SECTION 3
WINDOW FABRICATORS

ARTICLE 1 RESPONSIBILITIES AND DUTIES FOR WINDOW FABRICATORS

3-l .l General

The responsibilities set forth herein relate only to compliance with this Standard.

3-l .2 Responsibilities

3-1.2.1 Definition of a Window Fabricator. As used in this Standard, the term ***Window Fabricator*** is defined as that fabricator of PVHO windows who assumes responsibility for certifying that the windows comply with Section 2 of this Standard with respect to material, design, fabrication, testing, inspection, certification, and marking in accordance with Section 2.

3-1.2.2 Examples of the Window Fabricator's Responsibilities. The window fabricator's responsibilities include the following:

(a) compliance with this and the appropriate referenced standard(s);

(b) procurement control of material, parts, and services in accordance with para. 3-2.6;

(c) establishing and maintaining a Quality Assurance Program in accordance with Article 2 of this Section;

(d) documenting the Quality Assurance Program in accordance with para. 3-l .2.6;

(e) furnishing the purchaser with appropriate Certification Report(s) in accordance with para. 3-1.2.7.

3-1.2.3 Compliance With This Standard. The PVHO window fabricator has the responsibility for fabrication of windows in compliance with Section 3.

3-1.2.4 Subcontracting. It is the PVHO window fabricator's responsibility to assure that the subcontracted activities comply with the appropriate requirements of this Standard. The PVHO window fabricator shall retain overall responsibility, including certifying and marking PVHO windows.

3-1.2.5 Responsibility for Quality Assurance of Subcontracted Activities. The PVHO window fabricator shall be responsible for evaluation and qualification of suppliers of subcontracted services. On-site supplier evaluation is required prior to procurement of all subcontracted activities. All subcontracted activities shall be audited at least annually.

3-l .2.6 Documentation of Quality Assurance Program. The PVHO window fabricator shall be responsible for documenting his Quality Assurance Program with a Quality Assurance Manual in accordance with Article 2 of this Section.

3-1.2.7 Certification Report. The PVHO window fabricator shall certify compliance with this Standard by furnishing the purchaser with an appropriate Certification Report and by marking the window in accordance with Section 2.

3-1.2.8 Right of Access. The PVHO window fabricator shall afford the purchaser or his designated agent reasonable access to facilities and documents to ascertain that the window being purchased is being fabricated to the requirements of this Standard.

ARTICLE 2 QUALITY ASSURANCE PROGRAM FOR FABRICATION OF THE WINDOW

3-2.1 General

This Article sets forth the requirements for establishing and maintaining Quality Assurance Programs to control the quality of work performed by the fabricators of windows that are used in pressure vessels for human occupancy, in accordance with the applicable edition of this Standard.

3-2.2 Organization

(a) The window fabricator required to comply with this Standard shall have a documented organizational structure, with responsibilities, authorities, and lines of communication clearly delineated in writing for activi-

ties affecting quality. Persons or organizations responsible for the Quality Assurance Program shall have authority and organizational freedom to:

(I) identify problems affecting quality;

(2) initiate, recommend, or provide solutions to quality problems, through designated channels;

(3) verify implementation of solutions; and

(4) control further processing, delivery, or assembly of a nonconforming item, deficiency, or unsatisfactory condition until proper corrective action has been taken.

(6) The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the fabricator's organization (including factors such as number and experience level of employees and number of viewports produced).

3-2.3 Quality Assurance Program

(a) A documented program for the assurance of quality of activities, items, and services shall be planned, implemented, and maintained in accordance with specified requirements of this Standard.

(b) The program shall apply to activities, materials, parts, assemblies, and services which affect the quality of the windows. It need not apply to other activities, products, and services at the same location.

(c) The program shall identify the PVHO activities to which it applies.

(d) The program shall provide for indoctrination and training of personnel to assure compliance with this Standard.

(e) Management shall, at least annually, assess the program and take corrective action, if necessary.

3-2.4 Quality Assurance Manual

(a) The Quality Assurance Program shall be described in a Quality Assurance Manual.

(b) The Quality Assurance Manual must provide a mechanism to document issuance and revision, and must include a method to identify and/or highlight the revisions.

3-2.5 Drawing, Design, and Specification Control

(a) The window fabricator shall establish measures to assure that window Design Drawings and all applicable documents and requirements of this Standard relative to the design of windows are received from the designer, and are correctly translated into fabrication specifications, drawings, procedures, and shop instructions for the windows.

(b) Procedures shall be established for the review, approval, release, distribution, and revision of fabrication documents.

3-2.6 Procurement Control

(a) Applicable requirements necessary to assure compliance with this Standard shall be specified or included in documents for procurement of materials, items, or services to be used by the window fabricator.

(b) The procurement of materials, items, and services shall be controlled by the fabricator to assure conformance with specified requirements.

(c) These controls shall include, but not be limited to, any of the following, as appropriate:

(I) source evaluation and selection;

(2) appraisal of objective evidence of quality furnished by the supplier including all necessary material certification documents;

(3) inventory control;

(4) material identification;

(5) examination of supplied items upon delivery.

(d) Procedures for assuring continued compliance with pertinent requirements, including identification of procedural revisions, shall be described in the Quality Assurance Manual.

3-2.7 Identification and Control of Items

(a) Identification shall be maintained on all items or in documentation traceable to these items.

(b) Controls shall be established to prevent use of incorrect or defective items.

(c) The window fabricator, based on his judgment. shall also maintain additional identification and documentation to assure that significant problems can be identified and proper corrective action taken.

(d) Traceability procedures shall be described in the Quality Assurance Manual.

(e) Traceability of the completed window shall extend to identification of the immediate purchaser.

3-2.8 Control of Processes

(a) Processes affecting quality shall be controlled in accordance with specified requirements using process control documents such as process sheets and travelers.

(0) Special processes affecting quality, such as bonding and nondestructive examination, shall be performed by qualified personnel using qualified procedures referenced in this Standard.

3-2.9 Inspection

(a) Inspection shall be planned and controlled by the fabricator.

(b) These inspections shall verify conformance to documented instructions, procedures, and drawings describing the activities.

(c) Inspection results shall be documented.

(d) Inspection for acceptance shall be performed by qualified persons other than those who performed or supervised the work.

(e) Inspection documents shall contain appropriate criteria for determining that such activities have been satisfactorily accomplished.

3-2.10 Test Control

(a) Testing required to demonstrate that the windows will perform in accordance with this Standard shall be so defined, controlled, and documented.

(b) Tests shall be performed in accordance with written instructions stipulating acceptance criteria.

(c) Test results shall be recorded on the required forms.

(d) Examination, measurement, and testing equipment used for activities affecting quality shall be controlled, calibrated, and adjusted at specified periods to maintain required accuracy.

(e) Specifications, calibration, and control of measuring and testing equipment used for acceptance shall be described in written instructions or procedures.

(f) Calibrations shall be traceable to National Standards where such exist.

3-2.11 Handling, Storage, and Shipping

Handling, storage, cleaning, packaging, shipping, and preservation of items shall be controlled to prevent damage or loss, and to minimize deterioration, and shall be documented.

3-2.12 Documentation and Status of Test Activities

(a) The status of inspection and testing activities shall be indicated either on the items, or in records traceable to the items, to assure that required inspections and tests are performed.

(b) Items which have satisfactorily passed required inspections and tests shall be identified.

3-2.13 Corrective Action

(a) Items, services, or activities which do not conform to specified requirements shall be controlled to assure proper disposition and prevent inadvertent use.

(b) Controls shall provide for identification, documentation, evaluation, segregation when practical, and disposition of nonconformances and notification to affected organizations.

(c) Conditions adverse to quality shall be promptly investigated, documented, evaluated, and corrected.

(d) In the case of a significant condition adverse to quality, the cause of the condition shall be determined and corrective action taken to preclude recurrence.

(e) The identification, cause, and corrective action planned and taken for significant conditions shall be documented and reported to appropriate levels of management.

(f) Follow-up action shall be taken to verify implementation of corrective action.

3-2.14 Quality Assurance Records

(a) Records shall be specified, compiled, and maintained to furnish documentary evidence that services, materials, items, and completed windows meet this and applicable referenced standards.

(b) Records shall be legible, identifiable, and retrievable.

(c) Records shall be protected against damage, deterioration, or loss.

(d) Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.

(e) Records required for traceability shall be retained for the maximum allowable design life plus a minimum of 2 years.

3-2.15 Quality Assurance Audits

(a) The window fabricator shall schedule and perform regular internal audits to verify compliance with all aspects of the Quality Assurance Program.

(b) These audits shall be performed at least annually and stipulated in the Quality Assurance Manual.

(c) These audits shall be performed by qualified personnel who do not have direct responsibility for performing or controlling the activities being audited.

(d) The audits shall be performed in accordance with written instructions.

(e) Audit results shall be reported to and reviewed by management having responsibility and authority to take any necessary corrective action. Follow-up action shall be taken where indicated.

SECTION 4
PIPING SYSTEMS

ARTICLE 1 GENERAL

4-1.1 Temperature Limitations

Piping systems constructed under the rules contained in this Standard are limited to design temperatures between 0°F and 150°F, inclusive.

Additional precautions may be required if temperatures outside that range are expected.

4-1.2 Certification of Design and Fabrication

The following requirements relate solely to compliance with this Standard.

4-1.2.1 User's Design Specification. The user, or an agent on his behalf, who intends that a piping system be designed, fabricated, tested, and certified to be in compliance with this Standard shall provide, or cause to be provided, a written User's Design Specification. This shall set forth requirements as to the intended use and operating conditions in such detail as to constitute an adequate basis for designing, fabricating, and inspecting the system as required to comply with this Standard. Those requirements shall include, as a minimum, the following:

(a) required pressurization and depressurization rates, ventilation rates, and the conditions under which those rates are to be maintainable (paras. 4-7.1.1 and 4-7.1.2);

(b) requirements affecting the required amounts of stored gas reserves (para. 4-7.1.3);

(c) required number of breathing gas outlets and their characteristics (para. 4-7.6.1).

4-1.2.2 Design Certification. Conformance of the piping system design to the requirements of this Standard and the User's Design Specification shall be established by one of the two following procedures.

(a) A Professional Engineer, registered in one or more of the states of the United States of America, or the provinces of Canada, and experienced in piping systems designs, shall certify that the piping system was designed either by him or under his direct supervision, or that he has thoroughly reviewed a design prepared by others, and that to the best of his knowledge, within the User's Design Specification, the piping system design complies with this Standard.

(b) The piping system design shall be reviewed by an independent classification society competent in pressure vessels for human occupancy systems, and such organization shall provide a certification that, within the User's Design Specification, the piping system design complies with this Standard.

4-1.2.3 Fabricator's Certification. The fabricator of the piping system shall be responsible for complying with the requirements of this Standard. The fabricator shall provide written certification as to compliance with this Standard and with the User's Design Specification.

4-1.2.4 Data Retention. A copy of the Fabricator's Certification and supporting data (test data, material test reports, as applicable, etc.) shall be retained by the fabricator for at least 5 years. A copy of the piping system User's Design Specification and the Fabricator's Certification shall be provided to the user with the system.

ARTICLE 2 MATERIAL REQUIREMENTS

4-2.1 Acceptable Materials

4-2.1.1 Pipe and Tube. Pipe and tube for use in chamber piping systems, except as otherwise restricted or permitted, shall be seamless and shall be of a material for which allowable stress values are listed in Appendix A of ASME B31.1 or are listed in Table 4-2.1. Cast pipe shall not be used.

4-2.1.2 Fittings. Unless otherwise restricted or permitted:

(a) fittings which are attached to a pipe or tube by welding, brazing, or threading shall conform to the specifications and standards listed in Table 126.1 of ASME B31.1;

TABLE 4-2.1 MAXIMUM ALLOWABLE STRESS VALUES FOR SEAMLESS PIPE AND TUBE MATERIALS NOT LISTED IN APPENDIX A OF ASME B31.1

Material	Specification	Temper or Grade	Strength, ksi	Max. Allowable Stress Values in Tension, ksi
Alpha-brass	British Standard 1306	.	54	10.8
Copper water tube	ASTM B 88, Types K & L	Drawn	36	6.0

GENERAL NOTE: 1 ksi = 1000 psi.

(b) fittings which are attached to a pipe or tube by other methods shall be of a material and type recommended by the fitting manufacturer for the application.

4-2.2 Limitations on Materials

4-2.2.1 Service Requirements. All metallic materials used for oxygen service, breathing gas service, and all components subject to the requirements of para. 4-7.3, Pressure Boundary Valve Requirements, shall be one of the following:

(a) copper;
(b) brass;
(c) bronze;
(d) austenitic stainless steel;
(e) copper-nickel alloy; or
(f) nickel-copper alloy.

Aluminum materials may be used as permitted in para. 4-2.2.3.

4-2.2.2 Carbon Steel. The use of carbon steel pipe, tube, valves, and fittings in chamber piping systems not subject to the requirements of para. 4-2.2.1 is permitted provided that they are compatible with anticipated cleaning and operational procedures and are adequately protected against corrosion, both internally and externally. The following guidelines apply to the usage of carbon steel components.

(a) Hot trisodium phosphate cleaning solutions can remove cadmium plating.

(b) Unprotected plain carbon steel, especially when cleaned in accordance with the requirements for breathing gas service, is subject to accelerated corrosive attack and its use should be avoided.

(c) Plated carbon steel components such as chrome plated carbon steel balls for ball valves have poor service histories in applications involving exposures to humid gases containing oxygen and their use in such applications shall be avoided.

(d) The effects of the migration of rust and other corrosion products into downstream components such as valves and regulators must be considered.

4-2.2.3 Aluminum. Aluminum can, under some conditions, react violently with the fluorocarbon lubricants frequently used in oxygen and breathing gas systems. It may also react with the CO_2 absorbent chemicals used in life-support systems. Aluminum may be used only when adequate precautions are taken to prevent contact with fluorocarbon lubricants and hydroxide based absorbents. Further, the corrosive effect of seawater must be considered in alloys intended for use in marine systems.

4-2.2.4 Castings. Cast components are subject to possible porosity and should be avoided in helium service, unless there is a prior record of satisfactory service. Cast, ductile, and malleable iron pipe, tube, pipe fittings, and tube fittings shall not be used. Cast components of other materials may be used if not otherwise prohibited by other paragraphs of this Standard.

4-2.2.5 Seawater Service. Materials which will be repeatedly or continuously exposed to seawater shall be compatible with seawater service. In particular, brasses and bronzes should be selected for resistance to dezincitication and dealuminification. Materials which comply with the requirements of MIL-B-24480 (SHIPS), *Military Specifications: Bronze, Nickel-Aluminum Castings for Seawater Service*, may be considered acceptable without further investigations. Materials with a zinc content in excess of 1.5% may also be considered acceptable if they give satisfactory results in a mercurous nitrate test performed in accordance with the requirements of ASTM B 154.

4-2.2.6 Pressure Ratings. When possible, all pipe and tubing of the same material and diameter used in a single chamber piping system shall have the same pressure rating. When this is not possible, special precautions shall be taken to prevent inadvertent mixing of materials.

4-2.2.7 Dissimilar Metals. The designer shall consider galvanic effects of corrosion when combinations of dissimilar metals are used in the presence of an electrolyte, e.g., seawater.

4-2.3 Nonmetallic Materials

4-2.3.1 Lubricants and Sealants. Lubricants and sealants shall meet the requirements of para. 4-7.12.

4-2.3.2 Hose Materials. Nonmetallic hose materials shall meet the requirements of para. 4-4.5.1.

4-2.3.3 Nonmetallic Pipe and Tube. This Standard recognizes the existence of a wide variety of nonmetallic piping materials which may be used in corrosive (either internal or external) or other specialized applications such as pneumatic control circuits. Extreme care must be taken in their selection as their design properties vary greatly and depend upon the materials, type, and grade. Particular consideration shall be given to the possibility of:

(a) destruction where fire hazard is involved;

(b) decrease in tensile strength at slight increase in temperature; and

(c) effects of toxicity.

Another consideration is that of providing adequate support for flexible pipe.

4-2.4 Deterioration of Materials in Service

The selection of materials to resist deterioration in service is generally outside the scope of this Standard. It is the responsibility of the designer to select materials suitable for the conditions of operation.

4-2.5 Prohibited Materials

Components of beryllium or those containing mercury shall not be used. Components containing asbestos shall not be used for breathing gas service applications.

ARTICLE 3 DESIGN OF COMPONENTS

4-3.1 Straight Piping Under External Pressure

For determining wall thickness and stiffening requirements for straight pipe and tubing under external pressure, the requirements of Section VIII. Division I or 2, of the ASME Boiler and Pressure Vessel Code shall be followed.

4-3.2 Straight Piping Under Internal Pressure

4-3.2.1 Minimum Wall Thickness. The thickness of pipe or tubing shall not be less than

$$t_m = \frac{PD_o}{2SE + 0.8P} + A \qquad (1)$$

$$t_m = \frac{Pd + 2SEA + 0.8PA}{2(SE - 0.6P)} \qquad (1a)$$

Design pressure shall not exceed

$$P = \frac{2SE(t_m - A)}{D_o - 0.8(t_m - A)} \qquad (2)$$

$$P = \frac{2SE(t_m - A)}{d - 0.8(t_m - A) + 2t_m} \qquad (2a)$$

where

t_m = minimum required wall thickness, in. (mm)

(a) If piping is specified by its nominal wall thickness, the manufacturing tolerance on wall thickness must be taken into account. After the minimum wall thickness t_m is determined, this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable specification.

(b) If piping is specified by its nominal diameter and schedule weight, the next heavier commercial wall thickness shall then be selected from thickness schedules as contained in ASME B36.10M, or from manufacturers' schedules for other than standard thickness.

P = internal design pressure, psi gage

D_o = outside diameter of pipe or tube, in. For design calculations, the outside diameter of piping as given in tables of standards and specifications shall be used in obtaining the value of t_m. When calculating the allowable working pressure of piping on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness at the thinner end of the pipe or tube may be used to calculate this pressure.

d = inside diameter of piping, in. For design calculations, the inside diameter of piping is the maximum possible value allowable under the purchase specification. When calculating the allowable working pressure of piping on hand or in stock, the actual measured inside diameter and actual measured minimum wall thickness at the thinner end of the pipe or tube may be used to calculate this pressure.

SE = maximum allowable stress in material due to internal pressure and joint efficiency at the design temperature, psi. The value of ***SE*** shall not exceed the value given in Appendix A of ASME B31.1, or the value given in Table ***4-2.*** I.

A = an additional thickness

(a) To provide for corrosion and/or erosion, refer to para. 4-3.3.1.

(b) To compensate for material removed in threading, grooving, etc., required to make a mechanical joint, refer to para. 4-3.3.2.

(c) To provide for additional mechanical strength of the piping, refer to para. 4-3.3.3 (not intended to provide for extreme conditions of misapplied external loads or for mechanical abuse).

(d) To compensate for thinning in bends, refer to paras. 4-3.3.4 and 4-3.4.1.

4-3.2.2 Additional Thickness Requirements. While the thicknesses determined from the formulas in para. 4-3.2.1 are theoretically ample for both bursting pressure and material removed in threading, the following minimum requirements are mandatory to furnish added mechanical strength.

(a) Threaded steel or stainless steel pipe for use at pressures over 500 psig shall have a minimum ultimate tensile strength of 48,000 psi (330 MPa) and a wall thickness at least equal to Schedule 80 of ASME B36.10M. For pressures of 500 psi and less, threaded pipe shall have a wall thickness at least equal to Schedule 40 of ASME B36.10M.

(b) When threaded brass or copper pipe is used for the services described above, it shall have a wall thickness at least equal to that specified above for steel pipe.

(c) For chambers subject to external pressure due to immersion in seawater, the piping between penetrations and the corresponding first stop valves on the chamber interior shall be adequate for the design pressure in accordance with para. 4-3.2, but shall not be less than the equivalent of Schedule 160 of ASME B36.10M for nominal diameters of $^3/_4$ in. and greater, and Schedule 80 for smaller sizes.

(d) Pipe ***or*** tubing subject to bending shall comply with the wall thickness requirements of para. 4-3.3.4.

TABLE 4-3.1 BEND THINNING ALLOWANCE

Radius of Bends [Notes (1)–(3)]	Min. Thickness Recommended Prior to Bending [Note (4)]
6 pipe dia. or greater	1.06 t_m
5 pipe dia.	1.08 t_m
4 pipe dia.	1.14 t_m
3 pipe dia.	1.25 t_m

NOTES:
(1) Radius of bend is measured at the centerline of the pipe or tube.
(2) Interpolation is permissible for bending to intermediate radii.
(3) Pipe diameter is the nominal diameter as tabulated in ASME B36.10M, Table 2, and ASME B36.19M, Table 2. For pipe with diameter not listed in these tables and also for tubing, the nominal diameter corresponds with the outside diameter.
(4) t_m is determined by the formulas in para. 4-3.2.1.

4-3.3 Additional Thickness Allowances

4-3.3.1 Corrosion or Erosion. When corrosion or erosion is expected, an increase in wall thickness of the piping shall be provided over that required by other design requirements. This allowance, in the judgment of the designer, shall be consistent with the expected life of the piping.

4-3.3.2 Threading and Grooving. The calculated minimum thickness of pipe or tubing which is to be threaded shall be increased by an allowance equal to thread depth; dimension h of ASME B 1.20.1 or equivalent shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $^1/_{64}$ in. (0.40 mm) in addition to the specified depth of cut.

4-3.3.3 Mechanical Strength. Where necessary for mechanical strength to prevent damage, collapse, excessive sag, or buckling of pipe or tube due to superimposed loads from supports or other causes, the wall thickness of the pipe shall be increased; or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods (see Article 5). The requirements of para. 4-3.5 shall also apply.

4-3.3.4 Bending. Except as permitted in para. 4-3.4. I, the minimum wall thickness at any point in a completed bend shall not be less than that required by the formulas of para. 4-3.2.1.

(a) Table 4-3.1 is a guide to the designer who must specify wall thickness for ordering pipe or tube. In general, it has been the experience that when good shop practices are employed, the mmimum thicknesses of straight pipe and tubing shown in Table 4-3.1 should be sufficient for bending, and still meet the minimum thickness requirements of para. 4-3.2. I.

(b) The bend thinning allowance in Table 4-3.1 may be provided in all parts of the cross section of the pipe or tube circumference without any detrimental effects being produced.

4-3.4 Bending of Pipe and Tube

4-3.4.1 Wall Thickness Allowance

(a) The allowances for pipe and tube wall thinning as a result of bending contained in para. 4-3.3.4 are mandatory except as permitted by para. 4-3.4.1(b).

(b) When fully annealed tube is bent as permitted under para. 4-3.4.2, the increase in tensile strength due to work hardening normally offsets the loss in wall thickness due to thinning. For fully annealed tube only, the bending allowances of para. 4-3.3.4 may be reduced or eliminated if the fabricator can demonstrate by actual test that the bending procedures used do not reduce the tube burst pressure below a level of 4.0 times the design pressure for the tube.

(c) Tube bent under the provisions of (b) above shall not be annealed following bending or subjected to welding or brazing operations within 12 in. of the nearest bend.

4-3.4.2 Bending Requirements

(a) Pipe and tube may be bent by any hot or cold method and to any radius that will result in a bend surface free of cracks, as determined by a method of inspection specified in the design, and substantially free of buckles. Additionally, the radii of pipe and tube bends shall be controlled so that they fall in the region below the $D_o/(R_b)_f$ and $D_o/(R_b)_b$ curves in Fig. 4-3.1, where

D_o = outside diameter, in.

t_w = wall thickness, in.

e = nominal percent elongation limit typical of the pipe or tube material

$(R_b)_f$ = bend radius causing fracture of the pipe or tube along the outside of the bend

$(R_b)_b$ = bend radius causing buckling of the pipe or tube along the inside of the bend

Table 4-3.2 lists the percent elongation limits for some typical types of pipe and tube materials. Bending coordinates should be maintained below the outer wall fracturing curve for e = 10% and the inner wall buckling curve, as those two curves define a coordinate region where failure due to either fracture or buckling is unlikely.

(b) Bends in pipe or tube with a wall thickness equivalent to that of Schedule 40 pipe or thicker, and all bends where heating of the material is required, shall also conform to the requirements of ASME B31.1, paras. 104.2.1 and 129.3.

4-3.5 Stress Analysis of Piping Components

It shall be the responsibility of the designer to determine if the completed piping system must be subjected to a detailed stress analysis. Factors to be considered shall include, but not necessarily be limited to, the following:

(a) stresses due to thermal expansion;

(b) effects of vibration, where appropriate;

(c) dynamic effects of shipboard motion, where appropriate;

(d) handling loads, especially in transportable systems;

(e) vessel expansion and contraction due to pressure changes;

(f) effects of differential movement in the supporting structures;

(g) other factors, such as earthquake loads, where appropriate.

Should a stress analysis be required, it shall be performed in accordance with the requirements of paras. 102.3 and 104.8 of ASME B31.1.

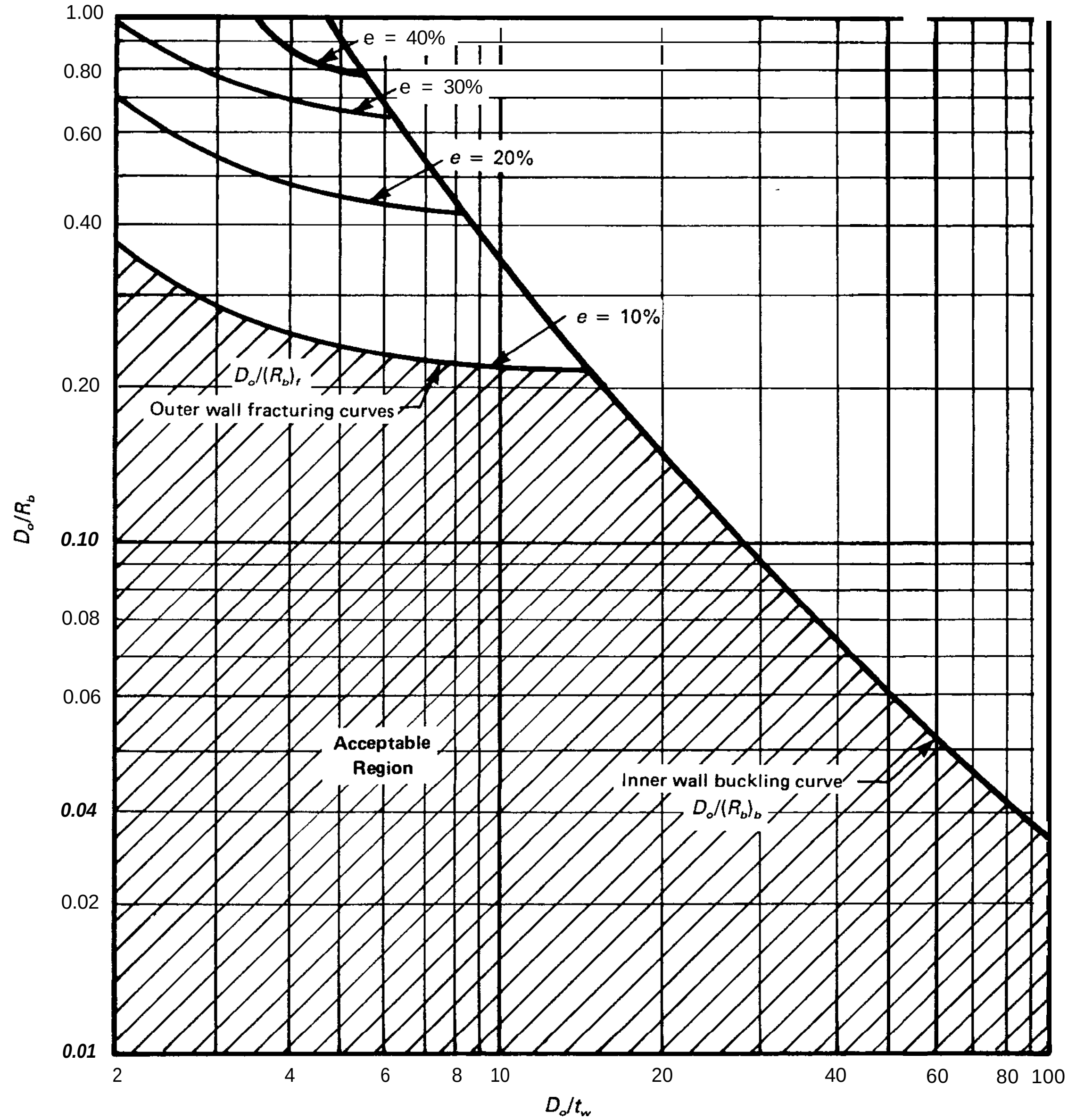
4-3.6 Pressure Design of Fabricated Joints and Intersections

Except as permitted in (c), where joints and intersections are not made with fittings but must be fabricated, the design rules of para. 104.3 of ASME B31.1 shall be followed, with the following additional restrictions.

(a) Fabricated tees and elbows and miter joints consisting only of pieces of pipe or tube jointed together shall not be used except in vent lines (or other locations) that are subject to internal or external pressures of less than 5 psig.

(b) Fabricated branch connections with angles of other than 90 deg. shall not be used except in vent lines (or other locations) that are subject to internal or external pressures of less than 5 psig. Fabricated branch connections with angles of 90 deg. shall be of a type that either does not require reinforcement or uses integrally reinforced outlets.

(c) Fabricated branch joints made by brazing a branch line into an extruded opening in the run line may be used provided:



GENERAL NOTE:
This figure has been reprinted from Aerojet Nuclear Systems Co. Report RN-TM-0599, ***Minimum Bend Radius Recommendations for Pneumatic Instrumentation Lines,*** R. D. Samuelson, July 1970, supported by U.S. government funds.

FIG. 4-3.1 CURVES FOR DETERMINING THE MINIMUM BEND RADIUS NOT PRODUCING OUTER WALL FRACTURING OR INNER WALL BUCKLING

TABLE 4-3.2 ELONGATION LIMITS FOR TUBING MATERIALS (METAL)

Material	% Elongation	Material	% Elongation	Material	% Elongation
Stainless steel 303	45	Duranickel 301	35	Aluminum 7078	10
Stainless steel 304	45	Monel 400	32	Aluminum 7079	IO
Stainless steel 305	45	Monel 404	32	Oxygen-free copper	35
Stainless steel 309	40	Monel R-405	30	Everdur 1010	43
Stainless steel 310	40	Monel K-500	28	Chromium copper	23
Stainless steel 316	40	Nickel 200	30	Cupronickel 10	31
Stainless steel 321	40	Nickel 201	32	A	40
Stainless steel 347	38	Nickel 211	30	Aluminum brass	37
Stainless steel 348	38	Nickel 270	32	Leaded-tube brass, 0.25%	41
Stainless steel 403	25	NI-0-HEL 825	35	Leaded-tube brass, 0.50%	39
Stainless steel 410	25	NI-span "C"	30	Leaded-tube brass, 1 .OO%	37
Stainless steel 430	25	Waspaloy	35	Naval brass	30
Stainless steel 446	20	Aluminum 1060	15	Red brass, 85%	33
Stainless steel 502	27	Aluminum 1100	15	Yellow brass	37
Nickel alloy A-286	25	Aluminum 2014	12	Aluminum bronze, 5%	37
30% Cupronickel	30	Aluminum 2024	12	Commercial bronze, 90%	32
Hastelloy "C"	25	Aluminum 2219	12	Nickel-silver, 18%	23
Hastelloy "X"	25	Aluminum 3003	20	Phosphor bronze, 10%	39
Haynes 25	40	Aluminum 5050	16	Molybdenum	30
Inconel 600	35	Aluminum 5086	14	Titanium	22
Inconel 702	25	Aluminum 5154	12	Tungsten-26% rhenium	11
Inconel 718	30	Aluminum 5454	12	Tantalum	30
Inconel X-750	40	Aluminum 5456	12		
Inconel 800 (Incoloy)	35	Aluminum 6061	14		
Invar	30	Aluminum 7075	10		

GENERAL NOTES:

(a) Normal room temperature % elongation limit values (2 in. sample) for tubes whose wall thickness equals or exceeds 0.015 in., whose outside diameter equals or exceeds 0.125 in., and whose outside diameter to wall thickness ratio (D_o/t_w) does not exceed 16.

(b) This Table has been reprinted from Aerojet Nuclear Systems Co. Report RN-TM-0599, *Minimum Bend Radius Recommendations for Pneumatic Instrumentation Lines,* R.D. Samuelson, July 1970, supported by U.S. government funds.

(I) line MAWP is 175 psig or less;

(2) the joint meets the reinforcement requirements of para. 104.3.1(g) of ASME B31.1.

4-3.7 Pressure Design of Bolted Flanges and Blanks

The pressure design of bolted flanges and blanks shall be in accordance with para. 104.5 of ASME B3 I. I with the following additional restrictions.

(a) Flanges shall be joined to the pipe by butt welding, socket welding, threading, or other proven mechanical joining techniques.

(b) Gasket materials and design shall be suitable for the intended service. For breathing gas service, O-ring flanges are recommended over conventional gasket or ring-joint flanges.

(c) Gasket materials containing asbestos shall not be used for breathing gas service.

4-3.8 Design of Penetrations Through the Pressure Boundaries of Chambers

The design of penetrations through the pressure boundaries of chambers should consider ease of maintenance and repair as well as structural adequacy. Nonmandatory Appendix III contains guidelines for the design of piping penetrations through the pressure boundaries of chambers.

ARTICLE 4 SELECTION AND LIMITATIONS OF PIPING COMPONENTS

4-4.1 Pressure Requirements

4-4.1.1 Maximum Allowable Working Pressure (MAWP). The MAWP of all components shall be equal to or greater than the design pressure of the system or line of which they form a part.

4-4.1.2 Differential Pressures. Where components may be subject to differential pressures, the differential pressure capacity of the component must be equal to, or greater than, the maximum possible differential pressure; otherwise suitable overpressure protection shall be provided.

4-4.1.3 Alternating Internal and External Pressures

(a) Components subject to alternating (i.e., both internal and external) pressure shall be designed for the maximum differential pressure that may exist in both directions. Note that the pressure, internal or external, which controls the required design thickness may vary depending upon circumstances and both conditions must be considered.

(b) O-rings subject to reversing pressures occurring as a result of submergence have been known to permit small amounts of seawater to penetrate the system by working past the O-ring as it moved from one side of the groove to the other. System designs shall take this into consideration.

4-4.2 Valves

4-4.2.1 Valves Subject to Internal and External Pressures. Valves subject to both internal and external pressures shall employ seals and stem packings suitable for bidirectional pressures.

4-4.2.2 Stop Valves. Stop valves shall be selected and installed so that all stop valves close with a clockwise rotation of the valve handle.

4-4.2.3 Ball Valves. Ball valves shall employ blowout proof stem designs.

4-4.2.4 Valve Seats. Except as permitted in para. 4-7.7.2, all valves used for breathing gas service shall be of a “soft seat” design; valves employing metal-to-metal seats shall not be used.

4-4.2.5 **Service Access.** Stop, regulating, and ball valves in breathing gas and other life-sensitive systems shall be selected and installed so that service access to the working parts of the valves is readily available. In situations when the valve body, as a whole, cannot be removed from the line for service, three-piece, top-entry body, or other designs permitting service access. to the valve internals with the end pieces or valve body in place shall be used.

4-4.2.6 Quick Opening Valves. Quick opening valves shall not be used in oxygen systems operating at over 125 psig. Quick closing valves (e.g., an excess flow check valve) may be used regardless of pressure, provided that their capacity is enough smaller than the capacity of upstream components so that closure of the valve will not result in a pressure rise at the inlet to the valve large enough to cause hazardous adiabatic compression heating of the gas.

4-4.2.7 Remotely Operated Valves. Remotely operated valves, when used, shall be selected and installed so that, where possible, they fail in the safe position.

4-4.2.8 Relief Valves. Relief valves used for protection against overpressures in excess of system design pressures shall be "V" stamped valves manufactured in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.

4-4.3 Filters

4-4.3.1 Element Collapse Pressure Rating. Elements used in filters in breathing gas and other life-sensitive systems shall have a collapse pressure rating equal to or greater than the design pressure of the line in which they are installed, or the filter shall be fitted with a differential pressure device indicating when the element needs renewal or cleaning.

4-4.3.2 Element Construction. Except as otherwise permitted, all particulate filters in breathing gas and other life-sensitive systems shall use elements of the woven wire, screen, or sintered metal types. Particulate filters requiring very low flow resistance, such as on compressor intakes and atmospheric conditioning systems, may employ any suitable noncombustible elements. Sintered metal elements should be avoided in high flow, high vibration, or other applications conducive to element deterioration. Cloth and paper elements shall not be used.

4-4.3.3 Bypass Requirements. In systems where the ability to maintain uninterrupted service is required, all particulate filters shall be installed so that a clogged filter can be bypassed without disrupting the fluid flow to the end-use point.

4-4.4 Mufflers

Mufflers used for oxygen service, or installed in a chamber or the piping communicating with a chamber (including vent lines downstream from exhaust control valves) shall be fabricated of materials which are noncombustible.

4-4.5 Hoses

4-4.5.1 Hose Materials

(a) Liner. The principal limitation on the selection of liner materials is that the liner shall not give off noxious or toxic gases or vapors. Liners for use with breathing gases containing helium should also be relatively impervious to helium. Nylon, polytetrafluoroethylene (PTFE), and many natural and synthetic rubbers will normally satisfy these requirements.

(1) Liner materials are acceptable for breathing gas service if they will pass the off-gassing test contained in Appendix A. PTFE, nylon, and flexible metal liners meeting the requirements of para. 4-2.2 and which have been cleaned for breathing gas service are acceptable for breathing gas and oxygen service without an off-gassing test.

(2) Hoses to be used for oxygen service shall use liner materials which are suitable for use with gaseous oxygen at the design pressure of the hose.

(b) Reinforcement Layer. For marine systems, reinforcement layer materials shall be compatible with seawater service. Hoses employing carbon steel reinforcing wire shall not be used in marine systems unless the wire has been plated or otherwise protected from corrosion if seawater penetrates the outer jacket.

(c) Outer Jacket. For marine systems, outer jacket materials shall be compatible with seawater service and extensive exposure to the elements. The outer jacket on hoses intended for helium service shall be perforated or sufficiently permeable to allow escape of gas which may seep through the inner liner. For other gas service applications, the designer should consider the possible needs for outer jacket perforation.

(d) Fittings. Fitting materials shall comply with para. 4-2.2. Fittings used on divers' umbilicals shall be types which are resistant to inadvertent disengagement.

4-4.5.2 Pressure Ratings

(a) ***MA WP.*** All hoses used in chamber piping systems shall have a MAWP equal to or greater than the design pressure of the line in which they are used, or a suitable relief valve set at the MAWP of the hose shall be provided.

(b) Burst Pressure. The burst pressure rating of any hose shall be at least four times its rated MAWP. The effect of fittings on the burst pressure is to be considered in establishing MAWP.

4-4.5.3 Installation

(a) All permanently installed hoses shall be installed such that they are not subject to bending at radii less than the manufacturer's minimum rated bend radii and in accordance with all other applicable manufacturer's recommendations.

(b) Permanently installed hoses used to compensate for expansion and contraction in piping systems shall be installed in accordance with manufacturer's recommendations. Where possible, hoses should be installed to always be in single plane bending and free of torsional or axial loadings.

4-4.5.4 Marking. Hoses shall be marked with the manufacturer's name or trademark, type or catalog number, and MAWP. This information shall be either permanently printed on the hose or on a permanently attached corrosion resistant metal tag. Metal tags, when used, shall be affixed so as not to abraid the hose or prevent the hose from normal bending or expansion due to pressure.

4-4.5.5 Testing

(a) Hoses which are received made-up from the hose manufacturer ***and*** which were tested by the manufacturer in a manner substantially equivalent to the procedure described in Article 9 need not be retested.

(b) Locally assembled hose assemblies shall be tested as prescribed in Article 9 before being placed in service. Hose assemblies may be tested individually or as a portion of the system of which they form a part.

4-4.5.6 Hoses Subject to External Pressure

(a) Hoses subject to external pressure are very sensitive to any form of structural damage to the reinforcing layer. The following guidelines are recommended for hoses subject to external pressure.

(I) The reinforcement layer should be of a type which is resistant to collapse. Spiral-wound metal wire constructions usually give good service. Wire braid and synthetic reinforcement layers should be avoided unless there is adequate test data to support their use.

(2) The liner should be securely bonded to the reinforcing layer. Hoses with separable liners, e.g., nylon tubes, are subject to liner collapse if depth pressure penetrates the outer jacket.

(3) Fittings should be of a type that forms a good seal at the end of the hose. Many field-attachable-type fittings leave the cut end of the hose open to external pressure. This can result in depth pressure penetrating the hose outer jacket via the cut end and collapsing the liner.

(4) The hoses should be installed in a manner that minimizes the chances of structural damage to the hose. Minor kinks, crushes, etc., that may not harm the internal working pressure capability of the hose may cause it to collapse when subject to external pressure.

(5) Tight radius bends and torsional loads should be avoided.

(b) Hoses intended for external pressure service shall be tested as follows.

A I0 ft section of hose shall be fitted with fittings of the type intended for use with the hose using normally expected attachment procedures. The section of hose shall be bent 180 deg. around a mandrel at a bend radius equal to the minimum bend radius expected in service. The hose shall be exposed to an external pressure I.5 times its maximum rated external pressure for 1 hr. Air is an acceptable pressurizing medium. The hose shall show no evidence of collapse, either of the casing (outer jacket and reinforcing layer) and liner together or of the liner separately. Hose collapse may be determined by flowing a fluid, usually air, through the hose at a specific rate and observing the resulting pressure drop. The pressure drop will increase significantly when collapse occurs. Note that liner collapse may occur with no visible deformation occurring in the casing. Hose collapse may also be determined by filling the hose with oil-free water and measuring the amount of water displaced as the hose is pressurized.

ARTICLE 5 SELECTION AND LIMITATIONS OF PIPING JOINTS

4-5.1 Welded Joints

Welding procedures, welders, and welding operators shall be qualified in accordance with Section IX of the ASME Code. Welded joints in chamber piping systems shall be constructed in accordance with the requirements of paras. 127, 13 I, and 132 of ASME B3 I. I, subject to the following additional restrictions.

(a) Welded joints of $2\frac{1}{2}$ in. pipe size or smaller may be socket welded or buttwelded. Welded joints over $2\frac{1}{2}$ in. pipe size shall be buttwelded.

(b) The finished interior surface of pipe joints shall be as smooth as practically possible to reduce the amount of noise generated. Backing rings, when used, shall either be removed or be of a consumable type.

4-5.2 Brazed Joints

4-5.2.1 Fabrication Requirements and Pressure Limitations. Except as required in paras. 4-5.2.2 and 4-5.2.3, brazing shall be in accordance with the requirements of Section IX, Part QB, of the ASME Code.

4-5.2.2 Brazing Materials

(a) Corrosion Resistance. All brazed materials, components, and fittings shall be of corrosion resistant metals (stainless steel, copper, brass, bronze). The effect of the filler metal and flux are also of concern when brazing austenitic stainless steel, due to the possibility of intergranular attack of the base metal by the filler metal or flux. Material combinations from Section IX, Part QB, of the ASME Code are recommended.

*(b) **Filler*** Metal. The filler metal used in brazing shall be a nonferrous metal or alloy having a melting point above 1000°F and below that of the metals being joined. The filler metal shall melt and flow freely within the desired temperature range and, in conjunction with a suitable flux or controlled atmosphere, shall wet and adhere to the surfaces to be joined.

(c) ***Flux.*** Fluxes that are fluid and chemically active at the brazing temperature shall be used when necessary to prevent oxidation of the filler metal and the surfaces to be joined, and to promote free flowing of the filler metal. Fluxes shall be soluble in hot water to facilitate flushing from the piping system.

4-5.2.3 Preparation and Procedure

(a) Surface Preparation. The surfaces to be brazed shall be clean and free from grease, oxides, paint, scale, and dirt of any kind. A suitable chemical or mechanical cleaning method shall be used to provide a clean wettable surface for brazing.

(b) Joint Clearance. The clearance between surfaces to be joined shall be no larger than is necessary to ensure complete capillary distribution of the filler metal.

(c) Heating. The joint shall be brought to brazing temperature in as short a time as possible to minimize oxidation. Also the brazing heat shall be concentrated towards the center of the sleeve to minimize thermal degradation of the strength properties of the pipe or tubing material where it enters the sleeve.

(d) Brazing Qualification. The qualification of the brazing procedure and of brazers and brazing operators shall be in accordance with the requirements of Section IX, Part QB, of the ASME Code.

4-5.3 Mechanical Unions

4-5.3.1 Seal Selection. Flat-face O-ring unions and other mechanical joint designs employing self-energizing seals where effective sealing is not dependent on bolt preloading are recommended over bolted flanges. Where bolted flanges are used, consideration should be given to using O-ring flanges in place of gasket or ring-joint flanges.

4-5.3.2 Special Requirements for Bolted Flanges

(a) All bolted flanged joints shall be aligned so that the gasket contact faces bear uniformly on the gasket, and then shall be made up with relatively uniform bolt stress. The gasket shall be properly compressed in accordance with the design principles applicable to the type of gasket used.

(b) All bolts shall be of sufficient length so that when the joint is completed there are at least $1\frac{1}{2}$ full threads visible beyond the nut or threaded attachment.

(c) Where bolted flange joints are used in breathing gas systems, the fabricator shall provide making and unmaking instructions with the system. The instructions shall include as a minimum: required bolt and nut materials, required gasket material compatible with breathing gas service, maximum and minimum allowable nut torques, and torquing sequence.

4-5.4 Threaded Joints

4-5.4.1 Pressure Limitations

(a) Except as permitted in para. 4-3.6, all threaded branch connections shall be made with fittings.

(b) Fittings shall have a pressure rating equal to or greater than the design pressure of the system in which they are used.

(c) Size-pressure limits for pipe threaded joints shall be as follows:

Size	Pressure
Over 3 in.	Not permitted
$2\frac{1}{2}$ to 3 in.	400 psig
2 in.	600 psig
$1\frac{1}{4}$ to $1\frac{1}{2}$ in.	800 psig
1 in.	1500 psig
$\frac{3}{4}$ in or smaller	MAWP of the fittings or pipe, whichever is less

(d) Straight thread O-ring sealed fittings may be used up to the manufacturer's rated MAWP with no limitation on size.

4-5.4.2 Helium Service. For helium service, pipe threads should be avoided, especially in the larger sizes, at higher pressures or where stainless-on-stainless joints are required. Straight thread O-ring sealed fittings are recommended over pipe thread fittings for helium service.

4-5.4.3 Lubricants. Any compound or lubricant used in threaded joints shall be suitable for the service conditions and shall not react unfavorably with either the service fluid or the piping materials.

4-5.4.4 Seal Welding. Threaded joints which are to be seal welded shall be made up without any thread compound, and the weld shall provide complete (360 deg.) coverage. Seal welding shall be done by using qualified welders in accordance with Section IX of the ASME Code per para. 127.5 of ASME B3 1.1. Seal welds shall not be considered as contributing to the mechanical strength of a joint.

4-5.4.5 Stainless Steel Threads. To reduce the possibility of galling where pipe threads are to be used between stainless steel components, there shall be a hardness difference between the thread surfaces of the two components of at least 5 Rockwell B, or some other method of galling prevention shall be used.

4-5.4.6 Straight Threads. When straight thread O-ring sealed fittings are used in locations that may subject the fitting to vibration or a torque that would tend to unscrew it, provision shall be made to prevent inadvertent loosening of the fitting.

4-5.4.7 Aluminum Threads. A suitable thread compound shall be used in making up threaded joints in aluminum pipe to prevent seizing. Aluminum pipe in the annealed temper should not be threaded.

4-5.5 Joitits and Fittings in Tubes

Piping systems used with marine chambers are often subjected to vibration loads. Portions of chamber piping systems are also subject to frequent disassembly and reassembly. These factors shall be considered in the types of tube fittings to be used.

4-5.5.1 Limitations. Flared and compression-type fittings may be used for tube sizes not exceeding 2 in. (50 mm) O.D. Compression-type fittings of aluminum shall not be reused. Bite-type fittings shall not be used in chamber piping systems. Welded fittings may be used subject to the requirements of para. 4-5.1. Brazed fittings may be used subject to the requirements of para. 4-5.2.

4-5.5.2 Restrictions. Fittings and their joints shall be compatible with the tubes with which they are to be used and shall conform to the range of wall thicknesses and method of assembly recommended by the manufacturer except that brass fittings may be used on stainless steel or nickel–copper tube under the following restrictions.

(a) Flared Tube. The tube shall be flared using a suitable flaring tool and a crushable metal gasket shall be used between the tube and the body of the fitting.

(b) Compression Fittings. The nuts and ferrules used shall be of the same material type (e.g., stainless steel or nickel-copper) as the tube and the tube end shall be pre-swaged using a swaging tool or a suitable temporary fitting.

(c) System design pressure shall not exceed the maximum value recommended by the fitting manufacturer for the fittings when used with copper tube.

4-5.5.3 Flare Fitting Gaskets. The use of crushable metal gaskets between the sealing surfaces of flare fittings should be used for helium service, particularly for stainless steel fittings and locations subject to disassembly/reassembly.

4-5.5.4 Cutting of Tube. Tubing cutters can cause work hardening of the tube end, especially if the cutter wheel has lost its edge. This work hardening, plus the additional work hardening resulting from flaring operations, can embrittle the tube and render the tube more susceptible to brittle fracture. All tube which is to be used with flare tube fittings should be saw cut. Stainless steel tube which is to be flared shall be saw cut.

4-5.5.5 Fittings Subject to Frequent Disassembly. The designer shall pay special attention to the selection of fittings in locations where frequent disassembly and reassembly is likely. For these locations, the following fitting types should be used:

(a) flare fittings with crushable metal gaskets;

(b) welded or brazed fittings employing a flat-face seal mechanical union integral to the fitting.

4-5.5.6 Other Types of Joints

(a) Expanded or Rolled Joints. Expanded or rolled joints **may** be used where experience or test has demonstrated that the joint is suitable for the design conditions and where adequate provisions are made to prevent separation of the joint.

(b) ***Shrink Joints.*** Fittings that shrink upon heating to a previous dimension from which they were mechanically expanded may be used where experience or test has demonstrated that the joint is suitable for the design conditions.

ARTICLE 6 SUPPORTS

It shall be the responsibility of the designer to determine the support requirements of the piping system. The following guidelines, however, are considered good practice regarding support spacing:

Size	Maximum Support Spacmg
I in. nominal and larger	In accordance with Table 121.1 9 of ASME 831.1
$\frac{1}{8}$ to $\frac{3}{4}$ in.	75 times the square root of the nominal diameter, in.

Where detailed support designs and calculations are required, they shall be performed in accordance with para. 127 of ASME B31.1.

ARTICLE 7 SYSTEM DESIGN REQUIREMENTS

4-7.1 Pressurization and Depressurization Systems

4-7.1.1 Pressurization and Depressurization Rates. The pressurization and depressurization systems shall be capable of providing the full range of pressurization and depressurization rates specified in the User's Design Specification. When the pressurization gas comes from a stored gas system, the pressurization rates specified in the User's Design Specification must be maintainable at maximum chamber pressure at all storage pressures over 50% of maximum.

4-7.1.2 Ventilation Rates. On all medical chambers and on all other chambers designed for operation in a continuous ventilation mode, the pressurization and depressurization system shall be capable of maintaining all required ventilation rates while holding depth stable to within the range specified by the User's Design Specification. Such systems should also be provided with a means of indicating the rate of flow of ventilation gas through the chamber.

4-7.1.3 Stored Gas Reserves. The requirements for stored gas reserves vary with the application for which a chamber system is to be used. The designer shall consider all pertinent operational and jurisdictional requirements.

4-7.1.4 Exhaust Inlet Protection. The inlets to all chamber exhaust lines shall be fitted with a device that prevents a chamber occupant from inadvertently blocking the opening to the line with a part of his body or be located in normally unoccupied areas, such as under the chamber floor. Chamber exhaust line inlets shall also be located such that, where applicable, discharge of the fire suppression system will not result in water collecting in the bottom of the chamber being injected into the exhaust line.

4-7.1.5 Exhaust Locations. The exhausts from the depressurization system of chambers located inside enclosures shall be piped to a location outside the enclosure and at least IO ft away from any air intake.

4-7.2 Noise

Noise in a chamber may interfere with voice communication as well as present a risk of hearing damage if severe. The designer shall consider all sources of noise in the chamber and shall take appropriate actions to minimize the amounts of noise generated by routine chamber operations.

4-7.3 Pressure Boundary Valve Requirements

4-7.3.1 Internal Pressure Chambers. All lines penetrating the pressure boundary of a chamber subject to internal pressure only shall have a stop valve or a check valve, as appropriate, on the outside of the chamber as close as practically possible to the penetration. Where check valves are used, consideration shall be given to preventing chattering of the valve. Where stop valves are placed in locations which prevent ready access in an emergency, they shall be provided with operators which are controllable from suitable accessible locations. Depressurization lines, drain lines, and other lines that normally communicate between chamber pressure and outside atmospheric pressure shall also have a second valve. This second stop valve may be located either inside or outside of the chamber.

4-7.3.2 External Pressure Chambers. All lines penetrating the pressure boundary of a chamber normally subject to external pressure only shall have a stop valve or check valve, as appropriate, as close as practically possible to the penetration on the inside of the chamber. A second stop valve shall be provided on lines which are normally open to external pressure.

4-7.3.3 Internal and External Pressure Chambers. Chambers which may be subject to both internal and external pressure shall meet the requirements of paras. 4-7.3.1 and 4-7.3.2.

4-7.3.4 External Override. When valves are provided inside a chamber for the purpose of permitting the chamber occupants to control the pressure in the chamber, an external means of overriding the effect of those valves shall be provided. Note that the external override need not be on the same lines or on lines of similar capacity. The fundamental requirement is that there be some means provided, in advance, for gaining access to the chamber in the event the inside personnel become incapacitated.

4-7.3.5 Special Requirements for Chambers Used for Saturation Service. For chambers designed to be used for saturation applications, all lines which are open to chamber pressure except pressure relief lines and pressure reference lines (e.g., all lines used for pressurization, depressurization, external gas, or water conditioning systems) shall be double valved with one stop, or check, valve inside the chamber and the other valve outside.

4-7.3.6 Flow Rate Sensitive Valves. When check valves cannot be used or are not desired, a flow rate sensitive valve which closes automatically in the event of excess flow (out of an internal pressure chamber or into an external pressure chamber) shall be used in each line of 2 in. nominal size or larger, and should be used in any line with a ratio of cross-sectional flow area (in square inches) to chamber volume (in cubic feet) of over 0.0015. Flow rate sensitive valves, when used, may be used to satisfy the second stop valve requirement of paras. 4-7.3.1, 4-7.3.2, and 4-7.3.5, provided that the valves are designed to be closed manually should the primary stop valve develop a leak, as well as automatically upon the development of excess flow.

4-7.3.7 Remotely Operated Stop Valves. Remotely operated stop valves, whose operation is triggered either automatically or manually upon uncontrolled loss of pressure, are an acceptable alternative to the flow rate sensitive valves described in para. 4-7.3.6. Such valves may be used to satisfy the second stop valve requirements of paras. 4-7.3.1, 4-7.3.2, and 4-7.3.5 provided individual valves may be closed manually without triggering closure of other valves. Remotely operated valves used in pressure boundary applications shall also have a manual actuation capability, or a secondary means of pressurizing/depressurizing the chamber shall be provided for use in the event the valve becomes inoperable.

4-7.4 Depth Gages

4-7.4.1 Quantity and Location

(a) Each internal pressure chamber in a chamber system shall have at least one dedicated depth gage (chamber pressure indicator) indicating chamber internal pressure to the chamber operator or chamber system operator. Each chamber in chamber systems other than monoplace medical chambers shall also have a second depth gage which may be located either inside or outside the chamber.

(*b*) External pressure chambers and chambers subject to both internal and external pressure shall have dedicated gages indicating both internal and external pressures to the chamber operator or chamber system operator, and separate gages indicating these pressures to the chamber occupants, unless the occupants are also the operators, as in the case of a submersible.

4-7.4.2 Calibration. A means shall be provided to permit depth gages to be checked, while in use, against other system depth gages normally accessible to the chamber or system operator or an external master gage for accuracy.

4-7.4.3 Piping. The lines connecting depth gages to their associated chambers shall not be used for any other purpose. The inside diameter of depth gage lines shall not be smaller than 0.12 in. (3 mm).

4-7.4.4 Valving Arrangements. Valving arrangements used with depth gages shall be designed so that the pressure source to which each gage is connected is clearly indicated to the system operator.

4-7.5 Pressure Gages Other Than Depth Gages

All breathing gas and life-sensitive systems shall be fitted with at least one pressure gage equipped with a gage isolation valve. Measures to protect gages from excessive vibration or sudden pressure changes shall be taken where appropriate.

4-7.6 Breathing Gas Systems

4-7.6.1 Breathing Gas Outlets. The number of breathing gas outlets provided in chambers. shall be not less than the maximum rated number of occupants plus one, except for diving bells where the number of breathing gas outlets shall not be less than the maximum rated number of occupants. Each gas outlet shall have a stop valve. Each gas outlet shall be compatible (pressure and flow rate capacity, connection type, etc.) with the type of breathing apparatus listed in the User's Design Specification.

4-7.6.2 Redundancy of Breathing Gas Supply. The piping system shall be designed so that breathing gas can be delivered to the breathing gas outlets in chambers and to the divers' breathing gas manifold in diving bells from at least two different supply sources.

4-7.6.3 Stored Gas Reserves. The requirements for stored breathing gas vary with the application for which a chamber system is to be used. The designer shall consider all pertinent operational and jurisdictional requirements.

4-7.6.4 Multiple Gases. Where gases of different composition are connected to a distribution manifold or other distribution system, a positive means shall be provided to ensure that leaking valves will not result in an improper gas being supplied to the end-use point or result in backflow from one supply gas into the distribution system for another supply gas.

4-7.6.5 Labeling of Breathing Gas Outlets. All breathing gas outlets shall be labeled. Where the gas supplied is always known, the label shall indicate the type of gas supplied, such as "Oxygen." Where the gas supplied is subject to change based on operational requirements, the label shall contain a generic term such as "Breathing Gas."

4-7.6.6 Separation of Breathing Gases. This Standard recognizes that complete separation of breathing gases of different types is generally not possible in PVHO applications. However, the designer should take all reasonable steps to minimize the number of locations/situations where gases of different compositions need to use common distribution equipment and/or common outlets.

4-7.6.7 Pressure Control Valves in Demand Breathing Systems. Where pressure control valves are used in demand breathing systems, they shall meet the requirements of para. 4-7.7.6.

4-7.7 Pressure Control Valves

4-7.7.1 Performance Characteristics. The performance of a pressure control valve is characterized primarily by two factors, both of which must be taken into account by the designer. These factors are:

(a) the rate at which the outlet pressure falls (drops) as flow demand increases. In many designs there is a significant difference between outlet pressure at lockup (no flow) and the outlet pressure at useful flow rates. Outlet pressure may also be influenced by changes in inlet pressure, especially in unbalanced single stage designs. However, the flow effect usually dominates.

(b) limit flow capacity. This factor is a function of upstream pressure, orifice size, downstream pressure, and outlet porting size. Developing the full rated capacity on many large capacity pressure control valves is frequently possible only at relatively high outlet pressures due to the development, at lower outlet pressures, of choked flow conditions in the outlet ports.

4-7.7.2 **Seats.** Pressure control valves used in applications requiring complete shutoff shall employ soft seats. Where complete shutoff is not required, pressure control valve seats meeting the requirements for Class IV leakage rates under ANSI/FCI 70-2 may be used.

4-7.7.3 Filters. All pressure control valves used in life-sensitive systems, except those used in overboard dump systems for breathing masks, shall be provided with an upstream particulate filter which meets the requirements of para. 4-4.3.

4-7.7.4 **Gages.** Gages indicating the controlled pressure shall be provided with all pressure control valves, and they shall be located so as to be clearly visible to a person adjusting the setting of the pressure control valve.

4-7.7.5 Bypass Requirements. Except as otherwise required in para. 4-7.7.6(b), in systems where the ability to maintain uninterrupted service is required, all regulators shall be provided with either a redundant regulator of equal size or a manually operated bypass valve.

4-7.7.6 Pressure Control Valves Used in Demand Breathing Systems

(a) Capacity Requirements. The peak respiratory flow rates, both inspiratory and expiratory, in a demand breathing system are normally 3.0 to 3.14 times the net average flow as represented by the user's respiratory minute volume. Therefore, the capacity of pressure control valves used to support demand type breathing apparatus shall be computed as follows:

$$Q = 3.14(N)(D)(RMV)(F)$$

where

N = maximum number of breathing apparatus to be supported at one time

D = maximum usage depth in atmospheres absolute

RMV = maximum anticipated user respiratory minute volume, in cu ft per min at usage pressure. The minimum RMV that may be used is 1.41 cu ft per min (40 L per min) for a working diver and 0.7 cu ft per min (20 L per min) for a resting diver or chamber occupant

Q = regulator capacity at minimum design inlet pressure, standard cu ft per min

F = factor, to be taken as 1.0 unless data is available to support a lower number. *F* = 1 assumes all gas users inhale or exhale simultaneously. Consequently, as N becomes large, *F* will approach 0.5. For N = 1 or 2, *F* shall be taken as 1.0. For N > 2, *F* may be reduced as warranted by testing or experience with prior designs. *F* may also be reduced if it can be shown, either experimentally or analytically, that sufficient volume exists between the pressure regulation point and the usage point(s) to provide an accumulator effect capable of providing whatever differences may exist between the instantaneous flow rate requirements and the regulator capacity provided. In no case may *F* be reduced below 0.5.

(b) ***Bypass Requirements.*** The unsteady nature of the flow in demand breathing circuits makes use of hand-operated valves for bypass purposes around pressure control valves inappropriate in many situations.

(I) The pressure control valves in circuits supplying breathing gas to divers using demand breathing apparatus in the water or in a diving bell shall either be:

(a) provided with a bypass loop containing a second pressure regulator of equal capacity and appropriate related components; or

(b) arranged as a series of two or more pressure control valve stations each with a hand-operated bypass, appropriate related components, and a pressure control valve capable of accepting full initial supply pressure and providing regulated outlet conditions appropriate for the end-use function.

(2) Hand-operated bypass valves may be used in systems supplying gas to chamber mask breathing gas outlets provided that adequate overpressure relief is provided.

(3) Bypass capability is not required for pressure control valves supporting single consumers where a service interruption is tolerable, such as for pressure control valves dedicated one to each of several mask breathing gas outlets in a chamber.

(4) Bypass capability is not required for pressure control valves supporting overboard dump manifolds in chambers.

4-7.8 Pressure Relief Requirements

4-7.8.1 Overpressure Relief

(a) All systems potentially subject to internal pressures in excess of their design pressure shall be provided with overpressure relief devices capable of maintaining system pressure at not more than 110% of design pressure.

(b) Systems located inside of chambers which are normally pressurized at less than chamber pressure shall be equipped with relief devices (check valves are acceptable) if any of the components in the system (such as vacuum gages) are subject to damage if chamber pressure is released without a concurrent release of system pressure.

4-7.8.2 Underpressure Relief

(a) Systems located inside of chambers which are normally pressurized in excess of chamber pressure shall be equipped with vacuum breakers if any of the components on the system (such as pressure gages) are subject to damage if the chamber is pressurized without pressure in the system.

(b) Systems located inside of chambers which are normally pressurized to a level less than chamber pressure (mask overboard dump lines, medical suction lines) shall be provided with vacuum relief valves capable of relieving underpressures in excess of the maximum limits established by the system designer.

4-7.8.3 Rupture Disks. Rupture disks shall not be used except on gas containers with less than 2.0 cu ft water volume.

4-7.8.4 Division Valves. Where piping systems operating at different pressures are connected, a division valve shall be provided which shall be designed for the higher pressure.

4-7.8.5 Pressure Reducing Valves. Where pressure reducing valves are used, one or more relief devices shall be provided on the low pressure side of the system, or the piping and equipment on the low pressure side shall meet the requirements for the full initial pressure. The relief devices shall be located adjoining or as close as possible to the reducing valve. The total relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded by more than 10% if the reducing valve fails open,

4-7.8.6 Bypass Valves. Where manually operated bypass valves are permitted around pressure control valves, they shall not have a maximum flow capacity greater than the reducing valve unless the downstream piping is adequately protected by relief valves or meets the design requirements of the higher system pressure.

4-7.8.7 **Stop Valves.** There shall be no intervening stop valves between piping being protected and its protective device or devices, except that stop valves may be installed between a relief valve and the piping being protected under the following conditions:

(a) when, in the judgment of the designer, the hazard from a relief valve failing open exceeds the hazard presented by the possible concurrent occurrence of system overpressure plus a closed stop valve;

(b) when a stop valve is provided between a relief valve and the associated protected piping, the valve shall be of a quarter turn design and it shall be wired open with frangible wire.

4-7.8.8 Exhausts From Relief Devices

(a) Exhausts from relief devices which are located inside enclosed spaces shall be piped outside of the space if operation of the relief device could result in overpressurizing the space.

(b) Exhausts from relief devices which are located inside enclosed spaces on lines containing gases other than air shall be ducted out of the space except that this requirement does not apply to relief devices on individual gas storage bottles when the individual bottle capacity is less than 400 standard cu ft and the requirements of (a) above are satisfied.

4-7.9 Color Coding

4-7.9.1 Consistent Color Codes. Chamber piping systems shall employ a consistent color coding system. Suggested guidelines are listed in Nonmandatory Appendix IV.

4-7.9.2 Owner's Responsibility. Color code requirements vary substantially between the various jurisdictions in which chamber systems may be used. It shall be the responsibility of the owner to specify the required color coding system.

4-7.10 Labeling

4-7.10.1 Piping and Gas Storage Vessels. All piping and gas storage bottles shall be labeled to show contents, direction of flow (when appropriate), and MAWP.

4-7.10.2 Critical Components. All critical 'components whose function is not obvious from their location and appearance shall be labeled, as to function. Except as required in para. 4-7.9.2, it is the responsibility of the designer to establish labeling requirements unless such requirements are specified by the owner.

4-7.10.3 Panel-Mounted Components. All components which are mounted in panels shall be labeled as to function. The panel face shall contain a schematic representation of the internal connections between all panel-mounted components and of the external connections between the panel-mounted components and the associated elements of the piping system.

4-7.11 Soft Goods

4-7.11.1 Breathing Gas Systems. Soft goods used in breathing gas service shall be compatible with intended service fluids at the anticipated maximum pressures and shall be compatible with all anticipated cleaning procedures.

(a) PTFE O-rings shall be avoided. PTFE O-rings may cold flow, "take a set," and fail.

(b) Soft goods for use in breathing gas and oxygen systems shall carry manufacturers' recommendations as listed below:

Service	Manufacturer's Service Recommendation
Air	Air
Mixed gas with oxygen concentrations of less than 25% by volume	Air
Mixed gas with oxygen concentrations equal to or greater than 25% by volume	Oxygen
Oxygen	Oxygen

4-7.11.2 Other Systems. Soft goods used in other systems shall be compatible with the fluids contained, at the maximum anticipated pressures.

4-7.12 Lubricants and Sealants

Lubricants and sealants are necessary in breathing gas systems for lubricating O-rings, lubricating moving parts of pressure control valves, and lubricating and sealing pipe thread joints. However, due to the possible presence of oxygen-enriched gases and the ultimate use of the gas for respiratory purposes, lubricants and sealants must be selected with care.

(a) Lubricants and. sealants used in breathing gas and oxygen systems shall be of a type recommended by the manufacturer for the intended service.

(b) Where there is a possibility that lubricants selected for use on piping system components may also be used for O-rings contacting acrylic windows, the lubricants shall be compatible with acrylic.

(c) Fluorocarbon-based lubricants shall not be used on aluminum.

(d) Some chemicals used to remove rust from carbon steel can react with fluorocarbon compounds to form very strong acids. If fluorocarbon lubricants have been used on carbon steel components, they shall be removed prior to the initiation of any chemical rust removal operations.

4-7.13 Cleaning Requirements

4-7.13.1 Oxygen and Breathing Gas Systems. The internal cleaning of oxygen and breathing gas systems is an essential part of chamber piping system design and fabrication. The following guidelines are recommended.

(a) A written cleaning procedure with well-defined procedures, personnel responsibilities, and acceptance/recleaning criteria should be developed and implemented.

(b) Component handling procedures should be developed and implemented so that components and systems, once cleaned, are not recontaminated.

(c) The intended cleaning procedures should be considered by the designer during the selection of all materials, especially soft goods, and during the layout of the piping runs.

4-7.13.2 Components Located inside Chambers. Components which are to be located inside chambers shall also be cleaned on their exteriors. The exteriors of components for use inside marine systems should show no visible signs of oil or grease. The exteriors of components for use inside medical chambers should show no fluorescence typical of oil or grease when examined under ultraviolet light.

4-7.13.3 Prohibited Cleaning Materials. Trichloroethylene shall not be used to clean breathing gas systems or any components to be located inside a chamber. When passed through a moderately heated alkali bed (such as those used in most CO_2 scrubbers), trichloroethylene can decompose into highly toxic dichloroacetylene.

ARTICLE 8 INSPECTION

4-8.1 Inspection of Welded Joints

All welds in chamber piping systems which are subject to stresses due to pressure shall be inspected in accordance with the requirements of Table 4-8.1. The inspection procedures and acceptance standards shall be in accordance with para. 136.4 of ASME B3 1.1. It shall be the responsibility of the fabricator (or his agent) to ensure that all inspection personnel are qualified to perform the required inspections.

4-8.2 Inspection of Brazed Joints

Brazed joints performed in accordance with Section IX, Part QB, of the ASME Code shall be subject to a visual inspection as a minimum. The following acceptance criteria shall apply.

(a) Pre-inserted alloy-type joints may be considered satisfactory when, before any face feeding, the total length of exposed brazing alloy between the outside surface of the pipe or tube and the outer end of the fitting is greater than $^3/_4$ of the circumference, with the greatest unexposed portion not exceeding 10% of the circumference.

(b) Face-fed joints shall show a complete ring of brazing alloy between the outside surface of the line and the outer end of the fitting.

ARTICLE 9 TESTING

4-9.1 Hydrostatic Tests

4-9.1.1 Air Vents. Vents shall be provided at all high points of the piping system in the position in which the test is to be conducted to permit purging of air while the component or system is filling. If required, additional venting during the filling of the system may be provided by the loosening of flanges, tube fittings, or union joints in pipelines, or by the use of equipment vents.

4-9.1.2 Test Fluid. Water shall normally be used for a hydrostatic test fluid unless otherwise specified by the owner. Test water shall be clean, and oil free, and shall be of such purity as to minimize corrosion of the material in the piping system.

4-9.1.3 Test Pressure. Piping systems shall be subjected to a hydrostatic test pressure so that every point in the system is not less than I.5 times the design

TABLE 4-8.1 MANDATORY MINIMUM NONDESTRUCTIVE EXAMINATIONS FOR PRESSURE WELDS IN PIPING SYSTEMS FOR PRESSURE VESSELS FOR HUMAN OCCUPANCY

Type of Weld	Examination Requirements
Butt welds (girth and longitudinal)	Pressure boundary and life-sensitive piping RT. all sizes Otherwise, RT for NPS over 2 in., MT or PT for NPS 2 in. and less
Branch welds (intersection and nozzle); size indicated is branch size	RT for NPS over 4 in., MT or PT for NPS 4 in. and less
Fillet welds, socket welds	PT or MT for all sizes and thicknesses

GENERAL NOTES:
(a) For vent lines not subject to chamber pressure, MP or PT may be substituted for RT.
(b) All welds must be given a visual examination in addition to the type of specific nondestructive test specified.
(c) NPS = nominal pipe size.
(d) RT = radiographic examination; MT = magnetic particle examination; PT = liquid penetrant examination.
(e) It should be noted that it is impractical to radiograph some branch connections due to angle of intersection or configuration.
(f) Nondestructive examinations specified above do not apply to components made to standards listed in Table 126.1 of ASME B31.1

pressure, but shall not exceed the maximum allowable test pressure of any nonisolated component in the system.

4-9.1.4 Holding Time. The hydrostatic test pressure shall be continuously maintained for a minimum time of 10 min and for such additional time as may be necessary to conduct the examinations for leakage.

4-9.1.5 Examination. Examinations for leakage shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packings, shall show no visual evidence of weeping or leaking.

4-9.2 Pneumatic Tests

4-9.2.1 Limitations

(a) Pneumatic testing shall not be used in lieu of other means of leak testing except as limited in para. 4-9.2.3, or when one or more of the following conditions exist:

(I) when owner's specification requires or permits the use of this test as an alternative;

(2) when piping systems are so designed that they cannot be filled with water;

(3) when piping systems are to be used in service where traces of the testing medium cannot be tolerated, e.g., lines to gas analyzers.

4-9.2.2 Test Medium. The gas used as the test medium shall be oil free, nonflammable, and nontoxic. Since compressed gas may be hazardous when used as a testing medium, it is recommended that special precautions for protection of personnel shall be observed during pneumatic testing.

4-9.2.3 Preliminary Test. A preliminary pneumatic test not to exceed 25 psig may be applied, prior to other methods of leak testing, as a means of locating major leaks. If used, the preliminary pneumatic test shall be performed in accordance with the requirements of paras. 4-9.2.2 and 4-9.2.7.

4-9.2.4 Test Pressure. The pneumatic test pressure shall be not less than 1.2 nor more than 1.5 times the design pressure of the piping system. The test pressure shall not exceed the maximum allowable test pressure of any nonisolated component in the system.

4-9.2.5 Application of Pressure. The pressure in the system shall be gradually increased to not more than one-half of the test pressure, after which the pressure shall be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached.

4-9.2.6 Holding Time. The pneumatic test pressure shall be continuously maintained for a minimum time of 10 min, after which the pressure shall be reduced to system design pressure for examination for leakage.

4-9.2.7 Examination. Examinations for leakage detected by a soap bubble or equivalent method shall be made of all joints and connections. The piping system, exclusive of possible localized instances at valve packings, shall show no evidence of leaking, except that for oxygen systems detectable leaks shall not be permitted at any location.

MANDATORY APPENDICES

APPENDIX A
CERTIFICATION FORMS FOR ACRYLIC WINDOWS

(This Appendix is an integral part of ASME PHVO-1 and is placed after the main text for convenience.)

Appendix A

ENCLOSURE 1
ACRYLIC WINDOW DESIGN CERTIFICATION

Window Description — Window Drawing No. ____________

Maximum allowable working pressure ________ psi ________ MPa

Maximum design temperature ________ °F ________ °C

Minimum design temperature ________ °F ________ °C

Window shape ____________

Conversion factor table number ____________

pressure range, N ____________

Conversion factor, CF ____________

Short-term critical pressure and Fig. No. ____________

Experimental verification*

- Thickness t (actual) ________
- D_o (actual) ________
- D_i (actual) ________
- Water temperature ____ °F ____ °C

No. 1 ________ No. 2 ________

No. 3 ________ No. 4 ________

No. 5 ________ STCP ________

(Note each test specimen FS for full scale and MS for model scale.)

Type of failure ____________

Test conducted at ____________

Test supervised by ____________

Window Design

Inner diameter, D_i (nominal) ____________

Included angle (nominal) ____________

External radius of curvature (nominal) ____________

Minimum t/D_i (calculated) ____________

*If STCP is determined experimentally according to para. 2-2.5.2, then the critical pressures of all five windows tested, the testing laboratory, and the test supervisor should be noted here.

Minimum t (calculated) ____________________

D_o/D_i (nominal) ____________________

Minimum D_i (calculated) ____________________

Diametral interference/clearance between D_o of window and window seat at maximum design temperature (calculated) ____________________

Diametral interference/clearance between D_o of window and window seat at minimum design temperature (calculated) ____________________

Actual t (specified on drawing) ____________________

Actual D_i (specified on drawings) ____________________

Actual D_o (specified on drawings) ____________________

Actual external radius of curvature (specified on drawings) (spherical or cylindrical) ____________________

Drawing No. of window ____________________

Drawing No. of flange ____________________

Drawing No. of assembly ____________________

Description of pressure vessel (for which the window has been designed) ____________________

____

____

____

The viewport design complies with all of the requirements of the Safety Standard for Pressure Vessels for Human Occupancy, Section 2, Article 2.

____ ____________________
Viewport Designer Date

____ ____________________
Authorized representative of chamber manufacturer or owner Date

____ ____________________
Name and address of chamber manufacturer or owner Date

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Appendix A

ENCLOSURE 2
MATERIAL MANUFACTURER'S CERTIFICATION FOR ACRYLIC

The ____________ centimeters x ____________ centimeters acrylic sheet/custom castings of ____________________

centimeters nominal thickness in Lot No. __________ have been produced by ______________________________

under the trademark of____

These castings possess typical physical properties satisfying the minimum values specified in Safety Standard for Pressure Vessels for Human Occupancy, Section 2, Table 2-3.1, in accordance with the material manufacturer's Quality Assurance Manual Edition ____________, Rev. __________, dated __________

____ ______________________
Authorized representative of manufacturer of plastic Date

____
Name and address of manufacturer of plastic

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Appendix A

ENCLOSURE 3
MATERIAL TESTING CERTIFICATION FOR ACRYLIC

1. Test specimens have been ☐ cut from casting or ☐ supplied already cut by ____________________

2. Test specimen taken from ☐ acrylic sheet or ☐ custom castings No. __ in Lot No. - of ____ centimeters nominal thickness that have been produced by ____________________ (matenal manufacturer) under the trademark of ____________________ possess the following physical and chemical properties:

Test Method	Property	Results
ASTM D 621	Compressive deformation at 4000 psi (27.6 MPa) and 122°F (50°C)	________
ASTM D 638	Tensile: (a)Ultimate strength (b)Elongation at break (c)Modulus of elasticity	 ________ ________ ________
ASTM D 695	Compressive: (a)Yield strength (b)Modulus of elasticity	 ________ ________
ASTM E 308	Ultraviolet transmittance [for 1/2 in. (12.5 mm) thickness]	________
PVHO-1, para. 2-3.7(e)	Visual clarity	________
PVHO-1, para. 2-3.8	Total residual methyl methacrylate and ethyl acrylate monomers	________% ________%

The experimentally proven properties satisfy the minimum values specified in Table 2-3.2 of the Safety Standard for Pressure Vessels for Human Occupancy.

____ ____________________
Authorized representative of matenal testing laboratory — Date

____
Name and address of matenal testing laboratory

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Appendix A

ENCLOSURE 4
PRESSURE TESTING CERTIFICATION

Window Identification ______________________

Window Description

Maximum allowable working pressure ______________________

Maximum design temperature ______________________

Test Arrangement

Windows tested in operational viewport/simulated viewport ______________________
(operational/simulated)

Operational/simulated viewport Drawing No. ______________________

Window tested according to Section 2, Article 7 ______________________
(yes/no)

Test pressure __________ psi __________ MPa

Overpressure ratio (test pressure/maximum allowable working pressure) ______________________

Pressurizing medium temperature __________ “F __________ “C

Rate of pressurization (average) ______________________

Duration of sustained pressurization ______________________

Test Observations (yes/no)

Leakage ______________________

Permanent Deformation ______________________

Crazing ______________________

Cracking ______________________

The acrylic window was pressure tested according to the procedure of Section 2, Article 7, of the Safety Standard for Pressure Vessels for Human Occupancy and was found to perform satisfactorily without any visible permanent deformation, crazing, or cracking.

______________________________ ______________
Pressure test supervisor — Date

____
Name and address of pressure testing laboratory

______________________________ ______________
Authorized representative of chamber manufacturer (windows for new chamber).
or user (windows for replacement in an existing chamber) — Date

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APPENDIX B
REFERENCE CODES, STANDARDS, AND SPECIFICATIONS

(This Appendix is an integral part of ASME PVHO-1 and is placed after the main text for convenience.)

Codes, standards, and specifications incorporated in this Standard by reference, and the names and addresses of the sponsoring organizations, are shown below. The most current edition, including addenda, of referenced codes, standards, and specifications are to be used.

ASME Codes and Standards

ASME Boiler and Pressure Vessel Code

ASME B31.1, Power Piping

ANSI/ASME B 1.20.1, Pipe Threads, General Purpose (Inch)

ASME B36.10M, Welded and Seamless Wrought Steel Pipe

ASME B36.19M, Stainless Steel Pipe

ASTM Specifications

ASTM B 88, Specification for Seamless Copper Water Tube

ASTM B 1.54, Method of Mercurous Nitrate Test for Copper and Copper Alloys

ASTM D 256, Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials

ASTM D 542, Test Methods for Index of Refraction of Transparent Organic Plastics

ASTM D 570, Test Method for Water Absorption of Plastics

ASTM D 62 I, Test Methods for Deformation of Plastics Under Load

ASTM D 638, Test Method for Tensile Properties of Plastics

ASTM D 648, Test Method for Deflection Temperature of Plastics Under Flexural Load

ASTM D 695, Test Method for Compressive Properties of Rigid Plastics

ASTM D 696, Test Method for Coefficient of Linear Thermal Expansion of Plastics

ASTM D 732, Test Method for Shear Strength of Plastics by Punch Tool

ASTM D 785, Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials

ASTM D 790, Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

ASTM D 792, Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement

ASTM E 208, Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

ASTM E 308, Method for Computing the Colors of Objects by Using the CIE System

FCI Stundurd

ANSI/FCI 70-2, American National Standard for Control Valve Seat Leakage

Other References

***NASA Technical Manual TMX** 64711*, Compatibility of Materials with Liquid Oxygen, October 1, 1972

***Naval Ships' Technical Manual NAVSEA** 0901-LP-450-*0002 ***(change** I), Chapter 9450, "Lubricating Oils, Greases and Hydraulic Fluids, and Lubricating System," September I, 1967 (changed October 15, 1976)

ASME
The American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

ASME Order Department
22 Law Drive
P.O. Box 2300
Fairfield, NJ 07007-2300

ASTM
The American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

FCI
Fluid Controls Institute, Inc.
P.O. Box 9036
31 South Street
Morristown. NJ 07960

APPENDIX C
REPAIR OF DAMAGED WINDOWS PRIOR TO BEING PLACED IN SERVICE

(This Appendix is an integral part of ASME PVHO-1 and is placed after the main text for convenience.)

Cl

New fabricated windows that do not meet acceptance criteria of Section 2, Article 5, or windows that have been damaged during inspection, shipment, pressure testing, storage, handling, or installation in chambers but prior to being placed in service, may be repaired, provided the requirements of this Appendix are met.

c2

For the purpose of this Standard, a damaged window is one which meets the criteria of Section 2, is marked per Section 2, Article 6, and has a Window Certification but has sustained damage which requires repair prior to being placed in service.

c3

Windows are considered to be damaged when the window can no longer meet the dimensional tolerances and surface finishes specified by Section 2, Article 5. The assessment of damage shall be performed by an authorized representative of the chamber manufacturer or user, or an accredited window fabricator.

c4

The damage to windows, depending on its severity, may be repaired by the chamber user himself, or by an accredited fabricator of windows. Only slightly damaged windows may be repaired by the chamber user or his authorized agent, while the severely damaged windows must be repaired solely by an accredited window fabricator.

c5

The damage to windows is considered slight when it consists solely of scratches on the surfaces less than 0.020 in. deep or chips on the window edges less than 0.125 in. wide. Scratches deeper than 0.020 in., edge chips wider than 0.125 in., gouges, cracks, and crazing are considered severe damage.

C6

Slightly damaged windows may be repaired by the chamber user or his authorized agent, provided only hand sanding/polishing techniques are utilized, and the thickness and surface finish of the window after repair meet the requirements of Section 2. The use of power driven tools (disk sanders, buffing wheels, lathes, milling machines, etc.) is not allowed. These repairs do not require post annealing.

c7

Special conditions are applicable to the repair of severely damaged windows.

(a) Severely damaged windows must be repaired by an accredited window fabricator.

(0) Repair of severely damaged windows is to be initiated by the window fabricator only after receipt of written authorization from the chamber manufacturer or user and inspection of the damaged window for identification marking. Damaged windows whose identification does not correspond to the written authorization shall not be repaired.

(c) The written authorization must be accompanied by the original Design (Appendix A, Enclosure I) and the Fabrication Certification (Form PVHO-2).

(d) During the repair, the window fabricator may utilize all the fabrication processes customarily employed in the fabrication of new windows that meet the requirements of Section 2, Article 4.

(e) Upon completion of repair, the window is to be annealed according to the schedule of Table 2-4. I.

(f) After annealing, the repaired window shall be inspected to assure that the tinishcd window meets the material quality, minimum thickness, dimensional

tolerance, surface finish, and inclusion limitation requirements of Section 2.

(g) Repair windows shall be marked with the identification of the window fabricator performing the repair.

(h) The repair identification shall consist of 0.5 in. letters and numbers made with indelible black marker, or 0.125 in. letters and numbers made with epoxy ink located on the window's seating surface.

(i) The repair identification shall contain the following information, as per the example below:

Δ–PS–12–81 → Year repair performed
→ Fabricator's serial number of repair
→ Window fabricator's initials
→ Repair logo

The repair identification shall not obscure in any manner the original window identification.

(j) Original window identification marking that has been accidentally or intentionally removed during repair operations may be reapplied at this time, provided the restored original identification marking has identical wording to the original one which has been removed, and the Repair Certification reflects this fact.

(k) The design life of the repaired window is determined by the original fabrication date shown on the window identification marking.

C8

Windows with spherical surfaces whose dimensional tolerances, surface finish, or inclusions exceed the limits specified in paras. 2-2.12, 2-5.3, and 2-5.5 may be repaired by spot casting, provided the following conditions are satisfied.

(a) The repaired spot shall be subjected only to compressive stresses in service.

(b) The casting mix used for spot repairs shall have the same chemical composition and shall be polymerized in the same manner as the casting mix in the window casting.

(c) For repaired spots located in areas within 2 deg. of the window's edge circumference, or areas not visible from the interior of the pressure vessel by an observer in a typical position required for operation of the vessel, the following limitations apply:

(I) The volume of a single repaired spot shall not exceed 10%, and the cumulative volume of all repaired spots shall not exceed 20% of the total window volume;

(2) There is no limit on the number of repaired spots.

(d) For repaired spots located in areas outside 2 deg. of the window's edge circumference, and visible from the interior of the pressure vessel to an observer in a typical position required for operation of the vessel, the following limitations apply:

(I) The area of any repaired spot shall not exceed 0.025% of the total window area;

(2) Only two repaired spots are permitted.

(e) After completion of machining and polishing operations, the window is to be annealed per para. 2-4.4.

(f) Location and extent of spot casting repairs are to be noted on a sketch attached to the Window Certification.

Appendix C

ENCLOSURE 1
ACRYLIC WINDOW REPAIR CERTIFICATION

Window Identification ______________________

1 Window Shape (From Visual Inspection)

Conical frustum ______________________

Double beveled ______________________

Spherical sector with conical edge ______________________

Spherical sector with square edge ______________________

Hemisphere with equatorial flange ______________________

Flat disk ______________________

Hyperhemisphere with conical edge ______________________

NEMO ______________________

Cylinder ______________________

2 Design Data (From Attached Appendix A, Enclosure 1)

Original Design Certification prepared by ______________________

Maximum allowable working pressure ______________________

Maximum design temperature ______________________

Minimum thickness (calculated *t*) for above temperature and pressure ______________________

3 Original Fabrication Date (From Form PVHO-2)

Original fabrication certification prepared by ______________________
(Name of preparer)

____
(Name of fabricator)

Fabricated according to drawing ____________________

Identification marking ____________________

Actual minimum thickness t ____________________

Actual inside diameter D_i ____________________

Actual outside diameter D_o ____________________

4 Repair instructions

Refinish the following surfaces

High pressure face ____________________

Low pressure face ____________________

Bearing surfaces ____________________

Beveled edges ____________________

Sealing surfaces ____________________

Spot casting meeting requirements of paras. 2-3.10 and C8 is authorized where appropriate ____________________

The minimum thickness *t* of the repaired window is to meet or exceed ____________________

The inside diameter D_i of the repaired window is to meet or exceed ____________________

Repair of window has been authorized by ____________________
(Name of company)

____
(Name of authorized representative)

____
(Signature of authorized representative)

5 Repair History

The following surfaces were refinished

High pressure face ____________________

Low pressure face ____________________

Bearing surfaces ____________________

Beveled edges ____________________

Spot casting process

Resin used ______________________

Catalyst used ______________________

Polymerization technique ______________________

Tensile strength of bond with acrylic per para. 2-3.10(a) ______________________

Sketch of spot casting locations attached to Appendix C, Enclosure 1 __________ (Yes) __________ (No)

Minimum thickness of repaired window ______________________

The minimum thickness t of repaired window meets or exceeds minimum calculated thickness of paras. 2-2.2 through 2-2.5 __________ (Yes) __________ (No)

The repaired window was annealed at __________ for __________ hr

During fabrication the original window identification markings were Left intact ______________________

Removed and reapplied ______________________

The repair marking applied to the window reads as follows ______________________

The refinished surfaces, spot castings, and minimum thickness of the repaired window meet all the requirements of Section 2 and the attached Design Certification (Appendix A, Enclosure 1).

____
Authorized representative of window fabricator

____
Name and address of window fabricator

GENERAL NOTES:
(a) The data for Parts 1 through 4 of this Enclosure are to be provided and certified by the company/individual authorizing the repair of windows.
(b) The repair process information required by Part 5 is to be provided and certified by the window fabricator performing the repair.
(c) This form may be reproduced and used without written permission from ASME if used for purposes other than republication.

APPENDIX D
DEFINITIONS

(This Appendix is an integral part of ASME PVHO-1 and is placed after the main text for convenience.)

acrylic: methyl methacrylate plastic possessing physical and mechanical properties shown in Tables 2-3.1 and 2-3.2

actual values: dimensions and angles of fabricated chamber components as measured during quality control inspection at 70 to 75°F material temperature range

breathing gas service: any line which carries gas that is intended for use as a respirable environmental gas in an occupied space or is intended for use in some type of breathing apparatus is considered to be in breathing gas service

breathing gas system: any system which is used to handle gas (including air) intended for human respiration. All oxygen systems are considered breathing gas systems.

chamber.. a pressure vessel intended for occupancy by humans. The chamber may be pressurized internally, externally, or both. Diving bells, decompression chambers, altitude chambers, medical chambers whether fixed or transportable, submersible pilot spheres, and submersible lock-out compartments are all considered chambers under this Standard.

chamber system: two or more chambers intended to function as an operational unit. For purposes of this Standard, each compartment in a multicompartment vessel that is capable of occupancy by humans at a pressure different from the pressure in other compartments is considered a chamber.

component: component as used in this Standard is defined as consisting of, but not limited to, items such as pipe, piping subassemblies, parts, valves, strainers, relief devices, fittings, etc.

conversion factor (CF): an empirical ratio of short-term critical pressure to design pressure specified on the basis of long experience as the safe relationship between the two variables for a given temperature

critical density of population: number of significant inclusions or scratches per specified contiguous area or volume of window that cannot be exceeded in a finished window

critical dimension: the dimension of inclusion or scratch that cannot be exceeded. For inclusions it is diameter or length, whichever is largest. For scratches it is the maximum depth measured from the smooth surface to the bottom of the scratch.

critical location: the location where inclusions or scratches whose size exceeds the significant dimension cannot be tolerated

critical pressure: hydrostatic pressure that, acting on one side of the window, causes it to lose structural integrity and ability to remain impermeable to water

critical size of population: total number of inclusions or total length of scratches with significant dimensions that cannot be exceeded in a finished window

critical spacing: the minimum allowable spacing between peripheries of inclusion or scratches with significant dimensions in a finished window

custom casting: a casting of any shape that is not carried as a standard production item in a manufacturer's sales catalog

cyclic fatigue life: the number of pressure cycles that a window must withstand prior to catastrophic failure when pressure cycled to design pressure in design temperature environment. This Standard defines the cyclic fatigue life as 10^4 standard pressure cycles.

cyclic proof pressure (CPP): the pressure that a window must withstand without cracking under intermittent pressurization in the form of 1000 standard pressure cycles (4 hr long pressure phase followed by 4 hr long relaxation phase) in design temperature environment. This Standard defines cyclic proof pressure as equal to design pressure.

cylindrical window: a window consisting of a tube with circular cross section *design qualification:* an experimental procedure for verifying the conformance of a nonstandard window design to mandatory structural requirements of this Standard

elastomer: a natural or synthetic material which is elastic or resilient and in general resembles rubber in its deformation under tensile or compressive stresses (i.e., at least 50% elastic compression and 70% elastic extension)

fabricator of windows: the party who fabricates finished acrylic windows from castings, marks them with identification, and provides fabrication certification

fpm: a rate of pressure change equivalent to 1 ft seawater/min (0.445 psi/min)

fsw: pressure equivalent to 1 ft seawater (0.445 psig/fsw)

full-scale window: a window, all of whose dimensions are identical to the window in actual service

helium service: any portion of a piping system which may contain gases containing helium shall be considered to be in helium service

inclusion: a foreign substance in the body of acrylic. An inclusion may take the form of a void, a grain of sand, a pebble, or chunk of plaster, or a piece of silicone rubber that flaked off from the mold.

inventory control identification: identification assigned to a single sheet or custom casting by the fabricator of windows when lot identification is not provided by the manufacturer of plastic

life-sensitive system: any system where an interruption of service represents a hazard to the health and well-being of the chamber occupants. All breathing gas systems are considered life-sensitive systems.

long-term proof pressure (LTPP): pressure that a window must withstand without catastrophic failure under sustained pressurization of 80,000 hr duration in design temperature ambient environment. This Standard defines long-term proof pressure as equal to design pressure.

lot identification: identification affixed by the manufacturer of plastic to all castings constituting a lot of material

lot of material: a unit of manufacture consisting of a single production run poured from the same mix of monometric material and made at the same time, undergoing identical processing from monomer to polymer

manufacturer of plastic: the party who converts methyl methacrylate resin into acrylic castings, and who provides Material Manufacturer's Certification for Acrylic (Appendix A, Enclosure 2), and may also provide Material Testing Certification for Acrylic (Appendix A, Enclosure 3)

marine system: a chamber or chamber system that is to be used in a marine environment. For the purposes of this Standard, all chambers and chamber systems that are not exclusively land-based are considered marine systems.

material testing laboratory: the party who tests material specimens cut from plastic casting and provides Material Testing Certification for Acrylic (Appendix A, Enclosure 3)

MA WP: maximum allowable working pressure

medical chamber: a chamber or chamber system that is intended for use as part of a clinical setting for administering hyperbaric oxygen therapy or other hyperbaric medical treatments

megapascal (MPa): the metric unit of pressure equal to 10 bar, or 145 psi

model-scale window: a window whose dimensions are all scaled down linearly from the window in actual service

nominal values: specified dimensions or angles for components of a chamber to which dimensional tolerances are subsequently applied on fabrication drawings

nonstandard window geometry: unproven window geometry that must be first experimentally qualified for the intended design pressure and temperatures

operational temperature range: the range of ambient temperatures to which the chamber can be subjected while pressurized

oxygen service: any portion of a piping system which may contain a gas containing over 25% by volume oxygen shall be considered to be in oxygen service

personal breathing equipment: breathing apparatus carried on the wearer's person such as SCUBA gear, umbilical supplied helmets, etc. For purposes of this Standard, the boundary between *PVHO piping systems* as defined in this Standard and excluded *personal breathing equipment* occurs at the normal disconnection point closest to the apparatus. For underwater breathing apparatus, that point will normally be the point where the umbilical connects to the breathing apparatus. For devices where the umbilical or supply hose is an integral part of the device (such as is often the case with medical masks), or is disposable, that point will normally be the point where the hose or hoses connect to the permanently installed parts of the PVHO piping system.

pipe ***and tube:*** The fundamental difference between pipe and tube is the dimensional standard to which each is manufactured. A pipe is a tube with a circular cross section conforming to the dimensional requirements for nominal pipe size as tabulated in ASME B36.10M, Table 2 and ASME B36.19M, Table 2. For special pipe having a diameter not listed in these tables, and also for round tube, the nominal diameter corresponds with the outside diameter. A tube is a hollow product of circular or any other cross section having a continuous periphery. Circular tube size may be specified with respect to any two, but not all three, of the following: outside diameter, inside diameter, wall thickness; types K, L, and M copper tube may also be specified by nominal size and type only. Dimensions and permissible variations (tolerances) are specified in the appropriate ASTM or ASME standard specifications.

piping: The term piping refers to all circular cross section conduit and is used generically to include both pipe and tube used for the transmission of fluids. The use of noncircular tubing for pressure piping within the scope of this Standard is not permitted.

piping system: the assembly of piping and components required to form a functional system

pressure control valve: a valve used to reduce or maintain the pressure in a piping system by admitting or releasing fluid pressure, as required, to maintain pressure at or near a designated setpoint. Other commonly used terms include ***pressure reducing valve, pressure regulator,*** and ***back pressure regulator.***

pressure testing laboratory: the party who pressure tests windows installed in viewport flanges and provides pressure testing certification

pressure vessel for human occupancy: a chamber that encloses a human being within its pressure boundary while it is under internal or external pressure, regardless of the pressure magnitude. Examples are submersibles, diving bells, personnel transfer capsules, decompression chambers, recompression chambers, hyperbaric chambers, high altitude chambers, and medical hyperbaric oxygenation facilities. This does not include nuclear reactor containments, pressurized airplane and aerospace vehicle cabins, and caissons.

saturation: any manned exposure to pressure in a chamber where the normally resultant decompression obligation exceeds 12 hr, any exposure which exceeds 12 hr and has a resultant decompression obligation, or any exposure to pressure in excess of 24 hr regardless of cause or pressure

scratch: a mark on the smooth surface of a window. Its origin may be a deep cut by machining tool, or contact with a sharp object during handling.

shall: Shall or ***shall not*** is used to indicate that a provision is mandatory.

sheet castings: sheets of plastic cast on a production line basis and carried as a standard production item in a manufacturer's sales catalog

short-term critical pressure (STCP): the pressure required to catastrophically fail a window at a 650 psi/min (4.5 MPa/min) pressurization rate in 70 to 77°F (21 to 25°C) ambient temperature environment

short-term proof pressure (STPP): the pressure that a window must withstand without catastrophic failure under short-term pressurization at 650 psi/min (4.5 MPa/min) rate in design temperature ambient environment. This Standard defines short-term proof pressure as equal to four times the design pressure.

should: Should or ***it is recommended*** is used to indicate that a provision is not mandatory but is recommended as good practice.

significant dimension: when the dimension of an inclusion or a scratch exceeds a specified value, and is considered as being present in the window for inspection purposes

soft goods: O-rings, gaskets, seals, and other elastomer components used in a piping system

standard temperature: the range of material temperatures from 70 to 75°F (21 to 24°C) at which all the dimensions in this Standard are specified

standard window geometry: proven window geometry that, because of its safe service record, has been incorporated in this Standard. Windows with standard geometries may be used in pressure vessels for human occupancy without having to undergo experimental design qualification.

supplier of windows: the party who supplies finished windows with all required certifications to the chamber manufacturer (original equipment) or user (replacement).

There is nothing in this Standard prohibiting the supplier from performing the functions of plastic manufacturer, material testing laboratory, window designer, window fabricator, and pressure testing laboratory, providing that these functions generate the required certifications.

tube: see pipe and tube

tube fitting, brazed: any tube or pipe fitting which is attached to the pipe or tube by means of a brazing process

tube fitting, compression: any tube fitting which grips the tube by means of one or more ferrules which compress or swage the end of the tube without creating a definite notch in the tube wall

tube fitting, flare: any tube fitting which grips the tube by means of a flare which is applied to the end of the tube by mechanical means

tube or pipe fitting, bite type: any tube fitting which grips the tube by means of one or more teeth which bite or dig into the outside diameter of the tube creating a definite notch

tube or pipe fitting, welded: any tube or pipe fitting which is attached to the tube or pipe by means of a welding process

viewport: a penetration in the pressure vessel including the window, flange, retaining rings, and seals

window: a transparent, impermeable, and pressure resistant insert in the viewport

APPENDIX E
OFF-GASSING TESTS FOR HOSES USED FOR BREATHING GAS SERVICE

(This Appendix is an integral part of ASME PVHO-1 and is placed after the main text for convenience.)

El BACKGROUND

Some compounds used in the manufacture of hoses can give off vapors that are toxic if inhaled. For hoses to be considered acceptable for breathing gas service, they must be able to pass the off-gassing test described herein.

E2 DEFINITIONS

hydrocarbons: for the purposes of this Appendix, all organic compounds detectable by a total hydrocarbon analyzer

methane equivalent: concentration of methane in air that will cause a total hydrocarbon analyzer to give an indication equivalent to that obtained from the gas being analyzed, at standard conditions

mg/m^3: milligrams per cubic meter, at standard conditions

standard conditions: 73.4°F (23°C) and 14.7 psia (760 mm mercury)

total hydrocarbon analyzer: any suitable process analyzer employing a hydrogen flame ionization detector (FID) having a range of from 0 to at least 1000 mg/m^3 methane equivalents

E3 PROCEDURE

E3.1

Off-gassing measurements shall be made only on hoses which have not been flushed with air, gas, or water, or which have been stored at a temperature not lower than 73°F (22.8°C) for a period of at least 7 days since the hoses were last flushed or opened to the atmosphere. During the 7 day storage period, the ends of the hoses shall either be sealed shut or fastened together so that the confined gas cannot escape. Both the total hydrocarbon analyzer and the hose or hoses to be tested shall be maintained at a temperature not lower than 73°F (22.8°C) throughout the testing period.

E3.2

By this procedure, measurements are made of the increase in the hydrocarbon concentration of a stream of air flowing through the test hose at a flow rate of 28 L per min (1 cu ft per min). The temperatures of the test hose, air supply, and analyzer shall not be less than 73°F (22.8°C). A diagram of the flow arrangement is shown in Fig. El. Before the air passes through the test hose, the air shall be clean and shall contain not more than 1 mg/m^3 of hydrocarbons (methane equivalents). The analyzer shall be zeroed with air passing at the stipulated flow rate and temperature through the connector tubes only. The test hose shall then be inserted in the line and the airstream passed through it. For the ensuing 15 min, readings of the hydrocarbon concentration shall be recorded frequently, if not continuously. The test hose shall be rated on the reading at the end of the 15 min test period. Hoses which contaminate the air by greater amounts than specified in Table El shall not be acceptable.

E4 REFERENCES

Military Specijcation MIL-H-2815 (SHIPS), "Hose Assemblies, Rubber, Diver's Breathing Air and Gas Supply," June 2, 1978.

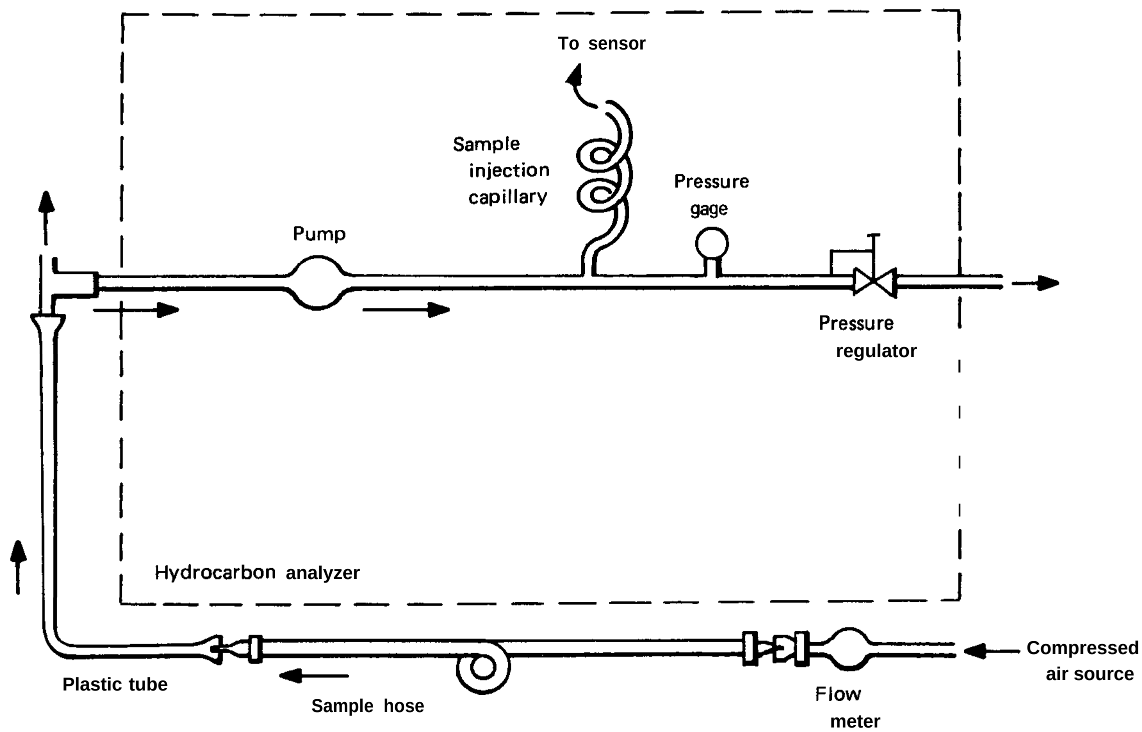


FIG. El FLOW DIAGRAM OF APPARATUS FOR MEASURING THE CONCENTRATION OF HYDROCARBONS IN A STREAM OF AIR OR OTHER GAS AFTER IT HAS PASSED THROUGH A TEST HOSE

TABLE El
MAXIMUM ALLOWABLE CONCENTRATION OF HYDROCARBONS IN AIR PASSING THROUGH HOSE

Hose Length, ft	Hydrocarbon Concentration as Methane Equivalents, mg/m^3
3	4
100	100

NONMANDATORY APPENDICES

APPENDIX I
DESIGN OF SUPPORTS AND LIFTING ATTACHMENTS

(This Appendix is not part of ASME PVHO-1 and is included for information only.)

The designer should consider using the provisions of the following studies, which appear in ***Pressure Vessels and Piping: Design and Analysis, Volume Two - Components and Structural Dynamics,*** The American Society of Mechanical Engineers, New York, 1972.

(a) "Local Stresses in Spherical and Cylindrical Shells Due to External Loadings," K. R. Whichman, A. G. Hooper, and J. L. Mershon, reprinted from Welding Research Council Bulletin 107, 1968.

(b) "Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports," L. P. Zick, reprinted from Welding Journal Research Supplement, 1971.

The use of these provisions shall not negate Code requirements.

APPENDIX II
GUIDELINES FOR APPLICATION OF THE REQUIREMENTS OF SECTION 2 TO ACRYLIC WINDOWS

(This Appendix is not part of ASME PVHO-1 and is included for information only.)

II-1 INTRODUCTION

(a) Section 2 presents the necessary information to design, fabricate, and pressure test acrylic windows which, when mounted and sealed in metallic seats, form the viewport assemblies acceptable as pressure resistant barriers in pressure vessels for human occupancy.

(b) Severe restrictions are imposed on the service conditions to which the viewport can be subjected to preclude catastrophic failure of the window during its rated life (see para. 2-1.4). In order for the window to meet the high standard of safety demanded by human occupancy of the pressure vessel, each step in the production of the windows must be certified for conformance to this Standard (see para. 2-1.7).

(c) Only high quality cast acrylic (polymethyl methacrylate) is acceptable as the material for fabrication of windows under this Standard. To preclude unintentional substitution during fabrication process of lesser quality acrylic, the conformance of the material to the specifications of this Standard must be proven by testing of material coupons (see Section 2, Article 3) and certified (Appendix A, Enclosures 2 and 3).

II-2 SAMPLE DESIGN PROCEDURE

(a) The design of windows according to this Standard follows a simplified procedure developed for the engineer with little knowledge of acrylic window technology. The design procedure consists of a series of steps which rapidly allow the engineer to design a window meeting the requirements of this Standard (see Section 2, Article 2).

Step 1. Determine the design pressure *P* and temperature of the pressure vessel. Use the values as maximum design allowables for windows.

Step 2. Select the desired window shape from available standard window geometries (Figs. 2-2.1 through 2-2.4). Note the restrictions on the service in which they can be placed (see paras. *2-2.2* and 2-2.3).

If the design requirements cannot be met by a standard window geometry, a nonstandard window geometry of your own design may be chosen. In that case, disregard the remainder of design steps in (a), (b), and (c) and follow instead the procedures specified in para. 2-2.6.

Step 3. Select the conversion factor (CF) appropriate for the chosen standard window geometry, pressure range, and temperature range (Tables 2-2.1 through 2-2.4). Utilize the pressure range into which the design pressure falls. The CF given by the table represents the lowest value acceptable to this Standard. Wherever feasible, select a higher value than shown in the tables.

Step 4. Calculate the short-term critical pressure (STCP) of the window by multiplying the design pressure *P* by the CF selected in Step 3.

Step 5. Calculate the dimensionless ratio(s) t/D, or t/R for the chosen window geometry by finding the appropriate graph which relates the short-term critical pressure to the window's dimensionless ratio (Figs. 2-2.5 through 2-2.16). Draw a horizontal line from the appropriate STCP on the ordinate to the graph and from where it intersects the graph drop a vertical line to the abscissa. The intersection with the abscissa provides the sought-after dimensionless ratio. For design pressures *P* above 10,000 psi (69 MPa), use Table 2-2.6 to derive the required dimensional ratios. This table applies only to conical frustum windows with an included conical angle $\alpha \geq 60$ deg.

Step 6. Calculate the nominal window's dimensions on the basis of the dimensionless ratio. Wherever it is feasible, increase the nominal thickness to provide extra stock for future operational contingencies.

Step 7. Apply angular and dimensional tolerances to the nominal dimensions and specify surface finishes on the window (see para. 2-2.12). Enter all applicable data on drawing and Appendix A, Enclosure I.

(b) The windows can achieve the predicted short-term critical pressures only if they are mounted in seats with appropriate cavity dimensions, stiffness, and surface finishes (see paras. 2-2.7, 2-2.10, and 2-2.12).

Step 1 Calculate the seat cavity dimensions on the basis of Figs. 2-2.20 through 2-2.27. For windows with conical bearing surfaces, the magnitude of seat cavity surface overhang depends on both the included conical angle and the operational pressure range. The magnitude of overhang is given in terms of D_i/D_f ratios for any given combination of operational pressure ranges and conical angles. Operational pressure ranges 1, 2, 3, and 4 correspond to O-2500, 2500-5000, 5000-7500, and 7500–10,000 psi. For operational pressures above 10,000 psi (69 MPa), utilize Table 2-2.6.

Step 2. Calculate the stiffness compliance of the window seat with analytical formulas or finite element stress analysis computer programs to meet the requirements of para. 2-2.9. Since the window mounting forms a reinforcement around the penetration in the pressure vessel, its cross section must also meet the requirements of the applicable Division of Section VIII of the Code.

Step 3. Apply angular and dimensional tolerances to the nominal dimensions and specify surface finishes on the seat cavity (see paras. 2-2.10 and 2-2.12). Enter all applicable data on the window seat drawing.

(c) Only certain sealing arrangements have been found to be successful with acrylic windows serving as pressure boundaries (see para. 2-2.1 I).

Step 1. Some of the proven seal designs acceptable under this Standard are shown on Figs. 2-2.5 through 2-2.10, 2-2.16, 2-2.21, and 2-2.24 through 2-2.27. Select the most appropriate sealing arrangement for your operational conditions. The bevels on the edges of windows cannot exceed the limits shown on Figs. 2-2.28 and 2-2.29.

Step 2. Seal designs that deviate from the requirements of this Standard must be subjected to an experimental validation program which will define their effect on the service life of the windows (see para. 2-2.7).

II-3 SAMPLE PURCHASE SPECIFICATION AND PRODUCT REVIEW

The designed window, in order to achieve the short-term critical pressure, must be fabricated by an accredited window fabricator utilizing materials and a production process that meet the requirements of Section 2, Articles 3 and 4, respectively.

Step 1. Request for quotation and all drawings should carry the following note.

"The cast acrylic, fabrication procedure, Quality Assurance Program, and finished window shall meet all the requirements of ASME PVHO-I."

This note alerts the fabricators to the additional factors imposed by certification requirements of this Standard.

Step 2. Provide the successful bidder with Acrylic Window Design Certification, Enclosure I (Appendix A), filled out by the window designer. Enclosure 1, together with the window drawing, will form the basis for future identification of the window.

Step 3. Upon receiving the window from the window fabricator, inspect the finished product dimensionally and visually for compliance to this Standard (see para. 2-2. 12 and Section 2, Article 4). Review all of the paperwork which must accompany the window (Form PVHO-2 and Appendix A, Enclosures I, 2, and 3). Check for completeness and signatures. Compare the marking on the window bearing surface with: (a) the identification number on the Fabrication Data Report Form PVHO-2; and (b) the design temperature and pressure on the Acrylic Window Design Certification, Enclosure I. Only when the window complies with the requirements imposed by this Standard, and the accompanying Window Certification, Form PVHO-2, and Enclosures I, 2, and 3 are complete, can the fabricator be considered to have met all of the contractual obligations imposed by the above note on the window drawing.

II-4 SAMPLE PRESSURE TEST INSTRUCTION

The window can now be installed into the new pressure chamber or pressure tested in a test fixture and placed in storage for future use as a replacement. If the window is tested in a new chamber (see Section 2, Article 7, for details of pressure testing), the test must be conducted without human occupants.

Step 1. Immediately after the pressure test, inspect the window visually for the presence of crazing, cracks, fractures, or permanent deformation.

Step 2. If the window passed the post-pressure test inspection successfully, fill out the Pressure Testing Certification, Enclosure 4.

Step 3. Review certifications, Enclosures 1 through 4, for completeness.

II-5 SAMPLE CALCULATIONS

Sample calculations of hypothetical window and window seat dimensions are presented here to illustrate the design procedure.

Step 1.1 Determine design conditions:
Design pressure = 1000 psi
Design temperature = 125°F
Window diameter = IO in.

Step 1.2 Select window shape:
Conical frustum with 90 deg. included angle (Fig. 2-2.1)

Step 1.3 Select conversion factor:
CF = IO N = 1
(Table 2-2.2)

Step 1.4 Calculate short-term critical pressure:
STCP = CF x P = 10 x 1000
= 10,000 psi
STCP = 10,000 psi/l45 psi/MPa
= 68.96 MPa

Step 1.5 Calculate the dimensionless ratio for windows:
t/D_i = 0.41 for STCP = 68.96 MPa
α = 90 deg. (Fig. 2-2.8)

Step 1.6 Calculate nominal window dimensions:
t/D_i = 0.41 D_i = IO in.
α = 90 deg.
t = 0.41 x IO in. = 4.1 in.
Add 0.1 in. to thickness for future operational contingencies:
Nominal angle = 90 deg.
Nominal D_i = IO in.
Nominal t = 4.2 in.
Nominal D_o = 18.4 in.

Step 1.7 Apply dimensional tolerances to windows:
D_o = 18.400 +O.OOO/-0.020 in. (to sharp edge)
t = 4.200 +0.020/−0.000 in.
α = 90 +0.25/−0.00 deg.
Bearing surface finish = 32 rms

Step 2.1 Calculate nominal dimensions for seat cavity:
D_o = 18.400 in. α = 90 deg.
D_i/D_f = 1.03 for pressure range NI and included angle 90 deg.
D_f = 10.000/1.03 = 9.709 in. (Fig. 2-2.2 I)

Step 2.2 Calculate cross section of window mounting. (Use procedure of your own choice; NSRDC Report 1737 "Structural Design of Viewing Ports for Oceanographic Vehicles," by J. A. Nott, 1963, can be very helpful.)

Step 2.3 Apply dimensional tolerances to window seat:
D_f = 9.704 +O.OlO/-0.000 in.
α = 90 +0.00/-0.25 deg.
D_o = 18.400 +0.20/−0.000 in.

Step 3.1 Select sealing arrangement: neoprene O-ring seal compressed against beveled edge of major window diameter by a flat retaining ring (Fig. 2-2.7). The magnitude of the bevel cannot exceed the limits shown in Fig. 2-2.28. The size of the bevel chosen will provide adequate compression to a nominal 0.25 in. diameter O-ring.

Step 3.2 Enter following dimensions on drawing.
Final Viewport Dimensions
Window:
D_o = 18.400 +O.OO/-0.020 in. (to sharp edge)
D_o = 17.800 +O.OO/-0.020 in. (to beveled edge)
t = 4.200 +0.020/−0.00 in.
α = 90 +0.25/−0.000 deg.
Seal:
O-ring thickness = ¼ in. (nominal)
O-ring inside diameter = 17.75 in. (nominal)
Seat:
D_o = 18.400 +0.020/−0.000 in.
D_f = 9.709 +0.0l0/-0.000 in.
α = 90 +0.000/-0.25 deg.

APPENDIX III
RECOMMENDATIONS FOR THE DESIGN OF THROUGH-PRESSURE BOUNDARY PENETRATIONS

(This Appendix is not part of ASME PVHO-1 and is included for information only.)

III-1 GENERAL

This Appendix provides several basic designs of through-pressure boundary piping penetration designs that have been found to give good service. Acceptable designs of through-pressure boundary piping systems are not necessarily limited to the designs shown. All pressure boundary penetrations must meet the reinforcement and weld detail requirements of ASME PVHO-1 and ASME Code Section VIII, Division 1 or 2, as appropriate.

III-2 PENETRATOR DESIGNS

Figure III-2.1 shows four basic penetrator designs intended principally for services as follows:

(a) full coupling intended for standard threaded pipe couplings or a special coupling dictated by the Design Specification. For most applications, a standard 6000 psi NPT coupling is acceptable in 316 or 316L stainless steel.

(b) half coupling, full penetration weld installation. This is generally used for pressure equalization in supply locks and transfer tunnels and can also be used for pressure gage penetrators.

(c) special forging. This category is intended for fully radiographable penetrators, generally to comply to Section VIII, Division 2, of the Code.

(d) flush mount coupling. This category is generally a 6000 psi or special forging type coupling. This configuration is used where a full coupling with internal and external threads is required, or where there are chamber drains, supply lock and tunnel equalizations, or in other applications where a flush internal mount is required.

III-3 COUPLING DETAILS

Figure 111-3.1 shows four acceptable coupling details.

III-3.1 Threaded Couplings

(a) NPT (National Pipe Thread) 6000 psi Coupling. For marine systems the coupling material should be a stainless steel per para. 111-4. The heavy wall of the 6000 psi coupling normally permits at least one field rethreading should the original threads be damaged.

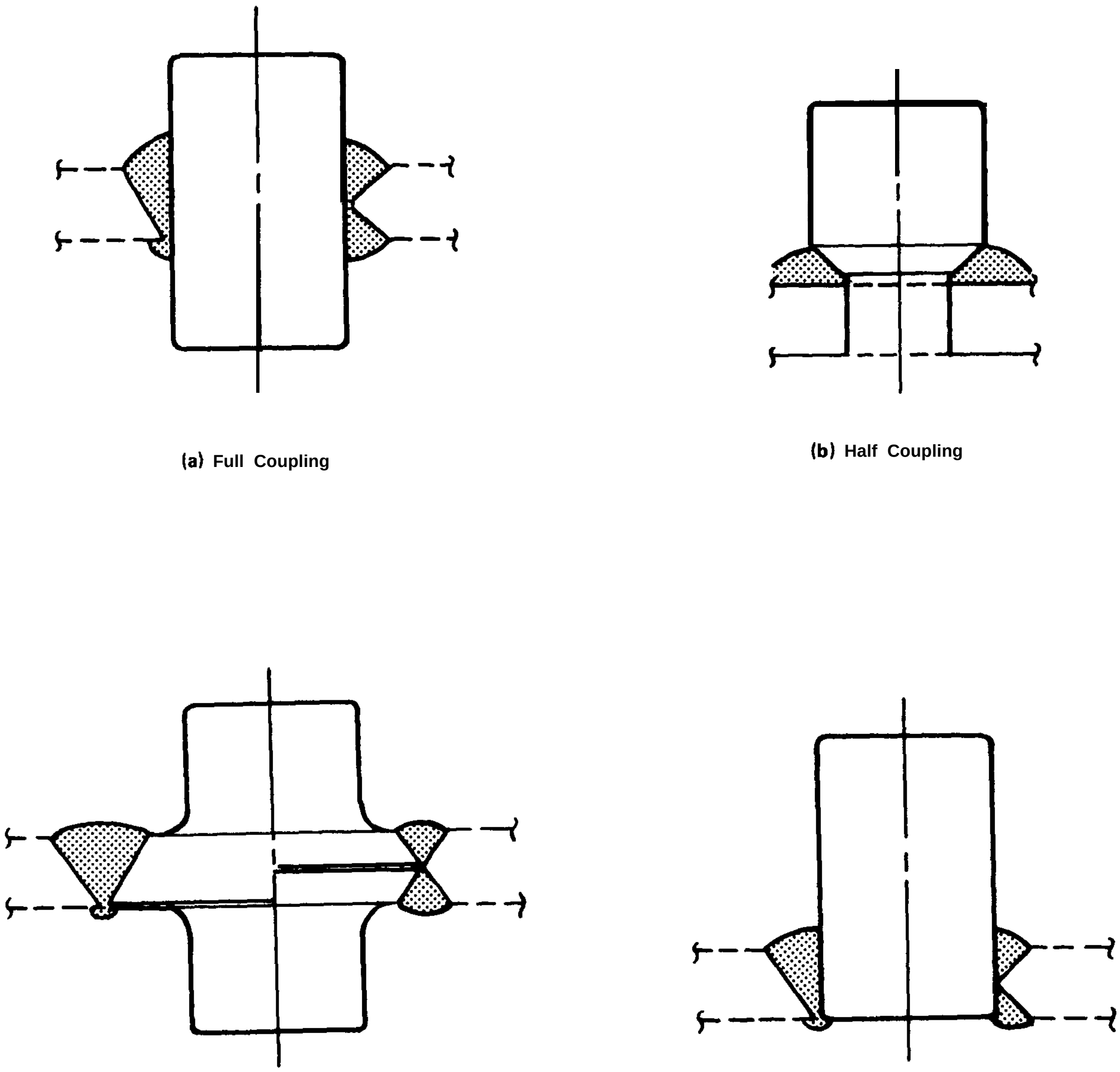
(b) Special Coupling With an SAE or MS (Military Standard) Straight Thread O-Ring Boss. This design is recommended over pipe threads when the contained fluid may be helium.

III-3.2 Threaded Insert Couplings

These are generally smooth bore couplings with threaded, flanged inserts with either pipe threads or straight thread O-ring seals. This installation can be sealed and secured with a fillet weld or assembled with a flat washer and locking nut with O-ring seals as shown. The latter installation is preferred but its cost often makes it impractical.

III-4 MATERIALS

Practical experience has shown that unthreaded (i.e., smooth bore) couplings in marine systems may be any Code-approved forged steel while threaded couplings and inserts should be of approved stainless steel (316 or 316L), brass, or bronze. Corrosion resistant alloys are strongly recommended to eliminate cleaning, maintenance, and material compatibility problems. Threaded couplings and inserts in land-based chambers may be of any Code-approved material.



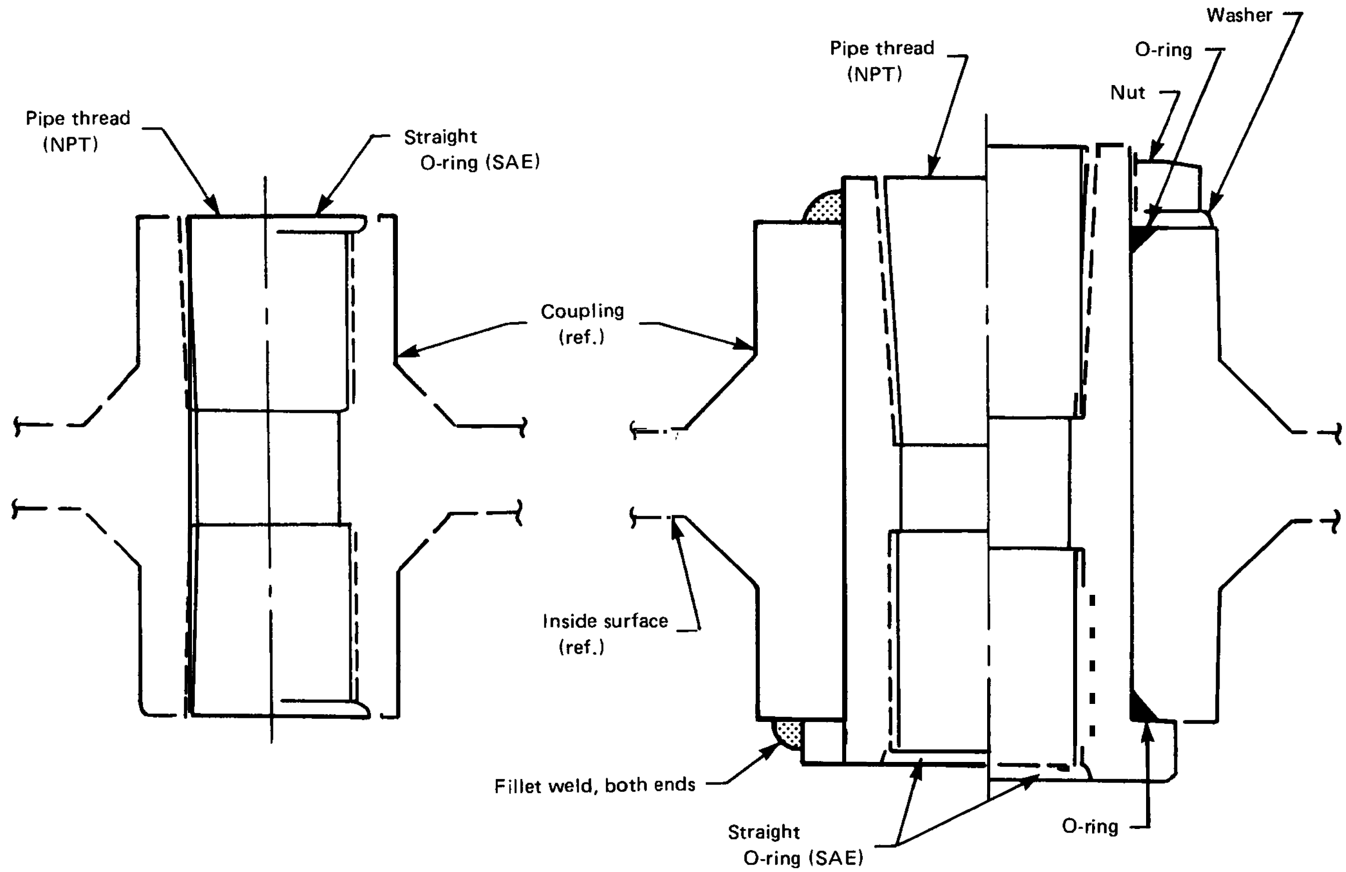
(a) Full Coupling

(b) Half Coupling

(cl Special Forging

(d) Flush Mount Coupling

FIG. M-2.1 ACCEPTABLE WELD NOZZLE PENETRATORS (2 in. Pipe and Under)



(a) Threaded Couplings

(b) Threaded Insert Couplings

FIG. III-3.1 ACCEPTABLE THREADS AND INSERTS

APPENDIX IV
RECOMMENDED PRACTICES FOR COLOR CODING AND LABELING

(This Appendix is not part of ASME PVHO-1 and is included for information only.)

All piping and gas storage bottles should be colored and labeled to indicate content, maximum allowable working pressure, and direction of flow. Except for certain pipe materials such as stainless steel, the color should be a continuous coat of paint. For stainless steel and similar corrosion resistant materials, color coding may be a I in. band of paint or tape. Bands should be applied at every bend and intersection, and at each side of obstructions. To aid in tracing the pipe, a minimum of three bands should be visible at any location. In addition to color coding, piping should be labeled with the name and/or symbol of its contents, direction of flow, and maximum allowable working pressure. This labeling should be applied at every intersection and at each side of obstructions. For labeling, a color which contrasts with that of the pipe should be used. Tables IV-I and IV-2 give the color codes required by the U.S. Navy and International Maritime Organization (IMO). Other color codes may also be used.

TABLE IV-I
U.S. NAVY

Name	Designation	Color
Oxygen	O_2	Green
Nitrogen	N	Light Gray
Air (Low Pressure)	ALP	Black
Air (High Pressure)	AHP	Black
Helium	He	Buff
Helium-Oxygen Mix	$He–O_2$	Buff and Green

GENERAL NOTE: Taken from *U.S. Navy Diving Manual NAVSHIPS 0994-001-9010.*

TABLE IV-2
IMO

Name	Symbol	Color
Oxygen	O_2	White
Nitrogen	N_2	Black
Air	Air	White and Black
Carbon Dioxide	CO_2	Gray
Helium	He	Brown
Oxygen-Helium Mix	$O_2–He$	White and Brown

GENERAL NOTE: Taken from *IMO Resolution A536,* "Code of Safety for Diving Systems."

ASME PVHO-1 CASES

(These Cases are not part of ASME PVHO-1 and are included for information only.)

The Pressure Vessels for Human Occupancy Committee meets regularly to consider proposed additions and revisions to the Standard and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing rules in the Standard. Those Cases which have been adopted will appear in the next issued Addenda and will be sent automatically to the purchasers of the Standard up to the publication of the 2000 edition.

A Case is the prescribed form of reply to an inquiry when study indicates that wording in the Standard needs clarification or when the reply modifies existing requirements of the Standard or grants permission to use new materials or alternative constructions. Proposed Cases are published in *Mechanical Engineering* for public review. In addition, the Case will be published as part of the subscription service to PVHO-1.

A Case is normally issued for a limited period, after which it may be reaffirmed, incorporated into the Standard, revised, or allowed to expire if there is no indication of further need for the requirements covered by the Case. However, the provisions of a Case may be used after its expiration or withdrawal, provided the Case was effective on the original contract date or was adopted before completion of the work, and the contracting parties agree to its use.

Requests for interpretation and suggestions for revision should be addressed to the Secretary, ASME PVHO Committee, The American Society of Mechanical Engineers, Mail Stop 10C, 345 East 47th Street, New York, NY 10017.

PVHO Case 2-1
Annealing Requirements for PVHO Acrylic Windows Under 1 in. Nominal Thickness

Approval Date: May 15, 1992
Expiration Date: May 15, 1995

This Case has been allowed to expire.

PVHO Case 3
Annealing of Windows After Initial Machining

Approval Date: July 3, 1991
Expiration Date: July 3, 1994

This Case has been allowed to expire.

PVHO Case 4
Increased Cyclic Life for Windows

Approval Date: July 30, 1992
Expiration Date: July 30, 1998

Inquiry: As an alternative to the provisions of para. 2-1.3(d) of PVHO-1, is it possible to increase the number of design pressure cycles for windows in excess of that stated in PVHO-I?

Reply: It is the opinion of the Committee that for standard geometry PVHO viewports having a design pressure of less than 2000 psi, other than hyperhemispherical and NEMO types, the number of design pressure cycles can be increased in excess of that stated in PVHO- I through experimental pressure testing procedures provided the following procedures and requirements are met:

(a) For each window design, at least one window of identical shape, dimensions, and design pressure–temperature rating shall be pressure cycled from zero (0) to design pressure to determine whether its cyclic fatigue life exceeds the 10,000 cycle limit stated in PVHO-I. The pressure tests shall take place with the window installed in a test fixture whose window seat dimensions, retaining ring, and seals are identical to those of the PVHO chamber.

(b) The window shall be pressurized with gas or water. The design pressure shall be maintained for a minimum of 15 min or 1.5 times the time it takes for creep to stabilize, whichever is greater, followed by depressurization which is to be maintained for a minimum of 10 min or 1.5 times the time it takes for creep to stabilize, whichever is greater. The pressurization and depressurization rates are not to exceed 650 psi/min (4.5 MPa/min).

(c) The temperature of the pressurizing medium during the test shall be the design temperature for which the window is rated with a tolerance of +O/-5°F (+0/ −2.6°C). Brief deviations from the above temperature tolerances are allowed, provided that the deviations do not exceed ± 10°F (5.5°C) and last less than IO min within each 24 hours of continuous testing.

(d) If leaks develop during pressure cycling, the window shall be removed and pertinent information (cycle count, cause, extent of damage, etc.) recorded. If no damage was noted to the window, new seals may be installed. The number of cycles credited to the window shall be those recorded at the last visual inspection prior to seal failure. After the new seal is installed, two pressure cycles (without leaks) shall be performed without credit to assure proper seating, temperature stabilization, and creep normalization. If the new seal performs satisfactorily, the numbering of test cycles shall continue from the number recorded at

the last visual inspection prior to seal failure, minus the above two cycles.

(e) At scheduled intervals during the pressure test, the windows shall be visually inspected for the presence of crazing, cracks, or permanent deformation. This examination may be performed without removal of the window from the chamber or test fixture.

(f) Presence of crazing, cracks, or excessive permanent deformation visible with the unaided eye (except for correction necessary to achieve 20/20 vision) shall be considered failure of the windows and shall be so noted on the test report. Permanent deformation more than 0.001 *D,* in magnitude measured at the center of the window shall be considered excessive, and shall be cause for rejection. The number of credited test cycles shall not exceed the number of cycles achieved during the previous successful inspection.

(g) Pressure test reports shall certify the results of the pressure test. Copies of the pressure test reports shall be furnished to the purchaser.

(h) For windows having a design pressure life of 10,000 cycles, an extension of one (1) cycle may be granted by the Standard for each two (2) test cycles after completion of the first 10,000 cycles, up to failure of the test window.

(i) This Case number (PVHO Case 4), along with the maximum number of design pressure cycles, shall be shown on the Window Certifications.

PVHO Case 5
Alternative Rules to the Provisions of Paras. 1.2.3, 2-6.2, 2-6.3, 3-3.1, and 3-3.9, Requirements for the Purchase of Acrylic Windows

Approval Date: June 14, 1993
Expiration Date: November 20, 1996

Inquiry: What alternative provisions to paras. 1.2.3, 2-6.2, 2-6.3, 3-3. I, 3-3.9, and Form PVHO-2 may a PVHO-I manufacturer or owner/user use to purchase acrylic windows from an organization not holding an ASME Certificate of Authorization and PVHO seal?

Reply: It is the opinion of the Committee that as an alternative to the requirements of paras. 1.2.3, 2-6.2, 2-6.3, 3-3. I, 3-3.9, and Form PVHO-2, the PVHO manufacturer or owner/user may purchase acrylic windows from window fabricators not holding an ASME Certificate of Authorization for use of the PVHO symbol provided the following provisions have been met.

(a) The PVHO manufacturer or owner/user shall be responsible for evaluation and qualification of the window fabricator's quality assurance program to assure that quality control programs are established and implemented in accordance with Section 3, Article 4 of PVHO-1. On-site window fabricator evaluation is required prior to procurement of windows. All window fabricator activities shall be audited at least annually.

(b) The window fabricator shall certify that all requirements for production of windows have been met, with the exception of holding an ASME Certificate of Authorization for the use of the PVHO symbol.

(c) Use of this Case shall be indicated on the window certification records, chamber report data, and Form PVHO Case 5, Fabrication Certification for Acrylic Windows.

FORM PVHO CASE 5 FABRICATION CERTIFICATION FOR ACRYLIC WINDOWS

Window Drawing No. ____________________

Window Identification ____________________

Material Stock Descriptions

Manufacturer of acrylic ____________________

Trade name ____________________

Casting shape ____________________

Nominal thickness ____________________

Lot number ____________________

Casting number ____________________

Certified for conformance to Table 2-3.1 by ____________________

Date ____________________

Certified for conformance to Table 2-3.2 by ____________________

Date ____________________

Window Description

Maximum allowable working pressure rating __________ psi __________ MPa

Maximum temperature rating __________ “F __________ “C

Window designed by ____________________
(Name of Company and Designer)

Joint bonding (if applicable)

Manufacturer of acrylic cement ____________________

Trade name of cement ____________________

Curing means and duration ____________________

Average tensile strength ____________________

Joint quality conforms to para. 2-3.10 (yes/no) ____________________

Polishing agents ____________________

Cleaning agent ____________________

Fabrication Process Data

First annealing temperature ____________________

Duration ____________________

Cooling rate (chart required) ____________________

Intermediate annealing temperature (if any) ____________________

Duration ____________________

Cooling rate (chart required) ____________________

Final annealing temperature ____________________

Duration ____________________

Cooling rate (chart required) ____________________

Dimensional checks

Actual outside diameter D_o ____________________

Actual inside diameter D_i ____________________

Actual thickness t_{max} and t_{min} ____________________

Actual included angle α ____________________

Actual sphericity (maximum deviation from specified sphericity measured by a template on the concave or convex surface) ____________________

Conforms/deviates from specification for spot casting repairs ____________________

The window identified above has been fabricated in accordance with the material and fabrication requirements of the Safety Standard for Pressure Vessels for Human Occupancy, ASME PVHO-1–----Edition, Addenda________, PVHO Case Enclosure 1 of Appendix A, and company____________________drawing number-:'revision-.-.-+ dated__________

____________________ ____________________

Authorized representative of window fabricator Date

____

Name and address of window fabricator

____

Name and address of window purchaser (vessel manufacturer or owner/user)

____

QA Program audited and accepted as in compliance by purchaser (vessel manufacturer, owner/user, or their designated agent) Date of last audit

PVHO Case 6
Use of Nonmetallic Vessels Under PVHO

Approval Date: September 11, 1993
Expiration Date: September 11, 1999

Inquiry: Under what conditions may nonmetallic flexible chambers be used in construction under the rules of PVHO-I?

Reply: It is the opinion of the Committee that portable nonmetallic flexible chambers may be constructed under the requirements of PVHO-I, and be marked only as a PVHO vessel for emergency use when the requirements of PVHO- I, with the following exceptions, have been met.

1 GENERAL

(a) The rated pressure is not greater than 31 psig.
(b) The maximum inside diameter is 24 in.
(c) The maximum length is 96 in.
(d) The vessel is a cylindrical vessel with removable end closures (windows).
(e) The rated life of filament-wound vessels shall be IO years from the date of manufacture.
(f) The design temperature is between 0°F and 100°F.
(g) The maximum number of occupants is one.

2 MATERIALS

Materials shall meet PVHO- l, para. 1.3, PVHO Materials, with the exception of the cylindrical shell which shall conform to Table I.

All materials used in the manufacture of the cylindrical shell shall be supplied with documentation certifying that each lot used in the manufacture of the PVHO meets those properties listed in Table l. Shelf life of materials shall be identified.

3 DESIGN AND MANUFACTURE

3.1 Design

The PVHO shall be designed in accordance with para. 1.2, General, of PVHO-I with the exception of paras. l.2.l, l.2.2, and 1.2.3.

3.2 Requirements

In para. l .4 of PVHO- l, Design and Fabrication of PVHOs, the design and manufacture of the PVHO shall only be in accordance with paras. I .4.2, l.4.5(a), I .4.7, and 1.4.8 of PVHO-I, and the following requirements.

(a) A detailed stress analysis shall be performed by a Professional Engineer registered in one or more of the states of the United States of America, or the provinces of Canada, and experienced in composite pressure vessel design and construction.

(b) The stress analysis shall include full geometric modeling and a detailed finite element analysis of the PVHO and the cylindrical shell-to-window interface during assembly, disassembly, and under varying pressures up to a minimum of five times the rated pressure.

(c) The design analysis shall consider the effects of aging of the shell materials plus the effects of folding, unfolding, and long-term storage of the cylindrical shell. The design shall ensure that no damage will occur to the fibers within the cylindrical shell by acute bending or by bending at less than the minimum bend radius of the fiber. ***Acute bending*** is defined as a bend in the cylindrical shell at an inside angle of less than 5 deg. The minimum bend radius for the fiber shall be no less than 0.05 in.

(d) The cylindrical shell of the PVHO shall be manufactured using a filament winding method. The cylindrical shell shall be wound as an integral unit without seams. The end closures shall have internal reinforced flanges as an integral part of the shell. The reinforced flange shall act as the closure-retaining ring and sealing surface for the closure (window). There shall be no penetrations in the cylindrical shell of the PVHO.

(e) The cylindrical shell shall be manufactured in three stages, each of which shall require curing after completion.

(I) The inner layer shall comprise an airtight skin of 100% room temperature vulcanizing (RTV) silicone rubber applied directly onto a suitably prepared collapsible mandrel.

(2) The middle layer shall comprise several windings of continuous uncut polyparaphenylene terephthalamide (para-aramid) fiber that has been treated with a 100% RTV silicone liquid elastomer. The winding

TABLE 1

Room Temperature Vulcanizing (RTV) Silicone Rubber (Cured)
Inner and Outer Gel Coat
Chemical Name: Vinylpolydimethylsiloxane

Test Procedure	Physical Properties	Min.	Max.
ASTM D 2240	Hardness Shore A durometer	55	65
ASTM D 412	Extension at break, %	200	.
ASTM D 412	Tear strength, psi	700	.

RTV Silicone Liquid Elastomer (Cured)
Main Wind
Chemical Name: Vinylpolydimethylsiloxane and Calcium Carbonate

Test Procedure	Physical Properties	Min.	Max.
ASTM D 2240	Hardness Shore A durometer	32	45
ASTM D 412	Extension at break, %	130	...
ASTM D 412	Tear strength, psi	100	..

Main Wind
Continuous Polyparaphenylene Terephthalamide Fiber

Test Procedure	Physical Properties	Min.	Max.
ASTM D 2343	Tensile strength, ksi	450	580
ASTM D 2343	Strength (breaking), lb	380	490
ASTM D 2343	Tensile modulus, psi x 10^6	17.5	20.5
ASTM D 1907 [Note (1)]	Denier (ASTM Option 5)	6675	7425
ASTM D 2257 [Note (2)]	Finish on yarn (DI-7), %	0.0	1.2
ASTM D 1505	Density, g/cc	1.4	1.5

NOTES:
(1) Zero twist, zero moisture, finish free.
(2) Using IR spectrophotometer, substitute ASTM method is Sozhlet extraction.

process shall ensure that the fiber is completely coated with the elastomer and that there are no areas of unbonded fiber within the cylindrical shell.

(3) The outer layer shall comprise 100% RTV silicone rubber.

(f) The design and manufacturing process shall produce a cylindrical shell such that the inner layer, outer layer, and the para-aramid fibers will not be damaged by the assembly, pressurization, disassembly, or storage of the PVHO.

(g) The rated pressure shall be based on a minimum ratio of burst pressure to rated pressure of 5: 1.

(h) The windows shall meet the requirements of PVHO-I, Section 2, Viewports, with the exception of para. 2-2.9, Viewport Flanges. The design of the viewport flange shall be conducted as a part of the stress analysis requirement of para. 3.2(b) of this Case.

(i) The windows shall be fitted with an endless nylon bead ring secured to the windows with a retainer rigidly attached to the bead ring and sealed with an "0" ring. The bead ring shall seal against the reinforced integral flange of the cylindrical shell.

(j) In lieu of the requirements of para. 4-7.6.1, Breathing Gas Outlets, the number of breathing gas outlets shall be one.

(k) Any changes to the design or manufacturing procedures of the cylindrical shell shall be cause for full prototype retesting.

3.3 Design Certification

Conformance of the design of the PVHO to the requirements of PVHO-1 shall be established by one of the two following procedures.

(a) A Professional Engineer registered in one or more of the states of the United States of America, or the provinces of Canada, and experienced in composite pressure vessel design shall certify that the PVHO was designed either by him or under his direct supervision, or that he has thoroughly reviewed a design prepared by others, and that to the best of his knowledge, the PVHO complies with PVHO-I and this Case.

(b) The design of the PVHO shall be reviewed by an independent third party agency competent in PVHO systems, and such organization shall provide a certificate that the PVHO complies with PVHO-I and this Case.

4 TESTING

All tests shall be witnessed by the purchaser/owner/user and/or by an independent third party agency designated by them. In lieu of the requirements of PVHO-I, para. 1.5, Inspection and Tests of PVHOs, the following requirements shall apply.

4.1 Prototype Testing

(a) A hydrostatic test to failure shall be performed on at least one completely assembled PVHO of the same design, shape, and form. Failure of the vessel under hydrostatic test shall occur at a pressure equal to or greater than five times the rated pressure. Failure shall only be by leakage caused by a breakdown of the RTV liquid elastomer in the cylindrical shell. Failure of the acrylic window, the nylon bead ring, the window insert, or the release of a window through the reinforced flange of the cylindrical shell shall be cause for failure of the prototype design.

(b) A drop test of at least one PVHO on concrete shall be conducted without failure. The PVHO shall be fitted with windows and loaded with 165 pounds of bagged sand and then pressurized to the rated pressure. The PVHO shall be inclined at 45 deg. and elevated to a height such that the minimum distance to the concrete impact surface is 3 ft, and then dropped. No leakage, damage, or permanent distortion of the PVHO is permissible.

(c) A cyclic hydrostatic pressure test of at least one completely assembled PVHO shall be conducted for a minimum of 4,000 cycles. The test shall comprise pressurization from zero to rated pressure and back to zero. The cycling time shall be between 10 and 100 sec per cycle. A I psi residual pressure is permissible to retain the windows in position. In order to establish the maximum number of cycles satisfactorily completed on the chamber under test, the pressure retention properties of the vessel shall be checked at agreed cyclic levels for leakage. At these levels, the PVHO shall be subjected to satisfactory completion of testing as in para. 4.2 of this Case, Production Testing. Should leakage occur during cyclic testing or at a cyclic level, then the maximum number of cycles achieved at the previous cyclic level shall be the cyclic limit for the chamber.

(d) A cold storage test demonstrating that the chamber can be assembled and inflated at minimum operating temperature shall be conducted.

(e) Cylindrical shells and windows used for prototype testing in (a), (b), and (c) above shall not be used in a production PVHO.

(f) Production chambers of this design, shape, and form may then be used for up to 25% of the number of cycles completed on the prototype PVHO.

4.2 Production Testing

(a) Every completely assembled PVHO shall be subjected to a hydrostatic test at a pressure of 1.5 times the rated pressure and held for a period of I hr without leakage.

(b) Every completely assembled PVHO shall be subjected to an air test at the ***rated*** pressure and held for a period of I hr with an allowable pressure loss not to exceed 1% of the rated pressure. Internal and external air temperatures shall be measured and recorded at the end of each air test so that compensation may be made for any temperature differences.

(c) Following (a) and (b) above, the PVHO will be inspected for damage to the sealing areas and be subjected to a dimensional check. Any permanent change will be grounds for rejection of the PVHO components.

5 QUALITY ASSURANCE PROGRAM

5.1 General

In lieu of the requirements of PVHO-I, para. 1.2.2, a Quality Assurance Program shall be developed for the design and manufacture of the PVHO. The Quality Assurance Program shall be reviewed and accepted by the purchaser/owner/user and/or an independent third party inspection agency designated by them. This section sets forth the requirements for establishing and maintaining a Quality Assurance Program to control the quality of work performed by the manufacturer of the PVHO.

5.2 Organization

(a) The manufacturer shall have a documented organizational structure, with responsibilities, authorities, and lines of communication clearly delineated in writing for activities affecting quality. Persons or organizations responsible for the Quality Assurance Program shall have authority and organizational freedom to:

(1) identify problems affecting quality;

(2) initiate, recommend, or provide solutions to quality problems, through designated channels;

(3) verify implementation of solutions; and

(4) control further processing, delivery, or assembly of a nonconforming item, deficiency, or unsatisfactory condition until proper corrective action has been taken.

(b) The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the manufacturer's organization (including factors such as number and experience level of employees and number of PVHOs produced).

5.3 Quality Assurance Program

(a) A documented program for the assurance of quality of activities, items, and services shall be planned, implemented, and maintained in accordance with specified requirements of PVHO-1.

(b) The program shall apply to activities, materials, parts, assemblies, and services which affect the quality of the PVHO. It need not apply to other activities, products, and services at the same location.

(c) The program shall identify the PVHO activities to which it applies.

(d) The program shall provide for indoctrination and training of personnel to assure compliance with PVHO- l.

(e) Management shall, at least annually, assess the program and take corrective action, if necessary.

5.4 Quality Control Manual

(a) The Quality Assurance Program shall be described in a Quality Assurance Manual.

(6) The Quality Assurance Manual must provide a mechanism to document issuance and revision, and must include a method to identify and/or highlight the revisions.

5.5 Drawing, Design, and Specification Control

(a) The manufacturer shall establish measures to assure that PVHO design drawings and all applicable documents and requirements of PVHO-I relative to the design of PVHOs are received from the designer, and are correctly translated into manufacturing specifications, drawings, procedures, and shop instructions for the PVHO.

(b) Procedures shall be established for the review, approval, release, distribution, and revision of manufacturing documents.

5.6 Production Control

(a) Applicable requirements necessary to assure compliance with this Case shall be specified or included in documents for procurement of materials, items, or services to be used by the manufacturer.

(b) The procurement of materials, items, and services shall be controlled by the manufacturer to assure conformance with specified requirements.

(c) These controls shall include, but are not limited to, any of the following, as appropriate:

(1) source evaluation and selection;

(2) appraisal of objective evidence of quality furnished by the supplier including all necessary material certification documents;

(3) inventory control;

(4) examination of supplied items upon delivery.

(d) Procedures for assuring continued compliance with pertinent requirements, including identification of procedural revisions, shall be described in the Quality Assurance Manual.

5.7 Identification and Control of Items

(a) Identification shall be maintained on all items or in documentation traceable to these items.

(b) Controls shall be established to prevent use of incorrect or defective items.

(c) The manufacturer, based on his judgment, shall also maintain additional identification and documentation to assure that significant problems can be identified and proper corrective action taken.

(d) Traceability of the completed PVHO shall extend to identification of the immediate purchaser.

5.8 Control of Processes

(a) Processes affecting quality shall be controlled in accordance with specified requirements using process control documents such as process sheets and travelers.

(b) Special processes affecting quality, such as laying back, curing, and nondestructive examination, shall be performed by qualified personnel using qualified procedures referenced in this Case.

(c) All personnel performing critical manufacturing procedures shall be documented as meeting a specific criteria qualifying them to perform those procedures.

5.9 Inspection

(a) Inspection shall be planned and controlled by the manufacturer.

(b) These inspections shall verify conformance to documented instructions, procedures, and drawings describing the activities.

(c) Inspection results shall be documented.

(d) Inspection for acceptance shall be performed by qualified persons other than those who performed or supervised the work.

(e) Inspection documents shall contain appropriate criteria for determining that such activities have been satisfactorily accomplished.

5.10 Test Control

(a) Testing required to demonstrate that the PVHO will perform in accordance with this Case shall be so defined, controlled, and documented.

(b) Tests shall be performed in accordance with written instructions stipulating acceptance criteria.

(c) Test results shall be recorded on the required forms.

(d) Examination, measurement, and testing equipment used for activities affecting quality shall be controlled, calibrated, and adjusted at specified periods to maintain required accuracy.

(e) Specifications, calibration, and control of measuring and testing equipment used for acceptance shall be described in written instructions or procedures.

(f) Calibrations shall be traceable to national standards where such exist.

5.11 Handling, Storage, and Shipping

Handling, storage, cleaning, packaging, shipping, and preservation of items shall be controlled to prevent damage or loss, and to minimize deterioration, and shall be documented.

5.12 Documentation and Status of Test Activities

(a) The status of inspection and testing activities shall be indicated either on the items, or in records traceable to the items, to assure that required inspections and tests are performed.

(b) Items which have satisfactorily passed inspections and tests shall be identified.

5.13 Corrective Action

(a) Items, services, or activities which do not conform to specified requirements shall be controlled to assure proper disposition and prevent inadvertent use.

(b) Controls shall provide for identification, documentation, evaluation, segregation when practical, and disposition of nonconformances and notification to affected organizations.

(c) Conditions adverse to quality shall be promptly investigated, documented, evaluated, and corrected.

(d) In the case of a significant condition adverse to quality, the cause of the condition shall be determined and corrective action taken to preclude recurrence.

(e) The identification, cause, and corrective action planned and taken for significant conditions shall be documented and reported to appropriate levels of management.

(f) Follow-up action shall be taken to verify implementation of corrective action.

5.14 Quality Assurance Records

(a) Records shall be specified, compiled, and maintained to furnish documentary evidence that services, materials, items, and completed PVHOs meet this and applicable referenced standards.

(b) Records shall be legible, identifiable, and retrievable.

(c) Records shall be protected against damage, deterioration, or loss.

(d) Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.

(e) Records required for traceability shall be retained for a minimum of 12 years.

5.15 Quality Assurance Audits

(a) The PVHO manufacturer shall schedule and perform regular internal audits to verify compliance with all aspects of the Quality Assurance Program.

(b) These audits shall be performed at least annually and be stipulated in the Quality Assurance Manual.

(c) These audits shall be performed by qualified personnel who do not have direct responsibility for performing or controlling the activities being audited.

(d) The audits shall be performed in accordance with written instructions.

(e) Audit results shall be reported to and reviewed by management having responsibility and authority to take any necessary corrective action. Follow-up action shall be taken where indicated.

5.16 Quality Assurance Overview by an independent Third Party Agency

An independent third party agency shall be employed to ensure that all PVHOs intended to be classified under this Case are designed and manufactured to the requirements of PVHO-I and this Case. This shall include but is not restricted to the following:

(a) The PVHO is designed in accordance with PVHO-I and this Case.

(b) The manufacturer is working to the requirements of the quality control systems.

(c) The materials used in construction of the PVHO comply with approved procedures by qualified operators as required by PVHO-1 and this Case.

(d) All manufacturing operations are conducted in accordance with approved procedures by qualified operators as required in PVHO-I and this Case.

(e) All defects are acceptably repaired.

(f) All prototype and production testing has been performed and witnessed as required by PVHO-I and this Case.

(g) The PVHO is marked in accordance with PVHO-I and this Case.

(h) A visual inspection of the PVHO is conducted to confirm that there are no material or dimensional defects.

The manufacturer shall arrange and give the third party inspection agency free access to all facilities associated with the manufacture of the PVHO. The manufacturer shall keep the third party inspection agency informed of the progress of the work and shall notify them reasonably in advance when PVHOs will be ready for any required tests or inspections.

6 MARKING

(a) In lieu of PVHO-I, paras. 1.2. I and I .6. Stamping and Reports of PVHOs, the internal surface of the cylindrical shell shall be permanently marked, close to one end, with the data required in PVHO-I, para. 1.6.1, and the following (sample) designation:

31–24–96–PVHO (CCxx)–CSC–0001–1993

where

31 = rated pressure, psig
24 = inside diameter, in.
96 = length of the vessel, in.
PVHO (CCxx) = PVHO designator and Case number
CSC = manufacturer's initials
0001 = manufacturer's unique identification for the PVHO
1993 = year of manufacture

The internal surface of the cylindrical shell shall also display the following information:

Restricted to Emergency Use Only

Maximum Working Pressure:	**69** FSW/21 **MSW**
Operating Temperature (min./max.)	0°F/100°F
Allowable Cyclic Life:	_____ **Cycles**
Cylindrical **Shell** Expiration **Date:**	(DD/MM/YY)

(6) Form PVHO Case 6, Manufacturer's Data Report for Pressure Vessels for Human Occupancy, shall be completed to certify that each PVHO meets the requirements of PVHO-1 and this Case.

FORM PVHO CASE 6 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS FOR HUMAN OCCUPANCY

1. Manufactured and certified by ____________________

2. Manufactured for ____________________

3. Vessel identification ____________________
(mfr. serial no.) (year built)

4. The design, construction, workmanship, and chemical and physical properties of all parts meet the applicable material specifications of PVHO-1– __________ (year) and Addenda __________ (date) and Case Nos. __________

5. Manufactured for a maximum allowable working pressure of __________ psi, a maximum working temperature of __________ °F, and a hydrostatic test pressure of __________ psi (internal).

6. Design analysis conducted by ____________________

7. Windows: Certification Reports, properly identified and signed by the viewport fabricator, are attached for the following items.

No.	Location	Type	Diameter or Size	Nominal Thickness	How Attached

CERTIFICATION OF DESIGN

User's Design Specification on file at ____________________

Manufacturer's Design Report on file at ____________________

Prototype test program attested by ____________________

Quality Assurance Program reviewed by ____________________

Fabrication documentation reviewed by ____________________
(name and date)

Production testing witnessed by ____________________
(name and date)

CERTIFICATION OF COMPLIANCE

We certify that the statements made in this report are correct and that all details of the design, material, construction, and workmanship of this vessel conform to the ASME Safety Standard for Pressure Vessels for Human Occupancy (PVHO-1) and PVHO Case 6.

Date __________ Company name ____________________ Signed ____________________

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ASME PHVO-1 INTERPRETATIONS NO. 3

Replies to Technical Inquiries
June 1, 1995, through May 31, 1996

It has been agreed to publish interpretations issued by the PVHO Committee concerning PVHO-1 as part of the update service. This publication includes interpretations concerning PVHO-1 issued between June 1, 1995 and May 3 1, 1996. They have been assigned interpretation numbers in chronological order. Each interpretation applies to the latest Edition or Addenda at the time of issuance of the interpretation or the Edition or Addenda stated in the reply. Subsequent revisions to PVHO-1 may have superseded the reply. **These interpretations are not a part of the Edition or its Addenda.**

These replies are taken verbatim from the original letters, except for a few typographical and editorial corrections made for the purpose of improved clarity.

ASME procedures provide for reconsideration of these interpretations when or if additional information is available which the inquirer believes might affect the interpretation. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Interpretation: 3-l

Subject: Window Repair

Date Issued: June 24. 1994

Question (1): May the allowable diameter of inclusions per para. C8 of Appendix C of PVHO- I be increased?

Reply (1): No.

Question (2): May repairs be made to window geometries other than those in para. C8 of Appendix C of PVHO-l?

Reply (2): No.
Repairs may only be performed on windows with spherical surfaces and the repaired spot only, subject to compressive stresses per para. C8 of Appendix C of PVHO-I.

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DRAFTER'S NOTE
FROM THE
LEGISLATIVE REFERENCE BUREAU

LRB–3474/P1dn
TY&RJM:wlj:hmh

September 27, 1999

I did not include a provision in this draft requiring physicians to abide by the Helsinki accords because I do not believe it is necessary. Section 448.30 requires a physician to inform a patient on all alternative, viable forms of treatment and about the benefits and risks of those treatments. If a doctor is suggesting a mode of treatment that is experimental for the disorder being treated, I do not see how a doctor following the law could get around explaining that the one mode is experimental while any others are conventional.

If you have any questions, please feel free to contact me.

Tina A. Yacker
Legislative Attorney
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E-mail: Tina.Yacker@legis.state.wi.us

1. The rule-making provision in proposed s. 101.20 (3) (b), stats., may constitute an unconstitutional delegation of legislative authority. Proposed s. 101.20 (3) (b), stats., requires the department of commerce (department) to promulgate rules regarding hyperbaric chambers. The rules must be as consistent as possible with the applicable national standards promulgated by the American Society of Mechanical Engineers (ASME) and the National Fire Protection Association (NFPA). This consistency requirement is not unusual. Other buildings and safety statutes similarly require rules to be consistent with specific national standards. For example, see s. 101.132 (2) (e) 2., stats.

However, proposed s. 101.20 (3) (b), stats., may be unconstitutional to the extent that it requires the department to amend the rules if the applicable national standards change. In passing this provision, the legislature may be unconstitutionally delegating its law-making power to the private bodies that draft these national standards. See 68 OAG 9 (1979).

You have at least two different options to eliminate this constitutional issue. First, you could specify which version of the standards the legislature intends to incorporate.

For example, the draft could specifically require the rules to be as consistent as possible with the 1997 safety standard for pressure vessels for human occupancy, promulgated by the ASME, and those portions of the 1999 standard for health care facilities, promulgated by the NFPA, that apply to hyperbaric chambers. However, this option may require the legislature to amend the statute over time to remain consistent with the national standards.

Second, you could eliminate the reference to the national standards altogether. Under this option, the department would still be free to adopt the national standards under the procedure outlined in s. 227.21 (2), stats. The department has used this procedure in the past to incorporate standards promulgated by the ASME. See COMM 41.10 (2), Wis. Adm. Code (incorporating 1995 ASME boiler and pressure vessel code into chs. COMM 41 and 42, Wis. Adm. Code).

I have drafted proposed s. 101.20 (3) (b), stats., based upon my initial understanding of your intent. If you desire any changes to this provision after reading this note, please feel free to call.

2. Per my telephone conversation with Greg Reiman, I have included a penalty provision in this draft. As currently drafted, the penalty for violating proposed s. 101.20, stats., or any rule promulgated under that section, is a forfeiture of up to $1,000 for each day of violation. See s. 101.02 (12) and proposed s. 101.20 (4), stats. It was difficult to locate a similar statute on which to base the penalty amount. A $1,000 forfeiture is the maximum forfeiture for violations of s. 101.09, stats., regarding the storage of flammable and combustible liquids. If this penalty is not consistent with your intent, please let me know.

3. This draft requires the department to expand its safety and buildings inspection services to include hyperbaric chambers. This draft allows the department to assess a fee to cover the cost of these inspections. See proposed s. 101.19 (1) (b), stats. Please let me know if you do not approve.

Robert J. Marchant
Legislative Attorney
Phone: (608) 261-4454
E-mail: Robert.Marchant@legis.state.wi.us

3-3-00

(1) nat'l standards relating to ... repeat lang. from p2, 23-25

T/C Colleen at state med. society.

- Re: DNOTE #1, remove reference to ASME & NFPA &, instead, require rules to be as consistent as possible w/ nat'l standards relating to (repeat language from p. 2, l 23-25).

- Re: other DNOTE issues, draft is OK as-is.

PRELIMINARY DRAFT – NOT READY FOR INTRODUCTION

AN ACT *to amend* 101.12 (3) (c) and 101.19 (1) (b); and *to create* 101.20 and 146.525 of the statutes; **relating to:** the design, installation, operation and maintenance of hyperbaric chambers; granting rule-making authority and providing a penalty.

Analysis by the Legislative Reference Bureau

~~This is a preliminary draft. An analysis will be provided in a later version.~~

The people of the state of Wisconsin, represented in senate and assembly, do enact as follows:

SECTION 1. 101.12 (3) (c) of the statutes is amended to read:

101.12 (3) (c) Determine and certify the competency of inspectors of boilers, unfired pressure vessels, <u>hyperbaric chambers</u>, refrigeration plants, elevators, escalators and power dumbwaiters.

SECTION 2. 101.19 (1) (b) of the statutes is amended to read:

101.19 (1) (b) The required inspection of boilers, pressure vessels, <u>hyperbaric chambers</u>, refrigeration plants, petroleum and liquefied petroleum gas vessels, anhydrous ammonia tanks and containers, elevators, ski towing and lift devices, escalators, dumbwaiters and amusement or thrill rides but not of amusement attractions.

SECTION 3. 101.20 of the statutes is created to read:

101.20 Hyperbaric chambers. (1) DEFINITION. In this section, "hyperbaric chamber" has the meaning given in s. 146.525 (1) (a).

(2) USE OF CERTIFIED HYPERBARIC CHAMBERS. No person may operate a hyperbaric chamber in this state without a valid certificate of inspection, received under sub. (3) (a), pertaining to the hyperbaric chamber. No person may operate a hyperbaric chamber that violates any applicable rules promulgated under sub. (3) (b). Every owner of a hyperbaric chamber shall maintain all certificates of inspection relating to the hyperbaric chamber as long as the hyperbaric chamber may be operated except that, if the owner transfers ownership of the hyperbaric chamber to another person, the owner shall transfer all of the certificates of inspection to the person.

(3) ENFORCEMENT. (a) *Inspection and certification.* The department shall inspect and certify each hyperbaric chamber in this state before the hyperbaric chamber is placed into operation. The department shall inspect and certify each hyperbaric chamber placed into operation in this state at least once every 36 months after the date of the initial certification.

(b) *Rules.* The department shall promulgate rules for the efficient administration of this section and to promote the use of safe hyperbaric chambers in this state. The rules shall establish standards for the design, fabrication, testing, marking, stamping and cleaning of hyperbaric chambers) and any ancillary equipment used in conjunction with hyperbaric chambers. The rules shall be as consistent as possible with the safety standard for pressure vessels for human occupancy, promulgated by the American Society of Mechanical Engineers, and with those portions of the standard for health care facilities, promulgated by the National Fire Protection Association, that apply to hyperbaric chambers.

(4) **PENALTY.** Any person who violates sub. (2) or any rule promulgated under sub. (3) (b) may be required to forfeit not more than $1,000 for each violation.

SECTION 4. 146.525 of the statutes is created to read:

146.525 Clinical hyperbaric chambers. (1) DEFINITIONS. In this section:

(a) "Hyperbaric chamber" means a pressure vessel that is designed to contain at least one individual entirely enclosed within it and that is operated at a pressure greater than atmospheric.

(b) "Hyperbaric physician" means a physician who meets all of the requirements of sub. (2) (e).

(c) "Physician" has the meaning given in s. 448.01 (5).

(2) **OPERATION OF HYPERBARIC CHAMBERS.** No individual may operate a hyperbaric chamber unless the individual meets all of the following requirements:

(a) The individual is a physician; physician assistant, as defined in s. 448.01 (6); registered nurse, as defined in s. 146.40 (1) (f); licensed practical nurse, as defined in s. 146.40 (1) (c); a respiratory therapist; emergency medical technician, as defined in s. 146.50 (1 (e); or an individual trained in commercial or navy diving chamber technology.

(b) The individual has completed basic training approved by the Undersea and Hyperbaric Medical Society for the operation of a hyperbaric chamber or has completed training that the board of medical examiners determines meets the same standards as the training approved by the Undersea and Hyperbaric Medical Society.

(c) The individual completes supplemental training specified by the department by rule. The department shall permit an individual to satisfy the supplemental training requirement under this paragraph by verifying in writing, including all information specified by the department by rule, that he or she operates a hyperbaric chamber for at least 480 hours per year under the direct supervision of another individual who is fully trained to operate a hyperbaric chamber.

(d) In the case of an individual operating a hyperbaric chamber that is designed to accommodate more than one individual at a time, the individual receives additional training specific to that type of hyperbaric chamber. The department shall promulgate rules specifying the training required to satisfy this paragraph. In promulgating the rules, the department shall permit an individual to satisfy the requirement under this paragraph by submitting to the department a letter from the medical director of the facility where the individual operates a hyperbaric chamber that verifies that the individual has mastered the skills necessary for the operation of a hyperbaric chamber designed to accommodate more than one individual at a time.

(e) The individual is supervised by a physician who meets all of the following requirements:

1. The physician has completed introductory training in hyperbaric medicine approved by the Undersea and Hyperbaric Medical Society, or has completed training that the board of medical examiners determines meets the same standards as the training approved by the Undersea and Hyperbaric Medical Society.

2. In the case of the supervision of an individual operating a hyperbaric chamber that is designed to accommodate more than one patient at a time, the physician receives additional training specific to that type of hyperbaric chamber. The department shall promulgate rules specifying the training required to satisfy this paragraph. In promulgating the rules, the department shall permit a physician to satisfy the requirements under this paragraph by submitting to the department a letter from the medical director of the facility where the physician supervises the operation of a hyperbaric chamber that verifies that the physician has mastered the skills necessary for the operation of a hyperbaric chamber designed to accommodate more than one patient at a time.

3. Biennially, the physician receives at least 16 hours of continuing medical education in hyperbaric medicine.

(3) **DUTIES OF HYPERBARIC PHYSICIANS AND CHAMBER OPERATORS.** (a) A hyperbaric physician shall do all of the following:

1. Make himself or herself immediately available, or designate a physician to be immediately available, to the operator of the hyperbaric chamber to manage patient emergencies.

2. Ensure that training of all hyperbaric chamber personnel is complete and documented.

3. Maintain complete records of patients for whom the hyperbaric physician prescribes hyperbaric treatment, including the indication and rationale for the treatment of each disorder treated.

(b) An individual who operates a hyperbaric chamber shall operate it only in accordance with operating protocols established by the department by rule, in consultation with the department of commerce. No individual may operate a hyperbaric chamber to treat another individual unless the treatment has been prescribed for that individual by a hyperbaric physician. A hyperbaric chamber operator shall maintain written records documenting all of the following with respect to each hyperbaric chamber session:

1. The purpose of the hyperbaric exposure.

2. The names and positions of all personnel present during the session.

3. The names of all of the individuals exposed to hyperbaric pressure during the session.

4. The pressure and time profile of the exposure.

5. Any equipment defects detected before, during or after the hyperbaric exposure. The operator of the hyperbaric chamber shall report all equipment defects to the hyperbaric physician and shall ensure that the detected defects are corrected before using, or continuing to use, the equipment.

(5) **FACILITY LICENSE REQUIRED.** The department shall provide uniform, statewide, biennial licensing of hyperbaric chamber facilities. No person may operate a hyperbaric chamber in a facility that is not licensed under this subsection. The department may not license a facility under this subsection unless the facility is operated within a hospital that is approved under s. 50.35, within a clinic that is affiliated with a hospital that is approved under s. 50.35 or within the primary place of business of a private practice physician. The department shall establish by rule a biennial fee for a license issued under this subsection.

SECTION 5. Nonstatutory provisions.

(1) **DEPARTMENT OF COMMERCE; RULES.** No later than the first day of the 3rd month beginning after publication, the department of commerce shall submit in proposed form the rules under section 101.20 (3) (b) of the statutes, as created by this

act, governing hyperbaric chambers, to the legislative council staff under section 227.15 (1) of the statutes.

(2) DEPARTMENT OF HEALTH AND FAMILY SERVICES; RULES. No later than the first day of the 3rd month beginning after publication, the department of health and family services shall submit in proposed form the rules under section 146.525 of the statutes, as created by this act, to the legislative council staff under section 227.15 (1) of the statutes.

SECTION 6. Effective dates. This act takes effect on the first day of the 6th month beginning after publication, except as follows:

(1) The treatment of SECTION 5 takes effect on the day after publication.

(END)

INSERT ANALYSIS

Currently, the department of commerce (department) has general authority to promulgate rules for the purpose of establishing safe public buildings and places of employment. Under this general grant of authority, the department has promulgated rules relating to the inspection, design, fabrication, testing, marking, stamping and cleaning of hyperbaric chambers that are installed in public buildings and places of employment.. Hyperbaric chambers are machines that are designed to contain at least one individual and that are operated at greater than atmospheric pressure. Among other things, hyperbaric chambers are used by hospitals and individuals for medical purposes. The rules of the department currently incorporate the safety standards promulgated by the American Society of Mechanical Engineers relating to hyperbaric chambers. Current law prohibits the installation or use of machines, including hyperbaric chambers, that do not fully comply with the orders of the department.

This bill expands the authority of the department to regulate hyperbaric chambers by requiring the department to regulate hyperbaric chambers that are installed in locations other than public buildings and places of employment. The bill establishes statutory inspection requirements that apply to all hyperbaric chambers intended for use in this state and specifies that only hyperbaric chambers that are certified by the department may be operated in this state. The bill requires the department to promulgate rules that establish standards for the design, fabrication, testing, marking, stamping and cleaning of all hyperbaric chambers used in this state and any ancillary equipment used in conjunction with the hyperbaric chambers.

This bill also specifies training and operation requirements that an individual must meet to operate hyperbaric chambers. Under the bill, the department of health and family services (DHFS), which regulates the provision of health care services generally, is required to promulgate rules that specify the type of training, in addition to that specified under the bill, that an individual must complete in order to operate a hyperbaric chamber. DHFS is also required under the bill to promulgate rules regarding the operating protocols of a hyperbaric chamber and is responsible for licensing hyperbaric chamber facilities. Under the bill, no person may operate a hyperbaric chamber without a license from DHFS.

For further information see the ***state and local*** fiscal estimate, which will be printed as an appendix to this bill.

SUBMITTAL FORM

LEGISLATIVE REFERENCE BUREAU
Legal Section Telephone: 266-3561
5th Floor, 100 N. Hamilton Street

The attached draft is submitted for your inspection. Please check each part carefully, proofread each word, and **sign** on the appropriate line(s) below.

Date: 03/06/2000

To: Representative Walker

Relating to LRB drafting number: LRB-3474

Topic
Regulation of hyperbaric chambers

Subject(s)
Health - miscellaneous, Buildings/Safety - misc.

1. **JACKET** the **draft** for introduction SCOTT WALKER

in the Senate ____ or the Assembly X (check only one). Only the requester under whose name the drafting request is entered in the **LRB's** drafting records may authorize the draft to be submitted. Please allow one day for the preparation of the required copies.

2. **REDRAFT.** See the changes indicated or attached ____________.

A revised draft will be submitted for your approval with changes incorporated.

3. Obtain **FISCAL ESTIMATE** NOW, prior to introduction ____________

If the analysis indicates that a fiscal estimate is required because the proposal makes an appropriation or increases or decreases existing appropriations or state or general local government fiscal liability or revenues, you have the option to request the fiscal estimate prior to introduction. If you choose to introduce the proposal without the fiscal estimate, the fiscal estimate will be requested automatically upon introduction. It takes about 10 days to obtain a fiscal estimate. Requesting the fiscal estimate prior to introduction retains your flexibility for possible redrafting of the proposal.

If you have any questions regarding the above procedures, please call 266-3561. If you have any questions relating to the attached draft, please feel free to call me.

Tina A. Yacker, Legislative Attorney
Telephone: (608) 261-6927