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# GUIDELINES FOR CLINICAL MULTIPLACE HYPERBARIC FACILITIES

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Report of the Hyperbaric Chamber

Safety Committee of the

Undersea and Hyperbaric Medical Society



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The opinions, conclusions, and recommendations contained in this report are those of the Committee and are not to be construed as official or necessarily reflecting the views of the Undersea and Hyperbaric Medical Society, Inc.

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## Chapter I

# INTRODUCTION

### Purpose

There are two basic types of clinical hyperbaric chambers: monoplace and multiplace. The monoplace chamber allows for the treatment of only one patient at a time in a 100% oxygen environment. The multiplace chamber allows more than one patient to be exposed to an air environment under increased atmospheric pressure while breathing oxygen through a mask, a hood, or endotracheal tube. The purpose of this document is to provide operators of clinical multiplace hyperbaric systems basic guidelines by which to operate such facilities.

The Undersea and Hyperbaric Medical Society (UHMS) is an acknowledged professional society for the field of diving and hyperbaric medicine. The UHMS has established guidelines for clinical applications for hyperbaric oxygen. The Society and its members are fully committed to increasing the body of knowledge available to encourage safe and effective use of hyperbaric facilities.

The technology for clinical multiplace hyperbaric facilities ranges from the simple "one man, one valve" concept to state-of-the-art, computer-controlled systems. As older systems remain in service and newer systems are initiated, the common denominator among all of them is a dynamic safety program. Operational safety and quality of care must be maintained as the highest priority.

## NOTES

4-1287

## Chapter II

# GOVERNING STANDARDS AND GUIDELINES

Historically, clinical hyperbaric facilities have used the following references for the design, installation, and use of multiplace chambers. The Safety Committee suggests that these references be readily available.

### **National Fire Protection Association (NFPA) Standard for Health Care Facilities**

NFPA 99 Chapter 19 addresses fire protection standards for hyperbaric facilities. This chapter governs the fire safety aspects of the facility housing a hyperbaric system, including: the room housing the hyperbaric systems, certain aspects of the pressure vessel for human occupancy, related equipment and support systems, and facility operational personnel.

This document is periodically updated and published by the National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9904.

### **American Society of Mechanical Engineers**

The American Society of Mechanical Engineers (ASME) provides the minimum requirements for designing, fabricating, inspecting, testing, and certifying pressure vessels. A standard for construction of clinical hyperbaric chambers is ASME's Pressure Vessels for Human Occupancy (PVHO-1) or an international equivalent. Chambers meeting these standards will be identified on the manufacturer's data plate with the notation of ANSI/ASME PVHO-1, which is affixed to the chamber exterior.

ASME codes are published by the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

### **Compressed Gas Association (CGA)**

The CGA publishes numerous guidelines that provide minimum safety standards for medical air/gases and related support systems. Applicable standards cover the storage and handling of compressed gases and the installation and cleaning of oxygen and related piping systems.

These guidelines are published by the Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

## Hyperbaric Oxygen Therapy, A Committee Report

The UHMS Hyperbaric Oxygen Therapy Committee report includes guidelines for clinical hyperbaric facilities which are proposed for inspections conducted by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). The guidelines describe the responsibilities of hospital management and the director of hyperbaric medicine.

*Hyperbaric Oxygen Therapy, A Committee Report* is published by the Undersea and Hyperbaric Medical Society (UHMS), 10531 Metropolitan Avenue, Kensington, MD 20814.

## Other References

*U.S. Navy Diving Manual*, Department of the Navy, Washington DC  
*NOAA Diving Manual*, Department of Commerce, Washington, DC  
Occupational Safety and Health Administration (OSHA), Washington, DC  
Joint Commission on Accreditation of Health Care Organizations, Chicago, IL  
*U.S. Air Force Pamphlet 161-27 Operation of Hyperbaric (Compression) Chambers*, U.S.  
Government Printing Office, Washington, DC

## Chapter III

# MULTIPLACE HYPERBARIC FACILITY

### Hyperbaric Facility

#### *Chamber Room*

The flooring must support the weight of the chamber. Placing the chamber on the ground floor with easy access is preferred, and this may avoid floor-loading problems. The plant engineer or an architectural firm should ensure that the floor can support the weight of the pressure vessel, both when moving the chamber into place and under operating conditions. Although hydrostatic pressure testing is performed at the manufacturer's site, there may be circumstances that require hydrostatic testing after the chamber is installed. Therefore floor loading should include capacity for the additional weight of the water in the chamber during hydrostatic testing.

The room housing the chamber should be large enough for the chamber and patient-support activities. In most cases, the pressure vessel will be fabricated off-site and moved into the facility. Chamber placement within the room should ensure adequate space for chamber operations, patient loading, and support equipment. Access to all sides of the chamber may be required. If the chamber is placed near a wall, it should not hamper the controls or viewports of the chamber.

#### *Chamber Room Fire Protection*

Fire protection requirements for hyperbaric facilities are listed in NFPA 99, Chapter 19.

The room should also be equipped with an adequate number of appropriate fire extinguishers.

NO SMOKING signs should be displayed in open view and the director should enforce a NO SMOKING policy.

All efforts should be made to eliminate static electricity in the chamber room.

A fire evacuation plan should be established, displayed, and periodically reviewed as addressed in NFPA 99, Appendix C-19.

#### *Emergency Systems*

In the event of a fire or a medical emergency in the facility, personnel should be able to call for assistance, or be able to activate the emergency response network without leaving the control console.

The chamber room should be equipped with an emergency lighting system that will automatically activate in the event of a power failure. This should include illumination for the chamber control console.

### ***Patient Support Considerations***

It is recommended that the chamber area have space allocated for patient examination and evaluation, wound care, medical supplies, patient locker rooms, restroom accommodations, and a waiting area.

### ***Other Space Considerations***

Additional space is required for equipment storage, gas cylinder storage, clean and soiled utility rooms, accumulator and compressor housing, administrative space, and equipment maintenance and repair.

## **Hyperbaric Treatment Chamber**

### ***Pressure Vessel (Chamber)***

When selecting the pressure vessel, consider the maximum treatment pressure, chamber internal layout and number of chamber compartments, patient treatment capacity, number and size of viewports, number of penetrators, configuration of doors, and type of medical lock.

The pressure vessel should be constructed to meet the safety standards for human occupancy as specified in ASME PVHO-1, or an international equivalent. ASME PVHO-1 specifies the inspections and tests necessary for certification, final code stamping, and final reports which the manufacturer retains on file for a period of five years. The owner should maintain a copy of the certification documents indefinitely; if the chamber is sold or transferred, all documentation should be transferred with the pressure vessel.

During chamber design and construction, consider equipment, piping, storage shelves, and other items (brackets, hangers, studs) that are to be permanently installed to support chamber operations or treatments. The internal size and layout can be determined from the anticipated number of ambulatory and litter patients, which will determine the number of bunks, gurneys, or seats to be accommodated. For safe operations, the pressure vessel should have a design pressure of 1.25 times the maximum working pressure. The maximum working pressure of the chamber should be based on the type of treatments to be performed under presently accepted and anticipated treatment protocols. Most current clinical multiplace hyperbaric chambers have a working pressure of 6 atmospheres absolute (atm abs).

### ***Viewports (Windows)***

Chamber viewports should be constructed in accordance with the ASME PVHO-1 standards in force at the time of construction. The number, size, and location of viewports depend on the chamber configuration external viewing requirements and the desired amount of external light to be transmitted inside the chamber.

The chamber design will dictate the physical size, number, and location of viewports that can be installed. Generally, viewports should be located so the patients can be observed and they can view outside. This will assist greatly in reducing the patients confinement anxiety. If possible, viewports should be located on both sides of the chamber and should allow transfer locks to be monitored.

Externally mounted closed circuit television cameras may require an extra viewport. This viewport should be positioned to give the best overall view of patients.

**CAUTION: Nonaqueous cleaning compounds and direct sunlight (ultraviolet) on acrylic viewports may cause viewport deterioration.**

### *Doors*

Chambers are occasionally equipped with a combination of round and rectangular entry doors. Round doors unless carefully designed will present difficulties for patient and staff entry and exit.

A rectangular door provides easy access for personnel, gurneys, and wheelchairs.

### *Penetrators*

Penetrators for gas/fluids should be separated from electrical/communication penetrators.

The number, size, and location of through-hull penetrations should be determined in the design phase. It is recommended that provisions be made for an abundance of spare penetrators (Table 1).

ASME PVHO-1 UG-100 requires that a chamber be hydrostatically retested and reinspected if, after installation, new penetrations are added to the chamber hull. Therefore, it is much less expensive to provide spare hull penetrations in the initial fabrication phase than to add them at a later date.

Some chambers utilize 6- to 12-inch ports covered with blanking or penetrator plates. These plates can be drilled or modified to provide additional through-hull penetrators without requiring a hydrostatic test of the entire chamber.

### *Chamber Flooring*

The floor plates should be designed to permit cleaning of spaces below floor level. The floor plates should have a non-slip surface. Current NFPA 99 Chapter 19 requires that the floor be noncombustible, be positively electrically grounded, and be attached firmly to the chamber so it will not move.

Table 1: Suggested Penetrators per Compartment ..

No.	Penetrator Type	Number Required	Typical Size, inches
1	Air supply	1	1½-3
2	Air exhaust	1	2-4
3	Oxygen supply	1	½
4	Oxygen exhaust	1	½
5	Pipe lights	(up to 4) <sup>a</sup>	1
6	Drains	1	1
7	Environmental condition	2	½
8	Pressure relief valve	1	1-3
9	Gauge	1	¼
10	Gas analysis	1	¼
11	Fire suppression	1	2
12	Medical suction	1	½
13	Communications, telephone	1	½
14	Electrical	2	1
15	Monitoring, physiological	2	1
16	Spare	2	2
17	Spare	10	1
18	Spare	10	¾
19	Spare	10	½
20	Spare	5	¼

<sup>a</sup>The number of lights per chamber depends on the size of the compartment.

If the supply or exhaust openings are under the floor, there must be appropriately designed baffles or perforations in the floor plates to ensure adequate mixing of chamber air.

### Chamber Paints

Paints and primers used inside the chamber should be fire resistant, durable, and should not produce a toxic environment. The paint should be inorganic-zinc-based or a high quality epoxy or equivalent. White or light tints are recommended to enhance internal light levels.

After painting the chamber interior, a minimum of 72 hours should elapse and off-gassing should no longer be detectable before commencing chamber operations with personnel aboard.

It is advisable to draw a gas sample at the completion of the curing to ensure that there is no continued off-gassing or undesirable odors.



### Seats and Bunks

All installed seats and bunks should be fabricated of noncombustible, non-sparking material (such as aluminum), free from sharp edges and corners, and should be designed for easy installation and removal. Bunks and seats should be grounded.

Seat cushions and mattresses should be made of fire-resistant materials.

### Pressure Relief

A pressure relief device should be installed on each chamber compartment to prevent over-pressurization. The pressure relief valve should be set in accordance with ASME, Section 8, Div. 1. UG-134 "at a pressure not to exceed the maximum allowable working pressure of the vessel." Except when a pilot-activated relief valve is installed it should have a manual actuation handle that is easily accessible.

A quarter turn ball valve should be installed between the chamber and the pressure relief valve so the relief valve can be overridden in the event of malfunction. The ball valve handle should be wired in the open position by a frangible safety wire.

— Relief valve pressure should be tested annually & test pressure should be recorded.

### Chamber Pressure Gauge

Each chamber compartment should be equipped with an independent pressure gauge which displays chamber pressure.

The gauge line plumbed from the chamber hull to the pressure gauge should have a shutoff valve near or at the chamber hull. In accordance with ASME PVHO-1, gauge lines should not supply any other devices.

Each chamber compartment should be equipped with an internal caisson gauge to allow the inside tender to be aware of the pressure.

→ Redundant pressure indicators are helpful when remote chamber pressure control stations are used.

The inside port for the gauge line should be protected with a shield to prevent inadvertent blockage which could cause inaccurate pressure indications.

The system tubing and components should be cleaned before being installed, and the gauges should be re-calibrated <sup>or tested against a master reference gauge every 6 months</sup> once a year to ensure accuracy.

The gauge lines should be checked periodically for leaks.

And when there is a discrepancy  
 > 2% of full scale between  
 any 2 gauges

— Columbia caisson testing & cal.  
 recorded in Appendix 400

## NOTES

## Chapter IV

# CHAMBER OPERATIONAL SYSTEMS

### General Information

The chamber has operational systems which consist of: air pressurization system, breathing gas system, environmental control unit, communication system, lighting, patient monitoring system, control console, and fire extinguishing system.

### Air Pressurization System (Figure 1)

The air pressurization system is used to increase the pressure of the chamber to the desired treatment pressure. Air is compressed and transported through the piping system to air storage flasks or accumulators. When the chamber is pressurized, air is transported through the piping system from the air storage system to the chamber. The piping, air compressor, and storage capacities should provide adequate flow and volume of air to support treatment protocols and conduct emergency operations.

### Air Compressor and Filter System (Figure 2)

Compressed atmospheric air contains natural trace gases and impurities which vary with proximity to industrial areas, other sources of transient pollution such as automotive exhaust, and helicopter operations. When atmospheric air is compressed during periods of rain or extremely high humidity, the water content of the source air is raised considerably and in-line water separators or dehumidification systems may be required. Water in itself is not considered an impurity, but can affect operation of the air purification system, chamber control systems, and accelerate corrosion in the air storage vessels.

The most common method of producing pressurized air is to compress ambient air to the desired working pressure. Compressors commonly used in health care facilities include lubricated and non-lubricated piston types, and rotary type compressors.

Compressed breathing air must meet the purity standards for medical air. Periodic sampling of air should be accomplished to verify its purity.

The compressor intake should be located where it will not be contaminated by carbon monoxide such as from automobiles, boilers, or diesel exhausts. The compressor intake should be equipped with a filter that removes solids such as dirt, dust, and airborne impurities that are 5  $\mu\text{m}$  or larger. The intake filter should be the dry type. The size of the intake piping should be

## Multiplace Chamber Safety

## NOTES:

- 1.- CHAMBER PRESSURE REFERENCE TO BIB SYSTEM AND OTHER SERVICES. MUST BE SEPARATE FROM DEPTH GAUGE LINE
- 2.- REQUIRED ONLY IF OUTER LOCK CAN BE PRESSURIZED INDEPENDENTLY OF INNER LOCK

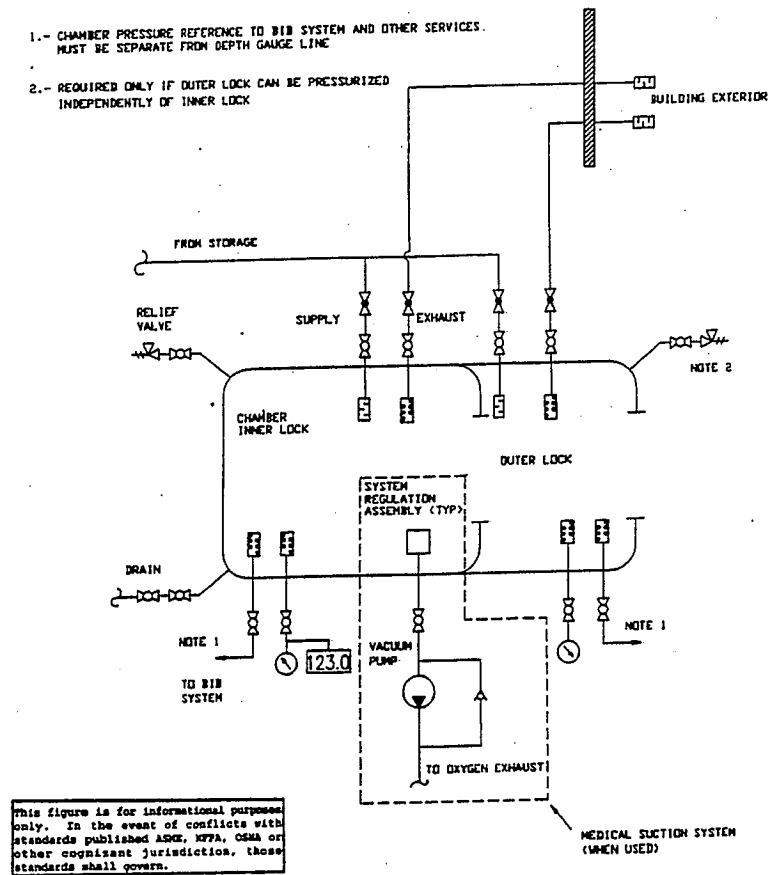


FIG. 1—Chamber Pressurization/Depressurization (Example)

## NOTE 1:

- 1.- COMPRESSOR DESIGNS THAT PERMIT THE AIR TO COME IN CONTACT WITH COMPRESSOR LUBRICATING OIL SHOULD BE AVOIDED

This figure is for informational purposes only. In the event of conflicts with standards published ASME, NFPA, OSHA or other cognizant jurisdiction, those standards shall govern.

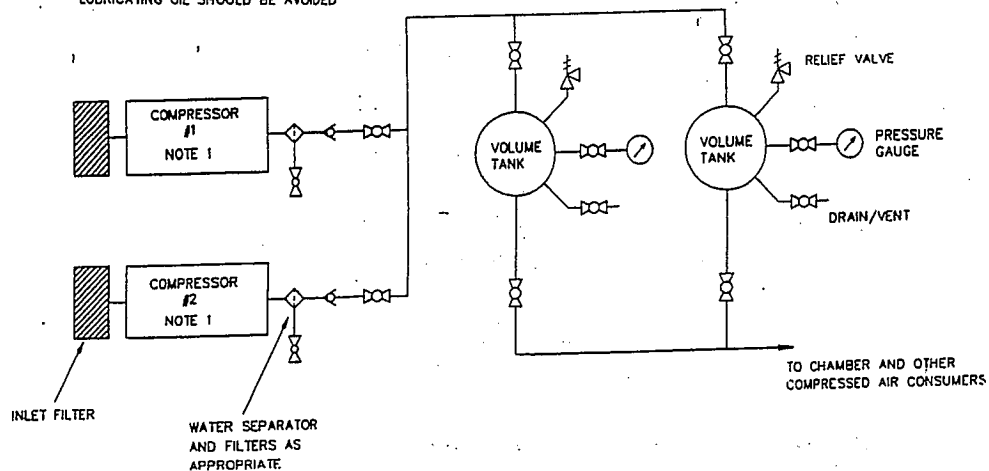


FIG. 2—Compressed Air System (Example)

large enough to avoid compressor starvation.

Consideration should be given to cooling the compressor discharge air to remove the condensate.

Filters should be placed after the cooling coil on the discharge side of the compressor to remove water, oil vapors, odors, and other contaminants before storage or use.

An activated charcoal filter will remove odors.

Carbon monoxide can be removed by using a hopcalite-type catalyst which first converts the carbon monoxide to carbon dioxide and then absorbs the carbon dioxide. Because hopcalite can be "poisoned" by water vapor, it is very important to locate the catalytic filter downstream from the water removal systems.

Filter housings should be equipped with a drain valve system to evacuate the condensate, oil, and particulate, and should be drained periodically. It is recommended that an automatic drain system be used on the filter housings.

### **Air Storage System (Figure 2)**

Air is stored in air storage flasks or accumulators. These storage flasks/accumulators are used as the receiver necessary to supply sufficient volume to the chamber, as a pulsation dampener to the chamber, and as an additional condensate collector.

Air flasks/accumulators are manufactured in a variety of sizes and configurations to meet the individual needs and space requirements of the facility. They should also be constructed to meet the ASME pressure vessel code (Section VIII, Division 1) and be registered with the National Board of Boiler and Pressure Vessel Inspectors. They should be designed for pressures equal to or greater than the normal working pressures of the compressors.

The air flasks should be equipped with a resettable pressure relief valve meeting ASME standards, a pressure gauge, and a condensate manual or automatic drain valve. An automatic drain valve is usually installed when it is inconvenient for a person to manually drain the condensate from the air flasks.

Piping from the compressors to the air flasks should be sized to accommodate the flow of compressed air without causing back pressure on the compressor.

### **Piping System**

The piping system should be copper, brass, or stainless steel. Galvanized, black iron, or steel pipes are unacceptable for corrosion considerations.

The pressurization system should be equipped with noise attenuators to prevent uncomfortable noise levels.

The piping system should be designed to maintain, as closely as possible, a 2.8 atm/min compression. Some chambers are too large to support this rate of compression and decompression.

**Note: Most clinical treatments use a rate of compression and decompression that is less than 2.8 atm/min.**

Exhaust gases from the chamber should be piped outside of the building and should be equipped with appropriate noise attenuators.

The depressurization system, relief valve, gauge, and sample line penetrators within the chamber should be equipped with a screen over the exhaust port to prevent injury.

All system components and piping should be cleaned using an approved cleaning procedure before installation. An example of a cleaning procedure is in Attachment A.

If a computer or remote pneumatic control system is used to operate the air pressurization valve it is recommended that a manual override or by-pass be installed as a backup in the event of remote system failure or computer malfunction.

## Breathing Gas System

### *Air Purity Standards*

The purity standards of compressed air for human respiration are defined by many organizations. These include the U.S. Navy, the Compressed Gas Association (CGA), and the National Fire Protection Association (NFPA) Medical Air Purity Test (Compressor) 4.5.1.3.10. (Table 2).

**Table 2: NFPA Medical Air Purity Test (Compressor) (1993)**

Dew point	+39°F (4°C) @ 50psig
Carbon monoxide	≤10 ppm
Carbon dioxide—air	±500 ppm
Gaseous hydrocarbons—air	≤25 ppm (as methane)
Halogenated hydrocarbons—air	≤2 ppm

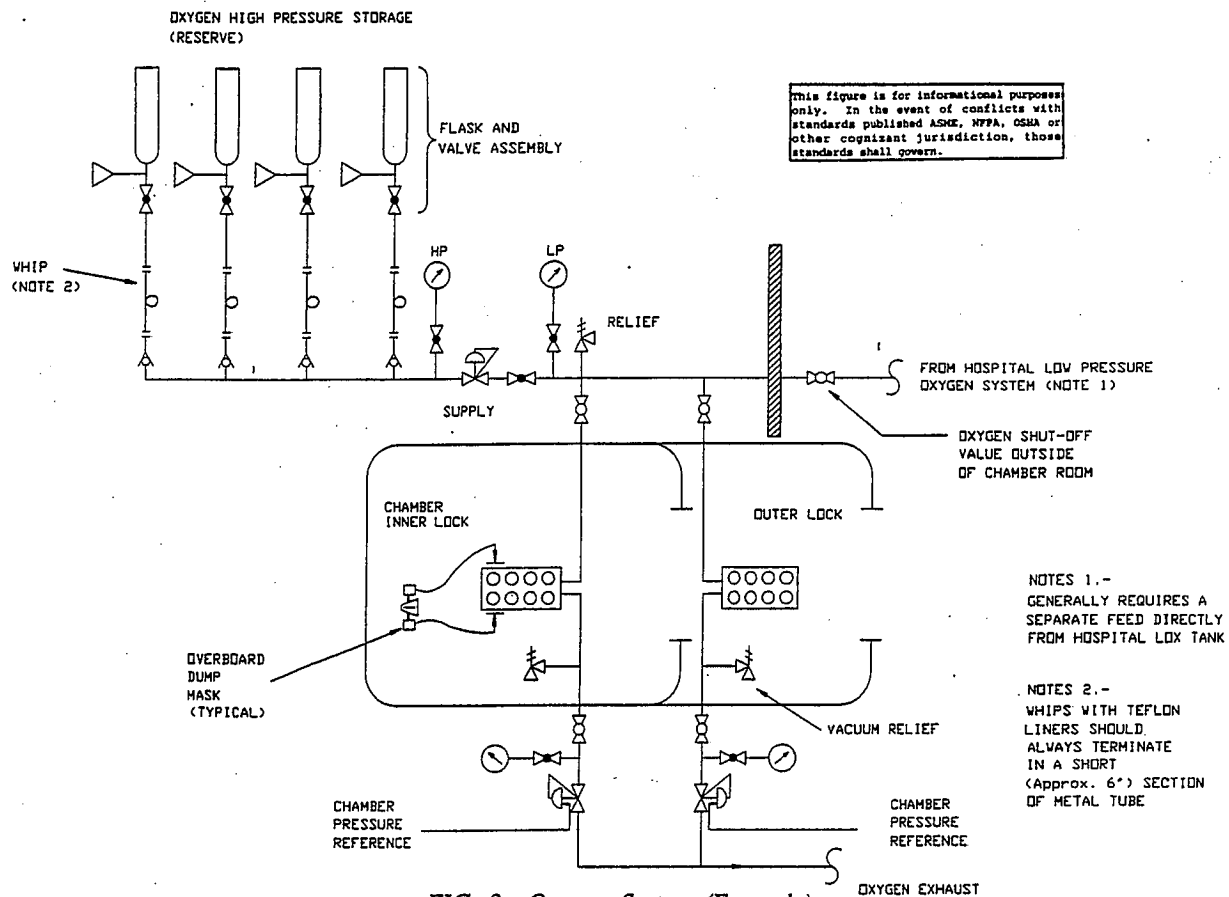
The American National Standards Institute/Compressed Gas Association (ANSI/CGA) G-7.1 provide a Directory of Limiting Characteristics for Quality Verification Levels (Grades) of Air. A table of nine grades of air ranging from industrial air to specifications for air as a drug are listed.

To determine air purity, a sample of the gas must be analyzed. A gas chromatograph or mass spectrometer may be used for this purpose. If the facility does not have access to a gas chromatograph, mass spectrometer, or Draeger sampling tubes, it is recommended that air samples be taken following compressor or system maintenance or at least semi-annually for analysis by a professional laboratory.

## Oxygen Supply and Exhaust System (Figure 3)

### *General Information*

The oxygen supply system provides breathing oxygen to patients and attendants as required. Oxygen is delivered inside the chamber through a variety of delivery systems (oronasal masks, oxygen hoods, endotracheal tubes).



The oxygen supply can be provided from the hospital main supply or from an independent source. In either case, the supply pressure will vary by facility but will usually range from 50 to 150 pounds per square inch gauge (psig). Pressures within this range are required at all oxygen outlets. The system should be equipped with a shutoff valve for emergency isolation. This valve preferably will be located at the chamber hull or operator console.

Consideration should be given to the pressure needed for the oxygen regulator to function inside the chamber (usually at least 50 psig above chamber pressure). Oxygen supply pressures should be displayed continuously at the chamber operator console.

A secondary (reserve) oxygen source should be provided in the event that the main service is interrupted.

An oxygen dump system is used to remove the exhaled gases from the patient-breathing device and exhaust them outside the building.

The dump system should be designed to limit the amount of negative pressure between the patient and the ambient pressure outside the chamber.

Oxygen is normally supplied from either a liquid (cryogenic) system or a high pressure gas source. A standby oxygen source should be plumbed into the hyperbaric system as emergency backup to the main supply.

### ***Oxygen Purity Standards***

Purity of the gas from a liquid oxygen source is normally at least 99.5% pure oxygen. However, oxygen in the gaseous form is produced in different purities. Care should be taken to use only oxygen bottles marked "Oxygen U.S.P." or "Aviators" grade and refrain from using industrial grade oxygen. When gaseous oxygen is ordered, it should be at least Grade E (99.5% pure).

When the oxygen is delivered, the percentage should be verified before placing on line for clinical use.

### ***Cryogenic Precautions***

The dedicated oxygen source should be sized to provide a reasonable number of treatments without refilling or replacing the tanks.

Liquid oxygen containers should never be installed on asphalt pavement or tile. The area in and around the oxygen storage vessels should be constructed of concrete, or at least have a gravel foundation.

When stored outside, all grasses, weeds and shrubbery should be kept clear at least 10 feet around the storage area. The oxygen storage area should have a secure fence at least 6 feet tall.

Piping should be well insulated, and appropriate "Danger" and "No Smoking" signs posted.

### ***Oxygen Piping***

Oxygen piping and manifold systems should be constructed under the supervision of a competently trained person who is thoroughly familiar with problems related to oxygen.

When brazing copper tubing, the tubing should be continuously purged with nitrogen to prevent the formation of copper oxide which would introduce contaminants into the oxygen system. All lines should be cleaned for oxygen service in accordance with CGA guidelines. An example is in Attachment A.

Material and fabrication considerations for oxygen piping in multiplace treatment chambers is available from the American Society of Mechanical Engineers Pressure Vessels for Human Occupancy (ASME/PVHO) standards, the National Fire Protection Association (NFPA) standards, and the guidelines of the Compressed Gas Association (CGA).

NFPA 99 Chapter 19 requires that an oxygen shutoff valve be installed where the oxygen enters the hyperbaric room.

At a point in the room where the oxygen is supplied, a separate oxygen control panel should be installed. This panel (Figure 4) should contain a shutoff valve and a pressure gauge. The valve provides the main safety shutoff in the event of a fire or when maintenance and calibration procedures are performed on the chamber.

The shutoff valve for most low pressure lines (equal to or less than 125 psig) should be a ball valve (quarter turn) for rapid control and for elimination of line flow restrictions. Ball valves should not be used in high pressure lines (equal to or above 125 psig) due to risk of fire and explosion.



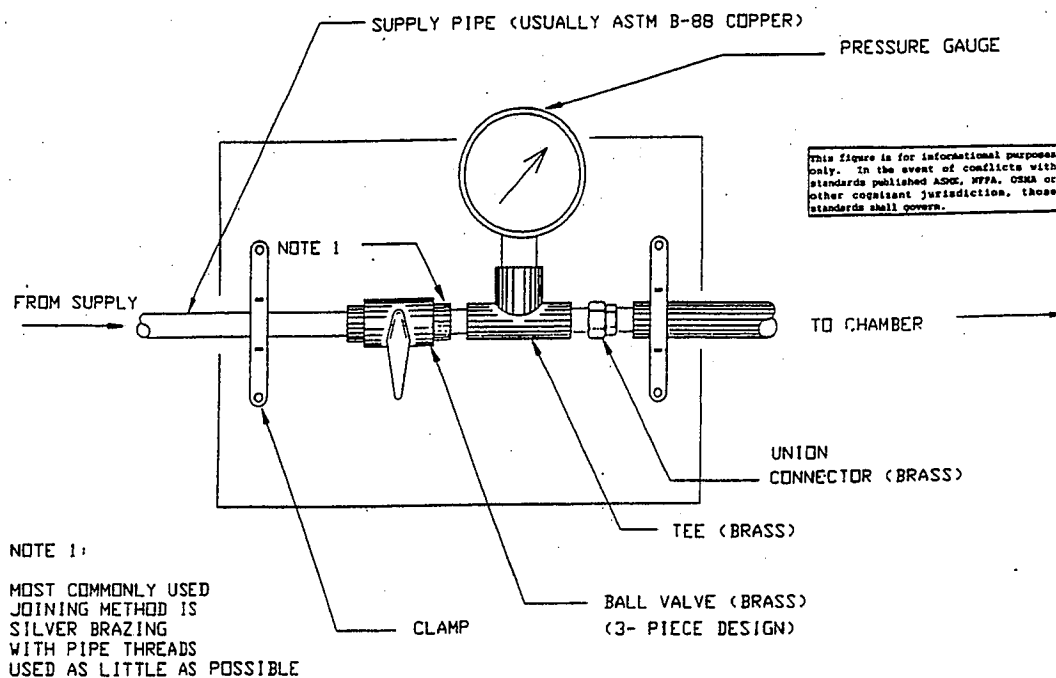


FIG. 4—Low Pressure Oxygen Control Valve

Oxygen supply piping should have no kinks, sharp bends, or restrictions. At the completion of the construction or any modification of the oxygen piping, it is required that a leak check be made on the joints and components to ensure system integrity. Attachment B provides a list of commercially available leak test solutions.

**CAUTION: Residue of the test solutions may be flammable. All surfaces to which leak test solutions have been applied should be rinsed with water to remove the residue.**

### *Safety Aspects of Oxygen*

Oxygen supports and greatly accelerates combustion. When pure oxygen is used, special precautions are needed to eliminate ignition sources and burnable materials. Some substances which do not normally burn in air will burn in an elevated oxygen environment.

Do not permit smoking or open flame in any area where oxygen is stored or used.

Keep organic materials and other flammable substances away from possible contact with oxygen, particularly oil, grease, kerosene, paints, petroleum products, tar, coal, dust, and dirt.

Use only oxygen-approved lubricants or greases on or around oxygen equipment (Attachment C). Also, avoid excessive amounts of lubricants and greases.

Maintain adequate ventilation in the oxygen storage areas at all times to prevent accumulation of oxygen and to minimize combustion hazards.

Use only equipment, parts, and apparatuses designed for use with oxygen. Ensure that equipment and replacement parts are compatible with oxygen and are cleaned for oxygen service.

Special tools used for oxygen service should be non-sparking (i.e. brass), maintained, cleaned, specially marked, and segregated from all other tools in the hyperbaric department.

Liquid oxygen is extremely cold and may cause severe frostbite to the eyes or skin. Caution should be taken to avoid touching frosted pipes or valves with bare hands.

High pressure oxygen piping should incorporate a needle or globe valve (multiple turn) to avoid rapid pressurization of the line and to prevent adiabatic heating.

**CAUTION: Ball valves should never be used in HIGH PRESSURE (above 125 psig) oxygen lines!**

The high pressure line should be equipped with a pressure regulator to reduce the high pressure to the desired working pressure of the chamber (Figure 5). This regulator should be located in the piping system downstream from the main shutoff valve. The pressure regulator should be an approved oxygen regulator that meets the recommendations of the Compressed Gas Association and the performance requirements for its application.

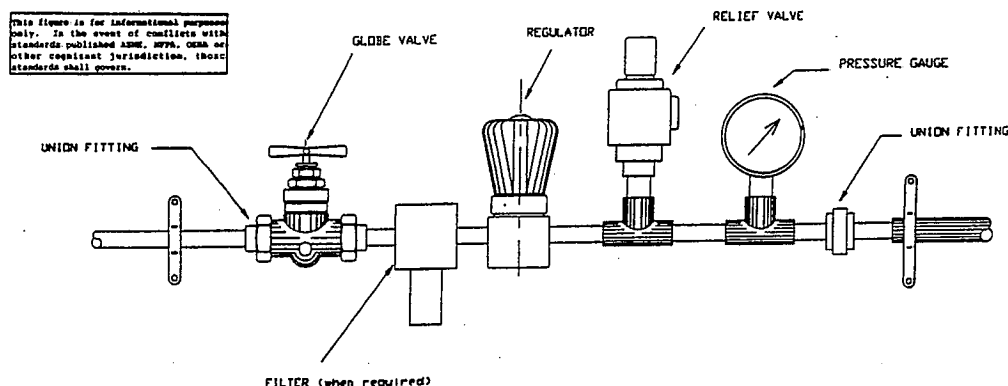


FIG. 5—High Pressure Oxygen Control System

A pressure gauge should be installed downstream of the regulator to provide visual indication of the oxygen pressure on line. A low oxygen pressure alarm can be installed in the line, but is not a mandatory feature.

The oxygen supply line from the pressure-reducing regulator to the chamber should be either rigid pipe or hose that is metal reinforced and internally lined with Teflon. The pipe or hose should have a minimum rating of 400 psig working pressure.

## Gas Analysis System (Figure 6)

### Oxygen Levels

Oxygen levels in the chamber are normally monitored continuously using a paramagnetic, chemical, or fuel-cell oxygen analyzer. It is recommended that a fuel-cell or paramagnetic oxygen analyzer be used if the intent is to use one analyzer to monitor both the oxygen levels in the patient hood and air in the chamber. Once calibrated, the fuel-cell and paramagnetic output are linear and do not require re-calibration between air and 100% oxygen.

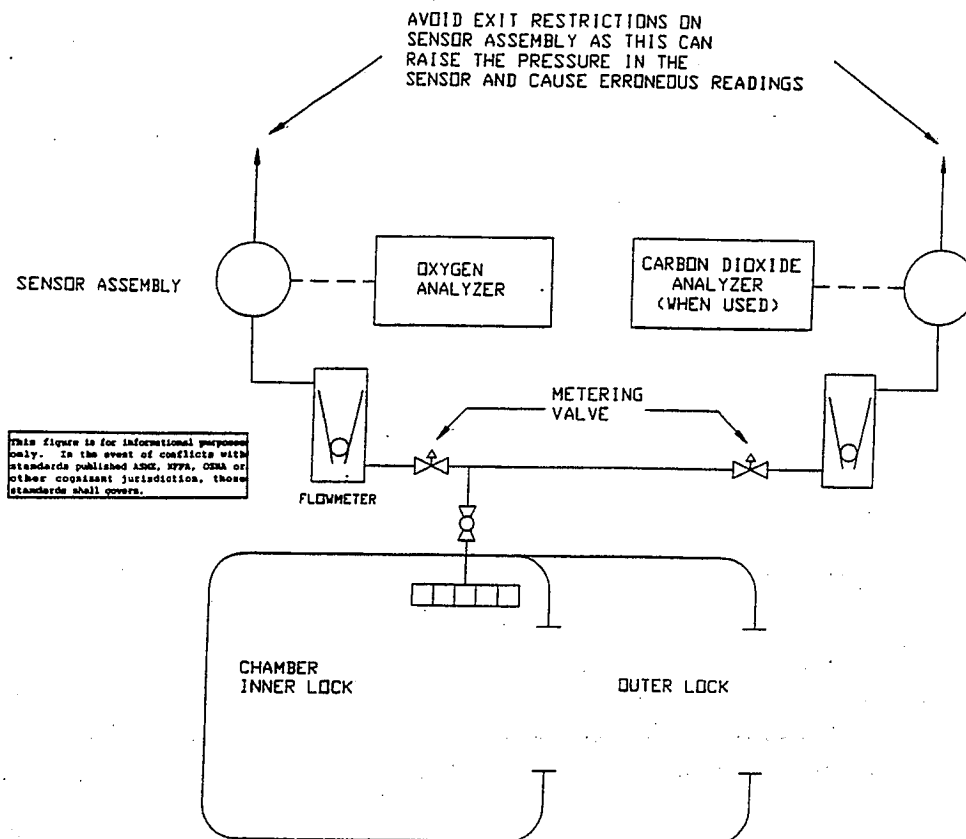


FIG. 6—Chamber Gas Analysis System

The tubing supplying the chamber gas to the analysis systems should be  $\frac{1}{4}$  inch or less to shorten the analysers response time to changing conditions in the chamber environment and/or patient breathing devices.

### Carbon Dioxide Levels

Ventilation of the chamber atmosphere may be required to maintain acceptable levels of oxygen and carbon dioxide. Carbon dioxide levels below 0.5% surface equivalent partial pressure are desired for long-term exposures.

If a continuous purge of chamber air is not used, or if saturation work is anticipated, use of a carbon dioxide analyzer is recommended.

### Environmental Conditioning System (Figure 7)

The chamber occupants can be subjected to extreme temperature changes during both compression (increase in temperature) and decompression (decrease in temperature). With the installation of a chamber environmental conditioning system, temperature and humidity conditions may be modified to make the environment more comfortable for the occupants.

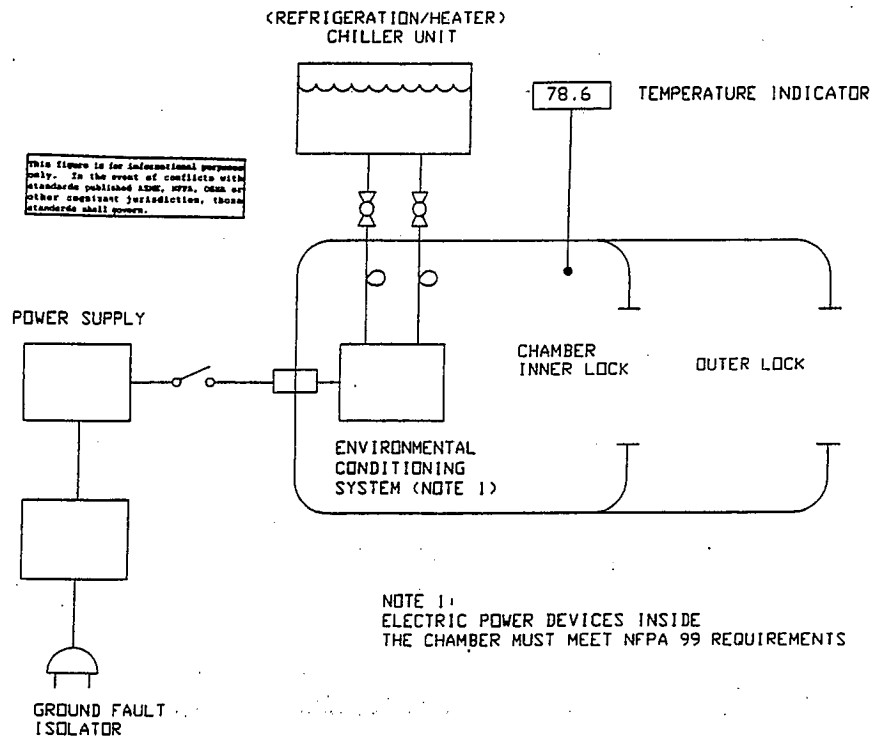


FIG. 7-Chamber Environmental Conditioning System

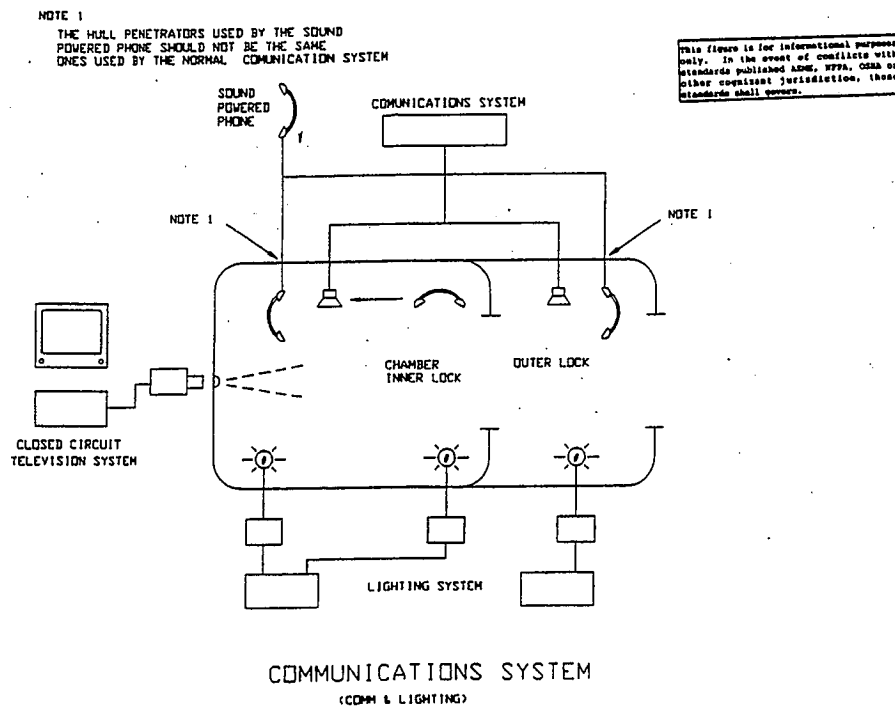
The environmental conditioning system usually contains a unit that flows hot or cold water from outside the chamber through coils located inside the chamber, with a fan circulating the chamber air.

Operational experience has demonstrated that maintaining relative humidity greater than 50% is of significant value in the reduction or elimination of static build up.

### Communication System (Figure 8)

The communications system is a vital link between the inside attendant and the chamber operator. A good, clear, understandable communications system, with a backup, is suggested.

The system should be designed to provide an "open" microphone inside the chamber so that



the control station, and personnel outside the chamber, can monitor all conversations and noises from inside the chamber. This will form an "open-mike" communication between all stations.

The main control communications system should be equipped with an emergency backup circuit capable of continuing communications if normal power is lost. There should be a provision for private communication between the inside observer and the outside attendant.

The entire system should be intrinsically safe for chamber operations.

In addition to the main communications system, a sound-powered, hand-held telephone system is recommended or a secondary emergency system with stand-alone battery which maintains communication between the chamber occupants and the chamber operator if the primary system fails.

The chamber communication system should meet the requirements of NFPA 99, Chapter 19.

## Patient Monitoring System

Closed-circuit television is a most valuable tool for safely monitoring chamber occupants. Television systems allow several persons located remotely to observe the chamber interior. The television cameras should be located for best overall viewing.

Closed circuit TV monitoring of the chamber interior is required by NFPA 99 Chapter 19 for chamber operators who do not have direct visual access to the chamber.

Patient monitoring equipment, unless modified or designed for chamber use, should be located outside of the chamber and the monitoring leads routed through an approved electrical penetrator.

## Lighting System

To reduce electrical power requirements in the chamber, one type of lighting system uses an external light source and an acrylic light pipe passing through the chamber hull. The acrylic rod is installed into the chamber using an internal O-ring design and is threaded into an existing coupling in the chamber hull. Because the light bulb is located outside, the heat generated is dissipated outside the chamber. Rheostats can be provided to alter light intensities.

Some light sources are designed to transmit light directly into the chamber through chamber viewports. This type of lighting is efficient but sacrifices use of the viewport for observation. Heat generated from external lights can damage the plastic viewport; therefore the light source should be kept a safe distance from the viewport.

Chamber lighting should be on the uninterruptable power source (UPS) or the hospital emergency power circuit.

## Electrical Systems

The requirements for electrical wiring and electrical equipment in hyperbaric chambers are governed by NFPA 70 (National Electric Code) and by NFPA 99, Chapter 19. All essential electrical equipment and circuits associated with the hyperbaric system should have a minimum of two independent sources of electrical power: a main power source and an emergency power system.

Electrical power supplied to the hyperbaric chamber is governed by the requirements of NFPA 99, Chapter 19.

Circuits and equipment installed within the chamber must meet the requirements of NFPA 99, Chapter 19. Switches, receptacles, attachment plugs, and connectors that emit sparks or arcs into the chamber under any operating conditions are prohibited.

Entertainment systems (stereos and television), unless designed for use within hyperbaric environments, shall be located outside the chamber. Electrical power for the entertainment system should be routed through the ground fault interrupter.

The chambers should be grounded in accordance with the requirements of NFPA 99, Chapter 19.

## Fire-Suppression System (Figure 9)

Fire spreads more rapidly as oxygen concentrations by volume increase in hyperbaric environments, and in some cases has no incipient or smoldering stage.

Multiplace hyperbaric chambers must be equipped with a fire-suppression system constructed in accordance with NFPA 99, Chapter 19. The system may be either automatically or manually activated.

An automatic fire suppression system is optional. Fire detectors may be installed to alert the operator. Fire detectors may be of two types: infrared and ultraviolet. For best results the sensors should be located where they are not blocked by installed equipment.

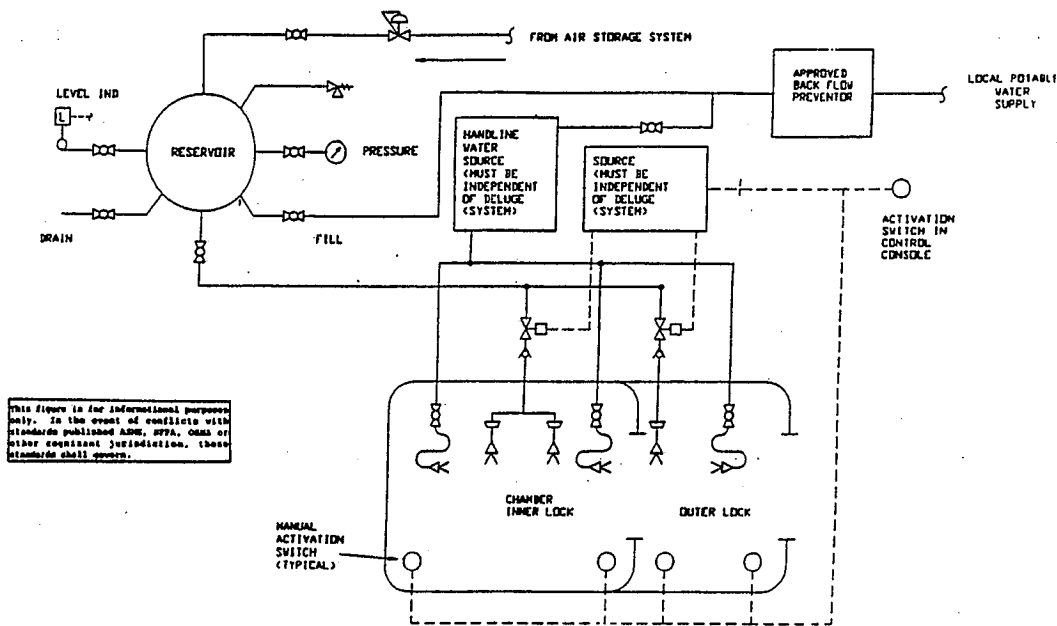


FIG. 9—Fire Suppressant System

The primary difference between manual and automatic systems is the mode of activation of water flow. The automatic system activates spontaneously in the presence of a flame. A manual system relies on the vigilance of the chamber operator or the inside attendant.

Upon activation of the fire-suppression system, communications should remain operable, oxygen should be shut off to the chamber, ventilation should cease, and the fan motor should be shut off so not to fan the flames.

Each compartment of the hyperbaric chamber should be protected in accordance with the requirements of NFPA 99, Chapter 19. The chamber interior should be equipped with protected manual actuators that cannot be unintentionally set off. Additionally, at least one protected manual actuator should be located outside the chamber, preferably at the control console.

The fire-suppression water reservoir is also a pressure vessel and should meet the standards of the ASME (Section VIII, Division 1). The reservoir should have an over pressure relief valve, water fill and drain valve, an air pressure source, and a chamber supply line. The air supply system should be able to supply sufficient air into the reservoir to pressurize the water and supply the required 2 gallons per minute (gpm) per square foot of floor area.

The size of the reservoir should be calculated to meet the requirements of NFPA 99, Chapter 19.

Deluge spray nozzles should be installed to provide a pattern to cover the entire chamber interior under all chamber operating pressures.

The fire-suppression system piping and nozzles should be constructed of copper, brass, or stainless steel to prevent corrosion and discoloration. It is good engineering practice to design a method of testing the system without actually dumping the water into the chamber.

Handlines should be provided in the chamber compartments in accordance with NFPA 99, Chapter 19.

If a portable fire extinguisher is used in the chamber, it should contain at least 2.5 gallons of

water and should be pressurized with air. The extinguisher should bear the label of the Underwriters Laboratories, Inc., and should be rated for at least 200 psig. The extinguisher should be equipped with a pressure gauge and a pressure relief valve set at 200 psig.

**A PORTABLE FIRE EXTINGUISHER IS NOT A SUBSTITUTE FOR THE HAND-HELD LINE.** Other extinguishers, such as carbon dioxide and halogenated compounds, are **strictly prohibited**.

Because the operator cannot leave the control panel while the chamber is pressurized, it is recommended that a self-contained breathing apparatus (SCBA) be installed in the chamber room for the operator to wear in the event of fire or heavy smoke. The apparatus should be Bureau of Mines approved or equivalent, supplying at least 30 minutes of air. An alternate method of supplying air to the chamber operator is to tap into the chamber air supply system with a quick disconnect fitting and a mask system, with a communication link to the chamber communication system.

Routine and periodic testing of the fire suppression system should be accomplished and coordinated with local fire department personnel. The fire-suppression deluge valves and handlines should be tested at least semi-annually.

### **Sound Attenuation**

The chamber environment presents a number of acoustical problems including echoes, resonance, and speech distortion which can disrupt communication. Frequency and resonance are characteristics of sound that affect the annoyance factor of noise. Noise levels in and around the chamber must conform to the standards set forth by the Occupation Safety and Health Act Hearing Conservation Amendment, April 7, 1983. This act addresses the noise exposure to individuals.

Most noisy equipment associated with multiplace chambers can be muffled to attenuate the noise level to acceptable standards. Numerous mufflers are made of materials that are compatible with the chamber environment.

Chambers of tubular design with bare walls cause accentuated reverberation and resonance. The reverberation problem can be reduced by installing stainless steel or aluminum acoustic baffling panels.

When noise levels cannot be lowered to acceptable levels, personal ear protection should be used.

### **Clothing**

NFPA 99, Chapter 19 approves the use of garments fabricated of 100% cotton or an anti-static blend of cotton and polyester fabric for use in chambers. Flame resistant/flame retardant materials are an effective and acceptable material, but expensive.



## PREVENTIVE MAINTENANCE

A regular preventive maintenance program should be established for the hyperbaric system and all ancillary equipment. The chamber and its operational systems, the chamber room, and the equipment used in and around the chamber should be maintained at the highest operational levels. This should also include the cleanliness of all elements of the interior and exterior systems.

### System Maintenance

"Preventive maintenance" is identified as scheduled items of maintenance required to prevent deterioration of the systems from an optimally safe state of readiness. "Corrective maintenance" is identified as: items of maintenance required to return the systems to an optimally safe state of readiness. The maintenance program and all repairs of the system should be performed by qualified personnel.

Preventive maintenance requirements for hyperbaric facilities are listed in NFPA 99, chapter 19. The section pertaining to "Maintenance" addresses the following: "The hyperbaric safety director shall be ultimately responsible for ensuring that all valves, regulators, meters, and similar equipment used in the hyperbaric chamber are properly compensated for safe use under hyperbaric conditions and tested periodically." A second section further states: "Installation, repairs, modifications of equipment, etc., related to a chamber shall be evaluated by engineering personnel, tested under pressure, and approved by the safety director. Logs of the various tests shall be maintained."

The preventive maintenance schedule should be a list of daily, weekly, monthly, quarterly, semi-annual, and annual maintenance requirements. Item testing intervals and testing durations should be approved and scheduled by the designated technical director (this may or may not be the safety director). Staff members or contractors approved by the technical director may accomplish items within their areas of expertise.

Maintenance activities should be documented. Discrepancies identified in hyperbaric systems and equipment should be documented as well as corrective actions taken. Entries should include a chronological number, date found, brief description of problem, date corrected, signature of person who corrected the problem, and signature of the person who inspected the correction.

A log should be maintained of all entries into the pressure boundaries affecting the hyperbaric systems and subsystems. There should be satisfactory resolutions to any pressure boundary entry **BEFORE** any manned chamber runs. Deviation from any complete resolution should be approved by the hyperbaric safety director or his appointed designee.

Maintenance personnel should have an area designated that can accommodate component teardowns, repairs, cleaning, and replacement operations. It is recommended that a separate

room be designated for these operations. The room should contain all special tools, work surfaces, chemicals, lubricants, and spare parts necessary to maintain the safety and operational readiness of the entire system to original factory specifications. This room should be maintained in a cleaned state, especially during operations of repairing and cleaning chamber gas components.

The preventive maintenance program should include checking the oxygen and air piping systems for leaks, proper gas pressures, and flows. The exhaust lines should be checked for obstructions and verification that gases from the chamber are exhausted outside the building.

Routine air compressor checks should include oil levels and pressures, loading and unloading pressures, cooling water flows and temperatures, and efficiency tests. Proper compressor maintenance and attention to even subtle changes can possibly save expensive repairs and unnecessary system "downtime."

Filters for intakes, air controls/instruments, overboard dumps, suction, analyzers, etc., should be routinely inspected, cleaned, and changed as necessary.

Pumps and other moving machinery should be inspected and lubricated.

Pressure regulators and switches should be inspected and adjusted.

Fire suppression reservoir tanks can have chlorox added to the water tank to reduce contaminants, otherwise the tank should be drained and refilled at least monthly to reduce the amount of contaminants present in the water. This could reduce the possibility of patient wound contamination in the event of inadvertent deluge.

Other recommended maintenance items include performing system operational tests, obtaining air samples, comparing and calibrating pressure gauges, inspecting viewports, inspecting air accumulator interiors, testing the fire-suppression deluge, and testing emergency power and equipment. This list is by no means all inclusive and each facility should establish a program that is specific to its system requirements.

## **System Cleaning Procedure**

Hyperbaric piping systems must be cleaned adequately to remove contamination before the introduction of oxygen or air.

When a newly manufactured treatment chamber is installed it is assumed to be cleaned for hyperbaric oxygen service; however, it is necessary to check with the supplier and obtain written proof.

If a used chamber has been acquired for installation it should be either cleaned or inspected for cleanliness by qualified personnel.

Uncleaned piping systems that carry oxygen and air to and from the chamber may harbor contaminants which include both organic and inorganic materials such as manufacturing oils, grease, brazing and welding slag, dirt, sand, paper, and other foreign debris. These contaminants could cause combustion in an elevated oxygen atmosphere or contaminate the oxygen or air.

In addition to proper cleaning of piping, consideration should be given to the placement of an oxygen filter at the point where hospital piping enters the hyperbaric facility. An oxygen service filter assembly (5  $\mu$ m nominal) with a stainless steel housing is recommended.

An example of cleaning oxygen and air piping is included in Attachment A.

**Note: WHEN SELECTING A PROCEDURE TO CLEAN OXYGEN OR AIR PIPING SYSTEMS, NEVER UNDER ANY CIRCUMSTANCE USE TRICHLOROETHYLENE OR CARBON TETRACHLORIDE AS THE CLEANING SOLVENT.**

Cleaning of the chamber and equipment after every compression and at the end of the workday is recommended to prevent the transmission of diseases and spread of contamination. An appropriate disinfectant for use in the chamber is a quaternary-based germicide combined with a synthetic detergent. This can also be used for cleaning all surfaces outside the chamber.

- Use only acceptable and compatible disinfectants on acrylic viewports.
- Use the manufacturers recommendations for the acceptable cleaners of acrylic viewports.
- Use of rubber gloves and eye protection is recommended when mixing cleaning solutions and during cleaning operations.
- Empty containers should be rinsed thoroughly with water before disposal.
- Contaminated clothing should be removed and washed before reuse.
- Proper infection control standards in accordance with international precautions should always be followed.
- Do not leave any bottles of cleaning solutions in the chamber. They may contaminate the atmosphere and be harmful to the occupants.
- Always be sure that the area or room used for cleaning operations is well ventilated.
- Keep all containers of cleaning solution covered, except those in immediate use. Both alcohol and Halon PCA vapors are potentially harmful if concentrated. Concentrated alcohol vapors also represent an explosion hazard.

**TRICHLOROETHYLENE IS NOT RECOMMENDED AS A CLEANING COMPOUND IN HYPERBARIC SYSTEMS.**

Trichloroethylene can break down on contact with carbon dioxide (CO<sub>2</sub>) absorbent chemicals to form highly toxic and explosive dichloroacetylene.

### **Approved Lubricants**

The special needs of the military, medical field, diving industry, space program, and chemical industry have promoted manufacturers to develop lubricants and sealants that are safe for use in pure oxygen environments.

The criteria for acceptance of safe lubricants should meet the following conditions:

- Safe with high and low pressure oxygen.
- Nontoxic in breathing systems.
- Nonreactive with standard elastomer O-ring materials.
- Nonreactive with stainless steel, aluminum, carbon steel, brass, nylon, or Teflon.
- Protective from corrosion.
- Good lubricants.
- Easy to use.

Lubricants and sealants found to be acceptable and readily available are in Attachment C.

All lubricants should be applied sparingly. Lubrication principles are based on the properties of the film of these substances; therefore excess amounts should be carefully wiped off with a clean, lint-free cloth or paper.

All lubricants, including Teflon tape, should be packaged in individual sealable containers to keep out dust and dirt and should be labeled clearly.

## Chapter VI

# EMERGENCY PROCEDURES

Following is a list of suggested emergency procedure for which facilities should have established written protocols.

- Loss of primary air
- Loss of primary oxygen source
- Rapid increase of chamber pressure
- Rapid decrease in chamber pressure
- Fire inside chamber
- Fire in facility, but outside chamber
- Loss of back-up air supply
- Loss of back-up oxygen source
- Contaminated air source
- Patient experiencing oxygen toxicity seizures
- Cardiac arrest
- Barotrauma on pressurization or depressurization
- Suspected pneumothorax
- Loss of communications
- Loss of power
- Omitted decompression
- Accidental firing of fire-suppression system

## NOTES

## Chapter VII

# ADMINISTRATION

### Consent Form

A document for the authorization of Hyperbaric Oxygen Therapy. The form should address:

- the purpose of treatment;
- the treatment procedure to be used;
- the potential for barotrauma;
- the materials allowed in chamber;
- the side effects of hyperbaric oxygen; and
- a reminder to inform medical attendants of any problems before each treatment.

### Physician's Order

The physician's order should provide the nursing and hyperbaric staff with the following information:

- the type of treatment;
- the number of treatments planned;
- the diagnosis;
- the appropriate wound care;
- the required medications;
- a suggested oxygen delivery device; and
- the rate of compression/decompression.

### Hyperbaric Checklist

This checklist should be a complete procedure to set up chamber before operation and shut down upon completion of treatment. Set-up and shut-down procedures should include a detailed list of all valves, their location, and position of operation.

This checklist should be completed daily before commencing and directly after completion of operations. The individual performing the checklist should date and sign along with the safety director before commencing operations and directly after.

### Hyperbaric Medicine Therapy Record

This is used to record progress of the patient during treatment. The form should include:

- patients names, addresses, dates of birth;
- allergies;
- brief medical history (IDDM, HTN, COPD, PVD, CAD,...);
- current diagnosis;
- admission date;
- laboratory/culture results;
- current antibiotic;
- HBO therapy;
- surgeries;
- TcPO<sub>2</sub> results;
- copy of consent form;
- wound care documentation; and
- photo documentation.

### Treatment/Therapy Log and Operational Log

Facilities should maintain a Patient Treatment/Therapy Log and Operational Log.

Patient treatment log should consist of:

- patients name;
- number of treatments;
- treatment table;
- diagnosis;
- name of physician responsible for treatment;
- names of chamber operator and medical attendant; and
- comments.

Operational treatment log should be a chronological log that notes each aspect of the treatment.

This log should include the following:

- start time;
- compression time;
- bottom time;
- end time;
- ventilation;
- changes in oxygen percentages;
- problems with patients;
- inside observer problems;
- type of oxygen delivery devices used



- names of operator and medical attendant;
- patients names;
- treatment table; and
- any other event occurring during the treatment.

Time and pressure should be noted for each event.

## **Personnel**

### ***Standards***

Hyperbaric oxygen services that meet the needs of patients, as determined by the medical staff, should be available at all times. They should be well organized, properly directed and appropriately integrated with other units and departments of the hospital, and staffed in a manner commensurate with the scope of services offered.

The scope of the diagnostic and therapeutic HBO services provided to inpatients and ambulatory care patients should be defined in writing. There should be written guidelines for the transfer or referral of patients who require hyperbaric oxygen services that are not provided by the hospital.

Vital signs, monitoring capability, i.v. infusion, and ventilator support for patients being treated in the chamber shall be appropriate for the level of hyperbaric service provided. These capabilities should be readily available to meet the needs of patients.

### ***Medical Director***

Direction of the hyperbaric unit should be provided by a physician member of the active medical staff who has special interest and knowledge in the diagnosis, treatment, and assessment of those disorders treated with hyperbaric oxygen.

The *Medical Director* should have special training and/or experience in the management of either clinical hyperbaric or diving medical problems or both, as appropriate for patient management.

The *Medical Director* should designate a qualified physician of the medical staff to act in his/her absence.

The *Medical Director* or a *qualified Hyperbaric Physician* should be available to provide any medical support for patients undergoing treatment with continuous ventilatory or oxygenation support.

The *Medical Director* should be responsible for ensuring that established policies are carried out; that overall direction is provided for HBO services; that the quality, safety, and appropriateness of hyperbaric services are monitored; and that appropriate actions are taken based on findings.

### ***Safety Director***

All hyperbaric facilities should have in writing a designated *Safety Director* as required by NFPA Chapter 19.

The *Safety Director* should be in charge of all hyperbaric equipment, operations, and maintenance. The *Safety Director* should have the authority to restrict potentially hazardous supplies and equipment from the chamber.

The *Safety Director* should be included in all phases of planning and regulations which involve the use of the hyperbaric facility.

### ***Technical Supervisor***

Hyperbaric oxygen services are to be provided by a sufficient number of qualified personnel under competent medical direction. When the scope of service warrants it, hyperbaric care is to be supervised by a *Technical Supervisor* who is certified by the National Board of Diving and Hyperbaric Medical Technology or who has documented equivalent education, training, and/or experience.

The *Technical Supervisor* could be a registered nurse, certified or registered respiratory therapist, ex-military diving medical technician, physician's assistant, or other person with documented experience and competence in delivering hyperbaric care.

The *Technical Supervisor's* duties should include supervision of hyperbaric personnel, safe operation of all equipment, maintenance, training, and chamber operations for the provision of HBO therapy.

Other duties and responsibilities may be assigned at the discretion of the *Medical Director*.

### ***Support Personnel***

Other qualified hyperbaric personnel may provide HBO services commensurate with their documented training, experience, and competence. Such personnel may include *Nurses, Respiratory Therapists or Respiratory Therapy Technicians, former military Diving Medical Technicians, former Hospital or Medical Corpsmen*, or other individuals with the documented equivalent in education, training, and/or experience.

Personnel who provide HBO services must comply with all applicable state and federal laws and regulations. Students must be directly supervised by the medical staff or a qualified HBO technologist or technician, particularly when engaged in patient care activities.

### ***Training***

The training and experience of the personnel who provide HBO services should be documented and related to each individual's level of participation in the hyperbaric services. A formal training program should be required as a prerequisite.

Non-physician HBO personnel may perform patient procedures associated with a potential hazard, including arterial puncture for obtaining blood samples and endotracheal intubation, only when he/she is authorized by the Hospital Policy/Procedure Manual, does not exceed Level of Certification, and is authorized by the Medical Director of the hyperbaric unit.

The Medical Director should maintain documentation of the qualifications of such personnel. New personnel should receive an orientation of sufficient duration and content to prepare them for their roles in the provision of HBO services.

Regular in-service continuing training education programs should be provided.

Before providing HBO services, individuals should receive instruction and demonstrate competence in the following:

- The fundamentals of hyperbaric physics and physiology, the gas laws, and the design, certification requirements, and operational principles of hyperbaric equipment.
- Recognition, interpretation, and required actions for symptoms, cardiopulmonary dysfunctions, and medication side effects, particularly those events that require notification of a physician.
- Cardiopulmonary resuscitation and other related life support procedures.
- Prevention of contamination or infection through appropriate aseptic techniques.
- Mechanics of ventilation and ventilator function, specifically with regard to the ventilator(s) in use.
- Principles of airway management including endotracheal and tracheostomy care.
- Use of masks, head tents, or other equipment for administering oxygen or other therapeutic gases and for providing humidification when required.
- Recognition and management of hyperbaric emergencies including oxygen toxicity, decompression sickness, gas embolism, pneumothorax at pressure, seizure at pressure, cardiac arrest at pressure, and fire inside or outside the chamber.
- Administration and management of intravenous fluids in the chamber.
- Administration of emergency drugs as authorized.
- Use of electrical and electronic life support equipment in the unit.
- Attention to the psychosocial needs of patients and their families.

Personnel who provide hyperbaric oxygen services should participate in relevant in-service education programs. The Medical Director or a qualified designee(s) should contribute to the in-service education.

- In-service education should include instruction in safety and infection control.
- Cardiopulmonary resuscitation training should be provided for HBO personnel as often as necessary, but not less than annually.
- Education programs for hyperbaric unit personnel should be based, at least in part, on the findings from the monitoring and evaluation of the HBO unit quality assurance program.
- Outside educational opportunities should be provided, as feasible, at least for supervisory personnel.
- Continuing education should be documented.

**Call List**

The chamber should maintain, in a location known to all chamber personnel, an up-to-date list of telephone numbers of resource persons in decompression and hyperbaric medicine available for additional consultation.

## **PIPE CLEANING PROCEDURE FOR AIR, OXYGEN, AND MIXED SYSTEMS**

Before cleaning, the following precautions are to be taken:

- Remove components from system piping to be cleaned.
- Connect pipe together using spools or jumpers.
- Use the single pass method to allow the cleaning agent to drain from all openings.
- Never allow dead ends where cleaning agent can be trapped.
- Never allow the temperature to drop below  $165^{\circ} \pm 5^{\circ}\text{F}$  at any point in the pipe run that is being cleaned.
- Do not clean copper piping with Trisodium Phosphate (TSP). See Non-Ionic Detergent Method below.

### **Trisodium Phosphate (TSP) Method**

1. To determine the volume of the cleaning solution to prepare, estimate the length of pipe (or tubing) to be cleaned and the size for the pipe. Calculate the volume of pipe to be cleaned by multiplying the length of the pipe by the volume per foot as indicated in Table A to convert to cubic inches.
2. After the volume is determined, multiply the volume by 20 cubic inches to determine the volume of solution required. To determine the volume in gallons required, multiply the answer by 0.04333 gallons/cubic inch.
3. Prepare the solution at the ratio of 2 pounds of TSP and 0.5 ounce Non-Ionic Detergent to each 80 gallons of Grade B or Deionized Water as described on page 33.
4. Heat the solution to  $165^{\circ} \pm 5^{\circ}\text{F}$  mixing the solution occasionally during the heating period.
5. Pump the cleaning solution through the pipe for 30 minutes at a rate listed in Table B using the solution pump, and maintain a constant temperature at all times. It may be necessary with some piping configurations to cap or plug some openings and alternate with others to maintain an even flow of cleaning solution to all segments of the pipe. If you run out of cleaning solution before the 30 minutes listed, prepare another volume of cleaning solution.
6. Prepare a second solution of TSP and Grade B water and flush. After the 30 minute cleaning cycle, draw off a 1000-ml sample of the TSP solution, and perform a hydrocarbon analysis by ultraviolet light as described on page 33.
7. Rinse by pumping Grade B or deionized water, heated to  $180^{\circ}\text{F}$  throughout the pipe or tubing until the water sample taken shows a pH of 6.0 to 8.0.

8. Dry the pipe by purging with filtered dry air, nitrogen, or helium (heated if possible).

**Note: IF SAMPLE SHOULD FAIL PARTICULATE COUNT ANALYSIS, REPEAT RINSE CYCLES 2.7 and 2.8.**

**Table A: TSP Cleaning Solution Volume**

Pipe/Tube Size, inches	Volume per 1 Foot Length
¼	0.6 cubic inches
½	2.4 cubic inches
¾	5.4 cubic inches
1	9.5 cubic inches
1½	21.2 cubic inches
2	37.7 cubic inches

**Table B: Cleaning Solution Flow Rate**

Tube Size, inches	GPM	Pipe Size, inches	GMP
¼	½	¼	2
3/8	2	3/8	3
½	3¾	½	5½
¾	6¾	¾	9½
1	12½	1	15½
		1¼	23
		1½	35
		2	50

### Non-Ionic Detergent (NID) Method

This method outlines the cleaning procedure for oil-free cleaning of metallic/nonmetallic components or assemblies using non-ionic detergent.

1. Mix cleaning solution by adding ½ ounce of non-ionic detergent to each 80 gallons of Grade B water.
2. Heat the cleaning solution to  $120^{\circ} \pm 5^{\circ}\text{F}$  and circulate through the piping assembly for 30 minutes minimum at a flow rate of not less than 1 gallon per minute.
3. Rinse the piping assembly with Grade B water heated to  $125^{\circ} \pm 5^{\circ}\text{F}$  for 30 minutes minimum at a flow rate of not less than 1 gallon per minute. Do not recirculate water.
4. Perform a shake test by collecting 1000-ml sample of rinse water in a flask that can be fitted with a rubber stopper. Shake the flask for a few seconds and if any bubbles form and remain on the surface of the water in the flask, continue to rinse until no bubbles form and remain in the sample flask.

5. Purge the system with clean, dry, oil-free nitrogen (preferably heated to  $200^{\circ} \pm 25^{\circ}\text{F}$ ) until all visible signs of water are absent. Maintain drying process for 1–2 hours after the initial purge (*Note:* At no time should the upstream purge pressure exceed 100 psig).

### **Large Object Cleaning**

This procedure is provided for the cleaning of large objects, vessels, chambers, or pipes sized greater than 2 inches.

1. Wipe down using a mixture of ½ ounce NID and 5 gallons of Grade B or deionized water.
2. Rinse with Grade B or deionized water until all traces of detergent have been removed.
3. Blow dry with clean air, nitrogen, or helium.
4. Visually inspect for hydrocarbons, using an ultraviolet light.

### **Ultraviolet Light Method**

The ultraviolet light method for detecting hydrocarbons may be employed in several different ways.

#### ***Direct Inspection***

The component may be examined directly with the ultraviolet light. By passing the component under the ultraviolet light, hydrocarbon surface contamination may exhibit fluorescence where some hydrocarbons exist.

#### ***Inspection of Cleaning Solution when Detergent is Used***

Used cleaning solution collected in a clean beaker when agitated will form bubbles. These bubbles, under ultraviolet light, may exhibit fluorescence.

**WARNING: MOST ULTRAVIOLET LAMPS CONTAIN MERCURY. EXTREME CAUTION SHOULD BE TAKEN NOT TO BREAK THE MERCURY VAPOR LAMP, WHICH WILL CONTAMINATE THE COMPONENT OR PIPE BEING INSPECTED AND MAY CAUSE HUMAN INJURY.**

## **COMMERCIAL LEAK-TEST SOLUTIONS**

**Sherlock Leak Detector, Type CG**  
Winston Products Company, Inc  
Charlotte, NC

**SNOOP Leak Detector**  
Nuclear Products Co.  
15635 Saranac Road  
Cleveland, OH 44110

**OXEQUIP 17-A Oxyleak**  
OXEQUIP Health Industries  
8335 S. Halsted Street  
Chicago, IL 60620

**F-3 Detergent**  
Dow Chemical Co.

**LEAK-TEC**  
American Gas and Chemicals, Inc.  
New York, NY

Concentrated soap solution using: Joy, Ivory, Tide, Fels-Naptha, and other similar soap liquids diluted with tap water.



## OXYGEN COMPATIBLE LUBRICANTS

### Material

### Manufacturer

Fluorolube Oil  
Fluorolube Oil T-80  
Fluorolube Grease GR-361

Occidental Chemical Co.  
P.O. Box 809050  
Dallas, TX 75380

Halocarbon Light Oil 4-11  
Halocarbon Light Oil 27S  
Halocarbon Grease 25-SS

Halocarbon Products  
82 Burlewa Court  
Hackensack, NJ

Kel-F Light Oil No. 1  
Teflon Tape, Pipe Tread  
No. 547 or No. 48

Minnesota Mining and Manufacturing Company  
2501 Hudson Road  
St Paul, MN

Krytox Oil 143  
Krytox Grease 240AC

E.I. Dupont de Nemours

Christo Lube MCG-111

Lubrication Technology, Inc  
310 Morton St.  
Jackson, OH 45640

**Notes:** Fluorolube may detonate when applied to aluminum or magnesium with pressure. Fluorolube causes significant swelling of Viton A and B which can affect seal integrity. Consult manufacturers Material Data Acquisition Safety Sheet for compatibility.

# NOTES

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