump served. Exhaust piping for vacuum pumps must be sized using the total standard cubic feet per minute (SCFM) for the system (both lead and lag pumps) and the total developed length of run. Exhaust piping must be sized and arranged to prevent moisture and back pressure from entering the pump. A valved drip-leg at the base of the exhaust stacks needs to be provided. Coordinating with a vacuum pump system technical representative and verifying that the proposed sizing of exhaust piping complies with the manufacturer's recommendations is important. Exhibit 5.25 shows a schematic of vacuum exhaust location requirements.

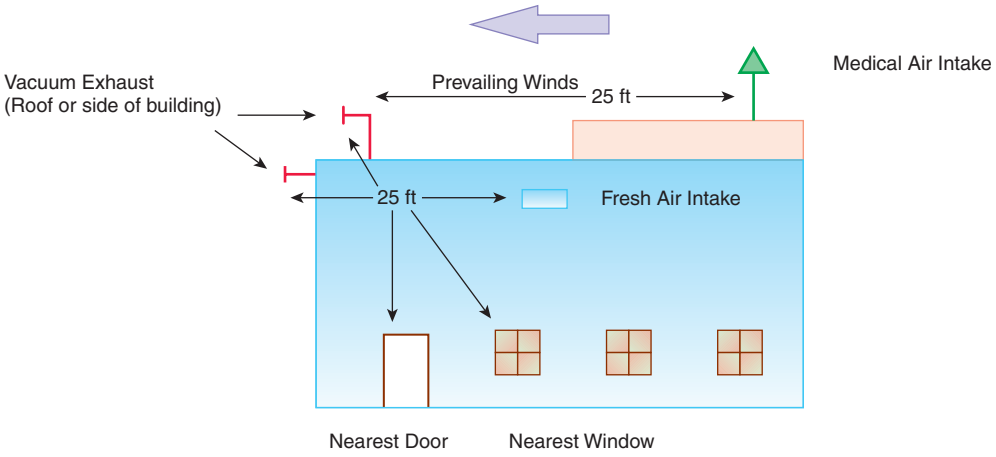


EXHIBIT 5.25

Schematic of Vacuum Exhaust Location Requirements.

5.1.3.7.7.3 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.

Suitable noncorroding materials that can be used for the screening of the exhaust might include galvanized steel, plastic, stainless steel, or other similar materials.

5.1.3.7.7.4 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.

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

(1) The common exhaust is sized to minimize back pressure in accordance with the pump manufacturer's recommendations.
(2) 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.

5.1.3.7.7.6 Vacuum exhaust piping shall be permitted to be made of materials and use a joining technique as permitted under 5.1.10.2 and 5.1.10.3.

5.1.3.7.8 Operating Alarms. When the capacity of the medical vacuum supply system not in use is less than the equivalent capacity of one pump, a local alarm shall activate *[see 5.1.9.5.4(4)]*. This signal shall require manual reset.

5.1.3.8* Waste Anesthetic Gas Disposal (WAGD) Central Supply Systems.

A.5.1.3.8 A functioning WAGD system allows the facility to comply with occupational safety requirements by preventing the accumulation of waste anesthetic gases in the work environment.

WAGD using an HVAC (heating, ventilation, and air-conditioning) system are not within the scope of Chapter 5.

Flammable and nonflammable gases are known to be incompatible with some seals and piping used in medical–surgical vacuum systems. If WAGD is to be included as part of the medical–surgical vacuum system, it should be recognized that this activity might cause deterioration of the vacuum system. The station inlet performance tests outlined in 5.1.12.4.10 are extremely important in maintaining the integrity of the medical–surgical vacuum system, and they should be made at more frequent intervals if WAGD is included in the vacuum system.

WAGD is sometimes called *scavenging* or *evacuation*. The term *scavenging*, however, is preferred in connection with the equipment used between the anesthesia machine and the inlet of a disposal system, rather than with the pipeline itself. WAGD systems are not required by NFPA 99, but where installed — either voluntarily or because they are required by another code or standard — they must comply with this section.

A medical–surgical vacuum system functions for suction therapies directly applied to patient care. WAGD is primarily an environmental system with occupational safety implications. However, because WAGD directly connects with the patient breathing circuit, its proper design, installation, and function are important to patient safety.

NFPA 99 explicitly includes requirements for three different WAGD methods. Which method to use is determined by clinical preferences and practice, economics, and safety issues. Along with the inclusion of three alternative methods, NFPA 99 requires a certain minimum level of operating safety, including alarms and redundant WAGD producers.

Following a number of TV news, newspaper, and periodical reports of fires in pumps for dual-use (WAGD and medical–surgical vacuum) service, particular emphasis was placed on fire safety in WAGD producers. This prompted the more stringent requirement of 5.1.3.8.1.2, because significant changes are occurring in WAGD at the anesthesia machine.

Research in the 1970s by the former Committee on Medical–Surgical Vacuum and ANSI Z79.11, *Standard for Anesthetic Equipment-Scavenging Systems for Excess Anesthetic Gases*, found that the maximum volume flowing into a WAGD terminal from a single patient was less than 15.3 SLPM (0.54 SCFM) during a worst-case displacement/momentary demand (maximum 5 seconds), or 1.27 L (0.045 SCF) during oxygen flush, or because of occluded scavenging equipment (as noted in Table A1 in ANSI Z79.11). Normal operational displacement was held to be less than 9.9 SLPM (0.35 SCFM). The design of WAGD systems in the United States has historically been based on these flow rates as the typical inflows at the terminals. As a result, U.S. WAGD systems have become little more than appendages of the vacuum system, often no more than an extra vacuum terminal marked with a different color.

This data is now outdated. WAGD interfaces are currently in use that flow a continuous 51.5 SLPM (1.8 SCFM) into the wall inlet, and others have been demonstrated to flow even greater volumes under some circumstances. These high inflows have a positive impact on anesthesia machine operation and patient and staff safety, but they greatly change the way WAGD must be addressed at the producer.

NFPA 99 has long included the following list of references and reasons for separating the WAGD systems from the vacuum systems:

1. ANSI Z79.11 states that the maximum safe negative pressure for the patient "shall not exceed 0.5 cm H_2O (0.014 in. gauge HgV)." This vacuum level is very low compared to the minimum 300 mm (12 in.) Hg of vacuum in the medical–surgical vacuum system.
2. The standard alarm systems and monitoring gauges required for a medical–surgical vacuum system cannot be used in a WAGD system. WAGD requires switches, sensors, and gauges appropriate for the very low vacuum levels encountered and, in some implementations, can require the use of flow in place of pressure as an operating indicator.
3. Nonrecirculating ventilation systems, dedicated blower systems, and passive systems (ambient differential) have all been demonstrated to be effective for WAGD. The intent of ANSI Z79.11 that the pressure of a scavenging system approximate ambient pressure in normal use can be met by these systems but not by a medical–surgical vacuum system.
4. The International Standards Organization (ISO) and the British Standards Institute oppose using a medical–surgical vacuum system for WAGD. Both organizations concur with 0.5 cm H_2O (0.014 in. gauge HgV) as the maximum safe negative pressure for patients.
5. High airflows between WAGD and vacuum may not be compatible, and problems can develop at the vacuum pumps.

5.1.3.8.1* **Supply Sources.** WAGD supply sources shall be chosen in consultation with the medical staff having knowledge of the requirements to determine the type of system, number and placement of terminals, and other required safety and operating devices.

A.5.1.3.8.1 Interfaces are provided with overpressure, underpressure, overflow, and underflow compensation to ensure the breathing circuit is isolated from the WAGD system.

5.1.3.8.1.1 WAGD shall be permitted to be produced through the medical–surgical vacuum source, by a dedicated producer, or by venturi.

5.1.3.8.1.2 If WAGD is produced by the medical–surgical vacuum source, the following shall apply:

(1) The medical–surgical vacuum source shall comply with 5.1.3.7.
(2) The total concentration of oxidizers (oxygen and nitrous oxide) shall be maintained below 23.6 percent, or the vacuum pump shall comply with 5.1.3.8.2.1.

(3) The medical–surgical vacuum source shall be sized to accommodate the additional volume.

Even when using a dual-use piped system, it is inappropriate to label WAGD terminals "suction" or to use a suction terminal for WAGD. Each area where nitrous oxide or halogenated anesthetic gas is to be administered should have at least one dedicated and labeled WAGD terminal. (See 5.1.5.16.) However, where the producer, alarms, and other components are common (or shared, as is true of all dual-use systems to some extent), dual labeling should be provided on alarms, on valves, and on the source.

5.1.3.8.1.3 If WAGD is produced by a dedicated WAGD producer with a total power equal to or greater than 1 horsepower in total (both producers), the following shall apply:

(1) The WAGD source shall be located in accordance with 5.1.3.3.
(2) The WAGD source shall be located indoors in a dedicated mechanical equipment area with any required utilities.
(3) The WAGD source shall be ventilated per 5.1.3.3.3.3.
(4) For air-cooled equipment, the WAGD source shall be located to maintain the ambient temperature range as recommended by the manufacturer.
(5) The WAGD producers shall comply with 5.1.3.8.2.

A health care facility's decision to have a dedicated WAGD producer (that is, a system that is independent from the medical–surgical vacuum systems), or have the WAGD tied into the medical–surgical vacuum systems (or other option, such as a venturi design), should take into consideration variables such as patient safety, effectiveness, and cost.

If a health care facility decides to have a dedicated WAGD system, then two different types of producers are available: high vacuum (pump driven) and low vacuum (blower or fan driven). WAGD is about moving the gas, not producing a deep vacuum. For small volumes at high vacuum, a pump can be used; for large volumes at low vacuum, a fan or blower can be used. The design and engineering of these two types of producers is different; pump-driven WAGD systems are normally designed to run at 130 mm (5 in.) gauge HgV or higher, whereas blower- or fan-driven systems are designed for operation below 130 mm (5 in.) gauge HgV. Both technologies and designs need to follow the requirements for dedicated WAGD producers in this section.

5.1.3.8.1.4 If WAGD is produced by a dedicated WAGD producer with a total power less than 1 horsepower in total (both producers), the following shall apply:

(1) The WAGD source shall be permitted to be located near the inlet(s) served.
(2) For air-cooled equipment, the WAGD source shall be located to maintain the ambient temperature range as recommended by the manufacturer.

The division between "greater than 1 horsepower" and "less than 1 horsepower" recognizes a division in the operating parameters of these two different styles of systems. One is a large central system and the other is a smaller producer mounted locally. The hazards associated with each are different, and burdening the small system with the same requirements as the large one makes it impractical.

5.1.3.8.1.5 For liquid ring pumps in WAGD service, seal water shall be of a quality as recommended by the pump manufacturer.

5.1.3.8.1.6 The WAGD source shall consist of the following:

(1) Two or more WAGD producers sufficient to serve the peak calculated demand with the largest single WAGD producer out of service

The WAGD system is installed and designed similarly to all the other MGVS. What is unique to a WAGD system is that the system is built for removing an occupational hazard — the waste gases from anesthesia. As with any MGVS, redundancies are critical for providing an adequate level of reliability.

(2) Automatic means to prevent backflow from any on-cycle WAGD producers through any off-cycle WAGD producers
(3) Shutoff valve to isolate each WAGD producer from the centrally piped system and other WAGD producers for maintenance or repair without loss of WAGD in the system
(4) Piping between the WAGD producers and the source shutoff valve compliant with 5.1.10.2, as recommended by the manufacturer
(5) Antivibration mountings installed for WAGD producers as required by equipment dynamics or location and in accordance with the manufacturer's recommendations
(6) Flexible connectors interconnecting the producers with their intake and outlet piping as required by equipment dynamics or location and in accordance with the WAGD producer manufacturer's recommendations

5.1.3.8.1.7 If WAGD is produced by a venturi, the following shall apply:

(1) The venturi shall not be user-adjustable (i.e., require the use of special tools).
(2) The venturi shall be driven using water, inert gas, instrument air, or other dedicated air source.
(3) Medical air shall not be used to power the venturi.

In a venturi system, compressed air is forced through a cone-shaped opening, and its velocity increases. This principle can be applied to generate vacuum economically without a single moving part. To optimize the levels of vacuum generated, the orifice size is selected to extract the maximum amount of energy from the compressed air flowing through it. So in a venturi vacuum producer, high-pressure gas (normally compressed air or instrument air) is forced through an orifice or restricting nozzle into an expansion chamber. As the air velocity increases, a negative pressure is produced.

Venturi vacuum systems have no moving parts and use no electricity. However, venturi vacuum systems are an inefficient use of compressed air and should only be used intermittently — for applications that pull a vacuum less than 25 percent of the time during normal load or continuous operation. When venturi vacuum producers are used, a solenoid shutoff valve should be installed on the compressed air supply line to shut the airflow down when a vacuum is not needed.

Venturi-driven systems have no central producer, but instead they use a venturi within each inlet. Each inlet is independently controlled with an adjustable venturi-driven suction point flow device and has its own operating indicator. Negative pressures can be adjusted by varying the venturi flow rate. The exhaust ports must be routed to the outside or to some other suitable discharge point. There are no alarms, but it is prudent to have an alarm on the gas used to create the venturi to indicate whether this supply is not operating.

5.1.3.8.2 WAGD Producers.

5.1.3.8.2.1 Vacuum pumps dedicated for WAGD service shall be as follows:

(1) Compliant with 5.1.3.7.2
(2) Designed of materials and using lubricants and sealants that are inert in the presence of oxygen, nitrous oxide, and halogenated anesthetics

FAQ Why is it important that the lubricants and sealants be inert in the presence of oxidizers?

Gases that are strong oxidizers (oxygen and nitrous oxide) might be present in a WAGD system. Therefore it is imperative that a vacuum producer use a sealant, such as water (in liquid ring pumps) or halogenated lubricants (in pumps requiring oil or grease), that will not react with explosive force when the sealant or lubricant comes in contact with oxidizers.

This paragraph was clarified to apply in the following two cases:

1. Where a producer is used for only WAGD service, as cited in 5.1.3.8.2.1
2. Where a system cannot be held below 23.6 percent oxidizer content (e.g., where it becomes an oxygen-enriched atmosphere)

See the commentary following A.3.3.12.2 for additional information on atmospheres of increased burning rate when ignited.

5.1.3.8.2.2 Vacuum producers (e.g., fans or blowers) designed for operation at vacuums below 130 mm (5 in.) HgV shall be as follows:

(1) Permitted to be made of any materials determined by the manufacturer as suitable for the service
(2) Provided with antivibration mountings as required by equipment dynamics or location and in accordance with the manufacturer's recommendation
(3) Connected with their intake and outlet piping through flexible connections
(4) Used only for WAGD service and not employed for other services
(5) Interconnected via piping, ductwork, and so forth, made of materials determined by the manufacturer as suitable to the service

5.1.3.8.3 WAGD Alarms.

5.1.3.8.3.1 When the WAGD system is served by a central source(s), a local alarm complying with 5.1.9.5 shall be provided for the WAGD source.

5.1.3.8.3.2 Where WAGD source systems have two or more producers, and the capacity of the WAGD system not in use is less than the equivalent capacity of one producer, a local alarm shall activate *[see 5.1.9.5.4(5)]*. This signal shall require manual reset.

The code was originally written around one type of control — on/off operation defined by pressure. Control methods for compressors and pumps are becoming more sophisticated and now can control for other conditions (e.g., flow) and in a variety of modes (e.g., continuous run with VSD). The revised text of this section accounts for these developments while preserving the performance characteristics inherent in the original text. Previously the signal required activation when the standby equipment was operating.

5.1.3.8.4 Electrical Power and Control.

Centrally piped WAGD systems follow the exact same electrical requirements as medical–surgical vacuum systems. All electrical installations and wiring must conform to *NFPA 70®, National Electrical Code®*. The requirements will follow the essential electrical system requirements of Chapter 6.

5.1.3.8.4.1 Additional producers shall automatically activate when the producer(s) in operation is incapable of maintaining the required vacuum.

5.1.3.8.4.2 Automatic or manual alternation of producers shall allow division of operating time. If automatic alternation of producers is not provided, the facility staff shall arrange a schedule for manual alternation.

This requirement is cited in 5.1.1.5 as applying to existing facilities. Where an existing WAGD system does not provide for automatic alternation, the facility must establish a schedule to do this manually in order to allow as close to an equal amount of operating time as possible.

5.1.3.8.4.3

N **(A)** WAGD source systems shall be controlled to ensure continuous flow under all conditions of system use as follows:

(1) Automatic activation of producer(s) as necessary to supply the demand.
(2) Managing the operation to equalize wear on all producers. Where this equalization is achieved manually, the facility staff shall arrange a schedule for manual alternation.

N **(B)** Controls shall provide the following functions:

(1) Where WAGD source systems having two or more producers employ any electrical circuit device which upon failure could stop the WAGD, the controls shall be provided with a automatically activated alternative method for ensuring supply (i.e., redundant component(s), an alternate electrical supply path or other equivalent method).
(2) Control circuits shall be arranged in such a manner that isolation of one producer or component from the system (e.g., for maintenance or repair) does not interrupt the operation of other pump(s) or component(s).
(3) An automatic restart function shall be included, such that the supply of WAGD will resume normally after power interruption without manual intervention.

N **(C)** Each producer motor shall be provided with electrical components including, but not limited to, the following:

(1) Dedicated disconnect switch installed in the electrical circuit ahead of each motor starter
(2) Motor starting device
(3) Overload protection

N **(D)** WAGD source system controls shall be provided with electrical systems including at least:

(1) Control circuits shall be arranged so that failure of any component of the control circuit, or shutdown of one producer (e.g. for service) does not interrupt automatic operation of the standby producer.
(2) Controls shall be provided with built in disconnect means to allow appropriate operation of multiple producer systems and protect service personnel from exposure to live voltages.
(3) Where components are common to more than one control circuit, the common device shall be provided with electrical protection to prevent loss of the control circuits(s) in the event of short circuit in the device.
(4) An automatic restart function shall be included, such that the pump(s) will restart after power interruption without manual intervention.

See the commentary for 5.1.3.6.3.10(D)(4).

Δ **5.1.3.8.4.4** Electrical installation and wiring shall conform to the requirements of *NFPA 70*.

5.1.3.8.4.5 Emergency electrical service for the producers shall conform to the requirements of the essential electrical system as described in Chapter 6.

5.1.3.8.5 WAGD Exhaust. The WAGD pumps shall exhaust in compliance with 5.1.3.7.7.

The WAGD exhaust needs to be located to minimize noise and contamination (such as that from the waste gases produced by the breathing circuits of the anesthesia machines), in the same manner as the medical–surgical vacuum exhaust. Exhausts need to be kept away from intakes, such as air-conditioning units and medical air systems, that could pull in these exhausted waste gases.

N 5.1.3.9* Oxygen Central Supply Systems Using Concentrator(s).

Any oxygen central supply system that includes one or more oxygen concentrator supply system(s) shall comply with 5.1.3.9.1 through 5.1.3.9.4.

This new section for the 2018 edition includes details for a central supply system that uses an oxygen concentrator as one of the supply sources. The requirements for the supply source itself are found at 5.1.3.5.11.

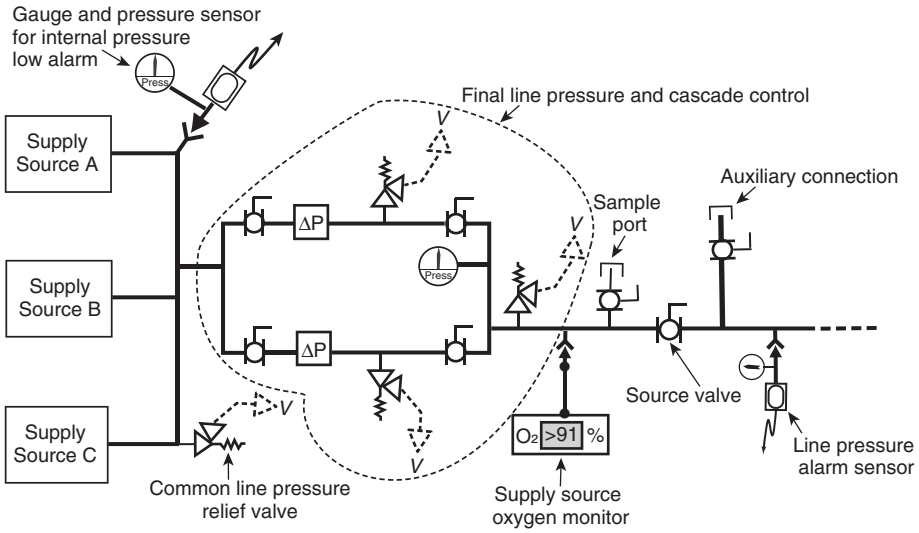
N A.5.1.3.9 See Figure A.5.1.3.9(a), Figure A.5.1.3.9(b), and Figure A.5.1.3.9(c).

N 5.1.3.9.1 Location. Oxygen central supply systems using concentrator(s) shall be located per 5.1.3.3 and as follows:

(1) Indoors in a dedicated mechanical equipment area, ventilated, and with any required utilities (e.g., electricity, drains, lighting).
(2)* In a room ventilated per 5.1.3.3.3.3.

N A.5.1.3.9.1(2) Oxygen concentrators have inherent risks because they might not be able to instantaneously begin producing oxygen of the necessary concentration and quantity from a "cold start." For these reasons, cylinder header(s) are often preferable as one or more of the three sources. The cylinders will supply the system while the concentrator pressurizes and purges itself to the desired concentration of oxygen. Cylinders are also independent of electricity and can provide a supply of oxygen in the event of power interruption.

(3) For air cooled equipment, in a room designed to maintain the ambient temperature range as recommended by the manufacturer.



Δ *FIGURE A.5.1.3.9(a)* *Elements of an Oxygen Concentrator Central Supply Source.*

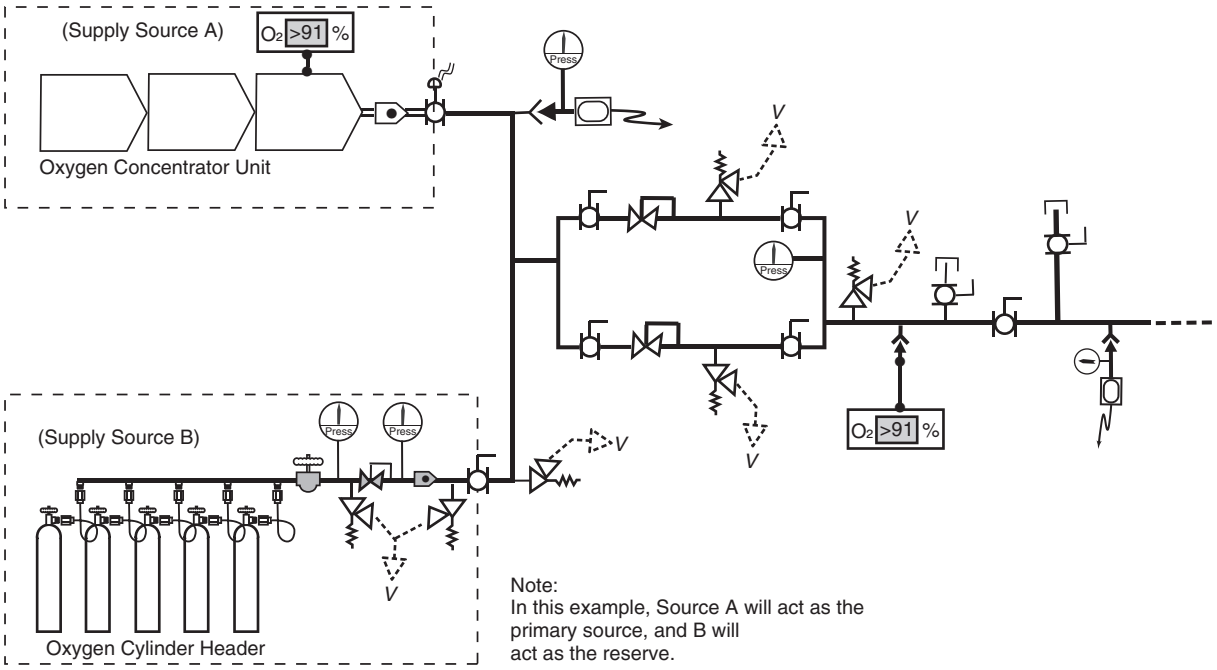


FIGURE A.5.1.3.9(b) *Elements of an Oxygen Concentrator Central Supply Source with Two Sources.*

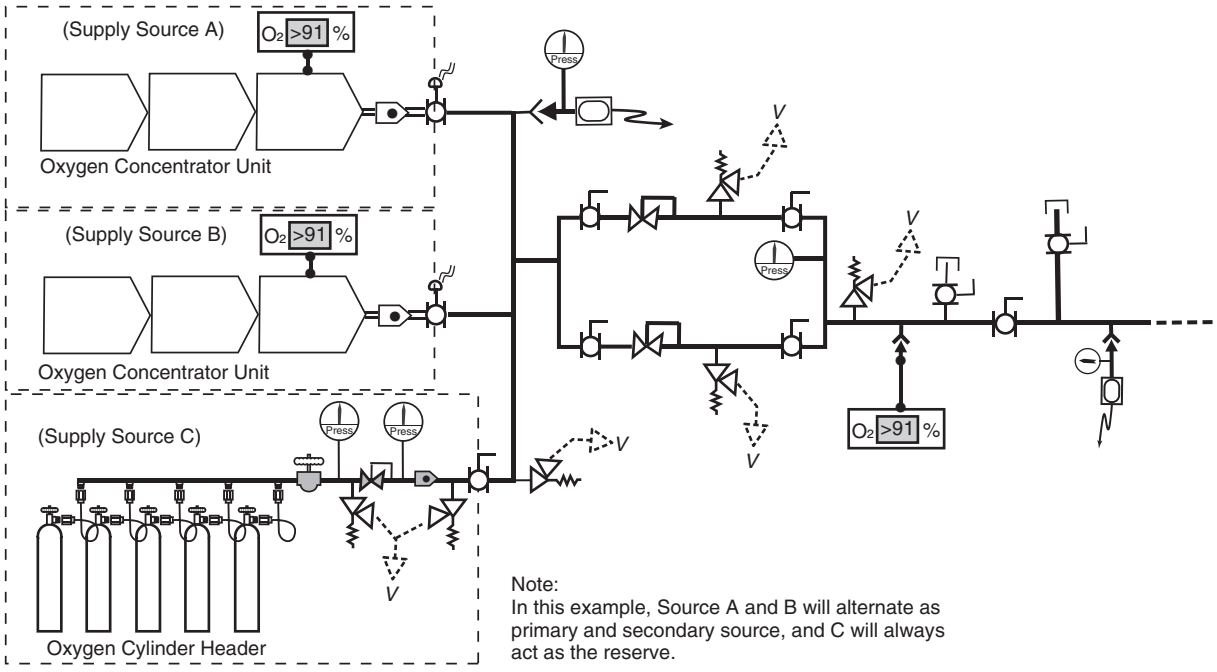


FIGURE A.5.1.3.9(c) *One Example of an Oxygen Concentrator Central Supply Source in Practice.*

(4) Rooms containing oxygen central supply systems using concentrators(s) that do not have the concentrator purge gas vented to the outside shall be equipped with oxygen depletion monitors with alarm indicators at the entrance(s) that will indicate ambient oxygen levels in the room below 19.5 percent.

A by-product of the oxygen concentration process is air with a lower than usual concentration of oxygen, which is vented from the concentrator. In the present state of these machines, this vent gas still contains considerable oxygen. Thus the risk of an anoxic atmosphere in the room is very low, provided there is ventilation sufficient to comply with 5.1.3.9.1(2) and (3). However, in a poorly ventilated room, it is possible to depress the oxygen level, so the provision of the oxygen depletion monitor is a sensible precaution.

(5)* Individual elements of the oxygen central supply system using concentrator(s) shall be permitted to be located in separate rooms or enclosures as necessary to meet 5.1.3.9.1(1) through 5.1.3.9.1(4).

N **A.5.1.3.9.1(5)** The method used elsewhere in this document to provide these characteristics will be found in the final line regulator requirements under 5.1.3.5.5. This method would be suitable for oxygen supply systems using concentrator(s) as well. However, the pressure differential between the output of the concentrator and the system line pressure is often very small, making the use of regulators problematic. In this case, alternate control arrangements (e.g., pressure control through variable speed drives) might be more effective.

N **5.1.3.9.2 Arrangement and Redundancies.** Oxygen central supply systems using concentrator(s) shall be permitted to consist of two or three supply sources, as follows:

(1) If two supply sources are provided, one shall be an oxygen concentrator supply unit and the second shall be a cylinder header complying with 5.1.3.5.10 with sufficient cylinder connections for one average day's supply. Containers shall not be used as a supply source.

(2) If three supply sources are provided, each shall be capable of independently supplying the full system demand in the event of the unavailability of one or both of the other sources. The three sources shall be permitted to be either of the following:
   (a) An oxygen concentrator supply system complying with 5.1.3.5.11.
   (b) A cylinder header complying with 5.1.3.5.10 with sufficient cylinder connections for one average day's supply. Containers shall not be used as a supply source.

(3) Use of oxygen concentrator supply systems as all three sources shall only be permitted after a documented risk analysis by the governing authority of the health care facility indicating understanding of the inherent risks and defining how those risks shall be mitigated.

(4) An isolation valve and automatic check valve shall be provided to isolate each of the three sources from the others and from the pipeline. The valves in 5.1.3.5.10(4), 5.1.3.5.10(6), 5.1.3.5.11.11, and 5.1.3.5.11.12 shall be permitted to be used for this purpose.

(5) Each of the three supply sources shall be provided with a pressure relief valve complying with 5.1.3.5.6 on the source side of its respective isolating valve.

(6) The three supply sources shall join to the pipeline systems through control arrangements with at least the following characteristics:
   (a) Able to maintain stable pressures within the limits of Table 5.1.11
   (b) Able to flow 100 percent of the peak calculated demand
   (c) Redundant, such that each component of the control mechanism can be isolated for service or replacement while maintaining normal operation
   (d) The cascade of sources described in 5.1.3.9.3
   (e) Protected against overpressure (*see 5.1.3.5.6*)

(7) A pressure relief valve shall be provided in the common line between the sources and the line pressure controls.

(8) A source valve as required in 5.1.4.2 shall be provided on the patient side of the line pressure controls.

(9) A gauge and switch or sensor shall be located between the three sources and the line pressure controls to monitor the pressure feeding the line pressure controls.

(10) An oxygen concentration monitor, sampling the gas on the patient side of the line pressure controls and on the source side of the source valve, shall be provided with the following characteristics:
   (a) The monitor shall be capable of monitoring 99 percent oxygen concentration with ±1.0 percent accuracy.
   (b) The monitor shall be attached to the pipeline through a demand check complying with 5.1.8.2.3.
   (c) The monitor shall continuously display the oxygen concentration and shall activate local alarm and master alarms when an oxygen concentration lower than 91 percent is observed.

This monitor is redundant to the monitor found on the concentrator supply source. One monitors the supply source and the other the system, but they will read identically most of the time.

(11) A DN8 (NPS 1/4) valved sample port shall be provided on the patient side of the line pressure controls and source side of the source valve for sampling the oxygen.
(12) An auxiliary source connection shall be provided complying with 5.1.3.5.7.
(13) Electrical installation and wiring shall conform to the requirements of *NFPA 70*.
(14) Emergency electrical service for all components of the oxygen supply system shall conform to the requirements of the essential electrical system as described in Chapter 6.

NFPA 99 is a two-source code, and in the absence of compelling reasons to deviate, all central supply systems in the document are structured around two sources of supply. This is true of an oxygen central supply system using concentrators as well. However, there are many reasons why a concentrator supply source may temporarily not be able to supply oxygen of the needed concentration. Because of this and because oxygen is so critical in health care, it was decided to also specifically mention the three-source configuration common in most other standards. Exhibit 5.26 shows a medical oxygen concentrator source installation with three concentrator supply systems.

EXHIBIT 5.26

Oxygen Concentrator Supply System with Three Concentrator Sources. (Courtesy of PCI Gases)

N **5.1.3.9.3 Operating Controls.** Oxygen central supply systems using concentrator(s) shall include means to provide the following functions:

(1) Selection of an appropriate primary supply source. When the primary supply source is in operation and oxygen quality is suitable, the secondary and reserve supply sources shall be prevented from supplying the system.

(2) Automatic activation of the secondary supply source shall be available if the primary supply source is not able to maintain pressure or concentration of oxygen.
(3) Automatic activation of the reserve supply source shall be available if the primary and secondary supply source are not able to maintain supply pressure or concentration of oxygen.
(4) Where two or more concentrator supply sources are included in the system, the oxygen concentrator supply sources shall be permitted to rotate as the primary supply source.
(5) Automatic operation such that the supply of gas will continue through interruption of the main electrical source.
(6) Oxygen concentrator supply source(s) in the system shall be capable of automatically returning to normal operation following a power interruption. If required by the technology, it shall be permitted to isolate the concentrator supply source(s) using the automatic valve(s) to restore normal oxygen concentration prior to reconnecting the oxygen concentrator supply source to the system by opening the automatic valve. The valve can be actuated automatically for this purpose as an exception to 5.1.3.5.11.12(4).

N **5.1.3.9.4 Operating Alarms and Local Signals.**

N **5.1.3.9.4.1** For each oxygen concentrator supply source in the system, the supply source's concentration monitor *(see 5.1.3.5.11.13)* shall be able to perform the following:

(1) Indicate low oxygen concentration when a concentration lower than 91 percent is observed.
(2) Activate a local alarm *(see 5.1.9.5)*.
(3) Activate an alarm signal at the master alarm *(see 5.1.9.2)* indicating that the oxygen concentration from that supply source is low.
(4) Activate the automatic isolating valve for that oxygen concentrator supply source *(see 5.1.3.5.11.12)* to prevent supply from that oxygen concentrator supply source.
(5) Close the automatic isolating valve for that oxygen concentrator supply source *(see 5.1.3.5.11.12)*, which activates an alarm signal at the master alarm *(see 5.1.9.2)* indicating that the oxygen concentrator supply source is disconnected.

N **5.1.3.9.4.2** For the entire oxygen central supply system, the system concentration monitor *[see 5.1.3.9.2(10)]* shall be able to perform the following:

(1) Indicate low oxygen concentration when a concentration lower than 91 percent is observed
(2) Activate a local alarm *(see 5.1.9.5)*
(3) Activate an alarm signal at the master alarm *(see 5.1.9.2)* indicating the oxygen concentration is low

N **5.1.3.9.4.3** For each header source *(see 5.1.3.5.10)* in the supply system, local signals and alarms shall be provided as follows:

(1) A pressure gauge for delivery pressure
(2) A means to activate an alarm signal at the master alarm *(see 5.1.9.2)* indicating the oxygen cylinders are in use
(3) A means to activate an alarm signal at the master alarm *(see 5.1.9.2)* indicating the content of the oxygen cylinder header is reduced below one average day's supply

N **5.1.3.9.4.4** The oxygen central supply systems using concentrator(s) shall be provided with operating alarms as follows:

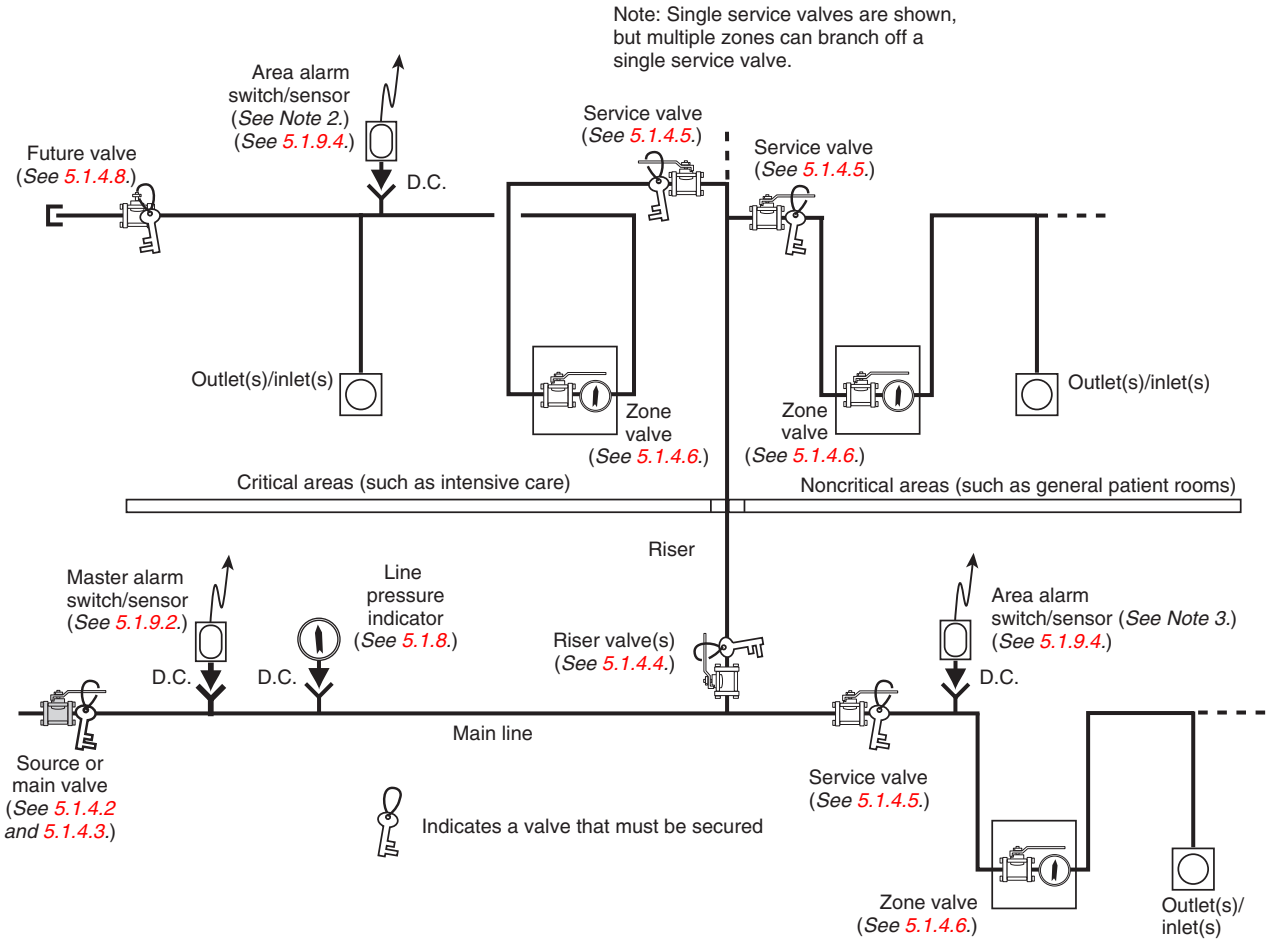
(1) *Change of Source*. An operating alarm shall be provided as follows:
   (a) If the supply source in use fails to supply the system and is changed in accordance with 5.1.3.9.3(2) or 5.1.3.9.3(3), a local alarm and a signal at the master alarm shall be activated, indicating an oxygen supply change has occurred.
   (b) The signal in 5.1.3.9.4.4(1)(a) shall not be activated if the system has rotated sources in accordance with 5.1.3.9.3(6).

(2) *Internal Pressure Low*. A local alarm and a signal at the master alarm shall be activated when or just before the pressure falls below the pressure required to drive the calculated required flow rate through the line pressure controls indicating the oxygen supply internal pressure is low [*see 5.1.3.9.2(9) for sensor location*].

5.1.4* Valves.

A.5.1.4 See Figure A.5.1.4.

Area alarms are required in critical care locations (e.g., intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, post-anesthesia recovery



Notes:
1. Drawing is representational, demonstrating a possible arrangement of components required by the text. The diagram is not intended to imply a method, materials of construction, or more than one of many possible and equally compliant arrangements. Alternative arrangements are permitted if they meet the intent of the text.

2. Area alarms are required in critical care locations (examples might include intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, post-anesthesia recovery rooms, and emergency rooms) and anesthetizing locations (examples might include operating rooms and delivery rooms). Refer to definitions for these areas.

3. Locations for switches/sensors are not affected by the presence of service or in-line valves.

Δ ***FIGURE A.5.1.4*** *Arrangement of Pipeline Components.*

rooms, and emergency rooms) and anesthetizing locations (e.g., operating rooms and delivery rooms). Refer to definitions for these areas.

The symbol illustrating "a valve that must be secured" is shown as a key in Figure A.5.1.4. The key image does not imply a lock, although that could be one way of securing the valve. Paragraph 5.1.4.1.2 simply requires that the valve be secure.

5.1.4.1 General.

General requirements that are applicable to a majority of the valves addressed are grouped in 5.1.4.1.

5.1.4.1.1 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.

Good design practice places valves where necessary to break the system into discrete, logical sections.

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

(1) Located in secured areas
(2) Locked or latched in their operating position
(3) Located above ceilings, but remaining accessible and not obstructed

FAQ Is the space above a drop ceiling considered a secure area?

Although it might be useful or even necessary to lock valves open or closed, the basic intent of 5.1.4.1.2 is to separate those valves that are intended for fire or other emergency use (such as the zone valves) from those that are intended to be operated only by staff in a controlled, planned way for maintenance or construction. A valve located above the ceiling cannot be seen by the casual passerby, is inaccessible to staff during an evacuation, and cannot be accessed without a ladder. Therefore the area above a drop ceiling can be considered secure for most purposes.

5.1.4.1.3 Labeling. All valves shall be labeled as to gas supplied and the area(s) controlled, in accordance with 5.1.11.2.

5.1.4.1.4 Accessibility.

(A) Zone valves shall be installed in valve boxes with removable covers large enough to allow manual operation of valves.

Only zone valves are meant to be accessible to staff during an emergency, especially a fire. Although there is concern about these valves being closed maliciously, these valves continue to be required because of the risk of an uncontrolled release of medical gases in an emergency or fire.

(B) Zone valves for use in certain areas, such as psychiatric or pediatric areas, shall be permitted to be secured with the approval of the authority having jurisdiction to prevent inappropriate access.

Zone valve box assemblies have for years been required to be readily accessible in an emergency. This may not be practical, however, in areas such as pediatric or psychiatric wards.

FAQ What are some examples of securing the shutoff valves in these areas?

Typical modifications for securing zone valves in these locations, where it may not be practical to have the box readily accessible, can include the following:

1. Provide a lockable valve box door to which only staff have the key
2. Utilize removable handles that are kept at the nurses' station
3. Install zone valves inside a locked area such as the nurses' station or the drug storage area in the unit

The practice of placing zone valves in a locked room should be considered carefully, as they must be relocated if the type of patients in that area changes. Instead, using a standard location for the valves and removing handles or installing a lockable door as the security feature would require less modification on a change of patient population.

5.1.4.1.5 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.

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

The parameters for valve types are based on performance (pressure drop) rather than specifying the types of valves that are permitted.

Exhibit 5.27 illustrates a typical medical gas shutoff valve. Exhibit 5.28 includes a "double port" style of valve with NPT-threaded ports with plugs on both sides of the ball valve. Medical gas valves can come with a single port (NPT-threaded opening with a plug normally located on the downstream or patient side of the valve after installation) or double ports. The code does not specify whether double-port or single-port valves must be used; either can be used at the convenience of the facility. The ports are used in the following ways:

- On zone valves, main valves, source valves, and some of the other valve locations, these ports are used for line pressure gauges.
- In construction, installers use them to purge nitrogen NF during pipeline installations.
- Verifiers may use them for testing pipeline installations.

Globe-type valves are not acceptable, since it cannot be visually determined if they are open or closed, and they usually require multiple turns to fully close or open.

Tables 5.1.4.1.6(a) and 5.1.4.1.6(b) are new to the 2018 edition of the code. While the 2015 edition made progress in allowing for new technology and for both ball and butterfly valves, the maximum pressure drop factors adopted in the 2015 edition could have allowed ball valve manufacturers to use smaller internal components inside larger valve bodies. For example, a 2 in. ball assembly could be used inside a 2½ in. ball valve. This was not the intent of the committee, and this revision ensures that this does not happen.

(1) They have a minimum Cv factor in accordance with either Table 5.1.4.1.6(a) or Table 5.1.4.1.6(b).
(2) They use a quarter turn to off.

The quarter-turn ball valve shown in Exhibit 5.28 has become the standard type of valve used in medical gas systems. It allows for the quick shutoff of gas, which is highly desirable in an emergency such as a fire.

N ***TABLE 5.1.4.1.6(a)*** *Positive Pressure Gases*

Valve Size (in.)	*Minimum Cv (full open)*
½	17
¾	31
1	60
1¼	110
1½	169
2	357
2½	390
3	912
4	1837

N ***TABLE 5.1.4.1.6(b)*** *Vacuum and WAGD*

Valve Size (in.)	*Minimum Cv (full open)*
¾	31
1	60
1¼	110
1½	169
2	357
2½	196
3	302
4	600
5	1022
6	1579
8	3136

EXHIBIT 5.27

Main Oxygen Shutoff Valve in a Hospital.

(3) They are constructed of materials suitable for the service.
(4) They are provided with copper tube extensions by the manufacturer for brazing or with corrugated medical tubing (CMT) fittings.
(5) They indicate to the operator if the valve is open or closed.
(6) They permit in-line serviceability.
(7) They are cleaned for oxygen service by the manufacturer if used for any positive-pressure service.

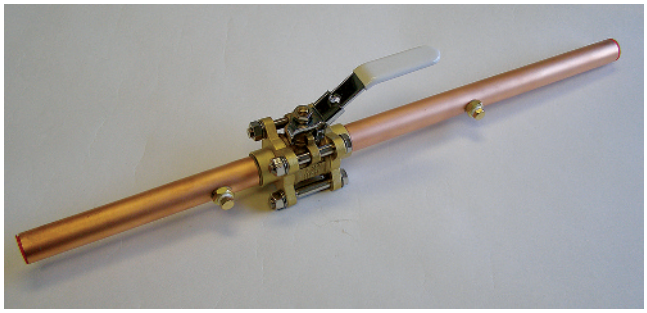


EXHIBIT 5.28

Quarter-Turn Medical Gas Shutoff Valve. (Courtesy of Tri-Tech Medical, Inc.)

Medical/surgical vacuum valves are not required to be cleaned for oxygen service, as are the medical gas valves. "Cleaned for oxygen service" by definition means the removal of combustible contaminants from the surface of any equipment or system in oxygen service, including all parts that make up those components. These contaminants include, but are not limited to, organic and inorganic substances such as hydrocarbon material — oils and greases, paper, fiber, coal dust, solvents, weld slag, rust, sand, and dirt. If these contaminants are not removed properly, a combustion reaction in an oxygen atmosphere or unacceptable product purity will result.

The vacuum pumps create a subatmospheric pressure and flow at inlets to remove fluids, blood, tissue, particles, and such items from patients' bodies. Essentially, a vacuum valve is part of a dirty system. Vacuum systems do not produce, store, or distribute medical gases to patients. Cleaning for oxygen service is intended for cleaning equipment used in production, storage, distribution, and use of liquid and gaseous medical gases.

5.1.4.2 Source Valve.

The source valve must be provided within the immediate vicinity of the source equipment. The source valve and main line valve serve a similar function. If the source valve is not accessible from within the facility (or the central supply source equipment with a source valve is not physically mounted to the wall of the building being served), a main line valve is installed inside the facility to isolate the distribution pipeline network from the central supply source.

The primary reason a source valve is installed is to isolate the central supply source equipment from the pipeline distribution network. This isolation is necessary during central supply equipment change-outs or main line damage such as breaks in the line or construction activities.

Caution should be exercised if turning off the source valve is part of the facility emergency action plan during a fire. Shutting down a source valve would stop the gas supply to 100 percent of the areas that are supplied by the pipeline network. Zone valves are designed to isolate the medical gas and vacuum in patient care areas in the case of a fire.

5.1.4.2.1 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.

5.1.4.2.2 The source valve shall be located in the immediate vicinity of the central supply system.

5.1.4.3* Main Line Valve.

A.5.1.4.3 The presence of a main line shutoff valve is optional where the source valve can equally or more effectively perform the same function. An example is a case where the

source is within the building or just on the outside of the building and, therefore, there would be no great distance separating the two valves. A source that was physically separate from the building would require both valves to ensure the intervening piping could be controlled.

The main line valve required by 5.1.4.3 is often misconstrued as a valve intended for the fire department to shut off the supply to the building in an emergency. However, it is not intended for this purpose. Under a "defend in place" fire protection strategy (for facilities that cannot easily be evacuated, such as hospitals and nursing homes), shutting off the main valve could have disastrous consequences. The primary function of the main valve is to isolate the source from the building, as might be required when changing the bulk system or if the main line is damaged. The main line shutoff valve is likely to be used only when a new source is being installed or the source is relocated.

5.1.4.3.1 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:

(1) The source and source valve are located inside the building served.
(2) 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.

5.1.4.3.2 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.

FAQ Are main line valves always required?

The source valve is allowed to substitute for the main line shutoff valve if both would be located inside the building, which is commonly the case with a medical air compressor system or with a manifold room in the basement. This substitution permitted by this requirement eliminates the redundant installation of a source valve and a main line valve located inches apart.

The main line valves and source valves serve a similar function. If the source valve is not accessible from within the facility (or the central supply source equipment with a source valve is physically mounted to the wall of the building being served), a main line valve is installed inside the facility to isolate the distribution pipeline network from the central supply source.

The charging sentence of 5.1.4.3.1 has been revised to say "inside of the buildings being served" to clarify that where there are multiple freestanding buildings being served by one central supply source, there will be more than one main line valve.

5.1.4.4 Riser Valve. Each riser supplied from the main line shall be provided with a shutoff valve in the riser adjacent to the main line.

This requirement allows one riser to be shut down without having to shut down the entire piped gas distribution system (such as for repairs or modifications). During new construction, a shutoff valve at the base of each riser allows isolation and testing of the system in increments.

Even though riser valves are often visually obscured or blocked by other service ducts or piping, they allow a facility more flexibility with future work or additions to the medical gas pipeline systems. These valves should always be accessible, albeit only to authorized personnel.

5.1.4.5 Service Valves.

Service valves provide a means to isolate each individual floor's pipelines for renovations, maintenance, or other tasks. Service valves are located on the lateral branch line at the immediate vicinity at which the riser pipeline and floor lateral branch line intersect. Each floor of a facility may have one or more service valves per gas service depending on the design of the vertical riser and lateral branch pipelines. If one lateral branch line immediately comes off the riser pipeline, then one service valve will be installed. If two or more lateral branch lines immediately come off the riser pipeline, then one service valve per lateral branch line is needed. The service valve is normally in a locked "open" position. All service valves need labels indicating the gas and areas of control. In addition to the service valves, downstream of the service valves (on the patient side) there will be the necessary amount of zone valves, in-line (maintenance) valves, and future valves on the floor.

5.1.4.5.1 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.

5.1.4.5.2 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.

5.1.4.5.3 Service valves shall be placed in the branch piping prior to any zone valve box assembly on that branch.

5.1.4.6 Zone Valves.

All of 5.1.4.6 has been reordered to make the requirements flow better and more cleanly. Redundant clauses were deleted to remove unnecessary requirements.

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

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

The purpose of requiring a "wall" between the valves and outlets/inlets is to allow someone to shut off the flow of gas to a fire site without being directly exposed to the fire and any products of combustion. There must be a wall (opaque or not) between the valve and the outlets/inlets that it controls. A doorway does not require a door unless one is needed to protect the "view" of the outlets/inlets from the valve. This does not mean that the walls/doors are or are not transparent. The intent is to provide some protection at the valve site by providing a barrier between the valve and the outlet/inlet. Note that item (5) of this same section still states that the valve cannot be located in the same room with the outlet/inlet it controls.

In many cases where there is a suite, such as in a post-anesthesia care unit, there may not be a wall intervening between the valve and the outlets/inlets that it controls. In those cases, careful coordination with the authority having jurisdiction is necessary to determine an agreeable location of the valve to obtain an equivalent level of protection.

(2)* It is readily operable from a standing position.

N **A.5.1.4.6.1(2)** A "standing position" is meant to refer to an average-height individual standing with their feet on the floor in front of the zone valve.

In the 2018 edition, the requirement of (2) has been made to stand alone, and annex material has been added to better define what is meant by standing position and that it is not meant to be standing on a ladder or anything other than the floor.

(3) It is installed where it is visible and accessible at all times.
(4) It is not installed where it can be hidden from plain view, such as behind normally open or normally closed doors.

Zone valve boxes cannot be blocked, hidden, or positioned out of the reach of personnel responsible for operating the zone valve in the case of an emergency. For instance, these valve boxes should not be installed behind doors that could be opened or beside doors that will be opened in an emergency, because such valve boxes might be hidden as patients are removed from a fire scene. Shelves, medical equipment, IV poles, or other furniture or equipment should not block the zone valve box from view. Also, beds, carts, and other medical equipment or furniture should not be parked in front of a zone valve box. Personnel may not be able to access the zone valve in the case of emergency if they have to reach over equipment or furniture.

(5) It is not installed in a room with the station outlets/inlets that it controls.
(6) It is not installed in rooms, areas, or closets that can be closed or locked.

5.1.4.6.2 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. These zone valves shall be located as follows:

(1) They are installed immediately outside the area controlled.
(2) They are readily accessible in an emergency.

The governing body of the facility or its designee must establish patient care room classifications in accordance with the type of patient care anticipated. Category 1 through 4 spaces may have medical gas outlets and vacuum inlets installed. All station outlets/inlets must be controlled through a zone valve. For example, when the governing body classifies a patient care room as a critical care room and also as a room in which general anesthesia will be administered, this room will require a zone valve box that controls only that room. This zone valve box will be located immediately outside the room near the primary door to allow the facility personnel to easily access the zone valve box in the case of an emergency. Exhibit 5.29 shows zone valve boxes that are located immediately outside of an anesthetizing location. The intent of the phrase *immediately outside* means "near the primary door to." If the valve is on a wall of the room, but on the outside of a back wall that requires extensive travel to be reached, it does not meet the intent.

EXHIBIT 5.29

Zone Valve Boxes Located Immediately Outside of Anesthetizing Location.

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

(1) 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.
(2) Service will only be to outlets/inlets located on that same story.
(3) 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.

A simple rule of valve placement is that zone valves must never be placed in series. Because closure of a single set of valves could create undesirable and unexpected effects, placing zone valves in series would compromise both fire safety and patient care. Note that other valves (such as source, main line, service, and in-line valves) will of course be in series with zone valves.

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

Piped gas and vacuum systems must have pressure indicators on the patient side of zone valve box assemblies to continuously monitor the line pressure of the zone. Exhibit 5.30 shows a typical zone valve box assembly in a facility. The pressure indicator is on the patient side of the zone valve (instead of the source supply side of the zone valve) primarily for safety reasons when maintenance, testing, construction, or repairs are occurring. A medical gas line that is under pressure should not be worked on. This pressure indicator is important anytime a person needs to verify that the working gas pressure is in the pipeline or, in the case of bleeding out the gas, that the working gas pressure is removed from the pipeline.

See Checklist 5.4 for a sample checklist that can be used to verify that the requirements of 5.1.4.6 have been met. An interactive PDF version of this checklist is also available as an "eForm" in the Purchase Products & Training tab at www.nfpa.org/99.

5.1.4.7 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.

For an intensive care unit with 20 beds arranged in a U-shaped pattern, having one set of valves in a box with the gas feeding from one end of the U is normal practice. However, if one outlet at a bedside in the middle of the unit has to be replaced, oxygen and medical gas for the entire unit would have to be shut down. A solution would be to install in-line valves for each bed in the ceiling. When one outlet has to be worked on, these valves could be closed, isolating only a bed or two.

Another example of an area where in-line shutoff valves would be helpful is the intensive care nursery. In most arrangements, the incubators are grouped in pods or along walls. In-line shutoff valves to isolate groups of these beds would prevent disruption of the flow of gases to all of the beds.

It should also be noted that these service valves do not need to be readily accessible in an emergency — they are not intended for that purpose. Typically, they would be located above ceiling tiles or inside casework.

5.1.4.8 Valves for Future Connections.

Future valves allow additions to be made to the medical gas pipeline without shutting down the complete medical gas zone of a facility. For example, a future valve installed at the end of a pipeline run of a medical gas zone will allow a facility to add medical gas outlets onto a medical gas zone of a facility without shutting down the patient wing. Caution should be taken as to when and for what purpose future valves can be used. Do not use future valving that creates zone valves in series (see 5.1.4.6.3). Valves for future connections are optional and are to be placed at the discretion of the facility.

Checklist

Checklist 5.4 Zone Valve

System: _____

Location: _____

Y = Satisfactory **N** = Unsatisfactory (explain below) **N/A** = Not applicable

Date _____ Inspector _____

	Y	*N*	*N/A*	*Comments*
Installed so that a wall intervenes between the valve and the outlets/inlets that it controls	☐	☐	☐	
Readily operable from a standing position	☐	☐	☐	
Installed where it is visible and accessible at all times	☐	☐	☐	
Not installed where it can be hidden from plain view, such as behind normally open or normally closed doors	☐	☐	☐	
Not installed in a room with the station outlets/inlets that it controls	☐	☐	☐	
Not installed in rooms, areas, or closets that can be closed or locked	☐	☐	☐	
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.	☐	☐	☐	
Service will only be to outlets/inlets located on that same story.	☐	☐	☐	
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.	☐	☐	☐	
A pressure/vacuum indicator is provided on the station outlet/inlet side of each zone valve.	☐	☐	☐	

5.1.4.8.1 Future connection valves shall be labeled as to gas content.

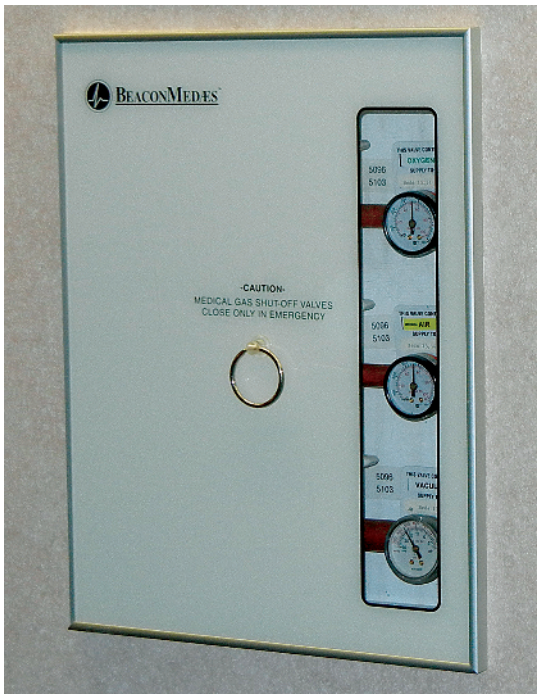
5.1.4.8.2 Downstream piping shall be closed with a brazed cap with tubing allowance for cutting and rebrazing.

Valves for future connections cannot serve as end-of-line devices. A cap must be brazed to the end of the tube, as shown in Exhibit 5.31.

5.1.4.9 In-Line Check Valves. New or replacement check valves shall be as follows:

(1) They shall be of brass or bronze construction.
(2) They shall have brazed extensions.
(3) They shall have in-line serviceability.

EXHIBIT 5.30



Typical Zone Valve Box Assembly in Unit of Facility: Cover on (left), Cover off (right).

EXHIBIT 5.31

End-of-Line Caps Brazed on End of Tube. (Courtesy of William G Frank Medical Gas Testing & Consulting, LLC)

(4) They shall not have threaded connections.
(5) They shall have threaded purge points of ⅛ in. NPT.

In-line check valves are required when an emergency oxygen supply connection or an in-building emergency reserve is installed.

5.1.5* Station Outlets/Inlets.

A.5.1.5 Station outlets/inlets should be located at an appropriate height above the floor to prevent physical damage to equipment attached to the outlet. The minimum number of station outlets/inlets for each system that is installed should be provided per the FGI *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* or other federal, state, or local codes.

The reference to the FGI *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* in A.5.1.5 has been added to the 2018 edition of the code. The FGI guidelines provide requirements for station outlets/inlets that must be provided within different spaces based on the type of health care facility being designed. See Commentary Table 5.3 for a snapshot of the requirements in the table in the FGI guidelines. Note that the table shows only a small selection of the locations detailed in that document.

COMMENTARY TABLE 5.3 *Sample of Station Outlet/Inlet Requirements from FGI Guidelines*

Location	*Oxygen*	*Vacuum*	*Medical Air*	*WAGD*
Critical care (general)	3/bed	3/bed	1/bed	-
Coronary critical care	3/bed	2/bed	1/bed	-
Operating room	2/room	5/room	1/room	1/room
Neonatal Intensive Care Unit (NICU)	3/infant care bed	3/infant care bed	3/infant care bed	-
Cesarean Delivery Room	2/room	4/room	1/room	1/room

Source: Extracted from Table 2.1-4 Station Outlets for Oxygen, Vacuum (Suction), and Medical Air Systems in Hospitals.

5.1.5.1 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.

Exhibit 5.32 shows an array of medical gas and vacuum outlets and inlets. Note that the oxygen outlet shown in Exhibit 5.33 is mechanically different from the medical air outlet to prevent a mix-up in gases when hoses are connected to outlets.

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

5.1.5.3 Each station inlet shall consist of a primary valve (or assembly) and shall be permitted to include a secondary valve (or assembly).

5.1.5.4 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.

5.1.5.5 Each outlet/inlet shall be legibly identified in accordance with 5.1.11.3.

5.1.5.6 Threaded outlets/inlets shall be noninterchangeable connections complying with the mandatory requirements of CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*.

5.1.5.7 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 5.1.5.1 and 5.1.5.9 cannot be interchanged between the station outlet/inlet for different gases.

EXHIBIT 5.32

Array of Medical Gases and Vacuum Outlets/Inlets.

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

5.1.5.9 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.

5.1.5.10 Components of inlets not specific to a vacuum shall not be required to be marked.

5.1.5.11 Factory-installed copper inlet tubes on station outlets extending no further than 205 mm (8 in.) from the body of the terminal shall be not less than DN8 (NPS ¼) (⅜ in. O.D.) size, with 8 mm (0.3 in.) minimum inside diameter.

5.1.5.12 Factory-installed copper outlet tubes on station inlets extending no further than 205 mm (8 in.) from the body of the terminal shall be not less than DN10 (NPS ⅜) (½ in. O.D.) size, with 10 mm (0.4 in.) minimum inside diameter.

5.1.5.13 Station outlets/inlets shall be permitted to be recessed or otherwise protected from damage.

5.1.5.14 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.

When installing gas station outlets, it is good practice to consider the space directly over the outlets as well as the distance between them. Because oxygen and vacuum therapy equipment frequently have a height of 180 mm (7 in.) or more, installing outlets directly beneath overbed lights or cabinets could cause the outlets to be inaccessible.

EXHIBIT 5.33

Close-Up of Oxygen Outlet with Equipment Attached. (Courtesy of Tri-Tech Medical, Inc.)

Similarly, many suction canisters in use today are at least 180 mm (7 in.) or more in diameter. Thus, if oxygen, vacuum, and air are specified at a patient bed location, the best installation sequence would be oxygen–air–vacuum. This arrangement would allow the vacuum outlet and equipment to be located on the end, rather than cramped between other equipment.

Δ **5.1.5.15** Station outlets in systems having nonstandard operating pressures shall meet the following additional requirements:

(1) They shall be gas-specific.
(2) 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 550 kPa (80 psi) shall not accept an adapter for oxygen at 345 kPa (50 psi)].
(3) If operated at a pressure in excess of 550 kPa (80 psi), they shall be either D.I.S.S. connectors or comply with 5.1.5.15(4).
(4) If operated at a gauge pressure between 1380 kPa and 2070 kPa (200 psi and 300 psi), 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.

Standard operating pressures can be found in Table 5.1.11, Standard Designation Colors and Operating Pressures for Gas and Vacuum Systems. Nonstandard operating pressures include line pressure, which is not listed in Table 5.1.11, or as defined in 5.1.5.15.

5.1.5.16 WAGD networks shall provide a WAGD inlet in all locations where nitrous oxide or halogenated anesthetic gas is intended to be administered.

The location in which WAGD inlets must be installed is a complex issue in a health care environment, where the nature of anesthesia is changing rapidly. At one time, most general anesthesia involved gaseous anesthetics; now much general anesthesia is performed by injection. As a result, almost any site in the hospital could now be an anesthetizing location, thereby greatly complicating the question of where to place WAGD inlets.

The designer should at least define an anesthetizing location for the purpose of WAGD as any site where nitrous oxide or halogenated anesthetic will be administered. It should also be taken into consideration that there are other instances for installing a WAGD inlet (such as for the use of portable supplies of nitrous oxide).

5.1.5.16.1 Station inlets for WAGD service shall have the following additional characteristics:

(1) They shall not be interchangeable with any other systems, including medical–surgical vacuum.
(2) Components necessary for the maintenance of WAGD specificity shall be legibly marked to identify them as components of a WAGD inlet.
(3) They shall be of a type appropriate for the flow and vacuum level required by the facility's gas anesthetic machines.
(4) They shall be located to avoid physical damage to the inlet.

N **5.1.5.17** Where installed in a down-facing position, such as in a ceiling or ceiling column, station outlets/inlets shall be D.I.S.S. connectors.

This is a new provision for the 2018 edition and is intended to prevent instances of hose assemblies occasionally disconnecting from quick connect outlets. DISS outlets provide a much safer/secure connection when in the down-facing position.

5.1.6* Manufactured Assemblies.

A.5.1.6 Manufactured assembly examples include headwalls, columns, ceiling columns, ceiling-hung pendants, movable track systems, and so forth. See Figure A.5.1.6.

Traditionally, the MGVS would be considered to end at the station outlet where the copper tubing terminates. However, in manufactured assemblies, several station outlets could be placed along the length of the assembly, ostensibly for "future convenience." The manufactured assembly is then placed over the station outlets, usually with a panel that can be removed for access to the outlets. Attached to some of the station outlets are flexible connectors (usually rubber hoses) connected to a remote terminal point where the user will actually make connections and disconnections. This user outlet forms an extension of the pipeline, which, in practice, is essentially a permanent extension of the pipeline. Hoses and station outlets are hidden behind or within the manufactured assembly.

Hiding the station outlets and using flexible hoses can lead to hazards in the operation of a safe MGVS. Some of these hazards are as follows:

1. Hidden station outlets are problematic for testing and certification. Unless the verifier is made aware of their presence and these items are left accessible, it is easy to overlook them during the testing process.
2. Flexible connectors, and particularly rubber hoses, are less fire resistant than copper pipe. Use of these items significantly increases risks to patients and staff if a fire occurs within or near the assembly.

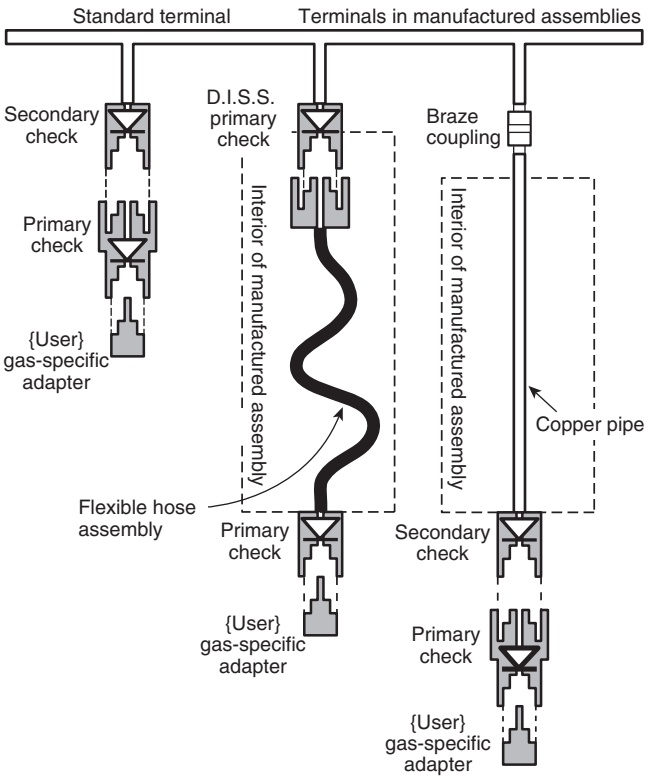


FIGURE A.5.1.6 *Terminals in Manufactured Assemblies.*

These hoses require periodic replacement because they deteriorate over time, and hiding them behind a panel where their physical condition cannot be readily inspected increases the risk of a rupture.

3. The number of connections and outlets from the pipeline that are enclosed in the manufactured assembly increases the risk of small leaks that can occur with any connection or seal. There is a risk that an oxygen-enriched atmosphere could develop behind the panel, which would greatly increase the speed with which a fire would spread.
4. The use of standard station outlets in series can create a significant flow restriction. This, in turn, could result in inadequate flow of gas or vacuum in some clinical situations.

Despite these risks, manufactured assemblies have been used with success for decades. NFPA 99 attempts to address these concerns without reducing the operational effectiveness of the assemblies. See 3.3.100 for the definition of the term *manufactured assembly,* and see Exhibit 5.34 for an example of a manufactured assembly.

5.1.6.1 Manufactured assemblies shall be pretested by the manufacturer prior to arrival at the installation site in accordance with the following:

(1) Initial blowdown test per 5.1.12.2.2
(2) Initial pressure test per 5.1.12.2.3
(3) Piping purge test per 5.1.12.2.5
(4) Standing pressure test per 5.1.12.2.6 or 5.1.12.2.7, except as permitted under 5.1.6.2
(5) Operational pressure test per 5.1.12.4.10, except that the test gas is permitted to be in accordance with the manufacturer's process requirements

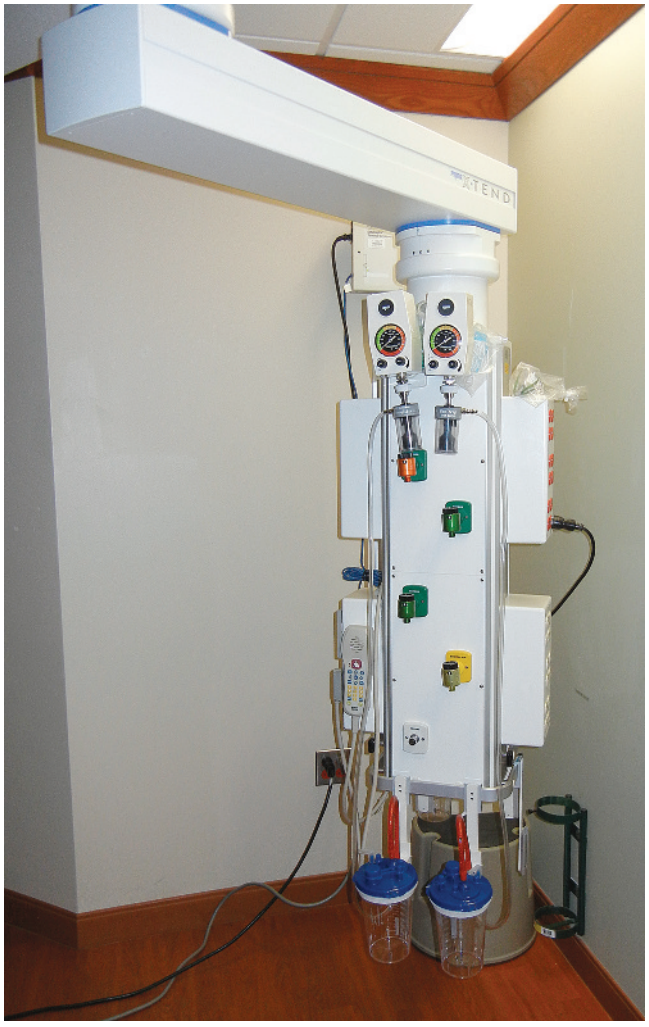


EXHIBIT 5.34

Example of Manufactured Assembly.

Piping internal to manufactured assemblies requires the same system integrity as the remainder of the piped system. Item (5) is new to the 2018 edition. The committee was advised that manufactured assemblies have failed the operational pressure test once installed. Requiring that this test be done by the manufacturer prior to installation will help alleviate this problem. An allowance has been added to let the manufacturer use a test gas other than the system gas as is required in the referenced test.

5.1.6.2 The leakage from a completed manufactured assembly shall not exceed 0.5 percent of the starting pressure when tested at 20 percent above operating pressure for pressure pipelines and 635 mm (25 in.) HgV for vacuum and WAGD systems [e.g., 2 kPa (0.3 psi) starting at 415 kPa (60 psig), 0.3 mm (0.125 in.) HgV starting at 635 mm (25 in.) HgV].

5.1.6.3 The manufacturer of the assembly shall provide documentation certifying the performance and successful completion of the tests required in 5.1.6.1.

5.1.6.4 Manufactured assemblies employing flexible hose shall use hose and flexible connectors with a minimum burst gauge pressure of 6895 kPa (1000 psi).

N **5.1.6.5** The manufacturer of the assembly shall provide documentation certifying that the flexible hose assembly has a minimum burst gauge pressure of 6895 kPa (1000 psi).

This section has been added to the 2018 edition after the technical committee was advised that some manufacturers of these assemblies were not using high-pressure hose or flex connectors and that oftentimes there were no markings on the hoses to allow for verification that the assemblies meet the minimum burst gauge pressure requirement. This revision will require documentation certifying that the assembly meets the requirement.

Δ **5.1.6.6** Components of manufactured assemblies shall have a flame spread index of not greater than 200 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, Standard for Test for Surface Burning Characteristics of Building Materials, or shall comply with the requirements for heat release in accordance with NFPA 286 as described in Section 10.2 of NFPA *101*.

This requirement has been revised for the 2018 edition to require that components, rather than the manufactured assembly itself, meet the testing criteria. In addition, ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials,* has been added as an alternative test method to ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials.* Tubing and flexible hoses used in manufactured assemblies must also have the rating required by 5.1.6.6.

5.1.6.7 Manufactured assemblies employing flexible hose or tubing shall be attached to the pipelines using station outlets/inlets.

5.1.6.8 Manufactured assemblies employing hose or flexible connectors, where the station outlet/inlet attached to the piping is not fully and immediately accessible (i.e., cannot be manipulated without the removal of panels, doors, and so forth), shall have station outlets/inlets with the following additional characteristics:

(1) They shall be gas-specific connections with positive locking mechanisms that ensure the connector is firmly seated and cannot detach without intentional actuation of the release (e.g., D.I.S.S. connectors).
(2) In pressure gases, they shall be permitted to omit the secondary valve (or assembly) required in 5.1.5.2.
(3) In vacuum and WAGD, they shall be permitted to omit both primary and secondary valves (or assemblies) for minimum restriction to flow.
(4) They shall be provided with a second terminal at which the user connects and disconnects that complies with 5.1.5.

This section is intended to apply only for manufactured assemblies that have station outlets/inlets. Not all manufactured assemblies have them and it is not the intent of the committee to require them.

N **5.1.6.9** Hose or flexible connectors employed in manufactured assemblies shall be labeled by stenciling or adhesive markers that identify the patient medical gas, the support gas, or the vacuum system and include the following:

(1) Name of the gas or vacuum system or the chemical symbol per Table 5.1.11
(2) Gas or vacuum system color code per Table 5.1.11
(3) Where positive-pressure piping systems operate at pressures other than the standard gauge pressure in Table 5.1.11, the operating pressure in addition to the name of the gas
(4) Date of installation

Item (4) is new to the 2018 edition. The committee was advised that it is common for manufactured assemblies to be deficient in their identification and labeling of their flexible hose or connectors. This requirement will help those providing care and maintenance better identify what gas they are dealing with on a given hose.

5.1.6.10 Station outlets/inlets installed in manufactured assemblies connected to the pipeline by brazing shall comply with 5.1.5.

5.1.6.11 The installation of manufactured assemblies shall be tested in accordance with 5.1.12.

5.1.7* Surface-Mounted Medical Gas Rails (MGR).

Surface-mounted medical gas rail systems are wall-mounted or surface-mounted integrated equipment management systems that distribute medical gases — typically oxygen, air, and vacuum. Normally placed along the headwall of patient beds, such as the one shown in Exhibit 5.35, the surface-mounted medical gas rail system can be fitted with accessories such as storage baskets, monitor shelves, holders for blood pressure monitors, blenders, suction containers, sharps containers, and other storage or organizational accessories. These systems can be customized based on the patient care area needs.

EXHIBIT 5.35

Surface-Mounted Medical Gas Rail.

A.5.1.7 It is the intent that surface-mounted medical gas rail systems would be permitted in individual patient rooms but would not be permitted to go directly through room walls to adjacent patient rooms. However, it is the intent to permit surface-mounted medical gas rails to be used in a given Category 1 space where there can be a partition separating certain patient care functions, essentially leaving the system within the given Category 1 space. As an example, two adjacent patient rooms outside of a Category 1 space care unit would not be permitted to have a surface-mounted medical gas rail interconnect between the two rooms through the wall. However, in a nursery where there might be one or two segregated areas for isolation, a medical gas rail system supplying more than one isolation room, but within the nursery area, would be permitted to be interconnected with the nursery system.

5.1.7.1 Medical gas rail (MGR) assemblies shall be permitted to be installed where multiple uses of medical gases and vacuum at a single patient location are required or anticipated.

The term *patient location* is used so that any new type of patient treatment configuration that might be developed, and might eventually lend itself to this type of system, can be utilized.

Also, a rail system can serve only one (single) patient location. A separate rail system must be installed for each patient location.

5.1.7.2 MGR assemblies shall be entirely visible in the room, not passing into or through walls, partitions, and so forth.

5.1.7.3 MGR assemblies shall be made of materials with a melting point of at least 538°C (1000°F).

This paragraph makes no reference to a specific type of material that can be used for MGR assemblies. Any material that is equivalent in mechanical, thermal, and sealing integrity to that of a brazed joint can be used. Note that this equivalency must be determined under actual operating conditions because the melting point of some materials (such as basic aluminum) is below 538°C (1000°F). However, with appropriate design consideration, aluminum alloys can be selected that have melting points above 538°C (1000°F). Aluminum medical gas rails shouldn't be restricted from installations on the basis of the melting point of pure aluminum. Instead the melting point of the specific aluminum alloy being used should be considered.

If the metal used for the medical gas rail system is dissimilar to that of the piping system to which it is connected, general health care industry practice is to use fittings compatible with both metals.

5.1.7.4 MGR assemblies shall be cleaned per 5.1.10.1.1.

5.1.7.5 Station outlets or inlets shall not be placed on the ends of MGR assemblies.

5.1.7.6 Openings for station outlets/inlets in the MGR shall be gas-specific.

Typically, MGR designs include port openings on the gas rail piping or at the end of the gas rail that can be used to add outlets/inlets or to extend rail systems. These "openings," if not connected for station outlet/inlet service, need to have a special type of capped or plugged seal removable only with a special tool.

5.1.7.7 Openings in the MGR not occupied by station outlets/inlets (e.g., for future use) shall be capped or plugged so that a special tool is required for removal (i.e., cannot be removed by a wrench, pliers, a screwdriver, or other common tool).

5.1.7.8 MGR assemblies shall connect to the pipeline through fittings that are brazed to the pipeline.

5.1.7.9* Where the pipeline and the MGR assembly are of dissimilar metals, the connections shall be plated or otherwise protected from interaction between the metals.

A.5.1.7.9 Typical plating would be nickel plating over copper or brass per Federal Specification QQ-N290, Class I, Type 7.

5.1.7.10 The installation of the MGR shall be tested in accordance with 5.1.12.

5.1.8 Pressure and Vacuum Indicators.

Pressure gauges or indicators are instruments for measuring the condition of a fluid in liquid or gas form; pressure is specified by the force that the fluid would exert when at rest, on a unit area, and is

measured in pounds per square inch (psi). Pressure gauges or indicators are crucial components of MGVS. In health care environments, a pressure gauge needs to be reliable, accurate, and easy to read to help prevent failure in everyday operations.

Analog indicators and pressure gauges are used for a variety of pressure monitoring applications specific to MGVS. Mechanical, or analog, pressure gauges have an analog face that displays the pressure reading (or vacuum reading) using a dial. Pressure gauges can be used for visual monitoring of gas pressure for compressors, vacuum equipment, process lines, and tank applications such as medical gas cylinders and receivers. In addition to visual indication, some pressure gauges are configured to provide electrical output of indicated pressure and monitoring of other variables such as temperature. See Exhibit 5.36 for an example of pressure and vacuum indicators.

EXHIBIT 5.36

Analog Indicators Located with Zone Valves.

5.1.8.1 General.

5.1.8.1.1 Pressure indicators and manometers for medical gas piping systems shall be cleaned for oxygen service.

5.1.8.1.2 Gauges shall comply with ANSI/ASME B40.100, *Pressure Gauges and Gauge Attachments*.

5.1.8.1.3* The scale range of positive pressure analog indicators shall be such that the normal operating pressure is within the middle third of the total range [e.g., an indicator of 0 to 2070 kPa

(0 to 300 psi) would have a lower third of 0 to 690 kPa (0 to 100 psig), a middle third of 690 kPa to 1380 kPa (100 psig to 200 psig), and a top third of 1380 kPa to 2070 kPa (200 psig to 300 psig)].

A.5.1.8.1.3 This gauge would therefore be suitable for any operating pressure of 690 kPa to 1380 kPa (100 psig to 200 psig).

These gauges are not highly accurate and are intended more for use "at a glance" than for precise readings of system pressure. That is why a range is specified here.

5.1.8.1.4 The accuracy of digital indicators shall be ±5 percent of the operating pressure at which they are used.

With the advent of electronics and LCDs, the dial face and analog display of some indicators have been replaced with digital displays. Digital indicators have some advantages over their analog predecessors. Some digital indicator models can record and transmit data electronically to a computer through an interface or USB. This facilitates statistical control of the process, because a computer can record the measurement results in a tabular dataset, such as a database table or spreadsheet, and interpret them by performing statistical analyses on them. This eliminates manual recording of long columns of numbers, which not only reduces the risk of the operator introducing errors but also improves the productivity of the process by freeing a person from time-consuming data recording and copying tasks. Another advantage is that they can be switched between metric and inch units with the press of a button, thus removing the unit conversion step of typing into a calculator or web browser and then typing the results.

5.1.8.1.5 The scale range of vacuum indicators shall be 0 to 760 mm (0 to 30 in.) gauge HgV. Indicators with a normal range display shall indicate normal only above 300 mm (12 in.) gauge HgV.

Pressure is the measurement used to describe either negative (below atmospheric) or positive (above atmospheric) pressure. Positive pressure is called *gauge pressure*. The term *vacuum* is used to describe the region *of* pressure below one atmosphere of pressure, also referred to as negative pressure. When speaking of vacuum, one must remember it as the opposite of pressure; high vacuum means low pressure. A vacuum (HgV) reading is similar to gauge pressure (psig) in that the gauge reading is referenced to the current atmospheric or barometric pressure (which changes over time and from place to place). When the reading is referenced to the theoretical absolute zero for a unit of measure, the reading is called an absolute value (psia, HgA). Standard atmospheric pressure is 29.92 HgA, 760 torr, or 14.7 psia.

5.1.8.1.6 Indicators adjacent to master alarm actuators and area alarms shall be labeled to identify the name of, or chemical symbol for, the particular piping system that they monitor.

5.1.8.2 Locations.

5.1.8.2.1 Pressure/vacuum indicators shall be readable from a standing position.

5.1.8.2.2 Pressure/vacuum indicators shall be provided at the following locations, as a minimum:

(1) Adjacent to the alarm-initiating device for source main line pressure and vacuum alarms in the master alarm system
(2) 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
(3) On the station outlet/inlet side of zone valves

Pressure or vacuum indicators are required on the main pipeline of an MGVS, the area alarm panel locations, and the zone valve box locations.

The pressure indicator (vacuum or medical gas) on the main pipeline is located on the patient side of the main or source valve and adjacent to the main line alarm-initiating devices. This pressure indicator measures the MGVS main line pressure or vacuum. Placement of this pressure indicator is critical for allowing facility staff to visually verify that the main lines are pressurized to the appropriate working line pressures. In the case of an oxygen system, the pressure indicator location is also downstream of the EOSC tie-in spot; when a temporary supply is connected to the EOSC, this pressure indicator helps visually verify that the main lines are pressurized to the appropriate working line pressures.

The pressure indicator for an area alarm panel is located adjacent to the area alarm-initiating device. This pressure indicator monitors the working line pressure of the area. If the area alarm indicates high or low pressure, this alarm condition can be verified by looking at the readout on the pressure indicator.

The pressure indicator located in or near the zone valve box is on the patient side of the zone valve. This pressure indicator monitors the zone's working line pressure. During routine maintenance where the MGVS in the zone is shut down, the maintenance person needs to know that the MGVS gas has been reduced to zero pressure, so that work on the MGVS can proceed. One way to confirm that the gas has been removed from the pipeline is to look at the readout on the pressure indicator.

5.1.8.2.3 All pressure-sensing devices and main line pressure gauges downstream of the source valves shall be provided with a gas-specific demand check fitting to facilitate service testing or replacement.

5.1.8.2.3.1 Gas-specific demand check fittings shall not be required on zone valve pressure indicators.

5.1.8.2.4 Demand check fittings shall be provided for all monitors.

FAQ Why do demand check fittings need to be gas-specific?

The need for gas-specific demand check fittings stems from the requirement that alarms be tested on a routine basis. Because the sensors are detached from the lines periodically, it is possible to reinstall the sensors on the wrong lines when reattaching them. Gas-specific connectors reduce this risk.

5.1.9* Category 1 Warning Systems.

Requirements for Category 1 warning systems are consistent between piped gas systems and vacuum systems. Alarms for both systems are often installed at the same time, and the critical nature of the alarms is similar for both systems.

Suction therapy is life-supporting. Patients receiving suction therapy are generally in serious condition, therefore failure of suction can be life-threatening. Thus, the proper functioning of alarms to indicate a failure or shutdown of a Category 1 vacuum system is essential.

The largest question regarding warning systems, or alarms, as well as with valves, is where exactly they are required. NFPA 99 calls for alarms for any "Category 1 location." In the 2018 edition, these areas need to be defined by the governing body of the health care facility at the time of construction or when alteration, renovation, or modernization is taking place (see Section 1.3), so the discussion about where and when they should be applied is no longer a Chapter 5 consideration.

A.5.1.9 See Figure A.5.1.4.

Δ **5.1.9.1 General.** All master, area, and local alarm systems used for medical gas and vacuum systems shall include the following:

(1) Separate visual indicators for each condition monitored, except as permitted in 5.1.9.5.2 for local alarms that are displayed on master alarm panels
(2) Visual indicators that remain in alarm until the situation that has caused the alarm is resolved
(3) Cancelable audible indication of each alarm condition that produces a sound with a minimum level of 80 dBA at 0.92 m (3 ft)

Safe levels can vary according to the duration of the exposure and the loudness level. Noises that are 80 decibels (dB) or less should not cause hearing damage, according to the Children's Hearing Institute. The suggested sound level for fire alarms is typically 5 to 15 dB above the normal sound level existing at the location, with a maximum at 110 to 120 dB (depending on the standard specifications in different locales).

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

Audible failure was added to item (4) for the 2015 edition to ensure that there will be indication that the feature of the alarm system has failed.

(5) Visual and audible indication that the communication with an alarm-initiating device is disconnected
(6) Labeling of each indicator, indicating the condition monitored
(7) Labeling of each alarm panel for its area of surveillance

Mislabeling is a common problem in health care facilities. In new installations, the "area of surveillance" must be identified by what that room or area is used for on a daily basis, not necessarily by what was written on the architect's original plans. Labeling should be verified for accuracy not only for new installations but also for existing ones.

(8) Reinitiation of the audible signal if another alarm condition occurs while the audible alarm is silenced
(9) Power for master, area alarms, sensors, and switches from the life safety branch of the essential electrical system as described in Chapter 6
(10) 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
(11) Where used for communications, wiring from switches or sensors that is supervised or protected as required by 517.30(C)(3) of *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
(12) Communication devices that do not use electrical wiring for signal transmission will be supervised such that failure of communication shall initiate an alarm.

Item (12) permits the use of master alarms that do not use wires for communication, provided that in instances where communication between sensors and panels is interrupted, an alarm is immediately initiated.

(13) Assurance by the responsible authority of the facility that the labeling of alarms, where room numbers or designations are used, is accurate and up-to-date
(14) 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
(15) Alarm switches/sensors installed so as to be removable

Item (15) requires that sensors be removable to facilitate testing and calibration, as well as for general service requirements.

5.1.9.2* 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.

Δ **A.5.1.9.2** See Table A.5.1.9.2.

5.1.9.2.1 The master alarm system shall consist of two or more alarm panels located in at least two separate locations, as follows:

(1) One master alarm panel shall be located in the office or work space of the on-site individual responsible for the maintenance of the medical gas and vacuum piping systems.
(2) In order to ensure continuous surveillance of the medical gas and vacuum systems while the facility is in operation, the second master alarm panel shall be located in an area of continuous observation (e.g., the telephone switchboard, security office, or other continuously staffed location).

Δ ***TABLE A.5.1.9.2*** *Requirements for Category 1 Master Alarms for Gas and Vacuum Systems*

Alarm Condition	*Manifold for Gas Cylinders (5.1.3.5.12)*	*Manifold for Cryogenic Liquid Cylinders with Reserve (5.1.3.5.13)*	*Cryogenic Bulk with Cryogenic Reserve (5.1.3.5.14)*	*Cryogenic Bulk with Cylinder Reserve (5.1.3.5.15)*	*Medical Air Proportioning System (5.1.3.6.3.13)*	*Medical Air Compressors (5.1.3.6)*	*Instrument Air Compressors (5.1.13.3.4)*	*Medical–Surgical Vacuum Pumps (5.1.3.7)*	*WAGD Producers (5.1.3.8)*	*Oxygen Concentrator (5.1.3.9)*
Nitrogen main line pressure high	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Nitrogen main line pressure low	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Nitrogen changeover to secondary supply	5.1.3.5.12.6 5.1.9.2.4(1)	5.1.3.5.13.9 (1), 5.1.9.2.4(1)	5.1.3.5.14.4(5)							
Nitrogen main supply less than 1 day (low contents)			5.1.9.2.4(2), 5.1.3.5.14.4(1)	5.1.9.2.4(2), 5.1.3.5.14.4(1)						
Nitrogen reserve in use		5.1.3.5.13.9(3), 5.1.9.2.4(3)	5.1.9.2.4(3), 5.1.3.5.14.4(2)	5.1.9.2.4(3), 5.1.3.5.14.4(2)						
Nitrogen reserve supply less than 1 day (low contents)		5.1.9.2.4(4), 5.1.3.5.13.9(4)	5.1.9.2.4(5), 5.1.3.5.14.4(3)	5.1.9.2.4(4), 5.1.3.5.14.4(3)						
Nitrogen reserve pressure low (not functional)			5.1.9.2.4(6), 5.1.3.5.14.4(4)							
Carbon dioxide main line pressure high	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						

(*Continued*)

Δ *TABLE A.5.1.9.2* *(Continued)*

Alarm Condition	*Manifold for Gas Cylinders (5.1.3.5.12)*	*Manifold for Cryogenic Liquid Cylinders with Reserve (5.1.3.5.13)*	*Cryogenic Bulk with Cryogenic Reserve (5.1.3.5.14)*	*Cryogenic Bulk with Cylinder Reserve (5.1.3.5.15)*	*Medical Air Proportioning System (5.1.3.6.3.13)*	*Medical Air Compressors (5.1.3.6)*	*Instrument Air Compressors (5.1.13.3.4)*	*Medical–Surgical Vacuum Pumps (5.1.3.7)*	*WAGD Producers (5.1.3.8)*	*Oxygen Concentrator (5.1.3.9)*
Carbon dioxide main line pressure low	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Carbon dioxide changeover to secondary supply	5.1.3.5.12.6 5.1.9.2.4(1)	5.1.3.5.13.9(1) 5.1.9.2.4(1)								
Carbon dioxide main supply less than 1 day (low contents)			5.1.9.2.4(2), 5.1.3.5.14.4(1)	5.1.9.2.4(2), 5.1.3.5.14.4(1)						
Carbon dioxide reserve in use		5.1.3.5.13.9(3), 5.1.9.2.4(3)	5.1.9.2.4(3), 5.1.3.5.14.4(2)	5.1.9.2.4(3), 5.1.3.5.14.4(2)						
Carbon dioxide reserve supply less than 1 day (low contents)		5.1.3.5.13.9(4)	5.1.9.2.4(5), 5.1.3.5.14.4(3)	5.1.9.2.4(5), 5.1.3.5.14.4(3)						
Carbon dioxide reserve pressure low (not functional)			5.1.9.2.4(6), 5.1.3.5.14.4(3)							
Medical air main line pressure high	5.1.9.2.4(7)					5.1.9.2.4(7)				
Medical air main line pressure low	5.1.9.2.4(7)					5.1.9.2.4(7)				
Medical air changeover to secondary supply	5.1.3.5.12.6 5.1.9.2.4(1)									
Medical air dew point high						5.1.3.6.3.13(1) 5.1.9.2.4(10)				
Medical air production stop					5.1.9.2.4(13)					
Oxygen main line pressure high	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Oxygen main line pressure low	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Oxygen changeover to secondary supply	5.1.3.5.12.6 5.1.9.2.4(1)	5.1.3.5.13.9 (1) 5.1.9.2.4(1)								
Oxygen main supply less than 1 day (low contents)			5.1.9.2.4(2), 5.1.3.5.14.4(1)	5.1.9.2.4(2), 5.1.3.5.14.4(1)						

Δ ***TABLE A.5.1.9.2*** *(Continued)*

Alarm Condition	*Manifold for Gas Cylinders (5.1.3.5.12)*	*Manifold for Cryogenic Liquid Cylinders with Reserve (5.1.3.5.13)*	*Cryogenic Bulk with Cryogenic Reserve (5.1.3.5.14)*	*Cryogenic Bulk with Cylinder Reserve (5.1.3.5.15)*	*Medical Air Proportioning System (5.1.3.6.3.13)*	*Medical Air Compressors (5.1.3.6)*	*Instrument Air Compressors (5.1.13.3.4)*	*Medical–Surgical Vacuum Pumps (5.1.3.7)*	*WAGD Producers (5.1.3.8)*	*Oxygen Concentrator (5.1.3.9)*
Oxygen reserve in use		5.1.3.5.13.9(3) 5.1.9.2.4(3)	5.1.9.2.4(3), 5.1.3.5.14.4(2)	5.1.9.2.4(3), 5.1.3.5.13.9(4) 5.1.3.5.14.4(2)						
		5.1.9.2.4(5)								
Oxygen reserve supply less than 1 day (low contents)			5.1.3.5.14.4(3)	5.1.3.5.14.4(3)						
Oxygen reserve pressure low (not functional)			5.1.9.2.4(6), 5.1.3.5.14.4(3)							
Nitrous oxide main line pressure high	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Nitrous oxide main line pressure low	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)	5.1.9.2.4(7)						
Nitrous oxide changeover to secondary supply	5.1.3.5.12.6 5.1.9.2.4(1)	5.1.3.5.13.9(1) 5.1.9.2.4(1)								
Nitrous oxide main supply less than 1 day (low contents)			5.1.9.2.4(2), 5.1.3.5.14.4(1)	5.1.9.2.4(2), 5.1.3.5.14.4(1)						
Nitrous oxide reserve in use		5.1.9.2.4(3), 5.1.3.5.13.9(3)	5.1.9.2.4(3), 5.1.3.5.14.4(2)	5.1.9.2.4(3), 5.1.3.5.14.4(2)						
Nitrous oxide reserve supply less than 1 day (low contents)			5.1.9.2.4(5), 5.1.3.5.14.4(3)	5.1.9.2.4(5), 5.1.3.5.14.4(2)						
		5.1.3.5.13.9(4)								
Nitrous oxide reserve pressure low (not functional)			5.1.9.2.4(6), 5.1.3.5.14.4(4)							
Medical–surgical main line vacuum low								5.1.9.2.4(8)		
WAGD main line vacuum low									5.1.9.2.4(11)	
Local alarm					5.1.9.2.4(9), 5.1.9.5.2, 5.1.3.6.3.14(C)(9)	5.1.3.6.3.12 5.1.9.2.4(9) 5.1.9.5.2	5.1.13.3.4.11 5.1.9.2.4(9) 5.1.9.5.2	5.1.3.7.8 5.1.9.2.4(9) 5.1.9.5.2	5.1.3.8.3.2 5.1.9.2.4(9) 5.1.9.5.2	

(*Continued*)

Δ ***TABLE A.5.1.9.2*** *(Continued)*

Alarm Condition	*Manifold for Gas Cylinders (5.1.3.5.12)*	*Manifold for Cryogenic Liquid Cylinders with Reserve (5.1.3.5.13)*	*Cryogenic Bulk with Cryogenic Reserve (5.1.3.5.14)*	*Cryogenic Bulk with Cylinder Reserve (5.1.3.5.15)*	*Medical Air Proportioning System (5.1.3.6.3.13)*	*Medical Air Compressors (5.1.3.6)*	*Instrument Air Compressors (5.1.13.3.4)*	*Medical–Surgical Vacuum Pumps (5.1.3.7)*	*WAGD Producers (5.1.3.8)*	*Oxygen Concentrator (5.1.3.9)*
Instrument air main line pressure high							5.1.9.2.4(7)			
Instrument air main line pressure low							5.1.9.2.4(7)			
Instrument air dew point high							5.1.13.3.4.11(A)(2) 5.1.9.2.4(12)			
Instrument air cylinder reserve in use (if provided)							5.1.13.3.4.11(B)(1)			
Instrument air cylinder reserve less than 1 hour supply							5.1.13.3.4.11(B)(2)			
Oxygen concentrator low concentration										5.1.3.5.11.13(2) 5.1.3.9.2(10)(c) 5.1.3.9.4.1(5) 5.1.9.2.4(14)(b)
Oxygen concentrator offline										5.1.3.5.11.12(5) 5.1.3.9.4.1(5) 5.1.9.2.4(14)(b)
Oxygen reserve in use										5.1.3.9.4.3(2) 5.1.9.2.4(3) 5.1.9.2.4(14)(c)
Oxygen reserve supply less than 1 day (low contents)										5.1.3.9.4.3(3) 5.1.9.2.4.(4) 5.1.9.2.4(14)(d)
Oxygen main line low concentration										5.1.3.9.4.2(4) 5.1.9.2.4(14)(g)
Oxygen main line high concentration										5.1.3.9.4.2(5) 5.1.9.2.4(14)(h)
Oxygen main line pressure high										5.1.9.2.4(7)
Oxygen main line pressure low										5.1.9.2.4(7)
Oxygen change of source										5.1.3.9.4.4(1)(a)
Oxygen concentrator internal pressure low										5.1.3.9.4.4(2) 5.1.9.2.4(14)(f)
Oxygen concentrator local alarm										5.1.9.2.4(9)

FAQ Why are two master panels needed in two locations?

The master panel listed in (1) allows the responsible person(s) to see which system alarm is activating and quickly respond to any alarm. This panel is not required to have continuous surveillance. The second master panel listed in (2) needs to be monitored "24/7/365" and is normally located in the security office, telephone switchboard office, or other similar area. When an alarm is activating, the person(s) monitoring the master alarm panel is required to immediately contact the person(s) responsible for maintaining the MGVS. See Exhibit 5.37 for an example of a master alarm panel.

If an alarm were to activate, it would indicate that an MGVS requires immediate attention and correction to operate properly for patient care. The master alarms, and the continuous monitoring of them, are critical to the safety of patients.

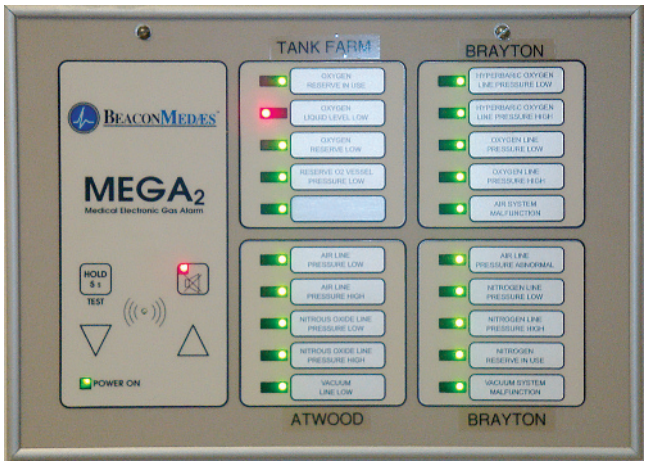


EXHIBIT 5.37

Master Alarm Panel Mounted on Wall in Hospital.

5.1.9.2.2 A centralized computer system shall be permitted to be substituted for one of the master alarms required in 5.1.9.2.1 if the computer system complies with 5.1.9.3.

A centralized computer system is permitted as a substitute for one of the medical gas and vacuum master alarm panels. An example of a centralized computer system is a building management system (BMS). The BMS is a computer-based system for centralizing and optimizing the monitoring, operation, and management of a building. Depending on the size of a facility and the installed hardware and software, the BMS may monitor and/or control the HVAC, security control systems, fire alarm systems, MGVS, elevators, power, and other facility utilities and functions.

5.1.9.2.3 The master alarm panels required in 5.1.9.2.1 shall communicate directly to the alarm-initiating devices that they monitor.

The subsections of 5.1.9.2.3 clarify the difference for requirements between wired communication (5.1.9.2.3.1) and other methods (5.1.9.2.3.2).

5.1.9.2.3.1 If communication is achieved by wires, the following shall apply:

(A) Each of the two mandatory alarms shall be wired independently to the initiating device(s) for each signal.

(B) The wiring between each mandatory alarm(s) and the initiating device(s) shall not utilize common conductors that, if interrupted, would disable more than one signal.

(C) Each set of wires (in whatever number as required by the alarm) shall run to the initiating device(s) without interruption other than in-line splices necessary to complete the necessary length of wire.

(D) Where initiating devices are remote from the building and the wiring is to run underground in compliance with *NFPA 70*, the following exceptions shall be permitted to be used:

(1) Wiring from the initiating device and through the underground section shall be permitted to be run to a junction box located where the wiring first enters the building.
(2) A single set of wires complying with 5.1.9.2.3.1(B) and 5.1.9.2.3.1(C) for each signal shall be permitted to connect the initiating device and the junction box.
(3) Between the junction box and the two mandatory alarm panels, wiring shall comply with 5.1.9.2.3.1(A) through 5.1.9.2.3.1(C), 5.1.9.2.3.4, and 5.1.9.2.3.5 in all respects.

Each master alarm panel requires independent wiring to each initiating device to ensure complete redundancy in the master alarm warning system. If one master panel loses power — if there is a disruption in the control boards of the master panel, if the control wires become separated from the dry connect connections, or if some other interruption occurs with one master panel — it will not affect the other master panel(s). The single initiating device can be wired to multiple panels; it is not necessary to have a single initiating device for each master panel. For example, if the central supply oxygen system has an oxygen reserve, there will be a single "oxygen reserve low" initiating device. This initiating device can be connected to multiple master alarm panels. The initiating device cannot be connected to one master alarm panel and wired in sequence, or "daisy chained," to a second master alarm.

5.1.9.2.3.2

In the 2015 edition the first allowance was made for "communication" between alarms and sensors rather than "wiring," which was previously the only allowed method. Wiring remains the standard against which other methods should be measured, as is reflected in the following language.

It is difficult to meet this standard with any of the other methods of communication available as of this writing. Wireless, the technique most often promoted for this application, suffers from short ranges and interferences of various kinds. Repeaters, which are the usual solution, introduce points of common failure that are proscribed under 5.1.9.2.3.2(B). Connections over networks (e.g., using the facility's IT network or a custom network) are equally powerful but require a variety of hardware to implement the network itself, any of which might pose a single point of failure. Other potential methods, such as fiber optics, are intriguing but not readily available or even well-suited to the application.

Therefore, this allowance is of interest mainly for the future, as techniques are developed that may overcome the drawbacks of the available technologies.

If communication is achieved by means other than wires, the following shall apply:

(A) Each of the mandatory alarms shall communicate independently to the initiating device(s) for each signal.

(B) The means of communication between each mandatory alarm(s) and the initiating device(s) shall not utilize a common communication device that, if interrupted, would disable more than one signal.

5.1.9.2.3.3 A single initiating device shall be permitted to actuate multiple master alarms.

5.1.9.2.3.4 The mandatory master alarm panels shall not be arranged such that failure of either panel would disable any signal on the other panel.

5.1.9.2.3.5 Where a relay is required to ensure correct operation of an initiating device, the control power for the relay shall not be such that disabling any master alarm panel would disable the relay.

5.1.9.2.3.6 Master alarm signals shall not be relayed from one master alarm panel to another.

5.1.9.2.3.7 Where multi-pole alarm relays are used to isolate the alarm-initiating signals to master alarm panels, the control power source for the relays shall be independent of any of the master alarm panels.

5.1.9.2.3.8 Multiple master alarms shall be permitted to monitor a single initiating device.

Δ **5.1.9.2.4** Master alarm panels for medical gas and vacuum systems shall each include the following signals:

(1) Alarm indication when, or just before, changeover occurs in a medical gas system that is supplied by a manifold or other alternating-type bulk system that has as a part of its normal operation a changeover from one portion of the operating supply to another
(2) Alarm indication for a bulk cryogenic liquid system when the main supply reaches one average day's supply, indicating low contents
(3) Alarm indication when, or just before, the changeover to the reserve supply occurs in a medical gas system that consists of one or more units that continuously supply the piping system while another unit remains as the reserve supply and operates only in the case of an emergency

The alarm condition in item (3) refers to the "reserve in use" signal, not the changeover alarm as listed in item (1). There has been some confusion due to the term *changeover* used to describe this alarm condition. When both the primary gas supply and the secondary gas supply — where a secondary gas supply is present, such as in manifolds for cryogenic containers — become depleted, the reserve source of medical gas will automatically activate and supply the medical gas distribution system. At this time, the "reserve in use" signal will activate and send a signal to the master alarm panels.

(4) Alarm indication for cylinder reserve pressure low when the content of a cylinder reserve header is reduced below one average day's supply
(5) For bulk cryogenic liquid systems, an alarm when or at a predetermined set point before the reserve supply contents fall to one average day's supply, indicating reserve low
(6) Where a cryogenic liquid storage unit is used as a reserve for a bulk supply system, an alarm indication when the gas pressure available in the reserve unit is below that required for the medical gas system to function

The alarm condition in item (6) refers to the "reserve low pressure" signal for a cryogenic liquid storage reserve tank. This alarm condition is similar to the "reserve low" signal listed in item (4) for high-pressure cylinders. As with high-pressure cylinder reserve supplies, the bulk liquid reserve source may supply the main medical gas distribution pipeline periodically, when the primary bulk liquid supply becomes depleted or is being serviced.

Other gas usage or losses of pressure in a bulk liquid reserve supply may be due to tank maintenance, leaks, or equipment failure. Whatever the case, this usage or loss of the liquid reserve over time may lead to a low-pressure point (before being filled by the gas supplier). If the low-pressure signal activation point is reached, a signal will be sent to the master panels indicating low pressure in the bulk liquid reserve supply.

(7) Alarm indication when the pressure in the main line of each separate medical gas system increases 20 percent or decreases 20 percent from the normal operating pressure
(8) Alarm indication when the medical–surgical vacuum pressure in the main line of each vacuum system drops to or below 300 mm (12 in.) gauge HgV

The alarm in item (8) is only required for low vacuum pressure. No alarm is required for high vacuum pressure. Unlike positive gas systems where the line pressure is regulated at the source of supply and failure of a component can cause elevated line pressure that can interrupt patient treatments, the vacuum system is regulated at the patient area usage point. Line pressure for vacuum ranges between 475 mm to 725 mm (19 in. to 29 in.) gauge HgV.

(9) Alarm indication(s) from the local alarm panel(s) as described in 5.1.9.5.2 to indicate when one or more of the conditions being monitored at a site is in alarm
(10) Medical air dew point high alarm from each compressor site to indicate when the line pressure dew point is greater than +2°C (+35°F)
(11) WAGD low alarm when the WAGD vacuum level or flow is below effective operating limits
(12) An instrument air dew point high alarm from each compressor site to indicate when the line pressure dew point is greater than −30°C (−22°F)
(13) Alarm indication if the primary or reserve production stops on a proportioning system
(14) When oxygen is supplied from an oxygen central supply system using concentrators *(see 5.1.3.9)*, the following signals shall be provided:

(a) For each concentrator unit used in the oxygen central supply system, an alarm indication that oxygen concentration from that oxygen concentrator unit is below 91 percent
(b) For each oxygen concentrator unit used in the oxygen central supply system, an alarm indication that the isolating valve for that oxygen concentrator unit is closed and the unit is isolated
(c) For each cylinder header used as a source, an alarm indication that the header is in use
(d) For each cylinder header used as a source, an alarm indication that the cylinder contents are below one average day's supply
(e) If the source in use changes because of a failure to appropriately supply the system, an alarm indication indicating an unexpected oxygen supply change has occurred
(f) An alarm indication that the pressure in the common line on the source side of the line pressure controls is low
(g) An alarm indication that the oxygen concentration from the supply system is below 91 percent

Item (14) and its subparts add requirements for the alarms that are needed to support the oxygen concentrator supply systems now permitted.

Δ **5.1.9.2.5** The alarm indications required in 5.1.9.2.4(7) and 5.1.9.2.4(8) shall originate from sensors installed in the main lines immediately downstream (on the patient or use side) of the source valves. Where it is necessary to install a main line valve in addition to a source valve *(see 5.1.4.3)*, the sensors shall be located downstream (on the patient or use side) of the main valve.

The main line shutoff valve can usually be eliminated if the source of equipment is within the facility. If the main line valve is eliminated, the actuating switch for these signals must be installed immediately

downstream (on the piping distribution side) of the source shutoff valve. Supply systems remote from the facility (such as oxygen bulk supplies) would still require both a source valve and a main valve just inside the facility. The pressure switch in this instance would be just downstream of the main valve where it first enters the facility or building. The requirements are constructed so no switch should ever need to be placed outdoors.

5.1.9.3 Master Alarms by Computer Systems. Computer systems used as substitute master alarms as required by 5.1.9.2.1(2) shall have the mechanical and electrical characteristics described in 5.1.9.3.1 and the programming characteristics described in 5.1.9.3.2.

The intent of this section is to make sure that a computer system functions both mechanically and electrically and includes programming that allows it to act as a stand-alone panel, with the addition of features such as pagers, autodialers, and so forth. The requirements are divided into physical requirements (5.1.9.3.1) and programming requirements (5.1.9.3.2). These computer functions must be verified under 5.1.12.4.5.1(G), which might require the assistance of a programmer.

Δ **5.1.9.3.1** Computer systems used to substitute for alarms shall have the following mechanical and electrical characteristics:

(1) The computer system shall be in continuous uninterrupted operation and provided with power supplies as needed to ensure such reliability.
(2) The computer system shall be continuously attended by responsible individuals or shall provide remote signaling of responsible parties (e.g., through pagers, telephone autodialers, or other such means).
(3) Where computer systems rely on signal interface devices (e.g., electronic interfaces, other alarm panels, 4 mA to 20 mA cards), such interfaces shall be supervised such that failure of the device(s) shall initiate an alarm(s).
(4) If the computer system does not power the signaling switches/sensors from the same power supply required in 5.1.9.3.1(1), the power supply for the signaling switches/sensors shall be powered from the life safety branch of the essential electrical system as described in Chapter 6.
(5) Computer systems shall be permitted to communicate directly to the sensors/switches in 5.1.9.2.3 in the same manner as an alarm panel if operation of another alarm panel(s) is not impaired.
(6) Communication from the computer system to the signaling switches or sensors shall be supervised such that failure of communication shall initiate an alarm.
(7) Computer systems shall be provided with an audio alert per 5.1.9.1(3), except the audio alert shall be permitted to be only as loud as needed to alert the system operator.
(8) The facility shall ensure compliance with 5.1.9.1(13).

Δ **5.1.9.3.2** The operating program for computer systems used to substitute for alarms shall include the following:

(1) The medical gas alarm shall be allocated the priority of a life safety signal.
(2) A medical gas alarm signal shall interrupt any other activity of a lesser priority to run the alarm algorithm(s).
(3) The alarm algorithm shall include activation of an audible alert, activation of any remote signaling protocol, and display of the specific condition in alarm.
(4) The alarm algorithm shall provide for compliance with 5.1.9.1(1) through 5.1.9.1(5), and 5.1.9.1(8).

The intent of the operating requirements in the 4 items listed in 5.1.9.3.2 is to make sure that the use of a computer system for a master alarm does not minimize the critical response that one of these alarms should initiate. One concern over the allowance for computer systems is that the computer will be monitoring too many functions, and an MGVS alarm will not take precedence. Requiring that these be programmed to have the priority of life safety signals is intended to alleviate the concerns that medical gas alarms interrupt lesser priority activities and that they still provide an audible alert.

5.1.9.4* Area Alarms. Area alarm panels shall be provided to monitor all medical gas, medical–surgical vacuum, and piped WAGD systems supplying the following:

(1) Anesthetizing locations where moderate sedation, deep sedation, or general anesthesia is administered
(2)* Category 1 space

A.5.1.9.4 See Table A.5.1.9.4.

TABLE A.5.1.9.4 *Requirements for Category 1 Area Alarms*

Alarm Condition	*Requirement Location*
High line pressure (for each gas piped to the area)	5.1.9.4 5.1.9.4.1 5.1.9.4.2 5.1.9.4.4
Low line pressure (for each gas piped to the area)	5.1.9.4 5.1.9.4.1 5.1.9.4.2 5.1.9.4.4
Low medical–surgical vacuum (if piped to the area)	5.1.9.4 5.1.9.4.1 5.1.9.4.3 5.1.9.4.4
Low WAGD vacuum (if piped to the area)	5.1.9.4 5.1.9.4.1 5.1.9.4.3 5.1.9.4.4

A.5.1.9.4(2) Examples of Category 1 Space include post-anesthesia recovery, intensive care units, and emergency departments.

Area alarm panels are installed in patient care areas such as, but not limited to, post-anesthesia care units (PACUs), NICUs, ICUs, emergency rooms, delivery rooms, and operating rooms. The decision of whether to alarm an area piped with medical gas or vacuum should not be based on the name of that area but, rather, be based on the risk to the patient if the medical gas and vacuum were disrupted. An area alarm panel is not required at all patient care areas where medical gas and vacuum are located. Any patient care area where the disruption of the supply of gas or vacuum will not adversely affect patient care treatment will not require an area alarm. Exhibit 5.38 shows an area alarm panel for an operating room.

EXHIBIT 5.38

Area Alarm Panel. (Courtesy of Tri-Tech Medical, Inc.)

5.1.9.4.1* Area alarms shall be located at a nurse's station or other similar location that will provide for surveillance.

The proper location for an area alarm is inside the room or area being monitored by the alarm panel, near the nurses' station, or in another location that is most likely to be staffed whenever patients are present. The area alarm could be mounted in the hall near the zone valve box assembly, such as across from the nurses' station, if it can be continuously monitored.

FAQ Where should the area alarm be mounted if there is no nurses' station?

In occupancies that do not have a classic nurses' station area, alarms might be on a common wall visible to several nurses at all times. It is also permitted to install more than one alarm panel or relay signal. This might be necessary in occupancies that have only one large zone for an entire area or floor plans that are divided into several "pods." This would ensure that staff are warned about gas delivery problems even if no one is near a particular alarm panel.

Alarms are sometimes placed in each anesthetizing location. This arrangement exceeds the requirements of NFPA 99 and is thus permitted. A common case involves an anesthetizing location, where NFPA 99 allows an alarm for a "suite" of rooms but does not require an alarm for each room. Paradoxically, this is due to the fact that the OR is typically able to deal with loss of gas better than any other location in the facility, and the desirability of an alarm in the OR itself is questionable.

Nevertheless, when a facility does put an alarm in each OR, does it also need the "suite" alarm? There are two schools of thought. The first contends that the facility is at liberty to exceed the requirements of NFPA 99 but must still meet the minimum standard; consequently, yes, a "suite" alarm is still required. The second school of thought contends that an alarm in each OR exceeds NFPA 99 and therefore no "suite" alarm is necessary. The code itself only purports to be a minimum safe standard and offers no guidance whatsoever in cases where the facility elects to exceed the minimum.

In such cases, the only guidance must derive from intent, and owners must make decisions based on their own procedures and their own emergency plan. Clearly, the intent of alarms in the OR is to inform the staff so that they can act to preserve patients' lives and perhaps resolve the problem. An alarm in the OR clearly best achieves the first goal but, in fact, might do little to address the second. In a typical OR, it

is undesirable and sometimes impossible to have anyone leave the room. Because no one can leave, the options for informing others of the problem in hopes of correcting it could be very limited. Therefore, an alarm at a central location (the "suite" alarm) might be preferable or desirable in addition. However, particularly with newer technology alarms, other options might exist that are equally good at achieving that objective, and the owner might in that case reasonably elect to eliminate the "suite" alarm.

When multiple alarms are installed at a common nurses' station and the alarms monitor separate areas controlled by distinct zone valves, the alarms should be clearly labeled for the specific areas they monitor. Exhibit 5.39 shows an area alarm panel that is located at a nurse's station.

EXHIBIT 5.39

Area Alarm Panel for Operating Room.

A.5.1.9.4.1 Area alarm panels should be placed in a location that will most closely fulfill the following criteria (recognizing that no existing location might fulfill all criteria):

(1) Near or within the location where the staff will most often be present (e.g., a staff base, a nurses' station)
(2) Where the audible alert will best carry throughout the unit being surveilled
(3) Where the panel is visible from the largest number of rooms, beds, or stations within the zone
(4) Where visualization of the panel will not be blocked (e.g., by cabinet doors, carts, room doors, curtains, supplies)
(5) At a height above the floor at which the panel can be comfortably viewed and at which the mute button can be conveniently accessed

5.1.9.4.2 Area alarm panels for medical gas systems shall indicate if the pressure in the lines in the area being monitored increases or decreases by 20 percent from the normal line pressure.

5.1.9.4.3 Area alarm panels for medical–surgical vacuum systems shall indicate if the vacuum in the area drops to or below 300 mm (12 in.) gauge HgV.

5.1.9.4.4 Alarm sensors for area alarms shall be located as follows:

(1)* Category 1 spaces shall have the alarm sensors installed on the patient or use side of each individual zone valve box assemblies.

A.5.1.9.4.4(1) This signal is intended to provide immediate warning for loss of, or increase in, system pressure for each individual vital life support and Category 1 space.

(2)* Anesthetizing locations where moderate sedation, deep sedation, or general anesthesia is administered shall have the sensors installed either on the source side of any of the individual room zone valve box assemblies or on the patient or use side of each of the individual zone valve box assemblies.

This permits the sensors/switches for an anesthetizing area to be on the source side of all zone valves (one switch/sensor) or on the patient side (one switch/sensor for each zone). Placing the sensor/switch on the patient side requires more switches but ensures that closure of a valve will in fact cause an alarm. See Exhibit 5.40 for a typical sensor for an area alarm.

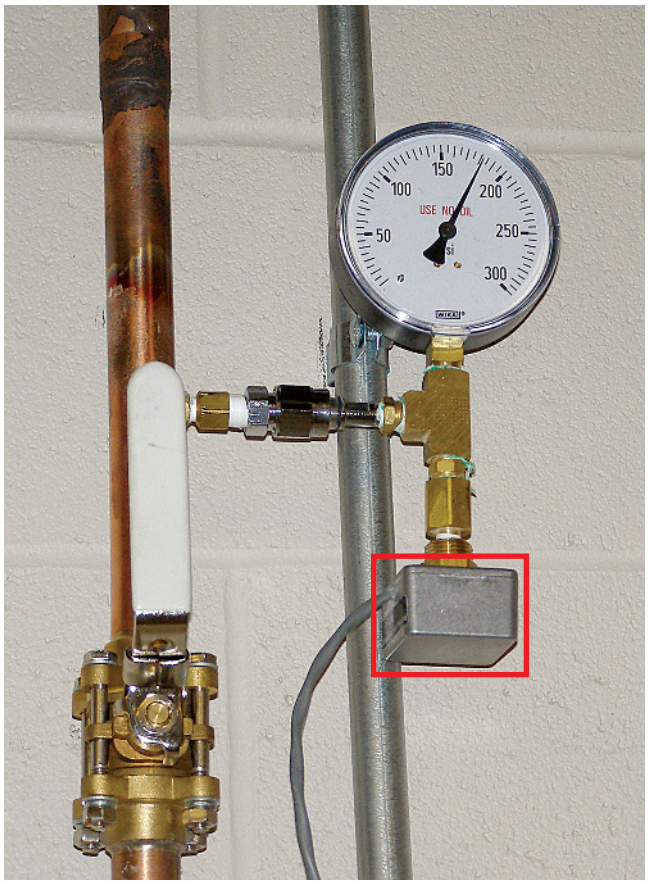


EXHIBIT 5.40

Sensor for Area Alarm. (Courtesy of Tri-Tech Medical, Inc.)

A.5.1.9.4.4(2) This signal is intended to provide immediate warning for loss of, or increase in, system pressure for all anesthetizing locations supplied from a single branch line — not for each individual operating or delivery room.

The requirements for locating actuating switches in anesthetizing locations differ from those for Category 1 spaces (vital life support and critical care units). Figure A.5.1.4 illustrates the different applications.

The service shutoff valve (see 5.1.4.5) does not have to be considered in the placement of the switches/sensors for the alarms. The service valve is a maintenance valve only and is located immediately where the lateral line(s) branches off the riser. Given that the switches/sensors are all placed on demand checks, they can be serviced without reference to any valve. Placing them on the patient side of the service valve might be preferred only because they then would indicate if the service valve is closed.

N **5.1.9.4.5** One area alarm panel shall be acceptable to monitor multiple rooms located within an immediate vicinity meeting the requirements of 5.1.9.4.4(2).

This section has been added to clarify 5.1.9.4.4(2) to show that the use of one area alarm panel for an operating room suite or similar space is acceptable.

5.1.9.4.6 Area alarm panels for medical gas systems shall provide visual and audible indication in the event a mismatch occurs between the transducer(s) and its associated circuit board(s).

A typical alarm sensor module contains a transducer that converts the pressure/vacuum source into a digital signal that is shown on the area alarm panel's display. The transducers used for medical gas area alarm panels are set up to be gas specific. The sensor modules are labeled, color coded, and contain a gas-specific D.I.S.S. fitting to ensure correct mechanical connection of the proper sensor to the respective gas. Sensors are factory-calibrated for the specific gas shown on the sensor housing. For example, if an oxygen transducer was mistakenly wired onto a medical air connection, an error message would be displayed on the area alarm panel. This electrical safeguard is mandated in 5.1.9.4.6.

5.1.9.5* Local Alarms. Local alarms shall be installed to monitor the function of the air compressor system(s), medical–surgical vacuum pump system(s), WAGD systems, instrument air systems, and proportioning systems.

A.5.1.9.5 Activation of any of the warning signals should immediately be reported to the department of the facility responsible for the medical gas piping system involved. If the medical gas is supplied from a bulk supply system, the owner or the organization responsible for the operation and maintenance of that system, usually the supplier, should also be notified. As much detail as possible should be provided. See Table A.5.1.9.5.

5.1.9.5.1 The signals referenced in 5.1.9.5.4 shall be permitted to be located as follows:

(1) On or in the control panel(s) for the central supply system or supply source being monitored
(2) Within a monitoring device (e.g., dew point monitor or carbon monoxide monitor)
(3) On a separate alarm panel(s)

The signals referenced in 5.1.9.5.4 are often built into the control enclosure, which is an acceptable configuration, provided the following basic principles of any alarm are considered:

- A continuous visual signal for each condition
- An audible signal with silence [see 5.1.9.1(3)]
- A test function for the lamps and horn

5.1.9.5.2 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.

This single signal allowance is most relevant for medical air, which can have six or more signals on the local alarm. In that case, a single signal marked "Medical Air Fault" or something similar can be used

for all except the dew point alarm, which must always have a separate signal. Paragraph 5.1.9.2.4 is the governing requirement for master signals and takes precedence.

Δ ***TABLE A.5.1.9.5*** *Requirements for Category 1 Local Alarms*

Alarm Condition	*Medical Air Compressors*						
	Oil-less (Sealed Bearing) 5.1.3.6.3.4(A)(1)	***Oil-Free (Separated) 5.1.3.6.3.4(A)(2)***	***Liquid Ring (Water-Sealed) 5.1.3.6.3.4(A)(1)***	***Instrument Air Compressors***	***Medical–Surgical Vacuum Pumps***	***WAGD Producers***	***Oxygen Concentrators***
Low Medical Air Reserve Capacity	5.1.3.6.3.12(F) 5.1.9.5.4(1)	5.1.3.6.3.12(F) 5.1.9.5.4(1)	5.1.3.6.3.12(F) 5.1.9.5.4(1)				
Low Medical Vacuum Reserve Capacity					5.1.3.7.8 5.1.9.5.4(4)		
Low WAGD Reserve Capacity						5.1.3.8.3.2 5.1.9.5.4(5)	
Low Instrument Air Reserve Capacity				5.1.13.3.4.11(A) 5.1.9.5.4(7)			
Carbon monoxide high	5.1.3.6.3.13(2) 5.1.9.5.4(2)	5.1.3.6.3.13(2) 5.1.9.5.4(2)	5.1.3.6.3.13(2) 5.1.9.5.4(2)				
High discharge air temperature	5.1.3.6.3.12(D) 5.1.9.5.4(10)	5.1.3.6.3.12(E)(1) 5.1.9.5.4(10)					
High water in receiver	5.1.3.6.3.12(B) 5.1.9.5.4(8)	5.1.3.6.3.12(B) 5.1.9.5.4(8)	5.1.3.6.3.12(B) 5.1.9.5.4(8)				
High water in separator			5.1.3.6.3.12(C) 5.1.9.5.4(9)				
Medical air dew point high	5.1.3.6.3.13(1) 5.1.9.5.4(3)	5.1.3.6.3.13(1) 5.1.9.5.4(3)	5.1.3.6.3.13(1) 5.1.9.5.4(3)				
Instrument air dew point high				5.1.9.5.4(6) 5.1.13.3.4.11(A)(2)			
Oxygen concentrator low concentration							5.1.3.5.11.13(1) 5.1.3.9.2(10)(c) 5.1.3.9.4.1(3)
Oxygen concentrator high concentration							5.1.3.5.11.13(3) 5.1.3.9.4.1(3)
Oxygen reserve in use							5.1.3.9.4.3(2) 5.1.9.5.4(13)(a)
Oxygen reserve supply less than 1 day (low contents)							5.1.3.9.4.3(3) 5.1.9.5.4(13)(b)
Oxygen main line low concentration							5.1.3.9.4.2(3) 5.1.9.5.4(13)(e)
Oxygen main line high concentration							5.1.3.9.4.2(3) 5.1.9.5.4(13)(f) 5.1.9.5.4(13)(c)
Oxygen change of source							5.1.3.9.4.4(1)(a)
Oxygen concentrator internal pressure low							5.1.3.9.4.4(2) 5.1.9.5.4(13)(d)

5.1.9.5.3 If there is more than one central supply system, for a specific gas or vacuum pipeline or more than one central supply system and pipeline for the same gas in the building, then it shall be necessary for each location to have separate local alarms per 5.1.9.5.4 and signals at the master panels per 5.1.9.2.4.

This requirement applies in the case where, for instance, a facility is served by two separate medical air plants. This master alarm would need at least two medical air fault signals and two dew point high signals, one set from each of the two plants.

5.1.9.5.4 The following functions shall be monitored at each local alarm site:

(1) Low medical air reserve capacity, to indicate when the medical air source is operating under a demand that could not be managed if one compressor ceased to operate
(2) High carbon monoxide level, to indicate when the carbon monoxide level in the medical air system is 10 ppm or higher
(3) Medical air dew point high, to indicate when the line pressure dew point is greater than +2°C (+35°F)
(4) Low medical vacuum reserve capacity, to indicate when the medical vacuum source is operating under a demand that could not be managed if one pump ceased to operate
(5) Low WAGD reserve capacity, to indicate when the WAGD source is operating under a demand that could not be managed if one producer ceased to operate
(6) Instrument air dew point high, to indicate when the line pressure dew point is greater than −30°C (−22°F)
(7) Low instrument air reserve capacity, if instrument air is provided by a source with more than one compressor, to indicate when the instrument air source is operating under a demand that could not be managed if one compressor ceased to operate
(8) For compressor systems using liquid ring compressors or compressors with water-cooled components, high water in the receiver tank, to indicate when the water level in the receiver tank has reached a level determined to be detrimental to the operation of the system
(9) For compressor systems using liquid ring compressors, high water in the separator
(10) For compressor systems using other than liquid ring compressors, high discharge air temperature
(11) Proportioning systems high/low indicator when the oxygen concentration is outside the 19.5 percent to 23.5 percent oxygen range
(12) Proportion systems reserve system in operation
(13) When oxygen is supplied from an oxygen central supply system using concentrators (*see 5.1.3.9*), the following signals shall be provided at the system's local alarm site(s):
    (a) For each cylinder header used as a source, an alarm indication that the header is in use
    (b) For each cylinder header used as a source, an alarm indication that the cylinder contents are below one average day's supply
    (c) If the source in use changes because of a failure to appropriately supply the system, an alarm indication indicating an unexpected oxygen supply change has occurred
    (d) An alarm indication that the pressure in the common line on the source side of the line pressure controls is low
    (e) An alarm indication that the oxygen concentration from the supply system is below 91 percent

Item (13) and its subparts have been added to the 2018 edition to provide the local alarm signals needed to support the oxygen concentrator supply systems now permitted.

5.1.10 Category 1 Distribution.

The pipeline distribution for gas and vacuum systems consists of an assembly of interconnecting tubing (piping) and components (valves, warning systems, outlets) working together to provide medical gases and vacuum for patient care. The proper piping materials, correct installation procedures, and required qualifications of installers are important variables that need to be followed to deliver a clean and safe MGVS.

5.1.10.1 Piping Materials for Field-Installed Positive Pressure Medical Gas Systems.

FAQ Can new piping for oxygen service be cleaned on-site?

All on-site cleaning of new piping construction is banned. The only exception is the cleaning necessary to prepare the immediate joint area for brazing. Suppliers and contractors need to protect material that has previously been cleaned for oxygen service during delivery to, and storage on, the job site. For instance, caps should not be removed from the ends of pipes until the piping is ready for installation and brazing; caps should be removed one at a time.

The publication of ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems,* was a major advance in the ability of NFPA 99 to specify tubing of an appropriate cleanliness. Since ASTM B819 became available, medical gas tubing can be purchased to that standard and received clean, which makes on-site cleaning unnecessary. This reference and use of such tubing permits on-site recleaning only in certain instances as noted. No other cleaning is allowed on-site.

5.1.10.1.1 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, *Cleaning Equipment for Oxygen Service*, except that fittings shall be permitted to be cleaned by a supplier or agency other than the manufacturer.

On-site cleaning of new piping prior to installation is prohibited because of the inability to properly prepare piping for oxygen service at the installation site. A second reason for the prohibition is the environmental hazards of using phosphates and other chemicals in an unregulated setting. The allowance for the cleaning of fittings is a recognition that most cleaning is done by parties other than the fitting manufacturer; it is not meant to be an allowance for on-site cleaning of fittings by the contractor.

5.1.10.1.2 Each length of tube shall be delivered plugged or capped by the manufacturer and kept sealed until prepared for installation.

When plugs are used, care must be taken to remove all plugs before installation. If plugs are not removed from the tube ends before the next section of piping is installed, a plug can be burned or melted during the brazing of the joint. The burnt plug will melt and off-gas, leaving a strong odor of burnt rubber and a melted film inside the pipeline. This represents a serious hazard if not detected. External capped tubes allow installers to see the caps and prevents the joining of tubing with fittings until the caps are removed.

5.1.10.1.3 Fittings, valves, and other components shall be delivered sealed and labeled and kept sealed until prepared for installation.

5.1.10.1.4* Tubes shall be one of the following:

(1) Hard-drawn seamless copper in accordance with ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*, medical gas tube, Type L, except Type K shall be used where operating pressures are above a gauge pressure of 1275 kPa (185 psi) and the pipe sizes are larger than DN80 [NPS 3 (3 ⅛ in. O.D.)].

FAQ Why can't soft-tempered copper be used with medical gas systems?

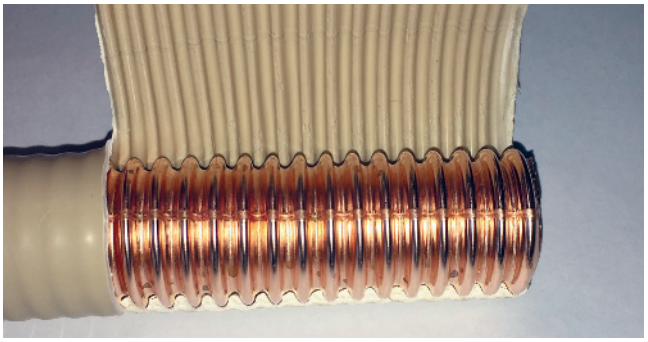
Any of the piping listed in 5.1.10.1.4(1) is acceptable for Category 1 piped gas systems, and piping for Category 1 piped gas systems has to be "hard-drawn." Part of the reason for requiring hard-drawn piping is that soft tubing kinks very easily, and kinking causes restriction of flow. All tubing must be ½ in. or greater, and the standard in the industry is already ½ in. drops for positive-pressure gases, such as oxygen, air, nitrogen, and nitrous oxide, and ¾ in. drops for vacuum.

(2)* Listed corrugated medical tubing (CMT) fabricated from copper alloy No. 51000 strip, meeting ASTM B103/B103M, *Standard Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar*, with a design margin of 3.5, externally coated with a nonmetallic sheath marked with the manufacturer's marking. The listing shall include testing to demonstrate that CMT systems can be consistently gas-purged with results equivalent to comparable medical gas copper tubing.

The allowance of corrugated medical tubing (CMT) is new to the 2018 edition of the code. A key provision of this allowance is that any CMT used must be listed (see 3.2.6 for the NFPA definition of listed). The material must be made from a copper alloy so that the tubing will have similar makeup of the previously allowed copper tubing and some of the antimicrobial effects that copper might have. Lastly this allowance includes a provision that the listing of the material must demonstrate that the tube can be effectively purged with results equivalent to comparable copper tubing. This is specified to alleviate the concerns of some that the ridges formed by the corrugation might limit the ability to be purged. There are other sections with requirements dictating the installation of CMT for medical gas systems, but it is 5.1.10.1.4(2) that now allows its use. Exhibit 5.41 illustrates CMT with the nonmetallic sheath cut and peeled off for demonstration purposes.

EXHIBIT 5.41

Sample of Corrugated Medical Tubing. (Courtesy of Omegaflex)



A.5.1.10.1.4 Operation of piped medical gas systems at gauge pressures in excess of 1275 kPa (185 psi) involves certain restrictions because of the limitations in materials.

N **A.5.1.10.1.4(2)** The listing should include a specific system geometry representative of medical gas systems.

N **5.1.10.1.5** CMT shall have a flame spread index of 25 or less and a smoke developed index of 50 or less as determined by ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*.

CMT is defined in part in 5.1.10.1.4(2) as externally coated with a nonmetallic sheath (plastic jacket). The requirement here ensures that, as assembled with the sheath, there is still a limited flame spread index and smoke developed index. The values specified are identical to those used for corrugated stainless steel tubing used for fuel gas service. These values are compliant with the flame and smoke indices for Class A interior finishes in NFPA *101*.

N **5.1.10.1.6** CMT shall be identified by the manufacturer as suitable for oxygen service at a minimum of every 0.92 m (3 ft).

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

Piping that has been cleaned and labeled "oxy" or "oxygen" indicates that it has been cleaned in such a manner as to be suitable for the piping of oxygen. This designation also means that the piping is suitable for use with any other nonflammable medical gas. The requirement that manufacturer-cleaned piping for all nonflammable medical piped gas systems be suitable for oxygen eliminates the possibility that some manufacturer-cleaned piping will be suitable for some nonflammable gases but not others and helps to ensure the correct piping is installed.

5.1.10.1.8 The installer shall furnish documentation certifying that all installed piping materials comply with the requirements of 5.1.10.1.1.

5.1.10.2 Piping Materials for Field-Installed Medical–Surgical Vacuum and WAGD Systems.

5.1.10.2.1 Tubes for Vacuum. Piping for vacuum systems shall be constructed of any of the following:

(1) Hard-drawn seamless copper tube in accordance with the following:
   (a) ASTM B88, *Standard Specification for Seamless Copper Water Tube*, copper tube (Type K, Type L, or Type M)
   (b) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, copper ACR tube
   (c) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*, copper medical gas tubing (Type K or Type L)

(2) Stainless steel tube in accordance with the following:
   (a) ASTM A269/A269M, TP304L or 316L, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*
   (b) ASTM A312/A312M, TP304L or 316L, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*
   (c) A312 TP 304L/316L, Sch. 5S pipe, and A403 WP304L/316L, Sch. 5S fittings

(3) CMT meeting the requirements of 5.1.10.1.4(2)

Item (3) extends the allowance for the use of CMT to medical-surgical vacuum systems and WAGD.

5.1.10.2.2 Vacuum Tube Marking Where Required.

5.1.10.2.2.1 If copper or CMT vacuum tubing is installed along with any medical gas tubing, the vacuum tubing shall, prior to installation, be prominently labeled or otherwise identified to preclude using materials or installation procedures in the medical gas system that are not suitable for oxygen service.

Δ **5.1.10.2.2.2** 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.

Vacuum tubing allows several types of tubing as described in 5.1.10.2.1. When ASTM B88, *Standard Specification for Seamless Copper Water Tube,* ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service,* or stainless steel tubing is installed for the vacuum system alongside medical gases tubing (ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems)* used on other medical gas systems, the required labeling of vacuum piping becomes even more important. This labeling allows the installer to identify which tubing is used strictly for the vacuum system and which tubing is not. Although vacuum systems allow these other types of tubing to be used, medical gas systems require ASTM B819 or CMT tubing.

5.1.10.2.3 WAGD System Piping. WAGD systems shall be piped as follows:

(1) Using materials compliant with 5.1.10.2.1 or 5.1.10.2.2
(2) In systems operated under 130 mm (5 in.) HgV maximum vacuum only, using any noncorroding tube or ductwork

This allowance reflects the inherent simplicity of low-vacuum WAGD systems, and it allows them to be installed at the lowest possible cost.

5.1.10.2.3.1 If joined to the vacuum piping, WAGD system piping shall be connected at a minimum distance of 1.5 m (5 ft) from any vacuum inlet.

When the WAGD system and medical–surgical vacuum system share the same pipeline network and source of supply, the pipeline tie-in point for the WAGD inlet piping and medical–surgical vacuum inlet must be separated by a minimum distance of 1.5 m (5 ft). It is important to note that this is the pipeline tie-in spot, not the inlets themselves. This minimum distance helps mitigate the possibility of both the vacuum and WAGD inlets losing suction if the vacuum line becomes clogged from the fluids that can bypass a vacuum canister. This fluid eventually hardens and can clog up a vacuum line over a distance of 0.3 m to 0.6 m (1 ft to 2 ft).

5.1.10.3 Joints.

5.1.10.3.1* Positive pressure patient gas systems, medical support gas systems, vacuum systems, and WAGD 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:

(1) Brazing, as described in 5.1.10.4
(2) Welding, as described in 5.1.10.5
(3) Memory metal fittings, as described in 5.1.10.6

(4) Axially swaged, elastic preload fittings, as described in 5.1.10.7
(5) Threaded, as described in 5.1.10.8

These requirements for the ways pipes are joined reflect concerns that piping remain intact during a fire and that piping withstand some degree of physical shaking and impact. Problems over the years have included mechanically weak joints and overheated piping and fittings. Requirements in NFPA 99 that address such problems include each of the following:

1. Reference to a specific American Welding Society (AWS) standard
2. Reference to the inclusion of a phosphorus element in the brazing alloy
3. Continuous purging of the pipe with an inert gas (e.g., nitrogen) while brazing
4. Permission to use other joining techniques that have been demonstrated to be equivalent to a brazed joint

The requirement to comply with ANSI/AWS A5.8, *Specification for Filler Metals for Brazing and Braze Welding,* means the melting point of the brazing alloy needs to be a minimum of 538°C (1000°F).

A.5.1.10.3.1 A distinction is made between deep-socket solder-joint fittings (ASME B16.22, *Wrought Copper and Copper Alloy Solder Joint Pressure Fitting*) and those having shallow sockets for brazing (ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze Joint Pressure Fitting*). The use of shallow-socket brazing fittings improves the quality of the brazement without decreasing its strength, particularly in larger sizes, which are difficult to heat. See Table A.5.1.10.3.1 for socket depths conforming to ANSI/ASME B16.50. The installer can use ANSI/ASME B16.50 fittings (if available) or have the sockets on ASME B16.22 fittings cut down to ASME B16.50 depths. Where shallow-socket fittings are used for the medical gas piping, care should be taken to avoid their use in other piping systems where joints could be soldered instead of brazed.

Δ **5.1.10.3.2** Positive pressure patient gas systems, medical support gas systems, vacuum systems, and WAGD systems constructed of CMT shall have turns, offsets, and other changes in direction made by bending the tubing up to the minimum bend radius or by fittings in accordance with 5.1.10.3.1.

This new section is specific to CMT and addresses the fact that this material is expected to have its listing show that turns, offsets, and other changes in direction can be made by bending the tubing up to a minimum bend radius without restricting the flow of gas.

5.1.10.3.3 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 5.1.10.4.

The extruded tee-branch connection or "tee drill" technique that is permitted on vacuum and WAGD systems can save time, but it should be properly used. If improperly applied, the tee-branch connection might block flow, or the process can leave cutting oil in the piping. Note that 5.1.10.3.4 prohibits these connections from being made in CMT systems.

N **5.1.10.3.4** Branch connections made using mechanically formed, drilled, and extruded tee-branch connections shall be prohibited in CMT systems.

TABLE A.5.1.10.3.1 *Socket Depths for ASME B16.50 Brazing Fittings*

Tube Size (in.)	*Socket Depth (in.)*
¼ (⅜ O.D.)	0.17
⅜ (½ O.D.)	0.2
½ (⅝ O.D.)	0.22
¾ (⅞ O.D.)	0.25
1 (1⅛ O.D.)	0.28
1¼ (1⅜ O.D.)	0.31
1½ (1⅝ O.D.)	0.34
2 (2⅛ O.D.)	0.40
2½ (2⅝ O.D.)	0.47
3 (3⅛ O.D.)	0.53
4 (4⅛ O.D.)	0.64
5 (5⅛ O.D.)	0.73
6 (6⅛ O.D.)	0.83

This new section prohibits mechanically formed, drilled, and extruded tee-branch connections as they are methods that are not suitable for corrugated medical tubing.

5.1.10.3.5 WAGD systems designed for operation below 130 mm (5 in.) HgV shall be permitted to be joined using any method that will result in a leak-free network when tested per 5.1.12.4.2.

This allowance reflects that low-vacuum WAGD systems are subjected to less stress than other types of WAGD systems, and it allows them to be installed at the lowest possible cost.

5.1.10.4 Brazed Joints.

5.1.10.4.1 General Requirements.

5.1.10.4.1.1 Fittings shall be wrought copper capillary fittings complying with ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*, or brazed fittings complying with ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*.

5.1.10.4.1.2 Cast copper alloy fittings shall not be permitted.

Cast fittings are prone to surface cracking, porosity problems, and the formation of internal cavities.

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

5.1.10.4.1.4 Brazed tube joints shall be the socket type.

5.1.10.4.1.5 Filler metals shall bond with and be metallurgically compatible with the base metals being joined.

5.1.10.4.1.6 Filler metals shall comply with ANSI/AWS A5.8 M/A.5.8, *Specification for Filler Metals for Brazing and Braze Welding*.

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

The copper–phosphorus and copper–phosphorus–silver (BCuP series) brazing filler metal is designed to be used with like metals only. The phosphorus within the (BCuP series) brazing rod acts as the flux. On dissimilar metals, a flux must be applied to wet the tube and fitting, as well as to stop oxidation caused by the heat of the torch.

5.1.10.4.1.8 Brazing performed between bulk cryogenic liquid vessels and their vaporizers (i.e., subject to cryogenic exposure) shall be permitted to be brazed using BAg brazing alloy with flux by a brazer qualified to the mandatory requirements of CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*.

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

5.1.10.4.1.10 Braze joints shall be continuously purged with nitrogen NF.

Nitrogen NF is used to remove and replace the air inside the MGVS tubing. The air contains approximately 21 percent oxygen, and during the brazing process it is necessary to remove all oxidizers that can cause the formation of copper oxide scale within the tubing. "Continuously" means uninterrupted in time. To purge the tube, the flow of nitrogen NF (purge gas) is directed from one end of the tube, past the joint to be brazed, and out the other end of the tube. Procedures for continuous purge for brazing are found in ASSE/IAPMO/ANSI 6010, *Professional Qualifications Standard for Medical Gas Systems Installers.*

5.1.10.4.2 Cutting Tube Ends.

5.1.10.4.2.1 Tube ends shall be cut square using a sharp tubing cutter to avoid deforming the tube.

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

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

5.1.10.4.3 Cleaning Joints for Brazing.

5.1.10.4.3.1 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.

5.1.10.4.3.2 The exterior surfaces of tube ends shall be cleaned prior to brazing to remove any surface oxides.

5.1.10.4.3.3 When cleaning the exterior surfaces of tube ends, no matter shall be allowed to enter the tube.

5.1.10.4.3.4 If the interior surfaces of fitting sockets become contaminated prior to brazing, they shall be recleaned for oxygen in accordance with 5.1.10.4.3.10 and be cleaned for brazing with a clean, oil-free, stainless steel or brass wire brush.

This section has been revised to require a stainless steel or brass brush to help prevent the potential of degreasing a steel wire brush, which could cause the brush to rust.

5.1.10.4.3.5 Clean, nonshedding, abrasive pads shall be used to clean the exterior surfaces of the tube ends.

5.1.10.4.3.6 The use of steel wool or sand cloth shall be prohibited.

FAQ Why is steel wool or sand cloth prohibited from cleaning the exterior ends of tubing?

Steel wool and sand cloth are prohibited from cleaning the exterior ends of tubing because they can scratch tubing and send dust and debris into the pipeline. Scratches can create pockets or barriers that will prevent the filler metals from flowing completely into and evenly distributing around the interior edges of the fitting cup (the area between the tubing and fittings) during the brazing process.

5.1.10.4.3.7 The cleaning process shall not result in grooving of the surfaces to be joined.

5.1.10.4.3.8 After being abraded, the surfaces shall be wiped using a clean, lint-free white cloth.

5.1.10.4.3.9 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.

5.1.10.4.3.10 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 450 g (1 lb) of sodium carbonate or trisodium phosphate to 11 L (3 gal) of potable water, and thoroughly rinsing them with clean, hot, potable water.

This is not intended to include cleaning fittings and pipe on-site but, rather, to allow a very limited on-site recleaning of items that have been already cleaned but have been inadvertently contaminated during installation.

5.1.10.4.3.11 Other aqueous cleaning solutions shall be permitted to be used for on-site recleaning permitted in 5.1.10.4.3.10, provided that they are as recommended in the mandatory requirements of CGA G-4.1, *Cleaning Equipment for Oxygen Service*, and are listed in CGA O2-DIR, *Directory of Cleaning Agents for Oxygen Service*.

5.1.10.4.3.12 Material that has become contaminated internally and is not clean for oxygen service shall not be installed.

5.1.10.4.3.13 Joints shall be brazed within 8 hours after the surfaces are cleaned for brazing.

Joints should be brazed as soon as possible after the surfaces have been cleaned to avoid contamination of the joint. During brazing, capillary action will occur only when the surfaces of the metals are clean. If they are "contaminated" — with oil, oxides, scale, or dust — those substances have to be removed. If the contaminants remain, they will form a barrier between the base metal surfaces and the brazing materials. Once the joints are thoroughly clean, they should be brazed as soon as possible to minimize the chance of recontamination of surfaces by local dust or body oils deposited through handling.

5.1.10.4.4 Brazing Dissimilar Metals.

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

5.1.10.4.4.2 Surfaces shall be cleaned for brazing in accordance with 5.1.10.4.3.

5.1.10.4.4.3 Flux shall be applied sparingly to minimize contamination of the inside of the tube with flux.

5.1.10.4.4.4 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.

5.1.10.4.4.5 Where possible, short sections of copper tube shall be brazed onto the noncopper component, and the interior of the subassembly shall be cleaned of flux prior to installation in the piping system.

When brazing dissimilar piping, such as copper to brass or bronze, flux is often used. To eliminate any chance of flux residue remaining inside the tubing and contaminating the pipeline, the dissimilar sections of tubing can be prefabricated and all interior flux residues removed; this allows for a cleaner installation. (See also 5.1.4.1.6.)

5.1.10.4.4.6 On joints DN20 (NPS ¾) (⅞ in. 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.

5.1.10.4.5* Nitrogen Purge.

The purging methods covered in this section are those under which an installer should qualify for the purposes of 5.1.10.11.11.

A.5.1.10.4.5 The intent is to provide an oxygen-free atmosphere within the tubing and to prevent the formation of copper oxide scale during brazing. This is accomplished by filling the piping with a low-volume flow of low pressure inert gas.

5.1.10.4.5.1 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.

FAQ Why is oil-free dry nitrogen the only gas allowed for purging?

Oil-free dry air, carbon dioxide, and argon are not permitted as purge gas because of the risk of contaminants. Industrial-grade carbon dioxide, in particular, might have oil contaminants that cannot be

cleaned out after brazing pipes. For gases other than nitrogen NF, there is also a risk of the release of carbon dioxide in large quantities. The user is cautioned that a risk also exists with nitrogen if the nitrogen is released into an enclosed space. Sufficient ventilation is mandatory during all purging operations.

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

The requirement to monitor the source of purge gas reflects a potential problem: If the nitrogen runs out during the brazing operations, there will be no way for the installer to know until it is too late and the quality of the braze is already compromised. The requirement for an audible alert can be met with an automatic device or by having an observer monitor the cylinder(s).

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

Nitrogen purging reduces the oxygen content inside a pipeline to less than 1 percent. To produce the nitrogen flow and pressure needed to remove the oxygen content to acceptable levels, this requires a controlled flow rate and pressure. A pressure regulator and flowmeter are used to achieve these controlled conditions. Too high a flow or pressure may cause the filler metals to not properly flow into and around the coupling and pipeline (fitting cup area) during the brazing process.

5.1.10.4.5.4 Pressure regulators alone shall not be used to control purge gas flow rates.

5.1.10.4.5.5 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 percent oxygen concentration before brazing begins.

This requirement addresses the problem that the installer has no way to know whether the purge was effective. The analyzer is a simple and relatively inexpensive device, and since the purge excludes oxygen, a reading of 0 (zero) indicates the oxygen is effectively gone.

5.1.10.4.5.6 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.

During construction activities, debris, odors, and other contaminants are present. These contaminants can accumulate inside an open pipeline. Oxidation can build up inside the pipeline if exposed to the atmosphere during the installation process. Openings in the piping system need to be kept sealed to maintain a nitrogen atmosphere inside the pipeline and reduce the possibility of contaminating the pipelines that will carry the medical gases and vacuum to patients.

5.1.10.4.5.7 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.

5.1.10.4.5.8 The flow of purge gas shall be maintained until the joint is cool to the touch.

5.1.10.4.5.9 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.

5.1.10.4.5.10 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.

New piped gas systems are purged with nitrogen during installation to prevent the formation of copper oxide scale. If the final connection — and only the final connection — is made without nitrogen, the small amount of scale that forms can easily be blown out during final purging and analysis.

If a valve is not present for isolation when making a final connection to an existing system (or if a valve is present but has a defective seal), an entire pipeline (both new and existing) can fill up with nitrogen during the tie-in. It would then be necessary to blow down all outlets in a facility to be sure that the nitrogen is removed from the system.

5.1.10.4.5.11 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 5.1.12.4.9.

This requirement serves as a reminder that the affected portion of the pipeline needs to be tested just like any new or modified portion of a system.

5.1.10.4.5.12* 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.

A.5.1.10.4.5.12 This is to ensure a quality joint and to prevent the formation of copper oxide on the inside and outside surfaces of the joint.

5.1.10.4.6 Assembling and Heating Brazed Joints.

Brazing is a metal-joining process whereby a filler metal is heated above melting point and distributed between two or more close-fitting parts by capillary action. The filler metal is brought slightly above its melting (liquidus) temperature. It flows over the base metal — a process known as wetting — and then cools to join the tube and fittings together. It is similar to soldering, except the temperatures used to melt the filler metal are higher [over 538°C (1000°F)]. Parts must be closely fitted, and the base metals must be clean and free of oxides. In most cases, joint clearances of 0.025 mm to 0.127 mm (0.001 in. to 0.005 in.) between the walls of the inner and outer tubes are needed for capillary action to occur and for best joint strength.

Pipeline materials need to be assembled in an approved manner (refer to ASSE/IAPMO/ANSI 6010) with the tubing inserted to the full depth of the fitting. The tubing and fittings need to be held in position for brazing and should remain in correct alignment during the heating and cooling cycles so that capillary action can occur.

5.1.10.4.6.1 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 ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*.

5.1.10.4.6.2 Where flux is permitted, the joint shall be heated slowly until the flux has liquefied.

5.1.10.4.6.3 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.

5.1.10.4.6.4 Techniques for heating the joint, applying the brazing filler metal, and making horizontal, vertical, and large-diameter joints shall be as stated in sections on applying heat and brazing and horizontal and vertical joints in Chapter VII, "Brazed Joints," in the CDA *Copper Tube Handbook*.

5.1.10.4.7 Inspection of Brazed Joints.

5.1.10.4.7.1 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.

5.1.10.4.7.2 Where flux has been used, the wash water shall be hot.

5.1.10.4.7.3 Each brazed joint shall be visually inspected after cleaning the outside surfaces.

After brazing a joint, the outside of the joint must be cleaned by washing with water and a wire brush to remove any residue, and a visual inspection is required. The purpose of a visual inspection is to see whether braze metal has flowed properly. The subsequent leak and pressure tests demonstrate, among other things, that the degree of penetration is adequate for the installation.

5.1.10.4.7.4 Joints exhibiting the following conditions shall not be permitted:

(1) Flux or flux residue (when flux or flux-coated BAg series rods are used with dissimilar metals)
(2) Base metal melting or erosion
(3) Unmelted filler metal
(4) Failure of the filler metal to be clearly visible all the way around the joint at the interface between the socket and the tube
(5) Cracks in the tube or component
(6) Cracks in the braze filler metal
(7) Failure of the joint to hold the test pressure under the installer-performed initial pressure test *(see 5.1.12.2.3)* and standing pressure test *(see 5.1.12.2.6 or 5.1.12.2.7)*

5.1.10.4.7.5 Brazed joints that are identified as defective under the conditions of 5.1.10.4.7.4(2) or 5.1.10.4.7.4(5) shall be replaced.

Δ **5.1.10.4.7.6** Brazed joints that are identified as defective under the conditions of 5.1.10.4.7.4(1), 5.1.10.4.7.4(3), 5.1.10.4.7.4(4), 5.1.10.4.7.4(6), or 5.1.10.4.7.4(7) shall be permitted to be repaired, except that no joint shall be reheated more than once before being replaced.

FAQ Why are there restrictions to heating and reheating a joint?

Normally, the failure of a brazed joint is caused by either underheating or overheating the joint. The alloy of silver and copper separates within the joint when overheated. The temperature needed to remelt the alloy is approximately 968°C (1800°F), which is much higher than the original melting temperature of the alloy of 649°C to 815°C (1200°F to 1500°F). The melting temperature

of copper is approximately 1065°C (1975°F). The temperature needed to repair the defective joint is therefore close to the melting temperature of the copper tubing. As a result, the copper tubing could melt when a brazed joint is being repaired or has become soft (annealed). If the repaired joint is moved, raised, or stepped on during additional work in the area, for example, the repaired joint has a high probability of leaking. Consequently, the repair compromises the integrity of the medical gas system.

This requirement addresses the issue of how much repair of a joint is reasonable and possible. Repeated repair of a joint would increase the probability of contaminating the pipe. Also, the probability of achieving an acceptable joint deteriorates with each attempted repair.

5.1.10.5 Welded Joints.

5.1.10.5.1 Gas Tungsten Arc Welding (GTAW) for Copper and Stainless Tube.

The requirements of this section permit the use of the gas tungsten arc welding (GTAW) autogenous procedure. This technique for joining piping was used for many years on high-purity piping in stainless steel and has been adapted for copper. It produces a very smooth, almost invisible joint that approaches the strength of the tubing itself.

The procedure requires a skilled operator properly trained in the use of the equipment (see 5.1.10.5.1.2 through 5.1.10.5.1.4) and a unique purge gas (nitrogen will *not* work; see 5.1.10.5.1.5). The procedure is subject to failure if quality control is not strict (see 5.1.10.5.1.7 through 5.1.10.5.1.10).

5.1.10.5.1.1 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.

5.1.10.5.1.2 The GTAW autogenous orbital procedure and the welder qualification procedure shall be qualified in accordance with Section IX, "Welding and Brazing Qualifications," of the ASME *Boiler and Pressure Vessel Code*.

5.1.10.5.1.3 Welder qualification procedures shall include a bend test and a tensile test in accordance with Section IX, "Welding and Brazing Qualifications," of the ASME *Boiler and Pressure Vessel Code* on each tube size diameter.

5.1.10.5.1.4 Each welder shall qualify to a welding procedure specification (WPS) for each tube diameter.

5.1.10.5.1.5* GTAW autogenous orbital welded joints shall be purged during welding with a commercially available mixture of 75 percent helium (±5 percent) and 25 percent argon (±5 percent).

A.5.1.10.5.1.5 Gas mixtures are commonly used in GTAW autogenous fusion welding. The identification of a gas mixture as "75He 25Ar" is a common industry term to define a commercially available grade from gas suppliers. If test welding results lead to questions about the mixture percentage or gas quality, another bottle should be substituted and test welds performed.

5.1.10.5.1.6 The shield gas shall be as required in 5.1.10.5.1.5.

5.1.10.5.1.7 Test coupons shall be welded and inspected, as a minimum, at 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.

5.1.10.5.1.8 Test coupons shall be inspected on the I.D. and O.D. by a qualified quality control inspector.

5.1.10.5.1.9 Test coupons shall also be welded at change of operator, weld head, welding power supply, or gas source.

5.1.10.5.1.10 All production welds shall be visually inspected on the O.D. by the operator, and any obvious weld failures shall be cut out and re-welded.

5.1.10.5.2 Welding for Stainless Tube.

Stainless tube is permitted in NFPA 99 for vacuum (and for air intakes and WAGD piping). Stainless steel is not brazed; it is welded using metal inert gas (MIG) welding, tungsten inert gas (TIG) welding, or other welding technique by a qualified welder.

5.1.10.5.2.1 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.

5.1.10.5.2.2 Welders shall be qualified to Section IX, "Welding and Brazing Qualifications," of the ASME *Boiler and Pressure Vessel Code*.

5.1.10.6 Memory Metal Fittings.

Memory metal fittings are radically different from those requiring the use of a hot flame and brazing metal to form a seal at each end of a fitting joining two pipes. They are made of a special alloy that contracts on heating; if they are kept very cold, contraction occurs on exposure to ambient temperatures. Thus, fittings must be stored in liquid nitrogen until ready for use.

When fittings are removed from the super-cold nitrogen, the installer has about 30 seconds to slip half the fitting over the end of one of the pipes and place the other pipe into the other half of the fitting before this contraction occurs. The fitting, because it is now exposed to a warmer temperature, will contract, creating a permanent and very tight seal. No flame or solder is required.

5.1.10.6.1 Memory metal fittings having a temperature rating not less than 538°C (1000°F) and a pressure rating not less than 2070 kPa (300 psi) shall be permitted to be used to join copper or stainless steel tube.

5.1.10.6.2 Memory metal fittings shall be installed by qualified technicians in accordance with the manufacturer's instructions.

5.1.10.7 Axially Swaged Fittings.

FAQ What is an axially swaged, elastic strain preload fitting?

An axially swaged, elastic strain preload fitting is a style of coupling assembled using a hydraulic press. The fitting does not have any elastomeric components but creates a metal-to-metal seal by virtue of the force exerted by the installation tool. The installation is relatively simple, but it does require several steps that are not needed with a braze fitting. The fitting is more expensive than a simple braze fitting,

but the fact that no purging is required could make this a particularly popular choice for quick installations and work where using a torch involves complications. These fittings are available and permitted for copper and stainless application.

5.1.10.7.1 Axially swaged, elastic strain preload fittings providing metal-to-metal seals, having a temperature rating not less than 538°C (1000°F) and a pressure rating not less than 2070 kPa (300 psi), and that, when complete, are permanent and nonseparable shall be permitted to be used to join copper or stainless steel tube.

5.1.10.7.2 Axially swaged, elastic strain preload fittings shall be installed by qualified technicians in accordance with the manufacturer's instructions.

5.1.10.8 Threaded Fittings. Threaded fittings shall meet the following criteria:

(1) 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.

Item (1) was revised for the 2015 edition to clarify that the only type of check valve that can be threaded in the pipeline is a gas-specific demand check valve (which is not in the main flow path).

(2) They shall be tapered pipe threads complying with ASME B1.20.1, *Pipe Threads, General Purpose, Inch*.
(3)* 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.

A.5.1.10.8(3) It is intended that the "recommended for oxygen service" apply to both polytetrafluoroethylene tape as well as the "other thread sealant."

Threaded fittings can only be used on main line gauges, zone valve gauges, alarm sensors, and gas-specific demand check fittings found on the piped distribution system. Central supply source equipment (such as gauges, sensors, and piping) also use threaded connections.

5.1.10.9 Special Fittings.

5.1.10.9.1 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.

5.1.10.9.2 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:

(1) They shall be of brass or copper construction with an appropriate dielectric.
(2) They shall be permitted to be a union.
(3) They shall be clean for oxygen where used for medical gases and medical support gases.

Magnetic resonance imaging (MRI) equipment requires absolute radio frequency shielding for its enclosures; the use of dielectric fittings is an allowance to prevent the medical gas lines from acting as antennae in the MRI rooms.

The user is cautioned to use these fittings only where absolutely required and to ensure that they are of a type and installation to prevent inadvertent disassembly (that is, that the union is pinned or otherwise prevented from "working" apart). Many of these fittings have elastomeric components internally that could require replacement over time, so where the fitting must be used, it should be placed so as to be readily accessible for this rare but necessary service.

5.1.10.10 Prohibited Joints. The following joints shall be prohibited throughout medical gas and vacuum distribution pipeline systems:

(1) Flared and compression-type connections, including connections to station outlets and inlets, alarm devices, and other components
(2) Other straight-threaded connections, including unions
(3) Pipe-crimping tools used to permanently stop the flow of medical gas and vacuum piping
(4) Removable and nonremovable push-fit fittings that employ a quick assembly push fit connector

Push-fit fittings that employ a quick assembly push-fit connector, come in a variety of makes and models. Some of the concerns with push-fit fittings are as follows:

- Although these fittings are categorized as being lead-free brass, some packaging includes a California Proposition 65 warning, "…this product contains chemicals known to the State of CA to cause cancer and birth defects or other reproductive harm.…" The Federal requirement for lead-free brass is any brass containing less than 8 percent lead; however, California's definition of "lead-free" is 0 percent lead, hence the warning on some packaging.
- Some of the push-fit fittings come with an O-ring inside the fitting. Fittings must have a gas-tight, metal-to-metal seal without O-rings or other elastomeric seals.
- Some push-fit fittings come with a built-in tube liner that is NOT intended for use when mating to copper.

5.1.10.11 Installation of Piping and Equipment.

Whenever a health care facility decides to renovate, expand, or construct a new facility, important decisions must be made concerning the function, style, image, versatility, and other features of the hospital building and equipment. When planning an MGVS for the facility, the minimum requirements within this code, local regulations and conditions, sizing, and component compatibility must be considered. The experience and qualifications of the designers, installers, and verifiers must also be taken into consideration. It is essential that adequate planning and review take place before the system is designed, ordered, and installed.

5.1.10.11.1 Pipe Sizing.

Proper sizing of the pipe is important so that each MGVS component receives enough gas or vacuum to perform properly. When designing an MGVS, each component has a minimum supply demand. If the supply is not met, flows and pressures decrease, and patient care can be compromised.

Also, oversizing is just as dangerous as undersizing a system. When a system is oversized, system ratings far exceed actual requirements, and the equipment is not used to its design capacity. There is a reduction in system efficiency and an increase in system costs.

5.1.10.11.1.1 Piping systems shall be designed and sized to deliver the required flow rates at the utilization pressures.

5.1.10.11.1.2 Mains and branches in medical gas piping systems shall be not less than DN15 (NPS ½) (⅝ in. O.D.) size.

5.1.10.11.1.3 Mains and branches in medical–surgical vacuum systems shall be not less than DN20 (NPS ¾) (⅞ in. O.D.) size.

5.1.10.11.1.4 Drops to individual station outlets and inlets shall be not less than DN15 (NPS ½) (⅝ in. O.D.) size.

5.1.10.11.1.5 Runouts to alarm panels and connecting tubing for gauges and alarm devices shall be permitted to be DN8 (NPS ¼) (⅜ in. O.D.) size.

5.1.10.11.2 Protection of Piping.

Piping shall be protected against freezing, corrosion, and physical damage.

There are too many scenarios to list for protection of piping from freezing, corrosion, and physical damage. The most common exposed areas include piping installed underground and piping installed in corridors. Piping underground needs to be protected in a continuous conduit. Piping exposed in a corridor needs to be protected by metal plating or similar protection that will not react with the copper piping. Pipes passing through concrete or cinder walls and floors or other corrosive material need to be protected against external corrosion by a protective sheathing or wrapping or other means that will withstand any reaction from the lime and acid of concrete or other corrosive material. Sheathing or wrapping allows for movement, including expansion and contraction of piping. Pipes that may be exposed to freezing should be fitted with insulation sleeves or wrapping, which slows the heat transfer — the more insulation the better.

Recently, there have reportedly been instances of firestopping chemicals attacking the copper pipe itself and weakening the pipe to the point that it could leak or break. This should be considered and assessed when passing medical gas and vacuum piping through fire walls.

5.1.10.11.2.1 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.

5.1.10.11.2.2 Piping underground within buildings or embedded in concrete floors or walls shall be installed in a continuous conduit.

5.1.10.11.3 Location of Piping.

Medical gas and vacuum pipelines need to be safely located in areas that will not affect the performance of the MGVS or the quality of the source gas in the MGVS. The locations chosen must not allow physical damage of a pipeline such as corrosion, cracks, dents, and pinching of the pipelines. Damage of the pipelines could allow air contaminants such as moisture, debris, chemicals, dusts, molds or fungi, bacteria, gases, vapors, or odors to enter the medical gas pipeline. These contaminants affect the quality of the gas and can cause internal failures of the system and ancillary components (such as ventilators).

Any leaks in a pipeline can waste finite resources (such as gas and, subsequently, money) and can create hazards such as a nitrogen leak, which can cause an oxygen-deficient atmosphere, or an oxygen leak, which can cause an oxygen-enriched atmosphere. In an oxygen-deficient atmosphere, asphyxiation can occur in environments where the oxygen is actually depleted by gases such as nitrogen. In an oxygen-enriched atmosphere, materials that may not burn in normal air may burn vigorously in an oxygen-rich environment.

The location of the pipeline should not allow large temperature variations. According to Charles' law (the law of volumes), for an ideal gas at constant pressure the volume is directly proportional to its temperature. The ambient temperature outside the pipeline will affect the temperature of the gas inside the pipeline. The volume of gas increases or decreases as the temperature increases or decreases, provided the amount of gas and pressure stay fixed. In some cases, moisture could build up inside the gas pipeline from these temperate changes. In addition, the gas from the outlets may be too cold or too hot for the patients to comfortably breathe the gas.

It should be noted that NFPA *101*, as well as most building codes, prohibits the installation of medical gas and vacuum piping in exit enclosures. This includes both exit stairs and exit passageways.

5.1.10.11.3.1 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.

Δ **5.1.10.11.3.2** 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:

(1) Room locations for medical air compressor supply systems and medical–surgical vacuum pump supply systems
(2) Room locations for secondary distribution circuit panels and breakers having a maximum voltage rating of 600 volts

Stairwells have been added to the charging language of 5.1.10.11.3.2 as a location where the installation of medical gas piping is prohibited. This is something that is already prohibited by most building codes as well as NFPA *101*, but including it here, where the designers and installers of these systems are more likely to see it, should clearly prohibit this.

5.1.10.11.3.3 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 54°C (130°F) maximum.

5.1.10.11.3.4 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.

The best way to reconcile the requirements of 5.1.10.11.3.3 and 5.1.10.11.3.4 is to avoid running medical gases and oil together whenever possible, as stipulated in 5.1.10.11.3.4. When separating them is unavoidable, run them as stipulated in 5.1.10.11.3.3. The intent is to prevent oil and medical gases from coming into contact under any circumstances, including serious problems like a simultaneous oil and medical gas leak.

5.1.10.11.4 Pipe Support.

5.1.10.11.4.1 Piping shall be supported from the building structure.

FAQ Can ductwork or other piping be used to support pipe?

The requirement in 5.1.10.11.4.1 that piping be supported directly from the building structure is meant to preclude the use of ductwork or other piping for support.

5.1.10.11.4.2 Hangers and supports shall comply with and be installed in accordance with MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*.

A pipe hanger is a device used to support a pipe or group of pipes from a slab, beam, ceiling, or other structural element. Pipe supports hold the pipe in position and, when properly spaced, prevent excessive deflections due to the weight of the pipe, gas, external insulation, and other loads. Maximum spacing between hangers for horizontal and vertical pipes can be found in Table 5.1.10.11.4.6. The values do not apply where loads are concentrated with valves, specialty equipment, and so forth. A common rule of thumb is to support this additional load with hangers on both sides of the load.

5.1.10.11.4.3 Supports for copper tube shall be sized for copper tube.

N **5.1.10.11.4.4*** Supports for CMT shall be in accordance with the CMT manufacturer's installation instructions.

N **A.5.1.10.11.4.4** CMT is coated with a nonmetallic jacket with an O.D. equal to a larger copper tube size than CMT. The CMT manufacturer's installation instructions should identify acceptable solutions.

Code section and annex material have been added to provide requirement and guidance for the support of CMT.

5.1.10.11.4.5 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.

5.1.10.11.4.6 Maximum support spacing shall be in accordance with Table 5.1.10.11.4.6.

TABLE 5.1.10.11.4.6 *Maximum Pipe Support Spacing*

	Hanger Spacing	
Pipe Size	***mm***	***ft***
DN8 (NPS ¼) (⅜ in. O.D.)	1520	5
DN10 (NPS ⅜) (½ in. O.D.)	1830	6
DN15 (NPS ½) (⅝ in. O.D.)	1830	6
DN20 (NPS ¾) (⅞ in. O.D.)	2130	7
DN25 (NPS 1) (1⅛ in. O.D.)	2440	8
DN32 (NPS 1¼) (1⅜ in. O.D.)	2740	9
DN40 (NPS 1½) (1⅝ in. O.D.) and larger	3050	10
Vertical risers, all sizes, every floor, but not to exceed	4570	15

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

Since health care facilities need to operate in adverse conditions, such as an earthquake, it is imperative that medical gas piping be properly braced for seismic incidents. This paragraph highlights the need to apply the many requirements for seismic bracing found in the applicable building code. (See also 5.1.10.11.6.3.)

5.1.10.11.5 Underground Piping Outside of Buildings.

The depth of buried pipe depends on such factors as the climatic conditions of the region, the type of traffic anticipated, and the routing of the piping.

5.1.10.11.5.1 Buried piping outside of buildings shall be installed below the local level of frost penetration.

5.1.10.11.5.2 The installation procedure for underground piping shall protect the piping from physical damage while being backfilled.

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

(1) Access shall be provided at the joints for visual inspection and leak testing.
(2) The conduit, cover, or enclosure shall be self-draining and not retain groundwater in prolonged contact with the pipe.

Underground oxygen piping is vulnerable to damage by lightning strikes, ground fault conditions, and soil corrosion. If protection of the underground pipe is warranted, a conduit, cover, or enclosure, normally of metal or plastic material, can be fitted over the entire length of buried piping. Prior to sealing the protective conduit or covers, split openings at 100 percent of the brazed joint areas need to be provided to allow for visual access and leak testing inspections.

Electrical continuity between underground oxygen piping and aboveground piping — or between same-trench piping or between underground piping and other metal structures — should be avoided to prevent cathodic protection problems. Due to the possibility of leaks and the risk of enriched atmosphere, it is preferable to have no flanged or threaded connections on the underground pipeline.

5.1.10.11.5.4 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.

5.1.10.11.5.5 The minimum backfilled cover above the top of the pipe or its enclosure for buried piping outside of buildings shall be 900 mm (36 in.), except that the minimum cover shall be permitted to be reduced to 450 mm (18 in.) where there is no potential for damage from surface loads or surface conditions.

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

5.1.10.11.5.7 Backfill shall be clean, free from material that can damage the pipe, and compacted.

Pipe trenches should be backfilled with clean earth that is free from large stones, boulders, construction debris, or other materials that could damage or break the piping or cause corrosion. Bulldozers, graders, and the like can be used to complete backfill to grade. Fill needs to be compacted. Suitable precautions must be taken to ensure permanent stability for the pipes in the trench and the ground above the pipes.

Different soil types have differing properties, and they require different construction techniques to ensure optimum performance. Selection and depositing of backfill materials should be done with special reference to the future safety of the pipes.

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

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

5.1.10.11.5.10 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.

5.1.10.11.6 Hose and Flexible Connectors.

5.1.10.11.6.1 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.

This paragraph applies only to those implementations that use a hose to extend a pipeline in a permanent or semipermanent way. It does not apply to the use of hose as a means to connect patient care equipment downstream of an outlet (such as after the pipeline has terminated). The key distinction is that patient care hoses themselves, and their connectors, are in plain view.

In most respects, the pipeline is considered to terminate in a station outlet or inlet that is brazed to the piping, as discussed in 5.1.5. However, where manufactured assemblies are installed, the function of these assemblies might require the flexibility of permanent hoses, which are more or less concealed. Because it is intended to be permanent and because access is limited, such hosing must be considered an integral part of the piped gas distribution system. See 5.1.6 for information on manufactured assemblies.

Hoses and connections for electrical and gas services are both contained inside ceiling service booms in operating rooms. If the gas begins to leak, it can create an oxygen-enriched atmosphere inside the arm and in the electrical devices, where a simple spark can cause ignition. Since the hoses are required to flex often and are often tightly fit, particularly inside the various bearing housings, these hoses are subject to abrasion, and the end fittings are subject to twisting. That twisting can loosen the fitting and allow for leakage. Periodic inspection, tightening of the end fittings, and replacement of any damaged hose inside such a device is vital to preventing leakage.

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

5.1.10.11.6.3 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:

(1) For all wetted surfaces, made of bronze, copper, or stainless steel
(2) Cleaned at the factory for oxygen service and received on the job site with certification of cleanliness
(3) Suitable for service at 2070 kPa (300 psig) or above and able to withstand temperatures of 538°C (1000°F)
(4) Provided with brazing extensions to allow brazing into the pipeline per 5.1.10.4
(5) Supported with pipe hangers and supports as required for their additional weight

N **5.1.10.11.6.4** Metallic flexible joints in accordance with 5.1.10.11.6.3 shall be permitted to be concealed in walls, ceilings, or partitions.

This section was added to the 2018 edition to clarify that it is not the intent that the prohibition against concealing hose or flexible connectors be applied to those used for the purposes listed in 5.1.10.11.6.3.

5.1.10.11.7 Prohibited System Interconnections.

5.1.10.11.7.1 Two or more medical gas or vacuum piping systems shall not be interconnected for installation, testing, or any other reason, except as permitted by 5.1.10.11.7.2.

5.1.10.11.7.2 Medical gas and vacuum systems with the same contents shall be permitted to be interconnected with an in-line valve installed between the systems.

The intent of 5.1.10.11.7.1 is to address the problem created if a temporary connection for pressure testing or purging is not removed. To avoid this problem, interconnection even on a temporary basis is prohibited, and each piping system is to be tested separately (5.1.10.11.7.3). The exception in 5.1.10.11.7.2 permits the interconnection of systems of the same contents with an in-line valve. This could be useful in situations where a large facility has two separate areas supplied by two source systems; the two systems could be connected with an in-line valve that is normally closed, and each source supply could serve as an additional redundancy to the other system if needed. This would not eliminate the need for secondary supplies for each individual system, since the respective rules of 5.1.3 would still need to apply to each source system.

5.1.10.11.7.3 Leak testing shall be accomplished by separately charging and testing each individual piping system.

5.1.10.11.8 Manufacturer's Instructions.

The elements of a manufacturer's instructions include the physical product design, installation and operations, user interface, warnings and messages, packaging, marketing, and training. Instructions should be viewed as a part of the product system.

5.1.10.11.8.1 The installation of individual components shall be made in accordance with the instructions of the manufacturer.

5.1.10.11.8.2 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.

5.1.10.11.8.3 Copies of the manufacturer's instructions shall be left with the system owner.

5.1.10.11.9 Changes in System Use.

5.1.10.11.9.1 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 5.1.10 shall apply as if the system were new.

5.1.10.11.9.2 A vacuum system shall not be permitted to be converted for use as a gas system.

The conversion of a vacuum pipeline into a gas pipeline is prohibited, because a pipeline is exposed to contamination when it is used for vacuum. A vacuum pipeline is unsuitable for ever carrying gas.

5.1.10.11.10 Qualification of Installers.

Qualification for installers to ASSE/IAPMO/ANSI 6010 ensures that all persons doing the work must be qualified to this standard, not simply the job foreman or supervisor.

5.1.10.11.10.1 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.

5.1.10.11.10.2 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 6010, *Professional Qualification Standard for Medical Gas Systems Installers*.

The ASSE/IAPMO/ANSI 6010 professional qualification standard applies to any individual who installs medical gas and vacuum distribution systems. MGVS and equipment covered in ASSE/IAPMO/ANSI 6010 include health care facilities within the scope of NFPA 99.

N **5.1.10.11.10.3** CMT systems shall be installed by ASSE 6010–qualified installers using the CMT manufacturer's instructions.

This section was added to make it clear that installers of medical gas systems utilizing CMT must still have ASSE 6010 certification.

5.1.10.11.10.4 Installers of medical gas and vacuum systems shall not use their certification to oversee installation by noncertified personnel.

5.1.10.11.10.5 Brazing shall be performed by individuals who are qualified in accordance with the provisions of 5.1.10.11.11.

5.1.10.11.10.6 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 5.1.10.11.11.

5.1.10.11.10.7 Health care organization personnel shall be permitted to install piping systems if all of the requirements of 5.1.10.11.10 are met during the installation.

This allowance permits health care facility personnel to perform installations as long as they meet the same requirements governing any medical gas installer.

5.1.10.11.11 Qualification of Brazing Procedures and Brazing.

This section covers requirements for qualifying a brazer. It is not the field test for determining the integrity of brazed joints in a piped gas or vacuum system, which is covered under 5.1.12. The requirements of this section are complementary to those in ASSE/IAPMO/ANSI 6010.

5.1.10.11.11.1 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/B2.2M, *Standard for Brazing Procedure and Performance Qualification*, both as modified by 5.1.10.11.11.2 through 5.1.10.11.11.5.

5.1.10.11.11.2 Brazers shall be qualified by visual examination of the test coupon followed by sectioning.

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

5.1.10.11.11.4 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.

Base metal has been added as an item to be documented because it is an essential variable and is critical to the brazing procedure.

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

(1) The brazing procedure specification and the procedure qualification records meet the requirements of this code.
(2) 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.
(3) The employer qualifies at least one brazer following each brazing procedure specification used.

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

(1) The brazer has been qualified following the same or an equivalent procedure that the new employer uses.
(2) 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.

5.1.10.11.11.7 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.

5.1.10.11.12 Breaching or Penetrating Medical Gas Piping.

Drills, saws, and other abrasive devices should not be used to cut into positive pressure medical gas piping, whether in use or not. The by-product of cutting into a pipeline using such methods may leave copper shavings in the pipeline that will migrate down the piping and clog up or tear up equipment such as outlets, alarm sensors, gauges, and ancillary equipment such as ventilators, mixers, and flowmeters.

5.1.10.11.12.1 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.

5.1.10.11.12.2 The breaching or penetrating process shall ensure that any debris created by the process remains contained within the work area.

5.1.11* Labeling, Identification, and Operating Pressure. Color and pressure requirements shall be in accordance with Table 5.1.11.

Δ ***TABLE 5.1.11*** *Standard Designation Colors and Operating Pressures for Gas and Vacuum Systems*

Gas Service	*Abbreviated Name*	*Colors (Background/ Text)*	*Standard Gauge Pressure*	
			kPa	*psi*
Medical air	Med air	Yellow/black	345–380	50–55
Carbon dioxide	CO_2	Gray/black or gray/white	345–380	50–55
Helium	He	Brown/white	345–380	50–55
Nitrogen	N_2	Black/white	1100–1275	160–185
Nitrous oxide	N_2O	Blue/white	345–380	50–55
Oxygen	O_2	Green/white or white/green	345–380	50–55
Oxygen/carbon dioxide mixtures	$O_2/CO_2 n\%$ (n = % of CO_2)	Green/white	345–380	50–55
Medical–surgical vacuum	Med vac	White/black	380 mm to 760 mm (15 in. to 30 in.) HgV	
Waste anesthetic gas disposal	WAGD	Violet/white	Varies with system type	
Other mixtures	Gas A%/Gas B%	Colors as above Major gas for background/ minor gas for text	None	
Nonmedical air (Category 3 gas-powered device)		Yellow and white diagonal stripe/black	None	
Nonmedical and Category 3 vacuum		White and black diagonal stripe/black boxed	None	
Laboratory air		Yellow and white checkerboard/black	None	
Laboratory vacuum		White and black checker-board/black boxed	None	
Instrument air		Red/white	1100–1275	160–185

Pressure requirements listed in Table 5.1.11 correspond to the minimum requirements for medical gas serving medical equipment and devices for patient care in the majority of instances. Pressure-compensating metering devices are being used in hospitals, therefore it is necessary to have constant line pressure. Most metering devices, such as oxygen devices, are calibrated for 345 kPa (50 psi) line pressure. Examples of the color designations shown in the table are included in Exhibit 5.42.

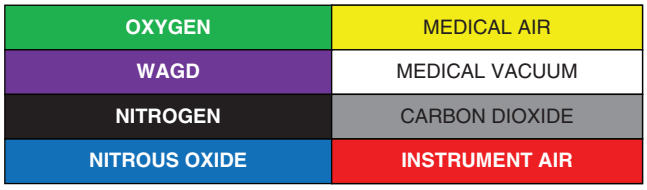


EXHIBIT 5.42

Examples of Color Designations for Gas and Vacuum Systems.

A.5.1.11 It is recommended that the facility's normal operating pressure of nitrous oxide be initially set and continually maintained at least 34.5 kPag (5 psig) below the normal operating pressures of the oxygen and medical air.

Piping systems that are connected though blending devices are in effect cross-connected through the device. In the rare event of a failure of the safeties inside the equipment, the possibility of having the gases flow across the device exists. When the device is an anesthesia machine, and one of the gases is nitrous oxide, a pressure in the nitrous oxide pipeline greater than the pressure in the medical air or oxygen system opens the possibility of nitrous oxide flowing into the other pipelines. A patient could then receive a lethal quantity of nitrous oxide from a labeled and indexed medical air or oxygen outlet. Adjusting the pressure as recommended can reduce the likelihood of the causative equipment failure and also reduce the severity of the problem in the event it does occur.

5.1.11.1 Pipe Labeling.

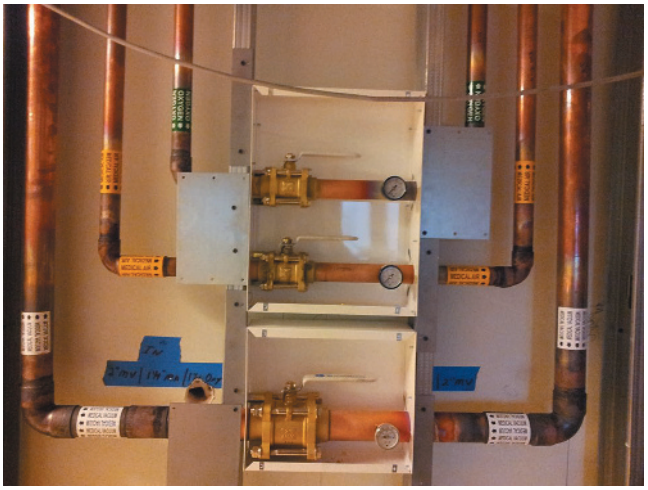
A wide variety of pipe labels are made. Some wrap completely around the pipe, some are of a fixed width, and some come with different adhesives and different preparation requirements. NFPA 99 does not stipulate what kind of label is to be used, provided the basic features in this section are included. Specifics of labels are left to the installer's discretion. See Exhibit 5.43 through Exhibit 5.45 for examples of labeled pipe. New systems are required to have labels indicating the name of the gas in the pipe and — if the pressure level of the gas is other than standard pressure — its pressure level.

EXHIBIT 5.43

Example of Gas Piping Systems Labeled with Name of Gas and Direction of Its Flow. (Courtesy of William G Frank Medical Gas Testing & Consulting, LLC)

EXHIBIT 5.44

Labeled Medical Gas and Vacuum Piping at Zone Valve Box Assemblies. (Courtesy of William G Frank Medical Gas Testing & Consulting, LLC)



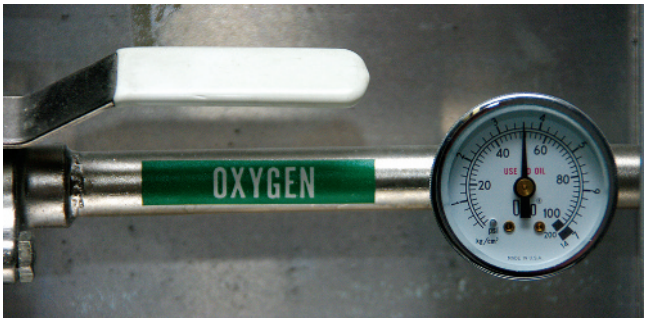


EXHIBIT 5.45

Labeled Pipe that Is Part of a Piped Gas System.

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

(1) Name of the gas or vacuum system or the chemical symbol per Table 5.1.11
(2) Gas or vacuum system color code per Table 5.1.11
(3) Where positive pressure gas piping systems operate at pressures other than the standard gauge pressure in Table 5.1.11, the operating pressure in addition to the name of the gas

5.1.11.1.2 Pipe labels shall be located as follows:

(1) At intervals of not more than 6.1 m (20 ft)
(2) At least once in or above every room
(3) On both sides of walls or partitions penetrated by the piping
(4) At least once in every story height traversed by risers

It should be noted that "at least once in or above every room" is not the same as "on both sides of walls or partitions penetrated by the piping." Often, room walls do not go above the ceiling. Also, there are walls that do not define a room, such as a smoke barrier wall above a corridor.

5.1.11.1.3 Medical gas piping shall not be painted.

5.1.11.2 Shutoff Valves.

5.1.11.2.1 Shutoff valves shall be identified with the following:

(1) Name or chemical symbol for the specific medical gas or vacuum system
(2) Room or areas served
(3) Caution to not close or open the valve except in emergency

5.1.11.2.2 Where positive pressure gas piping systems operate at pressures other than the standard gauge pressure of 345 kPa to 380 kPa (50 psi to 55 psi) or a gauge pressure of 1100 kPa to 1275 kPa (160 psi to 185 psi) for nitrogen or instrument air, the valve identification shall also include the nonstandard operating pressure.

5.1.11.2.3 Source valves shall be labeled in substance as follows:

SOURCE VALVE
FOR THE (SOURCE NAME).

5.1.11.2.4 Main line valves shall be labeled in substance as follows:

MAIN LINE VALVE FOR THE (GAS/VACUUM NAME) SERVING (NAME OF THE BUILDING).

5.1.11.2.5 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).

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

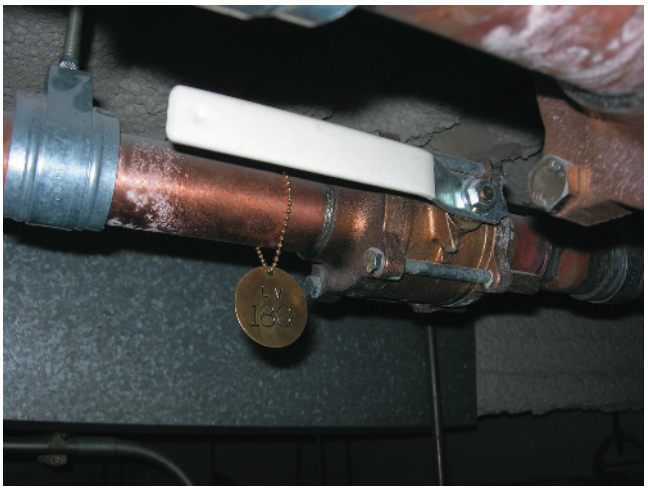
SERVICE VALVE FOR THE (GAS/VACUUM NAME) SERVING (NAME OF THE AREA/BUILDING SERVED BY THE PARTICULAR VALVE).

FAQ Are numbered valve tags an acceptable way to identify and label the valves?

The intent of this section is to offer ways of marking the valve so it is more visible and understandable, and thereby to prevent inadvertent closing of these valves. A numbered tag, such as the one shown in Exhibit 5.46, will serve this purpose only where the facility implements a unique numbering system for ease in identifying which areas and which gas are controlled by the valve. This unique valve numbering needs to be clear, updated, and accurate. The facility needs to place the valve location and unique number on a one-line medical gas and vacuum drawing or other MGVS utility map that will allow authorized personnel to quickly locate the valves for the affected system in the event of an emergency, utility disruption, or failure. In addition to the map, a medical gas and vacuum valve tag log listing the area of controls of the valves may be kept and located at the department responsible for care of the MGVS. The facility's plans should be referenced for utility shutdowns, and the number on the tag should be confirmed before closing the valve. For instant recognition, the tag should be clearly labeled, color coded, and marked for areas of control.

EXHIBIT 5.46

Numbered Valve Tag Used to Identify In-line Valve.



5.1.11.2.7* 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.

The requirements for zone valve box assemblies have been revised for the 2018 edition. Zone valves labeled "Emergency Department" are not specific enough when they actually control a dozen rooms in the department. A good example would be "Patient Rooms 201 thru 212 and 214 thru 220."

Labeling can be made visible from inside or outside the box when the cover has a clear area to view the labels. Labels should not be applied to the cover, as it can be lost or switched with another box.

A.5.1.11.2.7 It is not intended that every room be listed on the label, but an area that is easily identifiable by staff needs to be indicated. This can be accomplished with text or by graphical means such as a map or color coding. The label should be permanently affixed outside and near valve box. The label should not be affixed to a removable cover.

Poor labeling of zone valves is a common problem even in new construction. It is not uncommon to find valves labeled using the architect's room numbers, which are not the room numbers used by the facility. This is an issue that should be addressed even in existing installations due to the importance of proper labeling.

Exhibit 5.47 shows a vacuum zone valve with labeling that identifies the rooms controlled based on the room numbers. Exhibit 5.48 shows a zone valve box assembly with an adjacent map that indicates the areas served by the valves within the box.

EXHIBIT 5.47

Vacuum Zone Valve Labeled with Rooms Controlled.

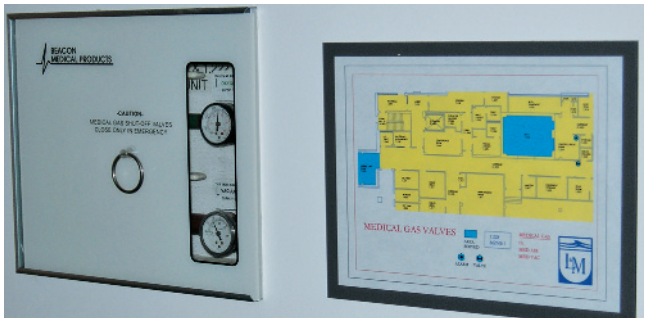
5.1.11.3 Station Outlets and Inlets.

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

5.1.11.3.1.1 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.

EXHIBIT 5.48

Zone Valve Box Assembly with Map for Labeling.



This section was added to the 2015 edition to prevent situations where sleep labs are built with outlets downstream of flow control devices and use standard labeling. The modified flow at these outlets is not suitable for many of the functions that typical outlets are able to serve, and this additional labeling can prevent inappropriate use of the outlets.

5.1.11.3.2 Where medical gas systems operate at pressures other than the standard gauge pressure of 345 kPa to 380 kPa (50 psi to 55 psi) or a gauge pressure of 1100 kPa to 1275 kPa (160 psi to 185 psi) for nitrogen, the station outlet identification shall include the nonstandard operating pressure in addition to the name of the gas.

5.1.11.4 Alarm Panels.

As with zone valves, the labels on the alarm panels must be kept up-to-date as the room names and/or numbers change. This is a common violation, especially in hospitals where changes are frequently made.

5.1.11.4.1 Labeling of alarm panels for each indicator shall indicate the condition monitored and its area of surveillance.

5.1.11.4.2* Area alarm panels shall be identified with the following:

(1) Name or chemical symbol of the specific medical gas or vacuum system being monitored
(2) Area(s) monitored by the alarm panel

A.5.1.11.4.2 It is not intended that every room be listed on the label, but an area that is easily identifiable by staff needs to be indicated. This can be accomplished with text or by graphical means such as a map or color coding.

N **5.1.11.5 Source Equipment.** Source equipment shall be labeled or tagged to identify the patient medical gas, the support gas, or the vacuum system and include the following information:

(1) Name of the gas or vacuum system
(2) Gas or vacuum system color code
(3) Rooms, areas, or buildings served
(4) Emergency contact information for the department or individual responsible for maintaining the equipment

Requirements for labeling of source equipment have been added for the 2018 edition. Many other components are required to be labeled with critical information. The source equipment should also be labeled with minimum information to allow for those responding to an issue to be able to understand the potential impact on patient care as quickly as possible.

5.1.12* Performance Criteria and Testing — Category 1 (Gases, Medical–Surgical Vacuum, and WAGD).

A.5.1.12 All testing should be completed before putting a new piping system, or an addition to an existing system, into service. Test procedures and the results of all tests should be made part of the permanent records of the facility of which the piping system forms a part. They should show the room and area designations, dates of the tests, and name(s) of the person(s) conducting the tests.

5.1.12.1 General.

Whenever an MGVS is installed, renovated, or has a major repair performed, specific performance and acceptance tests are required to verify that the system is operating within the design criteria and code requirements.

The testing measures three main areas of the MGVS: integrity of a delivery system, quality of delivered gases, and proper operation of the MGVS components. Because the gases and vacuum can be used for life supporting patient care, it is critical that systems and equipment meet the performance criteria of the code to ensure these systems are safe and reliable for patients, staff, and visitors within the hospital.

5.1.12.1.1 Inspection and testing shall be performed on all new piped medical gas and vacuum systems, additions, renovations, temporary installations, or repaired systems to ensure, by a documented process and procedure, that all applicable provisions of this document have been adhered to and system integrity has been achieved or maintained.

This section has been revised to apply to both gas and vacuum systems and to clarify that the process as well as the procedure needs to be documented.

5.1.12.1.2 Inspection and testing shall include all components of the system, or portions thereof, including, but not limited to, gas bulk source(s); manifolds; compressed air source systems (e.g., compressors, dryers, filters, regulators); source alarms and monitoring safeguards; master alarms; pipelines; isolation valves; area alarms; zone valves; and station inlets (vacuum) and outlets (pressure gases).

5.1.12.1.3 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.

5.1.12.1.4 Systems shall be deemed breached at the point of pipeline intrusion by physical separation or by system component removal, replacement, or addition.

5.1.12.1.5 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.

It can be difficult to determine which portions of a system must be tested and which tests must be conducted for any given project. Paragraph 5.1.12.1.12 defines what might be required after maintenance work. Some additional examples are provided as follows for guidance in making those determinations:

- If a single oxygen outlet were added to a 50-room zone, and the entire zone was drained of oxygen and refilled with nitrogen for the work, the entire zone would need to be retested prior to returning the system to normal operation and connecting patients to the system.
- If a five-story riser were shut down for a tie-in on the second floor, and nitrogen was not used for the tie-in, it should be necessary only to check the closest outlets upstream and downstream of the tie-in for particulate and concentration and to check on the furthermost outlet for concentration. (These steps are in addition to whatever tests are necessary for the new section itself prior to tie-in.)
- If a section of the piping could be isolated (e.g., by using valves already in place), and the system kept pressurized from an alternate source (e.g., by back-feeding from somewhere else), it would be acceptable to test the section in isolation. Tests would be performed on the new or modified section at each end. The isolated sections would be undisturbed, and a simple spot check would confirm that they had remained isolated.

5.1.12.1.6 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.

Test reports must be sent directly to the party contracting for the testing; that party will, in turn, distribute copies to the necessary parties requiring a copy of the report. This procedure reflects the difficulty at times in determining the authorities having jurisdiction for a particular installation and the additional parties that need to receive a copy of the report.

5.1.12.1.7 Reports shall contain detailed listings of all findings and results.

The requirement for detailed findings and results is an important one. This documentation allows for a review of these findings and results for system compliance and performance criteria and ensures all requirements of the code have been met. A simple pass/fail result does not meet this requirement.

5.1.12.1.8 The responsible facility authority shall review these inspection and testing records prior to the use of all systems to ensure that all findings and results of the inspection and testing have been successfully completed.

5.1.12.1.9 All documentation pertaining to inspections and testing shall be maintained on-site within the facility.

This documentation is required to be maintained on-site should it be required by the authority having jurisdiction.

5.1.12.1.10 Before piping systems are initially put into use, the facility authority shall be responsible for ascertaining that the gas/vacuum delivered at the outlet/inlet is that shown on the outlet/inlet label and that the proper connecting fittings are installed for the specific gas/vacuum service.

5.1.12.1.11 Acceptance of the verifier's final report shall be permitted to satisfy the requirements in 5.1.12.1.10.

This section has been added to clarify that the verifier's final report is sufficient to meet this requirement.

5.1.12.1.12 The removal of components within a source system for repair and reinstallation, or the replacement of components like for like, shall be treated as new work for the purposes of testing whenever such work involves cutting or brazing new piping, or both.

This is intended to prevent an unnecessarily burdensome testing regimen where a facility is simply replacing like for like, as might happen with an air compressor that has worn out. Although it is inappropriate to perform such work with no testing, the testing that would be performed on a new source would also be excessive.

FAQ If some source equipment needs replacing, what type of testing is required?

The principle is that the replaced equipment should be tested as appropriate to that piece of equipment (that is, they should be functional tests). However, when pipe is cut or brazed, more extensive tests — such as those required of new work — are called for. An entirely new source cannot be installed without testing simply because it is joined to an existing section of pipe.

5.1.12.1.12.1 Where no piping is changed, functional testing shall be performed as follows:

(1) To verify the function of the replaced device
(2) To ensure no other equipment in the system has been adversely impacted

5.1.12.1.12.2 Where no piping is changed, in addition to tests of general function required by 5.1.12.1.12.1, testing shall be performed as follows:

(1) Pressure gas sources shall be tested for compliance with 5.1.12.4.14.2 as applicable to the equipment type.
(2) Medical air and instrument air sources shall be tested to 5.1.12.4.14.3.
(3) Vacuum and WAGD systems shall be tested to 5.1.12.4.14.6.
(4) Alarm systems shall be tested to 5.1.12.4.5.2 and 5.1.12.4.5.3.
(5) All affected components shall be tested as appropriate to that specific component (e.g., a replaced dew point monitor would be tested to 5.1.3.6.3.13).

5.1.12.1.13 The rated accuracy of pressure and vacuum indicators used for testing shall be 1 percent (full scale) or better.

Testing requires highly accurate gauges designed for medical gas and vacuum use. Performance, reliability, and precision measurement with consistent accuracy are necessary in meeting the demanding service needs of numerous test gauge applications. These gauges are often used as master reference gauges for MGVS inspection and for verifying the accuracy of general service gauges.

5.1.12.2 Installer-Performed Tests.

System testing is divided into tests to be conducted by the installer prior to the final verification tests (5.1.12.2) and tests to be conducted by a technically qualified party experienced in testing piped gas systems, verifying the installation (5.1.12.4). Many of these tests are the same or similar for both the installer-performed testing and the verification testing. The verification of the system is to ensure both parties have gained the same results from the testing. This verification is required to be conducted with a documented procedure, which should demonstrate consistency in the testing process.

Since fatalities have occurred due to cross-connection of gases, it is essential to verify that the labeling of outlets matches the gas being delivered from it. Some of the tests listed in this section have been developed for that purpose.

5.1.12.2.1 General.

5.1.12.2.1.1 The tests required by 5.1.12.2 shall be performed and documented by the installer prior to the tests listed in 5.1.12.4.

5.1.12.2.1.2 The test gas shall be oil-free, dry nitrogen NF.

5.1.12.2.1.3 Where manufactured assemblies are to be installed, the tests required by 5.1.12.2 shall be performed as follows:

(1) After completion of the distribution piping, but before the standing pressure test
(2) Prior to installation of manufactured assemblies supplied through flexible hose or flexible tubing
(3) At all station outlets/inlets on installed manufactured assemblies supplied through copper tubing

5.1.12.2.2 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).

5.1.12.2.3 Initial Pressure Test.

It should be noted that there is a new requirement for this test to be witnessed by a third-party in order to verify the results of the test. See 5.1.12.3.2.1 for information about the witnessing requirements for this testing.

FAQ Why is the initial pressure test important?

Pressure testing is conducted as a means to find leaks. Leaks not only represent a fire hazard, they are also considered by many to pose significant health risks. Excessive exposure of staff to gases such as nitrous oxide has been linked to long-term health concerns. By reducing this waste, there is a financial benefit to a leak-free system as well. Exhibit 5.49 shows the leak testing of zone valves.

EXHIBIT 5.49

Leak Testing of Zone Valves. (Courtesy of Acute Medical Gas Services, Inc.)

Test Procedure: Zone Valve Leaks

1. Introduce nitrogen NF into the new piping system.
2. Increase the pressure to the test pressure determined by the operating pressure of the system, but not less than a gauge pressure of 1035 kPa (150 psi).
3. Visually examine every joint on the pipeline system to verify there are no leaks. This should be performed with a leak detectant that is safe for use with oxygen until every joint has been confirmed to be leak-free.

Note: It is required to perform all of the installer-performed testing and most of the verification testing prior to connecting a new pipeline to an existing pipeline system. A major reason is because the operating pressures of existing systems are generally much lower than the required initial test pressures. If these systems are connected together, this test at the pressures required could damage many components of the existing system and could allow nitrogen to leak into the existing systems.

5.1.12.2.3.1 Each section of the piping in medical gas and vacuum systems shall be pressure tested.

On smaller systems, it may be possible to test the pipeline all at once. However, on larger systems it is generally required to perform the initial pressure testing in sections. Since all the joints are required to be examined, the testing must be completed prior to concealing any of the joints.

5.1.12.2.3.2 Initial pressure tests shall be conducted as follows:

(1) After blowdown of the distribution piping
(2) After installation of station outlet/inlet rough-in assemblies

(3) 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)

5.1.12.2.3.3 The source shutoff valve shall remain closed during the tests specified in 5.1.12.2.3.

FAQ Why does the source shutoff valve have to remain closed during this test?

This requirement should only apply when a new source system is installed at the same time as the pipeline distribution system. A new source supply system would need to be verified prior to opening the source valve. It should be noted that the source valve should never be closed on an active system without the approval of the responsible facility authority as this would shut off the supply to patients.

5.1.12.2.3.4 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 1035 kPa (150 psi).

This test and the test pressure apply to both pressure and vacuum piping. Because this pressure may not be acceptable for system components (e.g., pressure alarm devices, pressure indicators, line pressure relief valves, manufactured assemblies, and hose), it is essential that the limitations in 5.1.12.2.3.2(3) be observed.

5.1.12.2.3.5* 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.

It is important that the leak-testing solution be specifically approved for oxygen service. This holds true for all medical gases, whether they convey oxidizers or not. Solutions approved for "compressed gas" are not necessarily approved for "oxygen service."

Ammonia-containing leak test solutions are prohibited because ammonia can attack copper and brass and physically weaken the materials.

A.5.1.12.2.3.5 Ammonia is known to cause stress cracking in copper and its alloys.

5.1.12.2.3.6 Leaks, if any, shall be located, repaired (if permitted), replaced (if required), and retested.

See also the commentary following 5.1.10.4.7.6, which specifies those joints that can be repaired.

5.1.12.2.4 Initial Cross-Connection Test. It shall be determined that no cross-connections exist between the various medical gas and vacuum piping systems.

The initial cross-connection test should be considered the most important installer-performed test. The installer ensures that there are no cross-connections in the systems that were installed, and then the verifier performs the same test to validate the results of the installer. The reason this test is performed by both the installer and the verifier is to demonstrate without question that there are no cross-connections between the systems, which are the main cause of deaths and injuries with medical gas systems.

Test Procedure: Cross-Connections

The following procedure should be conducted on one system at a time:

1. Reduce the pressure of all medical gas systems (e.g., oxygen, medical air, medical vacuum, nitrous oxide, and nitrogen) to atmospheric pressure.
2. Introduce nitrogen NF and pressurize one medical gas distribution system to 345 kPa (50 psig).
3. With appropriate gas-specific adapters matching the outlets, test and record the pressure at each individual station outlet and vacuum inlet. Only the outlets (or in-lets) on the system being tested should read 345 kPa (50 psig). All other outlets (inlets) should read 0 kPa (0 psig).
4. Disconnect the test gas from the system that was just tested and reduce the pressure in the system to atmospheric.
5. Proceed to test and record the results of each medical gas and vacuum system in accordance with steps 1 through 4 above, each time checking every outlet/inlet in every system.

5.1.12.2.4.1 All piping systems shall be reduced to atmospheric pressure.

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

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

5.1.12.2.4.4 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.

5.1.12.2.4.5 The cross-connection test referenced in 5.1.12.2.4 shall be repeated for each installed medical gas and vacuum piping system.

5.1.12.2.4.6 The proper labeling and identification of system outlets/inlets shall be confirmed during these tests.

During the initial cross-connection test, it is vital to confirm that the labeling and identification of the MGVS outlets/inlets is correct. At the initiation of this test, the installer should match up the patient terminal (outlet/inlet) rough-in assemblies with the faceplate assemblies. When the initial cross-connection test is being conducted, the installer verifies that the labels on the MGVS patient terminals match the correct pipeline system being checked.

5.1.12.2.5 Initial Piping Purge Test. The outlets in each medical gas piping system shall be purged to remove any particulate matter from the distribution piping.

5.1.12.2.5.1 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.

The pulse purge test has been found to effectively break up material in the pipeline, such as copper oxide scale and other by-products of fabrication, and transport it to the outlet being purged. This purge is to be conducted into a clean, white cloth loosely held over the adapter until the test produces no discoloration. For purposes of this test, the correct adapter is the only device that should be used to prevent damage to the internal components of the outlet/inlet. These types of adapters are generally available directly from the manufacturer. Exhibit 5.50 shows an example of an adapter, and Exhibit 5.51 shows an adapter being used with a clean white cloth held over it.

EXHIBIT 5.50

Medical Gas Adapter. (Courtesy of Bay Corporation, Westlake, OH)

EXHIBIT 5.51

Piping Purge Test Being Conducted with Adapter and Clean White Cloth. (Courtesy of Acute Medical Gas Services, Inc.)

5.1.12.2.5.2 The purging required in 5.1.12.2.5.1 shall be started at the closest outlet/inlet to the zone valve and continue to the furthest outlet/inlet within the zone.

Standard industry practice for purging pipelines involves starting at a point closest to the source of supply and moving in the direction of flow to the end of the pipeline. This allows particulate matter to move downstream with the flow of the gas and eventually to the end of the pipeline for removal.

Test Procedure: Standing Pressure

1. If this is an entirely new system, including new source equipment, the source valve must remain closed for the standing pressure test.
2. Introduce nitrogen NF into the new piping system.
3. Increase the pressure to the test pressure determined by the operating pressure of the system: 20 percent above normal operating pressure. For example, if the operating pressure is 345 kPa (50 psig), then the test pressure would be 415 kPa (60 psig).
4. Optional Best Practice Procedure: Let the system stand for 3 to 4 hours. Ensure the test pressure remains the same. If the pressure drops significantly, there may be a leak in the system.
5. Start the 24-hour standing pressure test. Document starting test time and pressure.
6. After 24 hours, verify test pressure remains unchanged (or has dropped less than the allowable amount identified in 5.1.12.2.6.5).
7. The authorized witness should sign off and document that the test was conducted properly and verify that the test has passed successfully.

5.1.12.2.6 Standing Pressure Test for Positive Pressure Medical Gas Piping. After successful completion of the initial pressure tests under 5.1.12.2.3, medical gas distribution piping shall be subject to a standing pressure test.

The standing pressure test ensures the integrity of the entire system after all components are installed, including all threaded joint, outlet/inlet assemblies, hoses, and any other final assemblies, and that the system is leak-free.

5.1.12.2.6.1 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, hose).

5.1.12.2.6.2 The source valve shall be closed during this test.

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

5.1.12.2.6.4 Test pressures shall be 20 percent above the normal system operating line pressure.

5.1.12.2.6.5* The leakage over the 24-hour test shall not exceed 0.5 percent of the starting pressure [e.g., 2 kPa (0.3 psi) starting at 415 kPa (60 psig), 0.3 mm (0.125 in.) HgV starting at 635 mm (25 in.) HgV] except that attributed to specific changes in ambient temperature.

Previous editions of the code stated that at the conclusion of tests there should be no change in test pressure except that attributed to ambient temperature changes. Those leakage requirements are very difficult, if not impossible, to meet. All systems leak to some extent, and the only reason one could pass the previous requirement was through the use of gauges, which naturally have a limit on their readability and resolution. Therefore, a user could estimate the "no change in the test pressure" required by the standard.

As gauges have improved and become more precise and digital, it is increasingly difficult to rely on this technique to pass the test. As a result, failures are being reported on processes that formerly passed. It was clear technology has outgrown this requirement, and something more realistic and fitting of the real conditions was needed. The new allowances for small percentage pressure drops should accomplish this.

A.5.1.12.2.6.5 The effect of temperature changes on the pressure of a confined gas is based on the Ideal Gas Law. The final absolute pressure (P2a) equals the initial absolute pressure (P1a) times the final absolute temperature (T2a), divided by the initial absolute temperature (T1a). The relationship is the same for nitrogen, nitrous oxide, oxygen, and compressed air.

Absolute pressure is the gauge pressure reading plus the absolute atmospheric pressure. See Table A.5.1.12.2.6.5 for the absolute atmospheric pressures for elevations at and above sea level.

Absolute temperature K (°R) is the temperature gauge reading °C (°F) plus the absolute zero temperature 273°C (460°F).

Examples of pressure test data at sea level in SI and IP units follow.

The initial test pressure is 415 kPag (60 psig) at 27°C (80°F). A temperature decrease to 18°C (65°F) will cause the test pressure to drop to 400 kPag (57.9 psig).

P1g = 415 kPag, T1g = 27°C, T2g = 18°C, P1g = 60 psig, T1g = 80°F, T2g = 65°F

P1a = 415 + 101 = 516 kPa	P1a = 60 + 14.7 = 74.7 psia
T1a = 27 + 273 = 300K	T1a = 80 + 460 = 540°R
T2a = 18 + 273 = 291K	T2a = 65 + 460 = 525°R
P2a = 516 × 291/300 = 501 kPa	P2a = 74.7 × 525/540 = 72.6 psia
P2g = 501 – 101 = 400 kPag	P2g = 72.6 – 14.7 = 57.9 psig

TABLE A.5.1.12.2.6.5 *Pressure Corrections for Elevation*

	Absolute Atmospheric Pressure			
Elevation (ft)	***kPa***	***psia***	***mmHg***	***inHg***
0	101.33	14.70	760.0	29.92
500	99.49	14.43	746.3	29.38
1000	97.63	14.16	733.0	28.86
1500	95.91	13.91	719.6	28.33
2000	94.19	13.66	706.6	27.82
2500	92.46	13.41	693.9	27.32
3000	90.81	13.17	681.2	26.82
3500	89.15	12.93	668.8	26.33
4000	87.49	12.69	656.3	25.84
4500	85.91	12.46	644.4	25.37
5000	84.33	12.23	632.5	24.90

5.1.12.2.6.6 Leaks, if any, shall be located, repaired (if permitted) or replaced (if required), and retested.

5.1.12.2.6.7 The 24-hour standing pressure test of the positive pressure system shall be witnessed by an ASSE 6020 inspector, an ASSE 6030 verifier, or the authority having jurisdiction 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 5.1.12.4.

This requirement makes clear that the third-party verification process is being emphasized throughout the system testing procedures. The addition of the ASSE 6020 inspector certification to NFPA 99 demonstrates that the MGVS should be treated like any other plumbing system and that independent witnessing of the critical testing is now a mandatory requirement. The witness should be someone with knowledge of NFPA 99 requirements (i.e., project verifier), a *qualified* representative of the hospital, or the regulatory authority for MGVS for the project. The documentation required for this testing should be made part of the final verification report. (See also 5.1.12.2.7.6.)

5.1.12.2.7 Standing Vacuum Test for Vacuum Piping. After successful completion of the initial pressure tests under 5.1.12.2.3, vacuum distribution piping shall be subjected to a standing vacuum test.

The purpose of the standing vacuum test is to ensure the integrity of the entire system after all components are installed, including all threaded joint, outlet/inlet assemblies, hoses, and any other final assemblies, and that the system is leak-free.

Test Procedure: Standing Vacuum

1. If this is an entirely new system, including new source equipment, the source valve must remain closed for the standing vacuum test.
2. Introduce vacuum into the new piping system. If allowed by the facility, the system vacuum can be used to fill the system with vacuum.
3. Increase the vacuum pressure to the test vacuum pressure. This vacuum pressure must be between 300 mm (12 in.) HgV and full vacuum.
4. Optional Best Practice Procedure: Let the system stand for 3 to 4 hours. Ensure the test vacuum pressure remains the same. If the pressure drops significantly, there may be a leak in the system.
5. Start the 24-hour standing vacuum test. Document starting test time and pressure.
6. After 24 hours, verify test pressure remains unchanged (or has dropped less than the allowable amount identified in 5.1.12.2.6.5).
7. The authorized witness should sign off and document that the test was conducted properly and verify that the test has passed successfully.

5.1.12.2.7.1 Tests shall be conducted after installation of all components of the vacuum system.

5.1.12.2.7.2 The piping systems shall be subjected to a 24-hour standing vacuum test.

5.1.12.2.7.3 Test pressure shall be between 300 mm (12 in.) HgV and full vacuum.

The purpose of the standing vacuum test is to determine the vacuum integrity of the vacuum pipeline after the final components have been installed. The level of vacuum used for this test can range from 300 mm (12 in.) HgV to full vacuum.

5.1.12.2.7.4 During the test, the source of test vacuum shall be disconnected from the piping system.

5.1.12.2.7.5* At the conclusion of the test, there shall be no change in the vacuum other than that attributed to changes of ambient temperature.

Δ **A.5.1.12.2.7.5** The effect of temperature changes on the vacuum of a confined gas is based on the Ideal Gas Law. The final absolute vacuum (V2a) equals the initial absolute vacuum (V1a) times the final absolute temperature (T2a), divided by the initial absolute temperature (T1a).

Absolute vacuum is the absolute zero pressure 101 kPa (30 inHg) less the vacuum reading below atmospheric. See Table A.5.1.12.2.6.5(b) for the absolute atmospheric pressures for elevations at and above sea level.

Absolute temperature K (°R) is the temperature gauge reading °C (°F) plus the absolute zero temperature 273°C (460°F).

Examples of vacuum test data at sea level in SI and IP units follow.

The initial test vacuum is 54 kPa or 16 inHg at 18°C (65°F). A temperature increase to 27°C (80°F) will cause the test vacuum to decrease to 52.5 kPa (15.6 inHg).

For SI units:

V1g = 54 kPa, T1g = 18°C, T2g = 27°C
V1a = 101 − 54 = +47 kPaV
T1a = 18 + 273 = 291K
T2a = 27 + 273 = 300K
V2a = 47 × 300/291 = +48.5 kPaV
V2g = 101 − 48.5 = 52.5 kPa

For IP units:

V1g = 16 inHg, T1g = 65°F, T2g = 80°F
V1a = 30 − 16 = +14 inHgV
T1a = 65 + 460 = 525°R
T2a = 80 + 460 = 540°R
V2a = 14 × 540/525 = +14.4 inHgV
V2g = 30 − 14.4 = 15.6 inHg

5.1.12.2.7.6 The 24-hour standing pressure test of the vacuum system shall be witnessed by the authority having jurisdiction 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 5.1.12.4.

5.1.12.2.7.7 Leaks, if any, shall be located, repaired (if permitted) or replaced (if required), and retested.

N **5.1.12.3 System Inspection.**

N **5.1.12.3.1 General.**

This new section of the code was introduced for the 2018 edition to ensure that all concealed piping and components are inspected for proper and correct labeling and tagging. This inspection should be viewed as a "rough" inspection similar to other plumbing systems installed on a hospital project. On larger projects, it may be required to have multiple inspections if concealing of the piping and/or components occurs in phases. In this case, each phase should be inspected as required.

N **5.1.12.3.1.1** System inspections shall be performed prior to concealing piping distribution systems in walls, ceilings, chases, trenches, underground, or otherwise hidden from view.

Much of the pipeline distribution system is hidden from plain view by the time the system verification (see 5.1.12.4) is conducted. To ensure that all piping, valves, and any other concealed components are labeled and tagged properly, an inspection prior to concealment is required.

N **5.1.12.3.1.2** The test gas shall be nitrogen NF.

N **5.1.12.3.1.3** 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 6020, *Professional Qualifications Standard for Medical Gas Systems Inspectors*, or ASSE 6030, *Professional Qualifications Standard for Medical Gas Systems Verifiers*.

FAQ What is an ASSE 6020 certified inspector?

The prerequisite requirements for this certification are that the individual seeking the certification must be employed by a governmental unit as a plumbing and/or mechanical inspector, or as an administrator of such inspectors, or be a person regularly involved in the design, inspection, or verification of medical gas systems, or be a 6010 installer, and the candidate for this certification must complete a 24-hour training program and pass a written exam. This is to ensure a qualified person with system knowledge is the party conducting these inspections. See ASSE Series 6000, *Professional Qualifications Standard for Medical Gas Systems Personnel,* for more information about this certification.

N **5.1.12.3.1.4** Inspections shall be performed by a party other than the installing contractor.

N **5.1.12.3.1.5** Where systems have not been installed by in-house personnel, inspections shall be permitted by personnel of the organization who meet the requirements of 5.1.12.3.1.3.

FAQ Why can't the in-house personnel install and inspect the system?

The inspector must have an independent role to check the work of the installer. If the same person or organization performs both duties, the independent function is defeated. It is best to keep the installation and inspection functions separate.

N **5.1.12.3.2 Inspections.**

N **5.1.12.3.2.1** The initial pressure tests performed by the installing contractor shall be witnessed by an ASSE 6020 inspector, an ASSE 6030 verifier, or the authority having jurisdiction 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 5.1.12.4.

FAQ Who is the authority having jurisdiction (AHJ)?

NFPA defines the AHJ as an organization, office, or individual responsible for enforcing the requirements of the code, or for approving equipment, materials, an installation, or a procedure. Depending on the work being performed on the system, this definition allows for many individuals or organizations to assume the role of the authority having jurisdiction. It may be clear on a large construction project who should perform the inspections (e.g., municipal/state authority, clerk of the works, department of health), but for small projects or system repairs, it becomes a matter of who the hospital views as the most appropriate person to perform the inspections. Ultimately, once the systems are in use by patients and caregivers, the hospital has the sole responsibility for compliance. See 3.2.2 and the associated commentary for more information.

N **5.1.12.3.2.2** The presence and correctness of labeling and valve tagging required by this code for all concealed components and piping distribution systems shall be inspected.

5.1.12.4 System Verification.

5.1.12.4.1 General.

5.1.12.4.1.1 Verification tests shall be performed only after all tests required in 5.1.12.2, Installer Performed Tests, have been completed.

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

FAQ When is it appropriate to use the system gas for testing?

System gas is allowed to be used in instances where it might not be practical to use nitrogen as the test gas. For example, if a small number of oxygen outlets are added to an existing in-use zone, the existing zone valve might be of older design and might leak nitrogen back across the seals into the oxygen system during pressure testing. Also, it would be inappropriate to pressurize the existing zone to a gauge pressure of 1034 kPa (150 psi) for the installer's initial pressure test. This allowance eliminates the need for the facility to do a major shutdown and the risk of cross-contamination due to older valves.

5.1.12.4.1.3 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 6030, *Professional Qualifications Standard for Medical Gas Systems Verifiers*, except as required by 5.1.12.4.1.4.

This requirement provides for the minimum credentialing that is necessary to perform the system verification. The certification demonstrates that the individual is properly trained in the inspection, testing, and performance verification requirements and procedures and qualified to ensure that the MGVS systems are tested properly and verified to be safe for patient use.

N **5.1.12.4.1.4** 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 6035, *Professional Qualifications Standard for Bulk Medical Gas Systems Verifiers*, in accordance with the mandatory requirements in CGA M-1, *Standard for Medical Gas Supply Systems at Health Care Facilities*.

The ASSE 6035, *Professional Qualifications Standard for Bulk Medical Gas Systems Verifiers*, certification is one of two new ASSE 6000 certifications introduced in the 2018 edition. The ASSE 6035 certification is equivalent to the ASSE 6030, *Professional Qualifications Standard for Medical Gas Systems Verifiers*, verifier's certification for bulk medical gas systems, which would require compliance with NFPA 55 in addition to NFPA 99. The ASSE 6035 certification is limited in scope to the source side of a source valve for bulk medical gas systems. See the definitions in 3.3.19 for more information.

5.1.12.4.1.5 Testing shall be performed by a party other than the installing contractor.

5.1.12.4.1.6 When systems have not been installed by in-house personnel, testing shall be permitted by personnel of that organization who meet the requirements of 5.1.12.4.1.3.

FAQ Why can't the in-house personnel install and verify the system?

The verifier must have an independent role to check the work of the installer. If the same person or organization performs both duties, the independent function is defeated. It is best to keep the installation and verification functions separate.

5.1.12.4.1.7 All tests required under 5.1.12.4 shall be performed after installation of any manufactured assemblies supplied through tubing or flexible hose.

5.1.12.4.1.8 Where there are multiple possible connection points for terminals, each possible position shall be tested independently.

This recognizes that some manufactured assemblies are built with multiple connection points to enhance future flexibility in outlet location or for other reasons but that each of these connectors must represent a separate termination of the medical gas piping. The user is warned that these connection points are frequently hidden behind panels or other finishing trim, and the trim might need to be removed to accomplish this testing.

5.1.12.4.1.9 The gas of system designation shall be permitted to be used for all tests, regardless of the size of the system, which include the following:

(1) Standing pressure *(see 5.1.12.4.2)*
(2) Cross-connection *(see 5.1.12.4.3)*
(3) Alarms *(see 5.1.12.4.5)*
(4) Piping purge *(see 5.1.12.4.6)*
(5) Piping particulates *(see 5.1.12.4.7)*

5.1.12.4.2* Standing Pressure Test.

Piping systems shall be subjected to a 10-minute standing pressure test at operating line pressure using the following procedure:

(1) After the system is filled with nitrogen or source gas, the source valve and all zone valves shall be closed.
(2) The piping system shall show no decrease in pressure after 10 minutes.
(3) Any leaks found shall be located, repaired, and retested per 5.1.12.2.6.

The purpose of the standing pressure test is to ensure the integrity of the entire system by verifying the results of the installer's standing pressure test that the system is leak-free. All new valves should be closed to verify that the valves are operating properly and hold pressure.

Test Procedure: Standing Pressure

1. Introduce pressure into the new piping system.
2. Close the source valve and all zone valves.
3. Wait 10 minutes. Verify no pressure drop in the system.
4. Drain all piping downstream of closed valves.
5. Wait 10 minutes. Verify no pressure has leaked by the valves to the downstream portion of the piping systems.

A.5.1.12.4.2 This is the final pressure test of the completely installed system and is intended to locate any leaks that would be more likely to occur at lower pressure (e.g., leaks in station outlet valve seals).

5.1.12.4.3 Cross-Connection Test. After the closing of walls and completion of the requirements of 5.1.12.2, it shall be determined that no cross-connection of piping systems exists by either of the methods detailed in 5.1.12.4.3.1 or 5.1.12.4.3.2.

As mentioned in 5.1.12.2.4, the cross-connection test is considered critically important. It ensures that there are no cross-connections in the installed systems, which are the main cause of deaths and injuries with medical gas systems.

To conduct a cross-connection test, there are two methods to choose from — the individual pressurization method or the pressure differential method. There are project situations that may require one or the other test to be performed due to existing conditions of the MGVS. For example, if a facility has an existing oxygen system and is adding a nitrous oxide system and medical air system, there is no need to shut down the existing oxygen system. With an active oxygen system of 345 kPa (50 psi) gauge pressure in the same zone being tested, the verifier may want to use the pressure differential method and charge the nitrous oxide to 275 kPa (40 psi) and the medical air to 415 kPa (60 psi), or use the individual pressurization method. Both methods will achieve the same results, which is to confirm that each outlet and inlet is connected to the proper piping system.

5.1.12.4.3.1 Individual Pressurization Method.

The individual pressurization method is the preferred testing procedure for new installations. When comparing the two methods allowed for cross-connection testing, there is less chance of an engineering failure with this test procedure. It can be thought of as a binary test for cross-connections, which is the main difference between the two methods. This test procedure identifies the correct system with positive pressure and the incorrect system with gauge pressure of zero (atmospheric pressure). This method provides for less chance of both mechanical and human error in identifying a cross-connection between the different medical gas systems.

(A) All medical gas and vacuum piping systems shall be reduced to atmospheric pressure.

(B) All sources of test gas from all of the medical gas and vacuum systems, with the exception of the one system to be checked, shall be disconnected.

(C) The system being checked shall be pressurized to a gauge pressure of 345 kPa (50 psi).

(D) With adapters matching outlet labels, each individual station outlet/inlet of all medical gas and vacuum systems installed shall be checked to determine that test gas is being dispensed only from the outlets/inlets of the piping system being tested.

(E) The source of test gas shall be disconnected, and the system tested reduced to atmospheric pressure.

(F) Proceed to test each additional piping system until all medical gas and vacuum piping systems are free of cross-connections.

5.1.12.4.3.2 Pressure Differential Method.

(A) The pressure in all medical gas systems shall be reduced to atmospheric.

(B) The test gas pressure in all medical gas piping systems shall be increased to the values indicated in Table 5.1.12.4.3.2(B), simultaneously maintaining these nominal pressures throughout the test.

TABLE 5.1.12.4.3.2(B) *Alternate Test Pressures*

Medical Gas	*Pressure (Gauge)*
Gas mixtures	140 kPa (20 psi)
Nitrogen/instrument air	210 kPa (30 psi)
Nitrous oxide	275 kPa (40 psi)
Oxygen	345 kPa (50 psi)
Medical air	415 kPa (60 psi)
Systems at nonstandard pressures	70 kPa (10 psi) greater or less than any other system
	HgV vacuum
Vacuum	510 mm (20 in.) HgV
WAGD	380 mm (15 in.) HgV (if so designed)

(C) Systems with nonstandard operating pressures shall be tested at a gauge pressure of at least 70 kPa (10 psi) higher or lower than any other system being tested.

(D) Any vacuum systems shall be in operation so that these vacuum systems are tested at the same time the medical gas systems are tested.

(E) Following the adjustment of pressures in accordance with 5.1.12.4.3.2(B) and 5.1.12.4.3.2(C), each station outlet for each medical gas system shall be tested using the gas-specific connection for each system with test gauge attached to verify that the correct test pressure/vacuum is present at each outlet/inlet of each system as listed in Table 5.1.12.4.3.2(B).

(F) Each test gauge used in performing this test shall be calibrated with the pressure indicator used for the line pressure regulator used to provide the source pressure.

When the pressure differential method is used, each of the medical gas and vacuum piping systems in the area being tested must be regulated to the test pressures in Table 5.1.12.4.3.2(B). When pressurizing the pipelines for this test, the verifier's test gauge must be used to confirm the static pressures of each of the pipelines prior to using the pressure differential method to test for cross-connections.

(G) Each station outlet shall be identified by label (and color marking, if used), and the pressure indicated on the test gauge shall be that listed in Table 5.1.12.4.3.2(B) for the system being tested.

The pressures listed in Table 5.1.12.4.3.2(B) are for testing purposes only and do not reflect the system operating pressures. The intent of the table is to create a consistent and significant pressure differential between systems. Therefore, it is necessary to use an accurate test gauge, as described in 5.1.12.1.13, for this testing.

5.1.12.4.4 Valve Test. Valves installed in each medical gas and vacuum piping system shall be tested to verify proper operation and rooms or areas of control.

This test should be performed in conjunction with the cross-connection test in 5.1.12.4.3 to confirm that any new control valves serve the areas that are indicated on the valve labeling. The testing procedure should confirm that the valves serve the areas and the station outlets/inlets in those areas only. The procedure applies to all new control valves, including service valves, zone valves, riser valves, and so on.

5.1.12.4.4.1 Records shall be made listing the rooms or areas controlled by each valve for each gas.

This record is used to assist the health care facility in developing an inventory of the critical medical gas components that is required in 5.1.14 and by other regulatory/accreditation agencies.

5.1.12.4.4.2 The information shall be utilized to assist and verify the proper labeling of the valves.

By physically closing the control valves to verify which outlets/inlets are controlled by the valves, a list that records the results can be generated. This test also verifies the labeling that is required to be on the valve.

5.1.12.4.5 Alarm Test.

MGVS alarms are the first systems that alert the medical and maintenance staff about a problem or failure of the gas or vacuum system that is supplying patients. The alarm system monitors both the sources of supply (such as bulk tanks, manifolds, compressed medical air, vacuum pumps) and the operating pressures of the various piping systems. Testing these alarm systems verifies that master and area alarm warning systems function properly and provide continuous visible and audible surveillance of the MGVS.

5.1.12.4.5.1 General.

(A) All warning systems for each medical gas and vacuum system(s) shall be tested to ensure that all components function properly prior to placing the system in service.

Test Procedure: Positive Pressure Systems

Test Procedure for Positive Pressure Systems (Best Practice):

Note: This is a best practice test procedure for the positive pressure gas alarms but should not be utilized on an active system that is serving patients. Using this test procedure on a system that is in use by patients and caregivers for testing purposes is never recommended as it may compromise patient safety. A utility shutdown plan should be developed anytime the operating pressures in an active medical gas system are adjusted for testing purposes.

1. Close the applicable service (shutoff) valve to the area.
2. Increase the line pressure in the piping system to the high-pressure alarm set point (20 percent above normal line pressure).
3. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
4. Check a test gauge in the area to ensure that the pressure reading is within ±10.3 kPa (±1.5 psi) gauge pressure of the reading on the alarm panel.
5. Silence the audible signal. The visible signal should remain activated.
6. Reduce the line pressure in the piping system to the normal operating pressure.
7. Check the applicable alarm panel for deactivation of the alarm signal.
8. Check a test gauge in the area to ensure that the pressure reading is back to normal.
9. Reduce the line pressure in the piping system to the low-pressure alarm set point (20 percent below normal line pressure).
10. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
11. Check a test gauge in the area to ensure that the pressure reading is within ±10.3 kPa (±1.5 psi) gauge pressure of the reading on the alarm panel.
12. Silence the audible signal. The visible signal should remain activated.
13. Open the service (shutoff) valve to the area.
14. Check the applicable alarm panel for deactivation of the alarm signal.
15. Disconnect the low-voltage alarm wiring from the alarm-initiating device (e.g., pressure switch, transducer).
16. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
17. Reconnect the low-voltage alarm wiring to the alarm initiating device.
18. Check the applicable alarm panel for deactivation of the alarm signal.
19. Document the test results.

Test Procedure: Positive Pressure Systems

Test Procedure for Positive Pressure Systems (Option #2):

Note: This test procedure can be performed on an active system, but because it removes the alarm-initiating device from the system for testing, it does not test the alarms as an integrated system.

1. Confirm there is a gas-specific demand check or other positive means of isolating the alarm-initiating device (e.g., pressure switch, transducer) from the pipeline.
2. Remove the alarm-initiating device from the piping system.
3. Connect the alarm-initiating device to a pressure testing device (e.g., hand pump, pressure regulator).
4. Increase the pressure on the alarm-initiating device to the high-pressure alarm set point (20 percent above normal line pressure).
5. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
6. Check the test gauge to ensure that the pressure reading is within ±10.3 kPa (±1.5 psi) gauge pressure of the reading on the alarm panel.
7. Silence the audible signal. The visible signal should remain activated.
8. Reduce the pressure on the alarm-initiating device to the normal operating pressure.
9. Check the applicable alarm panel for deactivation of the alarm signal.
10. Reduce the pressure on the alarm-initiating device to the low-pressure alarm point (20 percent below normal line pressure).
11. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
12. Silence the audible signal. The visible signal should remain activated.
13. Increase the pressure on the alarm-initiating device to the normal operating pressure.
14. Check the alarm panel for deactivation of the alarm signal.
15. Disconnect the low-voltage alarm wiring from the alarm-initiating device.
16. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
17. Reconnect the wiring to the alarm-initiating device.
18. Reconnect the alarm-initiating device to the piping system.
19. Check the applicable alarm panel for deactivation of the alarm signal.
20. Document the test results.

Test Procedure: Vacuum Systems

Test Procedure for Vacuum Systems (Best Practice):

Note: This is a best practice test procedure for the vacuum alarms but should not be utilized on an active system that is serving patients. Using this test procedure on a system that is in use by patients and caregivers for testing purposes is never recommended as it may compromise patient safety. A utility shutdown plan should be developed anytime the operating pressures in an active medical gas system are adjusted for testing purposes.

1. Close the applicable service (shutoff) valve to the area.
2. Reduce the vacuum pressure in the piping system to the low-pressure alarm set point 300 mm (12 in.) gauge HgV.
3. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
4. Check a test gauge in the area to ensure that the vacuum pressure reading is within ±38 mm (±1.5 in.) HgV of the reading on the alarm panel.
5. Silence the audible signal. The visible signal should remain activated.
6. Open the service (shutoff) valve to the area.
7. Check the applicable alarm panel for deactivation of the alarm signal.
8. Disconnect the low-voltage alarm wiring from the alarm-initiating device (e.g., vacuum switch, transducer).
9. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
10. Reconnect the low-voltage alarm wiring to the alarm-initiating device.
11. Check the applicable alarm panel for deactivation of the alarm signal.
12. Document the test results.

(B) Permanent records of these tests shall be maintained.

(C) Warning systems that are part of an addition to an existing piping system shall be tested prior to the connection of the new piping to the existing system.

The best method to test these alarms is as an integral system, which would require increasing and decreasing the line pressures in the piping system to ensure that all components function properly as a "system."

Test Procedure: Vacuum Systems

Test Procedure for Vacuum Systems (Option #2):

Note: This test procedure can be performed on an active system but because it removes the alarm-initiating device from the system for testing, it does not test the alarms as an integrated system.

1. Confirm there is a gas-specific demand check or other positive means of isolating the alarm-initiating device (e.g., vacuum switch, transducer) from the pipeline.
2. Remove the alarm-initiating device from the piping system.
3. Connect the alarm-initiating device to a vacuum testing device (e.g., hand pump, portable vacuum pump).
4. Increase the vacuum pressure on the alarm-initiating device to the low-pressure alarm set point 300 mm (12 in.) gauge HgV.
5. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
6. Check a test gauge in the area to ensure that the vacuum pressure reading is within ±38 mm (±1.5 in.) HgV of the reading on the alarm panel.
7. Silence the audible signal. The visible signal should remain activated.
8. Increase the vacuum pressure on the alarm-initiating device to the normal operating pressure.
9. Check the alarm panel for deactivation of the alarm signal.
10. Disconnect the low-voltage alarm wiring from the alarm-initiating device.
11. Check the applicable alarm panel to ensure that the properly labeled warning signal is activated (both visible and audible).
12. Reconnect the wiring to the alarm-initiating device.
13. Reconnect the alarm-initiating device to the piping system.
14. Check the applicable alarm panel for deactivation of the alarm signal.
15. Document the test results.

Raising and lowering operating pressures on a system that is in use by patients for testing purposes is never recommended as it may compromise patient safety. For that reason, the best practice is to perform the alarm testing prior to connecting to the existing system. A utility shutdown plan should be developed anytime the operating pressures in an active system are adjusted for testing purposes.

(D) Tests of warning systems for new installations (initial tests) shall be performed after the cross-connection testing *(see 5.1.12.4.3)*, but before purging the piping *(see 5.1.12.4.6)* and performing the remaining verification tests. *(See 5.1.12.4.7 through 5.1.12.4.14.)*

(E) Initial tests of warning systems that can be included in an addition or extension to an existing piping system shall be completed before connection of the addition to the existing system.

(F) Test gases for the initial tests shall be oil-free, dry nitrogen NF, the gas of system designation, or operating vacuum.

(G) Where computer systems are used as substitutes for a required alarm panel as permitted under 5.1.9.2.2, the computer system shall be included in the alarm tests as modified in 5.1.9.3.

5.1.12.4.5.2 Master Alarms.

(A) The master alarm system tests shall be performed for each of the medical gas and vacuum piping systems.

(B) Permanent records of these tests shall be maintained with those required under 5.1.12.1.7.

(C) The audible and noncancelable visual signals of 5.1.9.1 shall indicate if the pressure in the main line increases or decreases 20 percent from the normal operating pressure.

(D) The operation of all master alarm signals referenced in 5.1.9.2.4 shall be verified.

Alarm warning systems ensure safety of the patients who rely on medical gas and vacuum systems by monitoring the operation and function of these systems. The main purpose of the master alarm panels is to provide the user with important alarm conditions of the central supply systems and the operating pressures of the piping systems. Nonfunctional or missing master alarms pose an immediate threat to life and will most likely have a serious effect on patient safety during a failure of any of these systems.

5.1.12.4.5.3 Area Alarms. The warning signals for all medical gas piping systems shall be tested to verify an alarm condition if the pressure in the piping system increases or decreases 20 percent from the normal operating pressure for positive pressure gases, or when the vacuum system(s) drops below a gauge pressure of 300 mm (12 in.) HgV.

5.1.12.4.6 Piping Purge Test. 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.

5.1.12.4.6.1 The appropriate adapter shall be obtained from the facility or manufacturer, and high purge rates of at least 225 Nl/min (8 SCFM) shall be put on each outlet.

5.1.12.4.6.2 After the purge is started, it shall be rapidly interrupted several times until the purge produces no discoloration in a white cloth loosely held over the adapter during the purge.

5.1.12.4.6.3 In order to avoid possible damage to the outlet and its components, this test shall not be conducted using any implement other than the proper adapter.

The piping purge test is conducted by the verifier after all the pipeline distribution system components (such as outlet faceplates, pressure alarm devices, pressure indicators, and line pressure relief valves) are installed. This test is one element of the verification process to confirm whether the medical gas pipelines are free of visual particulates and/or other contamination that would result from poor installation practices.

5.1.12.4.6.4* No pronounced or objectionable odor shall be discernible from any positive pressure outlet.

The odor test has been added to the list of testing requirements for a few reasons. First, when the piping materials and other components have been properly cleaned by the manufacturer, they should not exhibit any objectionable odors in the system. Second, poor installation procedures may produce an objectionable odor in the piping system. Finally, many other contaminants that may be present (e.g., field-applied cleaning solvents) can be detected through the odor test. This test verifies the presence of many contaminants that may have an impact on the purity of the gas being dispensed to patients once the system is placed into service.

Test Procedure: Piping Purge

Piping Purge Test:

1. Initiate a heavy 225 Nl/min (8 SCFM) purge of the pipeline without the filter holder attached to the medical gas outlet adapter. Each new outlet within the facility must be purged in this manner. After the purge is started, it must be interrupted several times until the purge produces no discoloration on a white cloth loosely held over the adapter during the purge.
2. If large amounts of contamination are found in the area or zone, the removal of both the primary and secondary check valves in the station outlets may be required to effectively purge the contamination from the affected line.

Odor Test:

All positive pressure gas outlets should be tested for odor as follows:

1. Flow approximately 10 L/min (2.6 gpm) at all positive pressure outlets.
2. Deflect a portion of the gas stream toward the nose and sniff.
3. Do not direct the outlet gas stream toward the face and do not inhale the gas.
4. Test should be performed with nitrogen NF but may be performed with the source gas if required.
5. No pronounced or objectionable odor should be discernible from any positive pressure outlet.

Note: The system might produce odors that would be expected, such as the odor of copper. The purpose of this test is to detect odors that should not be present (e.g., chemical or industrial solvent odors). If objectionable odors are detected, a sample should be collected for a laboratory analysis to determine the cause of such odors.

A.5.1.12.4.6.4 Odor is checked by sniffing a moderate flow of gas from the outlet being tested. Specific measure of odor in gas is impractical. Gas might have a slight odor but the presence of a pronounced odor should render the piping unsatisfactory.

Odor is subjective, but the presence of a strong odor can indicate problems that other testing might not identify. Detecting an objectionable odor during the verification of a system is preferable to finding these problems after the system is placed into service.

5.1.12.4.7 Piping Particulate Test. For each positive pressure gas system, the cleanliness of the piping system shall be verified.

5.1.12.4.7.1 A minimum of 1000 L (35 ft^3) of gas shall be filtered through a clean, white 0.45 micron filter at a minimum flow rate of 100 Nl/min (3.5 SCFM).

5.1.12.4.7.2 Twenty-five percent of the zones shall be tested at the outlet most remote from the source.

5.1.12.4.7.3 The filter shall accrue no more than 0.001 g (1 mg) of matter from any outlet tested.

5.1.12.4.7.4 If any outlet fails this test, the most remote outlet in every zone shall be tested.

5.1.12.4.7.5 The test shall be performed with the use of oil-free, dry nitrogen NF.

The intent of this testing is to verify the cleanliness of the tubing. All the requirements for the materials, installation techniques, and procedures for installation of the equipment and piping are designed to ensure that the system does not become contaminated during these processes.

5.1.12.4.8* Verifier Piping Purity Test. For each medical gas system, the purity of the piping system shall be verified in accordance with 5.1.12.4.8.

A.5.1.12.4.8 The detector used for total hydrocarbons is calibrated with a gas that has a known quantity of methane. When a sample is run with this calibrated detector, the result will be total hydrocarbons as methane. Since methane is the one hydrocarbon that does not interact with the body and is present in all air and most oxygen, the actual amount of methane in the sample is subtracted from the total hydrocarbon result to give total non-methane hydrocarbons.

Test Procedure: Piping Particulate

The most remote outlet in 25 percent of the zones in each medical gas system must be tested for cleanliness using nitrogen NF.

1. Preweigh a 0.45 micron filter [see in item (2) on filter media].
2. Flow a minimum of 1000 L (35 ft^3) of gas, which is 1 m^3 (35 ft^3), at a flow rate of 100 Nl/min (3.5 SCFM) for 10 minutes, from the outlet in each zone being tested that is most remote from the source equipment through the clean, environmentally stabilized, preweighed 0.45 micron filter. A filter holder should be used to hold the filter during testing. Also, forceps should be used to handle the filter during testing to avoid introducing any contaminants to the filter from handling.
3. If any outlet deposits more than 0.001 g (1 mg) of matter on a filter, each zone of that gas system must be tested at its most remote outlet.
4. If necessary, the piping purge test can be repeated to clear the piping before repeating the piping particulate test.
5. Medical gas lines should be sampled undisturbed and not struck in an attempt to dislodge any material that may be on the interior surface of the pipe.

5.1.12.4.8.1 These tests shall be performed with oil-free, dry nitrogen NF or the system gas.

The intent of the piping purity test is to verify the cleanliness of the tubing through comparison tests. Comparisons are conducted between the test gas used (nitrogen NF or the source gas) and the test location for moisture (dew point), total nonmethane hydrocarbons (THC), and halogenated hydrocarbons (HHC).

For example, if a new medical gas pipeline is being installed, the test gas cylinder of nitrogen NF would be tested and recorded for the dew point, THC, and HHC. Then, the test gas nitrogen NF would be attached to one end of the new pipeline. Next, the test gas would flow through the new piping to the test location, and samples for dew point, THC, and HHC would be taken and recorded. These two samples would be compared. If the results exceed the limits listed in 5.1.12.4.8, the piping purity test fails and the piping may need to be cleaned and retested.

Test Procedure: Piping Purity

The following samples should be analyzed and compared to the contaminants identified in 5.1.12.4.8. This analysis should record the level of contaminants observed in the samples.

1. Connect the test gas to the newly installed portion of the system at or near the source gas equipment. For additions to existing systems, the test gas needs to be connected to the new piping at a point as close as possible to the intended connection to the existing system.
2. Purge the gas through the most remote outlet from the source equipment.
3. Using the appropriate gas-specific adapter, analyze and record the level of contaminants at the most remote outlet in each pressurized gas system. The gaseous contaminant variation between the test gas cylinder and the most remote outlet cannot exceed the limit stated in 5.1.12.4.8.
4. If the contaminant variation exceeds the required limit, the piping system must be purged with nitrogen NF until the contaminant variation is within the required limit.

5.1.12.4.8.2 The outlet most remote from the source shall be tested for total nonmethane hydrocarbons and halogenated hydrocarbons and compared to the source gas.

Halogenated hydrocarbons is a comparative test. This has been added to this subsection to clarify.

5.1.12.4.8.3 If the system gas is used as the source gas, it shall be tested at the source equipment.

5.1.12.4.8.4 The difference between the two tests shall in no case exceed 5 ppm of total nonmethane hydrocarbons.

5.1.12.4.8.5 The difference between the two tests shall in no case exceed 5 ppm halogenated hydrocarbons.

5.1.12.4.8.6 The moisture concentration of the outlet test shall not exceed 500 ppm or an equivalent pressure dew point of −12°C (10°F) at a gauge pressure of 345 kPa (50 psi).

Exhibit 5.52 shows a dew point meter that can be used for ensuring appropriate dew point levels.

5.1.12.4.9 Final Tie-In Test.

The final tie-in is the point at which the new work and existing systems are joined together. This final connection does not require the installer to use nitrogen NF to purge the pipeline when the final

EXHIBIT 5.52

Dew Point Meter. (Courtesy of Acute Medical Gas Services, Inc.)

connection is made. When air is allowed in the pipeline during the brazing process, oxidation will form on the copper tubing. The copper oxide scale that forms inside the tubing when a purge is not utilized may flake off when the system is placed into service. To mitigate this additional contamination in the MGVS, the verifier is required to purge the closest outlet to the final line tie-in on the new piping side until there is no discoloration in a white cloth, and then purge the closest outlet to the final line tie-in on the *existing* piping side until there is no discoloration in a white cloth. A leak test at the final tie-in is also required.

Completing a final tie-in without a purge does create a "dirty" joint. It is recommended whenever possible to complete the final tie-in with a nitrogen purge or join the new and existing piping with a nonbrazed joint (i.e., axially swaged fitting) that does not require a purge but keeps the system as clean as a purged brazed joint.

5.1.12.4.9.1 Prior to the connection of any work or any extension or addition to an existing piping system, the tests in 5.1.12.4.1 through 5.1.12.4.8 shall be successfully performed on the new work.

5.1.12.4.9.2 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.

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

5.1.12.4.9.4 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 5.1.12.4.6.

5.1.12.4.9.5 Before the new work is used for patient care, positive pressure gases shall be tested for operational pressure and gas concentration in accordance with 5.1.12.4.10 and 5.1.12.4.11.

5.1.12.4.9.6 Permanent records of these tests shall be maintained in accordance with 5.1.14.5.

5.1.12.4.10 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.

The title of this section has been revised to more accurately reflect what the test is evaluating. This test ensures required flow rates with maximum pressure drops in this section.

In health care facilities, the MGVS are essential for continuously supplying life supporting medical gases and vacuum services to patients. Emergency departments, anesthesia machines, ventilating machines, critical care areas, hyperbaric oxygen chambers, and general care areas all require the proper quality, pressure, flow, and purity of gases and vacuum for proper patient care.

The operational flow test is conducted on the MGVS to confirm that the gas and vacuum are delivered at the operating pressure and flow rates required for proper patient care. Positive pressure ventilating systems and anesthesia machines need a consistent, uninterrupted supply of medical gas to operate properly.

For standard positive pressure medical gas systems (such as oxygen, nitrous oxide, or medical air), typical anesthesia machines and breathing machines require 345 kPa to 380 kPa (50 psi to 55 psi) gauge pressure to operate. An alarm will be generated when the oxygen alarming pressure is less than 275 kPa (40 psi) gauge on most machines. For these medical gas systems, the normal flow rate of anesthesia machines is generally 0 L/min to 10 L/min (0 gpm to 2.6 gpm), and a high flow rate is between 35 L/min to 75 L/min (9.2 gpm to 19.8 gpm).

5.1.12.4.10.1 Tests shall be performed with the gas of system designation or the operating vacuum.

5.1.12.4.10.2 All gas outlets with a gauge pressure of 345 kPa (50 psi), including, but not limited to, oxygen, nitrous oxide, medical air, and carbon dioxide, shall deliver 100 SLPM (3.5 SCFM) with a pressure drop of not more than 35 kPa (5 psi) and static pressure of 345 kPa to 380 kPa (50 psi to 55 psi).

5.1.12.4.10.3 Support gas outlets shall deliver 140 SLPM (5.0 SCFM) with a pressure drop of not more than 35 kPa (5 psi) gauge and static pressure of 1100 kPa to 1275 kPa (160 psi to 185 psi) gauge.

5.1.12.4.10.4 Medical–surgical vacuum inlets shall draw 85 Nl/min (3 SCFM) without reducing the vacuum pressure below 300 mm (12 in.) gauge HgV at any adjacent station inlet.

The vacuum test reflects the limits of vacuum flow rate in a clinical setting. The flow rate of 85 Nl/min (3 SCFM) is about twice the maximum flow through a terminal connected to the normal ancillary equipment (i.e., vacuum regulator, suction trap bottle, connecting tubing, and suction tip). The 300 mm (12 in.) gauge Hg minimum vacuum level was selected in consultation with clinical staff and in coordination with the use of the ancillary vacuum equipment.

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

The transient flow test is to verify that any given outlet in an intensive care area could support the operation of a ventilator. Although few ventilators will ever need a continuous flow as high as 170 SLPM (6 SCFM), in some cases instantaneous flow rates could reach this volume, depending on the cycle of the ventilator. The test requires the outlet to deliver this flow rate for the brief time it is likely to be needed, and it ensures that the outlet will not "starve" the ventilator during peak flows. Exhibit 5.53 shows an outlet being performance tested in a Category 1 space.

EXHIBIT 5.53

Outlet Performance Test in Category 1 Space. (Courtesy of Acute Medical Gas Services, Inc.)

5.1.12.4.10.6* Where outlets are being fed with non-standard line pressure, volume, or gas content, for clinical reasons, they shall be labeled in accordance with 5.1.11.

A.5.1.12.4.10.6 Sleep laboratories are an example of where gas flow and concentration are frequently modified.

This requirement calls for the verifier to make sure that outlets being fed with nonstandard pressure are properly labeled. The labeling identifies the use of these outlets for equipment such as ventilators as inappropriate.

5.1.12.4.11 Medical Gas Concentration Test. After purging each system with the gas of system designation, the following shall be performed:

(1) Each pressure gas source and outlet shall be analyzed for concentration of gas, by volume.
(2) Analysis shall be conducted with instruments designed to measure the specific gas dispensed.
(3)* Allowable concentrations shall be as indicated in Table 5.1.12.4.11.

FAQ What is the purpose of the medical gas concentration test?

The intent of this test is to ensure that the concentration of the medical gas being dispensed at the patient use points has been proven to be the expected quality as indicated in Table 5.1.12.4.11. The concentration test is similar to the assay test required by the U.S. Pharmacopeia specifications for all the USP grade medical gases (e.g., Oxygen USP, Medical Air USP, Nitrous Oxide USP, Carbon Dioxide USP, and Helium USP), and the samples collected should be analyzed to confirm that they all meet the minimum requirement for concentration of the gas by volume. The test samples should be validated by a qualified verifier using the proper testing equipment or an accredited laboratory prior to the systems being used with patients. During smaller verifications (e.g., adding a single outlet to an existing zone), the test also assists in confirming that all the test gas (nitrogen NF) used for purging and brazing has been removed from the piping system. This should be the final test in the verification procedures sequence.

Since the USP grade positive pressure medical gas systems are considered a drug delivery and dispensing system as defined by the FDA, they should be tested in accordance with the USP requirements. This test should be conducted at least when the system is first placed into service. The concentration testing satisfies the requirement in the U.S. Pharmacopeia standard for assay testing but does not meet all the USP testing criteria. Testing for other contaminants should be conducted to certify that the gas being dispensed to patients meets the USP specifications. This testing should be completed at an outlet remote from the source for each system to confirm that USP grade gases are being dispensed.

Δ ***TABLE 5.1.12.4.11*** *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	19.5%–23.5% oxygen
Other gases	Named gases by ±1%, or per specification

A.5.1.12.4.11(3) The committee recognizes that current clinical practice is to use analyzers that might not be able to analyze oxygen to current USP requirements of 99 percent and that these analyzers frequently have an error of up to 3 percent.

5.1.12.4.12 Medical Air Purity Test for Compressor Sources.

These tests and analyses are for medical air that is produced by a compressor source system. A medical air compressor source system is unique in that it is the only system that produces, stores, and

dispenses a medical grade gas on-site. All the other medical grade gases are "prepackaged," that is, produced and packaged by a supplier operating under the Current Good Manufacturing Practices (cGMP) required by the Federal Drug Administration (FDA). Testing should be performed when the system is new or when modifications, major repairs (e.g., compressor replacement), or maintenance is completed on the system to ensure the quality of air meets the specifications provided in Table 5.1.12.4.12.3.

Many possible conditions can have an effect on the quality of the medical air produced on-site. For example, since the air used for this system is drawn, in most cases, from the exterior of the building, the air quality may change based on environmental factors. For this reason, it is recommended that this testing be conducted periodically to validate that the air continues to meet the NFPA specification identified in Table 5.1.12.4.12.3.

Since this is the only USP grade gas that is produced, stored, and distributed on site at health care facilities, it may be desirable to verify the system is producing Medical Air USP as well, which would require additional testing of the end product. This is not a requirement of NFPA, but arguably the U.S. Pharmacopeia does require that the producer of medical gases has a validation process for the gases they produce. The organization could perform the USP testing in coordination with the medical air purity testing at a frequency that can be determined by the organization.

5.1.12.4.12.1 The medical air source shall be analyzed for concentration of contaminants by volume prior to the source valve being opened.

5.1.12.4.12.2 A sample(s) shall be taken for the air system test at the system sample port.

5.1.12.4.12.3 The test results shall not exceed the parameters in Table 5.1.12.4.12.3.

TABLE 5.1.12.4.12.3 *Contaminant Parameters for Medical Air*

Parameter	*Limit Value*
Pressure dew point	2°C (35°F)
Carbon monoxide	10 ppm
Carbon dioxide	500 ppm
Gaseous hydrocarbons	25 ppm (as methane)
Halogenated hydrocarbons	2 ppm

For discussion on the derivation of these values, see the commentary on 5.1.3.6.1.

5.1.12.4.13 Labeling. The presence and correctness of labeling required by this code for all components (e.g., station outlets/inlets, shutoff valves, and alarm panels) shall be verified.

Labeling for the medical gas and vacuum systems must be verified. This includes not only all the components that require labeling and tagging but the pipeline distribution systems as well. To properly verify the pipe labeling, inspections should be done prior to the closing of walls and ceilings. It becomes very difficult to properly verify labeling once the finishes have been completed on a project. The addition of 5.1.12.3 for system inspections ensures that this will be done.

5.1.12.4.14 Source Equipment Verification.

5.1.12.4.14.1 General. Source equipment verification shall be performed following the installation of the interconnecting pipelines, accessories, and source equipment.

Source equipment verification must be conducted when the central supply system is initially installed, and the equipment should be retested after major repairs or replacement. As an example, the verification of a medical air compressor system should include the inspection for code compliance and testing for the proper operation of the compressors, dryers, filters, regulators, sensors, intake piping, dew point and CO monitors, control cabinets, emergency electrical power, and all other necessary components and equipment as installed.

5.1.12.4.14.2 Gas Supply Sources.

(A) The system apparatus shall be tested for proper function, including the changeover from primary to secondary supply (with its changeover signal) and the operation of the reserve (with its reserve-in-use signal), before the system is put into service.

(B) If the system has an actuating switch and signal to monitor the contents of the reserve, its function shall be tested before the system is put into service.

(C) If the system has an actuating switch and signal to monitor the pressure of the reserve unit, its function shall be tested before the system is put into service.

(D) Testing of the bulk supply signal and the master signal panel installations shall be arranged with the owner or the organization responsible for the operation and maintenance of the supply system for the testing of the bulk supply signals to ensure proper identification and activation of the master signal panels so that the facility can monitor the status of that supply system.

(E) The tests required in 5.1.12.4.14.2(D) shall also be conducted when the storage units are changed or replaced.

Gas supply source testing verifies that the source of supply — in relation to changeover and reserve-in-use signals (as applicable) — is operating correctly, and that the alarms and signals are working in conjunction with the alarm warning systems. Exhibit 5.54 shows verification testing being performed on a cylinder manifold.

5.1.12.4.14.3 Medical Air Compressor Systems.

Medical air compressor system testing verifies that the source of supply — such as lead-lag controls, compressed medical air quality monitors, and other maintenance controls (as applicable) — is operating correctly. The alarms and signals are tested to confirm they are working in conjunction with the alarm warning systems.

(A) Tests of the medical air compressor system shall include the purity test for air quality, and the test of the alarm sensors after calibration and setup per the manufacturer's instructions, as well as reserve capacity controls.

(B) Tests shall be conducted at the sample port of the medical air system.

(C) The operation of the system control sensors, such as dew point, air temperature, and all other air quality monitoring sensors and controls, shall be checked for proper operation and function before the system is put into service.

(D) The quality of medical air as delivered by the compressor air supply shall be verified after installation of new components prior to use by patients.

EXHIBIT 5.54

Cylinder Manifold Verification. (Courtesy of Acute Medical Gas Services, Inc.)

(E) The air quality tests in 5.1.12.4.14.3(D) shall be conducted after the medical air source system has been operating normally but with the source valve closed under a simulated load for an elapsed time of at least 12 hours.

(F) The aggregate run time on the compressors shall not be used to determine the elapsed time.

(G) Loading shall be simulated by continuously venting air at approximately 25 percent of the rated system capacity.

(H) A demand of approximately 25 percent of the rated compressor capacity shall be created to cause the compressors to cycle on and off continuously and the dryers to operate for the 12-hour period.

The new source equipment should be started and operated with a load for the designated time. This process allows the system to operate for a period of time prior to testing to eliminate any impurities that may be present from the manufacturing process and to permit the air treatment equipment and air quality monitoring system to gain stability and consistency. The required run cycle time is meant to be the elapsed time and not the compressor operating time.

Item (H) has been revised to match item (E), which states that the compressor system must operate for at least 12 hours prior to testing. This should have been revised for the 2015 edition but was an oversight.

N 5.1.12.4.14.4 Oxygen Central Supply System Using Concentrators.

This new section is provided for proper verification testing of oxygen concentrator supply systems.

The oxygen central supply system using concentrators shall be tested according to the following:

(1) The oxygen central supply system shall be tested for purity of the oxygen.
(2) Tests of the alarms after calibration and setup per the manufacturer's instructions shall be conducted as well as tests of the operational controls.
(3) Each concentrator supply system shall be operated with the supply system's isolating valve closed and the unit venting at a flow of 25 percent or more of nameplate capacity for an elapsed time of at least 12 hours prior to the tests in 5.1.12.4.14.4(4).

By having the system's isolating valve closed while the oxygen concentrator is operating, it ensures the oxygen product will not be delivered down the facility pipeline. Allowing the oxygen concentrator to vent/run for 12 hours before the tests provides time for the concentrator to operate at USP requirements. This can take a few hours or more, depending on the type and manufacturer of the oxygen concentrator, the first time that the concentrator runs.

(4) The oxygen quality from each concentrator supply system shall be validated as follows:
  (a) The operation of all control sensors/switches and the oxygen monitor shall be checked for proper operation and function.
  (b) The quality of the oxygen shall be confirmed to meet the USP monograph appropriate for the technology in use.

This testing can be completed using the procedures that are identified in the USP monograph at the sample port or downstream of the oxygen concentrator.

  (c) The accuracy of the oxygen monitor shall be validated against oxygen of known concentration, and the monitor calibrated in accordance with the manufacturer's specifications.

The manufacturer of the oxygen concentrator system should provide instructions for ensuring the alarms are operating correctly. For specific questions on a system, it is best to contact the manufacturer for this information. Exhibit 5.55 shows an oxygen monitor for an oxygen concentrator supply system.

EXHIBIT 5.55

Oxygen Monitoring System for an Oxygen Concentrator (Courtesy of Acute Medical Gas Services, Inc.)

(5) The central supply system shall be tested for correct operation of the cascade (i.e., primary — secondary — reserve). It shall be permitted to test source rotation for systems so constructed.
(6) The operation of all alarms *[see 5.1.9.2.4(14) and 5.1.9.5.4(13)]* shall be tested.
(7) The accuracy of the central system oxygen monitor shall be calibrated in accordance with the manufacturer's specifications.
(8) Tests in 5.1.12.4.14.4(3) to 5.1.12.4.14.4(5) shall be performed when any concentrator supply system has been opened to atmosphere (e.g., during service or replacement).

5.1.12.4.14.5 Proportioning Systems for Medical Air USP.

(A) The system apparatus shall be tested for proper function, including the changeover from primary to secondary (if applicable) and operation of the reserve, before the system is put into service.

(B) Tests shall include the purity of the air quality and test of the alarm sensors after calibration and setup per the manufacturer's instructions.

(C) Tests shall be conducted at the sample port of the proportioning system.

(D) The operation of the control sensors and all quality monitoring sensors and controls shall be checked for proper operation and function before the system is put into service.

5.1.12.4.14.6 Medical–Surgical Vacuum Systems. The proper functioning of the medical–surgical vacuum source system(s) shall be tested before it is put into service.

Medical–surgical vacuum source systems verification includes, but is not limited to, checking proper functioning of the system, checking the lag compressor operations, and operating the alarms.

5.1.13 Category 1 Support Gases.

5.1.13.1* Applicability.

A.5.1.13.1 Support gas systems are subject to the same hazards as are present in any piped medical gas system, with the additional hazard of operating at higher pressures.

Medical support gases are intended for medical gas support, but they are not intended for human respiration. They are typically piped into the operating room for the powering of medical devices such as surgical tools, air-driven booms, ceiling arms, and pendants. These gases can also be found in ICUs for air-driven booms, ceiling arms, and pendants; and in the central sterile supply for processing tools and equipment.

5.1.13.1.1 Support gases are any gases that are used primarily for powering equipment used in patient care procedures (typical support gases are nitrogen and instrument air). Support gas applications require delivery at pressures, cleanliness, or purities specific to their intended function(s) (e.g., to operate medical–surgical tools). Support gases shall be permitted to be piped into areas intended for any medical support purpose and, if appropriate to the procedures, to be piped into laboratories.

Δ **5.1.13.1.2** Support gas sources shall be permitted to be used for many general utility uses (e.g., to remove excess moisture from instruments before further processing, or to operate gas-driven booms, boom brakes, pendants, or similar applications). *(See Chapter 8 for general utility systems requirements.)*

5.1.13.1.3 Support gas systems shall not convey oxidizing gases other than air or gases intended for patient or staff respiration.

5.1.13.2 Nature of Hazards. Design, installation, and operation of support gas systems shall consider all hazards involved with any pressurized gas except those associated with oxidizing gases and hazards associated with the elevated pressures typical of these systems.

5.1.13.3 Sources.

5.1.13.3.1 Sources for support gases delivered from cylinders shall comply with 5.1.3.3 through 5.1.3.5.10.

5.1.13.3.2 Sources for support gases delivered from containers shall comply with 5.1.3.3 through 5.1.3.5.12 except 5.1.3.5.10.

5.1.13.3.3 Sources for support gases delivered from bulk sources shall comply with 5.1.3.3 through 5.1.3.5.12 except 5.1.3.5.10.

5.1.13.3.4* Instrument Air Supply Systems.

It is not required to have instrument air supply systems, but if provided, they must comply with NFPA 99. Instrument air is being installed in some facilities as an alternative to piped nitrogen. It operates at similar pressures, is filtered and dried to similar levels, and is intended to perform similar support functions within the facility. Instrument air is similar to the ambient air that we breathe so it is less hazardous than nitrogen. Using instrument air instead of nitrogen reduces the risk of displacing too much oxygen, which may cause an oxygen-depleted environment and may be more suitable for applications where the gas might be released into the workspace, such as blowing out instruments or running tools. Instrument air should not be confused with medical air, because it is provided with a different level quality, operates at a much higher pressure, and may contain contaminants unacceptable for patient treatment. Exhibit 5.56 shows an instrument air compressor installation.

EXHIBIT 5.56

Instrument Air Compressor Installation. (Courtesy of Koffel Associates, Inc.)

FAQ Is instrument air required, or is it an alternative to nitrogen for powering equipment or tools?

If a health care facility requires gas to operate booms, pendants, or other types of medical support equipment, instrument air or nitrogen can be used. The choice of an instrument air system versus a nitrogen system will usually be made on the basis of cost and suitability.

A.5.1.13.3.4 See Figure A.5.1.13.3.4.

5.1.13.3.4.1 Quality of Instrument Air. The quality of instrument air shall be as follows:

(1) Compliant with ANSI/ISA S-7.0.01, *Quality Standard for Instrument Air*
(2) Filtered to 0.01 micron
(3) Free of liquids (e.g., water, hydrocarbons, solvents)
(4) Free of hydrocarbon vapors
(5) Dry to a dew point of –40°C (–40°F)

Surgical pneumatic tools require very clean, dry gas to operate. The major reason for the historic transition to nitrogen from compressed air was the occurrence of inherent moisture in compressed air

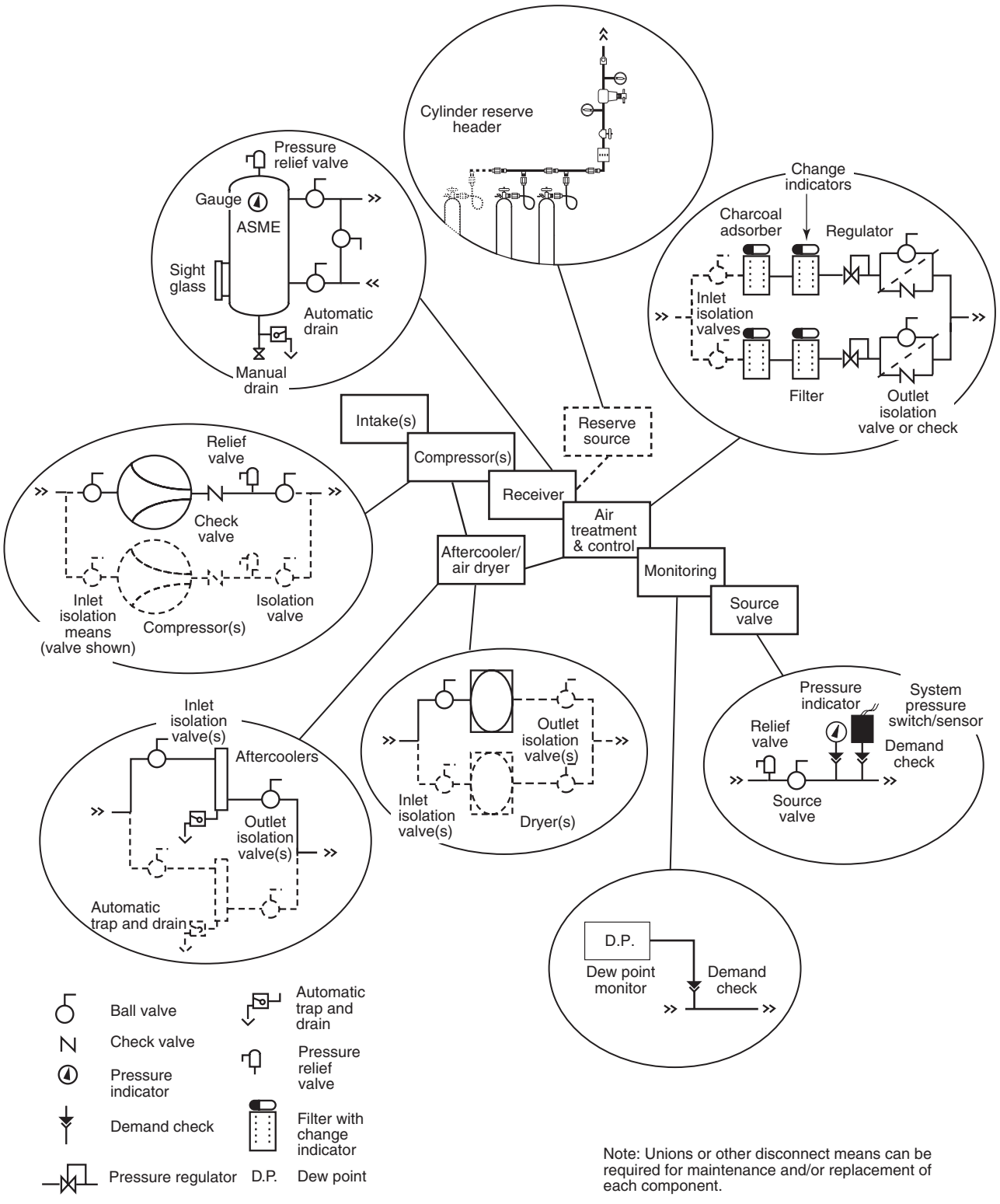


FIGURE A.5.1.13.3.4 *Elements of Typical Instrument Air Source.*

systems. Moisture or particulates in the gas stream can damage surgical tools or render them inoperable. The dew point required for instrument air is significantly lower than for compressed medical air and must be dried to a pressure dew point of –40°C (–40°F).

5.1.13.3.4.2 Instrument air supply systems shall be located per 5.1.3.3 as follows:

(1) Indoors, in a dedicated mechanical equipment area that is adequately ventilated and with any required utilities
(2) In a room ventilated per 5.1.3.3.3.3
(3) For air-cooled equipment, in a room designed to maintain the ambient temperature range as recommended by the equipment manufacturer

5.1.13.3.4.3 Instrument air sources shall provide air with the following characteristics:

(1) A gauge pressure adequate for the intended line pressure and pressure controls *(see Table 5.1.11)*
(2) The quality of instrument air, as described in 5.1.13.3.4.1

Item (1) has been revised to no longer specify a gauge pressure of 1380 kPa (200 psi) at the compressor but now to require pressure adequate for the intended line pressure. The original justification for 1380 kPa (200 psi) at the compressor was based on using classic pressure regulators to ensure a 1275 kPa (185 psi) line pressure. As regulators inevitably have some pressure drop, the pressure needed to drive the regulators had to be higher. This reasoning no longer pertains, as technologies now exist that can control the pressure by means other than pressure regulation, and not all facilities wish to operate their instrument air at 1275 kPa (185 psi).

5.1.13.3.4.4 Instrument air sources shall be of either of the following formats:

(1) At least two compressors
(2) One compressor and a standby header complying with 5.1.3.5.10

If the compressor fails, the cylinders allow enough time (at least 1 hour) to terminate any procedure requiring the use of the instrument air or to provide a temporary source. It might not be possible to maintain the system for an extended period of time with a standby header, which is a reflection of the less critical nature of instrument air systems.

5.1.13.3.4.5 Instrument air compressors shall be permitted to be of any type capable of the output pressure needed for the intended line pressure *see Table 5.1.11*, and of providing air meeting the definition of instrument air in 5.1.13.3.4.1.

This section has been revised to no longer specify a compressor capable of gauge pressure of 1380 kPa (200 psi) but now to require they are a capable of providing pressure adequate for the intended line pressure. The original justification for 1380 kPa (200 psi) at the compressor was based on using classic pressure regulators to ensure a 1275 kPa (185 psi) line pressure. As regulators inevitably have some pressure drop, the pressure needed to drive the regulators had to be higher. This reasoning no longer pertains, as technologies now exist that can control the pressure by means other than pressure regulation, and not all facilities wish to operate their instrument air at 1275 kPa (185 psi).

Δ **5.1.13.3.4.6 Instrument Air Standby Headers.** Where instrument air systems are provided with a standby header, the header shall meet the following requirements:

(1) It shall comply with 5.1.3.5.10, except that the number of attached cylinders shall be sufficient for 1 hour of normal operation.

The reference here to 5.1.3.5.10 implies that the reserve supply in the cylinders will be medical air. Since it is difficult to acquire instrument grade air from suppliers for this purpose, medical air is the gas of choice for backing up an instrument air compressor.

(2) It shall use connectors as for medical air in the mandatory requirements of CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1).
(3) It shall enter the system upstream of the final line filters.
(4) It shall automatically serve the system in the event of a failure of the compressor.

5.1.13.3.4.7* Intake Air. Intake air for instrument air compressors shall be permitted to be drawn from outside, from ducted air, or from the equipment location.

A.5.1.13.3.4.7 Drawing intake air from outside in compliance with 5.1.3.6.3.11 is recommended.

Instrument air is not required to be drawn from an outside location. However, an outside source might be desirable for other reasons, such as general cleanliness and a reduction of potential contaminants and odor.

5.1.13.3.4.8 Instrument Air Filters. Instrument air sources shall be provided with filtration sized for 100 percent of the system peak calculated demand at design conditions and with the following elements and characteristics:

(1) Activated carbon filters located upstream (source side) of the final line filters
(2) Line filters located upstream (source side) of the final line regulators and downstream of the carbon filters rated for a minimum of 98 percent efficiency at 0.01 μ
(3) Equipped with a continuous visual indicator showing the status of the line filter element life
(4) Constructed of materials deemed suitable by the manufacturer
(5) Filters combining the functions in (1) to (4) in a single unit shall be permitted to be used

5.1.13.3.4.9 Instrument Air Accessories. Accessories used for instrument air sources shall comply with the following subparagraphs:

(1) For aftercoolers, 5.1.3.6.3.5
(2) For air receivers, 5.1.3.6.3.6
(3) For air dryers, 5.1.3.6.3.7 [except 5.1.3.6.3.7(1)]
(4) For required components, 5.1.3.6.3.2

An instrument air dryer must comply with the general requirements for a medical air dryer (from 5.1.3.6.3.7), except that it must achieve a substantially lower pressure dew point as required in 5.1.13.3.4.1(5).

5.1.13.3.4.10 Instrument Air Piping Arrangement and Redundancies. Instrument air sources shall comply with 5.1.3.6.3.9, except for the following:

(1) Systems employing a standby header shall be permitted to have simplex aftercoolers and dryers.
(2) Systems employing a standby header shall not require a three-valve receiver bypass.
(3) Standby headers, where provided, shall be isolated from the compressor by a check valve to prevent backflow through the compressor.

5.1.13.3.4.11 Instrument Air Monitoring and Alarms.

(A) Instrument air sources shall include the following alarms:

(1) Local alarm that activates when or just before the backup compressor (if provided) activates, indicating that the lag compressor is in operation and must be manually reset
(2) Local alarm and alarms at all master alarm panels that activate when the dew point at system pressure exceeds −30°C (−22°F), indicating a high dew point

(B) For sources with standby headers, the following additional conditions shall activate a local alarm at the compressor site, a local signal at the header location, and alarms at all master alarm panels:

(1) Alarm that activates when or just before the reserve begins to supply the system, indicating reserve in use
(2) Alarm that activates when or just before the reserve falls below one average hour's supply, indicating reserve is low

If a standby reserve supply is installed in lieu of a second air compressor, the reserve supply must be sized for a minimum of 1-hour of normal operation. The pressure switch that monitors the reserve supply must activate when the reserve supply falls below an average hour's supply.

5.1.13.3.4.12 Electrical Power and Control.

N **(A)** Instrument air source systems with compressors shall be controlled to ensure continuous supply of air at pressures consistent with Table 5.1.11 under all conditions of system use as follows:

(1) Automatic activation of compressor(s) as necessary to supply the demand.
(2) If provided with more than one compressor, managing the operation to equalize wear on all compressors. Where this equalization is achieved manually, the facility staff shall arrange a schedule for manual alternation.

N **(B)** Controls shall provide the following functions:

(1) Where instrument air source systems having two or more compressors employ any electrical circuit device that upon failure could prevent supply of air, the controls shall be provided with an automatically activated alternative method for ensuring supply (e.g., redundant component(s), an alternate electrical supply path, or other equivalent method).
(2) Control circuits shall be arranged in such a manner that isolation of one compressor or component from the system (e.g., for maintenance or repair) does not interrupt the operation of other compressor(s) or component(s).
(3) An automatic restart function shall be included, such that the supply of air will resume normally after power interruption without manual intervention.

N **(C)** Each compressor motor shall be provided with electrical components including, but not limited to, the following:

(1) Dedicated disconnect switch installed in the electrical circuit ahead of each motor starter
(2) Motor starting device
(3) Overload protection

N **(D)** Instrument air compressor system controls shall be provided with electrical systems including at a minimum:

(1) Built-in disconnect means to allow appropriate operation of multiple compressor systems and protect service personnel from exposure to live voltages
(2) Control circuits shall be arranged so that failure of any component of the control circuit, or shutdown of one compressor (e.g., for service), does not interrupt automatic operation of the standby compressor
(3) An automatic restart function such that the compressor(s) will restart after power interruption without manual intervention
(4) Where components are common to more than one control circuit (e.g., autodrains), the common device shall be provided with electrical protection to prevent loss of the control circuits(s) in the event of short circuit in the device

N **(E)** Electrical installation and wiring shall conform to the requirements of *NFPA 70*.

N **(F)** Emergency electrical service for the compressors shall conform to the requirements of the essential electrical system, as described in Chapter 6.

Centrally piped instrument air systems follow the exact same electrical requirements as compressed medical air systems. All electrical installations and wiring must conform to *NFPA 70*. The requirements will follow the essential electrical system requirements of Chapter 6.

5.1.13.4 Valves. Requirements for support gas valves shall be in accordance with 5.1.4.1.1 through 5.1.4.8.

5.1.13.5 Outlets. Requirements for support gas outlets shall be in accordance with 5.1.5.1, 5.1.5.2, 5.1.5.4 through 5.1.5.8, 5.1.5.11, and 5.1.5.13 through 5.1.5.15.

5.1.13.6 Manufactured Assemblies. Requirements for support gases in manufactured assemblies shall be in accordance with 5.1.6.1 through 5.1.6.11.

5.1.13.7 Pressure Indicators. Requirements for support gas pressure indicators shall be in accordance with 5.1.8.1.1 through 5.1.8.1.4, 5.1.8.1.6, and 5.1.8.2.

N **5.1.13.8 Line Pressure Control.** Instrument air systems shall be provided with means to control line pressure at the source with at least the following characteristics:

(1) Able to maintain stable pressures within the limits of Table 5.1.11
(2) Able to flow 100 percent of the peak calculated demand
(3) Redundant, such that each component of the control mechanism can be isolated for service or replacement while maintaining normal operation
(4) Protected against overpressure *(see 5.1.3.5.6)*
(5) Be constructed of materials deemed suitable for the service by the manufacturer

5.1.13.9 Warning Systems.

5.1.13.9.1 General requirements for support gas warning systems shall be in accordance with 5.1.9.1.

5.1.13.9.2 Master alarm requirements for support gas shall be in accordance with 5.1.9.2.

5.1.13.9.3 Area alarm requirements for support gas shall be in accordance with 5.1.9.4.

5.1.13.9.4 Local alarm requirements for support gas shall be in accordance with 5.1.9.5.

5.1.13.10 Distribution. Requirements for support gas piping distribution shall be in accordance with 5.1.10.1, 5.1.10.3, 5.1.10.4, 5.1.10.4.1 through 5.1.10.4.6, 5.1.10.9, 5.1.10.9(1), 5.1.10.9(2), 5.1.10.9(3), and 5.1.10.11.

5.1.13.11 Labeling and Identification. Requirements for support gas labeling shall be in accordance with 5.1.11.1 through 5.1.11.4.

5.1.13.12 Performance Testing. Requirements for support gas performance testing shall be in accordance with 5.1.12, with the following exceptions:

(1) The piping purity test *(see 5.1.12.4.8)* shall be permitted to be omitted.
(2) The medical gas concentration test *(see 5.1.12.4.11)* shall be permitted to be omitted.

Since medical support gas is not intended for human respiration, the piping purity test and the medical gas concentration test are allowed to be omitted from the testing requirements.

5.1.14* Category 1 Operation and Management.

This section has been established to assist with developing an operation and management program for existing medical gas and vacuum systems. Per 5.1.1.5, it is mandatory for organizations with existing systems to address all the requirements in 5.1.14. The natural growth of this section over the last few editions demonstrates the increased awareness that it is necessary for these critical patient care systems to be operated and maintained in a way that ensures they will remain safe and reliable on an ongoing basis. A quality O&M program, appropriate preventive maintenance, and periodic inspections assist in achieving this goal.

To ensure compliance with this section of NFPA 99 and the standards for various accreditation agencies, the organization should create a comprehensive management plan that includes an inventory of all the equipment and system components, inspection and maintenance schedules with frequencies for task completion, and the procedures that will be used in performing this work.

Many of the regulatory/accreditation agencies also expect that policies for medical gas systems are established to deal with both expected situations (e.g., planned shutdown protocols, back feed procedures, hot work permitting, new employee training and certification) and unexpected situations (e.g., emergency preparedness, unplanned loss of critical gases). This will assist in identifying appropriate strategies for dealing with these situations before they arise.

A.5.1.14 All cylinders containing compressed gases, such as anesthetic gases, oxygen, or other gases used for medicinal purposes, whether these gases are flammable or not, should comply with the specifications and be maintained in accordance with regulations of the U.S. Department of Transportation.

Cylinder and container temperatures greater than 52°C (125°F) can result in excessive pressure increase. Pressure relief devices are sensitive to temperature and pressure. When relief devices actuate, contents are discharged.

5.1.14.1 Special Precautions — Patient Gas, Vacuum, WAGD, and Medical Support Gas Systems.

5.1.14.1.1* Piping systems shall not be used for the distribution of flammable anesthetic gases.

A.5.1.14.1.1 Piping systems for the distribution of flammable gases (e.g., hydrogen, acetylene, natural gas) are outside the scope of this chapter.

5.1.14.1.2 Piping systems shall not be used as a grounding electrode.

5.1.14.1.3* Liquid or debris shall not be introduced into the medical–surgical vacuum or WAGD systems for disposal.

Special precautions need to be observed when working with medical gases. One precaution should be a means to prevent liquid or debris from entering the vacuum system. Liquid that enters a vacuum system may dry up, clog the vacuum inlets, and possibly affect auxiliary equipment (such as vacuum regulators). It might also reduce the internal size of the pipeline and affect the flow and efficiency of the vacuum inlets. Liquid or debris that migrates down to the vacuum source of supply could damage the vacuum pumps as well. The introduction of liquid into the vacuum system can be avoided by utilizing fluid traps to stop the flow before liquid enters the system.

A.5.1.14.1.3 Vacuum systems from station inlets to the exhaust discharge should be considered contaminated unless proven otherwise. Methods exist to disinfect the system or portions thereof.

Clogging of regulators, for example, with lint, debris, or dried body fluids, reduces vacuum system performance.

5.1.14.1.4* The medical–surgical vacuum and WAGD systems shall not be used for nonmedical applications (e.g., vacuum steam condensate return).

The medical vacuum system may be considered a critical care or life support system (e.g., serving chest evacuation tubes), and the intent is to use the medical gas and vacuum system for patient care only and not for support services (e.g., laser plume evacuation). This guarantees the systems, including vacuum, are not compromised as a result of uses that are not directly related to caring for patients and their clinical needs.

A.5.1.14.1.4 Other examples of prohibited use of medical–surgical vacuum would be scope cleaning, decontamination, and laser plume.

5.1.14.2 Maintenance of Medical Gas, Vacuum, WAGD, and Medical Support Gas Systems.

5.1.14.2.1* General. Health care facilities with installed medical gas, vacuum, WAGD, or medical support gas systems, or combinations thereof, shall develop and document periodic maintenance programs for these systems and their subcomponents as appropriate to the equipment installed.

When developing and documenting a periodic maintenance program, the organization should consult with the manufacturer's recommendations to make sure the program will keep the equipment and all critical components operating properly.

A.5.1.14.2.1 The facility should retain a written or an electronic copy of all findings and any corrections performed.

5.1.14.2.2 Maintenance Programs.

5.1.14.2.2.1 Inventories. Inventories of medical gas, vacuum, WAGD, and medical support gas systems shall include at least all source subsystems, control valves, alarms, manufactured assemblies containing patient gases, and outlets.

A detailed list of all the equipment and components that will be maintained, inspected, or tested should be generated. This list should be used for tracking and documenting all the tasks that should be performed and the frequency of these tasks. These schedules should be identified through a risk assessment as described in 5.1.14.2.2.2 and 5.1.14.2.2.4.

5.1.14.2.2.2* Inspection Schedules. Scheduled inspections for equipment and procedures shall be established through the risk assessment of the facility and developed with consideration of the original equipment manufacturer recommendations and other recommendations as required by the authority having jurisdiction.

A.5.1.14.2.2.2 In addition to the minimum inspection and testing in 5.1.14, facilities should consider annually inspecting equipment and procedures and correcting any deficiencies.

5.1.14.2.2.3 Inspection Procedures. The facility shall be permitted to use any inspection procedure(s) or testing methods established through its own risk assessment.

Standard operating procedures should be documented for all the maintenance, inspections, or testing. These procedures should be detailed and provide sufficient guidance for the individual responsible for completing these tasks.

5.1.14.2.2.4 Maintenance Schedules. Scheduled maintenance for equipment and procedures shall be established through the risk assessment of the facility and developed with consideration of the original equipment manufacturer recommendations and other recommendations as required by the authority having jurisdiction.

5.1.14.2.2.5 Qualifications.

Since the MGVS provide life-supporting services to most critical care patients in the hospital, individuals who are responsible for the inspection, testing, and maintenance of these systems should be qualified to assume these roles. There are a few methods by which individuals may demonstrate their competence to perform this work. The code allows for two ASSE 6000 certifications to demonstrate this competence: ASSE 6030 and ASSE 6040. It is also acceptable for an individual to demonstrate the ability to perform specific tasks through a documented training program that is acceptable to the health care facility. This could include documented training for various tasks, such as manufacturer's training on repairing station outlets. This type of training would qualify the individual to perform this work, but training for other tasks may have to be documented as well to ensure the individual is "technically competent on the specific equipment installed in that facility." It should be noted that credentialing alone does not guarantee an individual is qualified to perform these tasks.

(A) Persons maintaining these systems shall be qualified to perform these operations.

(B) Appropriate qualification shall be demonstrated by any of the following:

(1) A documented training program acceptable to the health care facility by which such persons are employed or contracted to work with specific equipment as installed in that facility
(2) Credentialing to the requirements of ASSE 6040, *Professional Qualification Standard for Medical Gas Maintenance Personnel*, and technically competent on the specific equipment as installed in that facility.
(3) Credentialing to the requirements of ASSE 6030, *Professional Qualification Standard for Medical Gas Systems Verifiers*, and technically competent on the specific equipment as installed in that facility.

5.1.14.2.3* Inspection and Testing Operations.

A maintenance program should be developed and implemented to ensure that the MGVS continues to operate as designed and intended. Some of the key elements of an MGVS maintenance program are as follows:

- Evaluate the equipment status
- Develop policy and procedures
- Develop schedules for the performance of work
- Document and evaluate the results
- Educate all personnel that will be working on and using the MGVS

This testing and inspection does not replace the installer and verification testing that must be conducted following any new construction or modification.

Δ **A.5.1.14.2.3** The following should be considered in a routine testing, maintenance, and inspection program:

(1) Medical air source, as follows:
   (a) Room temperature
   (b) Shaft seal condition
   (c) Filter condition
   (d) Presence of hydrocarbons
   (e) Room ventilation
   (f) Water quality, if so equipped
   (g) Intake location
   (h) Carbon monoxide monitor calibration
   (i) Air purity
   (j) Dew point
(2) Medical vacuum source — exhaust location
(3) WAGD source — exhaust location
(4) Instrument air source — filter condition
(5) Manifold sources (including systems complying with 5.1.3.5.10, 5.1.3.5.12, 5.1.3.5.13, and 5.1.3.5.14), as follows:
   (a) Ventilation
   (b) Enclosure labeling
(6) Bulk cryogenic liquid source inspected in accordance with NFPA 55
(7) Final line regulation for all positive pressure systems — delivery pressure
(8) Valves — labeling
(9) Alarms and warning systems — lamp and audio operation
(10) Alarms and warning systems, as follows:
   (a) Master alarm signal operation
   (b) Area alarm signal operation
   (c) Local alarm signal operation
(11) Station outlets/inlets, as follows:
   (a) Flow
   (b) Labeling
   (c) Latching/delatching
   (d) Leaks
(12) Medical gas quality
   (a) Purity — Percent Concentration
   (b) Permanent particulates and contaminants
   (c) Odor and moisture

5.1.14.2.3.1 Manufactured Assemblies Employing Flexible Connection(s) Between the User Terminal and the Piping System.

(A) Nonstationary booms and articulating assemblies, other than head walls utilizing flexible connectors, shall be tested for leaks, per manufacturer's recommendations, every 18 months or at a duration as determined by a risk assessment.

(B) The system pressure to nonstationary booms and articulating arms shall be maintained at operating pressure until each joint has been examined for leakage by effective means of leak detection that is safe for use with oxygen.

(C) Safe working condition of the flexible assemblies shall be confirmed.

(D) D.I.S.S. connectors internal to the boom and assemblies shall be checked for leakage.

(E) Leaks, if any, shall be repaired (if permitted), or the components replaced (if required), and the equipment retested prior to placing the equipment back into service.

(F) Additional testing of nonstationary booms or articulating arms shall be performed at intervals defined by documented performance data.

These requirements reflect a concern that if articulating booms and manufactured assemblies are leaking a gas like oxygen, it poses a significant risk of a fire or explosion in these areas. Since these units employ internal hoses and the hoses can wear against the articulating areas of the assembly, the hoses need to be inspected periodically and replaced whenever appropriate or required.

There is also the potential of end fittings becoming disconnected due to the rotation of the hoses.

5.1.14.3 Medical Gas and Vacuum Systems Information and Warning Signs.

5.1.14.3.1 The gas content of medical gas and vacuum piping systems shall be labeled in accordance with 5.1.11.1.

5.1.14.3.2 Labels for shutoff valves shall be in accordance with 5.1.11.2 and updated when modifications are made changing the areas served.

It is required to keep the labeling for critical control valves up to date, because they would be used in an emergency situation. If the valves are closed during an emergency, the clinical staff must know which areas and patients are affected by a shutdown of these systems to ensure they are properly supported clinically.

Although a floor map is not required, many facilities include such a map above or adjacent to the shutoff valve. The map often features color-coding of rooms that are controlled by the valve, making it very easy to determine which rooms are controlled by which valve.

5.1.14.3.3 Station inlets and outlets shall be identified in accordance with 5.1.11.3.

5.1.14.3.4 Alarm panel labeling shall be in accordance with 5.1.11.4 and updated when modifications are made changing the areas served.

It is required to keep the labeling for these critical alarm panels up to date, because they provide warning information for the clinical staff in an emergency situation. During an emergency, the clinical staff must know which areas and patients are affected to ensure they are properly supported clinically.

N **5.1.14.4** Source equipment labeling shall be in accordance with 5.1.11.5.

The requirement for source equipment labeling, which has been added to 5.1.11 for this edition, must be confirmed as part of the operation and management program. This new labeling requirement is retroactive because all of 5.1.14 is specified by 5.1.1.5 as applying to existing facilities.

5.1.14.5 Medical Gas and Vacuum Systems Maintenance and Record Keeping.

5.1.14.5.1 Permanent records of all tests required by 5.1.12.4.1 through 5.1.12.4.14 shall be maintained in the organization's files.

Physical (paper copies) or electronic documentation should be maintained for all the work that is completed on the MGVS, including annual/periodic inspections, preventive maintenance, shutdowns, new installations, and so on.

5.1.14.5.2 The supplier of the bulk cryogenic liquid system shall, upon request, provide documentation of vaporizer(s) sizing criteria to the facility.

5.1.14.5.3 An annual review of bulk system capacity shall be conducted to ensure the source system has sufficient capacity.

This requirement is an extension of the requirement for an annual review of these systems that is mandated in NFPA 55. NFPA 99 requires the annual review to confirm there are no changes in the hospital's required capacity and/or flow requirements. While NFPA 55 demands a more robust review of these systems for compliance with specific site and equipment requirements, this NFPA 99 requirement provides for a connection between the review the organization that uses the system performs and that performed by the organization that owns and maintains the system, which are often not the same.

5.1.14.5.4 Central supply systems for nonflammable medical gases shall conform to the following:

(1) They shall be inspected annually.

This requirement led to the generally accepted norm for an "annual inspection" for existing facilities. This essential inspection of the central supply system is an opportunity to review the existing system for compliance, proper operation, overall condition, and any of the other inspection and testing tasks that are identified in this section of the code.

(2) They shall be maintained by a qualified representative of the equipment owner.
(3) A record of the annual inspection shall be available for review by the authority having jurisdiction.

5.1.14.5.5 A periodic testing procedure for nonflammable medical gas and vacuum and related alarm systems shall be implemented.

5.1.14.5.6 Whenever modifications are made that breach the pipeline, any necessary installer and verification test specified in 5.1.12 shall be conducted on the downstream portions of the medical gas piping system.

This paragraph helps confirm that 5.1.14 only applies to the ongoing operation and maintenance of the system and that when a breach of the system occurs it should be tested per the requirements in 5.1.12 and not 5.1.14.

5.1.14.5.7 Procedures, as specified, shall be established for the following:

(1) Maintenance program for the medical air compressor supply system in accordance with the manufacturer's recommendations
(2) Facility testing and calibration procedure that ensures carbon monoxide monitors are calibrated at least annually or more often if recommended by the manufacturer
(3) Maintenance program for both the medical–surgical vacuum piping system and the secondary equipment attached to medical–surgical vacuum station inlets to ensure the continued good performance of the entire medical–surgical vacuum system
(4) Maintenance program for the WAGD system to ensure performance

WAGD systems are unique in that they not only serve patients, but the WAGD system also protects caregivers and staff by properly collecting and evacuating waste anesthesia gases that are administered to patients in dedicated anesthetizing locations throughout the hospital. Therefore, it is important to make sure these systems are maintained properly to safeguard patients as well as caregivers.

(5) Facility testing and calibration procedure that ensures that oxygen concentration monitors are calibrated at least every three months, or more often if recommended by the manufacturer
(6) Where oxygen sources include concentrator units, maintenance programs for the oxygen concentrator units and all essential subcomponents

Items (5) and (6) are new to this section and support the maintenance requirements for the now allowed supply sources. Because the concentration of oxygen is essential, the monitors for these must be calibrated at least every 3 months.

5.1.14.5.8 Audible and visual alarm indicators shall meet the following requirements:

(1) They shall be periodically tested to determine that they are functioning properly.

Periodic testing of alarms for audible and visual function is a fairly simple test to perform. Typically, this is called the push-button test, and most manufacturers provide a test button to assist with this test. It should be noted that the staff notification of an alarm condition is almost solely dependent on the audible alarm function. For this reason, it is desirable to test the audible function regularly to verify it operates properly.

It is recommended, but not required, that the push-button test be conducted at least monthly to make sure the alarm panel notification functions properly. It is recommended, but not required, that alarm-initiating devices be tested at least annually to make sure they are operating properly.

(2) Records of the test shall be maintained until the next test is performed.

5.1.14.5.9 Medical–surgical vacuum station inlet terminal performance, as required in 5.1.12.4.10.4, shall be tested as follows:

(1) On a regular preventive maintenance schedule as determined by the facility maintenance staff

(2) Based on flow of free air (Nl/min or SCFM) into a station inlet while simultaneously checking the vacuum level

There is a subtle but important difference between this test and the one described in 5.1.12.4.10.4. Here the vacuum level and flow may be read at the same terminal, whereas in 5.1.12.4.10.4 they are read at adjacent terminals.

N **5.1.14.5.10** Where oxygen central supply systems using concentrators are used and one or more of the three sources is a cylinder header, the facility shall establish procedures to ensure the facility is always provided with one average day's supply of oxygen meeting the supply system product purity specification in reserve, as follows:

(1) The facility shall establish a minimum cylinder pressure that will permit one average day's supply. That value will be included as part of the standard operating procedure for the oxygen supply system.
(2) The cylinders shall be inspected daily and any loss of pressure noted.
(3) When the cylinders are found to have lost pressure due to use or leakage and thus are below the pre-established pressure, the cylinders shall be exchanged.

This section has been added to support the allowance for oxygen concentrator supply systems. This applies to the management of cylinders where a cylinder header is utilized for a reserve.

5.2 Category 2 Piped Gas and Vacuum Systems.

Based on the application of Chapter 4, Category 2 medical gas systems apply to patient care areas expecting a high level of reliability during patient treatments, but limited, short durations of MGVS downtime can be tolerated without significant impact on patient care. Category 2 medical gas system failure does not involve risk of loss of life or major injury to patients or caregivers, but it can cause minor injury to the patients and/or caregivers.

5.2.1* Applicability.

A.5.2.1 Section 5.1 covers requirements for Category 1 piped gas and vacuum systems; Section 5.2 covers Category 2 piped gas and vacuum systems; and Section 5.3 covers Category 3 piped gas and vacuum systems. Laboratory systems are no longer covered by Chapter 5 (2002 edition).

5.2.1.1 These requirements shall apply to health care facilities that qualify for Category 2 systems as referenced in Chapter 4.

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

(1) Only moderate sedation; minimal sedation, as defined in 3.3.65.3 and 3.3.65.4; or no sedation is performed. Deep sedation and general anesthesia shall not be permitted.
(2) The loss of the piped gas or piped vacuum systems is likely to cause minor injury to patients, staff, or visitors.
(3) The facility piped gas or piped vacuum systems are intended for Category 2 patient care space per 3.3.135.2.

When the risk assessment procedure required by Chapter 4 finds that the MGVS for a facility is Category 2, the user should then go to Section 5.2. However, 5.2.1.2 provides some further requirements as to what the limitations for a Category 2 MGVS are, and each of the three stipulated items must be true. Although a properly performed risk assessment will most likely place the user in Category 1 where any of these items are not true, it is possible that a risk assessment finds the system to be a Category 2, even though, for example, a patient is put into deep sedation. If this happens, then the provisions of 5.2.1.2 will dictate that the MGVS could not be Category 2, and Category 1 requirements would need to be used.

5.2.1.3 The following subsections of this chapter shall apply to the operation, management, and maintenance of Category 2 medical gas and vacuum systems in both new and existing health care facilities:

(1) 5.1.3.6.2
(2) 5.1.3.8.4.2
(3) 5.1.10.11.7.1
(4) 5.2.3.1
(5) 5.2.3.2
(6) 5.2.3.3
(7) 5.2.3.5(2)
(8) 5.2.3.7(2)
(9) 5.2.3.8(2)
(10) 5.2.13
(11) 5.2.14

Paragraph 5.2.1.3 stipulates the requirements of Chapter 5 that are meant to be applied to Category 2 MGVS in both new and existing facilities. Like the parallel section for Category 1 systems, the requirements applying to existing Category 2 systems are largely focused on proper storage, operational requirements, and providing a comprehensive maintenance program. Most of these, like all of Section 5.2 itself, will reference the user back to Category 1 requirements. The requirements that are unique to Category 2 systems will call for the existing facilities to have emergency plans to deal with the loss of medical air, vacuum, or WAGD, which is important because the main difference is that each of these systems is not required to have a backup.

5.2.2 Nature of Hazards of Gas and Vacuum Systems. The requirement of 5.1.2 shall apply to the nature of hazards of gas and vacuum systems.

5.2.3 Category 2 Sources.

5.2.3.1 Central Supply System Identification and Labeling. Category 2 systems shall comply with 5.1.3.1.

5.2.3.2 Central Supply Operations. Category 2 systems shall comply with 5.1.3.2.

5.2.3.3 Central Supply System Locations. Category 2 systems shall comply with 5.1.3.3.

5.2.3.4 Central Supply Systems. Category 2 systems shall comply with 5.1.3.5.

5.2.3.5 Category 2 Medical Air Supply Systems. Category 2 systems shall comply with 5.1.3.6, except as follows:

(1) Medical air compressors, dryers, aftercoolers, filters, and regulators shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of medical air.

It is debatable whether a patient care space requiring a Category 2 system would ever need medical air, given that medical air is generally associated with treatments that would exclude a facility from qualifying for installation of Category 2 systems. There is no hard rule that prohibits such an installation, however, and where medical air is provided, the systems do not need to be duplexed. Instead, the facility needs to develop plans for system failure.

N **5.2.3.6** 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.

This new section provides the allowance to use oxygen concentrator supply sources for a Category 2 system. This requirement is not necessarily needed, since this configuration is the same as that defined as the minimum allowed configuration under Category 1.

5.2.3.7 Category 2 Medical–Surgical Vacuum. Category 2 systems shall comply with 5.1.3.7, except as follows:

(1) Medical–surgical vacuum systems shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of medical–surgical vacuum.

5.2.3.8 Category 2 WAGD. Category 2 systems shall comply with 5.1.3.8, except as follows:

(1) Medical WAGD pumps shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of WAGD.

5.2.3.9 Instrument Air Supply Systems. Category 2 systems shall comply with 5.1.13.3.4.

5.2.4 Valves. Category 2 systems shall comply with 5.1.4.

5.2.5 Station Outlets and Inlets. Category 2 systems shall comply with 5.1.5.

5.2.6 Manufactured Assemblies. Category 2 systems shall comply with 5.1.6.

5.2.7 Surface-Mounted Medical Gas Rails. Category 2 systems shall comply with 5.1.7.

5.2.8 Pressure and Vacuum Indicators. Category 2 systems shall comply with 5.1.8.

5.2.9 Warning Systems (Category 2). Warning systems associated with Category 2 systems shall provide the master, area, and local alarm functions of a Category 1 system as required in 5.1.9, except as follows:

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

A medical gas warning system utilizing a single alarm panel, better known as a combination alarm panel, essentially integrates the alarm functions (refer to 5.1.9) of an area alarm and master alarm into a single alarm panel instead of having two independent alarm panels. Since this is a single alarm box, a single electrical power supply is provided rather than the two independent electrical power supplies that would be needed if an area alarm panel and a master alarm panel were installed.

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

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

5.2.10 Category 2 Distribution. Level 2 systems shall comply with 5.1.10.

5.2.11 Labeling and Identification. Category 2 systems shall comply with 5.1.11.

5.2.12 Performance Criteria and Testing — Category 2 (Gas, Medical–Surgical Vacuum, and WAGD). Category 2 systems shall comply with 5.1.12.

5.2.13 Category 2 Support Gases. Category 2 systems shall comply with 5.1.13.

5.2.14* Category 2 Operation and Management. Category 2 systems shall comply with 5.1.14.

A.5.2.14 Medical gas and vacuum systems should be surveyed at least annually for the items that follow and deficient items corrected. Survey of medical air and instrument air sources should include, but not be limited to, the following:

(1) Dew point monitor (operation and calibration)
(2) Carbon monoxide monitor (medical air only) (operation and calibration)
(3) Aftercoolers (condition, operation of drains)
(4) Operating pressures (cut-in, cut-out, and control pressures)
(5) All local alarms (verify presence of required alarms, perform electrical test, test lag alarm)
(6) Receiver elements (auto drain, manual drain, sight glass, pressure gauge)
(7) Filters (condition)
(8) Pressure regulators (condition, output pressure)
(9) Source valve (labeling)
(10) Intake (location and condition)
(11) Housekeeping around compressors

Survey of the medical vacuum and the WAGD source(s) should include, but not be limited to, the following:

(1) Operating vacuum (cut-in, cut-out, and control pressures)
(2) All local alarms (verify presence of required alarms, perform electrical test, test lag alarm)
(3) Receiver elements (manual drain, sight glass, vacuum gauge)
(4) Source valve (labeling)
(5) Exhaust (location and condition)
(6) Housekeeping around pump

Survey of the medical gas manifold source(s) should include, but not be limited to, the following:

(1) Number of cylinders (damaged connectors)
(2) Cylinder leads (condition)
(3) Cascade (switching from one header to another)
(4) All local alarms (verify presence of required alarms, perform electrical test, test all alarms)
(5) Source valve (labeling)
(6) Relief valves (discharge location and condition)
(7) Leaks
(8) Security (door or gate locks and signage)
(9) Ventilation (general operation, housekeeping)
(10) Housekeeping around manifolds

Survey of medical gas area alarms should include, but not be limited to, the following:

(1) Locations (visible to staff)
(2) Signals (audible and visual, use test function)
(3) Activation at low pressure
(4) Housekeeping around alarm

Survey of medical gas master alarms should include, but not be limited to, the following:

(1) Locations (visible to appropriate staff)
(2) Signals (audible and visual, use test function)
(3) Activation at low pressure
(4) Housekeeping around alarm

Survey of zone valves should include, but not be limited to, the following:

(1) Locations (relationship to terminals controlled)
(2) Leaks
(3) Labeling
(4) Housekeeping around alarm

Survey of medical gas outlet/inlets should include, but not be limited to, the following:

(1) Flow and function
(2) Latching/delatching
(3) Leaks
(4) General condition (noninterchangeable indexing)

The facility should retain a written or an electronic copy of all findings and any corrections performed.

N 5.3 Category 3 Piped Gas and Vacuum Systems.

Category 3 systems in the 2018 edition have undergone the most dramatic alteration. The requirements for dental gases that previously were included here are now in their own new chapter, Chapter 15. This is an acknowledgement that medical and dental requirements do not sit comfortably together.

Category 3 evolved from the Type II systems that were addressed in NFPA 56F for use by the dentist practicing in a one or two "operatory" office. Type II was never conceived to apply to medical settings and was never written to allow for such application. The requirements passed comfortably into the Level 2 requirements of the 1996 standard, because they were still only for application with office-based care (as defined by the occupancy chapters in that edition). With the advent of Chapter 4 in the 2012 edition and the reorganization of the requirements into "categories," any of which could be applied to any setting based purely on risk, it suddenly became possible to find these requirements being applied to purely medical settings. Through the last four editions, despite three extensive rewrites, the committee was unable to successfully reconcile the two applications.

A read through these Category 3 requirements will show that at present, there is no difference between the requirements as defined for Category 2 and those defined for Category 3. With the dental requirements removed, the Category 2 requirements were used as a safe starting point, but it is clear that Category 3 for medical only (the requirements herein) is more of a starting point than a finalized section of the code.

N 5.3.1 Applicability.

N 5.3.1.1 These requirements shall apply to health care facilities that require Category 3 systems as referenced in Chapter 4.

N 5.3.1.2 Category 3 piped gas and vacuum systems shall be permitted when all of the following criteria are met:

(1) Only moderate sedation; minimal sedation, as defined in 3.3.65.3 and 3.3.65.4; or no sedation is performed. Deep sedation and general anesthesia are not performed.
(2) The loss of the piped gas and vacuum systems is not likely to cause injury to patients, staff, or visitors but can cause discomfort.
(3) The facility piped gas and vacuum systems are intended for Category 3 or Category 4 patient care rooms per 3.3.135.3 and 3.3.135.4.

The "decision tree" included in this section assists facilities when they are conducting a risk assessment of their MGVS. This change to the code includes the change from an occupancy-based decision to a risk-based decision on facility systems, and as a result, it may be a difficult decision process to assign a risk category to the MGVS. The risk assessment process was designed to allow the individual facility to analyze the risk to patients, caregivers, and visitors based on factors such as physical risks, utility functions, maintenance requirements, and incidence history. The risk assessments are done by the individual facility, and as such, the MGVS risk assessment on similar procedures conducted on patients might be different from another facility's risk assessment using almost identical procedures, because they might use different variables in their risk assessments.

N 5.3.1.3 The following sections of this chapter shall apply to the operation, management, and maintenance of the medical gas and vacuum systems in both new and existing health care facilities:

(1) 5.1.3.6.2
(2) 5.1.3.8.4.2
(3) 5.1.10.11.7.1
(4) 5.3.3.1
(5) 5.3.3.2
(6) 5.3.3.3
(7) 5.3.3.5(2)
(8) 5.3.3.7(2)
(9) 5.3.3.8(2)
(10) 5.3.14

Paragraph 5.3.1.3 stipulates the requirements of Chapter 5 that are meant to be applied to Category 3 MGVS in both new and existing facilities. Like the parallel sections for Category 1 and Category 2 systems, the requirements applying to existing Category 3 systems are largely focused on proper storage, operational requirements, and a comprehensive maintenance program.

N 5.3.2 Nature of Hazards of Gas and Vacuum Systems. The requirement of 5.1.2 shall apply to the nature of hazards of gas and vacuum systems.

N 5.3.3 Category 3 Sources.

N **5.3.3.1 Central Supply System Identification and Labeling.** Category 3 systems shall comply with 5.1.3.1.

N **5.3.3.2 Central Supply Operations.** Category 3 systems shall comply with 5.1.3.2.

N **5.3.3.3 Central Supply System Locations.** Category 3 systems shall comply with 5.1.3.3.

N **5.3.3.4 Central Supply Systems.** Category 3 systems shall comply with 5.1.3.5.

N **5.3.3.5 Medical Air Supply Systems.** Category 3 systems shall comply with 5.1.3.6, except as follows:

(1) Medical air compressors, dryers, aftercoolers, filters, and regulators shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of medical air.

N **5.3.3.6 Oxygen Central Supply Systems Using Concentrators.** Category 3 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.

N **5.3.3.7 Medical–Surgical Vacuum.** Category 3 systems shall comply with 5.1.3.7, except as follows:

(1) Medical–surgical vacuum systems shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of medical–surgical vacuum.

N **5.3.3.8 WAGD.** Category 3 systems shall comply with 5.1.3.8, except as follows:

(1) Medical WAGD pumps shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of WAGD.

N **5.3.3.9 Instrument Air Supply Systems.** Category 3 systems shall comply with 5.1.13.3.4.

N **5.3.4 Valves.** Category 3 systems shall comply with 5.1.4.

N **5.3.5 Station Outlets and Inlets.** Category 3 systems shall comply with 5.1.5.

N **5.3.6 Manufactured Assemblies.** Category 3 systems shall comply with 5.1.6.

N **5.3.7 Surface-Mounted Medical Gas Rails.** Category 3 systems shall comply with 5.1.7.

N **5.3.8 Pressure and Vacuum Indicators.** Category 3 systems shall comply with 5.1.8.

N **5.3.9 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 5.1.9, except as follows:

(1) Warning systems shall be permitted to be a single alarm panel.
(2) The alarm panel shall be located in an area of continuous surveillance while the facility is in operation.
(3) Pressure and vacuum switches/sensors shall be mounted at the source equipment with a pressure indicator at the master alarm panel.

N **5.3.10 Distribution.** Category 3 systems shall comply with 5.1.10.

N **5.3.11 Labeling and Identification.** Category 3 systems shall comply with 5.1.11.

N **5.3.12 Performance Criteria and Testing — Gas, Medical–Surgical Vacuum, and WAGD.** Category 3 systems shall comply with 5.1.12.

5.3.13 Support Gases. Category 3 systems shall comply with 5.1.13.

N **5.3.14 Operation and Management.** Category 3 systems shall comply with 5.1.14.

The requirements for operations and management of MGVS are intended to be applied to existing facilities, and 5.3.14 refers the user to 5.1.14 for these requirements.

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Closer Look

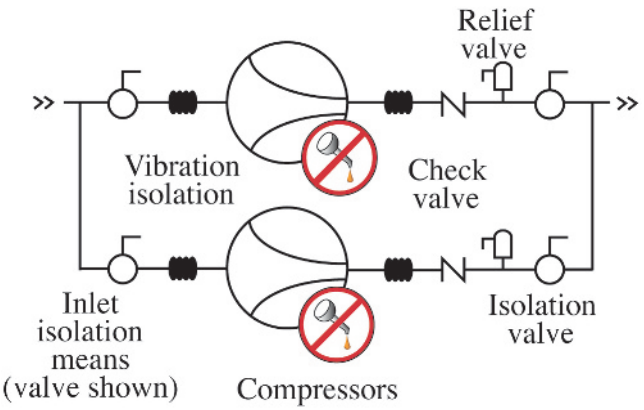
Medical Air

The Closer Look that follows is intended to provide a more in-depth look at the various components that make up a medical air compressor source system. In order to produce the required quality of medical air on site, the various and complex equipment of the compressor system must be carefully installed and maintained.

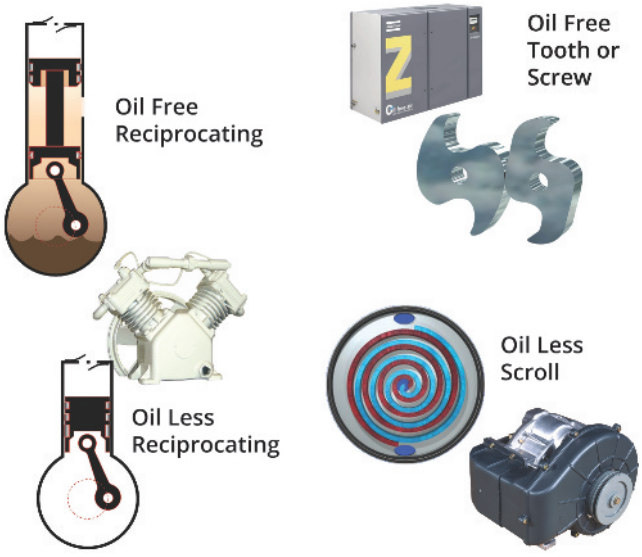
Compressors

Category 1 medical air systems must consist of at least two compressors.

Technology can be oil free or oil less (types adding no contamination to the air in the compression process). Typical compressors used include oil-free and oil-less reciprocating, oil-less scroll, oil-free tooth, and screw compressor types. Liquid ring compressors were once common as well, but are now rare.



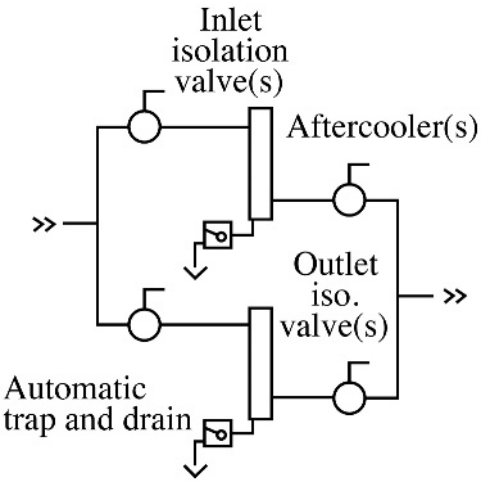
Oil-free compressors produce air without oil, but may themselves contain oil in the running gear. They are designed to prevent oil from reaching the compression chamber using a physical break (the "distance piece and vent").



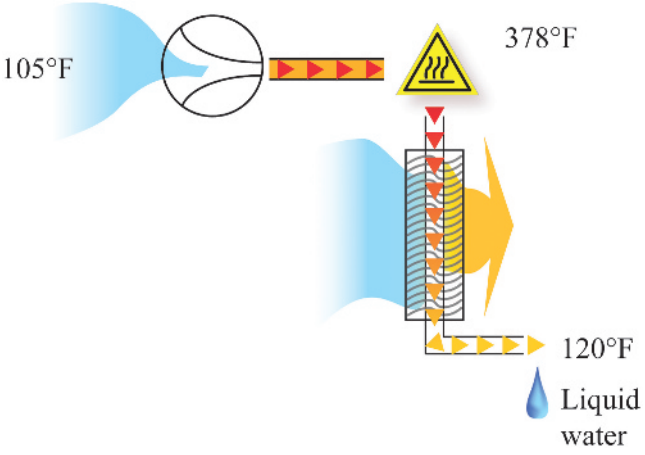
Aftercoolers

Typically one aftercooler is provided per compressor, but at least two are required.

Typical aftercoolers used are air-cooled radiator types, but liquid-cooled aftercoolers are sometimes used.



All air compressors heat the incoming air as a byproduct of the compression process. In some compressors, outlet temperatures can reach 378°F (190°C).



No standard dryer can function at these temperatures. The aftercooler serves to remove that excessive heat. An ideal aftercooler will reduce the temperature to the coolest temperature possible.

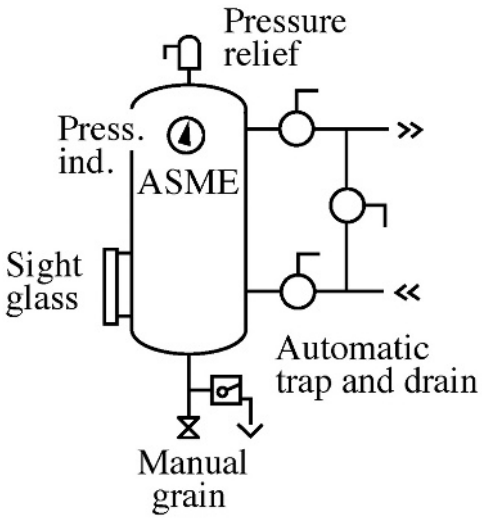
The aftercooler will also function to remove water and typically removes more water than the dryer.

Continues

Closer Look *(Continued)*

Receivers

Receivers must be ASME pressure vessels, coated to prevent interior corrosion.



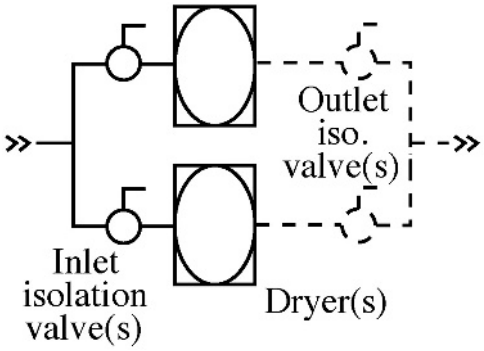
Receivers are used to smooth pulsations in the medical air flow and to allow compressors "off time," which is required by some technologies.

They can also function to reduce air temperature in systems under higher demand. It is therefore normal for water to form, and it is essential that they be regularly drained. Undrained, they can actually fill with water over time.

An automatic and a manual drain, plus a sight glass to see the water level, are required.

Dryers

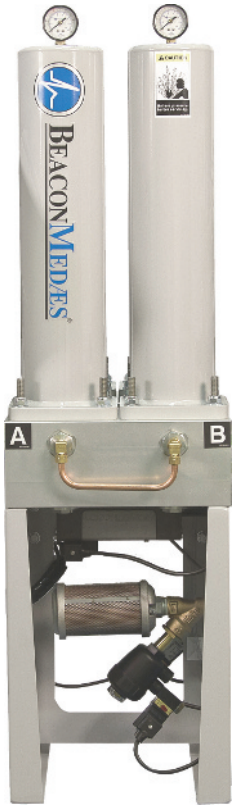
At least two dryers must be provided, arranged to allow either to be in service.



Dryers reduce the final air dew point to a temperature where no water can form in the piping. In the standard a *design* dew point for the system is stipulated as <32°F (<0°C) with an *alarm* dew point at 35°F (3°C). Both are measured at system pressure of 50–55 psig.

The standard does not prescribe dryer type, but does require that the dryer achieve the dew point at any level of demand, which does exclude some dryer designs.

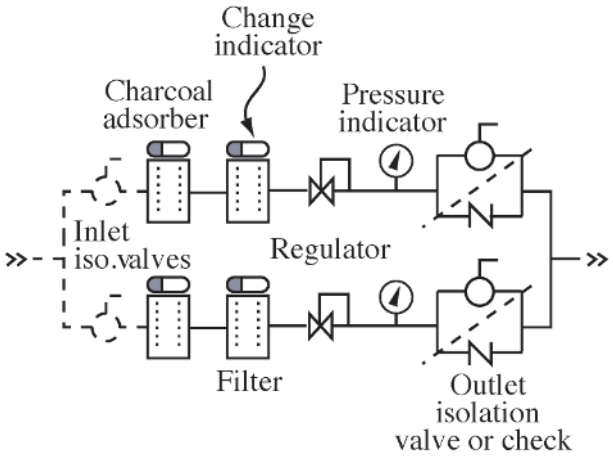
Refrigerant dryers are one such technology, which can achieve the required dew point (due to the operation of Dalton's Law) but have been shown to be unable to handle low flows. As a result, the most common dryer now in use is the twin tower regenerating desiccant type.

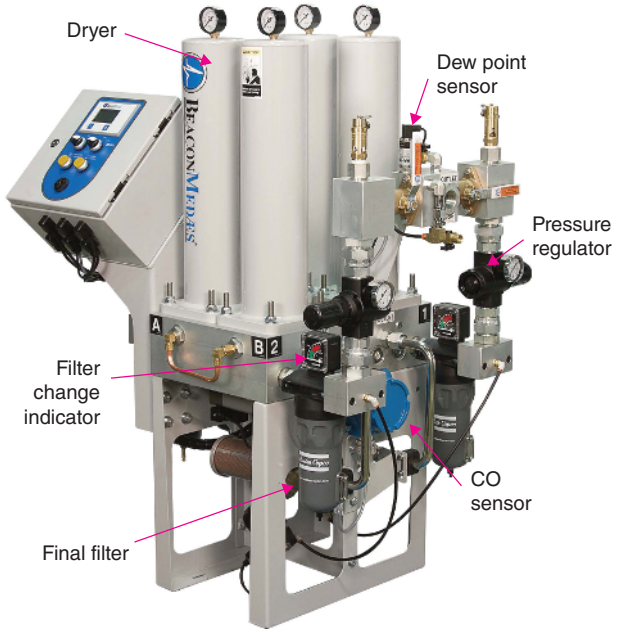


Air Treatment and Control

Intake air, the compression process, and the operation of the dryers can all leave particulate matter in the air that must be removed through filtration. A 0.1µ filter or better must be provided for this purpose.

Intake air can also contain trace odors, which the compression process will amplify. An activated charcoal will remove these, but only to the extent that the charcoal can absorb the chemicals involved (typically hydrocarbons). There are two styles of protection used here, an activated charcoal impregnated filter or a canister filled with activated charcoal. The filter contains only a small amount of the charcoal and therefore will have a short useful life if challenged with large amount of absorbable chemicals. The canisters can contain as much charcoal as desired, and thus can have much longer useful lives.





Pressure control is essential, since air dryers are more effective at higher pressure [100 psig (800 kPa) is typical] but the pipeline pressure must be held to 50–55 psig (375–390 kPa). Pressure regulators are typically used, but the 2018 of NFPA 99 now permits other methods to be employed if they can achieve the desired pressure, flow, and stability.

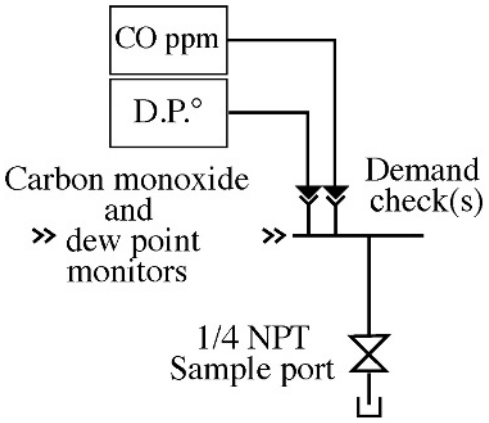
All components may require service or calibration and are set in redundant valve bypass arrangements to facilitate that work.

If the air were found to exceed any parameter of the pharmacopeia when tested, additional treatment for those contaminants would also need to be provided.

Monitors

Elevated dew point is a natural consequence of compressing air, and the proper operation of the aftercoolers, drains, and dryers is essential to preventing the formation of liquid water in the piping.

Since liquid water is a hazard for respiratory equipment and in severe cases a drowning hazard for patients, continuous proof that the dew point is low enough to prevent liquid formation is essential. High dew point will necessitate tuning the operation of the system, improving aftercoolers, and repairing or changing dryers.



Carbon monoxide (CO) is somewhat more complex. CO is not the most toxic of the trace gases mentioned in the pharmacopeia, but it is the most common and coincidentally easy to monitor. As a result, it serves as an indicator gas and is continuously monitored for these systems. High CO requires action to improve the quality of the intake air or in some cases to add additional purification apparatus to "scrub" the air. As an indicator gas, any high CO event should also trigger analysis of the air for other pharmacopeial components to ensure that they are not also over permitted levels.

All trace gases need to be checked periodically, which is the function of the sample port. If other trace gases are found to be outside the parameters for the pharmacopeia, then action must be taken to get better quality intake air or to remove the trace gas from the air. It may also be necessary to add monitoring for that constituent.

15

N Dental Gas and Vacuum Systems

***Editor's Note**: The following chapter is extracted from Chapter 15 of the 2018 edition of NFPA 99,* Health Care Facilities Code. *Commentary is also provided to explain the code and assist the user and is not part of the code. NFPA 99 can be viewed in full at: www.nfpa.org/99.*

Chapter 15 covers the equipment, installation, performance, testing, and maintenance of dental gas, dental support gas, dental vacuum, and nitrous oxide scavenging systems. The requirements of this chapter are based solely on which level of sedation or general anesthesia (see Chapter 3 for definitions) will be administered during various dental, oral, and maxillofacial procedures/surgeries. Once the facility, dental staff, and the authority having jurisdiction have outlined which level of sedation or general anesthesia will be administered, the appropriate category in Chapter 15 can be selected. Chapter 15 does not specify which level of sedation or anesthesia will be administered in any given facility for any specific procedure.

This chapter was added to the 2018 edition of NFPA 99 to provide specific guidance to dental and oral surgery facilities, and all references to this type of facility have been removed from Chapter 5.

N 15.1 Applicability.

This chapter shall apply to dental health care facilities that qualify to install dental gas and vacuum piping systems.

N 15.1.1 Category 1 dental piped gas and piped vacuum system requirements shall be applied in facilities where general anesthesia and deep sedation is performed, as defined in 3.3.65.1 and 3.3.65.2.

N 15.1.2 Category 2 dental piped gas and piped vacuum system requirements shall be applied in facilities where only moderate and minimal sedation is performed, as defined in 3.3.65.3 and 3.3.65.4.

N 15.1.3 Category 3 dental piped gas and piped vacuum system requirements shall be applied in facilities where minimal or no sedation is performed, as defined in 3.3.65.4.

Subsections 15.1.1 through 15.1.3 utilize the risk assessment approach of NFPA 99 as specified in Chapter 4 but modify it to be based specifically on the level of anesthesia or sedation that is being administered to patients.

N **15.1.4** A single facility shall be permitted to include dental gas and vacuum systems for more than one category of dental piped gas and vacuum systems.

This is an important statement that addresses the overall risk assessment approach of NFPA 99, which is meant to evaluate the risk to patients for each individual system based on the risk posed by failure of the system. However, because of the approach taken in 15.1.1 through 15.1.3, this section will probably not be applied because this chapter bases the risk assessment approach solely on the level of anesthesia or sedation being administered to patients on a facility-wide basis. This is a departure from the more general risk assessment approach of NFPA 99 that does, in fact, allow for more than one category of system to serve a certain area, space, or facility.

N **15.1.5** An existing system that is not in strict compliance with the requirements of this code shall be permitted to continue in use as long as the authority having jurisdiction has determined that such use does not constitute a distinct hazard to life.

N **15.1.6** The following sections of this chapter shall apply to the operation, management, and maintenance of Category 2 dental gas and vacuum systems in both new and existing facilities.

(1) 15.1.5
(2) 15.2
(3) 15.4.2.4.3
(4) 15.4.2.4.5
(5) 15.4.2.4.13
(6) 15.4.2.5.14
(7) 15.4.2.6.4
(8) 15.4.9

N **15.1.7** The following sections of this chapter shall apply to the operation, management, and maintenance of Category 3 dental gas and vacuum systems in both new and existing facilities.

(1) 15.1.5
(2) 15.2
(3) 15.5.8

As stated in Section 1.3 of this code, NFPA 99 is intended to largely apply only to new construction or altered, renovated, or modernized portions of facilities that affect the existing construction, with the following exceptions: (1) where modified by individual chapters and (2) where systems not in strict compliance pose a distinct hazard to life. Subsection 15.1.5 represents the latter of these two exceptions. The items listed in 15.1.6 and 15.1.7 represent the former and are intended to apply to both new and existing health care facilities.

N 15.2 Nature of Hazards of Gas and Vacuum Systems.

Potential fire and explosion hazards associated with positive-pressure dental gas systems and vacuum systems shall be considered in the design, installation, testing, operation, and maintenance of these systems.

The hazards associated with medical gas and vacuum systems are the same whether dealing with new or existing construction.

N 15.3 Category 1 Dental Gas and Vacuum Systems.

Requirements outlined under Section 15.3 are designed for dental, oral, and maxillofacial facilities that intend to administer general anesthesia or deep sedation during any given exam or procedure. Since failure of these systems while administering this level of anesthesia or sedation could have significant impact to patients and staff, the dental gas and vacuum systems are designed to have a high level of reliability. The application of this category must be determined solely by the level of sedation or general anesthesia defined in Chapter 3 and not by the procedure being performed.

N **15.3.1 General.** Facilities that perform deep sedation and general anesthesia associated with implant dentistry and oral surgery shall meet the requirements for Category 1 dental gas and vacuum systems.

Facilities performing deep sedation and general anesthesia associated with implant dentistry and oral surgery inherently present much greater risk to patients due to the complexity of procedures as compared to traditional dentist offices. For this reason, much of Section 15.3 refers users to Chapter 5 requirements for Category 1 or 2 medical gas and vacuum systems.

N **15.3.1.1** The requirements for Category 1 dental gas and vacuum systems for the operation, management, and maintenance of gas and vacuum piping systems shall apply to both new and existing facilities within the scope of this chapter and in accordance with 5.1.1.5.

N **15.3.2 Category 1 Medical Gas Systems (Dental).**

N **15.3.2.1 Medical Gas and Vacuum Sources.**

N **15.3.2.1.1 Central Supply System Identification and Labeling.** Category 1 systems shall comply with 5.1.3.1.

N **15.3.2.1.2 Central Supply Operations.** Category 1 systems shall comply with 5.1.3.2.

N **15.3.2.1.3 Central Supply System Locations.** Category 1 systems shall comply with 5.1.3.3.

N **15.3.2.1.4 Central Supply Systems.** Category 1 systems shall comply with 5.1.3.5.

N **15.3.2.1.5 Medical Air Supply Systems.** Category 1 systems shall comply with 5.1.3.6, except as follows:

(1) Medical air compressors, dryers, aftercoolers, filters, and regulators shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of medical air.

N **15.3.2.1.6** 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 an average day's supply.

N **15.3.2.1.7 Medical–Surgical Vacuum Systems.** Category 1 systems shall comply with 5.1.3.7, except as follows:

(1) Medical–surgical vacuum systems shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of medical–surgical vacuum.

N **15.3.2.1.8 WAGD Systems.** Category 1 systems shall comply with 5.1.3.8, except as follows:

(1) Medical WAGD pumps shall be permitted to be simplex.
(2) The facility staff shall develop their emergency plan to deal with the loss of WAGD.

N **15.3.2.2 Valves.** Category 1 systems shall comply with 5.1.4.

N **15.3.2.3 Station Outlets and Inlets.** Category 1 systems shall comply with 5.1.5.

N **15.3.2.4 Manufactured Assemblies.** Category 1 systems shall comply with 5.1.6.

N **15.3.2.5 Surface-Mounted Medical Gas Rails.** Category 1 systems shall comply with 5.1.7.

N **15.3.2.6 Pressure and Vacuum Indicators.** Category 1 systems shall comply with 5.1.8.

N **15.3.2.7 Warning Systems.** Warning systems associated with Category 1 systems shall provide the master, area, and local alarm functions of a Category 1 system as required in 5.1.9, except as follows:

(1) Warning systems shall be permitted to be a single alarm panel.
(2) The alarm panel shall be located in an area of continuous surveillance while the facility is in operation.
(3) Pressure and vacuum switches/sensors shall be mounted at the source equipment with a pressure indicator at the master alarm panel.

N **15.3.2.8 Medical Gas Distribution.** Category 1 systems shall comply with 5.1.10.

N **15.3.2.9 Labeling and Identification.** Category 1 systems shall comply with 5.1.11.

N **15.3.2.10 Performance Criteria and Testing (Medical Gas, Medical–Surgical Vacuum, and WAGD).** Category 1 systems shall comply with 5.1.12.

N **15.3.2.11 Support Gases.** Category 1 systems shall comply with 5.1.13 except as follows:

(1) Nitrogen source equipment shall be permitted to be installed in enclosures for Category 3 medical gases or in a mechanical room.
(2) Nitrogen source equipment shall include the following:

(a) One or more cylinders of nitrogen NF, each providing at least one average day's supply
(b) A manifold, if primary and secondary cylinders are provided
(c) A line pressure regulating valve
(d) A check valve downstream from the pressure regulating valve
(e) A pressure relief valve set at 50 percent above the normal line pressure and located downstream from the check valve
(f) A pressure relief valve discharge piped to outdoors at a point that will not create a probable hazard and that is turned down to prevent the entry of rain or snow

N **15.3.2.12 Medical Gas and Vacuum Operation and Management.** Category 1 systems shall comply with 5.1.14.

N 15.3.3 Category 1 Dental Air and Vacuum Piping Systems.

N **15.3.3.1 General.**

N **15.3.3.1.1** Dental air and vacuum piping systems shall include dental support gases and dental vacuum systems.

N **15.3.3.1.2** Dental vacuum systems shall include dental vacuum and nitrous oxide scavenging.

N **15.3.3.2 Equipment Locations for Dental Air and Vacuum Systems.**

N **15.3.3.2.1 General.** Any of the following systems shall be permitted to be located together in the same room:

(1) Medical air compressor supply sources
(2) Dental air compressor sources and reserve headers

(3) Dental-surgical vacuum sources
(4) Dental vacuum sources
(5) WAGD sources
(6) Any other compressor, vacuum pump, or electrically powered machinery

N **15.3.3.2.2 Cylinders and Containers.** Cylinders and containers for gases shall be handled in accordance with Chapter 11.

Chapter 11 includes many requirements that can form the basis of an effective medical gas cylinder and container handling program.

N **15.3.3.2.3 Ventilation.** The following source locations for motor-driven equipment shall be adequately ventilated to prevent accumulation of heat:

(1) Medical air sources
(2) Instrument air sources
(3) Dental compressed air sources
(4) Dental-surgical vacuum sources
(5) Dental vacuum sources
(6) WAGD sources

N **15.3.3.3 Dental Gas and Vacuum Source Equipment.**

N **15.3.3.3.1 General.**

N **15.3.3.3.1.1** The capacity of source equipment shall be based on the design requirements for the facility, including the number of gas outlets, vacuum inlets, and other connections, and their individual capacities.

N **15.3.3.3.1.2** The system design requirements shall be included in the data used for testing and verifying the operation of the gas and vacuum piping systems.

N **15.3.3.4* Dental Air.**

A.15.3.3.4 Dental air systems are used primarily to drive gas-powered power devices. See Figure A.15.3.3.4 for an illustration of this type of system. Similar applications are found in podiatry and plastic surgery. Examples of these are air used to drive turbine-powered drills and air used to dry teeth and gums. Some dental hand pieces have an internal self-contained air return system, while other hand pieces discharge air into the atmosphere. Some discharge a mixture of air and water. Nitrogen is often piped as an alternative or reserve supply to the compressor system.

Dental compressed air is not used for life-support purposes, such as respirators, intermittent positive pressure breathing (IPPB) machines, analgesia, anesthesia, and so forth. Air discharged into the oral cavity is incidental and not a primary source of air to sustain life.

A dental compressed air system should not be used to provide power for an air-powered evacuation system without specific attention paid to the discharge of the evacuated gases and liquids. An open discharge of evacuated gases into the general environment of an operatory could compromise the quality of breathing air in the treatment facility. Air discharge should be vented to the outside of the building through a dedicated vent.

An air-powered evacuation system might require significant quantities of air to operate.

Manufacturer's recommendations should be followed regarding proper sizing of the air compressor. Inadequate sizing can result in overheating, premature compressor failures, and inadequate operating pressures and flows.

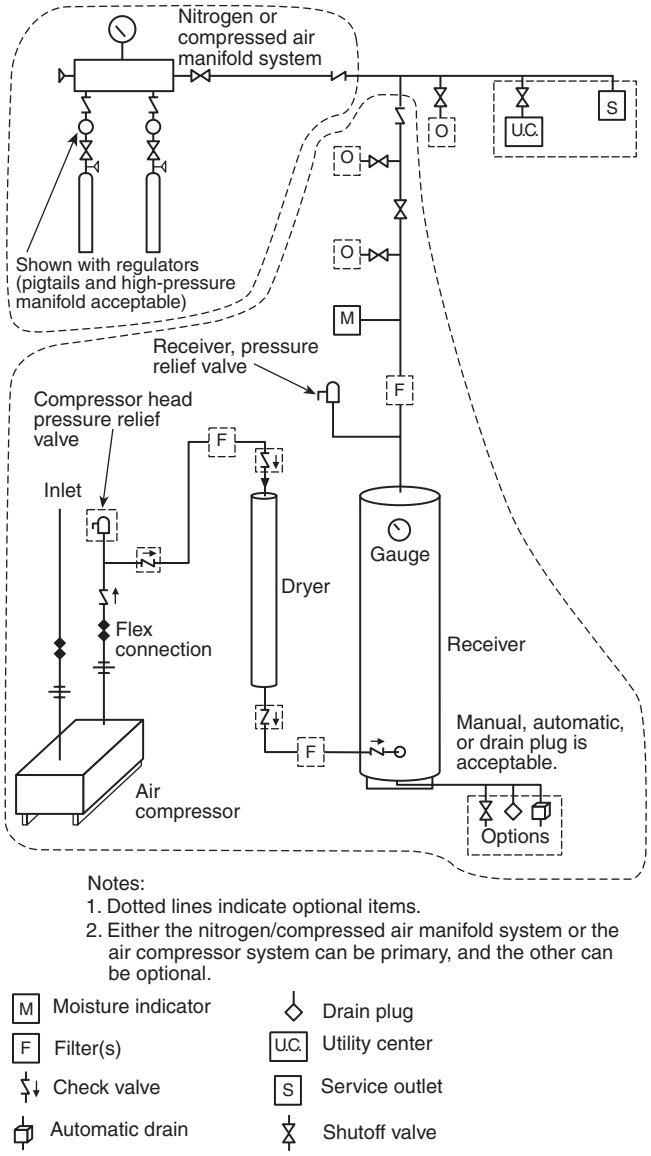


FIGURE A.15.3.3.4 *Drive Gas Supply System.*

N **15.3.3.4.1 General.**

N **15.3.3.4.1.1** Dental air shall be used as a support gas for driving dental tools and shall be permitted to be used to supply air-driven equipment. Dental compressed air shall not be used for respiration.

N **15.3.3.4.1.2** Dental air outlets shall not be interchangeable with any other gas outlets, including oxygen, nitrous oxide, medical air, instrument air, and nitrogen.

N **15.3.3.4.2 Dental Air Compressor Units.**

N **15.3.3.4.2.1** Dental air compressor units shall include dental air compressors, vibration isolation, air receivers, coalescent air filters, adsorption dryers, exhaust silencer/filters,

moisture indicators, and service access manifolds, electrical disconnects, motor wiring, and controls.

N **15.3.3.4.2.2** Air compressors shall be scroll dental, reciprocating dental, or the oil-free dental types.

N **15.3.3.5* Dental Vacuum.**

A.15.3.3.5 A dental vacuum system is not intended for medical-surgical vacuum applications. A wet piping system is designed to accommodate liquid, air–gas, and solids through the service inlet. A dry piping system is designed to accommodate air–gas only through the service inlet, with liquids and solids being trapped before entering the system. *[See Figure A.15.3.3.5(a) through Figure A.15.3.3.5(d).]*

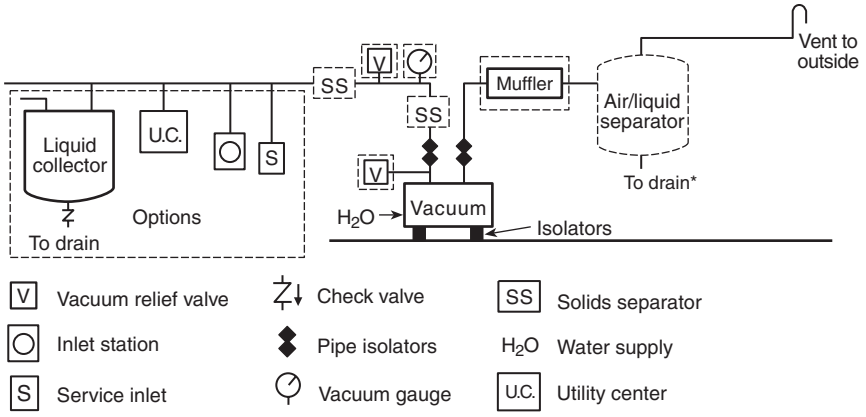


FIGURE A.15.3.3.5(a) *Typical Wet or Dry Piping System with Single Vacuum Pump Source.*

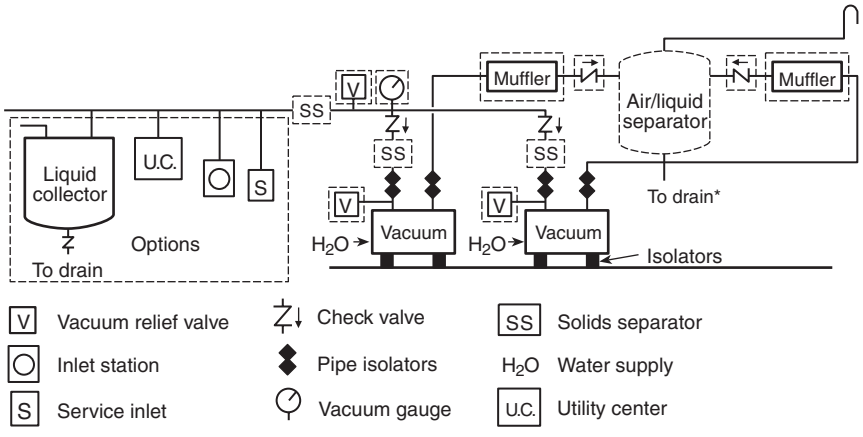
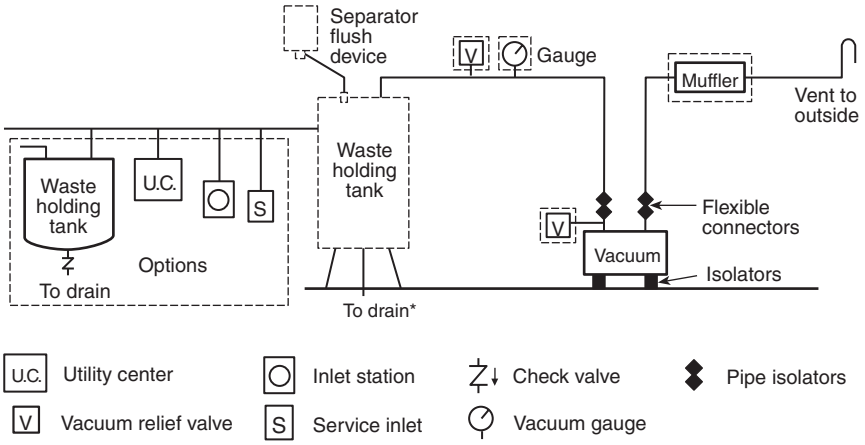
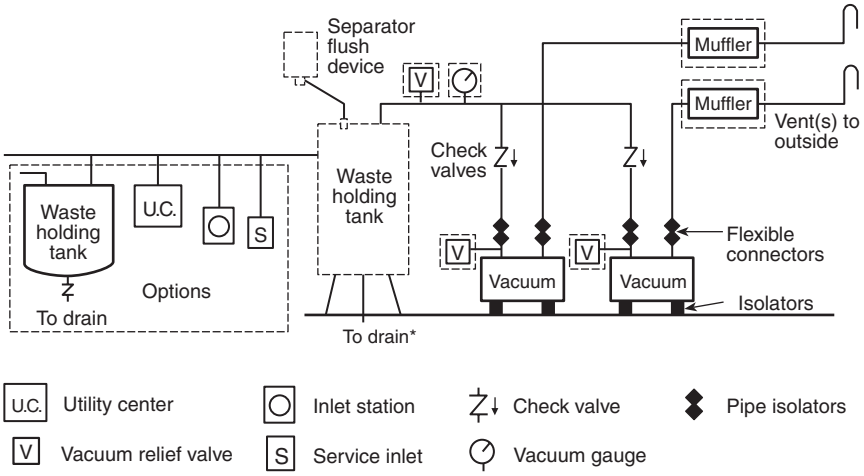


FIGURE A.15.3.3.5(b) *Typical Wet or Dry Piping System with Duplex Vacuum Source with Air/Liquid Separator.*



Note: Dotted lines indicate optional items.
*Does not have to be below floor.

FIGURE A.15.3.3.5(c) *Typical Wet or Dry Piping System with Single Vacuum Source.*



Note: Dotted lines indicate optional items.
*Does not have to be below floor.

FIGURE A.15.3.3.5(d) *Typical Wet or Dry Piping System with Duplex Vacuum Source with Waste Holding Tank.*

N 15.3.3.5.1 General.

Dental vacuum systems provide suction for use in removing fluids and residue from dental procedures in the oral cavity. This patient saliva evacuation must keep the oral cavity field clear and also control the infectious cloud of overspray, both without traumatizing the patient. The dental vacuum system sucks the particulates and water from the patient's mouth, giving the dentist a drier field in which to work. The tubes carrying these materials from each procedure area are consolidated into a larger central tube that empties into the dental vacuum system, often located in the equipment closet or mechanical room of the dental office.

Dental vacuums are available in both "wet" (systems that run on water) and "dry" (systems that use no water) systems. In a typical dental office using a wet dental vacuum, water creates the vacuum

power that allows suction to occur. Because water is required to operate the system, sediment and minerals from city water can wear down the impellers in a vacuum pump's housing.

A dry dental vacuum system is relatively clean compared to a wet system; this helps minimize bacterial contamination of the vacuum line, which could otherwise present a health hazard during maintenance of the units. The bacteria filter unit, if installed, should be marked with the legend "biohazard," together with a description of a safe procedure for changing and disposing the filters and emptying the drainage trap.

15.3.3.5.1.1 Dental vacuum shall be used for oral evacuation and nitrous oxide scavenging.

N **15.3.3.5.1.2** Dental vacuum inlets shall not be interchangeable with any other vacuum inlets, including dental-surgical vacuum.

N **15.3.3.5.2 Dental Vacuum Units.**

N **15.3.3.5.2.1** Dental vacuum units shall include dental vacuum pumps, vibration isolation, separation tanks, vacuum inlet, vacuum exhaust, condensate drain, motor wiring, and controls.

N **15.3.3.5.2.2** Dental vacuum pumps shall be dental dry vacuum or dental liquid (wet) ring pumps. Pumps shall be oil-free or oil-lubricated, and suitable for nitrous oxide scavenging.

N **15.3.3.6 Nitrous Oxide Scavenging.**

When nitrous oxide is used for a moderate or minimal sedation procedure performed on a patient, any waste gases produced through the sedation process will need to be removed safely from the room by a waste anesthetic gas disposal (WAGD) system or an active or passive scavenging ventilation system. Where deep sedation or general anesthesia is administered, only WAGD can be provided.

N **15.3.3.6.1 General.**

15.3.3.6.1.1 The use of scavenging shall be limited to portions of dental facilities where moderate or minimal sedation is administered. WAGD shall be provided where the dental treatment involves general anesthesia or deep sedation.

N **15.3.3.6.1.2** Active nitrous oxide scavenging shall include the use of a nasal mask on the patient. The nasal mask shall be connected to a scavenging inlet in the dental vacuum system through a flow-limiting adapter.

N **15.3.3.6.1.3** Nitrous oxide scavenging inlets shall not be interchangeable with any other vacuum inlets, including medical-surgical vacuum, dental vacuum, and WAGD.

N **15.3.3.6.2 Connection to Dental Vacuum.** Scavenging connections to the dental vacuum system shall be a direct high-volume evacuation (HVE) connection to a high-volume vacuum port with a capacity of 45 L/min (1.6 cfm).

N **15.3.3.7 Piping for Dental Air and Vacuum Systems.**

N **15.3.3.7.1 General.**

N **15.3.3.7.1.1** Piping for dental compressed air systems shall comply with 15.3.3.7.2.

N **15.3.3.7.1.2** Piping for dental vacuum systems and scavenging systems shall comply with 15.3.3.7.3.

N **15.3.3.7.2 Piping for Dental Air Systems.**

N **15.3.3.7.2.1 General.** Pipe, fittings, and joints in piping for dental compressed air systems shall be in accordance with 15.3.3.7.2.2 through 15.3.3.7.2.5.

N 15.3.3.7.2.2 Pipe. Pipe under 15.3.3.7.2 shall comply with the following:

(1) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems, Type L or K*.
(2) ASTM B88, *Standard Specification for Seamless Copper Water Tube, Type L or K*.
(3) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, ACR tube (O.D. size).

N 15.3.3.7.2.3 Copper tube shall be hard temper or annealed (soft temper).

The allowance for tube to be annealed (soft temper) is distinct for dental systems as it is not permitted for medical air and vacuum systems. In medical gas and vacuum systems, where the patients can be much more dependent on the piped gases, the concern with soft temper copper is the potential for kinks to form that can cause a restriction of flow. While this is still the case for dental air, the restriction of flow is not likely to have the risk associated with a medical gas system.

N 15.3.3.7.2.4 Fittings. Fittings for piping under 15.3.3.7.2 shall be permitted to be any of the following acceptable joining methods:

(1) Brazed or soldered fittings conforming to ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) Brazed fittings conforming to ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) Brazed fittings conforming to ASME B16.22 with socket depths equal to or greater than braze-joint pressure fittings in compliance with ANSI/ASME B16.50
(4) Flared fittings conforming to ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*
(5) Compression fittings (¾ in. maximum size)

Another difference between dental air systems (specified here) and medical air systems (specified in Chapter 5) is the allowance for soldered joints in dental air systems. This is not permitted for medical gas systems.

N 15.3.3.7.2.5 Joints. Joints for piping under 15.3.3.7.2 shall comply with the following:

(1) Joints shall be brazed, soldered, threaded, flared, or the compression type.
(2) Where joints are brazed, they shall comply with the requirements of 15.4.6.
(3) Soldered joints shall be made in accordance with ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, using a "lead-free" solder filler metal containing not more than 0.2 percent lead by volume that complies with ASTM B32, *Standard Specification for Solder Metal*.

N 15.3.3.7.3 Piping for Dental Vacuum Systems and Scavenging Systems.

N 15.3.3.7.3.1 General. Piping for dental vacuum systems and scavenging systems shall be copper, PVC plastic, or CPVC plastic.

N 15.3.3.7.3.2 Copper Piping. Copper piping under 15.3.3.7.3 shall be in accordance with 15.3.3.7.3.2(A) through 15.3.3.7.3.2(D).

N (A) Copper Tube. Copper tubing shall comply with the following:

(1) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems, Type L or K*
(2) ASTM B88, *Standard Specification for Seamless Copper Water Tube, Type L or K*

(3) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, ACR tube (O.D. size)

N **(B)** Copper tube shall be hard temper or annealed (soft temper).

N **(C) Copper Fittings.** Copper fittings shall comply with the following:

(1) Brazed or soldered fittings conforming to ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) Brazed fittings conforming to ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) Brazed fittings conforming to ASME B16.22 with socket depths equal to or greater than braze-joint pressure fittings conforming to ANSI/ASME B16.50
(4) Flared fittings conforming to ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*
(5) Compression fittings (¾ in. maximum size)

N **(D) Joints for Copper Piping.** Joints in copper tubing shall be in accordance with the following:

(1) Joints shall be brazed, soldered, threaded, flared, or the compression type.
(2) Where joints are brazed, they shall comply with the requirements of 15.4.6.
(3) Soldered joints shall be made in accordance with ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, using a "lead-free" solder filler metal containing not more than 0.2 percent lead by volume that complies with ASTM B32, *Standard Specification for Solder Metal*.

N **15.3.3.7.3.3 PVC Plastic Piping.** PVC plastic piping under 15.3.3.7.3 shall be in accordance with the following:

(1) PVC plastic pipe shall be Schedule 40 or Schedule 80, conforming to ASTM D1785, *Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120*.
(2) PVC plastic fittings shall be Schedule 40 or Schedule 80 to match the pipe, conforming to ASTM D2466, *Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40*, or ASTM D2467, *Standard Specification Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*.
(3) Joints in PVC plastic piping shall be solvent-cemented in accordance with ASTM D2672, *Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement*.

N **15.3.3.7.3.4 CPVC Plastic Piping.** CPVC plastic piping under 15.3.3.7.3 shall be in accordance with the following:

(1) CPVC IPS plastic pipe shall be Schedule 40 or Schedule 80, conforming to ASTM F441/F441M, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80*.
(2) CPVC IPS plastic fittings shall be Schedule 40 or Schedule 80 to match the pipe, conforming to ASTM F438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 40*, or ASTM F439, *Standard Specification for Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 80*.
(3) CPVC CTS plastic pipe and fittings ½ in. through 2 in. size shall be SDR 11, conforming to ASTM D2846/D2846M, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems*.
(4) Solvent cement for joints in CPVC plastic piping shall comply with ASTM F493, *Solvent Cements for CPVC Pipe and Fittings*.

N 15.4 Category 2 Dental Gas and Vacuum Systems.

Requirements outlined under Section 15.4 are designed for dental, oral, and maxillofacial facilities that at most intend to administer minimal to moderate sedation during any given exam or procedure. Failure of these systems (oxygen and nitrous oxide) while administering this level of sedation may cause discomfort but will not immediately affect patient care. Therefore, these systems are not required to have the same safeguards required by Section 15.3. The application of this category must be determined solely by the level of sedation defined in Chapter 3 and not by the procedure being performed.

N 15.4.1 General.

N 15.4.1.1 Category 2 dental gas and vacuum system shall be limited to facilities that, at most, provide moderate and minimal sedation.

N 15.4.1.2 The medical gases shall be limited to oxygen and nitrous oxide.

N 15.4.1.3 The dental support gases shall be provided from a dental air source system.

N 15.4.1.4 The vacuum systems shall be dental vacuum and nitrous oxide scavenging.

N 15.4.1.5 All connections within Category 2 medical gas (oxygen and nitrous oxide) shall be gas-specific to prevent cross-connections with other piping systems, including vacuum, water, and drive gas.

N 15.4.1.6 Station outlets and piped outlets for Category 2 medical gas and dental air having nonstandard operating pressures shall comply with the following additional requirements:

(1) Be gas-specific.
(2) Be pressure-specific where a single gas is piped at more than one operating pressure.
(3) Be a D.I.S.S connection if operated at a gauge pressure in excess of 550 kPa (80 psi).
(4) Be designed to prevent the removal of the adapter until the pressure has been relieved, if operated at a gauge pressure between 1380 kPa and 2070 kPa (200 psi and 300 psi).

N 15.4.1.7 Requirements for Category 2 dental gas and vacuum systems relating to the operation, management, and maintenance of oxygen and nitrous oxide piping systems shall apply both new and existing facilities as specified in 15.1.6.

N 15.4.2 Medical Gas Systems (Oxygen and Nitrous Oxide).

N 15.4.2.1 Installer Qualifications (Oxygen and Nitrous Oxide).

N 15.4.2.1.1 Installers of medical gas systems shall be certified in accordance with ASSE 6010, *Professional Qualification Standard for Medical Gas Systems Installers*, regardless of the capacity of the source equipment.

ASSE 6010, *Professional Qualification Standard for Medical Gas Systems Installers*, applies to any individual who installs medical gas and vacuum distribution systems. Medical gas and vacuum systems and equipment covered in ASSE 6010 include health care facilities within the scope of NFPA 99.

N 15.4.2.1.2 Installers of medical gas systems shall not use their certification to oversee installation by noncertified personnel.

This requirement ensures that all persons doing the installation work must be qualified to ASSE 6010, not simply the job foreman or supervisor.

N **15.4.2.1.3** Brazing of medical gas piping systems shall be performed by individuals who are qualified in accordance with 15.4.6.1.

N **15.4.2.1.4** Prior to any installation work involving brazing, the installer of the medical gas piping systems shall provide documentation required by 15.4.6.1 for the qualifications of the brazing procedures and individual brazers.

N **15.4.2.2 Central Supply System Identification and Labeling (Oxygen and Nitrous Oxide).**

N **15.4.2.2.1** Cylinders, containers, and tanks shall be designed, fabricated, tested, and marked (stamped) in accordance with regulations of DOT, Transport Canada (TC) *Transportation of Dangerous Goods Regulations*, or the ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," Section VIII. [**55:**7.1.5.1]

N **15.4.2.2.2** Cylinder contents shall be identified by attached labels or stencils naming the contents in accordance with the mandatory requirements of CGA C-7, *Guide to Classification and Labeling of Compressed Gases*.

N **15.4.2.2.3** Liquid containers shall have additional product identification visible from all directions with a minimum of 51 mm (2 in.) high letters such as a 360-degree wraparound tape for medical liquid containers.

Although it is not practical in most facilities to test the contents of each gas cylinder, it is easy to confirm that the labels (see Exhibit 5.1) are in place, are legible, and match the gas-specific connector. A simple go/no-go tester can be made of a known Compressed Gas Association (CGA) connector from an old cylinder lead — or from a lead purchased from a gas equipment supplier. Cylinders that are missing their labels, or that have cylinder connections not matching their labels, should be assumed to contain something other than the gas they are expected to contain. Such cylinders should not be used and should be quarantined and returned to the supplier immediately.

N **15.4.2.2.4** Cryogenic liquid containers shall be provided with gas-specific outlet connections in accordance with the mandatory requirements of CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*, or CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

N **15.4.2.2.5** Cylinder and cryogenic liquid container outlet connections shall be affixed in such a manner as to be integral to the valve(s), unremovable with ordinary tools, or so designed as to render the attachment point unusable when removed.

To reduce the number of incidents caused by mix-ups and contamination of medical gases, manufacturers have gone to great lengths to refit containers that had easily removable valves and outlet connections. Under this requirement and other regulations for manufacturers, any health care facility in the United States that buys its gases from a medical gas supplier should find the outlet connections "unremovable with ordinary tools."

N **15.4.2.2.6** The contents of cylinders and cryogenic liquid containers shall be verified prior to use.

One way to verify the contents of cylinders or cryogenic liquid containers is to receive a Certificate of Analysis (COA) from the medical gas supplier. Another way is to test the gas content on site with an FDA-approved or similar gas-specific analyzer.

N **15.4.2.2.7** Labels shall not be defaced, altered, or removed, and connecting fittings shall not be modified.

N **15.4.2.2.8** Locations containing positive-pressure gases other than oxygen and medical air shall have their door(s) labeled as follows:

Positive Pressure Gases
NO Smoking or Open Flame
Room May Have Insufficient Oxygen
Open Door and Allow Room to Ventilate Before Entering

As with any gas source, large-scale discharges from systems are very rare, but small leaks are almost universal. Although the greatest hazard arises with a massive discharge of gas (e.g., after a relief valve failure) — which, as mentioned, is extremely rare — the more commonplace problems include the cylinder lead that was not tightened properly, the connector that was nicked and does not quite seal, the pigtail that has a small break, or the connector that has lost its sealing O-ring.

Signage should clearly state that a hazard exists because gas can build up.

N **15.4.2.2.9** Locations containing central supply systems or cylinders containing only oxygen or medical air shall have their door(s) labeled as follows:

Medical Gases
NO Smoking or Open Flame

N **15.4.2.3 Central Supply System Operations (Oxygen and Nitrous Oxide).**

N **15.4.2.3.1** The use of adapters or conversion fittings to adapt one gas-specific fitting to another shall be prohibited.

The fittings prohibited by 15.4.2.3.1, often called "cheater" fittings, present a number of patient risks, including the mix-up of gases (cross-connections) or the contamination or overpressurization of ancillary equipment that could result if, for example, a nitrogen line and medical air line using a conversion fitting are mixed up.

N **15.4.2.3.2** Cylinders and containers shall be handled in strict accordance with 11.6.2.

N **15.4.2.3.3** Only gas cylinders, reusable shipping containers, and their accessories shall be permitted to be stored in rooms containing central supply systems or gas cylinders.

N **15.4.2.3.4** No flammable materials, cylinders containing flammable gases, or containers containing flammable liquids shall be stored in rooms with gas cylinders.

N **15.4.2.3.5** If cylinders are wrapped when received, the wrappers shall be removed prior to storage.

Wrappers can significantly add to the amount of combustible materials in the room and/or cover the cylinder labels. Examples of this might be cardboard or shrink wrap.

N **15.4.2.3.6** Cylinders without correct markings or whose markings and gas-specific fittings do not match shall not be used.

N **15.4.2.3.7** Cryogenic liquid storage units intended to supply gas to the facility shall not be used to transfill other liquid storage vessels.

See the commentary following 5.1.3.2.7 for details on the hazards of transfilling liquid oxygen.

N **15.4.2.3.8** Care shall be exercised when handling cylinders that have been exposed to freezing temperatures or containers that contain cryogenic liquids to prevent injury to the skin.

Cryogens are extremely cold and can cause instant, severe frostbite. Direct contact with cryogenic liquids, or with uninsulated cryogenic pipes or equipment, can cause freeze burns and tissue damage.

N **15.4.2.3.9** Cylinders containing compressed gases and containers for volatile liquids shall be kept away from radiators, steam piping, and like sources of heat.

N **15.4.2.3.10** Where cylinder valve protection caps are supplied, they shall be secured tightly in place unless the cylinder is connected for use.

If a cylinder that does not have a cylinder valve protection cap falls over, the cylinder valve could snap off. Depending on the cylinder size, the quantity of gas within the cylinder, and the orifice size at the break, the resulting expulsion of gas could propel the cylinder rapidly and/or violently about.

N **15.4.2.3.11** Containers shall not be stored in a tightly closed space.

N **15.4.2.3.12** Cylinders in use and in storage shall be prevented from reaching temperatures in excess of 52°C (125°F).

N **15.4.2.3.13** Central supply systems for nitrous oxide and carbon dioxide using cylinders or portable containers shall be prevented from reaching temperatures lower than the recommendations of the central supply system's manufacturer but shall never be lower than −7°C (20°F) or greater than 52°C (125°F).

N **15.4.2.4 Locations of Medical Gas Source Equipment (Oxygen and Nitrous Oxide).**

N **15.4.2.4.1** Gas storage locations in facilities with Category 2 medical gas systems with a total of all gases in cylinders or containers, except nitrogen, connected and in storage at one time that does not exceed 85 m^3 (3000 ft^3) at standard temperature and pressure (STP), or 142 m^3 (5000 ft^3) (STP) if oxygen is stored in a DOT specification 4 L (cryogenic liquid) container shall comply with 15.4.2.4.3 through 15.4.2.4.13.

N **15.4.2.4.2** Gas storage locations in facilities with Category 2 medical gas systems with a total of all gases in cylinders or containers exceeding quantities listed in 15.4.2.4.1 shall comply with 5.1.3.3.

If storing greater than 85 m^3 (3000 ft^3) of gas, then the requirements of Chapter 5 must be followed.

N **15.4.2.4.3** Enclosures shall serve no purpose other than to contain the medical gas source equipment (oxygen and nitrous oxide), except that nitrogen source equipment and compressed air cylinders shall be permitted in the enclosure.

This exception to allow cylinders in a dental air compressor equipment room is unique to the dental gas and vacuum systems, and it still requires the following:

1. Cylinders in use and in storage are to be prevented from reaching temperatures in excess of 54°C (130°F).
2. The location must be constructed with access to move cylinders, equipment, and so forth in and out of the location on hand trucks, complying with 11.4.3.1.1.
3. Racks, shelves, and supports, where provided, must be constructed of noncombustible materials or limited-combustible materials.
4. Full or empty medical gas cylinders, when not connected, need to be stored in locations complying with 5.1.3.3.2 through 5.1.3.3.3.
5. Nitrogen and dental air cylinders are permitted in the same location containing a dental air compressor when it is the only motor-driven machinery located within the room.

N **15.4.2.4.4** Storage of full or empty gas cylinders, or both, shall be permitted in the same enclosure.

N **15.4.2.4.5** Air compressors, vacuum pumps, and other equipment shall not be located in enclosures for medical gas cylinders (oxygen and nitrous oxide source equipment).

N **15.4.2.4.6** If enclosures are outdoors or remote from the treatment facilities that they serve, they shall be kept locked.

N **15.4.2.4.7** Cylinders in use and in storage shall be prevented from reaching temperatures in excess of 52°C (125°F). Nitrous oxide cylinders shall be prevented from reaching temperatures lower than −7°C (20°F).

N **15.4.2.4.8** Only gas cylinders, reusable shipping containers, and their accessories shall be permitted to be stored in rooms containing central supply systems or gas cylinders.

N **15.4.2.4.9** No flammable materials, cylinders containing flammable gases, or containers containing flammable liquids shall be stored in rooms with gas cylinders.

N **15.4.2.4.10** Indoor enclosures shall not communicate directly with medical gas (oxygen and nitrous oxide) use points or storage locations for oxidizers.

The statement that storage rooms "shall not communicate" means that the central supply system and storage locations for oxygen, nitrous oxide, and mixtures of these gases cannot be located in, or immediately adjacent to, use points.

N **15.4.2.4.11** Outdoor enclosures that are adjacent to a building wall shall be located such that the distance to any window or door of the adjacent building is greater than 3.05 m (10 ft).

N **15.4.2.4.12** Enclosures for medical gas (oxygen and nitrous oxide) source equipment shall be provided with doors or gates.

N **15.4.2.4.13** Cylinders in service or in storage shall be individually secured and located to prevent falling or being knocked over.

Paragraph 15.4.2.4.13 is unique to dental gas and vacuum systems in that it requires cylinders to be individually secured. Chapter 5 requires cylinders to be secured but does not require that this is done individually.

Requirements for the location of central supply sources are identified as applying to both new and existing facilities. These requirements deal with the location of the source for dental gas and vacuum systems and what items are permitted in the locations. Because these areas with stored gases present the same hazards in new and existing facilities, the requirements are required to be observed throughout the life of the system.

N 15.4.2.5 Medical Gas Source Equipment (Oxygen and Nitrous Oxide).

N 15.4.2.5.1 Mechanical means shall be provided to ensure that the medical gas source equipment is connected to the correct medical gas distribution piping system.

N 15.4.2.5.2 Cylinder valve outlets for oxygen and nitrous oxide shall comply with CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections.*

N 15.4.2.5.3 Threaded connections to manifolds shall comply with CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications).*

N 15.4.2.5.4 A check valve shall be provided downstream of each pressure regulator.

N 15.4.2.5.5 A pressure relief valve set at 50 percent above the normal line pressure shall be located downstream of the check valve in 15.4.2.5.4.

N 15.4.2.5.6 Pressure relief valves shall be brass, bronze, or stainless steel and designed for oxygen service.

See the commentary following 5.1.3.5.6.1 for additional detail on pressure relief valves.

N 15.4.2.5.7 Hose and flexible connectors shall have a gauge pressure rating not less than 6895 kPa (1000 psi).

N 15.4.2.5.8 Materials used in central supply systems shall meet the following requirements:

(1) In those portions of systems intended to handle oxygen at gauge pressures equal to or greater than 2413 kPa (350 psi), interconnecting hose shall contain no polymeric materials.
(2) 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.
(3) If potentially exposed to cryogenic temperatures, materials shall be designed for low temperature service.
(4) If intended for outdoor installation, materials shall be installed per the manufacturer's requirements.

N 15.4.2.5.9 Flexible connectors of other than all-metal construction that connect manifolds to the gas distribution piping shall not exceed 1.52 m (5 ft) in length and shall not penetrate walls, floors, ceilings, or partitions.

N 15.4.2.5.10 Medical gas source equipment that serves one or two treatment facilities shall include two banks of one or more cylinders of oxygen and (if used) two banks of one or more cylinders of nitrous oxygen, each bank containing at least one average day's supply.

N 15.4.2.5.11 The two banks of each medical gas source shall be manifolded so that either bank can supply its distribution piping system.

N 15.4.2.5.12 Where the source equipment is remote from a single treatment facility and an in use bank is unable to supply the system, the manifold shall automatically switch to the secondary bank.

N 15.4.2.5.13 Where the source equipment serves multiple treatment facilities and an in use bank is unable to supply the system, the manifold shall automatically switch to the secondary bank.

N 15.4.2.5.14 Where the source equipment is not remote and is accessible from a single treatment facility served and an in use bank is unable to supply the system, the manifold shall be manually or automatically switched to the secondary bank.

Paragraph 15.4.2.5.14 applies to both new and existing facilities. It is essentially an exception to 15.4.2.5.13, which requires automatic means of alternating headers, meaning that systems where the source is not remote can be provided with either manual or automatic means for alternating of the headers.

N 15.4.2.6 Emergency Shutoff Valves (Oxygen and Nitrous Oxide).

N 15.4.2.6.1* Where a central medical gas supply is remote from a single treatment facility, the main supply line shall be provided with an emergency shutoff valve located in the single treatment facility so as to be accessible from all use-point locations in an emergency.

N A.15.4.2.6.1 See Figure A.15.4.2.6.1 for an illustration of single treatment locations.

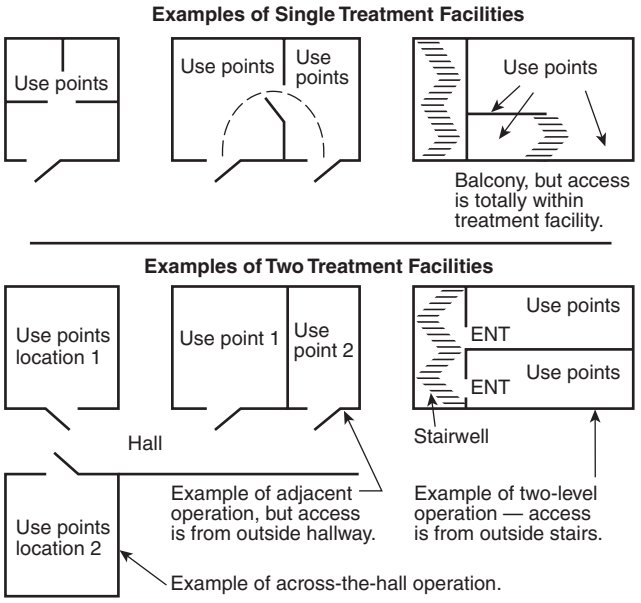


FIGURE A.15.4.2.6.1 *Examples of Single Treatment Locations.*

N 15.4.2.6.2 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.

N 15.4.2.6.3 Emergency shutoff valves shall be labeled to indicate the gas controlled by the shutoff valve and shall shut off only the gas to the treatment facility that they serve.

N 15.4.2.6.4 A remotely activated shutoff valve at a gas supply manifold shall not be used for emergency shutoff.

N 15.4.2.6.4.1 For clinical purposes, such a remote valve actuator shall not fail-close in the event of loss of electric power.

N 15.4.2.6.4.2 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.

These shutoffs are not used in the same way that zone valves are utilized in medical gas and vacuum systems; they are not, therefore, located in the same places.

An emergency shutoff valve is an exception unique to dental gas and vacuum systems. This valve is a cross between a zone valve and a main valve found in Category 1 and Category 2 medical gas and vacuum systems (as specified in Chapter 5). The location of valves for a dental gas and vacuum system depends on the equipment installed and the location of the equipment. Dental gas and vacuum systems can have a source valve, main valve, zone valve, emergency shutoff valve, or a combination of them. As an example, in a dental office clinic in which the oxygen manifold is installed within the single treatment facility, there might be only one oxygen valve. This oxygen valve serves as the emergency shutoff valve and is located for accessibility from all use points, in case the oxygen distribution system needs to be shut down. Exhibit 15.1 shows emergency shutoff valves for oxygen and nitrous oxide lines in dental gas systems.

In the case where a main valve or source valve is installed and the facility is installing an emergency shutoff valve, the valve must be located on the patient side of the source or main valve.

Paragraph 15.4.2.6.4 applies to both new and existing facilities. This means that if the source of gas is remote from the treatment facility, then each treatment facility being served by the dental gas and vacuum system needs to be provided with an emergency shutoff valve. Providing a valve at the supply manifold, even if it can be remotely activated from the treatment facility, does not count as the required emergency shutoff valve.

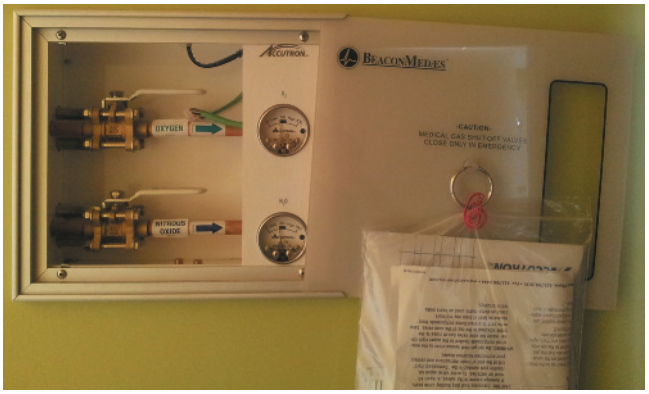


EXHIBIT 15.1

Emergency Shutoff Valves for Oxygen and Nitrous Oxide. (Courtesy of William G. Frank Medical Gas Testing & Consulting, LLC)

N 15.4.2.7 Station Outlets and Risers (Oxygen and Nitrous Oxide).

N 15.4.2.7.1 Each gas outlet shall be gas-specific.

Gas-specific outlets help reduce the chances for inadvertent connections and delivering the wrong gas to the patient.

N 15.4.2.7.2 Gas outlets shall consist of a primary and a secondary valve or assembly.

N 15.4.2.7.3 Each gas outlet shall be legibly identified.

N 15.4.2.7.4 Threaded outlets shall be noninterchangeable connections complying with the mandatory requirements of CGA V-5, *Diameter-Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications).*

N 15.4.2.7.5 Factory-installed copper inlet tubes on station outlets extending no further than 205 mm (8 in.) from the body of the terminal shall be not less than DN8 (NPS ¼) (⅜ in. O.D.) size, with 8 mm (0.3 in.) minimum inside diameter.

N 15.4.2.8 Manufactured Assemblies (Oxygen and Nitrous Oxide). Category 2 systems shall comply with 5.1.6.

N **15.4.2.9 Pressure and Vacuum Indicators (Oxygen and Nitrous Oxide).** Category 2 systems shall comply with 5.1.8.

N **15.4.2.10 Warning Systems (Oxygen and Nitrous Oxide).** Category 2 warning systems shall comply with 5.2.9, except as follows:

(1) Warning systems shall be permitted to be a single alarm panel.
(2) The alarm panel shall be located in an area of continuous surveillance while the facility is in operation.
(3) Pressure and vacuum switches/sensors shall be mounted at the source equipment with a pressure indicator at the master alarm panel.
(4) Warning systems for medical gas systems shall provide the following alarms:
    (a) Oxygen main line pressure low
    (b) Oxygen main line pressure high
    (c) Oxygen changeover to secondary bank or about to changeover (if automatic)
    (d) Nitrous oxide main line pressure low
    (e) Nitrous oxide main line pressure high
    (f) Nitrous oxide changeover to secondary bank or about to changeover (if automatic)
(5) Audible and noncancelable alarm visual signals shall indicate if the pressure in the main line increases or decreases 20 percent from the normal operating pressure.
(6) Visual indications shall remain until the situation that caused the alarm is resolved.
(7) 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 percent from the normal operating pressure.
(8) A cancelable 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.

A single master alarm panel is allowed for dental gas and vacuum warning systems. This unique exception is because oxygen and nitrous oxide are the only gases required to be monitored at the master alarm panel. A facility may include warning signals for any or all of the other medical gas and vacuum systems installed based on the facility's medical gas and vacuum system risk assessment. Exhibit 15.2 shows two different warning system alarm panels for oxygen and nitrous oxide systems.

N **15.4.2.11 Labeling and Identification.** Category 2 systems shall comply with 5.1.11.

Labeling for oxygen and nitrous oxide per 5.1.11 should look as shown in Exhibit 15.3.

N 15.4.3 Category 2 Dental Air and Vacuum Piping Systems.

N 15.4.3.1 General.

N **15.4.3.1.1** Dental air and vacuum piping systems shall include dental support gases and dental vacuum systems.

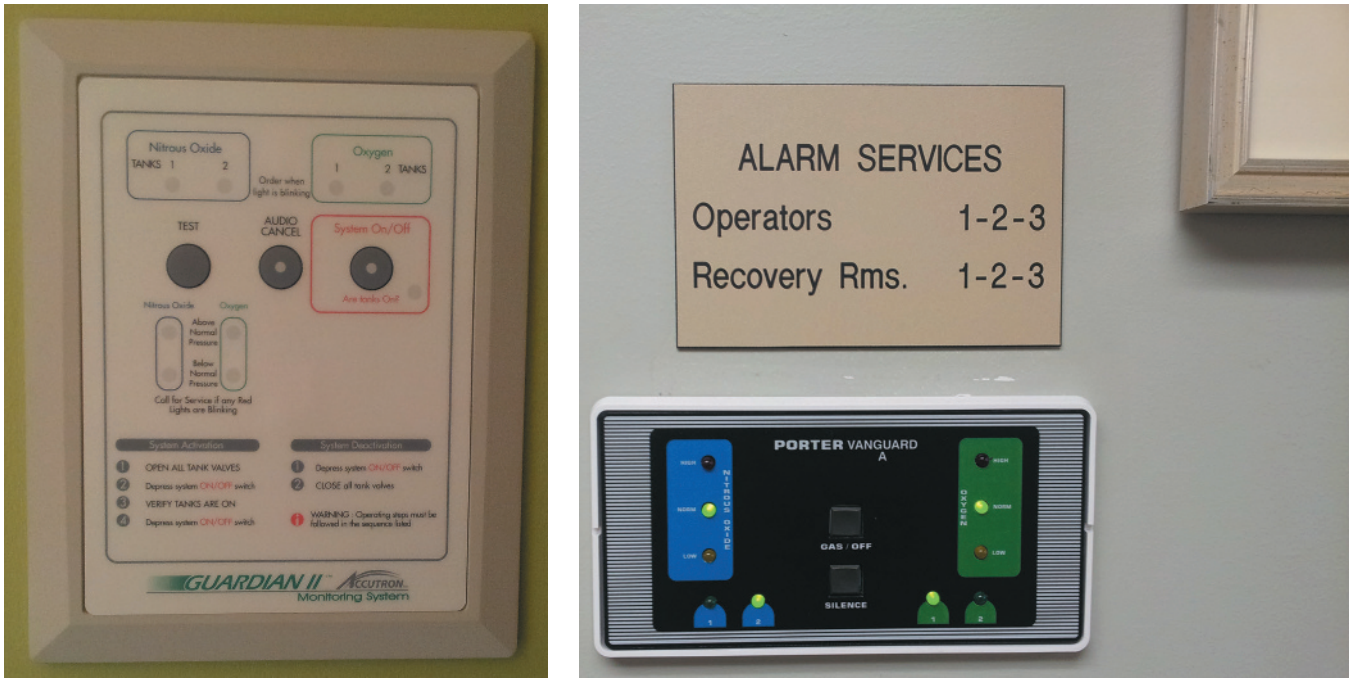
N **15.4.3.1.2** Dental vacuum systems shall include dental vacuum and nitrous oxide scavenging.

N 15.4.3.2 Equipment Locations for Dental Air and Vacuum Systems.

N **15.4.3.2.1 General.** Any of the following systems shall be permitted to be located together in the same room:

(1) Dental air compressor sources and reserve headers
(2) Dental-surgical vacuum sources

EXHIBIT 15.2



Warning System Alarm Panels for Oxygen and Nitrous Oxide Systems. (Courtesy of William G. Frank Medical Gas Testing & Consulting, LLC)

OXYGEN | NITROUS OXIDE

EXHIBIT 15.3

Labeling and Identification for Oxygen and Nitrous Oxide.

(3) Dental vacuum sources
(4) Any other compressor, vacuum pump, or electrically powered machinery

N **15.4.3.2.2 Cylinders and Containers.** Cylinders and containers for gases shall be handled in accordance with Chapter 11.

In lieu of a dental air compressor, dental air cylinders can be used. Medical grade (USP) cylinders are Grade N, but Grade D breathing air cylinders are typically used for this application.

N **15.4.3.2.3 Ventilation for Motor-Driven Equipment.** The following source locations shall be adequately ventilated to prevent accumulation of heat:

(1) Medical air sources
(2) Instrument air sources
(3) Dental compressed air sources
(4) Dental-surgical vacuum sources
(5) Dental vacuum sources
(6) WAGD sources

N 15.4.3.3 Dental Gas and Vacuum Source Equipment.

N 15.4.3.3.1 General.

N 15.4.3.3.1.1 The capacity of source equipment shall be based on the design requirements for the facility, including the number of gas outlets, vacuum inlets, and other connections, and their individual capacities.

N 15.4.3.3.1.2 The system design requirements shall be included in the data used for testing and verifying the operation of the gas and vacuum piping systems.

N 15.4.3.3.2 Dental Air.

Dental air is used primarily to drive gas-powered dental tools such as high-speed drills and tools used to dry the tooth surface and gums. Dental compressed air is not used for life-support purposes, such as respirators, IPPB machines, analgesia, or anesthesia. Air discharged into the oral cavity is incidental and not a primary source of air to sustain life. Dental air should be clean and dry in order to minimize the risk of contamination of the system by microorganisms and to improve the efficiency of the dental instruments. If the air system is wet or dirty, it will eventually cause corrosion and damage instruments.

N 15.4.3.3.2.1 General.

N (A) Dental air shall be used as a support gas for driving dental tools and shall be permitted to be used to supply air-driven equipment. Dental compressed air shall not be used for respiration.

N (B) Dental air outlets shall not be interchangeable with any other gas outlets, including oxygen, nitrous oxide, medical air, instrument air, and nitrogen.

N 15.4.3.3.2.2 Dental Air Compressor Units.

N (A) Dental air compressor units shall include dental air compressors, vibration isolation, air receivers, coalescent air filters, adsorption dryers, exhaust silencer/filters, moisture indicators, service access manifolds, electrical disconnects, motor wiring, and controls.

N (B) Air compressors shall be scroll dental, reciprocating dental, or the oil-free dental types.

N 15.4.3.3.3 Dental Vacuum.

N 15.4.3.3.3.1 General.

N (A) Dental vacuum shall be used for oral evacuation and nitrous oxide scavenging.

N (B) Dental vacuum inlets shall not be interchangeable with any other vacuum inlets, including dental-surgical vacuum.

N 15.4.3.3.3.2 Dental Vacuum Units.

N (A) Dental vacuum units shall include dental vacuum pumps, vibration isolation, separation tanks, vacuum inlet, vacuum exhaust, condensate drain, motor wiring, and controls.

N (B) Dental vacuum pumps shall be dental dry vacuum or dental liquid (wet) ring pumps. Pumps shall be oil-free or oil-lubricated and suitable for nitrous oxide scavenging.

N 15.4.3.3.4 Nitrous Oxide Scavenging.

N 15.4.3.3.4.1 General.

N (A) The use of scavenging shall be limited to portions of dental facilities where moderate or minimal sedation is administered. WAGD shall be provided where the dental treatment involves general anesthesia or deep sedation.

N **(B)** Active nitrous oxide scavenging shall include the use of a nasal mask on the patient. The nasal mask shall be connected to a scavenging inlet in the dental vacuum system through a flow-limiting adapter.

N **(C)** Nitrous oxide scavenging inlets shall not be interchangeable with any other vacuum inlets, including medical-surgical vacuum, dental vacuum, and WAGD.

N **15.4.3.3.4.2 Connection to Dental Vacuum.** Scavenging connections to the dental vacuum system shall be a direct high-volume evacuation (HVE) connection to a high-volume vacuum port with a capacity of 45 L/min (1.6 cfm).

N **15.4.3.4 Category 2 Warning Systems (Oxygen and Nitrous Oxide).**

N **15.4.3.4.1 General.**

N **15.4.3.4.1.1** The warning systems in Category 2 dental gas and vacuum systems shall comply with applicable requirements of 5.2.9 and 15.4.3.4.2 through 15.4.3.4.4.

N **15.4.3.4.1.2** The master, area, and local alarm functions shall be permitted to be provided by a single alarm panel, as indicated in 5.2.9.

N **15.4.3.4.2 Master Alarm Panels.**

N **15.4.3.4.2.1** A master alarm panel shall be located in the facility at a point of continuous surveillance when the facility is in operation.

N **15.4.3.4.2.2** The master alarm panel shall indicate the following:

(1) Oxygen supply pressure ±20 percent from normal
(2) Nitrous oxide supply pressure ±20 percent from normal
(3) Changeover of oxygen supply source
(4) Changeover of nitrous oxide supply source

N **15.4.3.4.3 Area Alarm Panels.**

N **15.4.3.4.3.1** An area alarm panel shall be centrally located where two or more treatment areas are supplied from the same zoned dental gas and vacuum piping.

N **15.4.3.4.3.2** Area alarm panels shall indicate the following:

(1) Oxygen supply pressure ±20 percent from normal
(2) Nitrous oxide supply pressure ±20 percent from normal

N **15.4.3.4.4 Local Alarms.**

N **15.4.3.4.4.1** Local alarms shall be located in source equipment control panels or separate control panels in the equipment rooms for source equipment.

N 15.4.4 Piping for Category 2 Medical Gas, Dental Air, and Vacuum Systems.

Dental gas and vacuum systems are installed with the same materials and procedures found in a medical gas and vacuum system (Chapter 5), with a few exceptions for dental air and dental vacuum systems. These exceptions are detailed in 15.4.4.

Dental compressed air is not used for life-support purposes and, as such, can be installed with soft-temper annealed copper tubing and joined by soldered joints, flared fittings, or compression fittings.

The vacuum and exhaust lines should be comprised of materials resistant to attack from substances carried and be so constructed as to withstand a negative (vacuum) pressure. Pipework made from PVC, CPVC IPS, or CPVC CTS plastic material is generally found to be suitable because these materials can handle chemical attack. Copper pipes will be attacked by dental amalgam if used in wet vacuum systems.

N 15.4.4.1 General.

N 15.4.4.1.1 Piping for the following systems shall comply with 15.4.4.2:

(1) Oxygen
(2) Nitrous oxide

N 15.4.4.1.2 Piping for dental air systems shall comply with 15.4.4.3.

N 15.4.4.1.3 Piping for dental vacuum systems and scavenging systems shall comply with 15.4.4.4.

N 15.4.4.2 Piping for Oxygen and Nitrous Oxide Systems.

N 15.4.4.2.1 Cleaning for Oxygen Service. For oxygen and nitrous oxide, the pipe, fittings, valves, gas/vacuum outlets/inlets, and other piping components shall be cleaned for oxygen by the manufacturer prior to installation in accordance with CGA G-4.1, *Cleaning Equipment for Oxygen Service*. Fittings shall be permitted to be cleaned by a supplier or agency other than the manufacturer.

N 15.4.4.2.2 Pipe. Pipe shall be hard-drawn seamless copper tube conforming to ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems, Type L or K.*

FAQ Why can't soft-tempered copper be used with Category 2 medical gas systems (oxygen and nitrous oxide)?

The piping specified in 15.4.4.2.2 is acceptable for Category 2 oxygen and nitrous oxide gas systems, and piping has to be "hard-drawn." Part of the reason for requiring hard-drawn piping is that soft tubing kinks very easily, and kinking causes restriction of flow. Soft-tempered, or annealed, tube is permitted with dental air and vacuum but not for the medical gases.

N 15.4.4.2.3 Fittings.

N 15.4.4.2.3.1 Fittings shall be brazed, memory metal, or axially swaged.

N 15.4.4.2.3.2 Brazed fittings shall be the wrought copper capillary type complying with the following:

(1) ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) ASME B16.22 with socket depths equal to or greater than brazed joint pressure fittings in accordance with ANSI/ASME B16.50

N 15.4.4.2.3.3 Cast copper alloy fittings shall not be used with field-brazed joints.

Cast fittings are prone to surface cracking, porosity problems, and the formation of internal cavities.

N 15.4.4.2.3.4 Memory metal fittings shall be rated for not less than 538°C (1000°F) and 2070 kPa (300 psi) and shall be installed by qualified technicians in accordance with the manufacturer's instructions.

See the commentary following 5.1.10.6 for additional information on memory metal fittings.

N **15.4.4.2.3.5** Axially swaged couplings shall be elastic strain preloaded with metal-to-metal seats, rated for not less than 538°C (1000°F) and 2070 kPa (300 psi), and shall provide permanent, nonseparable joints. Fittings shall be installed by qualified technicians in accordance with the manufacturer's instructions.

See the commentary following 5.1.10.7 for additional information on axially swaged fittings.

N **15.4.4.2.4 Joints.**

N **15.4.4.2.4.1 Brazed.** Brazing of copper joints shall be in accordance with 15.4.6.

N **15.4.4.2.4.2 Threaded.** Threaded joints shall be limited to connections to pressure indicators, alarm devices, and source equipment and shall comply with the following:

(1) Threads shall be tapered complying with ASME B1.20.1, *Pipe Threads, General Purpose, Inch*.
(2) Threads shall be made up with polytetrafluoroethylene (PTFE) tape or other thread sealant recommended for oxygen service, with the sealant applied to the male threads only.

Threaded fittings can only be used on main line gauges, zone valve gauges, alarm sensors, and gas-specific demand check fittings found on the piped distribution system. Central supply source equipment (such as gauges, sensors, and piping) also use threaded connections.

N **15.4.4.2.4.3 Prohibited Joints.** The following joints shall be prohibited under 15.4.4.2.4:

(1) Flared and compression connections, including connections to station outlets, alarm devices, and other components
(2) Push-lock connections
(3) Straight-threaded connections, including unions
(4) Pipe crimping tools used to permanently stop the flow of medical gas and vacuum piping

N **15.4.4.3 Piping for Dental Air Systems.**

N **15.4.4.3.1 General.** Pipe, fittings, and joints in piping for dental compressed air systems shall be in accordance with 15.4.4.3.2 through 15.4.4.3.4.

N **15.4.4.3.2 Pipe.** Pipe under 15.4.4.3 shall comply with the following:

(1) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems, Type L or K*.
(2) ASTM B88, *Standard Specification for Seamless Copper Water Tube, Type L or K*.
(3) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, ACR tube (O.D. size).

N **15.4.4.3.2.1** Copper tube shall be hard temper or annealed (soft temper).

N **15.4.4.3.3 Fittings.** Fittings for piping under 15.4.4.3 shall be permitted to be any of the following acceptable joining methods:

(1) Brazed or soldered fittings conforming to ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) Brazed fittings conforming to ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) Brazed fittings conforming to ASME B16.22 with socket depths equal to or greater than braze-joint pressure fittings in compliance with ANSI/ASME B16.50
(4) Flared fittings conforming to ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*
(5) Compression fittings (¾ in. maximum size)

N **15.4.4.3.4 Joints.** Joints for piping under 15.4.4.3 shall comply with 15.4.4.3.4.1 through 15.4.4.3.4.3.

N **15.4.4.3.4.1** Joints shall be brazed, soldered, threaded, flared, or the compression type.

N **15.4.4.3.4.2** Where joints are brazed, they shall comply with the requirements of 15.4.6.

N **15.4.4.3.4.3** Soldered joints shall be made in accordance with ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, using a "lead-free" solder filler metal containing not more than 0.2 percent lead by volume that complies with ASTM B32, *Standard Specification for Solder Metal*.

N **15.4.4.4 Piping for Dental Vacuum Systems and Scavenging Systems.**

N **15.4.4.4.1 General.** Piping for dental vacuum systems and scavenging systems shall be copper, PVC plastic, or CPVC plastic.

Note that copper pipe should not be used for wet vacuum systems, as it will be attacked by dental amalgam compounds. (Dental amalgam is a mixture of mercury, silver, tin, and copper.) In all dental systems, both wet and dry, drainage of water from the pumps or separators will pass into the normal foul drainage system. Efficient separation of detritus/amalgam will, therefore, help prevent pollution of sewerage systems. Exhibit 15.4 shows PVC piping used for a Category 3 vacuum system.

EXHIBIT 15.4

PVC Piping for a Category 3 Dental Vacuum System. (Courtesy of William G. Frank Medical Gas Testing & Consulting, LLC)

N **15.4.4.4.2 Copper Piping.** Copper piping under 15.4.4.4 shall be in accordance with 15.4.4.4.2.1 through 15.4.4.4.2.3.

N **15.4.4.4.2.1 Copper Tube.** Copper tubing shall be hard temper or annealed (soft temper) and shall comply with the following:

(1) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems, Type L or K*
(2) ASTM B88, *Standard Specification for Seamless Copper Water Tube, Type L or K*
(3) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service, ACR tube (O.D. size)*

N **15.4.4.4.2.2 Copper Fittings.** Copper fittings shall comply with the following:

(1) Brazed or soldered fittings conforming to ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) Brazed fittings conforming to ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) Brazed fittings conforming to ASME B16.22 with socket depths equal to or greater than braze-joint pressure fittings conforming to ANSI/ASME B16.50
(4) Flared fittings conforming to ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*
(5) Compression fittings (¾ in. maximum size)

N **15.4.4.4.2.3 Joints for Copper Piping.** Joints in copper tubing shall be in accordance with the following:

(1) Joints shall be brazed, soldered, threaded, flared, or the compression type.
(2) Where joints are brazed, they shall comply with the requirements of 15.4.6.
(3) Soldered joints shall be made in accordance with ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, using a "lead-free" solder filler metal containing not more than 0.2 percent lead by volume that complies with ASTM B32, *Standard Specification for Solder Metal*.

N **15.4.4.4.3 PVC Plastic Piping.** PVC plastic piping under 15.4.4.4 shall be in accordance with the following:

(1) PVC plastic pipe shall be Schedule 40 or Schedule 80, conforming to ASTM D1785, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120*.
(2) PVC plastic fittings shall be Schedule 40 or Schedule 80 to match the pipe, conforming to ASTM D2466, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40*, or ASTM D2467, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*.
(3) Joints in PVC plastic piping shall be solvent-cemented in accordance with ASTM D2672, *Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement*.

N **15.4.4.4.4 CPVC Plastic Piping.** CPVC plastic piping under 15.4.4.4 shall be in accordance with the following:

(1) CPVC IPS plastic pipe shall be Schedule 40 or Schedule 80, conforming to ASTM F441/F441M, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80*.
(2) CPVC IPS plastic fittings shall be Schedule 40 or Schedule 80 to match the pipe, conforming to ASTM F438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 40*, or ASTM F439, *Standard Specification for Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 80*.
(3) CPVC CTS plastic pipe and fittings ½ in. through 2 in. size shall be SDR 11, conforming to ASTM D2846/D2846M, *Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems*.
(4) Solvent cement for joints in CPVC plastic piping shall comply with ASTM F493, Solvent Cements for CPVC Pipe and Fittings.

Condensation of water will occur in the dental vacuum piping. To avoid accumulation of water in the distribution system, the piping should be sloped towards the dental vacuum supply a minimum of 7 mm per 3.05 m (¼ in. per 10 ft) (the slope is related to water speed). Too much slope and the water will outrun the waste it is carrying, leaving the waste behind to clog the line.

N **15.4.4.5 Piping for Nitrogen.** Nitrogen piping in dental facilities shall comply with 15.4.4.2, including cleaning for oxygen service.

N 15.4.5 Installation of Medical Gas, Dental Air, and Vacuum Piping.

N 15.4.5.1 General.

N **15.4.5.1.1** Gas and vacuum piping systems shall be as listed in Section 15.4.

N **15.4.5.1.2** Piping materials shall be as listed in 15.4.4.

N **15.4.5.2 Pipe Sizing.** Piping systems shall be designed and sized to deliver the required flow rates at the utilization pressures.

N **15.4.5.3 Minimum Pipe Sizes.** The minimum size of the following piping shall be as follows:

(1) Category 2 oxygen piping shall be not less than DN10 (NPS ⅜ in.) (½ in. O.D.) size.
(2) Category 2 nitrous oxide piping shall be not less than DN8 (NPS ¼ in.) (⅜ in. O.D.) size.

N **15.4.5.4 Location of Piping.** Piping shall not be located where subject to contact with oil.

N **15.4.5.5 Protection of Piping.**

There are too many scenarios to list for protection of piping from freezing, corrosion, and physical damage. The most common exposed areas include piping installed underground and piping installed in corridors. Piping underground needs to be protected in a continuous conduit. Piping exposed in a corridor needs to be protected by metal plating or similar protection that will not react with the copper piping. Pipes passing through concrete or cinder walls and floors or other corrosive material need to be protected against external corrosion by a protective sheathing or wrapping or other means that will withstand any reaction from the lime and acid of concrete or other corrosive material. Sheathing or wrapping allows for movement, including expansion and contraction of piping. Pipes that may be exposed to freezing should be fitted with insulation sleeves or wrapping, which slows the heat transfer — the more insulation the better.

N **15.4.5.5.1** Piping shall be protected against freezing, corrosion, and physical damage.

N **15.4.5.5.2** Piping exposed in corridors and other locations where subject to physical damage from the movement of equipment shall be protected.

N **15.4.5.6 Pipe Support.**

N **15.4.5.6.1** Piping shall be supported from the building structure.

The requirement in 15.4.5.6.1 that piping be supported directly from the building structure is meant to preclude the use of ductwork or other piping for support.

N **15.4.5.6.2** Hangers and supports shall comply with and be installed in accordance with MSSSP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation.*

See the commentary following 5.1.10.11.4.2 for additional information on pipe hangers.

N **15.4.5.6.3** Hangers and supports shall be sized for the tube or pipe being supported.

N **15.4.5.6.4** In potentially damp locations, copper tube hangers and supports that are in contact with the tube shall be plastic-coated or otherwise electrically insulated from the tube.

N 15.4.5.6.5 The maximum support spacing for copper tube shall be in accordance with Table 15.4.5.6.5.

N *TABLE 15.4.5.6.5* *Maximum Copper Tube Support Spacing*

	Hanger Spacing	
Pipe Size	***mm***	***ft***
DN8 (NPS ¼) (⅜ in. O.D.)	1520	5
DN10 (NPS ⅜) (½ in. O.D.)	1830	6
DN15 (NPS ½) (⅝ in. O.D.)	1830	6
DN20 (NPS ¾) (⅞ in. O.D.)	2130	7
DN25 (NPS 1) (1⅛ in. O.D.)	2440	8
DN32 (NPS 1¼) (1⅜ in. O.D.)	2740	9
DN40 (NPS 1½) (1⅝ in. O.D.) and larger	3050	10
Vertical risers, all sizes, every floor, but not to exceed	4570	15

N 15.4.5.6.6 The maximum support spacing for plastic pipe shall be in accordance with Table 15.4.5.6.6.

N *TABLE 15.4.5.6.6* *Maximum Plastic Pipe Support Spacing*

	Hanger Spacing	
Pipe Size	***mm***	***ft***
DN15 (NPS ½) (⅝ in. O.D.)	1220	4
DN20 (NPS ¾) (⅞ in. O.D.)	1220	4
DN25 (NPS 1) (1⅛ in. O.D.)	1320	4.33
DN32 (NPS 1¼) (1⅜ in. O.D.)	1320	4.33
DN40 (NPS 1½) (1⅝ in. O.D.)	1420	4.66
DN50 (NPS 2) (2⅜ in. O.D.)	1420	4.66
DN65 (NPS 2½) (2⅞ in. O.D.) and larger	1520	5
Vertical risers, all sizes, every floor, but not to exceed	3040	10

N 15.4.5.7 Underground Piping Outside of Buildings.

The depth of buried pipe depends on such factors as the climatic conditions of the region, the type of traffic anticipated, and the routing of the piping.

N 15.4.5.7.1 Buried piping outside of buildings shall be installed below the local level of frost penetration.

N 15.4.5.7.2 The installation procedure for underground piping shall prevent physical damage to the piping while being backfilled.

N 15.4.5.7.3 If the underground piping is protected by a conduit, cover, or other enclosure, the following requirements shall be met:

(1) Access during construction shall be provided at the joints for visual inspection and leak testing.

(2) The conduit, cover, or enclosure shall be self-draining and not retain groundwater in prolonged contact with copper tubing.

Underground oxygen piping is vulnerable to damage by lightning strikes, ground fault conditions, and soil corrosion. If protection of the underground pipe is warranted, a conduit, cover, or enclosure, normally of metal or plastic material, can be fitted over the entire length of buried piping. Prior to sealing the protective conduit or covers, split openings at 100 percent of the brazed joint areas need to be provided to allow for visual access and leak testing inspections.

Electrical continuity between underground oxygen piping and aboveground piping — or between same-trench piping or between underground piping and other metal structures — should be avoided to prevent cathodic protection problems. Due to the possibility of leaks and the risk of enriched atmosphere, it is preferable to have no flanged or threaded connections on the underground pipeline.

N **15.4.5.7.4** Buried piping that is subject to surface loads shall be buried at a depth that will protect the piping, its enclosure, or both, from excessive stresses.

N **15.4.5.7.5** The minimum backfill cover above the top of the piping or its enclosure shall be 900 mm (36 in.), except that the minimum cover shall be permitted to be reduced to 450 mm (18 in.) where there is no potential for damage from surface loads or surface conditions.

N **15.4.5.7.6** Trenches shall be excavated so that the piping or its enclosure has firm, substantially continuous bearing on the bottom of the trench.

N **15.4.5.7.7** Backfill shall be clean, free from material that can damage the pipe, and compacted.

Pipe trenches should be backfilled with clean earth that is free from large stones, boulders, construction debris, or other materials that could damage or break the piping or cause corrosion. Bulldozers, graders, and the like can be used to complete backfill to grade. Fill needs to be compacted. Suitable precautions must be taken to ensure permanent stability for the pipes in the trench and the ground above the pipes.

Different soil types have differing properties, and they require different construction techniques to ensure optimum performance. Selection and depositing of backfill materials should be done with special reference to the future safety of the pipes.

N **15.4.5.7.8** A continuous warning tape or marker shall be placed immediately above the piping or its enclosure to clearly identify the pipeline by specific name.

N **15.4.5.7.9** A continuous warning means shall also be placed above the pipeline at approximately one-half the depth of burial.

N **15.4.5.7.10** Where buried piping is extended into a building through a wall sleeve, the outdoor end of the sleeve shall be sealed watertight to prevent the entrance of groundwater into the building.

N **15.4.5.8 Underground Piping Within Buildings.**

N **15.4.5.8.1** The installation procedure for underground piping shall prevent physical damage to the piping while being backfilled.

N **15.4.5.8.2** If the underground piping is protected by a conduit, cover, or other enclosure, access shall be provided at the joints during construction for visual inspection and leak testing.

N **15.4.5.8.3** The piping shall be backfilled with clean sand or gravel.

These requirements are unique to dental gas and vacuum systems, recognizing that bringing the piping through the floor in dental facilities is a common practice.

N **15.4.5.9 Piping Within Floor Slabs Prohibited.** Dental gas and vacuum piping shall not be installed within floor slabs.

N **15.4.5.10 Hose and Flexible Connectors.**

N **15.4.5.10.1** 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.

See the commentary following 5.1.10.11.6.1 for additional information regarding hose and flexible connectors.

N **15.4.5.10.2** Hose and flexible connectors, metallic or nonmetallic, shall have a minimum burst gauge pressure of 6895 kPa (1000 psi).

N **15.4.5.10.3** Medical gas hose and flexible connectors shall be oxygen compatible.

N **15.4.5.10.4** Hose and flexible connectors shall be clearly identified as to the gas content.

N **15.4.5.10.5** Hose and flexible connectors for dental medical gases shall be gas-specific and not be permitted to conduct any other gas, gas mixture, or liquid.

N 15.4.6 Brazing Copper Tubing.

N 15.4.6.1 Qualification of Brazing Procedures and Brazers.

This section covers requirements for qualifying a brazer. It is not the field test for determining the integrity of brazed joints in a piped gas or vacuum system. The requirements of this section are complementary to those in ASSE/IAPMO/ANSI 6010, *Professional Qualification Standard for Medical Gas Systems Installers*.

N **15.4.6.1.1** Brazing procedures and brazer performance for the installation of dental piping shall be in accordance with either Section IX, "Welding and Brazing Qualifications," of the ASME Boiler and Pressure Vessel Code, or AWS B2.2/B2.2M, *Standard for Brazing Procedure and Performance Qualification,* both as modified by 15.4.6.

N **15.4.6.1.2** Brazers shall be qualified by visual examination of the test coupons followed by sectioning.

N **15.4.6.1.3** The brazing procedure specification shall address cleaning, joint clearance, overlap, internal purge gas, purge gas flow rate, and filler metal.

N **15.4.6.1.4** The brazing procedure qualification record and the record of brazer performance qualification shall document the filler metal used, cleaning, joint clearance, overlap, internal purge gas and flow rate during brazing of the coupon, and the absence of internal oxidation in the completed coupon.

N **15.4.6.1.5** Brazing procedures qualified by a technically competent group or agency shall be permitted under the following conditions:

(1) The brazing procedure specification and the procedure qualification record meet the requirements of this code.
(2) The employer obtains a copy of both the brazing procedure specification and the supporting qualification record 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.
(3) The employer qualifies at least one brazer following each brazing procedure specification used.

N **15.4.6.1.6** An employer shall be permitted to accept brazer qualification records of a previous employer under the following conditions:

(1) The brazer has been qualified following the same procedure that the new employer uses or an equivalent procedure.
(2) 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.

N **15.4.6.1.7** 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.

N **15.4.6.2 Brazed Joints.**

N **15.4.6.2.1** Brazed tube joints shall be of the socket type.

N **15.4.6.2.2** Brazed joints shall be made using a brazing alloy that exhibits a melting temperature in excess of 538°C (1000°F) to retain the integrity of the piping system in the event of fire exposure.

N **15.4.6.2.3** Filler metals shall bond with and be metallurgically compatible with the base metal being joined.

N **15.4.6.2.4** Filler metals shall comply with ANSI/AWS A5.8M/A5.8, *Specification for Filler Metals for Brazing and Braze Welding*.

N **15.4.6.2.5** Copper-to-copper joints shall be brazed using a copper-phosphorus or copper-phosphorus-silver brazing filler metal (i.e., BCuP series) without flux.

The copper–phosphorus and copper–phosphorus–silver (BCuP series) brazing filler metal is designed to be used with like metals only. The phosphorus within the (BCuP series) brazing rod acts as the flux. On dissimilar metals, a flux must be applied to wet the tube and fitting, as well as to stop oxidation caused by the heat of the torch.

N **15.4.6.2.6** Joints to be brazed in place shall be accessible for necessary preparation, assembly, heating, filler application, cooling, cleaning, and inspection.

N **15.4.6.3 Cutting Tube Ends.**

N **15.4.6.3.1** Tube ends shall be cut square using a sharp tubing cutter to avoid deforming the tube.

N **15.4.6.3.2** The cutting wheels on tubing cutters shall be free from grease, oil, or other lubricants not recommended for oxygen service.

N **15.4.6.3.3** 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.

N **15.4.6.4 Cleaning Joints for Brazing.**

N **15.4.6.4.1** 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.

N **15.4.6.4.2** The exterior surfaces of tube ends shall be cleaned prior to brazing to remove any oxides and surface dirt and to roughen the surfaces to prepare them for brazing.

N **15.4.6.4.3** Nonabrasive pads shall be used to clean the exterior surfaces of tube ends.

N **15.4.6.4.4** The use of steel wool, sand cloth, or wire brushes shall be prohibited.

Steel wool and sand cloth are prohibited from cleaning the exterior ends of tubing because they can scratch tubing and send dust and debris into the pipeline. Scratches can create pockets or barriers that will prevent the filler metals from flowing completely into and evenly distributing around the interior edges of the fitting cup (the area between the tubing and fittings) during the brazing process.

N **15.4.6.4.5** The cleaning process shall not result in grooving the surfaces to be joined.

N **15.4.6.4.6** After being abraded, the surfaces shall be wiped using a clean, lint-free white cloth.

N **15.4.6.4.7** 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.

N **15.4.6.4.8** Material that has become contaminated internally and is not clean for oxygen service shall not be installed.

N **15.4.6.4.9** Joints shall be brazed within 8 hours after being cleaned for brazing.

N **15.4.6.5 Brazing Dissimilar Metals.**

N **15.4.6.5.1** Flux shall only be used when brazing dissimilar metals, such as copper and bronze or brass, using a silver brazing filler metal (i.e., BAg series).

N **15.4.6.5.2** Cast metals shall not be field brazed.

N **15.4.6.5.3** Surfaces shall be cleaned for brazing in accordance with 15.4.6.4.

N **15.4.6.5.4** Flux shall be applied sparingly to minimize contamination of the inside of the tube with flux.

N **15.4.6.5.5** 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.

N **15.4.6.5.6** Where possible, short sections of copper tube shall be brazed onto the noncopper component, and the interior of the subassembly shall be cleaned of flux prior to installation in the piping system.

When brazing dissimilar piping, such as copper to brass or bronze, flux is often used. To eliminate any chance of flux residue remaining inside the tubing and contaminating the pipeline, the dissimilar sections of tubing can be prefabricated and all interior flux residues removed; this allows for a cleaner installation.

N **15.4.6.5.7** On joints DN20 (NPS ¾) (⅞ in. O.D.) size and smaller, flux-coated brazing rods shall be permitted to be used in lieu of applying flux to the surfaces to be joined.

N **15.4.6.6 Nitrogen Purge.**

N **15.4.6.6.1** While being brazed, joints shall be continuously purged with oil-free, dry nitrogen NF to prevent the formation of copper oxide on the inside surface of the joint.

This is important because nitrogen NF is used to remove and replace the air inside the system tubing. The air contains approximately 21 percent oxygen, and during the brazing process it is necessary to remove all oxidizers that can cause the formation of copper oxide scale within the tubing. "Continuously" means uninterrupted in time. In order to purge the tube, the flow of nitrogen NF (purge gas) is directed from one end of the tube, past the joint to be brazed, and out the other end of the tube. Procedures for continuous purge for brazing are found in ASSE 6010, *Professional Qualifications Standard for Medical Gas Systems Installers*.

N **15.4.6.6.2** The source of the nitrogen purge gas shall be monitored, and the installer shall be audibly alerted when the content is low.

The requirement to monitor the source of purge gas reflects a potential problem: If the nitrogen runs out during the brazing operations, there will be no way for the installer to know until it is too late and the quality of the braze is already compromised. The requirement for an audible alert can be met with an automatic device or by having an observer monitor the cylinder(s).

N **15.4.6.6.3** The nitrogen purge gas flow rate shall not be high enough to produce a positive pressure in the piping system.

Too high a flow or pressure may cause the filler metals to not properly flow into and around the coupling and pipeline (fitting cup area) during the brazing process.

N **15.4.6.6.4** The nitrogen purge gas flow shall be controlled by the use of both a pressure regulator and a flowmeter or a combination thereof.

N **15.4.6.6.5** Pressure regulators alone shall not be used to control nitrogen purge gas flow rates.

N **15.4.6.6.6** During and after installation, openings in the piping system shall be kept capped or plugged to maintain a nitrogen atmosphere within the piping and to prevent debris or other contaminants from entering the system.

Openings in the piping system need to be kept sealed to maintain a nitrogen atmosphere inside the pipeline and reduce the possibility of contaminating the pipelines that will carry the gases to patients.

N **15.4.6.6.7** While a joint is being brazed, a discharge opening shall be provided on the opposite side of the joint from where the nitrogen purge gas is being introduced.

N **15.4.6.6.8** The flow of nitrogen purge gas shall be maintained until the joint is cool to the touch.

N **15.4.6.6.9** After the joint has cooled, the purge discharge opening shall be plugged or capped to prevent contamination of the inside of the tube and maintain the nitrogen atmosphere within the piping system.

N **15.4.6.7 Assembling and Heating Brazed Joints.**

See the commentary following 5.1.10.4.6 for additional information on assembling and heating brazed joints.

N **15.4.6.7.1** Tube ends shall be inserted either fully into the depth of the fitting socket or to a mechanically limited depth that is not less than the minimum cup depth (i.e., overlap) specified in ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*.

N **15.4.6.7.2** Where flux is permitted, joints shall be heated slowly until the flux has liquefied.

N **15.4.6.7.3** After flux has 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.

N **15.4.6.7.4** Techniques for heating joints, applying the brazing filler metal, and making the horizontal, vertical, and large-diameter joints shall be as described in sections on applying heat and brazing horizontal and vertical joints in Chapter VIII, "Brazed Joints," in the CDA *Copper Tube Handbook*.

N **15.4.6.8 Inspection of Brazed Joints.**

N **15.4.6.8.1** 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.

N **15.4.6.8.2** Where flux has been used, the wash water shall be hot.

N **15.4.6.8.3** Each joint shall be visually inspected after cleaning the outside surfaces.

After brazing a joint, the outside of the joint must be cleaned by washing with water and a wire brush to remove any residue, and a visual inspection is required. The purpose of a visual inspection is to see whether braze metal has flowed properly. The subsequent leak and pressure tests demonstrate, among other things, that the degree of penetration is adequate for the installation.

N **15.4.6.8.4** Joints exhibiting the following conditions shall not be permitted:

(1) Flux or flux residue (where flux or flux-coated BAg rods are used with dissimilar metals)
(2) Base metal melting or erosion
(3) Unmelted filler metal
(4) Failure of the filler metal to be clearly visible all the way around the joint at the interface between the socket and the tube
(5) Cracks in the tube or component
(6) Cracks in the filler metal
(7) Failure of the joint to hold the test pressure under the installer-performed initial pressure test *(see 15.4.7.4.4)* and standing pressure test *(see 15.4.7.4.6)*

N **15.4.6.8.5** Joints that are identified as defective under conditions specified in 15.4.6.8.4(2) or 15.4.6.8.4(5) shall be replaced.

N **15.4.6.8.6** Joints that are found to be defective under conditions specified in 15.4.6.8.4(1), 15.4.6.8.4(3), 15.4.6.8.4(4), 15.4.6.8.4(6), or 15.4.6.8.4(7) shall be permitted to be repaired, except that no joint shall be reheated more than once before being replaced.

N 15.4.7 Performance Criteria and Testing (Oxygen and Nitrous Oxide).

The initial testing and final testing for all dental USP/NF gas systems installed are nearly identical to the testing conducted on a medical gas and vacuum system (Chapter 5). In a dental gas or vacuum system, the pipeline distribution systems for medical support gas, dental air, and dental vacuum supply for testing of plastic pipeline systems and soft copper tubing require different testing methods as outlined in 15.4.8.

N **15.4.7.1 Testing and Verification.**

N **15.4.7.1.1 General.**

N **15.4.7.1.1.1** Inspection and testing shall be performed on all new piped oxygen and nitrous oxide systems, additions, renovations, temporary installations, or repaired systems to ensure, by a documented procedure, that the following have been completed:

(1) All applicable provisions of this code have been adhered to.
(2) System integrity has been achieved or maintained.
(3) Piping systems are ready for testing and verification.
(4) Piping systems are performing in accordance with their design requirements.

N **15.4.7.1.1.2** The inspection and testing reports shall be submitted directly to the party that contracted for the testing, who shall submit the reports through channels to the responsible authority and any others that are required.

Test reports must be sent directly to the party contracting for the testing; that party will, in turn, distribute copies to the necessary authorities, insurers, and other parties requiring a copy of the report. This procedure reflects the difficulty at times of determining the authorities having jurisdiction for a particular installation and the additional parties that need to receive a copy of the report. The installing contractor should be in a better position to know this than the verifier.

N **15.4.7.1.1.3** Reports shall contain detailed listings of all findings and results.

N **15.4.7.1.1.4** The responsible facility authority shall review the inspection and testing records prior to the use of any systems to ensure that all findings and results of the inspection and testing have been successfully completed before use.

N **15.4.7.1.1.5** All documentation pertaining to inspections and testing shall be maintained onsite within the facility.

N **15.4.7.2 Required Testing and Verification.**

N **15.4.7.2.1 Category 2 Medical Gas Systems (Oxygen and Nitrous Oxide).** All Category 2 oxygen and nitrous oxide piping systems indicated in 15.4.2 shall be initially tested in accordance with 15.4.7.4.

N **15.4.7.2.2** The oxygen and nitrous oxide piping systems shall be verified in accordance with 15.4.7.5.

N **15.4.7.3 Qualification of System Testers and Verifiers (Oxygen and Nitrous Oxide).**

N **15.4.7.3.1** Individuals who perform the initial and final tests of the oxygen and nitrous oxide piping systems shall be certified to ASSE 6010, *Professional Qualifications Standard for Medical Gas Systems Installers,* or verifiers who comply with 15.4.7.3.2.

N **15.4.7.3.2** Individuals who verify the oxygen and nitrous oxide piping systems shall be certified to ASSE 6030, *Professional Qualifications Standard for Medical Gas Systems Verifiers*.

N **15.4.7.4 Initial Testing of Piping Systems (Oxygen and Nitrous Oxide).**

N **15.4.7.4.1 General.**

N **15.4.7.4.1.1** The initial tests required by 15.4.7.4 shall be performed prior to either the final tests or the verification tests listed in 15.4.7.5.

N **15.4.7.4.1.2** The test gas for gas piping systems shall be oil-free, dry nitrogen NF.

N **15.4.7.4.1.3** Where manufactured assemblies are to be installed, the initial tests required by 15.4.7.4 shall be performed as follows:

(1) After completion of the distribution piping but before the standing pressure test
(2) Prior to installation of manufactured assemblies supplied through flexible hose or flexible tubing
(3) For all station outlets/inlets on installed manufactured assemblies supplied through copper tubing

N **15.4.7.4.1.4** Where plastic vacuum and plastic scavenging piping systems are installed, they shall be visually inspected for cross-connections to positive-pressure systems before applying positive test pressures to the copper piping systems.

N **15.4.7.4.1.5** Where brazed joints in copper tubing are found to be defective, they shall be repaired if permitted by 15.4.6.8.6 or replaced if required by 15.4.6.8.5, and retested. The piping shall be repurged if necessary.

N **15.4.7.4.1.6** During the process of initial testing, the identification and labeling of the medical gas and vacuum piping shall be checked.

N **15.4.7.4.2 Initial Piping Blowdown (Oxygen and Nitrous Oxide).** Piping in dental air 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, and source equipment).

N **15.4.7.4.3 Initial Cross-Connection Test for Copper Piping Systems.**

N **15.4.7.4.3.1** Copper piping shall not be tested before any plastic piping.

N **15.4.7.4.3.2** It shall be determined that no cross-connections exist between the various medical gas and vacuum piping systems.

N **15.4.7.4.3.3** All piping systems shall be reduced to atmospheric pressure.

N **15.4.7.4.3.4** Sources of test gas shall be disconnected from all piping systems except for the one system being tested.

N **15.4.7.4.3.5** The system under test shall be charged with oil-free, dry nitrogen NF to a gauge pressure of 345 kPa (50 psi).

N **15.4.7.4.3.6** 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 dispensed only from the piping system tested.

N **15.4.7.4.3.7** The initial cross-connection test in 15.4.7.4.3 shall be repeated for each installed medical gas and vacuum piping system with copper piping.

N **15.4.7.4.3.8** Any cross-connections shall be removed and the associated piping repaired and leak tested.

N **15.4.7.4.3.9** The proper labeling and identification of system outlets/inlets shall be confirmed during these tests.

N **15.4.7.4.4 Initial Pressure Test.**

Pressure testing is conducted as a means to find leaks. Leaks not only represent a fire hazard, they are also considered by many to pose significant health risks. Excessive exposure of staff to gases such as nitrous oxide has reportedly been linked to diseases. Financially, leaks represent waste.

N **15.4.7.4.4.1** 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.

N **15.4.7.4.4.2** Initial pressure tests shall be conducted as follows:

(1) After blowdown of the distribution piping
(2) After installation of station outlet/inlet rough-in assemblies
(3) 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)

N **15.4.7.4.4.3** The source shutoff valve shall remain closed during the pressure tests.

N **15.4.7.4.4.4** 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 1035 kPa (150 psi).

N **15.4.7.4.4.5*** 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.

N **A.15.4.7.4.4.5** Ammonia is known to cause stress cracking in copper and its alloys.

Ammonia-containing leak test solutions are prohibited because ammonia can attack copper and brass and physically weaken the materials.

N **15.4.7.4.4.6** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested.

See also 15.4.6.8.6, which specifies those joints that can be repaired.

N **15.4.7.4.5 Initial Piping Purge Test.**

See the commentary within 5.1.12.2.5 for additional information on the initial piping purge test.

N **15.4.7.4.5.1** The outlets in each oxygen and nitrous oxide piping system shall be purged to remove any particulate matter from the distribution piping.

N **15.4.7.4.5.2** 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.

N **15.4.7.4.5.3** The purging shall be started at the closest outlet to the piping shutoff valve and continue to the furthest outlet from the shutoff valve.

N **15.4.7.4.6 Standing Pressure Test for Oxygen and Nitrous Oxide Piping.**

N **15.4.7.4.6.1** After successful completion of the initial pressure tests in 15.4.7.4.4, the gas distribution piping shall be subject to a standing pressure test.

N **15.4.7.4.6.2** 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).

N **15.4.7.4.6.3** The source valve shall be closed during this test.

N **15.4.7.4.6.4** The piping systems shall be subjected to 24-hour standing pressure tests using oil-free, dry nitrogen NF.

N **15.4.7.4.6.5** Test pressures shall be 20 percent above the normal system operating line pressure.

N **15.4.7.4.6.6** At the conclusion of the tests, there shall be no change in the test pressure except that attributed to specific changes in ambient temperature.

N **15.4.7.4.6.7** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested. The piping shall be repurged if necessary.

N **15.4.7.4.6.8** The 24-hour standing pressure tests shall be witnessed by the authority having jurisdiction or its designee. A form indicating that these tests have been performed and witnessed shall be provided to the verifier at the start of the verification tests in 15.4.7.5.

This procedural requirement emphasizes that the verifier will normally not witness the installer tests but mandates that someone is required to do so. That person must be determined by the authority having jurisdiction.

N **15.4.7.5 Verification of Piping Systems (Oxygen and Nitrous Oxide).**

N **15.4.7.5.1 General.**

N **15.4.7.5.1.1** The oxygen and nitrous oxide piping systems requiring initial testing and verification shall be as indicated in 15.4.7.2 for the different dental facilities.

N **15.4.7.5.1.2** Required verification of oxygen and nitrous oxide piping systems shall be performed only after all initial tests required in 15.4.7.4 have been completed.

N **15.4.7.5.1.3** The test gas shall be oil-free, dry nitrogen NF or the system gas or vacuum where permitted.

N **15.4.7.5.1.4** Verification shall be conducted by a party technically competent and experienced in the field of medical gas and vacuum piping system testing and certified for ASSE 6030, *Professional Qualifications Standard for Medical Gas Systems Verifiers*.

N **15.4.7.5.1.5** Verification shall be performed by a party other than the installing contractor.

N **15.4.7.5.1.6** All required verification tests shall be performed after installation of any manufactured assemblies supplied through tubing or flexible hose.

N **15.4.7.5.1.7** Where there are multiple possible connection points for terminals, each possible position shall be tested independently.

This requirement recognizes that some manufactured assemblies are built with multiple connection points to enhance future flexibility in outlet location and for other reasons, but that each of these connectors must represent a separate termination of the medical gas piping. The user is warned that these connection points are frequently hidden behind panels or other finishing trim, and the trim might need to be removed to accomplish this testing.

N **15.4.7.5.1.8** Where brazed joints in copper tubing are found to be defective, they shall be repaired if permitted by 15.4.6.8.6 or replaced if required by 15.4.6.8.5, and retested. The piping shall be repurged if necessary.

N **15.4.7.5.1.9** During the process of verification, the presence and proper labeling of source equipment, station outlets/inlets, zone valve boxes, shutoff valves, and alarms shall be checked.

N **15.4.7.5.2 Verifier Standing Pressure Test.** Oxygen and nitrous oxide piping systems requiring verification shall be subjected to a 10-minute standing pressure test at operating line pressure using the following procedure:

(1) After the system is filled with nitrogen or the source gas, the source valve shall be closed.
(2) The piping system shall show no decrease in pressure after not less than 10 minutes.
(3) Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested.

This is the final pressure test of the completely installed system and is intended to locate any leaks that would be more likely to occur at lower pressure (e.g., leaks in station outlet valve seals).

N **15.4.7.5.3 Verifier Cross-Connection Test.** The piping systems shall be tested for cross-connections between the systems using the following procedure:

(1) All medical gas and vacuum piping systems shall be reduced to atmospheric pressure.
(2) All sources of test gas for all of the gas and vacuum systems, with the exception of the one system to be checked, shall be disconnected.
(3) The system being checked shall be pressurized to a gauge pressure of 345 kPa (50 psi).
(4) With adapters matching outlet labels, each individual station outlet/inlet of all medical gas and vacuum systems installed shall be checked to determine that test gas is dispensed only from the outlets/inlets of the piping system being tested.
(5) The source of test gas shall be disconnected, and the system that was tested reduced to atmospheric pressure.
(6) Each additional piping system shall be tested until all gas and vacuum piping systems requiring verification are free of cross-connections.
(7) Any cross-connections shall be removed and the associated piping repaired and tested for leaks.

N **15.4.7.5.4 Verifier Piping Purge Test.**

The piping purge test conducted by the verifier is conducted after all the distribution system components (such as outlet faceplates, pressure alarm devices, pressure indicators, and line pressure relief valves) are installed. The initial piping purge test conducted by the installer is conducted with the outlet faceplates attached but prior to other distribution components being attached. This test is considered the final piping purge test and, for a verifier, this test is one element of the verification process to confirm whether the medical gas pipelines are free of visual particulates.

N **15.4.7.5.4.1** To remove any traces of particulate matter deposited in the oxygen and nitrous oxide piping during construction, a heavy, intermittent purging of the piping shall be done.

N **15.4.7.5.4.2** The appropriate adapter shall be obtained and high purge rates of at least 225 Nl/min (8 SCFM) shall be put on each outlet.

N **15.4.7.5.4.3** After each purge is started, it shall be rapidly interrupted several times until the purge produces no discoloration in a white cloth loosely held over the adapter during the purge.

N **15.4.7.5.4.4** To avoid possible damage to the outlet and its components, this test shall not be conducted using any implement other than the proper adapter.

N **15.4.7.5.4.5** No pronounced or objectionable odor shall be discernible from any positive pressure outlet.

The requirement that a verifier check for odor was added to the 2015 edition of NFPA 99. Odors can be a sign that tubing plugs were brazed into the system during installation. Odor is subjective, and there is no specific test to determine if an odor is present or when it becomes pronounced or objectionable.

The presence of a strong odor can indicate problems that other testing might not identify. Detecting an objectionable odor in the verification of a system is preferable to finding these problems further down the line. It can save time and money and support patient safety.

N 15.4.7.5.5 Verifier Piping Particulate Test.

The intent of testing is to verify the cleanliness of the tubing. All the requirements for the installation of the medical gas and vacuum system equipment and for the materials, techniques, and procedures are designed to ensure that the piping system does not add contamination to the medical gas and vacuum system beyond the limits in this code.

N 15.4.7.5.5.1 For each oxygen and nitrous oxide system, the cleanliness of the piping system shall be verified.

N 15.4.7.5.5.2 The test shall be performed with the use of oil-free, dry nitrogen NF.

N 15.4.7.5.5.3 A minimum of 1000 L (35 ft^3) of gas shall be filtered through a clean, white 0.45 micron filter at a minimum flow rate of 100 Nl/min (3.5 SCFM).

N 15.4.7.5.5.4 Twenty five percent of the zones shall be tested at the outlet most remote from the source.

N 15.4.7.5.5.5 The filter shall accrue no more than 0.001 g (1 mg) of matter from any outlet tested.

N 15.4.7.5.5.6 If any outlet fails this test, the most remote outlet in every zone shall be tested.

N 15.4.7.5.6 Verifier Piping Purity Test.

The intent of the piping purity test conducted by the verifier is to check the cleanliness of the tubing. This is done by comparison tests between the test gas used (nitrogen NF or the source gas) and the test port for added moisture (DP), added total non-methane hydrocarbons (THC), and added halogenated hydrocarbons (HHC). See the commentary following 5.1.12.4.8.1 for additional information.

N 15.4.7.5.6.1 For each oxygen and nitrous oxide system, the purity of the piping system shall be verified in accordance with 15.4.7.5.6.

N 15.4.7.5.6.2 These tests shall be performed with oil-free, dry nitrogen NF or the system gas.

N 15.4.7.5.6.3 The outlet most remote from the source shall be tested for total nonmethane hydrocarbons and compared to the test of the source gas.

N 15.4.7.5.6.4 If the system gas is used as the source gas, it shall be tested at the source equipment.

N 15.4.7.5.6.5 The difference between the two tests shall in no case exceed 5 ppm of total non-methane hydrocarbons.

N 15.4.7.5.6.6 The difference between the two tests shall in no case exceed 5 ppm of halogenated hydrocarbons.

N 15.4.7.5.6.7 The moisture concentration of the outlet test shall not exceed 500 ppm or an equivalent pressure dew point of −12°C (10°F) at a gauge pressure of 345 kPa (50 psi).

N 15.4.7.5.7 Verifier Final Tie-in Test.

See the commentary following 5.1.12.4.9 for additional information on the verifier final tie-in test.

N **15.4.7.5.7.1** Prior to the connection of any work or any extension or addition to an existing piping system, the verification tests in 15.4.7.5 shall be successfully performed on the new work.

N **15.4.7.5.7.2** 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.

N **15.4.7.5.7.3** For oxygen and nitrous oxide, 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 15.4.7.5.4.

N **15.4.7.5.7.4** Before the new work is used for patient care, oxygen and nitrous oxide shall be tested for operational pressure and gas concentration in accordance with 15.4.7.5.8 and 15.4.7.5.9.

N **15.4.7.5.7.5** Permanent records of these tests shall be maintained.

N **15.4.7.5.8 Verifier Operational Pressure Test.**

The operational flow test is conducted on the medical gas and vacuum system to confirm that the gas and vacuum is delivered at the operating pressure and flow required for proper patient care. See the commentary following 5.1.12.4.10 for additional information on the operational flow pressure drop test.

N **15.4.7.5.8.1** Operational pressure tests shall be performed at each station outlet or terminal where the user makes connections and disconnections.

N **15.4.7.5.8.2** Tests shall be performed with the gas of system designation.

N **15.4.7.5.8.3** All medical gas outlets with a gauge pressure of 345 kPa (50 psi), including oxygen and nitrous oxide, shall deliver 50 SLPM (1.8 SCFM) with a pressure drop of not more than 35 kPa (5 psi) and static pressure of 345 kPa to 380 kPa (50 psi to 55 psi).

N **15.4.7.5.9 Verifier Gas Concentration Test.**

The gas concentration test is necessary to ensure that the medical gas being distributed through the pipeline is safe for patient care. The intent of the analysis is to make sure that the right gas goes to the right outlet, and it also acts as an additional cross-connection test. See the commentary following 5.1.12.4.11 for additional information on this test.

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

(1) Each pressure gas source and outlet shall be analyzed for concentration of gas, by volume.
(2) Analysis shall be conducted with instruments designed to measure the specific gas dispensed.
(3) Allowable concentrations shall be as follows:
    (a) Oxygen ≥99 percent
    (b) Nitrous oxide ≥99 percent
    (c) Other gases ±1 percent unless otherwise specified

N 15.4.8 Performance Criteria and Testing (Dental Air and Vacuum).

While the initial testing and final testing for dental USP/NF gas systems installed are nearly identical to the testing conducted on a medical gas and vacuum system (Chapter 5), in a dental gas or vacuum

system, the pipeline distribution systems for medical support gas, dental air, and dental vacuum supply for testing of plastic pipeline systems and soft copper tubing require different testing methods as outlined in the following sections.

N **15.4.8.1 Dental Air and Vacuum Systems Testing.**

N **15.4.8.1.1 General.**

N **15.4.8.1.1.1** Inspection and testing shall be performed on all new piped dental gas and vacuum systems, additions, renovations, temporary installations, or repaired systems to ensure, by a documented procedure, that the following have been completed:

(1) All applicable provisions of this code have been adhered to.
(2) System integrity has been achieved or maintained.
(3) Piping systems are ready for testing and verification.
(4) Piping systems are performing in accordance with their design requirements.

N **15.4.8.1.1.2** The inspection and testing reports shall be submitted directly to the party that contracted for the testing, who shall submit the reports through channels to the responsible authority and any others that are required.

N **15.4.8.1.1.3** Reports shall contain detailed listings of all findings and results.

N **15.4.8.1.1.4** The responsible facility authority shall review the inspection and testing records prior to the use of any systems to ensure that all findings and results of the inspection and testing have been successfully completed before use.

N **15.4.8.1.1.5** All documentation pertaining to inspections and testing shall be maintained on-site within the facility.

N **15.4.8.1.2 Category 2 Dental Air and Vacuum Systems.**

N **15.4.8.1.2.1** All Category 2 dental gas and vacuum piping systems indicated in 15.4.3 shall be initially tested in accordance with 15.4.8.1.

N **15.4.8.1.2.2** The support gas systems and vacuum systems (i.e., dental air, dental vacuum, and scavenging) shall be final tested in accordance with 15.4.8.1.7 and 15.4.8.1.8.

N **15.4.8.1.3 Initial Testing of Piping Systems.**

N **15.4.8.1.3.1 General.**

N **(A)** Where plastic vacuum and plastic scavenging piping systems are installed, they shall be visually inspected for cross-connections to oxygen and nitrous oxide systems before applying positive test pressures to the copper piping systems.

N **(B)** During the process of initial testing, the identification and labeling of the dental gas and vacuum piping shall be checked.

N **15.4.8.1.4 Initial Cross-Connection Test for Plastic Vacuum and Plastic Scavenging Piping Systems.**

N **15.4.8.1.4.1** Plastic piping shall be tested before copper piping.

N **15.4.8.1.4.2** Tests shall be conducted to determine that no cross-connections exist between any plastic vacuum piping systems or plastic scavenging piping systems and any copper piping systems.

N **15.4.8.1.4.3** The vacuum or scavenging source shutoff valves for the vacuum or scavenging piping systems shall remain closed during the tests, unless they are being used for the cross-connection test vacuum source.

N **15.4.8.1.4.4** The cross-connection test vacuum shall be a minimum of 300 mm (12 in.) HgV.

N **15.4.8.1.4.5** The source of test vacuum shall be connected only to the vacuum or scavenging piping system being tested.

N **15.4.8.1.4.6** All individual gas system outlets and vacuum or scavenging system inlets shall be checked to determine that the test vacuum is only present in the vacuum or scavenging piping system being tested.

N **15.4.8.1.4.7** The cross-connection tests shall be repeated for each installed vacuum and scavenging system with plastic piping.

N **15.4.8.1.4.8** Any cross-connections shall be removed and the associated piping repaired and leak tested.

N **15.4.8.1.4.9** The proper labeling and identification of system outlets/inlets shall be confirmed during the initial tests.

N **15.4.8.1.5 Initial Pressure Test.**

N **15.4.8.1.5.1** Each section of the piping in dental air systems and copper vacuum systems shall be pressure tested. Plastic vacuum and plastic scavenging piping shall not be pressure tested.

N **15.4.8.1.5.2** Initial pressure tests shall be conducted as follows:

(1) After installation of station outlet/inlet rough-in assemblies
(2) 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)

N **15.4.8.1.5.3** The source shutoff valve shall remain closed during the pressure tests.

N **15.4.8.1.5.4** The test pressure for dental air piping and copper vacuum piping shall be 1.5 times the system operating pressure but not less than a gauge pressure of 1035 kPa (150 psi).

N **15.4.8.1.5.5** 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.

N **15.4.8.1.5.6** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested.

N **15.4.8.1.6 Initial Piping Purge Test.**

N **15.4.8.1.6.1** The outlets in each dental air piping system shall be purged to remove any particulate matter from the distribution piping.

N **15.4.8.1.6.2** 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.

N **15.4.8.1.6.3** The purging shall be started at the closest outlet to the piping shutoff valve and continue to the furthest outlet from the shutoff valve.

N **15.4.8.1.7 Standing Pressure Test for Dental Air and Copper Vacuum Piping.**

N **15.4.8.1.7.1** After successful completion of the initial pressure tests in 15.4.8.1, the dental air systems and copper vacuum systems shall be subject to a standing pressure test.

N **15.4.8.1.7.2** 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).

N **15.4.8.1.7.3** The source valve shall be closed during this test.

N **15.4.8.1.7.4** The piping systems shall be subjected to 24-hour standing pressure tests using oil-free, dry nitrogen NF.

N **15.4.8.1.7.5** Test pressures shall be 20 percent above the normal system operating line pressure.

N **15.4.8.1.7.6** At the conclusion of the tests, there shall be no change in the test pressure, except that attributed to specific changes in ambient temperature.

N **15.4.8.1.7.7** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested. The piping shall be repurged if necessary.

N **15.4.8.1.8 Standing Vacuum Test for Plastic Vacuum Piping.**

N **15.4.8.1.8.1** After successful completion of the initial pressure tests in 15.4.8.1, vacuum distribution piping, including scavenging, shall be subjected to a standing vacuum test.

N **15.4.8.1.8.2** Tests shall be conducted after installation and connection of all components of the vacuum system.

N **15.4.8.1.8.3** The piping systems shall be subjected to a 24-hour standing vacuum test.

N **15.4.8.1.8.4** Test pressure shall be between 300 mm (12 in.) HgV and full vacuum.

N **15.4.8.1.8.5** During the test, the source of test vacuum shall be disconnected from the piping system.

N **15.4.8.1.8.6** At the conclusion of the test, there shall be no change in the vacuum pressure other than that attributed to changes of ambient temperature.

N **15.4.8.1.8.7** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested.

N 15.4.9 Operation and Management.

The requirements for operation and management of dental gas and vacuum systems are intended to be applied to existing facilities.

N **15.4.9.1 System Shutdowns.**

N **15.4.9.1.1** Gas and vacuum piping systems shall be shut down at the end of each workday.

N **15.4.9.1.2** Emergency shutoff valves or remote actuators shall not be used for daily shutdown of the systems. Cylinder gas valves shall be used for daily shutdowns.

N **15.4.9.2 Prohibited Interconnections.** Two or more piping systems for different gases or different vacuums shall not be interconnected for testing or any other reason.

The intent of this section is to address the problem created if a temporary connection for pressure testing or purging is not removed. To avoid this problem, interconnection even on a temporary basis is prohibited. An exception in 5.1.10.11.7.2 was new to the 2015 edition and permits the interconnection of systems of the same contents with an in-line valve. This could be useful in situations where a large facility has two separate areas supplied by two source systems; the two systems could be connected with an in-line valve that is normally closed, and each source supply could serve as an additional redundancy to the other system if needed. This would not eliminate the need for secondary supplies for each individual system, since the general rules for source systems would still apply to each source system. Even though that same exception is not found in Chapter 15, it is logical to assume that the same logic applies to the intent of the prohibition of interconnections.

N 15.4.9.3 Manufacturer's Instructions.

N 15.4.9.3.1 Piping system components shall be installed, adjusted, operated, and maintained in accordance with the manufacturer's instructions.

N 15.4.9.3.2 Copies of the manufacturer's instructions shall be provided to the facility and maintained at the facility.

N 15.4.9.4 Maintenance.

Any facility with a preventive maintenance program for its medical gas systems should already have lists and schedules that will meet these requirements. NFPA 99 allows the facility latitude in how it meets these requirements. It is not expected that the facility repeat the tests required for a new piping system, and it is not expected that the same testing techniques and methods need to be employed. No schedules are provided, which allows the facility to determine the frequency of maintenance based on the original quality, age, longevity, and known characteristics of the equipment it uses.

N 15.4.9.4.1 Gas and vacuum system equipment shall be maintained by a qualified person.

N 15.4.9.4.2 Every facility shall establish a procedure for manually turning off the gas supply at the cylinder valves of Category 2 dental gas and vacuum systems at the end of each day.

N 15.4.9.5 Periodic Testing.

N 15.4.9.5.1 Station outlets for oxygen and nitrous oxide shall be tested for flow and pressure on an approved schedule.

N 15.5 Category 3 Dental Gas and Vacuum Systems.

Requirements outlined under Section 15.5 are designed for dental, oral, and maxillofacial facilities that intend to administer only minimal sedation or no sedation at all. Failure of systems in this category will have no impact on patient care. These facilities have no medical gases. The application of this category must be determined solely by the level of sedation defined in Chapter 3 and not by the procedure being performed.

N 15.5.1 General.

N 15.5.1.1 Category 3 dental gas and vacuum systems shall be limited to facilities that perform minimal or no sedation.

N 15.5.1.2 There shall be no medical gases.

N 15.5.1.3 The dental support gases shall be provided from a dental air source system.

N 15.5.1.4 The vacuum system shall be dental vacuum.

As specified in 15.5.1.1, Category 3 systems are only installed in facilities in which minimal sedation is the maximum level of anesthesia/sedation that patients will be subjected to. Therefore, no medical gases should be needed, and these sections address only dental air source systems and dental vacuum systems.

N 15.5.2 Category 3 Dental Air and Vacuum Piping Systems.

N 15.5.2.1 General. Dental air and vacuum piping systems shall include dental support gases and dental vacuum systems.

N **15.5.2.2 Vacuum Systems.** Dental vacuum systems shall include dental vacuum and nitrous oxide scavenging.

N 15.5.3 Equipment Locations for Dental Air and Vacuum Systems.

N **15.5.3.1 General.** Any of the following systems shall be permitted to be located together in the same room:

(1) Dental air compressor sources and reserve headers
(2) Dental vacuum sources
(3) Any other compressor, vacuum pump, or electrically powered machinery

N **15.5.3.2 Cylinders and Containers.** Cylinders and containers for gases shall be handled in accordance with Chapter 11.

N **15.5.3.3 Ventilation for Motor-Driven Equipment.** The following source locations shall be adequately ventilated to prevent accumulation of heat:

(1) Dental compressed air sources
(2) Dental vacuum sources

N 15.5.4 Dental Gas and Vacuum Source Equipment.

N **15.5.4.1 General.**

N **15.5.4.1.1** The capacity of source equipment shall be based on the design requirements for the facility, including the number of gas outlets, vacuum inlets, and other connections, and their individual capacities.

N **15.5.4.1.2** The system design requirements shall be included in the data used for testing and verifying the operation of the gas and vacuum piping systems.

N **15.5.4.2 Dental Air.**

N **15.5.4.2.1 General.**

N **15.5.4.2.1.1** Dental air shall be used as a support gas for driving dental tools and shall be permitted to be used to supply air-driven equipment. Dental compressed air shall not be used for respiration.

This requirement limits the application of dental air to driving dental tools and supplying air-driven equipment. In no way can dental air be used for respiration purposes.

N **15.5.4.2.1.2** Dental air outlets shall not be interchangeable with any other gas outlets, including oxygen, nitrous oxide, medical air, instrument air, and nitrogen.

N **15.5.4.2.2 Dental Air Compressor Units.**

N **15.5.4.2.2.1** Dental air compressor units shall include dental air compressors, vibration isolation, air receivers, coalescent air filters, adsorption dryers, exhaust silencer/filters, moisture indicators, and service access manifolds, electrical disconnects, motor wiring, and controls.

N **15.5.4.2.2.2** Air compressors shall be scroll dental, reciprocating dental, or the oil-free dental types.

N **15.5.4.3 Dental Vacuum.**

N **15.5.4.3.1 General.**

N **15.5.4.3.1.1** Dental vacuum shall be used for oral evacuation and nitrous oxide scavenging.

N **15.5.4.3.1.2** Dental vacuum inlets shall not be interchangeable with any other vacuum inlets, including dental-surgical vacuum.

N **15.5.4.3.2 Dental Vacuum Units.**

N **15.5.4.3.2.1** Dental vacuum units shall include dental vacuum pumps, vibration isolation, separation tanks, vacuum inlet, vacuum exhaust, condensate drain, motor wiring, and controls.

N **15.5.4.3.2.2** Dental vacuum pumps shall be dental dry vacuum or dental liquid (wet) ring pumps. Pumps shall be oil-free or oil-lubricated and suitable for nitrous oxide scavenging.

N **15.5.5 Piping for Category 3 Dental Gas and Vacuum Systems.**

N **15.5.5.1 General.**

N **15.5.5.1.1** Piping for dental air systems shall comply with 15.5.5.2.

N **15.5.5.1.2** Piping for dental vacuum systems and scavenging systems shall comply with 15.5.5.3.

N **15.5.5.2 Piping for Dental Air Systems.**

N **15.5.5.2.1 General.** Pipe, fittings, and joints in piping for dental compressed air systems shall be in accordance with 15.5.5.2.2 through 15.5.5.2.4.

N **15.5.5.2.2 Pipe.** Pipe under 15.5.5 shall comply with the following:

(1) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems, Type L or K*.
(2) ASTM B88, *Standard Specification for Seamless Copper Water Tube, Type L or K*.
(3) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, ACR tube (O.D. size).

N **15.5.5.2.2.1** Copper tube shall be hard temper or annealed (soft temper).

N **15.5.5.2.3 Fittings.** Fittings for piping under 15.5.5.2 shall be permitted to be any of the following acceptable joining methods:

(1) Brazed or soldered fittings conforming to ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) Brazed fittings conforming to ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) Brazed fittings conforming to ASME B16.22 with socket depths equal to or greater than braze-joint pressure fittings in compliance with ANSI/ASME B16.50
(4) Flared fittings conforming to ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*
(5) Compression fittings (¾ in. maximum size)

N **15.5.5.2.4 Joints.** Joints for piping under 15.5.5.2 shall comply with the following:

(1) Joints shall be brazed, soldered, threaded, flared, or the compression type.
(2) Where joints are brazed, they shall comply with the requirements of 15.4.6.
(3) Soldered joints shall be made in accordance with ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, using a "lead-free" solder filler metal containing not more than 0.2 percent lead by volume that complies with ASTM B32, *Standard Specification for Solder Metal*.

N **15.5.5.3 Piping for Dental Vacuum Systems and Scavenging Systems.**

N **15.5.5.3.1 General.** Piping for dental vacuum systems and scavenging systems shall be copper, PVC plastic, or CPVC plastic.

N **15.5.5.3.2 Copper Piping.** Copper piping under 15.5.5.3 shall be in accordance with 15.5.5.3.2.1 through 15.5.5.3.2.3.

N **15.5.5.3.2.1 Copper Tube.**

(A) Copper tubing shall comply with the following:

(1) ASTM B819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*, Type L or K
(2) ASTM B88, *Standard Specification for Seamless Copper Water Tube*, Type L or K
(3) ASTM B280, *Standard Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*, ACR tube (O.D. size)

(B) Copper tube shall be hard temper or annealed (soft temper).

N **15.5.5.3.2.2 Copper Fittings.** Copper fittings shall comply with the following:

(1) Brazed or soldered fittings conforming to ASME B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*
(2) Brazed fittings conforming to ANSI/ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*
(3) Brazed fittings conforming to ASME B16.22 with socket depths equal to or greater than braze-joint pressure fittings conforming to ANSI/ASME B16.50
(4) Flared fittings conforming to ASME B16.26, *Cast Copper Alloy Fittings for Flared Copper Tubes*
(5) Compression fittings (¾ in. maximum size)

N **15.5.5.3.2.3 Joints for Copper Piping.** Joints in copper tubing shall be in accordance with the following:

(1) Joints shall be brazed, soldered, threaded, flared, or the compression type.
(2) Where joints are brazed, they shall comply with the requirements of 15.4.6.
(3) Soldered joints shall be made in accordance with ASTM B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*, using a "lead-free" solder filler metal containing not more than 0.2 percent lead by volume that complies with ASTM B32, *Standard Specification for Solder Metal*.

N **15.5.5.3.3 PVC Plastic Piping.** PVC plastic piping under 15.5.5.3 shall be in accordance with the following:

(1) PVC plastic pipe shall be Schedule 40 or Schedule 80, conforming to ASTM D1785, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120*.
(2) PVC plastic fittings shall be Schedule 40 or Schedule 80 to match the pipe, conforming to ASTM D2466, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40*, or ASTM D2467, *Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*.
(3) Joints in PVC plastic piping shall be solvent-cemented in accordance with ASTM D2672, *Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement*.

N **15.5.5.3.4 CPVC Plastic Piping.** CPVC plastic piping under 15.5.5.3 shall be in accordance with the following:

(1) CPVC IPS plastic pipe shall be Schedule 40 or Schedule 80, conforming to ASTM F441/F441M, *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80*.
(2) CPVC IPS plastic fittings shall be Schedule 40 or Schedule 80 to match the pipe, conforming to ASTM F438, *Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 40*, or ASTM F439, *Standard*

Specification for Chlorinated Poly (Vinyl Chlorinated) (CPVC) Plastic Pipe Fittings, Schedule 80.

(3) CPVC CTS plastic pipe and fittings ½ in. through 2 in. size shall be SDR 11, conforming to ASTM D2846/D2846M, *Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems*.

(4) Solvent cement for joints in CPVC plastic piping shall comply with ASTM F493, *Solvent Cements for CPVC Pipe and Fittings*.

N 15.5.6 Installation of Dental Air and Vacuum Piping.

N 15.5.6.1 General.

N 15.5.6.1.1 Dental air and vacuum piping systems shall be as listed in Section 15.5.2.

N 15.5.6.1.2 Piping materials shall be as listed in Section 15.5.5.

N 15.5.6.2 Pipe Sizing. Piping systems shall be designed and sized to deliver the required flow rates at the utilization pressures.

N 15.5.6.3 Protection of Piping.

N 15.5.6.3.1 Piping shall be protected against freezing, corrosion, and physical damage.

N 15.5.6.3.2 Piping exposed in corridors and other locations where subject to physical damage from the movement of equipment shall be protected.

N 15.5.6.4 Pipe Support.

N 15.5.6.4.1 Piping shall be supported from the building structure.

N 15.5.6.4.2 Hangers and supports shall comply with and be installed in accordance with MSS SP-58, *Pipe Hangers and Supports — Materials, Design, Manufacture, Selection, Application, and Installation*.

N 15.5.6.4.3 Hangers and supports shall be sized for the tube or pipe being supported.

N 15.5.6.4.4 The maximum support spacing for copper tube shall be in accordance with Table 15.5.6.4.4.

N *TABLE 15.5.6.4.4* *Maximum Copper Tube Support Spacing*

	Hanger Spacing	
Pipe Size	***mm***	***ft***
DN8 (NPS ¼) (⅜ in. O.D.)	1520	5
DN10 (NPS ⅜) (½ in. O.D.)	1830	6
DN15 (NPS ½) (⅝ in. O.D.)	1830	6
DN20 (NPS ¾) (⅞ in. O.D.)	2130	7
DN25 (NPS 1) (1⅛ in. O.D.)	2440	8
DN32 (NPS 1¼) (1⅜ in. O.D.)	2740	9
DN40 (NPS 1½) (1⅝ in. O.D.) and larger	3050	10
Vertical risers, all sizes, every floor, but not to exceed	4570	15

N 15.5.6.4.5 The maximum support spacing for plastic pipe shall be in accordance with Table 15.5.6.4.5.

N ***TABLE 15.5.6.4.5*** *Maximum Plastic Pipe Support Spacing*

	Hanger Spacing	
Pipe Size	***mm***	***ft***
DN15 (NPS ½) (⅝ in. O.D.)	1220	4
DN20 (NPS ¾) (⅞ in. O.D.)	1220	4
DN25 (NPS 1) (1⅛ in. O.D.)	1320	4.33
DN32 (NPS 1¼) (1⅜ in. O.D.)	1320	4.33
DN40 (NPS 1½) (1⅝ in. O.D.)	1420	4.66
DN50 (NPS 2) (2⅜ in. O.D.)	1420	4.66
DN65 (NPS 2½) (2⅞ in. O.D.) and larger	1520	5
Vertical risers, all sizes, every floor, but not to exceed	3040	10

N **15.5.6.5 Underground Piping Outside of Buildings.**

N **15.5.6.5.1** Buried piping outside of buildings shall be installed below the local level of frost penetration.

N **15.5.6.5.2** The installation procedure for underground piping shall prevent physical damage to the piping while being backfilled.

N **15.5.6.5.3** If the underground piping is protected by a conduit, cover, or other enclosure, the following requirements shall be met:

(1) Access during construction shall be provided at the joints for visual inspection and leak testing.
(2) The conduit, cover, or enclosure shall be self-draining and not retain groundwater in prolonged contact with copper tubing.

N **15.5.6.5.4** Buried piping that is subject to surface loads shall be buried at a depth that will protect the piping, its enclosure, or both, from excessive stresses.

N **15.5.6.5.5** The minimum backfill cover above the top of the piping or its enclosure shall be 900 mm (36 in.), except that the minimum cover shall be permitted to be reduced to 450 mm (18 in.) where there is no potential for damage from surface loads or surface conditions.

N **15.5.6.5.6** Trenches shall be excavated so that the piping or its enclosure has firm, substantially continuous bearing on the bottom of the trench.

N **15.5.6.5.7** Backfill shall be clean, free from material that can damage the pipe, and compacted.

N **15.5.6.5.8** A continuous warning tape or marker shall be placed immediately above the piping or its enclosure to clearly identify the pipeline by specific name.

N **15.5.6.5.9** A continuous warning means shall also be placed above the pipeline at approximately one-half the depth of burial.

N **15.5.6.5.10** Where buried piping is extended into a building through a wall sleeve, the outdoor end of the sleeve shall be sealed watertight to prevent the entrance of groundwater into the building.

N **15.5.6.6 Underground Piping Within Buildings.**

N **15.5.6.6.1** The installation procedure for underground piping shall prevent physical damage to the piping while being backfilled.

N **15.5.6.6.2** The piping shall be backfilled with clean sand or gravel.

N **15.5.6.7 Piping Within Floor Slabs Prohibited.** Dental gas and vacuum piping shall not be installed within floor slabs.

N **15.5.7 Performance Criteria and Testing (Dental air and Vacuum).**

N **15.5.7.1 Dental Air and Vacuum Systems Testing.**

N **15.5.7.1.1 General.**

N **15.5.7.1.1.1** Inspection and testing shall be performed on all new piped dental gas and vacuum systems, additions, renovations, temporary installations, or repaired systems to ensure, by a documented procedure, that the following have been completed:

(1) All applicable provisions of this code have been adhered to.
(2) System integrity has been achieved or maintained.
(3) Piping systems are ready for testing and verification.
(4) Piping systems are performing in accordance with their design requirements.

N **15.5.7.1.1.2** The inspection and testing reports shall be submitted directly to the party that contracted for the testing, who shall submit the reports through channels to the responsible authority and any others that are required.

N **15.5.7.1.1.3** Reports shall contain detailed listings of all findings and results.

N **15.5.7.1.1.4** The responsible facility authority shall review the inspection and testing records prior to the use of any systems to ensure that all findings and results of the inspection and testing have been successfully completed before use.

N **15.5.7.1.1.5** All documentation pertaining to inspections and testing shall be maintained on-site within the facility.

N **15.5.7.1.2 Required Testing.**

N **15.5.7.1.2.1 Category 3 Dental Air and Vacuum Systems.**

N **(A)** All Category 3 dental gas and vacuum piping systems indicated in 15.5.2 shall be initially tested in accordance with 15.5.7.1.3.

N **(B)** The support gas systems and vacuum systems (i.e., dental air, dental vacuum, and scavenging) shall be final tested in accordance with 15.5.7.1.3.4 and 15.5.7.1.3.5.

N **15.5.7.1.3 Initial Testing of Piping Systems.**

N **15.5.7.1.3.1 General.**

N **(A)** Where plastic vacuum and plastic scavenging piping systems are installed, they shall be visually inspected for cross-connections to oxygen and nitrous oxide systems before applying positive test pressures to the copper piping systems.

N **(B)** During the process of initial testing, the identification and labeling of the dental gas and vacuum piping shall be checked.

N **15.5.7.1.3.2 Initial Pressure Test.**

N **(A)** Each section of the piping in dental air systems and copper vacuum systems shall be pressure tested. Plastic vacuum and plastic scavenging piping shall not be pressure tested.

N **(B)** Initial pressure tests shall be conducted as follows:

(1) After installation of station outlet/inlet rough-in assemblies
(2) 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)

N **(C)** The source shutoff valve shall remain closed during the pressure tests.
N **(D)** The test pressure for dental air piping and copper vacuum piping shall be 1.5 times the system operating pressure but not less than a gauge pressure of 1035 kPa (150 psi).
N **(E)** 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.
N **(F)** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested.

N **15.5.7.1.3.3 Initial Piping Purge Test.**

N **(A)** The outlets in each dental air piping system shall be purged to remove any particulate matter from the distribution piping.
N **(B)** 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.
N **(C)** The purging shall be started at the closest outlet to the piping shutoff valve and continue to the furthest outlet from the shutoff valve.

N **15.5.7.1.3.4 Standing Pressure Test for Dental Air and Copper Vacuum Piping.**

N **(A)** After successful completion of the initial pressure tests in 15.5.7.1.3.2, the dental air systems and copper vacuum systems shall be subject to a standing pressure test.
N **(B)** 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).
N **(C)** The source valve shall be closed during this test.
N **(D)** The piping systems shall be subjected to 24-hour standing pressure tests using oil-free, dry nitrogen NF.
N **(E)** Test pressures shall be 20 percent above the normal system operating line pressure.
N **(F)** At the conclusion of the tests, there shall be no change in the test pressure except that attributed to specific changes in ambient temperature.
N **(G)** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested. The piping shall be repurged if necessary.

N **15.5.7.1.3.5 Standing Vacuum Test for Plastic Vacuum Piping.**

N **(A)** After successful completion of the initial pressure tests in 15.5.7.1.3.2, vacuum distribution piping, including scavenging, shall be subjected to a standing vacuum test.
N **(B)** Tests shall be conducted after installation and connection of all components of the vacuum system.
N **(C)** The piping systems shall be subjected to a 24-hour standing vacuum test.
N **(D)** Test pressure shall be between 300 mm (12 in.) HgV and full vacuum.
N **(E)** During the test, the source of test vacuum shall be disconnected from the piping system.
N **(F)** At the conclusion of the test, there shall be no change in the vacuum pressure other than that attributed to changes of ambient temperature.
N **(G)** Any leaks shall be located, repaired (if permitted), or replaced (if required) by the installer, and retested.

N **15.5.8 Operation and Management.**

N **15.5.8.1 System Shutdowns.** Gas and vacuum piping systems shall be shut down at the end of each workday.

N **15.5.8.2 Manufacturer's Instructions.**

N **15.5.8.2.1** Piping system components shall be installed, adjusted, operated, and maintained in accordance with the manufacturer's instructions.

N **15.5.8.2.2** Copies of the manufacturer's instructions shall be provided to the facility and maintained at the facility.

N **15.5.8.3 Maintenance.** Dental air and vacuum system equipment shall be maintained by a qualified representative of the equipment manufacturer.

References Cited in Commentary

1. ASSE 6010, *Professional Qualifications Standard for Medical Gas Systems Installers*, 2015, American Society of Sanitary Engineering, Westlake, OH.

ANNEX

A

Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

Annex A material is useful information, numbered to correspond with the applicable text paragraphs, and it is included solely to help the user of the document understand the intent of the requirements by providing further information, diagrams, examples, and so forth.

Annex A material can be considered "official" commentary, as it is not only explanatory material for specific portions of the code, but it is voted on by the code's technical committee, as is all material in the mandatory portions of the code. On the other hand, the commentary in this handbook consists of the opinions of the editors of, and contributors to, this handbook to help further explain provisions in the code.

For the convenience of readers of this handbook, Annex A text follows the appropriate code paragraphs and, therefore, is not repeated here.

ANNEX B

Additional Explanatory Notes

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Annex B provides additional explanatory information on the main requirements of NFPA 99. This material includes details, in addition to those contained in Annex A, and provides helpful examples, historical contexts, and sample procedures and processes. The information in this annex is numbered to correspond with the applicable code chapters. Only the material related to Chapters 1 through 5 has been included here.

B.1 Reserved.

B.2 Reserved.

B.3 Reserved.

B.4 Reserved.

B.5 Additional Information on Chapter 5.

Numbers in brackets refer to paragraphs in Chapter 5.

B.5.1 General. This section sets out a minimum recommended guide for testing. Testing requirements are listed in 5.1.12 and summarized in Table B.5.1. Tests specified in 5.1.12 should be carried out by an experienced person or persons designated by the administration of the health care facility. Such a person(s) should certify the results of tests to the administration. The designated person(s) should be experienced in medical gas testing and verification of piping systems with cross-connection testing. A member of the health care facility should be present to verify the testing.

Δ ***TABLE B.5.1*** *Performance Criteria and Testing — Level 1 (Gases, Medical–Surgical Vacuum, and WAGD)*

Responsibility	*Test Reference*	*Test (as Applicable)*	*Purpose of Test*
Installer	5.1.12.2.1	General	
Installer	5.1.12.2.2	Initial blow down	Distribution piping is blown down to remove particulates
Installer	5.1.12.2.3	Initial pressure test	Distribution piping is free from pressure loss
Installer	5.1.12.2.4	Cross-connection test	Distribution piping is free from cross-connections
Installer	5.1.12.2.5	Piping purge test	Distribution piping is purged to remove particulates
Installer	5.1.12.2.6	Standing pressure test for positive pressure medical gas piping	Distribution piping is free from excessive pressure loss
Installer	5.1.12.2.7	Standing vacuum test for vacuum system	Distribution piping is free from excessive vacuum loss
System verification	5.1.12.4.1	General	
System verification	5.1.12.4.2	Standing pressure test	Distribution piping is free from leaks
System verification	5.1.12.4.3	Cross-connection test	Distribution piping is free from cross-connections
	5.1.12.4.3.1	Individual pressurization	
	5.1.12.4.3.2	Pressure differential	
System verification	5.1.12.4.4	Valve test	Shutoff valves are functioning and labeled properly
System verification	5.1.12.4.5	Alarm test	Alarms are functioning and labeled properly
	5.1.12.4.5.1	General	
	5.1.12.4.5.2	Master alarm	
	5.1.12.4.5.3	Area alarm	
System verification	5.1.12.4.6	Piping purge test	Distribution piping is purged to remove particulates
System verification	5.1.12.4.7	Piping particulate test	Distribution piping is free from particulates
System verification	5.1.12.4.8	Piping purity test	Distribution piping is free from excessive water vapor, total hydrocarbons, and halogenated hydrocarbons
System verification	5.1.12.4.9	Final tie-in test	The new and existing distribution system is free from leaks at the point of connection, and no additional contamination was added to the existing system
System verification	5.1.12.4.10	Operational pressure test	Distribution piping is free from excessive pressure/vacuum loss
System verification	5.1.12.4.11	Medical gas concentration test	Proper concentration of system gas is present at each outlet
System verification	5.1.12.4.12	Medical air purity test (compressor system)	Proper quality of medical air is present

Responsibility	*Test Reference*	*Test (as Applicable)*	*Purpose of Test*
System verification	5.1.12.4.13	Labeling	Distribution piping, outlets/inlets, shutoff valves, alarms, and source equipment are labeled correctly
System verification	5.1.12.4.14	Source equipment verification	Source equipment properly functions
	5.1.12.4.14.1	General	
	5.1.12.4.14.2	Gas supply sources	
	5.1.12.4.14.3	Medical air compressor systems	
	5.1.12.4.14.5	Medical–surgical vacuum systems	

The commentary in Annex B contains only general recommendations. Testing requirements for medical gas and vacuum systems are listed in 5.1.12, 5.2.12, and 5.3.12. The recommendations in this annex apply to a Category 1 piped gas system, although portions might be applicable to a Category 2 or Category 3 piped gas system.

B.5.2 Retesting and Maintenance of Nonflammable Medical Piped Gas Systems (Level 1 Systems).

B.5.2.1 [5.1.3.5.10] These systems should be checked daily to ensure that proper pressure is maintained and that the changeover signal has not malfunctioned. Periodic retesting of the routine changeover signal is not necessary, as it will normally be activated on a regular basis.

B.5.2.2 [5.1.3.5.12] These systems should be checked daily to ensure that proper pressure is maintained and that the changeover signal has not malfunctioned. Periodic retesting of the routine changeover signal is not required. Annual retesting of the operation of the reserve and activation of the reserve-in-use signal should be performed.

B.5.2.3 [5.1.3.5.12] If the system has an actuating switch and signal to monitor the contents of the reserve, it should be retested annually.

B.5.2.4 [5.1.3.5.14] Maintenance and periodic testing of the bulk system is the responsibility of the owner or the organization responsible for the operation and maintenance of that system.

The staff of the facility should check the supply system daily to ensure that medical gas is ordered when the content's gauge drops to the reorder level designated by the supplier. Piping system pressure gauges and other gauges designated by the supplier should be checked regularly, and gradual variation, either increases or decreases, from the normal range should be reported to the supplier. These variations might indicate the need for corrective action.

Periodic testing of the master signal panel system, other than the routine changeover signal, should be performed. Assistance should be requested from the supplier or detailed instruction if readjustment of bulk supply controls is necessary to complete these tests.

B.5.2.5 [5.1.8.2.3] The main line pressure gauge should be checked daily to ensure the continued presence of the desired pressure. Variation, either increases or decreases, should be investigated and corrected.

B.5.2.6 [5.1.3.6.3.14] Quarterly rechecking of the location of the air intake should be made to ensure that it continues to be a satisfactory source for medical compressed air.

FAQ What comprises the quarterly check?

The quarterly check recommended in B.5.2.6 might include the following:

1. A physical inspection for accumulations of debris around the intake
2. An examination of the immediate area around the intake for new exhausts that could pollute air being drawn in or for any changes that might affect the air circulation in the area of the intake
3. An examination of Environmental Protection Agency reports on air quality in the locality

If any of these examinations raises concerns about the air purity or quality, a more detailed purity examination should be conducted.

B.5.2.7 [5.1.3.6.3.14] Proper functioning of the pressure gauge and high water level sensor should be checked at least annually. The receiver drain should be checked daily to determine if an excessive quantity of condensed water has accumulated in the receiver.

B.5.2.8 [5.1.3.6] An important item required for operation of any medical compressed air supply system is a comprehensive preventive maintenance program. Worn parts on reciprocating compressors can cause high discharge temperatures, resulting in an increase of contaminants in the discharge gas. Adsorber beds, if not changed at specified time intervals, can become saturated and lose their effectiveness. It is important that all components of the system be maintained in accordance with the manufacturers' recommendations. It is important that any instrumentation, including analytical equipment, be calibrated routinely and maintained in operating order. Proper functioning of the dew point sensor should be checked at least annually.

B.5.2.9 [5.1.9] When test buttons are provided with signal panels, activation of the audible and visual signals should be performed on a regular basis (monthly).

B.5.2.10 [5.1.9.2.4] Changeover Warning Signals. As these are routine signals that are activated and deactivated at frequent intervals, there is no need for retesting unless they fail. If the reserve-in-use signal is activated because both units of the operating supply are depleted without the prior activation of the changeover signal, it should be repaired and retested.

B.5.2.11 [5.1.9.2.4] Reserve-In-Use Warning Signal. All components of this warning signal system should be retested annually. Audible and visual signals should be tested periodically during the year (monthly).

B.5.2.12 [5.1.9.2.4] Reserve Supply Low (Down to an Average One-Day Supply) High Pressure Cylinder or Liquid Reserve. All components of these signal warning systems should be retested annually. If test buttons are provided, audible and visual signals should be periodically tested throughout the year (monthly).

B.5.2.13 [5.1.9.2.4] The medical compressed air system alarms in 5.1.3.6.3.12 should be checked at least annually.

B.5.2.14 [5.1.8.2.2(1)] This pressure gauge should be checked on a daily basis to ensure proper piping system pressure. A change, increase or decrease, if noted, could be evidence that maintenance is required on the line pressure regulator and could thus avoid a problem.

B.5.2.15 [5.1.9] Annual retesting of all components of warning systems, if it can be done without changing piping system line pressure, should be performed.

B.5.2.16 [5.1.9] If test buttons are provided, the retesting of audible and visual alarm indicators should be performed monthly.

B.5.2.17 [5.1.4] Shutoff valves should be periodically checked for external leakage by means of a test solution or other equally effective means of leak detection that is safe for use with oxygen.

B.5.2.18 [5.1.5] Station outlets should be periodically checked for leakage and flow. Manufacturer instructions should be followed in making this examination.

Flow rates for a given pressure vary among systems due to the differences among manufacturers and among the various models of a manufacturer. A recommended value for existing systems is not included. What is important, however, is the consistency of readings over a period of time after a facility has determined the minimum acceptable flow rates for the devices intended for connection to the system.

B.5.3 Oxygen Service–Related Documents. The following publications can be used for technical reference:

(1) ASTM G63, *Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service*
(2) ASTM G88, *Standard Guide for Designing Systems for Oxygen Service*
(3) ASTM G93, *Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments*
(4) ASTM G94, *Standard Guide for Evaluating Metals for Oxygen Service*

Supplements

Part 2

Part 2 of the *Medical Gas and Vacuum Systems Handbook* includes three supplements to provide the reader with more detailed information on specific topics. These supplements are not part of NFPA 99, *Health Care Facilities Code*, but are included here as additional information for the reader of this handbook. The supplements included in this handbook are as follows:

Supplement 1 Qualifications for Personnel Performing Medical Gas Work and General Brazing Procedures

Supplement 2 Cleaning for Oxygen Service and Preparing a Joint for Brazing

Supplement 3 Installation Testing and Documentation

Supplement 1

Qualifications for Personnel Performing Medical Gas Work and General Brazing Procedures

Supplement 1 summarizes the ASSE/IAPMO/ANSI professional qualifications for medical gas systems installers, inspectors, verifiers, and maintenance personnel. This supplement also presents information on brazing procedures and performance and hot work from the Copper Development Association, the American Welding Society, and NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

PROFESSIONAL QUALIFICATIONS FOR INSTALLERS

All installers of medical gas and vacuum systems are required in 5.1.10.11.10 and 5.2.10 of NFPA 99, *Health Care Facilities Code*, to meet the requirements of ASSE/IAPMO/ANSI 6010, *Professional Qualification Standard for Medical Gas and Vacuum System Installers*. ASSE/IAPMO/ANSI 6010 is a standard published by the American Society of Sanitary Engineering (ASSE), and it is based on the requirements of NFPA 99. Table S1.1 is a summary of the ASSE/IAPMO/ANSI 6010 requirements.

Brazing Procedure and Performance Qualifications

Installers are required to be qualified under ASSE/IAPMO/ANSI 6010, which, in turn, requires individuals seeking qualification in brazing procedures to be tested and qualified by performing brazing and examination of a series of test joints. Brazing procedures and brazer performance must be qualified according to either of the following standards:

- ASME *Boiler and Pressure Vessel Code*, Section IX, Welding and Brazing Qualifications
- ANSI/AWS B2.2, *Standard for Brazing Procedures and Performance Qualifications*

Brazing procedure qualifications and brazing performance qualifications cover such areas as acceptance criteria, variables, visual examination, test specimens, base and filler metal groups, brazing atmospheres, brazing of different types of joints, and the cutting plan for the test specimens. (For a detailed examination of these requirements, the reader should review the references listed at the end of this supplement.)

Brazing Techniques

Additional information on the basic technique for heating a joint, applying brazing filler metal, and making horizontal and vertical joints is described in *The Copper Tube Handbook*. The steps can be summarized as follows:

1. Use a neutral flame to heat the tube first [about 2.54 cm (1 in.) from the edge of the fitting] by sweeping the flame around the tube in short strokes. It is important to keep the flame moving and to not concentrate on one point, as this will damage the tubing.
2. Move the flame to the base of the cup of the fitting and sweep the flame over both the tube and the fitting. Heat the tubing and the fitting uniformly.
3. Sweep the flame over the fitting and the tubing and maintain the heat on the parts to be joined, especially on the base of the fitting.
4. Apply brazing filler to the intersection of the tube and the joint. When the proper temperature is reached, the filler metal

TABLE S1.1 *Summary of ASSE 6010 Requirements for Installers*

Requirement	*Comments*
General Requirements	Must know applicable codes, notification procedures, and basic concepts of pressure, vacuum, and oxygen.
Product Installation Knowledge	Must be able to identify and describe both the proper and improper installation of gas and vacuum systems, particularly the piping.
Product Performance Knowledge	Must know the major components of gas and vacuum systems and must know the proper application of the systems in various occupancies. Must also understand the operation and interrelationships of various gas and vacuum system components.
System Component Knowledge	Must understand the various system components, including pipe materials, brazing alloys, and test equipment.
Documenting and Recording	Must be able to read a drawing, construct an as-built drawing, and understand the reporting requirements of the various authorities.
Vocabulary and Definitions	Must demonstrate a working knowledge of common terms and acronyms used in the industry.
Certification of Medical Gas Installers	Must understand the relationship of the various different entities working on and testing the medical gas systems, including the installer (ASSE/IAPMO/ANSI 6010), verifier (ASSE/IAPMO/ANSI 6030), inspector (ASSE/IAPMO/ANSI 6020), and maintenance personnel (ASSE/IAPMO/ANSI 6040).
Field Installation Procedures	Must understand the various installation procedures required on-site, including such examples as site preparation, tools and equipment, materials, supports and penetration requirements, site rules, assembly methods, and brazing technique.
Testing Procedures	Must understand and be able to execute the various tests required for quality assurance and for pre-acceptance testing. Must understand the tools and procedures, how to interpret results, and how to complete the required documentation. Must also understand the role of the verifier and the tests required by that entity.

will flow into the joint. The flame should be kept in motion between the tubing and the joint.

Hot Work Requirements

Brazing usually involves open flame, so brazing operations should also comply with NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*. NFPA 51B is not referenced in NFPA 99 but may be required by local jurisdictions. In either event, the practices detailed in NFPA 51B should be incorporated as prudent safety precautions during any brazing operations. The following is a summary of the basic requirements of NFPA 51B.

During any hot work, management is responsible for safe operations and appoints a permit authorizing individual (PAI). The PAI determines fire hazards and ensures the following:

- Combustible materials are swept clean, wetted, relocated, or otherwise protected.
- Any openings are protected.
- A fire extinguisher is available.
- Any sprinkler heads in close proximity to hot work are protected.
- A fire watch is established and properly equipped to deal with any unexpected fire.

Once these criteria are met, the PAI will issue the hot work permit, defining the permissible areas, designated areas, permit-required areas, and areas in which hot work is not permitted. Then the brazing may begin. An example of a hot work permit is shown in Exhibit S1.1.

PROFESSIONAL QUALIFICATIONS FOR VERIFIERS

The testing process in NFPA 99 requires two separate sets of tests. One set will be performed by the qualified installer, as described earlier, and the second by the verifier who is qualified to ASSE 6030, described next. The verifier and the installer must be separate entities, and an installer or installing contractor may not verify his/her own work, even if the individual holds both qualifications. Table S1.2 provides a summary list of the requirements for verifiers qualified to ASSE 6030.

PROFESSIONAL QUALIFICATIONS FOR MAINTENANCE PERSONNEL

Hospital maintenance personnel are permitted to be qualified to ASSE/IAPMO/ANSI 6040, as described in Table S1.3. This qualification is not mandated, as are ASSE/IAPMO/ANSI 6010 and ASSE/IAPMO/ANSI 6030, but may be desirable should the facility seek to credential their maintenance staff for medical gas work.

HOT WORK PERMIT

Seek an alternative/safer method if possible!

Before initiating hot work, ensure precautions are in place as required by NFPA 51B and ANSI Z49.1.
Make sure an appropriate fire extinguisher is readily available.

This Hot Work Permit is required for any operation involving open flame or producing heat and/or sparks. This work includes, but is not limited to, welding, brazing, cutting, grinding, soldering, thawing pipe, torch-applied roofing, or chemical welding.

Date	Hot work by ❑ employee ❑ contractor
Location/Building and floor _____	Name (print) and signature of person doing hot work
Work to be done _____	I verify that the above location has been examined, the precautions marked on the checklist below have been taken, and permission is granted for this work.
Time started _____ Time completed _____	Name (print) and signature of permit-authorizing individual (PAI)
THIS PERMIT IS GOOD FOR ONE DAY ONLY	

❑ Available sprinklers, hose streams, and extinguishers are in service and operable.

❑ Hot work equipment is in good working condition in accordance with manufacturer's specifications.

❑ Special permission obtained to conduct hot work on metal vessels or piping lined with rubber or plastic.

Requirements within 35 ft (11 m) of hot work

❑ Flammable liquid, dust, lint, and oily deposits removed.
❑ Explosive atmosphere in area eliminated.
❑ Floors swept clean and trash removed.
❑ Combustible floors wet down or covered with damp sand or fire-resistive/noncombustible materials or equivalent.
❑ Personnel protected from electrical shock when floors are wet.
❑ Other combustible storage material removed or covered with listed or approved materials (welding pads, blankets, or curtains; fire-resistive tarpaulins), metal shields, or noncombustible materials.
❑ All wall and floor openings covered.
❑ Ducts and conveyors that might carry sparks to distant combustible material covered, protected, or shut down.

Requirements for hot work on walls, ceilings, or roofs

❑ Construction is noncombustible and without combustible coverings or insulation.
❑ Combustible material on other side of walls, ceilings, or roofs is moved away.

Requirements for hot work on enclosed equipment

❑ Enclosed equipment is cleaned of all combustibles.
❑ Containers are purged of flammable liquid/vapor.
❑ Pressurized vessels, piping, and equipment removed from service, isolated, and vented.

Requirements for hot work fire watch and fire monitoring

❑ Fire watch is provided during and for a minimum of 30 min. after hot work, including any break activity.
❑ Fire watch is provided with suitable extinguishers and, where practical, a charged small hose.
❑ Fire watch is trained in use of equipment and in sounding alarm.
❑ Fire watch can be required in adjoining areas, above and below.
❑ Yes ❑ No Per the PAI/fire watch, monitoring of hot work area has been extended beyond the 30 min.

 NFPA 51B

EXHIBIT S1.1 *Sample of a hot work permit. (Source: Figure A.5.4.1, NFPA 51B, 2014)*

TABLE S1.2 *Summary of ASSE/IAPMO/ANSI 6030 Requirements for Verifiers*

Requirement	*Comments*
General Knowledge	Must know all applicable codes, notification procedures, and basic concepts of pressure and vacuum.
Product Performance Knowledge	Required to identify major components of gas and vacuum systems, understand the proper application of gas and vacuum systems in various occupancies, and understand the proper operation of various gas and vacuum system components.
Product Installation Knowledge	Must be capable of identifying proper and improper installations of gas and vacuum systems. Therefore, must also be qualified to ASSE/IAPMO/ANSI 6010.
System and System Component Test Knowledge	Must understand and execute test procedures for all system components.
Documenting and Recording	Must be able to read a drawing, produce a detailed test report, and understand the reporting requirements of the various authorities.
Vocabulary and Definitions	Must demonstrate working knowledge of the many terms and acronyms commonly used in the industry.
Field Verification Testing	Must understand and be able to execute all the tests required under NFPA 99 for final verification. Must understand the tools and procedures, how to interpret results, and how to complete the required documentation.

TABLE S1.3 *Summary of ASSE 6040 Requirements for Maintenance Personnel*

Requirement	*Comments*
General Knowledge	Must know all applicable codes, notification procedures, and basic concepts of pressure and vacuum.
Product Performance Knowledge	Required to identify major components of gas and vacuum systems, understand the proper application of gas and vacuum systems in various occupancies, and understand the proper operation of various gas and vacuum system components.
Product Maintenance Knowledge	Must be capable of identifying components and their relationship to one another, be familiar with maintenance instructions and know how to find them, and be familiar with hazards to themselves and patients in general and as a result of improper maintenance.
System and System Component Test Knowledge	Must understand and execute maintenance-related test procedures for all system components.
Documenting and Recording	Must be able to complete a checklist and describe all performed maintenance operations as they are completed.
Vocabulary and Definitions	Must demonstrate working knowledge of the many terms and acronyms commonly used in the industry.

REFERENCES

ANSI/AWS B2.2, *Standard for Brazing Procedures and Performance Qualifications,* 1991, American Welding Society, Miami, FL.

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications, 2010, American Society of Mechanical Engineers, New York, NY.

ASSE/IAPMO/ANSI 6010, *Professional Qualification Standard for Medical Gas and Vacuum System Installers*, 2006, American Society of Sanitary Engineering, Westlake, Ohio.

ASSE/IAPMO/ANSI 6020, *Professional Qualification Standard for Medical Gas Systems Inspectors*, 2006, American Society of Sanitary Engineering, Westlake, OH.

ASSE/IAPMO/ANSI 6030, *Professional Qualification Standard for Medical Gas Systems Verifiers*, 2006, American Society of Sanitary Engineering, Westlake, OH.

ASSE/IAPMO/ANSI 6040, *Professional Qualification Standard for Medical Gas Systems Maintenance Personnel*, 2006, American Society of Sanitary Engineering, Westlake, OH.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2014 edition, National Fire Protection Association, Quincy, MA.

NFPA 99, *Health Care Facilities Code*, 2018 edition, National Fire Protection Association, Quincy, MA.

The Copper Tube Handbook, Chapter VIII, "Brazed Joints," Applying Heat and Brazing, 2010. Copper Development Association, New York, NY.

Supplement 2

Cleaning for Oxygen Service and Preparing a Joint for Brazing

This supplement provides additional information for the reader on the importance of cleaning a medical gas system for oxygen service and also how to prepare a joint for brazing.

CLEANING FOR SERVICE

Tubes, valves, fittings, station outlets, and other piping components in a positive pressure medical gas system must be cleaned for oxygen service. While not required, it is common for cleaned tubing and fittings to be used in vacuum systems as well. Fittings are permitted to be cleaned for oxygen service by a supplier or agency other than the manufacturer (see 5.1.10.1.1 of NFPA 99, *Health Care Facilities Code*). However, that does not mean that cleaning in the field is permitted, except under specific conditions.

The requirement in 5.1.10.1.1 of NFPA 99 does *not* permit an installer to utilize tubing that was not received cleaned and capped for oxygen service. Cleaning on-site was allowed at one time but is no longer permitted for tubing or fittings because on-site cleaning does not meet the quality control measures required under CGA G-4.1, *Cleaning Equipment for Oxygen Service,* or ASTM B 819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems.* Without appropriate quality controls, the cleanliness of the tube and fittings cannot be guaranteed.

However, 5.1.10.4.3.10 of NFPA 99 does allow limited on-site cleaning of the interior surfaces of tube ends, fittings, and other components if they were originally cleaned for oxygen service by the supplier but became contaminated prior to being installed. This exception to the general rule is simply to prevent hardship if the end of a cleaned tube or a clean fitting becomes lightly contaminated during manipulation prior to installation. Light contamination of a previously clean item can be cleaned, and thus the fitting or section of pipe can be conserved. Note that the procedure allowed is hardly easy and is labor intensive, so it is often better to set the item aside and use another clean part, reserving the recleaning for some later time.

To properly clean these parts, NFPA 99 requires the interior surface to be thoroughly scrubbed in either clean hot water–alkaline solution (sodium carbonate or trisodium phosphate are the usual agents) or a limited few aqueous cleaning solutions. The part must then be thoroughly rinsed with clean, potable hot water.

Note that any aqueous cleaning solutions must be as recommended in CGA G-4.1. It is not permitted to clean with trichloroethylene, Freon, or any halogenated- or hydrocarbon-based degreaser.

BRAZING PREPARATION

Preparing a joint for the brazing process is an important process that requires some skill and should only be performed by an installer qualified to ASSE/IAPMO/ANSI 6010, *Professional Qualification Standard for Medical Gas and Vacuum System Installers*.

The cutting of tubing must be done with a sharp tubing cutter, and never with any form of saw. Saws leave particulate contamination in the piping that is very difficult to remove. A sharp tubing cutter will prevent these particulates but poses the risk of compressing the inner diameter of the tube. Satisfactory use of tubing cutters requires maintaining a moderate cutting rate with only enough pressure on the tubing to keep the cutter biting. Tubing cutters suitable for this application do not require lubricants, and they must be avoided, so cutters for medical gases must not be used for other purposes.

After the tubing is cut, traditional practice called for it to be deburred. However, beginning with the 2012 edition, this requirement

was removed, and deburring is only permitted where the tool used will not produce chips or shavings. This means that a rolling-style deburring tool is the only type that should be used. The rolling tool does not cut off the burr but rather forces the tube end back into shape, smoothing the burr. In practice, these tools can produce some limited particulates, so the operator must prevent these from falling down into the tube or remove them if they do.

The exterior surface of the tube ends must be cleaned to remove the surface oxidation before any brazing is started. The exterior surface can be cleaned with a nonabrasive pad. Steel wool, emery paper, and sand cloth, for example, are never suitable, since they work by scratching the tubing, which releases filings that are impossible to remove from the finished piping.

The interior of the fitting can then be cleaned in a similar manner. Before assembly, the surfaces of the tubing and fitting should be wiped with a clean, lint-free cloth and visually examined to determine that they are clean and free of particulates. The joint can then be assembled and the brazing completed.

The entire process is intended to keep the piping clean and free from particulates, which would otherwise remain in the piping and risk blocking therapeutic equipment. Achieving this goal does require some preplanning, since, for instance, it is very difficult to perform this procedure properly when standing on a ladder with the piping half completed. Good mechanics usually clean and assemble the work in sections and then complete the brazing. This enables them to do the cleaning and visual examination where they have good light and access to view the parts. It is also a more efficient use of their time and motion.

REFERENCES

ASSE/IAPMO/ANSI 6010, *Professional Qualification Standard for Medical Gas and Vacuum System Installers*, 2006, American Society of Sanitary Engineering, Westlake, OH.

ASTM B 819, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*, 2006, ASTM International, West Conshohocken, PA.

CGA G-4.1, *Cleaning Equipment for Oxygen Service*, 2009, Compressed Gas Association, Chantilly, VA.

NFPA 99, *Health Care Facilities Code*, 2018 edition, National Fire Protection Association, Quincy, MA.

Supplement 3

Installation Testing and Documentation

Supplement 3 provides examples of the documentation described in NFPA 99, *Health Care Facilities Code,* for the installer and the verifier to provide to the AHJ after a new medical gas and vacuum system is installed and tested or an existing system has been modified. An additional resource for sample documentation is the Medical Gas Professional Healthcare Organization (www.mgpho.org). This supplement does not address existing systems, unless such system has been modified or repaired.

Testing in NFPA 99 is in two parts. The first set of tests is performed by the installer. The tests are intended to be a check for the completeness of the installer's work and are for the installer's own benefit. In theory, the installer's results should always be perfect, because, if they are not, the installer should make corrections until they are. The second set of tests is performed by the verifier. The verifier must be an unrelated third party who will repeat many of these tests and also perform additional tests as outlined below. The details of these tests are found in 5.1.12.

REQUIREMENTS FOR INSTALLER DOCUMENTATION

Under the installer test requirements of 5.1.12.2 in NFPA 99, the installer of medical gas and vacuum systems needs to document the information covered in Exhibit S3.1 through Exhibit S3.5. These exhibits are not mandatory but are examples.

Exhibit S3.1 can be used to document an initial blow down, which is an operation performed at each outlet rough-in, before the outlets are assembled, and consisting of a simple purge of the system, using the rush of the gas to clear any residual particulate from the system. (See 5.1.12.2.2 for more information.)

Exhibit S3.2 can be used to document the initial pressure test, which consists of pressurizing the systems, again only against the outlet rough-in and before the outlets are assembled. The piping is the objective, and the systems are pressurized to 1034 kPa (150 psig) long enough to check each joint with some form of leak detector. This may be a liquid (bubble check), an ultrasonic detector, a sniffer or gas analyzer, or any other apparatus that will reveal any leaks from badly formed joints. (See 5.1.12.2.3 for more information.)

Exhibit S3.3 can be used to document the cross-connection test, which consists of pressurizing the systems one by one and checking to see that only the outlets of that specific gas have pressure. In this way, it can be ensured that the right sources are piped to the right outlets. Every outlet must be checked, and every system must be checked in turn. It is a slow process, but a vital one. (See 5.1.12.2.4 for more information.)

The systems are now completely assembled. A final purge is done to ensure all particulate is removed, which is validated by a simple "white cloth" test to ensure there are no particulates visible. Exhibit S3.4 can be used to document this test. (See 5.1.12.2.5 for more information.)

Now the systems are pressurized to 20 percent above normal operating pressure [300 mm (12 in.) HgV for vacuum], isolated from the sources, and left for 24 hours. The pressures should not visibly change. Exhibit S3.5 can be used to document the standing pressure test. (See 5.1.12.2.6 for more information.)

Exhibit S3.6 can be used to document the standing vacuum test, which is very similar to the standing pressure test. The integrity of the piping network is tested under vacuum for 24 hours. The system is placed under vacuum and left for a 24-hour period and then checked to see if the vacuum has changed. If it has changed, and the installer has compensated for expansion and contraction, then there is a leak in the system (See 5.1.12.2.7 for more information.)

Installer's Name	Gas System	Date	Outlet Location	Initial Standing Pressure	Final Standing Pressure	Test Passed	Test Failed

EXHIBIT S3.1 *Initial blow down test.*

Installer's Name	Gas System	Date	Outlet Location	Test Passed	Test Failed

EXHIBIT S3.2 *Initial pressure test.*

Installer's Name	Outlet Designated Gas	Date	Location	System A	Test Passed	Test Failed	System B	Test Passed	Test Failed	System C	Test Passed	Test Failed

EXHIBIT S3.3 *Cross-connection test.*

Installer's Name	Gas System	Date	Outlet Location	Test Passed	Test Failed

EXHIBIT S3.4 *Piping purge test.*

Installer's Name	Gas System	Date	Location	Initial Standing Pressure	Final Standing Pressure	Test Passed	Test Failed

EXHIBIT S3.5 *Standing pressure test (24 hours).*

Installer's Name	Gas System	Date	Location	Initial Standing Pressure	Final Standing Pressure	Test Passed	Test Failed

EXHIBIT S3.6 *Standing vacuum test.*

Verifier's Name	Gas System	Date	Location	Initial Standing Pressure	Final Standing Pressure	Test Passed	Test Failed

EXHIBIT S3.7 *Standing pressure test (10 minutes).*

Verifier's Name	Gas System	Date	Location	Outlet A (psi)	Test Passed	Test Failed	Outlet B (psi)	Test Passed	Test Failed	Outlet C (psi)	Test Passed	Test Failed

EXHIBIT S3.8 *Cross-connection test.*

Verifier's Name	Gas System	Date	Valve A Location	Valve A Control	Test Passed	Test Failed	Valve B Location	Valve B Control	Test Passed	Test Failed	Valve C Location	Valve C Control	Test Passed	Test Failed

EXHIBIT S3.9 *Valve test.*

Verifier's Name	Gas System	Date	Alarm Location	Alarm Type (Master, Area)	Signal	Test Passed	Test Failed

EXHIBIT S3.10 *Alarm test.*

At this point, the installer should have a complete set of documents showing that the tests have been completed successfully, or the installer should go back and make any required corrections and retest. Then, the verifier can be called.

REQUIREMENTS FOR VERIFIER DOCUMENTATION

The verifier will now repeat certain parts of the most important tests and then conduct additional tests that are usually outside the capability of the installer.

First, the verifier will validate the leak test, but instead of testing for 24 hours at 120 percent of normal pressure, the verifier will simply test for 10 minutes at system pressure or vacuum. Exhibit S3.7 can be used to document the standing pressure test. (See 5.1.12.4.2 for more information.)

The verifier can then repeat the cross-connection test. Exhibit S3.8 can be used to document this test. (See 5.1.12.4.3 for more information.)

During the cross-connection testing, the verifier is also required to ascertain which valves control which outlets. This information is not typically recorded on a form, as such, but is usually made clear through the basic organization of the documentation (all outlets are grouped into their respective zones). Exhibit S3.9 can be used to document this information. The valves themselves are also checked to ensure that they seal when closed. (See 5.1.12.4.4.)

During the valve tests, and also as a separate set of examinations, the verifier will test the alarms. The verifier must test that the proper alarms exist and that they operate. Exhibit S3.10 can be used to document the verifier's alarm test. (See 5.1.12.4.5 for more information.)

Each outlet is now given a quick purging to ensure that any particulate is cleared, and then a test is performed in 25 percent of the zones (chosen randomly) to ensure there is no particulate detectable. This test involves a microbalance and the use of very fine preweighed filters to detect very small quantities of particulates. Exhibit S3.11 and Exhibit S3.12 can be used to document this purging and particulate testing. Should the system fail these tests, it must be repeated on a more extensive basis until all zones are proven to be clear. (See 5.1.12.4.6 and 5.1.12.4.7 for more information.)

A test is now done at the source, and a second at the most distant outlet from the source, to validate that the pipeline contains no halogenated hydrocarbons (usually from cleaning solvents), hydrocarbons (usually from contamination), or water (usually from storing the pipe or fittings poorly). Exhibit S3.13 can be used to document this information. Except for the dew point, these are differential tests, looking for any change between the source and the furthest outlet. The dew point is absolute, looking at the

Verifier's Name	Gas System	Date	Sample Outlet A	Purging Complete	Purging Not Complete	Sample Outlet B	Purging Complete	Purging Not Complete	Sample Outlet C	Purging Complete	Purging Not Complete

EXHIBIT S3.11 *Piping purge test.*

Verifier's Name	Gas System	Date	Sample Outlet A	Preweight	Postweight	Delta	Sample Outlet B	Preweight	Postweight	Delta

EXHIBIT S3.12 *Piping particulate test.*

actual value. Exhibit S3.14 can be used to document this test. (See 5.1.12.4.8 for more information.)

The operational pressure test is actually a flow test for the performance of the outlets. The verifier will look for a certain minimum flow with less than a certain maximum pressure drop. It is performed for each outlet, with an additional test for instantaneous flow being performed only in critical care areas where ventilators are usually used. Exhibit S3.15 can be used to document this test. (See 5.1.12.4.10 for more information.)

The verifier will sample the gas at each outlet to ensure that it meets a purity specification (percent purity). This test requires the use of specialized analyzers specific for the gas being piped. Most verifiers will then draw a sample from the air pipeline to send to a laboratory that will perform more detailed examination to prove the level of contaminants is below allowed levels. (Some verifiers can also perform this test on-site.) Exhibit S3.16 and Exhibit S3.17 can be used to document these tests. (See 5.1.12.4.11 and 5.1.12.4.12 for more information.)

Along the way, the verifier will be noting the labeling of each component and ensuring that the labeling is complete, accurate, and correct. This labeling is commonly incorrect in a new installation, because an architect's room numbers and the actual room numbers are not always the same. (See 5.1.12.4.13 for more information.)

The testing and verification process can be long and seems to have considerable repetition built in to the process, which is very true. This is intentional to ensure that a failure or flaw in the installation will be detected and can be corrected. The redundancy in the testing ensures that crucial elements are tested repeatedly and by different methods, therefore reducing the chance of an oversight. Ideally, any flaws can be caught by the installer and corrected before anyone is even aware, but, if not, the verifier is there to ensure the first patient remains protected.

REFERENCE

1. NFPA 99, *Health Care Facilities Code*, 2018 edition, National Fire Protection Association, Quincy, MA.

Verifier's Name	Gas System	Date	Source	Outlet	Delta
	Halogens, 5ppm				
	Total hydrocarbons (excluding methane), 5ppm				
	Total non-methane hydrocarbons (as methane)				

EXHIBIT S3.13 *Piping purity test.*

Verifier's Name	Medical Air System	Date	Source	Outlet	Test Passed	Test Failed

EXHIBIT S3.14 *Dew point test.*

Verifier's Name	Gas System	Date	Outlet Location	Static Pressure	Flow Rate	Test Passed	Test Failed

EXHIBIT S3.15 *Operational pressure test.*

Verifier's Name	Gas Type	Date	ppm or Limit Value	Outlet Location	Test Passed	Test Failed
	CO					
	CO_2					
	Dew point @ X psig					
	Hydrocarbons					
	Halogens					

EXHIBIT S3.16 *Medical gas concentration test.*

Verifier's Name	Gas Type	Date	ppm or Limit Value	Outlet Location	Test Passed	Test Failed
	O_2					
	NO					
	N_2					
	Medical air					
	Other gases					

EXHIBIT S3.17 *Medical air purity test.*

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