1999 DRAFTING REQUEST

Bill

Received: **08/19/1999**

Received By: **yacketa**

Wanted: **As time permits**

Identical to ERB:

For: **Scott Walker (608) 266-9180**

By/Representing: **Greg Reiman**

This file may be shown to any legislator: NO

Drafter: **yacketa**

May Contact: **Colleen Wilson (Med. Soc) 257-6781**

Ah. Drafters: **rmarchan**

Subject: **Health - miscellaneous**
Buildings/Safety - misc.

Extra Copies: **DAK**
RCT

Pre Topic:

No specific pre topic given

Topic:

Regulation of hyperbaric chambers

Instructions:

See Attached

Drafting History:

Vers.	Drafted	Reviewed	Typed	Proofed	Submitted	Jacketed	Reauired
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Vers.	Drafted	Reviewed	Typed	Proofed	Submitted	Jacketed	Reauired
	03/03/2000			_______			
/1			jfrantze 03/06/2000	_______ _______	lrb_docadmin 03/06/2000	lrb_docadmin 03/08/2000	S&L

FE Sent For:

<END>

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3/6 3/6 lr

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/P1	yacketa 09/08/1999 rmarchan	/p1 wlj 9/27	lH 9/27	CH/CH 9/27			

FE Sent For:

<END>

Scott Walker
Wauwatosa's Representative in the Wisconsin State Assembly

TINA -

SCOTT WOULD LIKE A BILL DRAFTED TO REQUIRE REGULATION OF HYPERBARIC CHAMBERS.

COLLEEN WILSON OF THE STATE MEDICAL SOCIETY CAN PROVIDE ADDITIONAL INFO IF NEEDED HER PH # IS 608 257-6781.

PLEASE CALL ME W/ QUESTIONS

THANKS!

GREG REIMAN

Erick Kindwall 414-641-0393
erick@aya.yale.edu

P.O. Box 8953, State Capitol, Madison, WI 53708-8953 . (608) 266-9180
Message Hotline: 800-362-WISC (9472)
2334 N. 73rd Street. Wauwatosa, WI 53213 . (414) 258-1086

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DEC - 6 1998

PROPOSED DRAFT REGULATION
FOR CLINICAL HYPERBARIC CHAMBERS

WISCONSIN ADMINISTRATIVE CODE
DEPARTMENT OF REGULATION AND LICENSING

Installation, Maintenance, and Operation of Clinical Hyperbaric Chambers

Chapter XX

Article 1.

APPLICATION

xX-00.01 Application of Orders.

(1) The following rules shall apply to the installation, maintenance, and operation of hyperbaric chambers used for the clinical treatment of **humans.** Equipment, processes, and operations not specifically covered by these rules shall be governed **by** other applicable administrative codes.

Amer Soc mech engineers Press. vessels for human occupancy

(2) With respect to compliance with the design parameters of ASME-PVHO-1, the 3
rules shall apply only to hyperbaric chambers installed after the effective date of these orders.

(3) **Exceptions.** The following hyperbaric facilities are excluded from these regulations:

a) Hyperbaric chambers maintained at work sites solely for the decompression and/or treatment of commercial divers. (OSHA regulations apply to diver support chambers.)

b) Hyperbaric chambers maintained solely for the treatment of compressed air workers. Their regulation is covered by Wisconsin Administrative Code Chapter Ind 12, Work Under Compressed Air. (Register No. 188, August 1971.)

c) Hyperbaric chambers owned, maintained, and operated by the military.

Article 2.

DEFINITIONS

xX-00.02 Definitions. The following definitions shall apply in the application of these rules. The singular number includes the plural and the plural includes the singular.

(1) **HYPERBARIC CHAMBER.** Any pressure vessel which is designed to contain one or more people entirely enclosed within its confines and which is operated at pressure greater than atmospheric.

(2) **MULTIPLACE CHAMBER.** A multiplace chamber is pressurized with compressed air and designed to accommodate more than one patient at a time.

(3) **DUO-PLACE CHAMBER.** A duo-place chamber is pressurized with compressed air and has room for only one patient and an inside tender, or two unattended patients.

(4) **MONOPLACE CHAMBER.** A single-compartment hyperbaric chamber pressurized with oxygen or air, designed to accommodate one person at a time. If chamber is pressurized with compressed air, oxygen is supplied to the patient by means of mask, head tent, or endotracheal tube.

(5) **OXYGEN ENVIRONMENT.** In the above chamber definitions, an air-pressurized environment is less than 23% oxygen by volume. An oxygen-pressurized environment is above 23.5% oxygen by volume.

(6) CONTROL PANEL. The control panel is the place where hyperbaric chamber treatment is controlled and monitored. Provision shall be made for record-keeping and for summoning emergency assistance at the control panel.

(7) **COMMUNICATION SYSTEM.** The communication system is a system of microphones designed to permit auditory communication between a person inside a hyperbaric chamber and an attendant on the outside. In the 'monoplace chamber the communication system is a vital link between the patient and the chamber operator. In a multiplace chamber it serves as the link between the inside tender and the chamber operator.

(8) **MONITORING SYSTEM..** A patient monitoring system is a set of electronic or mechanical devices designed to provide information on the physical status of a patient being treated in a hyperbaric chamber. This system may consist of (a) closed circuit television, (b) clinical patient monitoring such as EKG, temperature, blood pressure, EEG, etc.

(9) INSIDE TENDER. That person who attends the patient(s) inside a multiplace chamber. The inside tender routinely breathes air while at pressure during patient treatment.

(10) OVERBOARD DUMP SYSTEM. A series of valves and tubing to collect and remove exhaled gas from oxygen breathing masks or other apparatus and direct it from the chamber through the pressure hull so that oxygen levels do not build up within the chamber.

(11) ABSOLUTE PRESSURE. Normal atmospheric pressure plus gauge pressure. Achieved by adding one atmosphere or 14.7 lb./sq. in. to chamber pressure. Pressure given in atmospheres is always absolute unless otherwise noted.

(12) GAUGE PRESSURE. Pressure in lbs./sq. in (psig) above normal atmospheric pressure.

(13) HYPERBARIC OXYGEN THERAPY (HBO_2). Treatment of selected human disorders by breathing 100% oxygen at greater than 1.4 atmospheres absolute in a hyperbaric chamber.

Article 3.

LICENSURE

xX-00.03 Licensure. (1) All hyperbaric facilities operated within the State of Wisconsin shall maintain a valid license issued by the Department of Regulation and Licensing. This license shall be renewed biennially.

(2) All hyperbaric facilities specified in these regulations shall be installed within hospitals or other inpatient medical facilities. Hyperbaric chambers shall not be installed in free-standing clinics, except when the clinic is owned by and under the direct supervision of a fully-accredited hospital.

(3) Renewal of licensure shall be contingent on compliance with all portions of this regulation.

Article 4.

HYPERBARIC CHAMBER SPECIFICATIONS

xX-00.04 Monoplace Chambers. Monoplace chambers are restricted to a maximum of 3.0 atmospheres absolute pressure. Monoplace chambers shall be constructed to meet the safety standards for human occupancy specified by the ASME PVHO-I Code. ASME PVHO-1 specifies the inspections and tests necessary for certification, final code stamping, and final reports. The owner shall maintain a copy of the certification documents indefinitely. Any chamber modifications shall be in accordance with the ASME Code. If the chamber is sold or transferred, all documentation shall be transferred with the pressure vessel. Additionally, the chamber shall comply with all provisions of the National Fire Protection Association Publication 99, Standard for Health Care Facilities, Chapter 19, concerning hyperbaric facilities.

Duo-place Chambers. A duo-place chamber is a hybrid between a monoplace and a multiplace chamber. Often duo-place chambers are of modular construction, allowing them to be used as a monoplace chamber, but with the addition of a pressurized module they can accommodate an inside tender. They are pressurized with air when used with an inside tender, and the patient breathes oxygen via mask, head tent, or endotracheal tube. Duo-place chambers shall be constructed to meet the safety standards for human occupancy specified by the ASME PVHO-1 Code. ASME PVHO-1 specifies the inspections and tests necessary for certification, final code stamping, and final reports. The owner shall maintain a copy of the certification documents indefinitely. Any chamber modifications shall be in accordance with the ASME Code. If the chamber is sold or transferred, all documentation shall be transferred with the pressure vessel. Additionally, the chamber shall comply with all provisions of the National Fire Protection Association Publication 99, Standard for Health Care Facilities, Chapter 19, concerning hyperbaric facilities.

Multiplace Chambers. Multiplace chambers used for patient treatment shall be of minimally double lock construction, having at least one compartment which can be used to lock personnel, medications, and/or equipment in or out during treatment. The maximum working pressure of this chamber may be greater than 3.0 ATA. Any chamber modifications shall be in accordance with the ASME Code. Oxygen or other therapeutic gas is supplied to the patient via mask, head tent, or endotracheal tube. Patients receiving oxygen shall use breathing equipment provided with an overboard dump system to remove exhaled gas from the chamber environment. Multiplace chambers shall be pressurized with compressed air only and shall meet all the provisions of ASME PVHO-1. ASME PVHO-1 specifies the inspections and tests necessary for certification, final code stamping, and final reports. The owner shall maintain a copy of the certification documents indefinitely. If the chamber is sold or transferred, all documentation shall be transferred with the pressure vessel. Additionally, the hyperbaric facility shall comply with all provisions of the National Fire Protection Association Publication 99, Standard .for Health Care Facilities, Chapter 19, concerning hyperbaric facilities.

Is this ASME's code?

Communication System. A clear communication system shall be provided. This system should continue to function in the event of electrical power failure. (a) The system should be designed to provide an open microphone inside the chamber so that those at the control panel can monitor continuously all conversation and noises from inside the chamber; (b) There should be a provision for private communication between the inside attendant and the outside staff. The entire system shall be constructed in accordance with the provisions of NFPA 99, Chapter 19.

Nat'l Fire Protection Assn

Monitoring System. (a) A closed circuit TV of the chamber interior is required at the control panel for chamber operators who do not have direct visual access to the chamber. (b) Multiplace chambers shall have a continuous oxygen monitoring system to prevent oxygen levels from rising above 23%. (c) Clinical patient-monitoring equipment shall be approved for in-chamber use or designed and modified for that purpose. Unless approved or modified as required, it shall be located outside of the chamber, with the monitoring leads routed through an approved electrical penetrator. All patient monitoring shall comply with NFPA 99, Chapter 19.

Article 5.

PERSONNEL

XX.00.05 Personnel. To ensure patient safety, hyperbaric facilities shall be operated only **by** competent personnel who have had adequate training. Minimum training requirements for physicians and chamber operators are set forth below.

1. **HYPERBARIC PHYSICIAN.**

(a) Hyperbaric treatments shall be prescribed only by a fully licensed M.D. or D.O. registered with the Wisconsin State Board of Medical Examiners.

(b) The operation of the hyperbaric facility shall be supervised by a fully licensed M.D. or D.O.

(c) This physician shall have successfully completed an approved introductory course in hyperbaric medicine. The appropriate curriculum of an individual course for physicians and chamber operators will: 1) include at least 40 hours of instruction; 2) involve formal assessment upon completion; 3) involve some element of practical chamber-side instruction during patient treatment; 4) cover all the following topics:

a. physics and physiology of hyperbaric exposure
b. oxygen and carbon dioxide toxicity
c. hyperbaric chamber systems
d. breathing gas systems
e. infection control
f. mechanisms of action of HBO_2
g. selection of patients for hyperbaric oxygen therapy
h. assessment of progress and end point
i. scientific basis for indications treated with HBO_2
j. hyperbaric chamber safety and emergency procedures
l. contraindications
m. complications and side effects and their management
n. literature review and key papers
o. record keeping and quality assurance.

(d) The introductory course must be approved by the Undersea and Hyperbaric Medical Society (UHMS) or have the same length, content, and instructor competency as UHMS-approved courses. For multiplace chamber supervision, additional training of the physician shall be required, with specific skills verification for multiplace chamber operation. The physician supervising treatment in the multiplace chamber shall be physically qualified to enter the hyperbaric environment.

(e) A letter to the Department of Regulation and Licensing from the medical director of a multiplace chamber facility indicating that the applicant physician has mastered the skills necessary for multiplace chamber operation shall constitute skills verification.

(f) To retain hyperbaric skills qualification, the hyperbaric physician shall provide documentation of a minimum of 16 hours continuing medical education in hyperbaric medicine every 2 years.

2. **CHAMBER OPERATOR.** A chamber operator shall be a competent person with previous training in nursing and be a registered nurse or licensed practical nurse, a respiratory therapist, trained physician's assistant, emergency medical technician, paramedic, former military corpsman, or someone trained in commercial or Navy diving chamber technology. The chamber operator shall have completed the 40-hour introductory course for physicians and chamber operators described above. In addition, he or she shall have completed, as a minimum, a supplementary operator training course which shall include:

a. safe handling/use of oxygen
b. patient oxygen therapy delivery systems
c. the use of decompression tables, repetitive dive tables, and training in the safe decompression of inside tenders when operating multiplace facilities
d. management of hyperbaric emergencies
e. equipment-specific training, including but not limited to, patient monitoring systems, intravenous infusion systems, ventilator operation, and transcutaneous oxygen measuring systems.

As an alternative, a chamber operator may gain the equivalent of the supplementary operator training course by working at a chamber facility under the direction of a trained chamber operator for at least ~~100~~ hours. He/she shall provide written verification of specific chamber operating skills to comply with these regulations. The chamber operator working with a multiplace chamber shall be physically qualified to enter the hyperbaric environment.

A letter to the Department of Regulation and Licensing from the medical director of a monoplace or multiplace chamber facility, as applicable, indicating that the applicant chamber operator has mastered the skills necessary for the operation of the monoplace or multiplace chamber and any ancillary equipment, as required, shall constitute skills verification.

Chamber operators and inside tenders shall have appropriate medical training of a level adequate to manage the types of patients treated in the hyperbaric chamber.

Article 6.

RESPONSIBILITIES OF CHAMBER PERSONNEL

xX.00.06 Personnel Responsibilities

(1) Responsibilities of Hyperbaric Physician. Thehyperbaric physician shall:

a) have ultimate responsibility for all aspects of the hyperbaric facility's functions,
b) examine and select patients for hyperbaric treatment (Hyperbaric treatment shall only be by physician's prescription.),
c) be immediately available to manage patient emergencies which may occur in the chamber or be responsible for having a designated physician immediately available,
d) assure that training of all hyperbaric personnel is complete and documented,
e) keep complete patient records listing the indication and rationale for treatment of the disorders treated,
f) abide by the Helsinki accords [Appendix 1] with regard to any experimental or investigational treatment of disease with the hyperbaric chamber.

(2) Chamber Operator Responsibilities. The chamber operator shall be responsible for: (1) the safe operation of the chamber, according to established operating protocols; (2) the appropriate medical management of patients in the chamber; (3) the completion of written records documenting:

a) the purpose of the hyperbaric exposure,
b) the names and roles of personnel,
c) the names of persons exposed to pressure,
d) the pressure/time profile of the exposures,
e) any equipment faults detected before, during, or after hyperbaric exposure Any faults shall be reported immediately to the physician in charge and corrected before the equipment is used again.

Article 7.

APPLICABLE CODES

xX.00.07 Applicable Codes.

(1) ASME PVHO-1 (American Society of Mechanical Engineers Pressure Vessels for Human Occupancy-l) provides the minimum requirements for designing, fabricating, inspecting, testing, and certifying pressure vessels for human occupancy. A standard for construction of clinical hyperbaric chambers is ASME PVHO-1. Chambers meeting these standards shall be identified on the manufacturer date plate with a notation of ANSYASME PVHO-1, which is affixed to the chamber exterior.

ASME PVHO-1 is published by the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

(2) The National Fire Prevention Association NFPA 99, Chapter 19, addresses minimum fire safety and operating standards for hyperbaric facilities. This document is periodically updated and is published by the National Fire Protection Association, 1 Battery March Park, P.O. Box 9 101, Quincy, MA 02269-9904.

(3) Undersea and Hyperbaric Medical Society. The Undersea and Hyperbaric Medical Society (UHMS) publishes the following documents:

a) Hyperbaric Oxygen Therapy. A committee report which is updated periodically and lists those disorders which are approved by the UHMS for hyperbaric treatment. This report also includes guidelines for inspections conducted by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). Additionally, quality assurance guidelines are provided for assessment of hyperbaric unit operations.

b) UHMS Report - Monoplace Hyperbaric Chamber Safety Guidelines.

c) UHMS Report- Guidelines for Clinical Multiplace Hyperbaric Facilities.

The address of the Undersea and Hyperbaric Medical Society is 10531 Metropolitan Avenue, Kensington, MD 20895.

Recommendations from the DECLARATION OF HELSINKI

BASIC PRINCIPLES

1. Clinical research must conform to the moral and scientific principles that justify medical research and should be based on laboratory and animal experiments or other scientifically established facts.

2. Clinical research should be conducted only by scientifically qualified persons and under the supervision of a qualified medical man.

3. Clinical research cannot legitimately be carried out unless the importance of the objective is in proportion to the inherent risk to the subject.

4. Every clinical research project should be preceded by careful assessment of inherent risks in comparison to foreseeable benefits to the subject or to others.

5. *Special* caution should be exercised by the doctor in performing clinical research in which the personality of the subject is liable to be altered by drugs or experimental procedure.

CLINICAL RESEARCH COMBINED WITH PROFESSIONAL CARE

I. *In* the treatment of the sick person. the doctor must be free to use a new therapeutic measure, if in his judgment it offers hope of saving life, reestablishing health, or alleviating suffering.

If at all possible. consistent with patient psychology. the doctor should obtain the patient's freely *given* consent after the patient has been given a full explanation. In case of legal incapacity. consent should also be procured from the legal guardian: in case of physical incapacity the permission of the legal guardian replaces that of the patient.

2. The doctor can combine clinical research with professional care. the objective being the acquisition of new medical knowledge. only to the extent that clinical research is justified by its therapeutic value for the patient.

NON-THERAPEUTIC CLINICAL RESEARCH

I. In the purely scientific application of clinical research carried out on a human being. it is the duty of the doctor to remain the protector of the life and health of that person on whom clinical research is being carried out.

2. The nature, the purpose. and the risk of clinical research must be explained to the subject by the doctor.

3a. Clinical research on a human being cannot be undertaken without his free consent after he has been informed: if he is legally incompetent. the consent of the legal guardian should be procured.

3b. The subject of clinical research should be in such a mental. physical. and legal state as lo be able to exercise fully his power of choice.

3c. Consent should. as a rule, be obtained in writing. However. the responsibility for clinical research always remains with the research worker. it never falls on the subject even after consent is obtained.

4a. The investigator must respect the right of each individual to safeguard his personal integrity. especially if the subject is in a dependent relationship to the investigator.

4b. At any time during the course of clinical research the subject or his guardian should be free to withdraw permission for research to be continued.

The investigator or the investigating team should discontinue the research if in his or their judgment. it may. if continued. be harmful to the individual.

Guiding Principles in the Care and Use of Animals

Only animals that arc lawfully acquired shall be used in this laboratory. and their retention and use shall be in every case in strict compliance with state and local laws and regulations.

Animals in the laboratory must receive every consideration for their bodily comfort: they must be kindly treated. properly fed. and their surroundings kept in a sanitary condition.

Appropriate anesthetics must be used to eliminate sensibility to pain during operative procedures. Where recovery from anesthesia is necessary during the study. acceptable technique to minimize pain must be followed. Curarizing agents are not anesthetics. Where the study does not require recovery from anesthesia, the animal must be killed in a humane manner at the conclusion of the observations.

The postoperative care of animals shah be such as to minimize discomfort and pain. and in any case shall be equivalent io accepted practices in schools of Veterinary 'Medicine.

When animals arc used by students for their education or the advancement of science such work shall be under the direct supervision of an experienced teacher or investigator. The rules for the care of such animals must be the same as for animals used for research.

STATE OF WISCONSIN -LEGISLATIVE REFERENCE BUREAU - LEGAL SECTION
(608-266-3561)

Hyperbaric Chambers

9-2

to operate must ~~meet~~ ~~be~~ complete introductory coursework approved by Undersea ~~[illegible]~~ & hyperbaric medical society or military fellowship in clinical hyperbaric medicine

violation: FORFEIT Chamber

operate only in hospital or clinic affil w/ hosp. except licensed physician operating in ~~private~~ primary place of business

No person may operate HBC unless can demonstrate:

completed course work

Operator must be supervised by physician

Kindwall Consulting
Hyperbaric Medicine Training
Diving Medicine
Compressed Air Work

Eric P. Kindwall, M.D.
Associate Professor Emeritus
Medical College of Wisconsin

260 Bunker Hill Drive
Brookfield, Wisconsin
53005 USA

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FROM The Orange County Register

Chamber explosion' injures 5 in office

ACCIDENT: Medical office 'looks like a bomb went off inside.'

By TERESA PUENTES
The Orange County Register

12-10-94

LAKE FOREST — An explo-ber rocked a medical office Friday night, sending five people to the hospital.

Firefighters and paramedics were called about 6 p.m. to the Health Restoration Center, located in a small business complex at 22706 Aspan St.

"I thought it could've been a plane crash or a real loud sonic boom," said Dan L. Plies from his real estate and property-management business office.

He went outside after he heard sirens and fire trucks.

"I saw several people who were very bloody and had been cut up," Plies said.

The explosion in one of the steel hyperbaric chambers, equipped with windows of 2-inch thick clear plastic, virtually destroyed the interior of the office. Shards of the window plastic blew holes through the front office windows and landed all over the parking lot. Ceiling panels collapsed and art work fell from the walls.

"It looks like a bomb went off in there," Orange County fire Capt. Dan Young said.

The facility treats stroke and burn victims and patients with neurological problems in so-called hyperbaric chambers, Young said. Such treatment, which changes the atmospheric pressure in the body and promotes healing by increasing oxygen flow to tissues, is most commonly administered to people

Please see BLAST Page 2

A. TRAFFORD TEMPLETON/The Orange County Registe

CHAMBER BLAST: Firefighters inspect the damage to a medical office caused by an explosion Friday in a so-called hyperbaric chamber. Five people were injured, including two inside the pressurized chamber.

BLAST: 5 hurt in therapy chamber explosion

FROM 1

who have diving accidents.

About 12 to 15 patients were in the health center when the accident occurred. Only two, however, were in the hyperbaric chamber.

The victims were taken to Mission Hospital Regional Medical Center in Mission Viejo. The two in the chamber were suffering from rapid decompression, Young said. Doctors were consulting experts at the University of Southern California to determine whether the patients should be transferred to Western Medical Center in Santa Ana or to a facility on Catalina Island that has state-of-the-art hyperbaric chambers, Young said.

"Like in a diving accident, when someone shoots to the surface, they could suddenly have a heart attack," Young said.

One employee suffered a skull fracture. Another employee and an elderly woman suffered lacerations. They were also treated at Mission.

One patient was in serious condition and, the rest in good condition. Names were not available.

"It's amazing it didn't kill anyone," Young said.

Late Friday firefighters had not determined the cause of the explosion, which did not cause a fire.

Liquid oxygen flows from stainless-steel tanks through tubes into the chambers, Young said. But they have not pinpointed where the system failed, he said.

Residents of the office complex said elderly people frequented the health center. They voiced concerns to the city and local authorities when the operator brought in the hyperbaric chambers a few months ago.

"This whole accident is not unexpected to us," said Rick Wells, a property manager who occupies the office next to the health center. "We had complained to various authorities and nothing was done."

The doctor who runs the center could not be reached for comment late Friday.

9/2/99 Mtg. re: regulation of hyperbaric chambers

(1) Fire danger of using O_2 Chamber

(2) Prevent "quackery" / use of chamber for illegitimate treatments

(1)

Currently chamber is a pressure vessel
- inspected by state boiler inspector when installed
- installed up to ASME standards incorporated into state code

May want to check ASME (American Society of mechanical engineers) PVHO-1-1997 (Safety Standard for pressure vessels for human occupancy). Deals w/ chamber design

Also Nat'l Fire Protection Association has addressed fire concerns, too. Probably covers installation.

Are these chambers already installed / required to be installed up to these standards? Ask state boiler inspector.

Derive this from "Article IV" of model draft

101.12 (3) deals w/ inspection of boilers + unfired pressure vessels

101.17 steam boilers

Hyp. ch. are subject to (ASME) construction standards but are not subject to inspection for permit to operate.

Comm 41 : pressure vessel

41.08 adopts certain ASME standards
"Human occupancy code"?

Mike Verhagen in Waukesha office may have more info.
262-548-8617

Do nonstat requiring agency to try + adopt by reference in s. 227.21?

OR

How about "to extent consistent w/ this section and the public safety + welfare, dep. ~~shall adopt~~ ~~ASME~~ rules shall conform to ASME PVHO standards.

OR

Rules shall, to extent feasible, conform to any standards for PVHO established by ASME.

PRELIMINARY **DRAFT - NOT READY FOR INTRODUCTION**

AN ACT ...; **relating to:** 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, hvnerbaric chambers, 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, hyperbaric chambers, 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. Every hyperbaric chamber operated in this state shall have a valid certificate of inspection under sub. (3) (a) and shall comply with the applicable rules promulgated under sub. (3) (b). The owner of any 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 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. As nearly as is practicable, the rules shall be consistent 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. Notwithstanding s. 101.02 (13) (a), 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. (3) (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 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 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 **requirement 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.

(4) DUTIES OF HYPERBARIC CHAMBER OPERATORS AND PHYSICIANS. (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** ~~the administration of section 101.20 of the statutes, as created by this act, and governing the safe use of~~ hyperbaric chambers ~~in this state~~**, 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 6. Effective dates. This act takes effect on the day after publication, except as follows:

(1) The treatment of sections 101.12 (3) (c) and [redacted] (1) (b) of the statutes and the creation of sections 101.20 and 146.525 of the statutes take effect on the first day of the 6th month beginning after publication.

(END)

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.

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DRAFTERS NOTE FROM THE LEGISLATIVE REFERENCE BUREAU

LRB-3474/P1dn2
RJM:...

1. The rule-making provisions 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 2 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 consistent 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 s. 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. However, 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.

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The American Society of Mechanical Engineers

A N A M E R I C A N N A T I O N A L S T A N D A R D

SAFETYSTANDARDFOR PRESSURE VESSELS FO HUMAN OCCUPANCY

ASME PVHO-1-1997

(Revision ASMPVHO-1-1993)

Date of Issuance: June 13, 1997

The 1997 Edition of this Standard is being issued with an automatic addenda subscription service. The use of an addenda allows revisions made in response to public review comments or committee actions to be published on a yearly basis; revisions published in addenda will become effective 6 months after the Date of Issuance of the addenda. The next edition of this Standard is scheduled for publication in 2000.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. The interpretations will be included with the above addenda service. Interpretations are not part of the addenda to the Standard.

Cases. Proposed new and revised Cases, as well as notices of their approval, issued by the PVHO Main Committee appear in *Mechanical Engineering.* Once approved, the Cases are published with the next regularly scheduled addenda or edition as a service to the subscribers. The Cases are not part of the Standard or its addenda and are included for information only, following the Nonmandatory Appendices.

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

FOREWORD

(97)

(This Foreword is not part of ASME PVHO-I-1997.)

Early in 197 I an Ad Hoc Committee was formed by action of the ASME Codes and Standards Policy Board to develop design rules for pressure vessels for human occupancy. The importance of this task was soon recognized, and the ASME Safety Code Committee on Pressure Vessels for Human Occupancy was established in 1974 to continue the work of the Ad Hoc Committee. Initially, this Committee was to confine its activity to the pressure boundary of such systems. It was to reference existing ASME Boiler and Pressure Vessel Code Sections, insofar as practicable, adapting them for application to pressure vessels for human occupancy. The common practice hitherto has been to design such chambers in accordance with Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. However, a number of important considerations were not covered in those rules. Among these were requirements for viewports and the inservice use of pressure relief valves, and special material toughness requirements. This Standard provides the necessary rules to supplement that Section, and also Section VIII, Division 2, of the Code. The user is expected to be familiar with the principles and application of the Code Sections.

Boiler and Pressure Vessel Code criteria furnish the baseline for design. In PVHO-I, design temperature is limited to 0°F (-18°C) to 150°F (66°C). Supporting structure and lifting loads are given special attention. Certain design details permitted by Section VIII are excluded. A major addition is the inclusion of design rules for acrylic viewports (Section 2). The formulation of rules for these vital and critical appurtenances was one of the reasons for establishing the PVHO Committee. Finally, all chambers designed for external pressure are required to be subjected to an external pressure hydrostatic test.

Subsystem design (e.g., life support) is not covered (with the exception of piping systems), nor are designs which fall outside of the scope of Section VIII.

Section 4 of this Standard has been added to provide design requirements for piping systems used in association with a pressure vessel for human occupancy (PVHO). The ASME B3 I. l Power Piping Code is a required supporting document. This Standard represents a set of design requirements that have been found to give satisfactory service in circumstances appropriate to PVHO piping systems. It also reflects consideration of the requirements that relate specifically to operational aspects of PVHOs. These include, but are not limited to:

(a) operation in marine and medical environments;
(b) transportability of the chamber system;
(c) materials compatibility with oxygen and gases intended for human respiration;
(d) unique functional requirements;
(e) consistency with design rules required by other jurisdictions where systems built under this Standard may need to be operated.

The Committee still has important work under review in the following areas: design procedures for external pressure, dynamic and impact loadings, and design procedures for quick-acting, spherically dished, and flared and dished covers. As each part of this work is completed, the Committee will consider it for inclusion in this Standard.

This 1997 Edition is a compilation of the 1993 Edition and its addenda a, b, and c, which included the elimination of the ASE Accreditation for Window Fabricators. Previous editions were published in 1977, 1981, 1984, 1987, and 1993.

ASME PRESSURE VESSELS FOR HUMAN OCCUPANCY COMMITTEE (97)

(The following is the roster of the Committee as of August 13, 1996.)

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CONTENTS

(97)

Figures

Forms

Tables

ASME PVHO-1-1997 EDITION
SUMMARY OF CHANGES

ASME PVHO-I-1997 Edition is a compilation of ASME PVHO-I-1993 and its Addenda a, b, and c, with the editorial revisions and errata shown below. These editorial revisions and errata are identified on the listed pages by a margin note, **(97)**, placed next to the affected area.

Page	*Location*	*Change*
iii	Foreword	Last paragraph revised
v-vii	Roster	Revised in its entirety
ix-xiii	Contents	Updated
17	Fig. 2-2.3	*t* added to sketch (b)
19	Fig. 2-2.5	Revised
20	Fig. 2-2.6	Revised
21	Fig. 2-2.7	Reconditioned
22	Fig. 2-2.8	Reconditioned
23	Fig. 2-2.9	Revised
24	Fig. 2-2.10	Reconditioned and title revised
25	Fig. 2-2.11	Reconditioned and title revised
26	Fig. 2-2.12	Revised
27	Fig. 2-2.13	Reconditioned
28	Fig. 2-2.14	Reconditioned
29	Fig. 2-2.15	Reconditioned
30	Fig. 2-2.16	Reconditioned
31	Fig. 2-2.17	Reconditioned
32	Fig. 2-2.18	Revised
33	Fig. 2-2.19	Revised
	Table 2-2.1	General note revised
34	Table 2-2.2	General note revised
35	Table 2-2.3	General note revised
36	Table 2-2.4	General note revised
	Table 2-2.5	General notes revised

38	2-2.8.3	First sentence revised
39	Fig. 2-2.20	Title and second sketch revised
42	Fig. 2-2.24	Sketch (b) revised to include R
47	Fig. 2-2.28	Title revised and t added to first sketch
48	2-2.12.9	First sentence revised

SPECIAL NOTE:

The cases and interpretations to PVHO-I follow the last page of this edition. Neither the cases nor the interpretations, however, are part of the Standard itself.

SAFETY STANDARD FOR PRESSURE VESSELS FOR HUMAN OCCUPANCY

SECTION 1 GENERAL REQUIREMENTS

1.1 Scope

1.1.1 This Standard provides requirements for the design, fabrication, inspection, testing, marking, and stamping of pressure vessels for human occupancy, hereafter called PVHOs or chambers. This Standard also provides requirements for the design, fabrication, inspection, testing, cleaning, and certification of piping systems for PVHOs. A PVHO is a pressure vessel that encloses a human being within its pressure boundary while it is under internal or external pressure, regardless of the pressure magnitude. PVHOs include, but are not limited to, 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.

1.1.2 The requirements contained in this Standard are supplemented by the ASME Boiler and Pressure Vessel Code, hereafter referred to as the Code, and the ASME Code for Pressure Piping, B31 .1 Power Piping, also referred to herein as ASME B3 I. I.

1.1.3 In relation to the geometry of pressure containing parts, the following are considered to be parts of chambers:

(a) shells of revolution;
(b) openings and their reinforcement;
(c) nozzles and other connections;
(d) flat heads;
(e) quick-actuating closures;
(f) attachments and supports, including method of attachment;
(g) access openings;
(h) windows;
(i) where external piping is to be connected to the vessel:

(I) the welding end connection for the first circumferential joint for welded connections;
(2) the first threaded joint for screwed connections;
(3) the face of the first flange for bolted, flanged connections;
(4) the first sealing surface for proprietary connections or fittings;

(j) pressure retaining covers for vessel openings;
(k) the first sealing surface for proprietary fittings for which rules are not provided by this Standard;
(I) devices providing pressure relief to a chamber.

1.1.4 Piping systems, as covered by this Standard, include all pressure piping and component parts which fall under the definition of breathing gas systems and life-sensitive systems as defined in Mandatory Appendix D. Piping systems subject to the requirements of this Standard include, but are not necessarily limited to, the following:

(a) piping systems communicating with chamber pressure;
(b) breathing gas supply systems;
(c) ballast blow systems in submersibles;
(d) hydraulic systems in diving bell or submersible handling systems.

Piping that is part of personal breathing equipment and cylinders and other containers used for the storage of gases are excluded from the requirements of this Standard.

1.2 General

1.2.1 The PVHOs shall be designed, fabricated, inspected, tested, marked, and stamped in accordance with the requirements of this Standard and Section VIII of the Code. The user, or the user's agent, shall specify which Division of Section VIII of the Code shall be used.

1.2.2 PVHO manufacturers shall hold a valid Certificate of Authorization for use of the ASME U or U2 Code Symbol Stamp, and shall complete Form PVHO-1, Manufacturer's Data Report for Pressure Vessels for Human Occupancy, to certify that each PVHO meets the requirements of this Standard and the applicable Division of Section VIII of the Code.

1.2.3 PVHO window fabricators shall complete Form PVHO-2, Fabrication Certification for Acrylic Windows, to certify that each window meets the requirements of this Standard.

1.2.4 Piping systems shall meet the requirements of Section 4 of this Standard.

1.2.5 Revisions to this Standard, published in Addenda, may be utilized upon publication and shall become mandatory 6 months after the Date of Issuance of the Addenda.

1.3 PVHO Materials

1.3.1 All chamber materials shall meet the requirements of this Standard and the specified Division of Section VIII of the Code. The following materials shall not be used for pressure parts: SA-36, SA-283, SA-5 1.5, and cast and ductile iron.

1.3.2 Ferrous materials of chambers shall also comply with the following requirements.

(a) Except as provided for in (b), (c), (d), or (e) below, drop-weight tests in accordance with ASTM E 208 shall be made on all wrought and cast ferrous materials. For plates, one drop-weight test (two specimens) shall be made for each plate in the as-heat-treated condition. For product forms other than plate, one drop-weight test (two specimens) shall be made for each heat in any one heat treatment lot. The sampling procedure for each form of material shall comply with the requirements of the specifications listed in the Code in either Table UG-84.3 or Table AM-204.3, as applicable. The test shall be conducted at a temperature 30°F (17°C) lower than the design minimum temperature for seamless and postweld heat-treated chambers, and 50°F (28°C) lower for as-welded chambers. The two specimens shall both exhibit *no break* performance.

(b) When, due to the material thickness or configuration, drop-weight specimens cannot be obtained, Charpy V-notch tests shall be conducted. The Charpy V-notch test of each form of material shall comply with the requirements of the specifications listed in either Table UG-84.3 or Table AM-204.3, as applicable, in all respects, except the test temperature shall not be higher than that specified in (a) above.

(c) As an alternative to the provisions of (a) above, those materials listed in Table Al.15 of Section II, Part A, SA-20, of the Code may be accepted on the basis of Charpy V-notch testing. Testing shall be in accordance with the procedures contained in the specified Division of Section VIII of the Code, except that the acceptance criteria for plate shall be from each plate *as heat treated.* The test temperature shall not be higher than that specified in (a) above regardless of the temperature shown in Table AI.15 of SA-20.

(d) Ferrous materials which are 0.625 in. (16 mm) or less in thickness are exempted from the additional toughness tests of (a), (b), and (c) above provided these materials are:

(I) normalized, fully killed, and made in accordance with fine grain practice; or

(2) fully killed, made in accordance with fine grain practice with a grain size of 5 or finer, and an operating temperature of 50°F (10°C) or higher.

(e) The additional toughness tests of (a), (b), and (c) above may be waived for the 300 series stainless steels.

(f) When the material has a specified minimum yield strength exceeding 60 ksi (414 MPa), weld metal and heat-affected zone impact properties for weld procedure qualifications and weld production tests shall also meet the requirements of the specified Division of Section VIII of the Code at a test temperature 30°F (17°C) lower than the design minimum temperature, regardless of the value of the design minimum temperature.

1.3.3 PVHOs constructed of ferrous materials which are exposed to the corrosive effects of seawater or seawater atmosphere shall have provision made for the desired life by a suitable increase in the thickness of the material over that required by the design procedures, or by using some other suitable method of protection. In no case shall the corrosion allowance be less than that specified in Section VIII, Part UCS, of the Code for Division 1 vessels or less than that specified in the User's Design Specification for Division 2 vessels.

1.4 Design and Fabrication of PVHOs

The design and fabrication of PVHOs shall be in accordance with the specified Division of Section VIII of the Code and the following requirements.

1.4.1 Joint Design. All PVHOs shall be designed with joints as follows.

(a) All joints of Categories A, B, and C shall be

Type No. 1 of Table UW-12 for Division 1 vessels or shall comply with AF-221 for Division 2 vessels, except as permitted in (c) below.

(b) All joints of Category D shall be full penetration welds extending through the entire thickness of the vessel or nozzle wall. Backing strips shall be removed.

(c) Intermediate heads may be installed in accordance with Fig. UW- 13. I(f), and per UW-13(c)(1) and UW-13(c)(2) for Division I vessels only, provided that all of the following conditions are met:

(I) the maximum allowable working pressure is less than or equal to 135 psig;

(2) the allowable stress used in the calculations for the two shells and intermediate head is 70% of the allowable stress found in Section II, Part D;

(3) the flange of the intermediate head shall be at least 1½ in. long and shall be welded to the shell with a minimum fillet weld of $t_h/2$ or ¼ in., whichever is less; and

(4) the allowable shear stress value of the butt weld and the fillet weld shall be 20% of the stress value for the vessel material [see UW-13(c)(2)].

1.4.2 Temperature Limit. The design temperature shall not be below 0°F (-I 8°C) or above 150°F ***(66°C).***

1.4.3 Drain Openings. Drain openings shall be provided.

1.4.4 Opening Reinforcements. All opening reinforcement shall be integral with the nozzle and/or shell. Reinforcement pads are not permitted.

1.4.5 Supports and Attachments

(a) The design must consider the external local forces transmitted to the chamber. For marine design purposes, these forces shall be at least 2.0g (19.6 m/s*) vertical, I .0g (9.8m/s^2) transverse, and I .Og (9.8 m/s*) longitudinal, all acting simultaneously while the chamber is pressurized.

NOTE: The term 2.0g (19.6 m/s^2) indicates a force which is equal to two times the weight of the component. The term 1.0g (9.8 m/s^2) is a force equal to one times the weight of the component.

(b) Only those materials permitted for shells may be used for welded lifting attachments, and the material is to be compatible with that of the shell.

(c) Lifting attachments for submersible PVHOs are to be designed for the maximum anticipated load, given in (a) above, including shock. Weld details shall conform to the requirements of AD-9 IO of Section VIII, Division **2,** of the Code.

1.4.6 Brazed or Riveted Construction. Brazed or riveted construction is prohibited.

1.4.7 External Pressure Design of Spheres and Spherical Segments

(a) Nomenclature

C = a factor used to determine minimum shell thickness and length of the template used in checking local shell deviations

E = modulus of elasticity for the material at design temperature, psi (MPa). (For this value, for Division I vessels, see the applicable material chart in Subpart 3 of Section II, Part D of the Code; for Division 2 vessels, see Tables TM-I through TM-5 in Subpart 2 of Section II, Part D.)

L_c = chord length of template used to measure deviation from nominal circulatory, in. (mm)

P, = external design pressure, psi (MPa)

PT = external test pressure, equal to I.25 P,, psi (MPa)

R_o = nominal outside radius of spherical shell, in. (mm)

S_y = minimum yield strength for the material at design temperature, psi (MPa). (For yield strength values, see Table Y-l, Section II, Part D, of the Code.)

t = required minimum thickness of spherical shell exclusive of corrosion allowances, in. (mm)

(6) ***Thickness.*** The minimum required thickness for the spherical shell under external pressure exclusive of corrosion allowance shall be determined by the following procedure.

Step I. Calculate the value of C from the following two equations.

$$C = \text{the larger of } C_1 \text{ or } C_2$$

$$C_1 = \frac{0.75PT}{S_y}$$

$$C_2 = \sqrt{\frac{1.79PT}{E}}$$

Step 2. Enter the left ordinate of Fig. 1.4-l with the value of C calculated in Step I. Move horizontally to an intersection with the solid curve. Extrapolation beyond the upper or lower limit of the curve is prohibited. When values of C fall outside the limits of

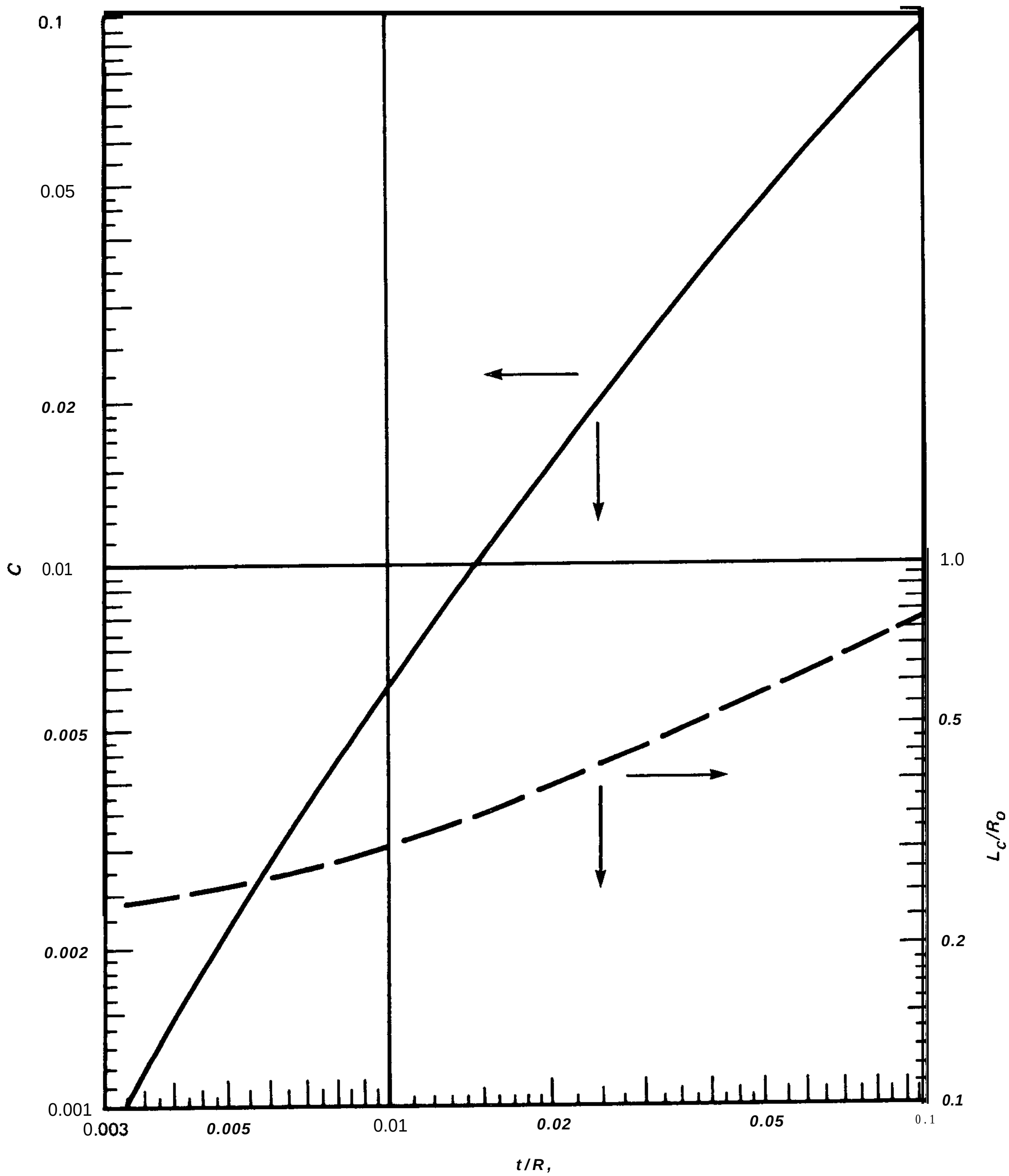

FIG. 1.4-1 VALUES OF t/R_o AND L_c/R_o

Fig. 1.4-1, design shall follow rules of Section VIII, UG-28(d) for Division 1 or AD-320 for Division 2.

Step 3. From the intersection obtained in Step 2, move vertically down and read the required minimum ratio of thickness to outside radius ***r/R,***. This required minimum ratio applies to the spherical shell for the chosen material yield strength, elastic modulus, and test pressure.

Step 4. Determine the minimum required thickness *t* for the given outside radius ***R,***. The value of *t* shall not be less than 3/8 in. (IO mm) nor greater than 2 in. (50 mm). If the maximum thickness of the spherical shell including corrosion allowance exceeds 2 in. (50 mm), the rules of Section VIII, UG-28(d) (Division I) or Article D-3 (Division 2), shall apply.

(c) Tolerances

(I) Out-of-Roundness. The difference between the maximum and minimum inside diameters at any cross section shall not exceed 1% of the nominal inside diameter at the cross section under consideration. The diameters may be measured on the inside or outside of the sphere. If measured on the outside, the diameters shall be corrected for the plate thickness at the cross section under consideration. When the cross section passes through an opening, the permissible difference in inside diameters given above may be increased by 2% of the inside diameter of the opening.

(2) Local Shell *Tolerances*

(a) The maximum plus or minus deviation from the true spherical form, measured radially on the outside or inside of the vessel, shall not exceed 0.5% of the nominal outside radius of the spherical shell and shall not be abrupt. Measurements shall be made from a segmental template having the design inside or outside radius (depending where the measurements are taken) and a chord length ***L,*** equal to the arc length determined as follows.

(b) From the required minimum ratio of thickness to outside radius t/R_o obtained in Step 3 of (b) above, move vertically upward on Fig. 1.4-I to the intersection of the dashed line. Move horizontally to the right from the dashed line and determine the ratio of critical arc length to outside radius L_c/R_o. The chord length L_c is obtained by multiplying this ratio by the outside radius ***R,***.

(d) Limitations. The following limitations apply to PVHOs designed in accordance with para. 1.4.7. For PVHOs not conforming to the following limitations, the external pressure design shall be as required by the specified Division of Section VIII of the Code.

(I) The maximum outside radius ***R,*** shall not exceed 60 in. (1.500 mm).

(2) The maximum shell thickness, including corrosion allowance, shall not exceed 2 in. (50 mm).

(3) The minimum shell thickness, excluding corrosion allowance, shall not be less than 3/8 in. (IO mm).

(4) The maximum external design pressure shall not exceed 900 psig (6.2 MPa gage).

(5) The fabricated vessel, regardless of thickness, shall be postweld heat treated in accordance with the requirements of Section VIII, Part UCS (Division 1 design) or Article F-4 (Division 2 design). The PWHT shall be accomplished prior to conducting the external pressure test.

(6) Materials of construction are limited to ferrous materials.

(7) These rules are applicable only for spheres and spherical segments and are not applicable to cylindrical vessel parts and forms of other shapes.

(e) External Pressure Test

(I) Test Pressure. All spherical vessels and vessels with spherical segments designed in accordance with para. 1.4.7 shall be subjected to an external hydrostatic pressure test that subjects every part of the vessel to an external pressure *PT* not less than $1.25P_e$ to be marked on the vessel.

(2) Post Test Measurements. Measurements for determining the deviations specified in (c) above shall be taken after the external pressure hydrostatic test. Any deviations exceeding the limits of (c) above shall be corrected and the external pressure test repeated.

1.4.8 Windows

(a) The design pressure and temperature of the transparent materials shall meet, or exceed, the design pressure and temperature of the chamber.

(b) The design of transparent materials and their attachments to the chamber shall meet the requirements of Section 2 of this Standard.

(c) The transparent materials shall be fabricated by processes specihed in Section 2 of this Standard.

(d) The designer shall consider all loadings including, but not limited to, internal, external, hydrodynamic, hydrostatic, and thermal forces on the vessel.

1.5 Inspection and Tests of PVHOs

1.5.1 All Categories A, B, C, and D butt welds shall be 100% radiographed.

1.5.2 The reverse side of the root pass of double-welded joints must be sound. This must be shown by MT or PT examination. If necessary, chipping, grinding, or melting-out may be required to assure sound metal. Weld metal shall then be applied from the reverse side.

1.5.3 After hydrostatic tests, all pressure retaining welds shall be examined in accordance with the requirements for either magnetic particle examination (Section V, Article 7, of the Code), or liquid penetrant testing (Section V, Article 6, of the Code). The acceptance criteria shall be those of the applicable requirements of Section VIII of the Code.

1.5.4 All PVHOs designed for external pressure service shall be subjected to an external pressure hydrostatic test at 1.25 times the design pressure.

PVHOs designed for both internal and external pressure shall also be subjected to the internal hydrostatic test required by the specified Division of Section VIII of the Code.

1.5.5 PVHOs which incorporate viewports in their pressure boundary shall be subjected to the required internal and/or external pressure tests with the transparent materials mounted in their seats per Section 2, Article 7, at the time of the original chamber certification by the PVHO manufacturer.

1.5.6 In PVHO vessels which incorporate an intermediate head per 1.4.1(c), the butt weld joint shall be 100% radiographed and 100% ultrasonic examined per the requirements of Division 1.

1.6 Stamping and Reports of PVHOs

1.6.1 Each PVHO shall be marked with the following:

(a) the designation of this Standard, PVHO-1;

(6) name of the manufacturer of the pressure vessel, preceded by the words “certified by”;

(c) maximum allowable working pressure __ psi (internal) and/or __ psi (external) at _______“F maximum and/or _______°F minimum;

(d) manufacturer’s serial number; and

(e) year built.

1.6.2 The marking described in para. 1.6.1 shall be on a nameplate substantially as shown in Fig. 1.6-1. Nameplates shall be metal suitable for the intended service. Required nameplates shall be located in a conspicuous place on the vessel.

PVHO-1

Certified by

____

(Name of manufacturer)

__________ psi internal __________ psi external
(Max. allowable working pressures)

__________“F maximum __________“F minimum
(Design temperature range)

____

(Manufacturer’s serial number) (Year built)

FIG. 1.6-1 FORM OF NAMEPLATE

1.6.3 Nameplates may have markings produced by either casting, etching, embossing, debossing, stamping, or engraving, except that the PVHO-1 lettering shall be stamped on the nameplate.

(a) The required markings on a nameplate shall be in characters not less than $^5/_{32}$ in. high, except the lettering PVHO-1 shall be not less than $^3/_8$ in. high.

(6) Characters shall be either indented or raised at least 0.004 in. and shall be legible and readable.

1.6.4 The nameplate may be marked before it is affixed to the vessel, in which case the manufacturer shall ensure that the nameplate with the correct marking has been applied to the proper vessel.

1.6.5 The nameplate shall be attached to the vessel or to a pad, bracket, or structure which is welded or soldered directly to the vessel. The nameplates shall be located within 30 in. of the vessel. Removal shall require the willful destruction of the nameplate or its attachment system.

(a) Nameplates may be attached either by welding, brazing, or soldering.

(6) Nameplates may be attached by tamper-resistant mechanical fasteners of suitable metal construction.

1.6.6 In addition to the requirements of paras. 1.6.1 through 1.6.5, the stamping requirement of the specified Division of Section VIII of the Code shall be met.

1.6.7 The data report form from the specified Division of Section VIII of the Code shall be attached to the Manufacturer’s Data Report, Form PVHO- I.

1.6.8 Windows in the PVHO shall be marked as required by Section 2 of this Standard.

FORM PVHO-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS FOR HUMAN OCCUPANCY
As Required by the Provisions of ASME PVHO-1

1. Manufactured and certified by ______
2. Manufactured for ______
3. Location of installation ______
4. Type ______
(drawing no.) (mfr serial no.) (year built)
5. The chemical and physical properties of all parts meet the requirements of material specifications of ASME PVHO-1-______ (year) and Addenda to ______ (date) and Case Nos. ______ In addition, the design, construction, and workmanship conform to ASME Section VII, Division ___ (1 or 2), ______ (year) and Addenda to ______ (date) and Code Case Nos. ______
6. Constructed for maximum allowable working pressure of ______ psi (internal) and/or ______ psi (external); at a maximum temperature of ______ °F and/or minimum temperature of ______ °F; and hydrostatic test pressure of ______ psi (internal) and/or ______ psi (external).
7. Service: Fatigue analysis required ______
(yes or no) (describe service)
8. Windows: Certification Reports, properly identified and signed by the window fabricator, are attached for the following items.

No.	Location	Type	Diameter or Size	Nominal Thickness	How Attached

9. Manufacturer's Data Reports/Partial Data Reports, completed in accordance with the ASME BPV Code, Section VIII, Division ______ (1 or 2), and properly identified and signed by Commissioned Inspectors, are attached for the following items (use Form PVHO-1S for additional items, if necessary).

Data Report	Remarks (name of part, manufacturer's name, and identifying stamp)

CERTIFICATION OF DESIGN

User's Design Specification on file at ______
Manufacturer's Design Report on file at ______
User's Design Specification certified by ______ P.E. State - Reg. no. ______
Manufacturer's Design Report certified by ______ P.E. State - Reg. no. ______

CERTIFICATION OF COMPLIANCE

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

ASME Certificate of Authorization ______ (U or U2) Certificate no. ______ Exp. date ______
Date ______ , 19 ______ Company name ______ Signed ______
(PVHO mfr.) (representative)

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FORM PVHO-1S MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET
As Required by the Provisions of ASME PVHO-1

1. Manufactured and certified by ____________________
2. Manufactured for ____________________
3. Location of installation ____________________
4. Type ____________________ (drawing no.) (mfr. serial no.) (year built)

Data Report	Remarks (name of part, manufacturer's name, and identifying stamp)

Date __________, 19____ Company name ____________________ (PVHO mfr.) Signed ____________________ (representative)

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1.7 PVHO Pressure Relief Devices

1.7.1 The need to maintain control of the pressure within chambers necessitates the inclusion of in-service operational requirements for pressure relief devices. Pressure excursions can be hazardous to individuals undergoing decompression, and there shall always be persons in attendance to monitor the PVHO in the event of an accident. Therefore, the following requirements shall be met for pressure relief devices installed on chambers.

(a) The applicable provisions of Section VIII, UG-125 through UG-136 (Division I), or Part AR (Division 2), shall be met.

(b) A quick-operating manual shutoff valve shall be installed between the chamber and the pressure relief valve, and shall be normally sealed open with frangible seal as permitted in Section VIII, UG-135(e) and Appendix M of Division 1 and Appendix A of Division 2. The valve shall be readily accessible to the attendant monitoring the operation of the chamber.

(c) Rupture disks shall not be used, except in series, with pressure relief valves to prevent gas leakage, and shall meet all other applicable requirements of the Code.

SECTION 2
VIEWPORTS

ARTICLE 1 GENERAL

2-1.1

The term *viewport* is defined, for the purpose of this Standard, as a penetration in the pressure vessel including the window, flange, retaining rings, and seals. The term window shall refer to the transparent, impermeable, and pressure resistant insert in the viewport.

2-1.2

The windows covered by this Standard are intended for use only in chambers with window service conditions defined by:

(a) maximum allowable working pressure, equal to design pressure;

(b) maximum temperature at design pressure, equal to design temperature;

(c) pressure cycles at design pressure and temperature.

2-1.3

The windows covered by this Standard are not intended for chambers where any of the following restrictions on design parameters are exceeded.

(a) The operating temperature shall be within the 0 to 150°F (-18 to 66°C) temperature range:

(b) The pressurization or depressurization rate shall be less than 145 psi/sec (1 MPa/s).

(c) The contained fluid (external or internal) shall be only water, seawater, air, or gases used in life support systems.

(d) The number, or the total duration, of pressure cycles during the operational life of the window shall not exceed 10,000 cycles or 40,000 hr, respectively.

(e) The maximum operational pressure shall not exceed 20,000 psi (138 MPa).

(f) The exposure to nuclear radiation shall not exceed 4 megarads.

(g) The design life of the windows shall not exceed the time limits specified in para. 2-2.7.

2-1.4

Windows covered by this Standard include windows manufactured during original construction and windows used as replacements during the service life of the chamber.

2-1.5

Each window shall be individually identified by the window fabricator in accordance with para. 2-6.1.

2-1.6

The window fabricator shall provide an overall window certification which shall certify that the window has been fabricated in accordance with all applicable requirements of the Standard (see Form PVHO-2 for a representative certification form). The window certification shall provide traceability of the window throughout all processes, associated with its manufacture.

2-1.7

In addition to the overall window certification, the following certifications shall be required for a window to be considered acceptable for use in chambers.:

(a) a *design certification* for each window and matching viewport assembly that shall include a summary of engineering calculations and/or a description of the experimental method and data used to verify compliance of the window design with the requirements. of this Standard (see Section '2, Article 2, for design requirements);

(b) a *material manufacturer's certification* for each lot: of acrylic that shall certify that the material meets

or exceeds the minimum values of physical properties specified in Table 2-3.1 for each lot and verify for each casting or lot (see Section 2, Article 3, for material certification requirements);

(c) a ***material certijcation*** for each window shall certify that the material meets the minimum values specified in Table 2-3.2 and that these properties have been experimentally verified. Average values specified in Table 2-3.2 shall be reported (see Section 2, Article 3, for material certification requirements); and

(d) a ***pressure testing certification*** for each window that shall describe the pressure, temperature, pressurization rate, duration of sustained loading, and viewport flange or test fixture used during the pressure test (see Section 2, Article 7, for pressure testing requirements).

ARTICLE 2 DESIGN

2-2.1 General

The manufacturer of the chamber shall be responsible that the viewport design is adequate for the design conditions of the chamber. Particular attention shall be paid to design consideration of the window, including, but not limited to, the design pressure, the temperature at design pressure, and the cyclic life at design pressure.

2-2.2 Standard Window Geometry

2-2.2.1 Acrylic windows in chambers must have one of the standard geometries shown in Figs. 2-2.1 through 2-2.4. Minimum acceptable thickness ratios shall comply with the requirements of Figs. 2-2.1 through 2-2.4 for the specific window geometry. (For acceptance of nonstandard window geometries, see para. 2-2.6.)

2-2.2.2 Calculations of the short-term critical pressure (STCP), on the basis of Figs. 2-2.1 through 2-2.4, satisfy the requirements of the design certification required by this Standard under para. 2-1.7(a).

2-2.2.3 It shall also be acceptable to establish the STCP by conducting a series of destructive tests on full-scale or model-scale windows performed in accordance with the procedure in para. 2-2.5.2.

2-2.3 Determination of Dimensions for Standard Geometry Windows

2-2.3.1 The dimensions of a standard window in the 0 to 10,000 psi (0 to 69 MPa) design pressure range shall be based solely on the window's STCP and the approved conversion factor (CF) for the given maximum ambient temperature. Minimum STCP values of standard window geometries are given in Figs. 2-2.5 through 2-2.16. Conversion factor values for standard window geometries are given in Tables 2-2.1 through 2-2.5.

2-2.3.2 The dimensions of windows in the 10,000 to 20,000 psi (69 to 138 MPa) design pressure range shall be based solely on nondestructive tests in the form of long-term and cyclic pressutizations. Dimensions of approved windows for this design pressure range are given in Table 2-2.6. Only conical frustum windows with included angle of 90 deg. or larger are qualified for this pressure range.

2-2.4 Determination of Conversion Factor by Table Method

2-2.4.1 When selecting the conversion factors from Tables 2-2.1 through 2-2.5, temperature ranges must be chosen on the basis of highest ambient sustained temperature expected during operation of the chamber at the design pressure.

(a) If the chamber interior is illuminated by externally mounted incandescent lights shining through the windows, the 150°F (66°C) temperature range shall be mandatory in the selection of conversion factors for all windows.

(b) If the chamber is not illuminated with externally mounted lights, the temperature ranges shall be chosen on the basis of environmental temperature where the chambers reach design pressure. If the design pressure is reached when:

(1) ***only submerged in water,*** use the ambient temperature of water at that depth;

(2) ***only in air,*** use the average of the maximum ambient external and internal air temperatures;

(3) either in air or in water, use the average maximum ambient external and internal air temperatures.

2-2.4.2 When a viewport is subjected to pressurization from both sides, the conversion factor used for the window design must be determined on the basis of the highest design pressure, regardless of whether this pressure is external or internal to the chamber.

FORM PVHO-2 FABRICATION CERTIFICATION FOR ACRYLIC WINDOWS
As Required by the Provisions of ASME PVHO-1

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 (per ASTM D 638) ______________________

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

Polishing agents ______________________

Cleaning agent ______________________

Fabrication Process Data

First annealing temperature ______________________

Duration ______________________

Cooling rate ______________________

Intermediate annealing temperature (if any) ______________________

Duration ______________________

Cooling rate ______________________

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 ________ and company ______________________ drawing number ________, revision ________, dated ______________________

____
Authorized representative of window fabricator

____
Date

____
Name and address of window fabricator

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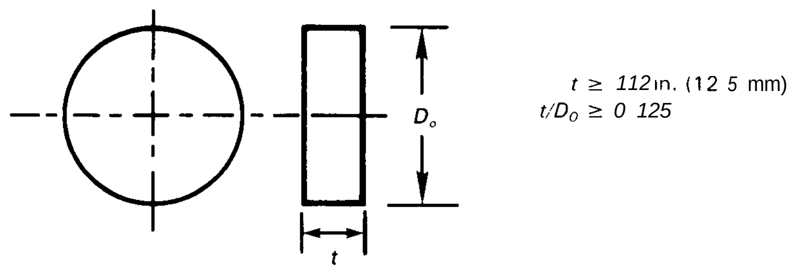
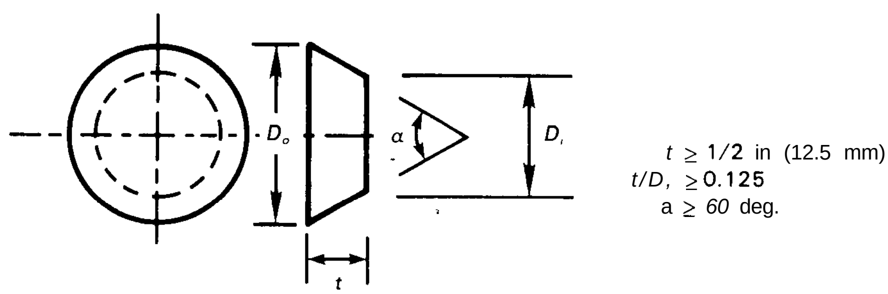
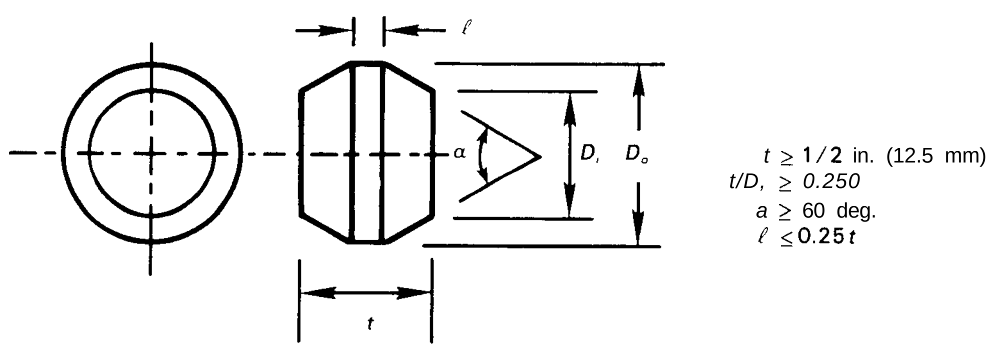


(a) Flat Disk Window

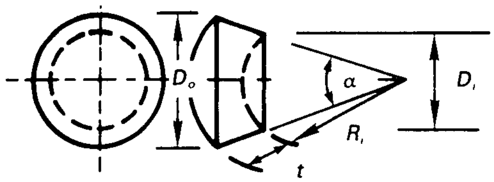


(b) Conical Frustum Window



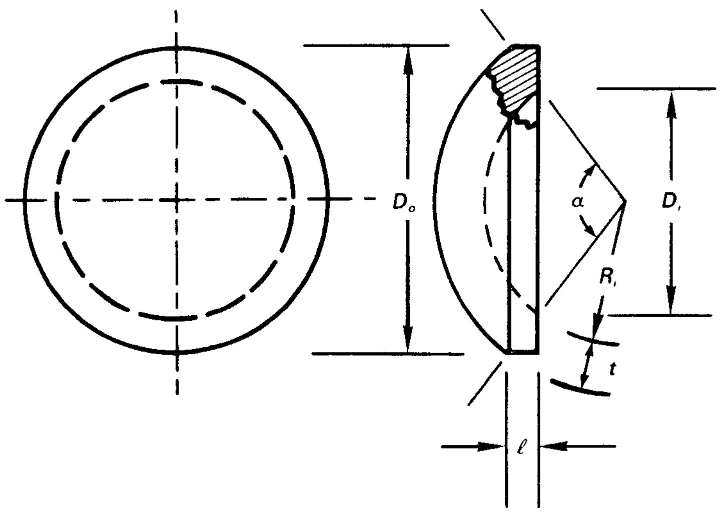
(c) Double Beveled Disk Window

FIG. 2-2.1 STANDARD WINDOW GEOMETRIES



$t \geq 1/2$ in. (12.5 mm)
$\alpha \geq 60$ deg.
$t/R_i \geq 0.09$ for $\alpha \geq 60$ deg.
$t/R_i \geq 0.06$ for $\alpha \geq 90$ deg.
$t/R_i \geq 0.03$ for $\alpha = 180$ deg.

(a) Spherical Sector Window With Conical Edge



$t \geq 1/2$ in. (12.5 mm)
$30 \text{ deg.} \leq \alpha \leq 150$ deg.
$t/R_i \geq 0.03$
$D_i = 2 R_i \sin \alpha/2$
$D_o = 2 R_o \sin \alpha/2$
$R_o = R_i + t$
$\ell = t \sin (90 \text{ deg.} - \alpha/2)$

(b) Spherical Sector Window With Square Edge

FIG. 2-2.2 STANDARD WINDOW GEOMETRIES

2-2.5 Determination of Short-Term Critical Pressure

2-2.5.1 The STCP of a window accepted for service in chambers, without the use of experimental data, shall not be less than

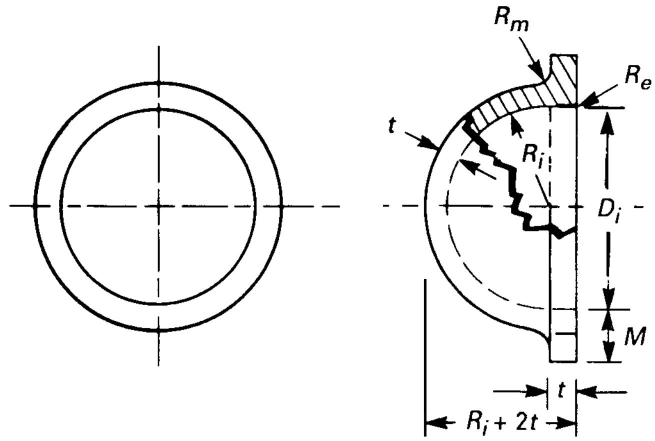
$$\text{STCP} = (\text{CF} \times P)$$

where CF and P are the conversion factor and design pressure, respectively.

(a) For *flat disk acrylic windows,* shown in Fig. 2-2. I, use conversion factors from Table 2-2. 1 and STCPs from Figs. 2-2.5, 2-2.6, and 2-2.7. Figure 2-2.5 shall be utilized for determination of critical pressures in the 72.5 to 1160 psi (0.5 to 8 MPa) range. Figure *2-2.6* shall be used for the 1160 to 7250 psi (8 to 50 MPa) range, and Fig. 2-2.7 shall be used for the 7250 to 43,500 psi (50 to 300 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2.

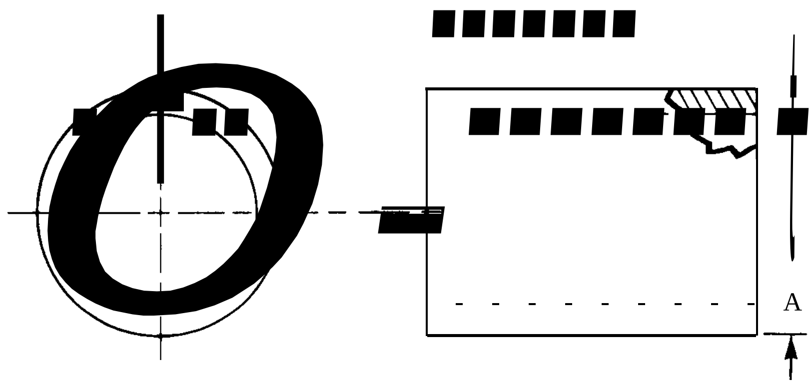
(b) For *conical frustum acrylic windows,* shown in Fig. 2-2.1, use conversion factors from Table 2-2.2 and STCPs from Figs. 2-2.8 and 2-2.9. Figure 2-2.8 shall be utilized for determination of critical pressures in the 290 to 7250 psi (2 to 50 MPa) range, while Fig. 2-2.9 shall be used for the 7250 to 43,500 psi (50 to 300 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2. Windows of this type are accepted for service only where the pressure is applied to the base of the frustum.

(c) For *double beveled disk acrylic windows,* shown in Fig. 2-2.1, use conversion factors from Table 2-2.2 and STCPs from Figs. 2-2.8 and 2-2.9. Figure 2-2.8 shall be utilized for determination of critical pressures in the 290 to 7250 psi (2 to 50 MPa) range, while Fig. 2-2.9 shall be used for the 7250 to 43,500 psi (50 to 300 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2.



$t \geq 1/2$ in. (12.5 mm)
$t/R_i > 0.03$
$D_o = (D_i + 4t)$
$R_m \geq 1/8$ in. (3.0 mm)
0.5 mm $\leq R_e \leq 0.125t$
$1.5t \leq M \leq 2.0t$

(a) Hemispherical Window With Equatorial Flange



$t \geq 1/2$ in. (12.5 mm)

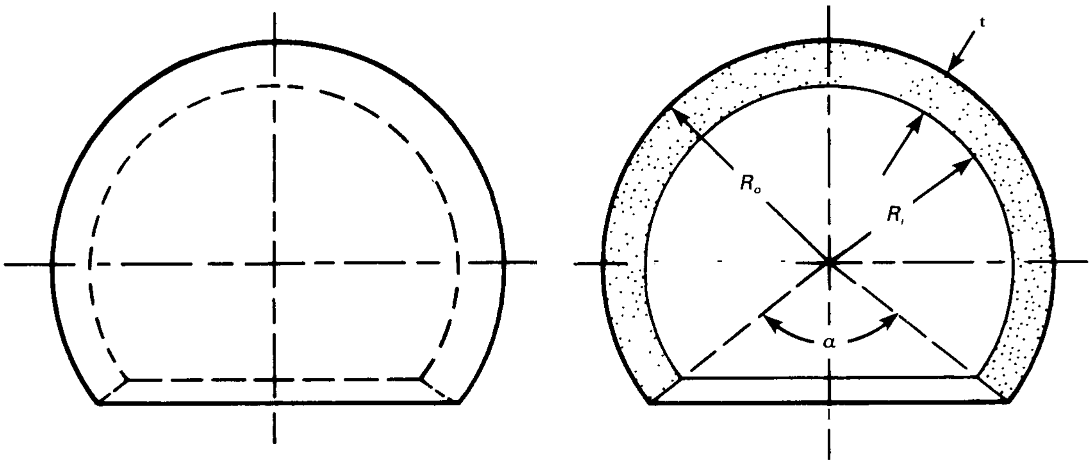
(b) Cylindrical Window

(97) FIG. 2-2.3 STANDARD WINDOW GEOMETRIES

(d) For *spherical Sector acrylic windows with conical edge,* shown in Fig. 2-2.2, use conversion factors from Table 2-2.3 and STCPs from Figs. 2-2.10 and 2-2.1 l. Figure 2-2.10 shall be utilized for determination of critical pressures in the 725 to 7250 psi (5 to 50 MPa) range, while Fig. 2-2.1 l shall be used for the 7250 to 34,800 psi (50 to 240 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2. Windows of this type are accepted for service only where the hydrostatic pressure is applied to the convex face.

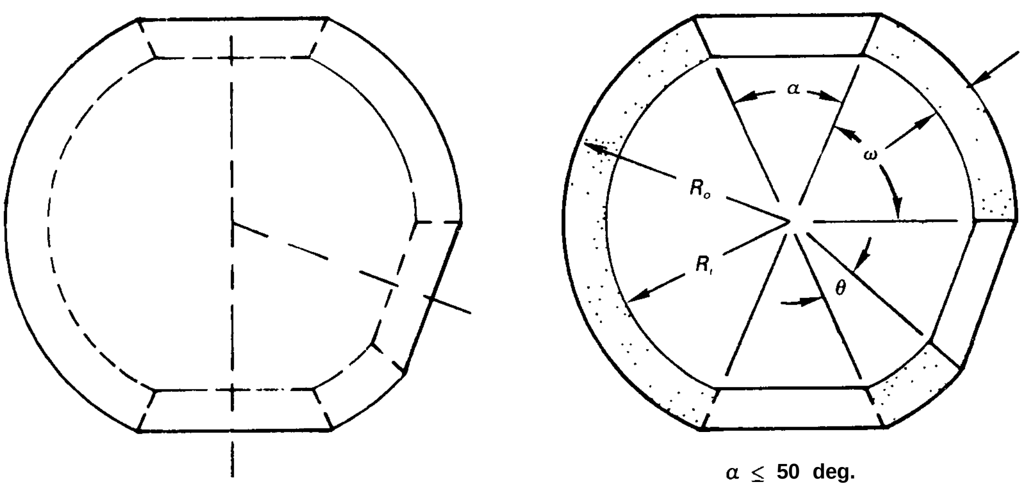
(e) For *spherical sector acrylic windows with square edge,* shown in Fig. 2-2.2, use conversion factors from Table 2-2.4 and STCPs from Figs. 2-2. IO and 2-2. I I. Figure 2-2.10 shall be utilized for determination of critical pressures in the 725 to 7250 psi (5 to 50 MPa) range, while Fig. 2-2.1 I shall be used for the 7250 to 34,800 psi (50 to 240 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2. Windows of this type are accepted for service only where the hydrostatic pressure is applied to the convex surface.

(f) For *hemispherical windows with equatorial flange*, shown in Fig. 2-2.3, use conversion factors from Table 2-2.4 and short-term critical pressures from Figs. 2-2.10 and 2-2.1 l. Figure 2-2.10 shall be utilized for determination of critical pressures in the 725 to 7250 psi (5 to 50 MPa) range, while Fig. 2-2.1 l shall be used for the 7250 to 34,800 psi (50 to 240 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2. Windows of this type are accepted for service only where the hydrostatic pressure is applied to the convex surface.



$t \geqslant 1/2$ in. (12.5 mm)
$0.03 \leqslant t/R_o \leqslant 0.355$
$\alpha \leqslant 100$ deg.

(a) Hyperhemispherical Window



$t \geqslant 1/2$ in. (12.5 mm)
$0.03 \leqslant t/R_o \leqslant 0.355$

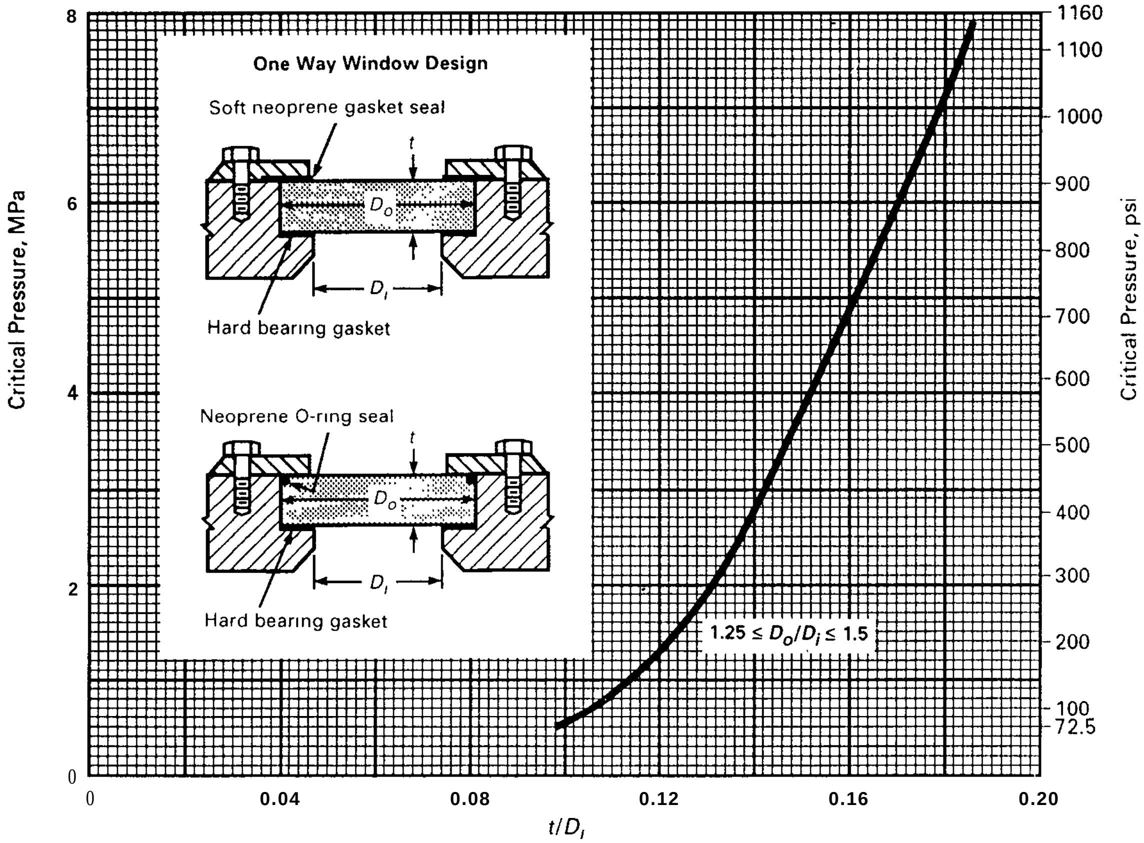
$\alpha \leq 50$ deg.

ω, θ = spacing between adjacent penetrations shall exceed $\alpha/2$ of the larger penetrations

(b) NEMO Window

FIG. 2-2.4 STANDARD WINDOW GEOMETRIES

Reference: Technical Report R 527, "Windows for External or Internal Hydrostatic Pressure Vessels - Part II," J.D. Stachiw et al., Naval Civil Engineering Laboratory, Port Hueneme, California, USA, 1967.

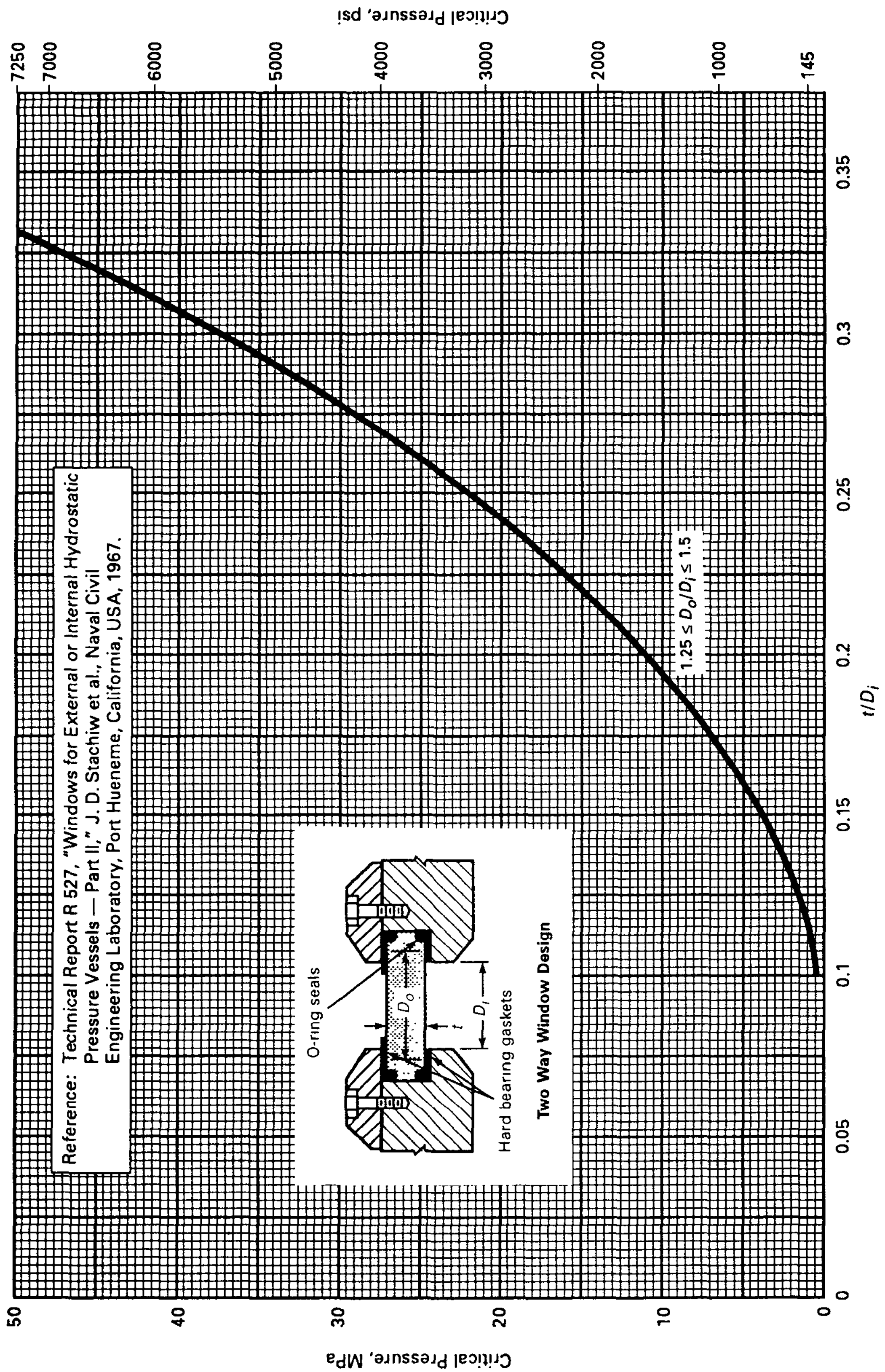


(97) FIG. 2-2.5 SHORT-TERM CRITICAL PRESSURE OF FLAT DISK ACRYLIC WINDOWS [For Pressures in the 72.5-1160 psi (0.5-S MPa) Range1

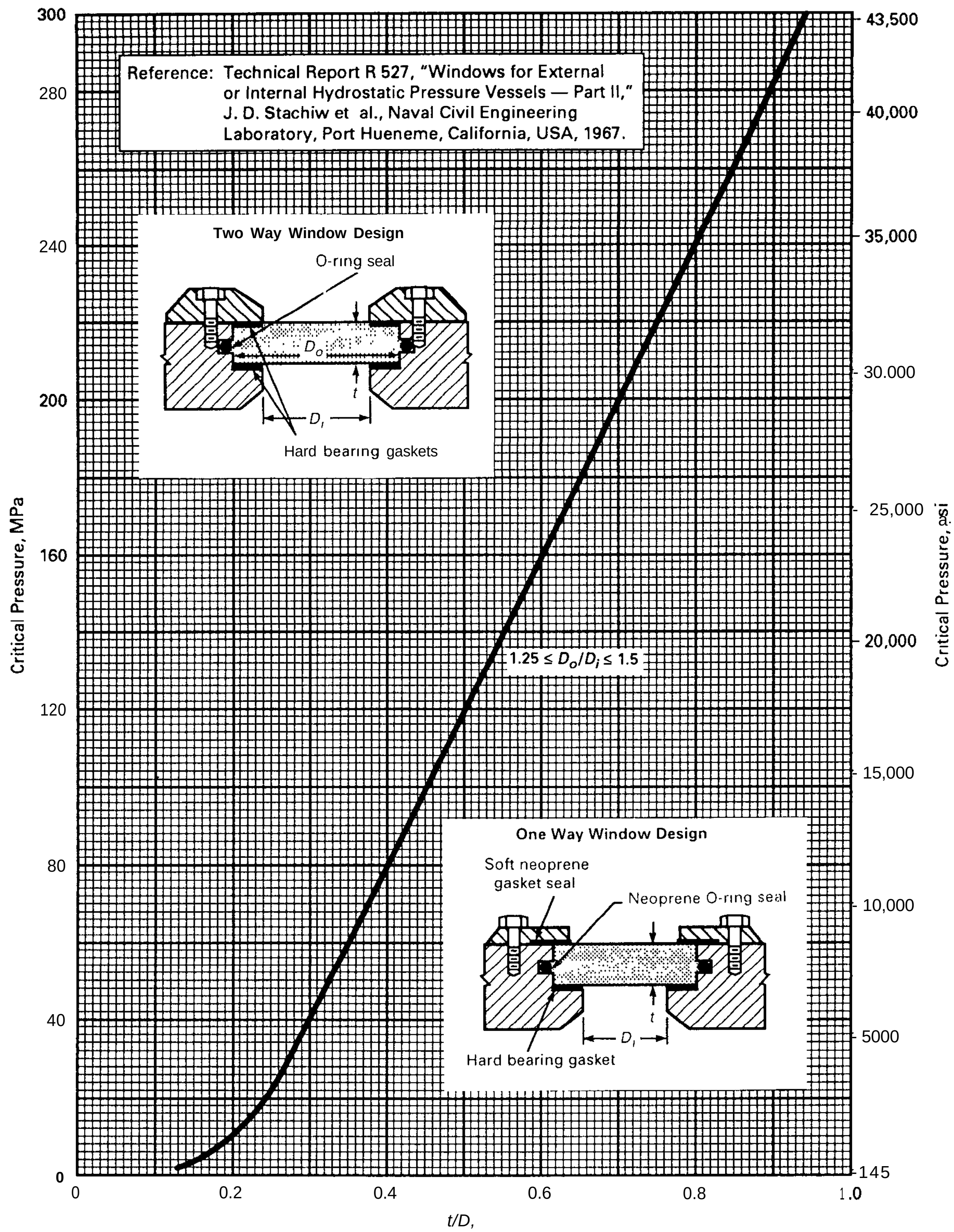
(g) For *cylindrical acrylic windows,* shown in Fig. 2-2.3, use conversion factors from Table 2-2.5 and STCPs from Figs. 2-2.12 through 2-2.17. Table 2-2.5, Part A, and Figs. 2-2.12 and 2-2.13 shall be utilized only in determination of conversion factors and critical pressures for internal pressure service. Figure 2-2.12 shall be utilized for determination of critical pressures in the 14.5 to I 160 psi (I to 8 MPa) range, while Fig. 2-2.13 shall be used for the 1 160 to 5800 psi (8 to 40 MPa) range. Table 2-2.5, Part B, and Figs. 2-2.14 through 2-2.17 shall be utilized only in determination of conversion factors and critical pressures for external pressure service. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2.

(h) For *hyperhemispherical acrylic windows,* shown in Fig. 2-2.4, use conversion factors from Table 2-2.3 and STCPs from Figs. 2-2. 18 and 2-2.19. Figure 2-2. I8 shall be utilized for determination of critical pressures in the 435 to 5800 psi (3 to 40 MPa) range, while Fig. 2-2.19 shall be used for the 5800 to 23,200 psi (40 to 160 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2. Windows of this type are accepted for service where the hydrostatic pressure is applied only to the convex surface, or the hydrostatic pressures are applied to either surface, but the magnitude of internal design pressure does not exceed 5% of the external design pressure.

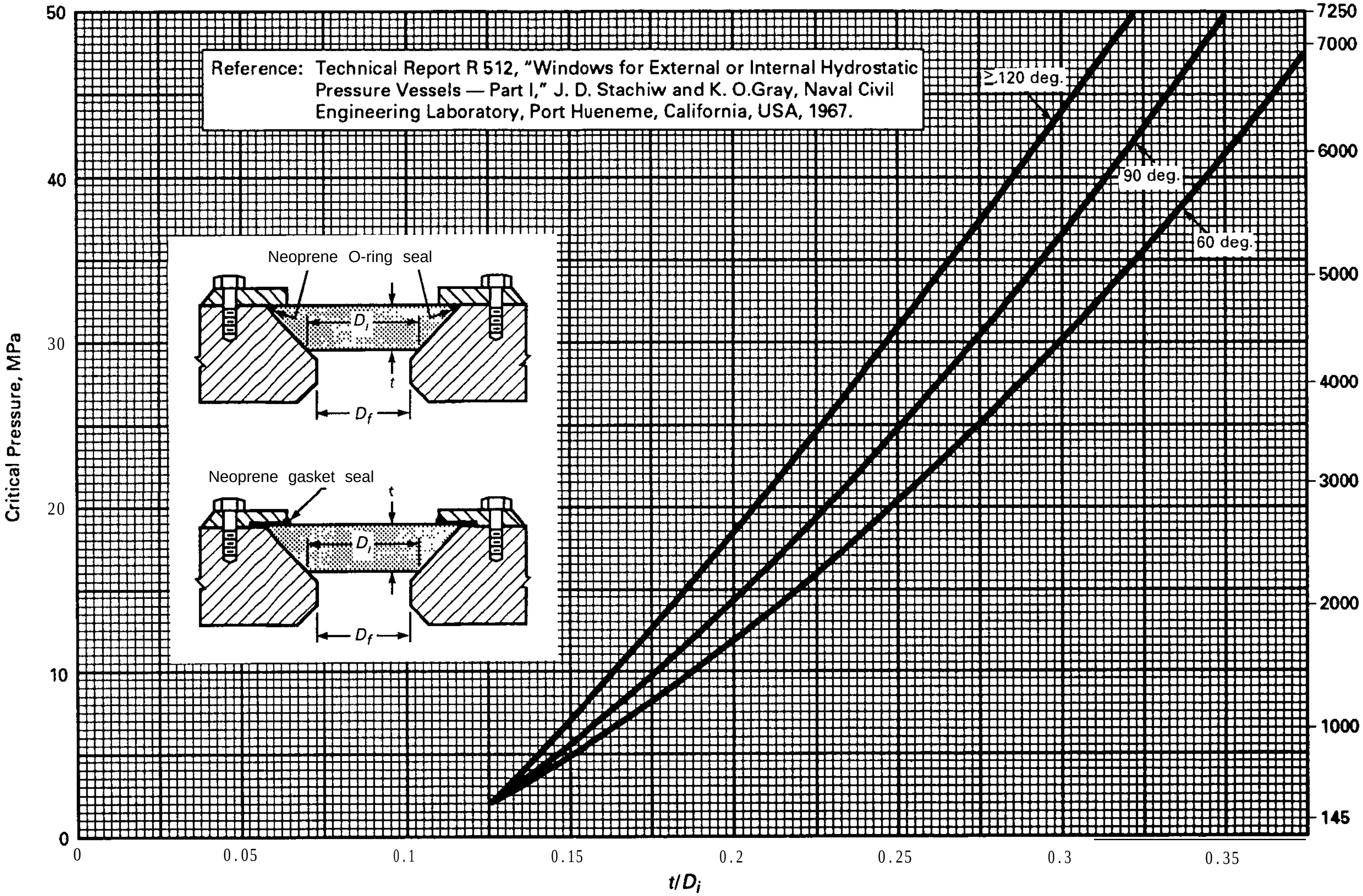
(i) For *NEMO acrylic windows,* shown in Fig. 2-2.4, use CFs from Table 2-2.3 and STCPs from Figs. 2-2. I8 and 2-2.19. Figure 2-2.18 shall be utilized for determination of critical pressures in the 435 to 5800 psi (3 to 40 MPa) range, while Fig. 2-2. 19 shall be used for the



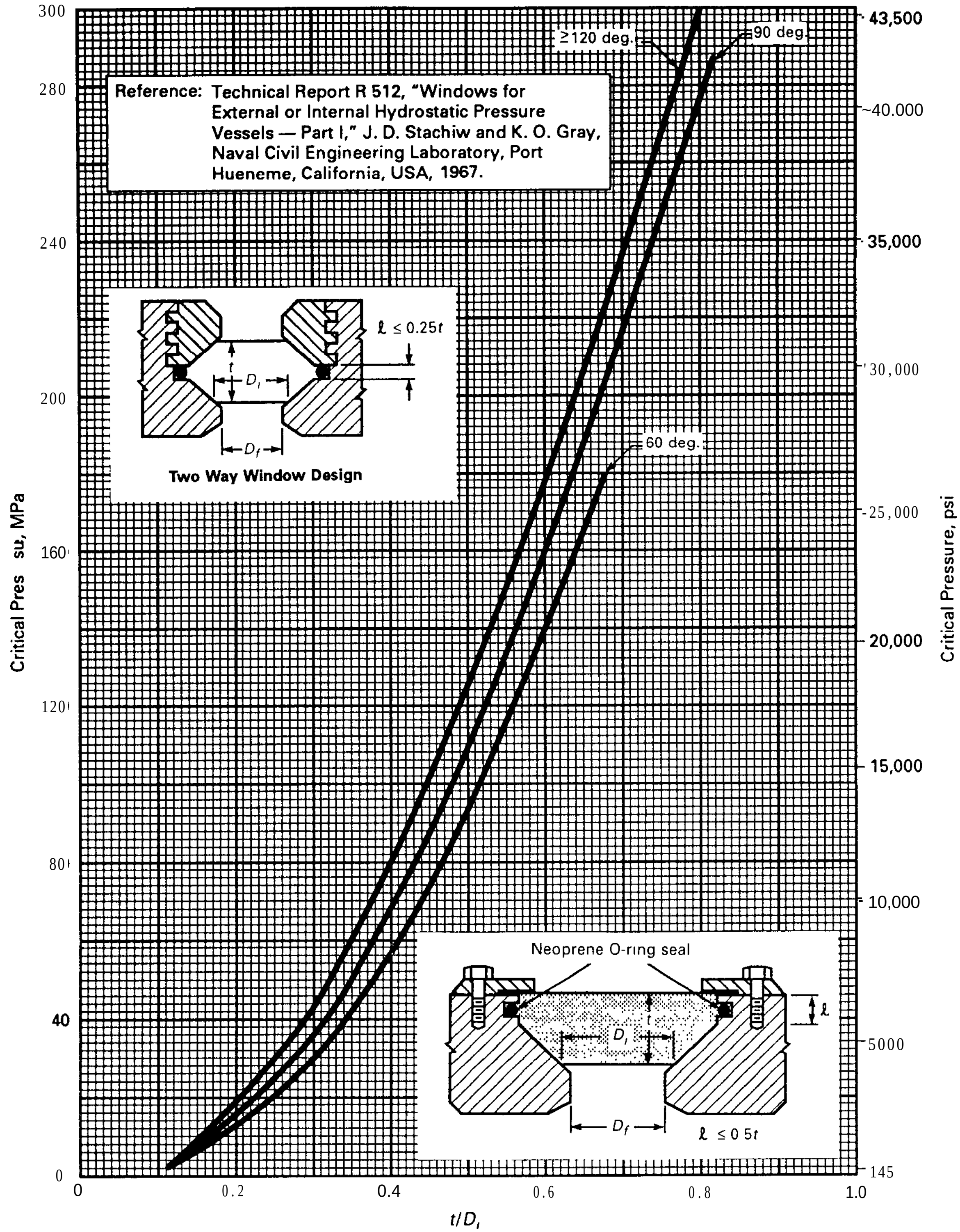
(97) **FIG. 2-2.6 SHORT-TERM CRITICAL PRESSURE OF FLAT DISK ACRYLIC WINDOWS**
[For Pressures in the 1160–7250 psi (8–50 MPa) Range]



(97) FIG. 2-2.7 SHORT-TERM CRITICAL PRESSURE OF FLAT DISK ACRYLIC WINDOWS
[For Pressures in the 7250–43,500 psi (50–300 MPa) Range]

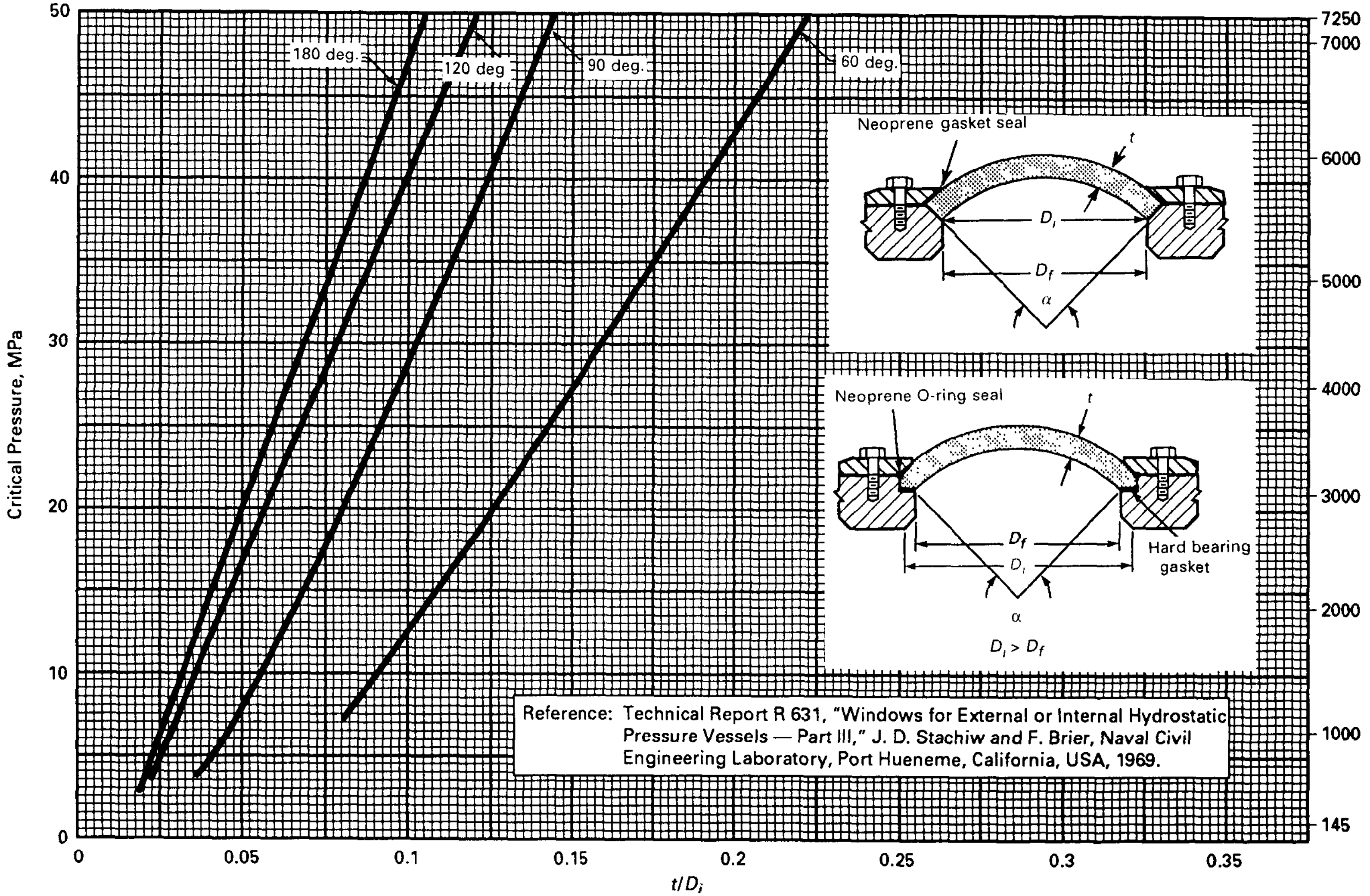


(97) **FIG. 2-2.8 SHORT-TERM CRITICAL PRESSURE OF CONICAL FRUSTUM ACRYLIC WINDOWS [For Pressures in the 290-7250 psi (2–50 MPa) Range1**

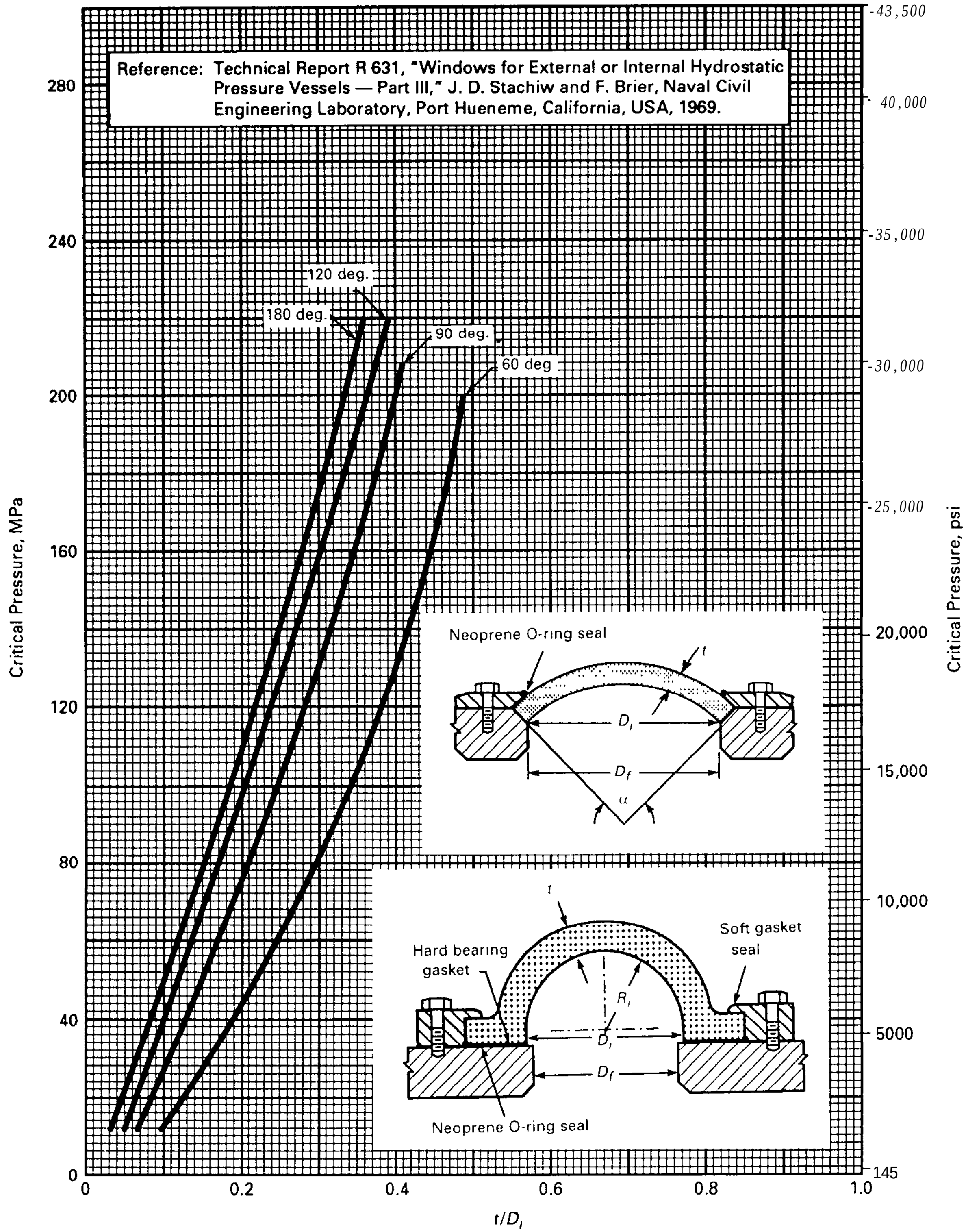


(97)

FIG. 2-2.9 SHORT-TERM CRITICAL PRESSURE OF CONICAL FRUSTUM ACRYLIC WINDOWS
[For Pressures in the 725043,500 psi (50-300 MPa) Range1

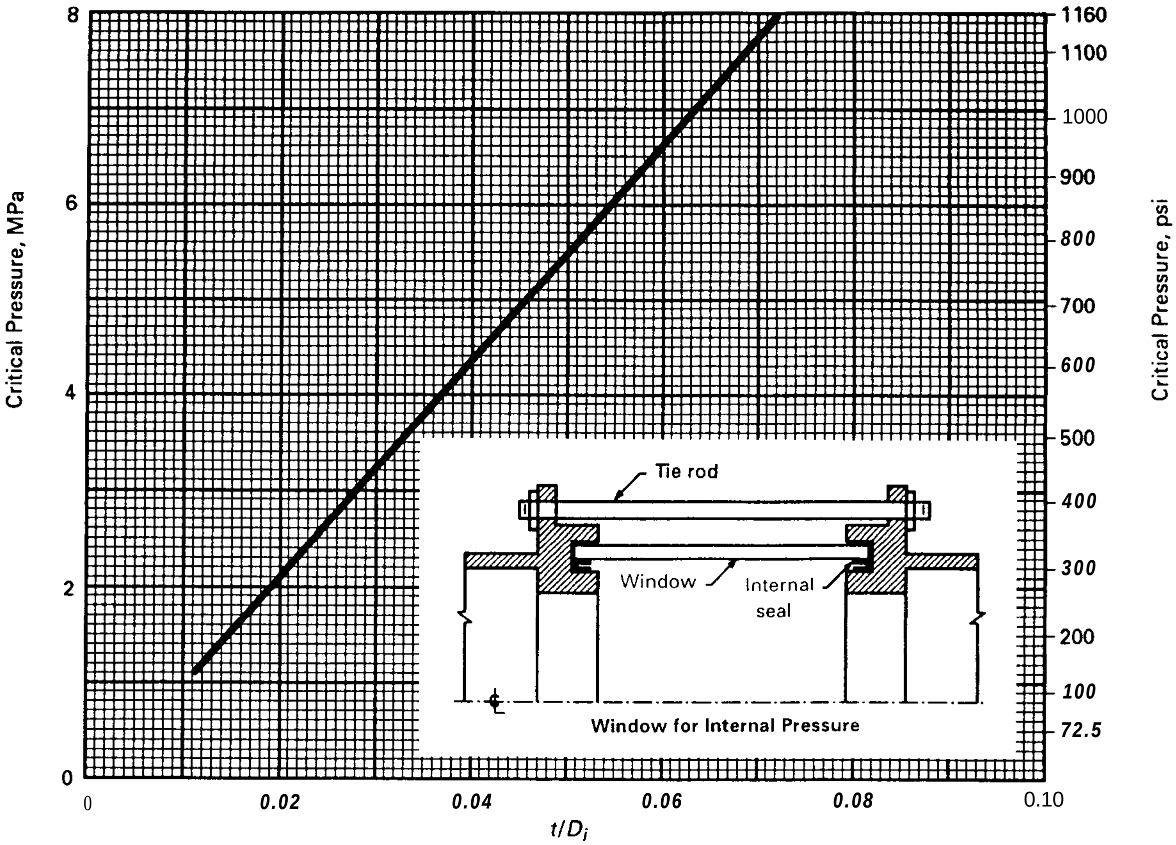


(97) **FIG. 2-2.10 SHORT-TERM CRITICAL PRESSURE OF SPHERICAL SECTOR ACRYLIC WINDOWS [For Pressures in the 725-7250 psi (5–50 MPa) Range1**



(97)

FIG. 2-2.11 SHORT-TERM CRITICAL PRESSURE OF SPHERICAL SECTOR ACRYLIC WINDOWS
[For Pressures in the 7250–34,800 psi (50-240 MPa) Range1



(97)

FIG. 2-2.12 SHORT-TERM CRITICAL PRESSURE OF CYLINDRICAL ACRYLIC WINDOWS PRESSURIZED INTERNALLY [For Pressures in the 145–1160 psi (1–8 MPa) Range1

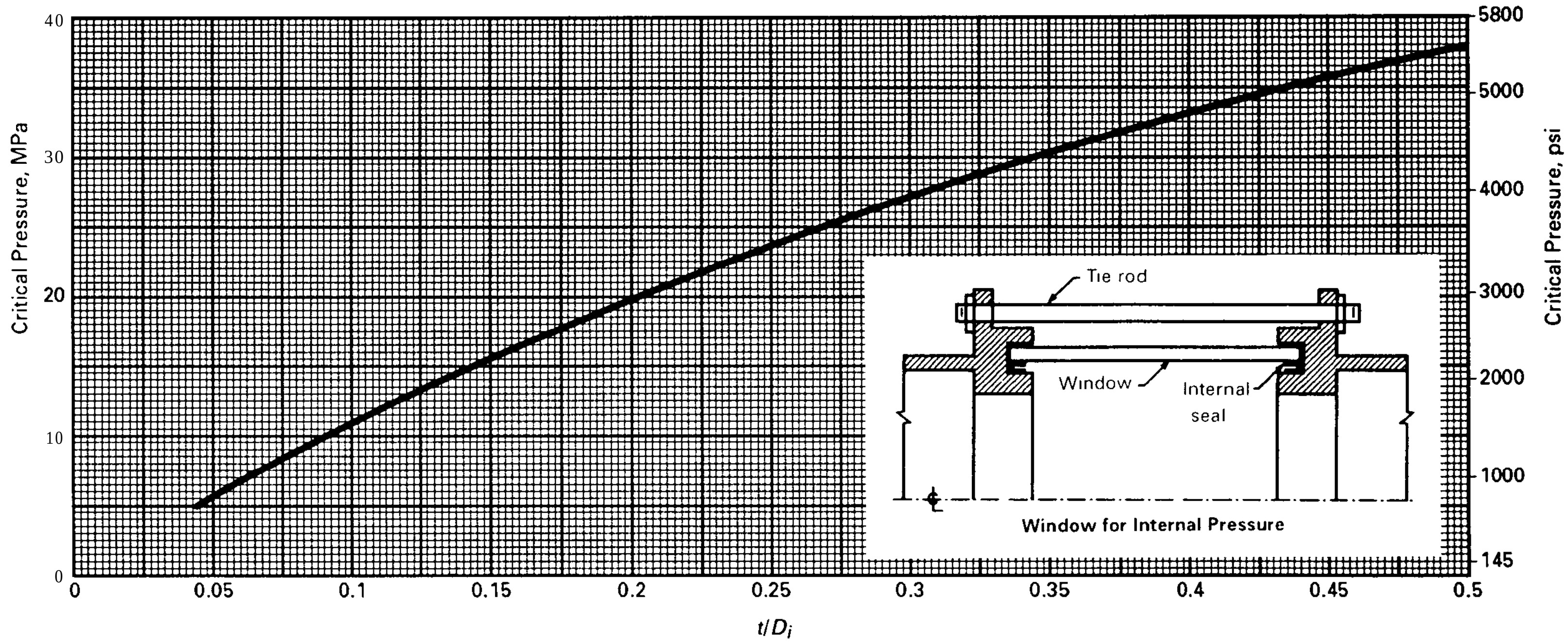
5800 to 23,200 psi (40 to 160 MPa) range. Short-term critical pressures may also be experimentally determined according to the procedure in para. 2-2.5.2. Windows of this type are accepted for service where the hydrostatic pressure is applied only to the convex surface, or the hydrostatic pressures are applied to either surface but the magnitude of the internal design pressure does not exceed 5% of the external design pressure.

2-2.5.2 The experimental determination of STCP of an acrylic window shall be conducted by subjecting the window to hydrostatic pressure which is increased, from ambient, at a constant rate of approximately 650 psi/min (4.5 MPa/min). The pressurization shall take place at ambient temperature range of 70 to 77°F (21 to 25°C) in a flange that satisfies the requirements of para. 2-2.9.

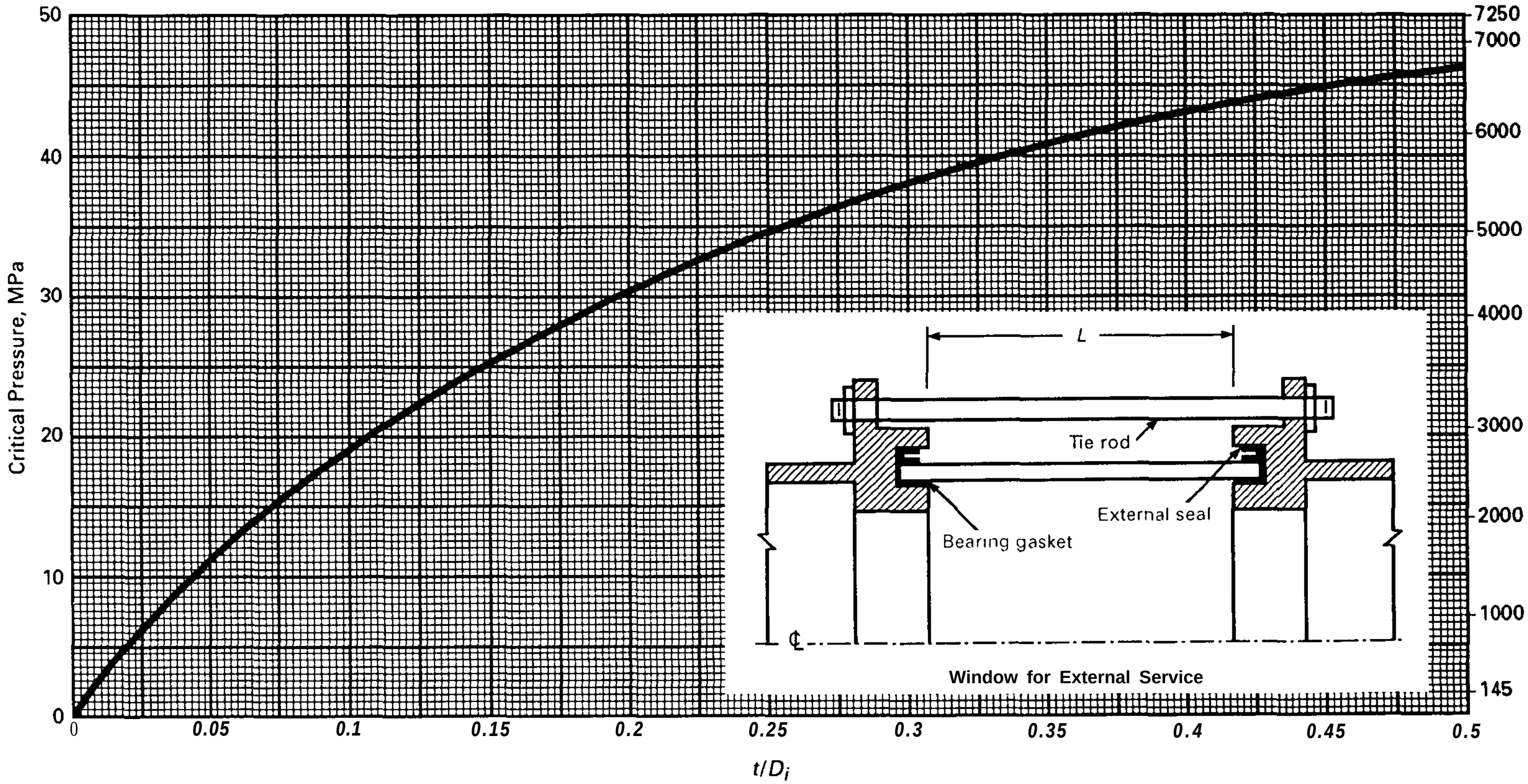
The evaluation of a window design is to be conducted on a minimum of five full-scale windows or on a minimum of five model-scale windows plus one full-scale window.

(a) For tests conducted on full-scale windows, the results generated will be considered representative only if the lowest STCP for any window is at least 75% of the mean STCP of the other four windows. In such a case, the STCP value of the window design is to be taken as the lowest critical pressure among the five tests. In the case where the lowest STCP does not meet this criterion, the STCP value of the window design is to be equal to the single lowest STCP among the five windows multiplied by a factor of 0.75.

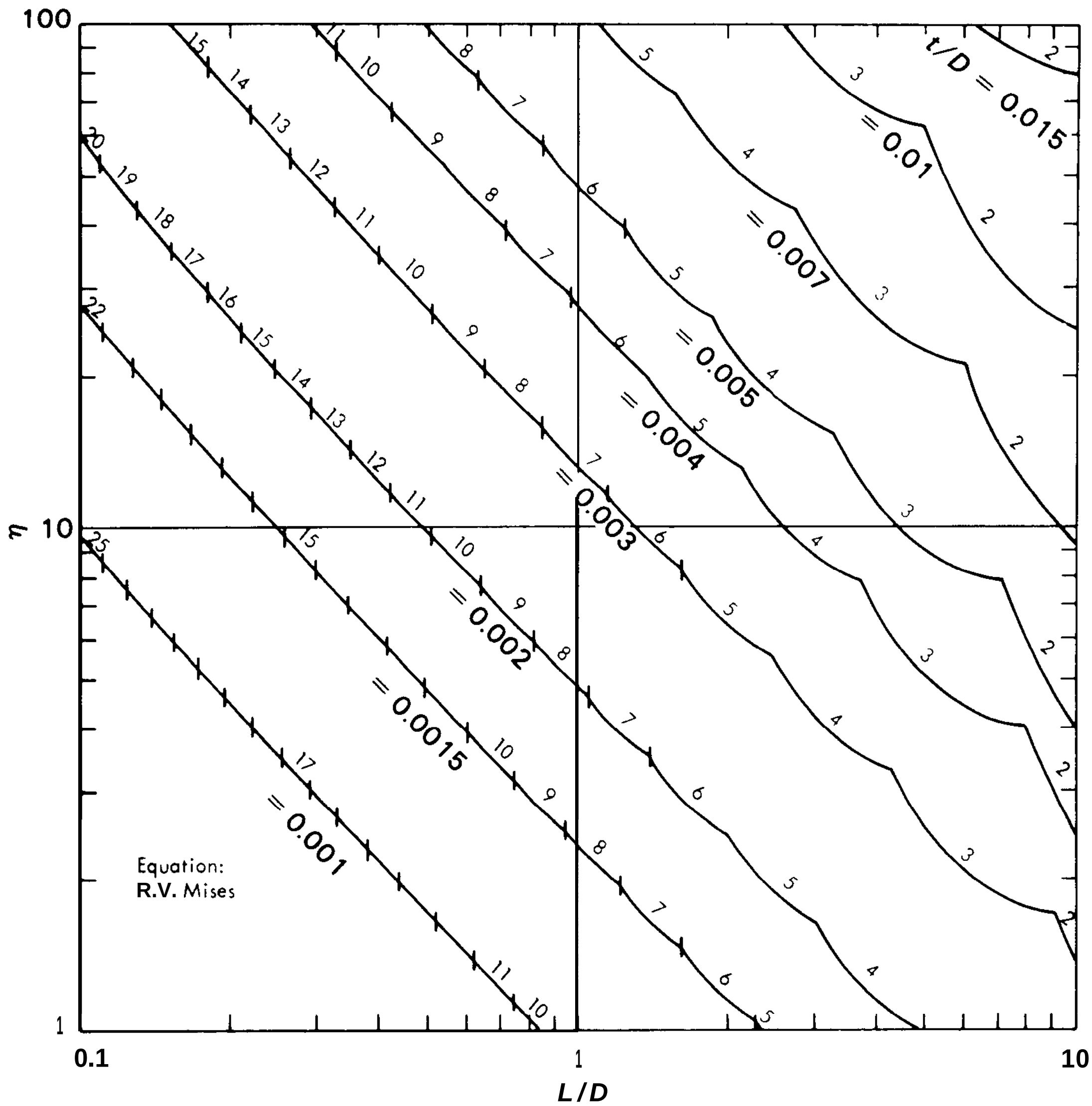
(b) For tests conducted on model-scale windows, the results will be considered acceptable only if the STCP of the full-scale window is equal to or above the single lowest STCP among the five model-scale windows. In case the STCP of the single full-scale window does not meet this criterion, four more full-scale windows shall be tested and the STCP value of the window design shall be calculated according to para. 2-2.5.2(a) solely on the basis of the full-scale window tests.



(97) FIG. 2-2.13 SHORT-TERM CRITICAL PRESSURE OF CYLINDRICAL ACRYLIC WINDOWS PRESSURIZED INTERNALLY
[For Pressures in the 1160-5800 psi (8–40 MPa) Range]



(97) **FIG. 2-2.14 SHORT-TERM CRITICAL PRESSURE OF CYLINDRICAL ACRYLIC WINDOWS PRESSURIZED EXTERNALLY**



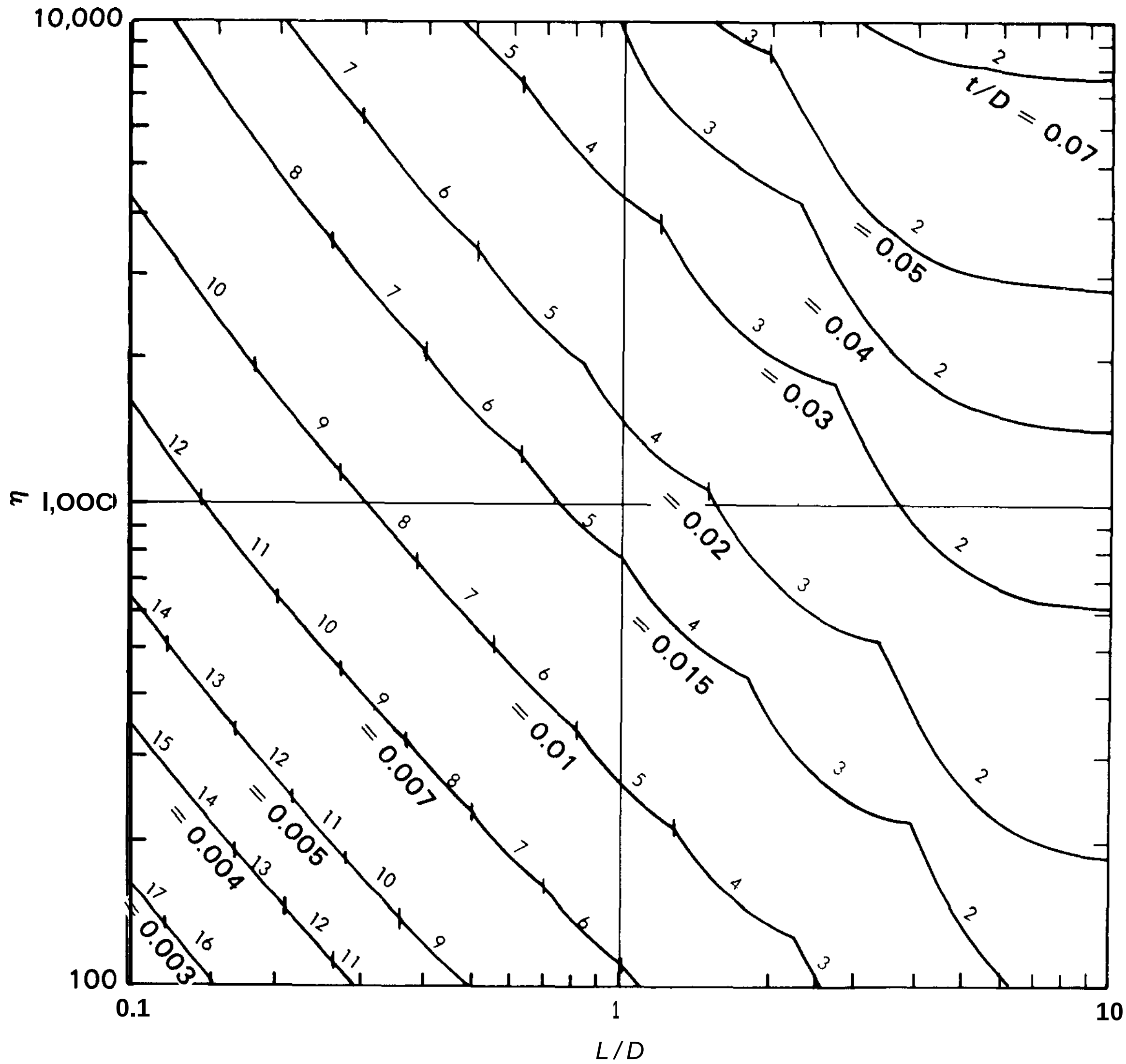
P_c = short term critical pressure

$P_c = \eta \times 3.499 \times 10^{-2}$ (psi)

$P_c = \eta \times 2.413 \times 10^{-4}$ (MPa)

$$D = \frac{D_i + D_o}{2}$$

(97) FIG. 2-2.15 SHORT-TERM ELASTIC BUCKLING OF CYLINDRICAL ACRYLIC WINDOWS BETWEEN SUPPORTS UNDER EXTERNAL HYDROSTATIC PRESSURE (t/D Range of 0.0014015)



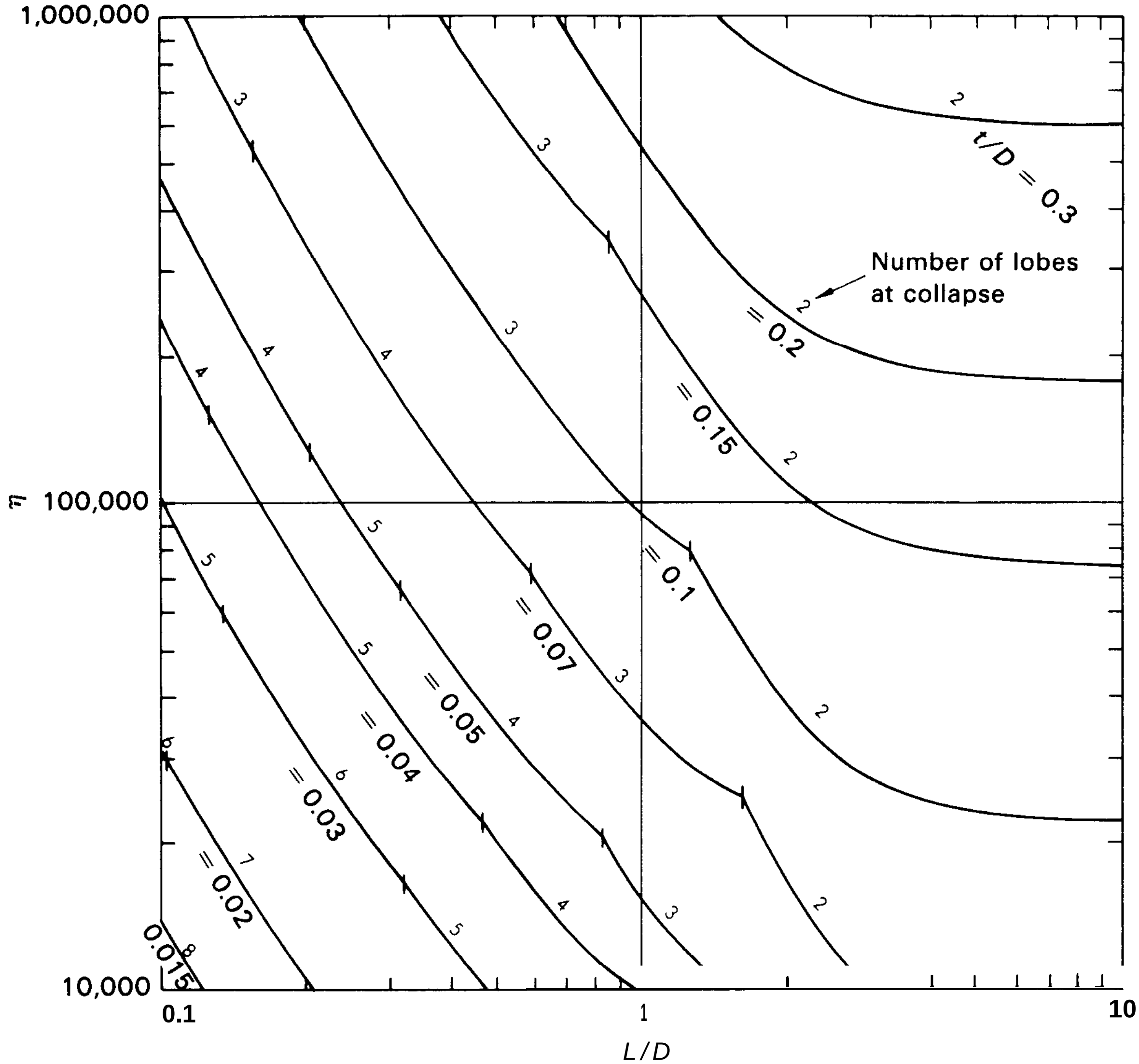
P_c = short term critical pressure

$P_c = \eta \times 3.499 \times 10^{-2}$ (psi)

$P_c = \eta \times 2.413 \times 10^{-4}$ (MPa)

$$D = \frac{D_i + D_o}{2}$$

(97) **FIG. 2-2.16 SHORT-TERM ELASTIC BUCKLING OF CYLINDRICAL ACRYLIC WINDOWS BETWEEN SUPPORTS UNDER EXTERNAL HYDROSTATIC PRESSURE**
(t/D **Range of 0.0034071**



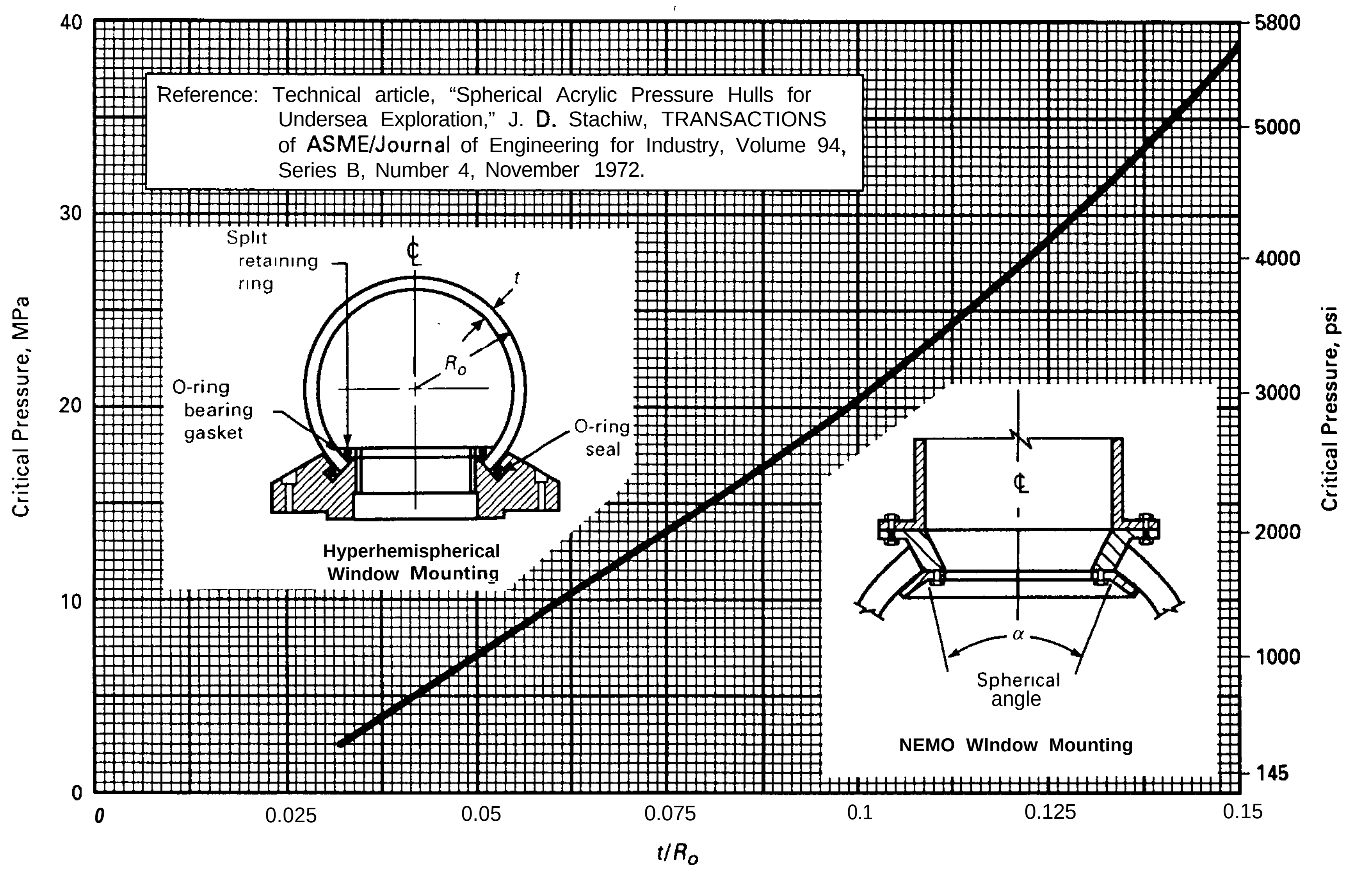
P_c = short term critical pressure

$P_c = \eta \times 3.499 \times 10^{-2}$ (psi)

$P_c = \eta \times 2.413 \times 10^{-4}$ (MPa)

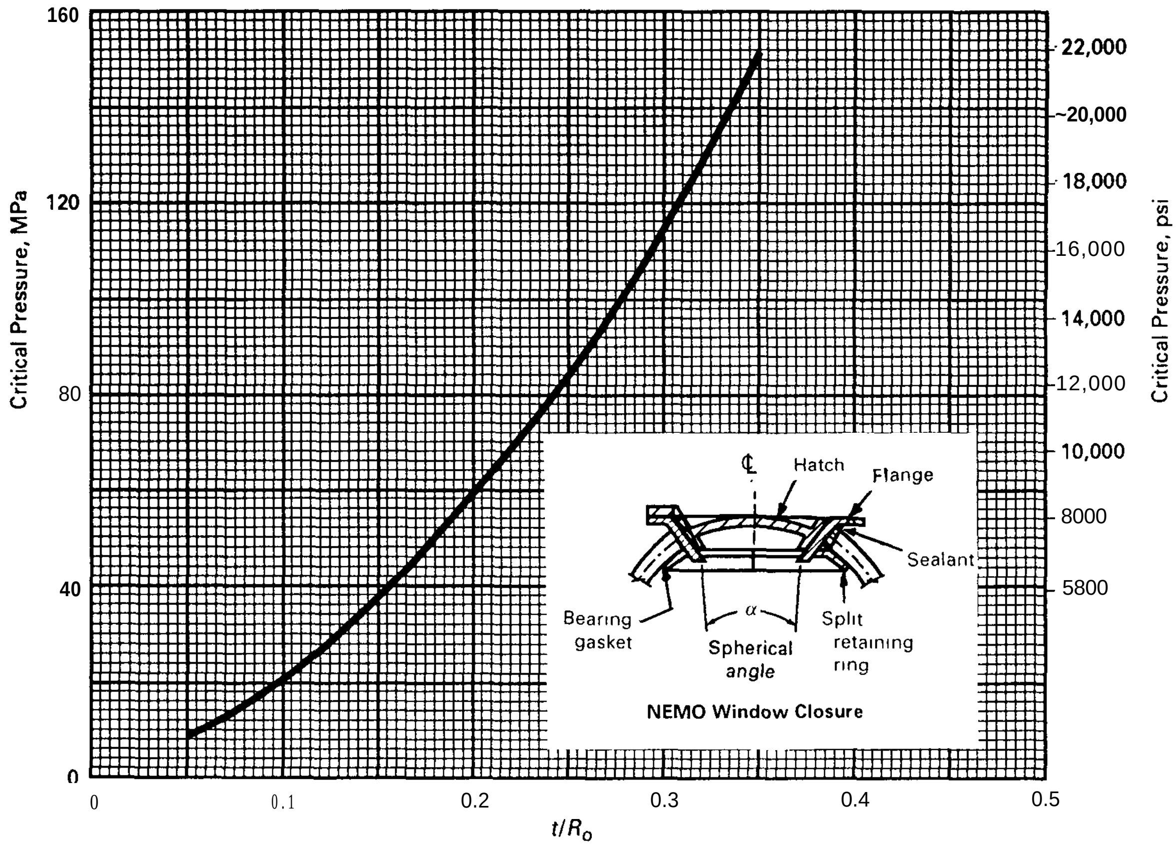
$$D = \frac{D_i + D_o}{2}$$

(97) **FIG. 2-2.17 SHORT-TERM ELASTIC BUCKLING OF CYLINDRICAL ACRYLIC WINDOWS BETWEEN SUPPORTS UNDER EXTERNAL HYDROSTATIC PRESSURE (*t/D* Range of 0.015–0.3)**



(97) **FIG. 2-2.18 SHORT-TERM CRITICAL PRESSURE OF HYPERHEMISPHERICAL AND NEMO TYPE ACRYLIC WINDOWS [For Pressures in the 435-5800 psi (340 MPa) Range]**

Reference: Technical Report R 631, "Windows for External or Internal Pressure Vessels - Part III," J. D. Stachiw and F. Brier, Naval Civil Engineering Laboratory, Port Hueneme, California, USA, 1967.



(97) FIG. 2-2.19 SHORT-TERM CRITICAL PRESSURE OF HYPERHEMISPHERICAL AND NEMO TYPE ACRYLIC WINDOWS
[For Pressures in the 5800–23,200 psi (40-160 MPa) Range]

(97) TABLE 2-2.1 CONVERSION FACTORS FOR ACRYLIC FLAT DISK WINDOWS

Operational Pressure Ranges	Temperature Ranges				
	≤ 50°F (10°C)	≤ 75°F (24°C)	≤ 100°F (38°C)	≤ 125°F (52°C)	≤ 150°F (66°C)
N = 1 2500 psi (17.2 MPa)	CF = 5	CF = 6	CF = 8	CF = 10	CF = 16
N = 2 5000 psi (34.5 MPa)	CF = 5	CF = 6	CF = 8	CF = 10	4000 psi (27.6 MPa)
N = 3 7500 psi (51.7 MPa)	CF = 5	CF = 6	7000 psi (48.3 MPa)		

GENERAL NOTE:
The conversion factors (CF) in this Table apply only to short-term critical pressures (STCP) plotted in Figs. 2-2.5, 2-2.6, and 2-2.7.

(97)

TABLE 2-2.2 CONVERSION FACTORS FOR ACRYLIC
1. Conical Frustum Windows
2. Double Beveled Disk Windows

Operational Pressure Ranges	Temperature Ranges ≤ 50°F (10°C)	≤ 75°F (24°C)	≤ 100°F (38°C)	≤ 125°F (52°C)	≤ 150°F (66°C)
N = 1 2500 psi (17.2 MPa)	CF = 5	CF = 6	CF = 8	CF = 10	CF = 16
	Conversion factors for these pressures must be interpolated between the upper and lower values shown.				4500 psi (31 MPa)
N = 2 5000 psi (34.5 MPa)	CF = 4	CF = 5	CF = 7	CF = 9	
N = 3 7500 psi (51.7 MPa)	CF = 4	CF = 5			
N = 4 10,000 psi (69 MPa)	CF = 4	CF = 5	8000 psi (55.2 MPa)		

GENERAL NOTE:
The conversion factors (CF) in this Table apply only to short-term critical pressures (STCP) plotted in Figs. 2-2.8 and 2-2.9.

2-2.6 Nonstandard Window Geometries and Standard Window Geometries With Lower Conversion Factors (CF)

2-2.6.1 Acrylic windows of nonstandard geometry, or of standard geometry but with nonstandard lower conversion factors (CF), may be submitted for consideration as a case for adoption by the ASME Pressure Vessels for Human Occupancy Committee and possible subsequent incorporation into the Standard as another standard geometry or standard conversion factor for windows.

(a) Prior to submission for review, the window design must be experimentally verified according to para. 2-2.6.3, and the window design, testing procedure, test results, and any other pertinent analytical or experimental data shall be summarized in a clear, concise, and legible technical report.

(b) Thirty copies of the report shall accompany the submission for consideration by the Committee. Submission of the report to the Committee places its content into the public domain for review and comment by the public.

2-2.6.2 Windows with nonstandard geometries, or with standard geometries and lower conversion factors (CF), may be incorporated into chambers for human occupancy provided their material properties and structural performance satisfy the mandatory short-term, long-term, and cyclic proof pressure requirements of this Standard.

2-2.6.3 Windows with standard or nonstandard geometry, but with lower CF, must meet the following mandatory requirements:

(a) short-term proof pressure (STPP) = 4 times the design pressure, sustained without catastrophic failure at design temperature environment under short-term pressurization;

(b) long-term proof pressure (LTPP) = design pressure sustained continuously for 80,000 hr in design temperature environment without catastrophic failure;

(c) crack-free cyclic proof pressure (CPP) = design pressure sustained intermittently during 1000 pressure cycles of 8 hr each duration in design temperature environment without cracking.

2-2.6.4 The STPP of the window with nonstandard geometry, or with standard geometry and lower CF, shall be experimentally verified with a minimum of five model-scale or full-scale windows.

(a) The windows shall be individually pressurized at 650 psi/min (4.5 MPa/min) rate in the design temperature environment until catastrophic failure takes place.

(b) The critical pressures of all five windows must exceed the STPP.

(97)

TABLE 2-2.3 CONVERSION FACTORS FOR ACRYLIC
1. Spherical Sector Windows With Conical Edge
2. Hyperhemispherical Windows With Conical Edge
3. NEMO Type Windows With Conical Penetrations

Operational Pressure Ranges	Temperature Ranges				
	≤ 50°F (10°C)	≤ 75°F (24°C)	≤ 100°F (38°C)	≤ 125°F (52°C)	≤ 150°F (66°C)
N = I 2500 psi (17.2 MPa)	CF = 4	CF = 6	CF = 8	CF = 10	CF = 16 . 1500 psi (10.3 MPa)
N = 2 5000 psi (34.5 MPa)	CF = 4	CF = 6	CF = 8	CF = 10 3500 psi (24.1 MPa)	3000 psi (20.7 MPa)
N = 3 7500 psi (51.7 MPa)	CF = 4				

GENERAL NOTE:
The conversion factors (CF) in this Table apply only to short-term critical pressures (STCP) plotted in Figs. Z-2.10 and 2-2.11 (for spherical sector windows with conical edge), and 2-2.18 and 2-2.19 (for hyperhemispherical windows with conical edge and, NEMO type windows with conical penetrations).

2-2.6.5 The LTPP of the window with nonstandard geometry, or with standard geometry and lower CF, shall be experimentally verified with a minimum of five model-scale or full-scale windows.

(a) The windows shall be individually subjected to sustained pressure loading at design temperature.

(b) Each window shall be subjected to a different hydrostatic pressure and the duration of sustained pressure preceding the catastrophic failure shall be recorded.

(c) The pressures to which the individual windows shall be subjected are 0.9, 0.8, 0.75, 0.7, and 0.65 times the average short-term critical pressure established experimentally in para. 2-2.6.4.

(d) The experimental data points of (c) above shall be plotted on log-log coordinates, and the relationship between critical pressures and duration of loading shall be represented empirically by a straight line. The experimental points generated in para. 2-2.6.4 with zero sustained loading duration shall be also plotted on the same graph. The testing of any window specimen that has not failed in 10,000 hr of sustained loading may be terminated at that time and its data point omitted from the graph.

(e) The extension of the plotted line to 80,000 hr of sustained loading must exceed the LTPP.

2-2.6.6 The crack-free cyclic proof pressure (CPP) of the window with nonstandard geometry, or with standard geometry and lower CF, shall be experimentally verified on a minimum of two model-scale windows, or a single full-scale window.

(a) The window shall be pressure cycled 1000 times from zero to design pressure in design temperature environment.

(b) The length of the individual pressure cycles may vary from one cycle to another, but the average length of the sustained loading and relaxation phases in all of the pressure cycles must equal or exceed 4 hr.

(c) At the completion of 1000 pressure cycles, the window shall be visually inspected with the unaided eye (except for correction necessary to achieve 20/20 vision) for the presence of cracks.

(d) Absence of visible cracks shall be considered proof that the window design meets the crack-free CPP requirement of this Standard.

(97)

TABLE 2-2.4 CONVERSION FACTORS FOR ACRYLIC

1. Spherical Sector Windows With Square Edge
2. Hemispherical Windows With Equatorial Flange

Operational Pressure Ranges	Temperature Ranges				
	≤ 50°F (10°C)	≤ 75°F (24°C)	≤ 100°F (38°C)	≤ 125°F (52°C)	≤ 150°F (66°C)
N = I 2500 psi (17.2 MPa)	CF = 5	CF = 7	CF = 9	CF = 11	CF = 17 ....1500 psi (10.3 MPa)
N = 2 *5000* psi (34.5 MPa)	CF = 5	CF = 7	CF = 9 . . . . 3000 psi (20.6 MPa)		
N = 3 *7500* psi (*51.7* MPa)	CF = 5				

GENERAL NOTE:
The conversion factors (CF) in this Table apply only to short-term critical pressures (STCP) plotted in Figs. 2-2.10 and 2-2.11.

(97)

TABLE 2-2.5 CONVERSION FACTORS FOR ACRYLIC CYLINDRICAL WINDOWS

Part A — Internal Pressure

Operational Pressure Ranges	Temperature Ranges				
	≤ 50°F (10°C)	≤ 75°F (24°C)	≤ 100°F (38°C)	≤ 125°F (52°C)	≤ 150°F (66°C)
N = I *250* psi (1.7 MPa)	CF = 13	CF = 14	CF = 15	CF = 20	CF = 25

Part B — External Pressure

Operational Pressure Ranges	Temperature Ranges				
	≤ 50°F (10°C)	≤ 75°F (24°C)	≤ 100°F (38°C)	≤ 125°F (52°C)	≤ 150°F (66°C)
N = I 2500 psi (17.2 MPa)	CF = 6	CF = 7	CF = 9	CF = 11	CF = 17

GENERAL NOTES:

(a) The conversion factor (CF) in Part A of this Table applies only to the short-term critical pressures (STCP) plotted in Figs. 2-2.12 and 2-2.13.

(b) The conversion factors (CF) in Part B of this Table apply only to short-term critical pressures (STCP) plotted in Figs. 2-2.14 through 2-2.17. Since the tube may fail due to yielding of material (Fig. 2-2.12) or elastic buckling (Figs. 2-2.13 through 2-2.15), both modes of failure must be considered in selection of t/D ratio. Which mode of failure is chosen as the design criterion depends on which of the failure modes requires a higher t/D_i ratio for the desired short-term critical pressures. The mode of failure requiring a higher t/D_i ratio is chosen as the design criterion.

TABLE 2-2.6 CONICAL FRUSTUM WINDOWS FOR DESIGN PRESSURES IN EXCESS OF 10,000 psi (69 MPa)

Design Pressure		Temperature Ranges ≤ 50°F (10°C)					≤ 75°F (24°C)				
			D_i/D_f					D_i/D_f			
psi	MPa	t/D_i	60 deg.	90 deg.	120 deg	150 deg	t/D_i	60 deg.	30 deg.	120 deg	50 deg
11,000	75.86	1.0	1.13	1.17	1.23	1.69	1.1	1.13	1.17	1.23	1.69
12,000	82.76	1.1					1.2				
13,000	89.66	1.2					1.3				
14,000	96.55	1.3					1.4				
15,000	103.45	1.4	↓	↓	↓	↓	1.5	↓	I	↓	↓
16,000	110.34	1.5	1.20	1.26	1.53	2.48	1.6	1.20	1.26	1.53	2.48
17,000	117.24	1.6					1.7				
18,000	124.14	1.7					1.8				
19,000	131.03	1.8					1.9				
20,000	137.93	1.9	↓	↓	↓	↓	2.0	↓	↓	↓	↓

GENERAL NOTE: D_i/D_f ratio refers to the conical frustum seat specification shown in Fig. 2-2.20.

2-2.6.7 The temperature of tap water serving as pressurizing medium during the performance of proof tests is allowed to deviate from the specified design temperature by the following margin:

(a) for the short-term pressurization of para. 2-2.6.4, + 10°F (55°C);

(b) for the long-term pressurization of para. 2-2.6.5, +10°F (5.5°C);

(c) for the cyclic pressurization of para. 2-2.6.6, +25°F (14°C).

2-2.6.8 The successful qualification of a window design with nonstandard geometry, or with standard geometry and lower CF, for a chosen design pressure and temperature under the procedures of paras. 2-2.6.2 through 2-2.6.6, does not automatically qualify other windows with the same geometry but different *D,* ratios.

2-2.7 Design Life

2-2.7.1 The design life of a window is a function of its geometry, conversion factor, *t/D,* ratio, and service environment. Windows that are exposed to only compressive, or very low tensile stresses, have a longer design life than those that are exposed to high tensile stresses. The design life of windows in the first category shall be 20 years, while for the windows in the latter category it shall be IO years. Paragraphs 2-2.7.2 through 2-2.7.8 define the design life of windows under this Standard.

2-2.7.2 The design life of flat disk windows shown in Fig. 2-2.1 and meeting the requirements of this Standard shall be 10 years from the date of fabrication.

2-2.7.3 The design life of conical frustum windows shown in Fig. 2-2.1 and meeting the requirements of this Standard shall be 10 years from the date of fabrication for *t/D,* < 0.5 and 20 years for *t/D,* > *0.5.*

2-2.7.4 The design life of double beveled disk windows shown in Fig. 2-2.1 and meeting the requirements of this Standard shall be IO years from the date of fabrication for *t/D,* < 0.5 and 20 years for *t/D,* ≥ *0.5.*

2-2.7.5 The design life of spherical sector with conical edge, hyperhemisphere with conical edge, and NEMO type windows with conical edge penetrations shown in Figs. 2-2.2 and 2-2.4 and meeting the requirements of this Standard shall be 20 years from the date of fabrication.

2-2.7.6 The design life of spherical sector windows with square edge and hemispherical windows with equatorial flange, shown in Figs. 2-2.2 and 2-2.3 and meeting the requirements of this Standard, shall be IO years from the date of fabrication.

2-2.7.7 The design life of cylindrical windows for internal pressure applications shown in Fig. 2-2.3 and meeting the requirements of this Standard shall be 10 years from the date of fabrication.

2-2.7.8 The design life of cylindrical windows for external pressure applications shown in Fig. 2-2.3 and meeting the requirements of this Standard shall be 20 years from the date of fabrication.

2-2.8 Temperature Considerations

2-2.8.1 Thermal expansion of acrylic shall be taken into account during specification of the dimensional tolerance for the window diameter to be shown on the fabrication drawing, when the material temperature range required by the fabrication (para. 2-2.4) substantially differs from the operational temperature range.

2-2.8.2 For wide operational temperature ranges, a window shape and sealing arrangement should be selected that will perform satisfactorily at both the maximum and minimum operational temperatures. Radially compressed O-ring seals and spherical sector windows with a square edge are not suitable for such service when the change in window diameter over the operational temperature range results in a diametral clearance greater than 0.020 in. (greater than 0.5 mm) between the window and its seat.

(97) 2-2.8.3 The diametral interference between the window and its seat cavity at maximum operational temperature shall not exceed $0.001D_o$ for flat disk and spherical sector windows with square edges. The external diameter of the conical frustums and spherical shell windows with conical edge may exceed the major diameter of the conical seat in the flange by 0.0020, at maximum operational temperature, provided the edge of the window is beveled in such a manner that the conical bearing surface of the window never extends beyond the bearing surface of the seat.

2-2.8.4 The nominal diameters of the window and of the window seat in the flange shall be identical. The actual diameters at standard temperature will differ, but still will be within the dimensional tolerances specified in para. 2-2.12.

2-2.9 Viewport Flanges

2-2.9.1 Due to the moduli of elasticity of the plastic window and the metallic flange, it must be assumed in stress calculations that the window does not provide any reinforcement for the hull material around the penetrations.

2-2.9.2 Any of the analytical or empirical methods for stress and displacement calculations acceptable to the applicable Division of Section VIII of the Code may be used for dimensioning the thickness, width, and location of the flange around the viewport penetration.

2-2.9.3 Reinforcement for penetrations of chambers must meet the requirements of para. 1.4.5 and the requirements of the applicable Division of Section VIII of the Code.

2-2.9.4 The following minimum requirements shall be met by viewport flanges shown in Figs. 2-2.20 through 2-2.23, with a finished diameter opening in excess of 24 in. (635 mm).

(a) Radial deformation of the window seat at maximum internal or external design pressure must be less than ***0.0020,.***

(b) Angular deformation of the window seat at maximum internal or external design pressure must be less than 0.5 deg.

2-2.9.5 Viewport flanges shown in Figs. 2-2.24 through 2-2.27 do not have to meet the radial and angular deformation limits stated in paras. 2-2.9.4(a) and (b) above.

2-2.10 Window Seats

2-2.10.1 The window seat cavity in the viewport flange must be dimensioned to provide the window bearing surface with support during hydrostatic testing and subsequent operation at maximum design pressure. The dimensions of window seat cavities for standard window geometries are shown in Figs. 2-2.20 through **2-2.27.**

2-2.10.2 The surface finish on the window seat cavity must be 64 rms or finer.

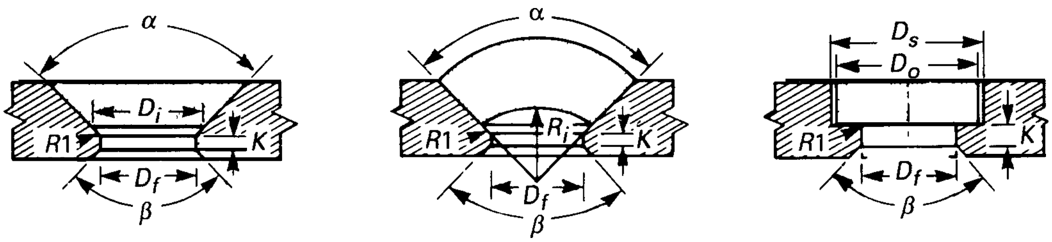
2-2.10.3 If the window seat is not fabricated of inherently corrosion resistant material, the surface of the window seat cavity shall be protected against corrosion expected in the design environment. A weld overlay of corrosion resistant material prior to final machining is acceptable. Other acceptable means are painting, anodizing, or plating with electroless nickel.

2-2.11 Window Seals

2-2.11.1 As ***primary seals*** for standard window geometries shown in Figs. 2-2.1 through 2-2.4, a soft elastomer compressed between the high pressure face of the window and retainer ring will be acceptable. The soft elastomeric seal may take the form of a flat gasket, or a seal ring with 0, U, or X cross section. The gasket or seal ring must be of sufficient thickness

1/32 in. (1.0 mm) ≤ $R1$ ≤ 1/16 in. (2.0 mm)

K is selected on the basis of structural analysis.
β is selected on the basis of optical requirements.



Conical Frustum Window

Spherical Sector Window With Conical Edge

$1.250 \leq D_o/D_f \leq 1.50$
Fiat Disk Window

D_i/D_f RATIOS

Operational Pressure Range	Included Angle, deg.			
	60	90	120	150
N = I	1 02	1.03	1 06	1 14
N = 2	1 04	1 06	1 12	1.28
N = 3	1 08	1 09	1 17	1 36
N = 4	1.10	1.15	1.20	1.42

$[2 R_i \sin(\alpha/2)]/D_f$ RATIOS

Operational Pressure Range	Included Angle, deg.				
	60	90	120	150	180
N = I	1.02	1.02	1.02	1 02	1.02
N = 2	1.03	1 03	1.03	1 03	1 03
N = 3	1.05	1 05	1.05	1 05	1.05

GENERAL NOTE
For α between values shown, Interpolation is required

(97) **FIG. 2-2.20 SEAT CAVITY REQUIREMENTS - CONICAL FRUSTUM WINDOW, SPHERICAL SECTOR WINDOW WITH CONICAL EDGE, AND FLAT DISK WINDOW**

to permit adequate compression without permanent set. Double beveled disk and cylindrical windows shall utilize, as a primary seal, a seal ring radially compressed between the cylindrical surface of the window facing the pressure and the cylindrical window seat in the flange. Hyperhemispherical and NEMO type windows may also utilize, as a primary seal, an elastomeric potting compound that adheres to both the external spherical surface of the window and the lip of the mounting flange.

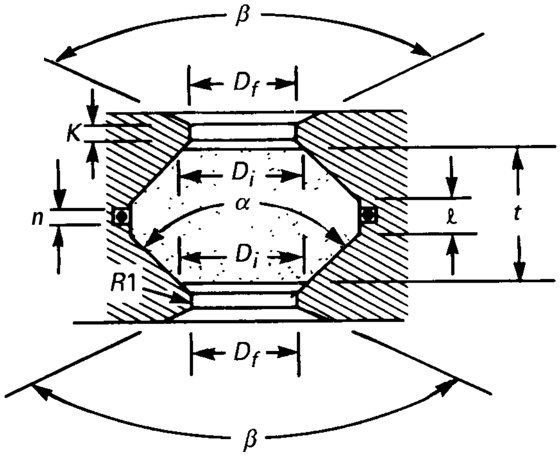
2-2.11.2 Flat disk windows with design pressure less than 15 psig may utilize as the primary seal an elastomeric potting compound that, after injection into the annular space between the edge of the window and the cylindrical surface of the seat (which have been coated beforehand with appropriate primer), shall, after room temperature cure, adhere to both the window and the seat surfaces. The primer and elastomeric potting compound selected for this application must be compatible with the window material, and the potting compound must retain its elastomeric characteristics in the operational temperature range and environment.

2-2.11.3 Retainer rings must provide the following minimum initial compression of the gasket in inches (millimeters).

(a) Conical frustum acrylic windows

$$0.010 + \left(\frac{0.025\sqrt[3]{D_i}}{\tan \alpha/2}\right) \text{ (inches)}$$

$$0.254 + \left(\frac{0.211\sqrt[3]{D_i}}{\tan \alpha/2}\right) \text{ (millimeters)}$$



K is selected on the basis of structural analysis.
β is selected on the basis of optical requirements,
$\ell \leq 0.25\ t$
$n \leq \ell$
1/32 in. (1.0 mm) ≤ RI ≤ 1/16 in. (2.0 mm)

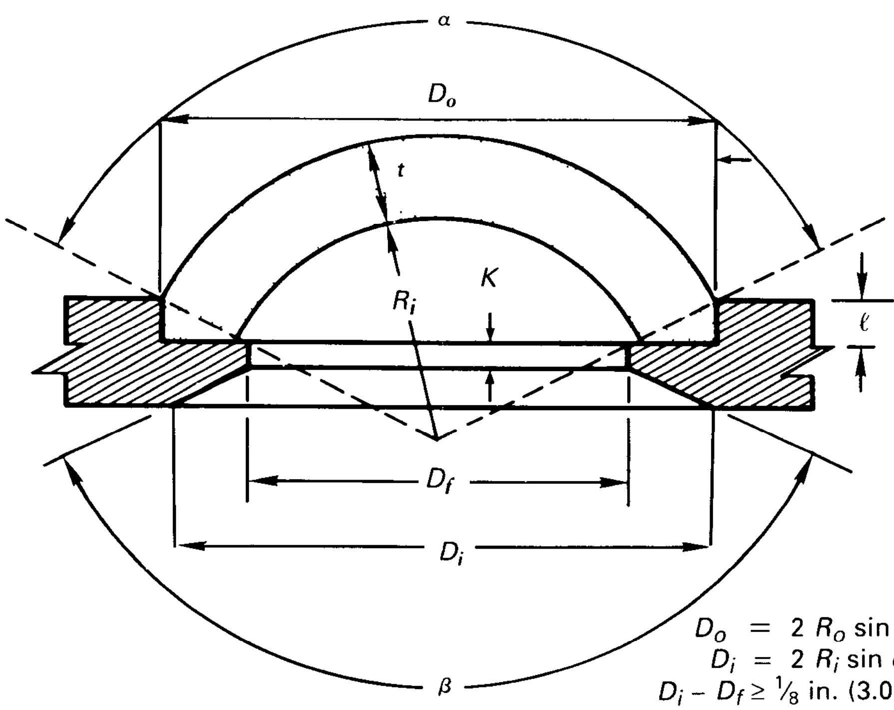
D_i / D_f RATIOS

Operational Pressure Range	Included Angle, deg.			
	60	90	120	150
N = I	1 02	1.03	1.06	1.14
N = 2	1 04	1.06	1 12	1.28
N = 3	1.08	1.09	1 17	1.36
N = 4	1.10	1.15	1 20	1.42

GENERAL NOTE
For α between values shown, Interpolation is required

FIG. 2-2.21 SEAT CAVITY REQUIREMENTS - DOUBLE BEVELED DISK WINDOW

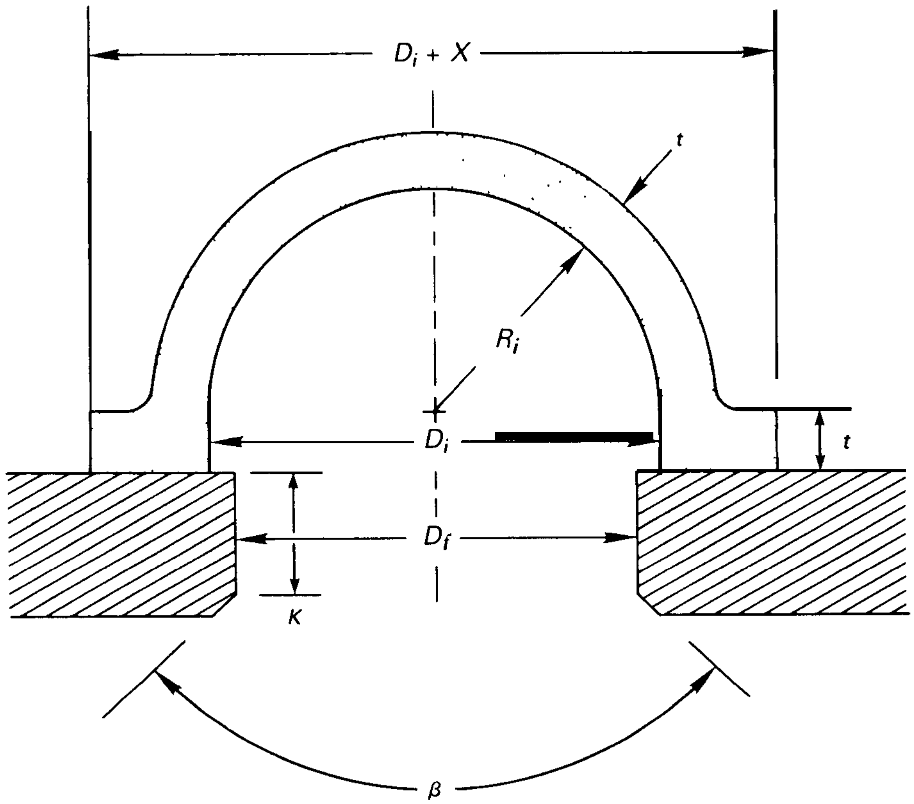
K is selected on the basis of structural analysts.
β is selected on the basis of optical requirements.



$D_o = 2\ R_o \sin \alpha/2$
$D_i = 2\ R_i \sin \alpha/2$
$D_i - D_f \geq 1/8$ in. (3.0 mm)
$\ell \geq t \sin (90 \text{ deg.} - \alpha/2)$

FIG. 2-2.22 SEAT CAVITY REQUIREMENTS - SPHERICAL SECTOR WINDOW WITH SQUARE EDGE

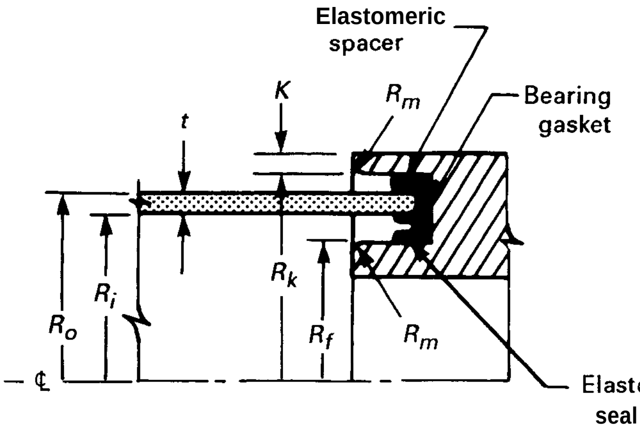
K is selected on the basis of structural analysis.
β is selected on the basis of optical requirements.



$3t \leq X \leq 4t$

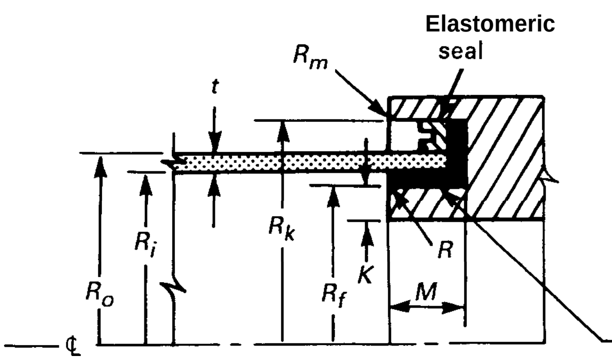
Operational Pressure Range	D_i/D_f
N = I	1.02
$N = 2$	1.03
$N = 3$	1.05

FIG. 2-2.23 SEAT CAVITY REQUIREMENTS - HEMISPHERICAL WINDOW WITH EQUATORIAL FLANGE



(a) Under Internal Pressure

K is selected on the basis of structural analysis
R_f = internal radius of window seat;
≤ calculated R_i of cylinder at zero internal pressure and -30°C minus gasket compressed 50%
R_k = external radius of window seat;
≥ calculated maximum R_o of cylinder under sustained internal design pressure of 8 hr duration at design temperature plus gasket compressed 50%
$R_m \geq$ 1/32 in. (1.0 mm)



(b) Under External Pressure

K is selected on the basis of structural analysis
R_f = internal radius of window seat;
≂ calculated R_i of cylinder under zero external pressure at design temperature minus thickness of gasket
R_k = external radius of window seat;
≤ calculated R_o of cylinder under zero external pressure at +52°C plus gasket compressed 50%
$R_m \geq$ 1/32 in. (1.0 mm)
$M \geq 0.05R_i$

(97) **FIG. 2-2.24 SEAT CAVITY REQUIREMENTS - CYLINDRICAL WINDOW**

(b) Spherical acrylic shell sector with conical edge

$$0.02 + 0.02\sqrt{R_i \sin \alpha/2} \text{ (inches)}$$

$$0.50 + 0.10\sqrt{R_i \sin \alpha/2} \text{ (millimeters)}$$

(c) Flat disk windows

$$0.01\,t + 0.01 \text{ in. (0.25 mm)}$$

(d) Spherical acrylic shell sector windows with square edges

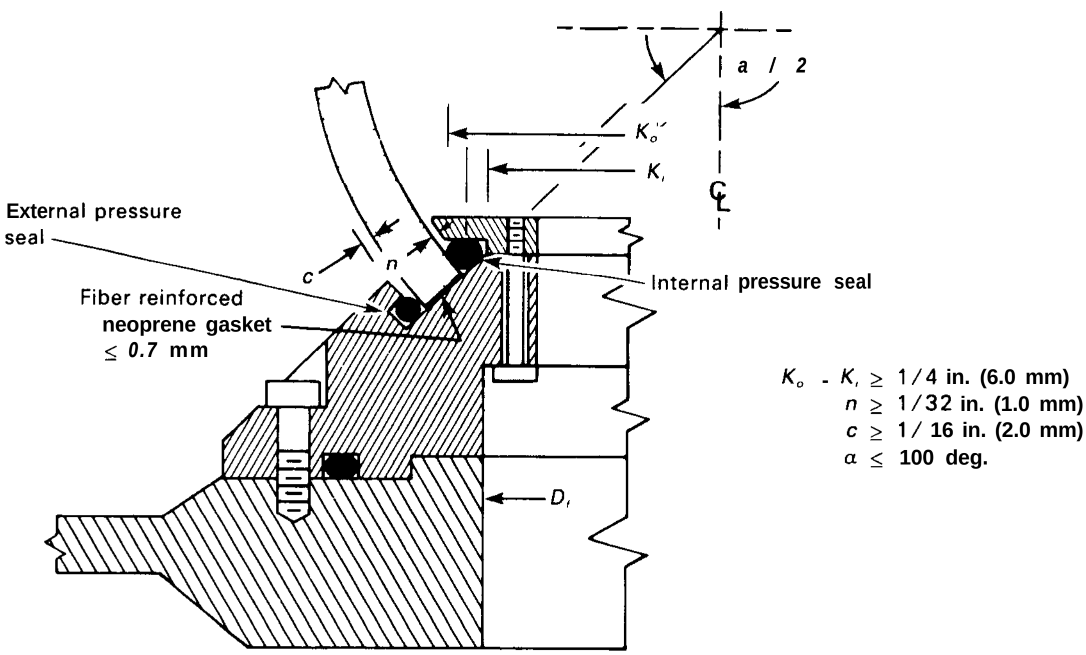
$$0.01\,t + 0.01 \text{ in. (0.25 mm)}$$

(e) Hemispherical acrylic windows with equatorial flange

$$0.01\,t + 0.01 \text{ in. (0.25 mm)}$$

where
t = thickness of the window

2-2.11.4 The compression of the soft elastomeric gasket by the retainer ring around the circumference of the window shall be uniform. The magnitude and uniformity of compression shall be checked by measuring, around the circumference of the window, the



a = included spherical angle of the opening
K_i = inner diameter of the conical seat
D_i = diameter of the opening in the pressure hull
K_i = inner diameter of the penetration in the window

FIG. 2-2.25 SEAT CAVITY REQUIREMENTS - HYPERHEMISPHERICAL WINDOW

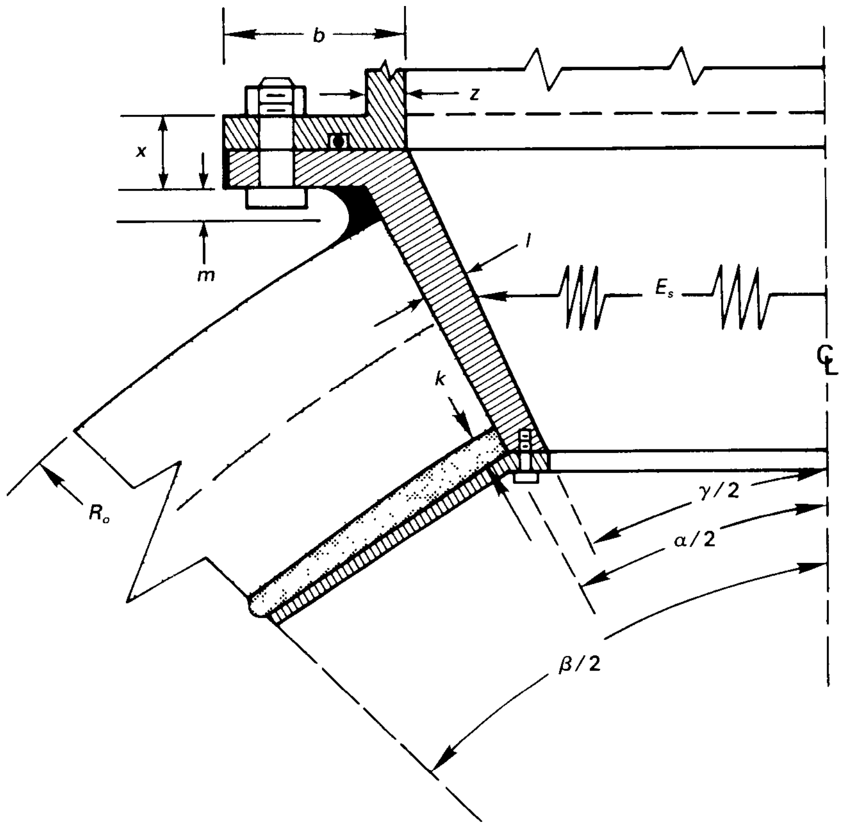
distance between the surface of the window and the external surface of the retainer ring before and after torquing down on the ring. The measured values of gasket compression measured at fastener locations and measured midway between fasteners shall not differ from each other by more than 25%, and the minimum value shall be equal to or exceed the magnitude of compression specified by para. 2-2.1 1 .3 at standard temperature.

2-2.11.5 The retainer ring and the fasteners shall be fabricated from materials which are electrogalvanically compatible with the viewport flanges. Unreinforced plastics and fiber reinforced plastic composites are not acceptable materials for this application.

2-2.11.6 The retainer ring and the associated fastening arrangement shall be designed with a safety factor of 4, based on the ultimate strength of materials and the design pressure forcing the window against the retainer ring. For applications where the magnitude of design pressure forcing the window against the retainer ring is zero, a minimum value of 15 psig shall be utilized in calculations.

2-2.11.7 The *minimum compression* of seal rings shall be governed by specifications of seal ring manufacturers for the given seal ring size and service.

2-2.11.8 A *secondary seal* is required between the window and the steel cavity seat for flat disks, spherical sectors with square edge, and hemispheres with equatorial flange. The secondary seal also serves as a bearing gasket for the window. This gasket must be bonded with contact cement to the metal flange seat. Thickness of the gasket must not exceed 1/8 in. (3.0 mm). Neoprene impregnated nylon cloth, neoprene of 90 durometer hardness, and cork gaskets are acceptable for such application.

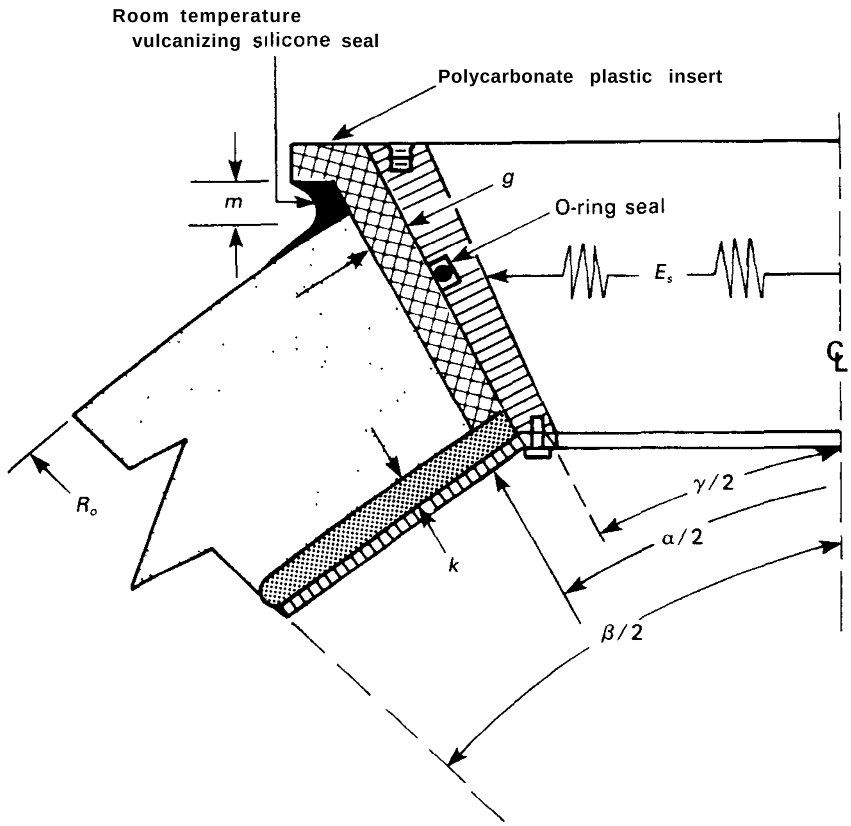


E_s = orientation of effective radial stiffness
γ = spherical angle of hatch seat
α = spherical angle of window penetration
k = thickness of compressed gasket
m = elevation of hatch ring
β = spherical angle of split retaining ring

$a \leq 50''$
$m \geq 0.01\ R,$
$k \geq 0.005\ R,$
$(a + 8\ \text{deg.}) \leq \beta \leq (a + 12\ \text{deg.})$

GENERAL NOTE:
x, 6, z, l, must be proportioned in such a manner that the effective radial stiffness of all Inserts at the penetration does not exceed the radial stiffness of acrylic sector with Included angle α by more than 3500%.

FIG. 2-2.26 SEAT CAVITY REQUIREMENTS - NEMO WINDOW (STANDARD SEAT)



E_s = orientation of effective radial stiffness
γ = spherical angle of hatch seat
a = spherical angle of window penetration
k = thickness of compressed gasket (neoprene)
m = elevation of hatch ring
j3 = spherical angle of split retaining ring
g = thickness of polycarbonate plastic gasket

a $\leq$, 50 deg.
$m \geq$ 001 R_o
$k \geq 0.005 R_o$
(a + 8 deg.) $\leq \beta \leq$ (a + 12 deg.)
g $\geq$ 0.03 R_o

GENERAL NOTE:
x, 6, *z, /,* must be proportioned in such a manner that the effective radial stiffness of all inserts at the penetration **does not exceed the** radial **stiffness of** acrylic **sector** with included **angle** α by more than 3500%

FIG. 2-2.27 SEAT CAVITY REQUIREMENTS - NEMO WINDOW (SEAT WITH EXTENDED CYCLIC FATIGUE LIFE)

2-2.11.9 Seal ring grooves are not permitted in the surface of any window shape, nor the bearing surface of the seat in the mounting, unless data showing that identical window assemblies that have successfully met the criteria of para. 2-2.6.6 are included with the window design certification package.

2-2.11 **.10** Seal ring grooves are permitted in the window seat in the mounting, providing that the groove is located in the nonbearing surface of the seat. The edges of the O-ring groove shall be beveled with a radius of $0.01 < R < 0.02$ in. ($0.25 < R < 0.50$ mm).

2-2.11 .I 1 Edges of bearing surfaces at the high pressure faces of windows may be beveled for containment of O-rings providing that the width of the bevel as shown on Figs. 2-2.28 and 2-2.29 shall not exceed $0.125t$ for spherical sectors, $0.062t$ for hyperhemispheres, $0.5t$ for conical frustums, $0.25t$ for flanged hemispheres, $0.125t$ for spherical sectors with square edges, $0.125t$ for cylinders, and $0.25t$ for flat disks under one-way pressurization. For flat disks serving as two-way windows, both edges may be beveled, provided $D_o/D_i > 1.25$, and D_i is measured only to the edge of the plane bearing surface.

2-2.11 **.12** The configuration of window mountings and seal arrangements shown in Figs. 2-2.5 through 2-2.19 represent designs acceptable under this Standard, and are shown there only for the guidance of designers.

2-2.11.13 Replacement windows for pressure chambers fabricated to design criteria of ANSI/ASME PVHO-l-1977 or ANSI/ASME PVHO-l-1981 may incorporate O-ring grooves in nonbearing surfaces of the window providing that:

(a) the window meets all the requirements of the 1977 or 198 1 edition; and

(b) the accompanying design certification notes that the window is a replacement for an existing pressure vessel built to the 1977 or 1981 edition.

2-2.12 Dimensional Tolerances and Surface Finish

2-2.12.1 Thickness of the window shall be everywhere equal to or greater than the nominal value determined by the procedures of para. 2-2.5.1.

2-2.12.2 The major diameter of the conical bearing surface on a window shall be machined within +O.OOO/ **-0.0020,** of the nominal value.

2-2.12.3 The included conical angle of the window must be within +0.25/-0.000 deg. of the nominal value.

2-2.12.4 The included conical angle of the window seat in the flange must be within +O.OOO/-0.25 deg. of the nominal value.

2-2.12.5 The conical seat in the flange shall not deviate more than 0.001 D_o in. from an ideal circle when measured with a feeler gage inserted between the mating conical surfaces of the seat and of the window at its outer circumference. The axial force used to seat the window during this test shall not exceed $10D_o$ lb **(4.530,** kg) applied uniformly around its circumference.

2-2.12.6 The major diameter of the conical seat cavity in the flange must be within $+0.002D_o/-0.000$ of the nominal value.

2-2.12.7 The concave or convex surface of a window shall not differ from an ideal spherical sector by more than ±0.5% of the specified nominal external spherical radius for standard CF values (see Tables 2-2.3 and 2-2.4, and Figs. 2-2.10, 2-2.11, and 2-2.18). Measurements shall be made from an external segmental template whose radius falls within specified dimensional tolerance, and whose length is equal to the window's included conical angle or $\pi/2$, whichever is the lesser value.

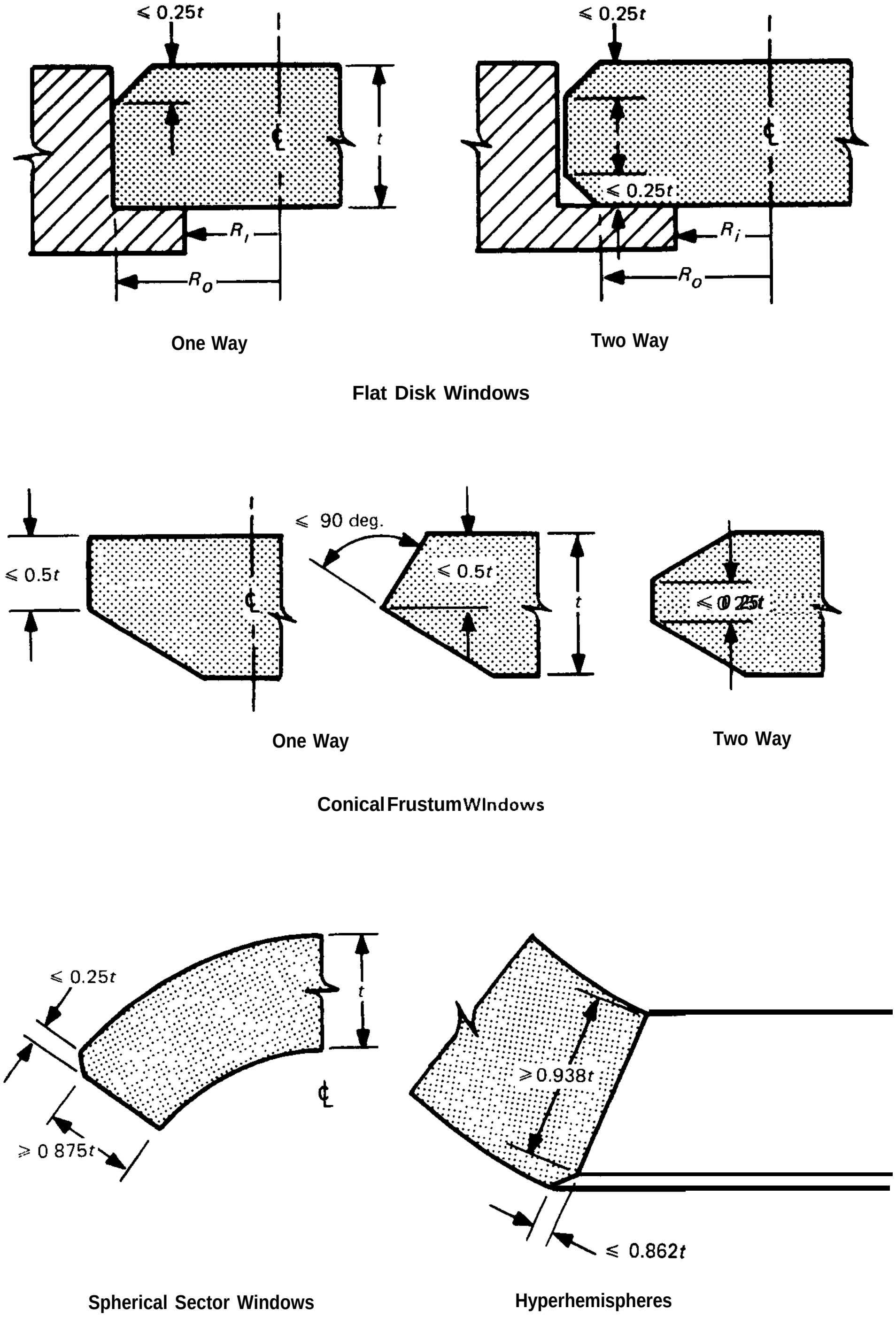
2-2.12.8 The dimensional tolerance on the external diameter of the window shall be based on the type of sealing arrangement for the window.

(a) The external diameter of the flat disk window shall be within +O.OOO/-0.010 in. (+O.OOO/-0.25 mm) of the nominal value if the window is to be sealed in the seat cavity with a radially compressed O-ring.

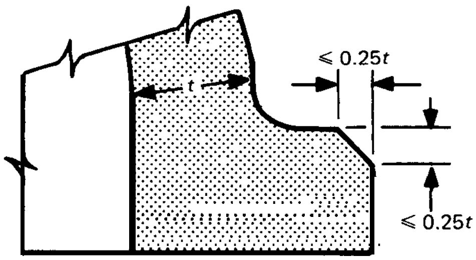
(b) The external diameter of the flat disk window shall be within +O.OOO/-0.060 in. (+O.OOO/-1.5 mm) of the nominal value if the window is to be sealed in the seat cavity with a seal ring wedged into the annular space between the retaining ring, the window's bevel, and the cylindrical surface of the seat cavity.

(c) The external diameter of the flat disk window shall be within +O.O/-0.125 in. (+O.O/-3.2 mm) of the nominal value if the window is to be sealed in the seat cavity with a flat elastomeric gasket axially compressed by the retaining ring.

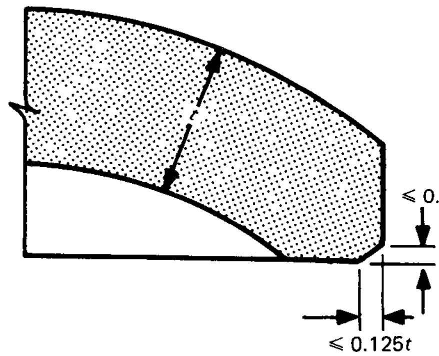
(d) The external diameter of the flat disk window shall be within +O.OO/-0.02 D_o of the nominal value if the window is to be sealed in the seat cavity with a room temperature curing elastomeric compound



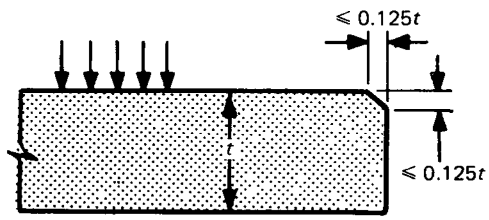
(97) **FIG. 2-2.28 BEVELS ON WINDOW EDGES - FLAT DISK WINDOWS, CONICAL FRUSTUM WINDOWS, SPHERICAL SECTOR WINDOWS, HYPERHEMISPHERES**



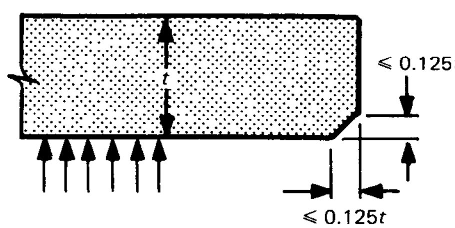
Flanged Hemispherical Window



Spherical Sector Window
With Square Edge



External Pressure



Internal Pressure

Cylindrical Windows

FIG. 2-2.29 BEVELS ON WINDOW EDGES - FLANGED HEMISPHERICAL WINDOW, SPHERICAL SECTOR WINDOW WITH SQUARE EDGE, EXTERNAL PRESSURE AND INTERNAL PRESSURE OF CYLINDRICAL WINDOWS

injected into the annular space between the edge of the window and the cylindrical surface of the seat.

(e) The plane bearing surface of the flat disk window shall not deviate more than 0.0010, from an ideal plane.

(97) **2-2.12.9** The dimensional **tolerance on the external** diameter of the window seat cavity shall be based on the type of sealing arrangement for the window.

(a) The diameter of the seat cavity for a flat disk window shall be within +0.01/–0.00 in. (+0.25/–0.00 mm) of the nominal value if the window is to be sealed in the seat cavity with a radially compressed O-ring.

(b) The diameter of the seat cavity for a flat disk window shall be within +0.06/–0.00 in. (+1.5/–0.00 mm) of the nominal value if the window is to be sealed in the seat cavity with a seal ring wedged into the annular space between the retaining ring, the window's bevel, and the cylindrical surface of the seat cavity.

(c) The diameter of the seat cavity for a flat disk window shall be within +0.125/–0.000 in. (+3.2/–0.00 mm) of the nominal value if the window is to be sealed in the seat cavity with a flat elastomeric gasket axially compressed by the retaining ring.

(d) The diameter of the seat cavity for a flat disk window shall be within $+0.01D_o/-0.000$ of the nominal value if the window is to be sealed in the seat cavity with a room temperature curing elastomeric compound injected into the annular space between the edge of the window and the cylindrical surface of the seat.

(e) The plane bearing surface of the seat cavity shall not deviate more than 0.0020, from an ideal plane when measured with a feeler gage inserted between the mating plane surfaces of the flat disk window or a circular plug gage and the bare seat cavity. The axial force used to seat the window or the plug gage shall not exceed $10D_o$ lb (4.530, kg) applied uniformly around its circumference.

2-2.12.10 The external diameter of the spherical window with square seat shall be within +O.OOO/ $-0.0005D_o$ of the nominal value.

2-2.12.11 The diameter of the seat cavity for a spherical window with square seat shall be within $+0.0005D_o/-0.000$ of the nominal value.

2-2.12.12 The plane bearing surface of the seat cavity shall not deviate more than 0.0010, from an ideal plane when measured with a feeler gage inserted between the mating plane bearing surfaces of the spherical window with a square edge and the seat cavity. The axial force used to seat the window shall not exceed $10D_o$ lb ($4.53D_o$ kg) applied uniformly around its circumference.

2-2.12.13 The maximum out-of-roundness of a cylindrical window shall not differ from an ideal cylinder by more than ±0.5% of the specified nominal external radius for standard CF values (see Table 2-2.5).

2-2.12.14 The bearing surface of the window shall have an as-cast or machined finish no rougher than 32 rms.

2-2.12.15 Viewing surfaces shall be polished to satisfy ASTM D 702 optical clarity requirements.

2-2.12.16 All other surfaces shall be machined or sanded to attain at least a 63 rms finish. Saw cut finish is not acceptable on any window surface.

2-2.13 Documentation

2-2.13.1 The manufacturer shall be responsible for the translation of the design of the window and its related viewport flange, retainer rings, and seals into drawings capable of being used for fabrication.

2-2.13.2 Drawings which provide construction details shall bear notice that the windows have been designed and shall be built to ASME PVHO-I. Drawings shall identify the appropriate edition with addenda.

2-2.13.3 The designer shall fill out a design *certification* as described in para. 2-1.7(a). All pertinent design data will be shown and any additional information utilized in the design will be referenced on the certification. The designer may develop an appropriate certification form using the form in Appendix A, Enclosure 1, as a representative sample.

2-2.13.4 The manufacturer shall transmit the design certification plus construction drawings to the window fabricator at the time of fabrication.

2-2.13.5 The design certification and additional referenced documentation plus copies of the fabrication drawings shall become a part of the permanent design package for the chamber.

2-2.14 Windows With Inserts for Penetrators

2-2.14.1 Inserts that serve as bulkheads for electrical, mechanical, optical, or hydraulic penetrators can be incorporated into acrylic windows provided that the penetrations and inserts meet the requirements of this paragraph. These requirements are grouped into categories of window shapes, pressure service, penetration location, penetration configuration, insert material, insert configuration, seating arrangements, insert retainment, pressure testing, and certification.

2-2.14.2 The window shapes in which penetrations can be incorporated without reducing their working pressure are spherical shell sectors with conical seats (see Fig. 2-2.2), hemispheres with or without flanges (see Fig. 2-2.3), hyperhemispheres (see Fig. 2-2.4), and NEMO spheres (see Fig. 2-2.4).

2-2.14.3 Windows with penetrations can be incorporated into pressure vessels for external or internal pressure service provided that the design pressure acts only upon the convex surface of the window.

2-2.14.4 On spherical shell sectors with conical seats, hemispheres without flanges, hyperhemispheres, and NEMO spheres, the penetrations may be located anywhere, provided that:

(a) the spacing between the window seat and the edge of the penetration exceeds two diameters of the penetration; and

(b) the spacing between edges of adjacent penetrations measured on the concave surface exceeds the radius of the larger penetration.

2-2.14.5 On hemispheres with flanges, the penetration may be located only within the area between the apex and latitude of 60 deg., provided that the spacing between edges of adjacent penetrations exceeds the radius of the larger penetration measured on the concave surface.

2-2.14.6 The penetrations shall have circular configurations.

2-2.14.7 The area of a single penetration shall not exceed 15% of the window's surface prior to machining of the penetration in the window.

2-2.14.8 The total area of all penetrations in a single window shall not exceed 30% of the window's concave surface.

2-2.14.9 All penetrations shall have conical seats forming surfaces of imaginary solid cones.

2-2.14.10 The included solid angle of any conical seat shall be chosen to make the imaginary apex of the solid cone coincide with the imaginary center of concave curvature.

2-2.14.11 The maximum size of the penetration diameter shall be defined by a solid cone angle of 50 deg., provided that the area of the penetration, defined as $\pi(M_o)^2/4$ (see Fig. 2-2.30), does not exceed the limits specified in paras. 2-2.14.7 and 2-2.14.8.

2-2.14.12 The angular and dimensional tolerances for penetrations, as well as for the surface finish on the seat, are shown in Fig. 2-2.1.

2-2.14.13 The inserts for the penetrations shall be made from metal or from plastic, provided the material properties satisfy the following criteria.

(a) Any metal approved by this Standard may be utilized for the fabrication of inserts, provided that the selected alloy is corrosion resistant to stagnant seawater and its tensile and compressive yield strength exceed 25,000 psi (172 MPa). Steel alloys without corrosion resistance may be substituted for corrosion resistant alloys if the insert is cadmium or nickel plated after completion of all machining operations.

(b) Acrylic meeting the criteria of Table 2-3.2 and polycarbonate plastic meeting the criteria of Table 2-2.7 are acceptable materials for the fabrication of inserts, provided that in service they shall only:

(I) come in contact with fluids and gases defined by para. 2-1.3(c); and

(2) be subjected to temperatures which are lower than the design temperature of the window.

2-2.14.14 Since the temperature of a shorted-out electrical connector may exceed the design temperature of the plastic insert, the designer must forestall the potentially unacceptable temperature rise by limiting the magnitude and/or duration of power input to the connector during an electrical short.

2-2.14.15 The angular and dimensional tolerances for inserts are shown in Fig. 2-2.31. All surfaces on the insert shall have a finish of 32 rms or finer.

2-2.14.16 The inserts shall have the shape of a spherical sector or of a truncated cone where:

(a) the solid included angle of the bearing surface on the insert matches the conical seat in the penetration; and

(b) the bearing surface of the insert extends past the edges of the seat in the penetration (Fig. 2-2.32).

2-2.14.17 Any number or size of holes may be drilled and tapped in the metal insert to receive hydraulic, electrical, optical, or mechanical bulkhead penetrators, provided that the openings and their reinforcements conform to the appropriate Division of Section VIII of the Code.

2-2.14.18 Smooth holes may be drilled in the polycarbonate insert to receive hydraulic, electrical, optical, or mechanical bulkhead penetrators, provided that:

(a) the spacing between edges of adjacent holes in the insert shall exceed the diameter of the larger adjacent hole;

(b) the spacing between the edge of the insert and the edge of any hole exceeds the diameter of that hole; and

(c) the surface finish inside the holes shall be 32 rms or finer. The holes shall be sized for the penetrators to support the edges of the holes when the window assembly is subjected to design pressure.

2-2.14.19 Smooth holes may be drilled in the acrylic insert to receive hydraulic, electrical, optical, or mechanical bulkhead penetrators provided that:

(a) the spacing between edges of adjacent holes in the insert shall exceed two diameters of the larger adjacent hole;

(b) the spacing between the edge of the insert and the edge of the hole exceeds two diameters of the hole; and

(c) the surface finish inside the holes shall be 32 rms or finer. The holes shall be sized for the penetrators to support the edges of the holes when the window assembly is subjected to design pressure.

2-2.14.20 The thickness of the insert shall depend on the material from which the insert is fabricated.

(a) For plastics, the thickness of the inserts in the shape of spherical sectors or conical frustums shall be calculated on the basis of maximum allowable tensile

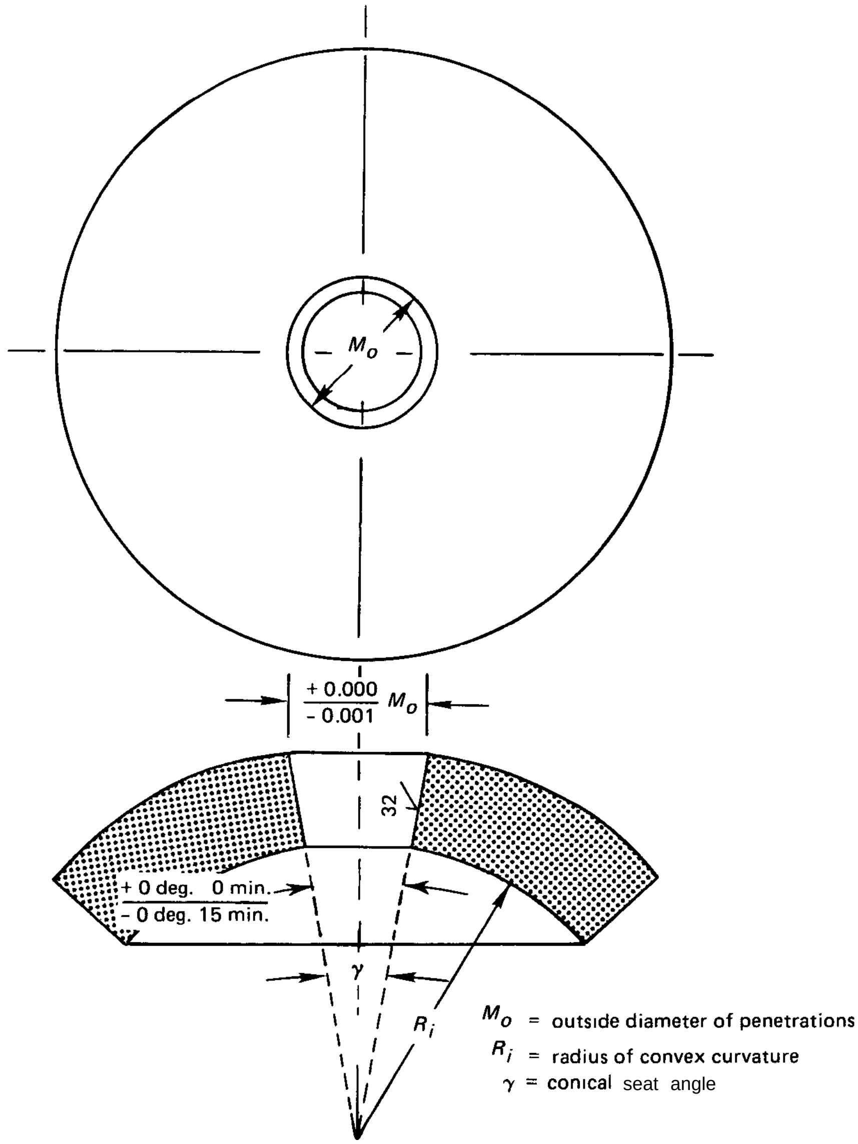


FIG. 2-2.30 DIMENSIONAL TOLERANCES FOR PENETRATIONS IN ACRYLIC WINDOWS

and compressive stresses specified for the chosen material by the appropriate Division of Section VIII of the Code.

(b) An alternate approach requires hydrostatic testing of the new insert design in an acrylic seat to 3 times the desired design pressure without producing permanent deformation ≥ 0.2%. The pressurization shall be at a 650 psi/min (4.5 MPa/min) rate.

2-2.14.21 Duplicate inserts of the same material, design, and construction need not be proof tested but shall be pressure tested according to Section 2, Article 7.

2-2.14.22 All inserts require two separate seals to prevent entry of water through the joint between the bearing surface of the insert and the seat in the window: a ***primary seal*** and a ***secondary seal.***

(a) Sealing between the insert and the window shall be provided by two seals. A primary seal shall serve as the contact between the two conical mating surfaces on the insert and window. A secondary seal shall serve as elastomeric material held captive between the convex window surface and a flange on the insert.

(b) Experimentally proven secondary seal designs

TABLE 2-2.7 SPECIFIED VALUES OF PHYSICAL PROPERTIES FOR POLYCARBONATE PLASTIC (To be verified by testing of specimen from each plate that serves as machining stock for inserts)

Test Procedures	Physical Property	Specified Values U.S. Customary Unit	Specified Values Metric Unit
ASTM D 638*	Tensile:		
	(a) ultimate strength	≥ 9000 psi	≥ 62 MPA
	(b) elongation at break	≥ 20%	≥ 20%
	(c) modulus of elasticity	≥ 300,000 psi	≥ 2069 MPa
ASTM D 695*	Compressive:		
	(a) yield strength	≥ 12,000 psi	≥ 82.8 MPa
	(b) modulus of elasticity	≥ 300,000 psi	≥ 2069 MPa
ASTM D 621'	Compressive deformation at 4000 psi (27.6 MPa) and 122°F (50°C). 24 hr	≤ 2%	≤ 2%
ASTM D 732*	Shear, ultimate strength	≥ 9000 psi	≥ 62 MPa
ASTM E 308	Ultraviolet transmittance [for 0.5 in. (13 mm) thickness]	≤ 5%	≤ 5%

GENRAL NOTE:
Tests marked with an asterisk require testing of a minimum of two specimens. For others, test a minimum of one specimen. Where applicable, use the sampling procedures described in para. 2-3.7. Where two specimens are required in the test procedure, the average of the test values will be used to meet the requirements of the minimum physical properties of this Table.

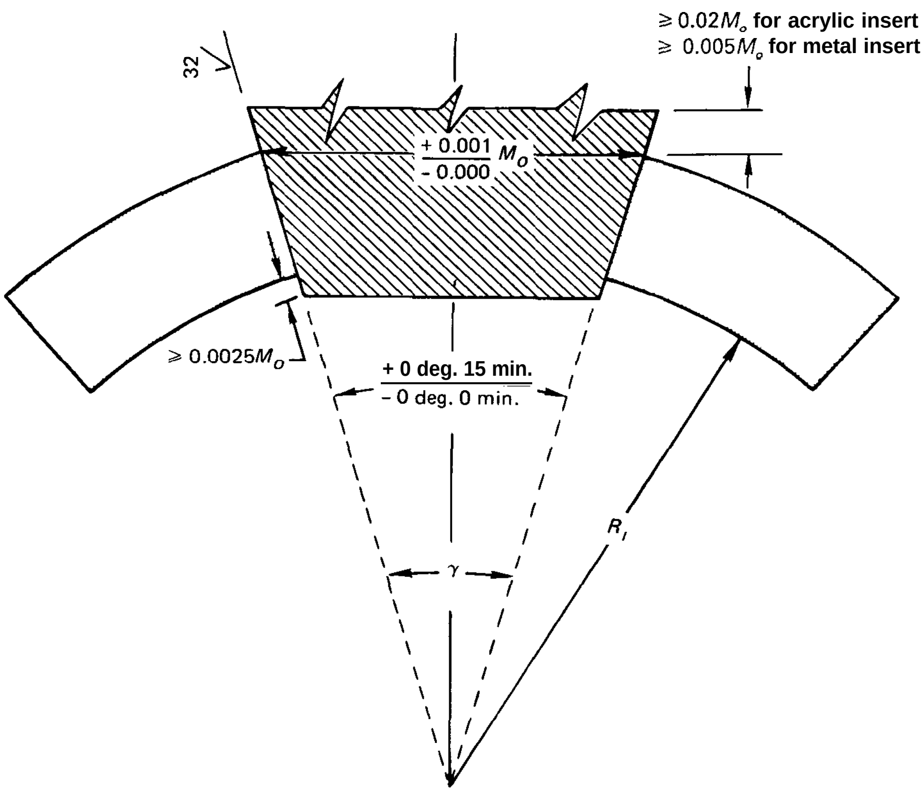


FIG. 2-2.31 DIMENSIONAL TOLERANCES FOR INSERTS IN ACRYLIC WINDOWS

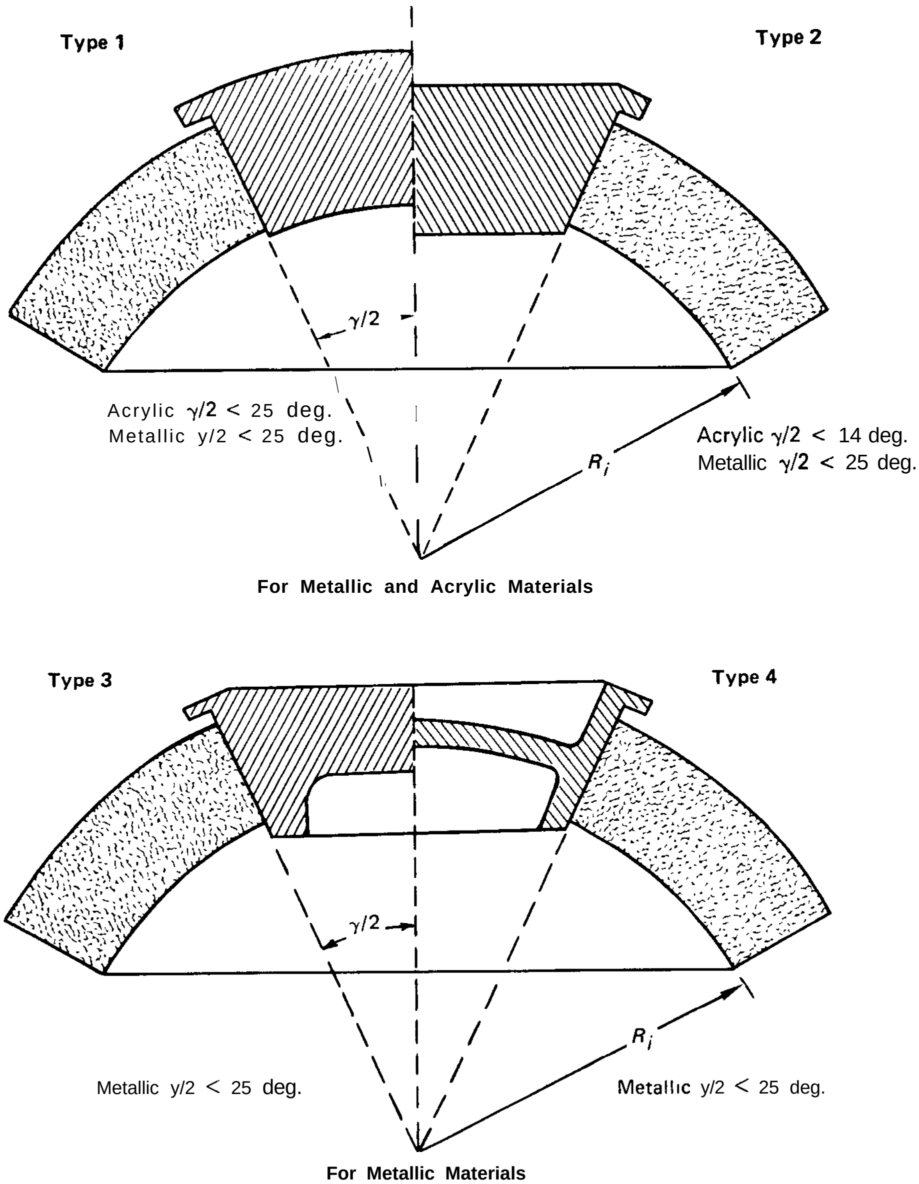


FIG. 2-2.32 TYPICAL SHAPES OF INSERTS

shown in Fig. 2-2.33 represent designs acceptable under this Standard and are provided for guidance only.

2-2.14.23 Grooves for containment of seals shall not be machined in either the conical seat on the window or the conical bearing surface on the insert in contact with the window. It is acceptable to incorporate an O-ring groove in the conical bearing surface of a metallic insert if a gasket of approved material is interposed between the metallic insert and the seat on the window (see Fig. 2-2.27).

2-2.14.24 The inserts shall be mechanically restrained against ejection from their seats in the window by accidental application of pressure to the concave surface of the window or bending moments to the feed-throughs.

(a) The mechanical restraint shall be capable of

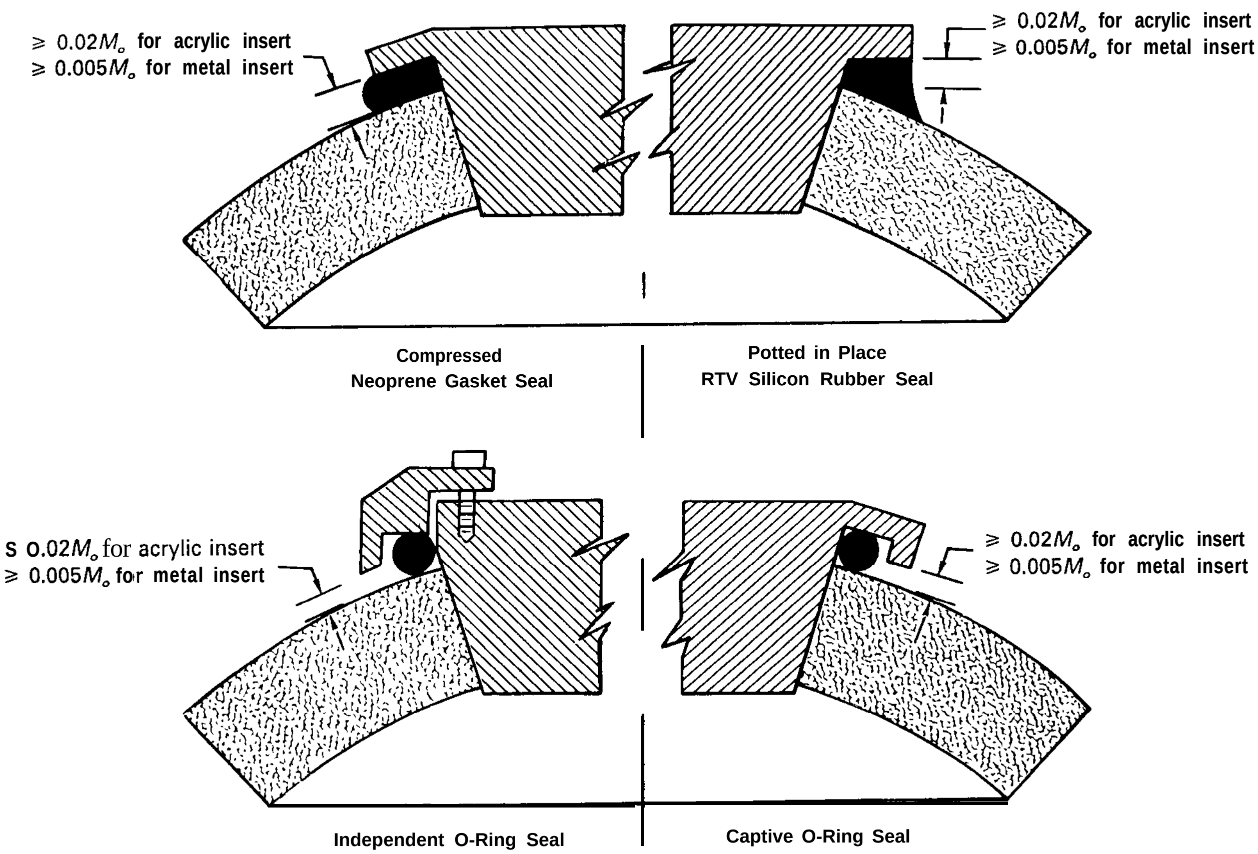


FIG. 2-2.33 SEAL CONFIGURATIONS FOR INSERTS IN ACRYLIC WINDOWS

retaining the insert against a pressure of 15 psi (0.1 MPa) applied against the concave surface of the window and bending moments generated by wave slap and hydrodynamic drag against cables, hydraulic lines, or mechanical linkages attached to the insert. The tensile stress resulting from bending moment shall not exceed 2500 psi (12.2 MPa).

(b) Experimentally proven restraint designs shown in Fig. 2-2.34 represent designs acceptable under this Standard and are provided for guidance only.

2-2.14.25 All inserts shall be stress relieved after all the fabrication processes have been completed. Acrylic shall be stress relieved according to the schedules of Table 2-4.1. Polycarbonate shall be stress relieved for a period of 8 hr at 250°F (120°C).

2-2.14.26 Each finished insert shall be subjected by the fabricator to a quality control inspection. The quality control inspection shall consist of dimensional and visual checks whose objective is to determine whether the finished insert meets the dimensional tolerances, material quality, and surface finish requirements specified in para. 2-2.13.

2-2.14.27 Each insert shall be pressure tested at least once prior to being accepted for service.

(a) The pressure test shall take place with the insert installed in the window, or an acrylic test fixture whose thickness, surface curvatures, and penetration dimensions are identical to those in the window.

(b) The pressure test shall be conducted according to procedures described in Section 2, Article 7.

(c) The test pressure and temperature shall be determined by the design pressure and temperature of the window in which the insert shall be installed for service.

2-2.14.28 Each insert shall be individually certified. The certification shall include the following:

(a) design certification
(b) material manufacturer's certification
(c) material properties certification
(d) fabrication data report
(e) pressure testing certification

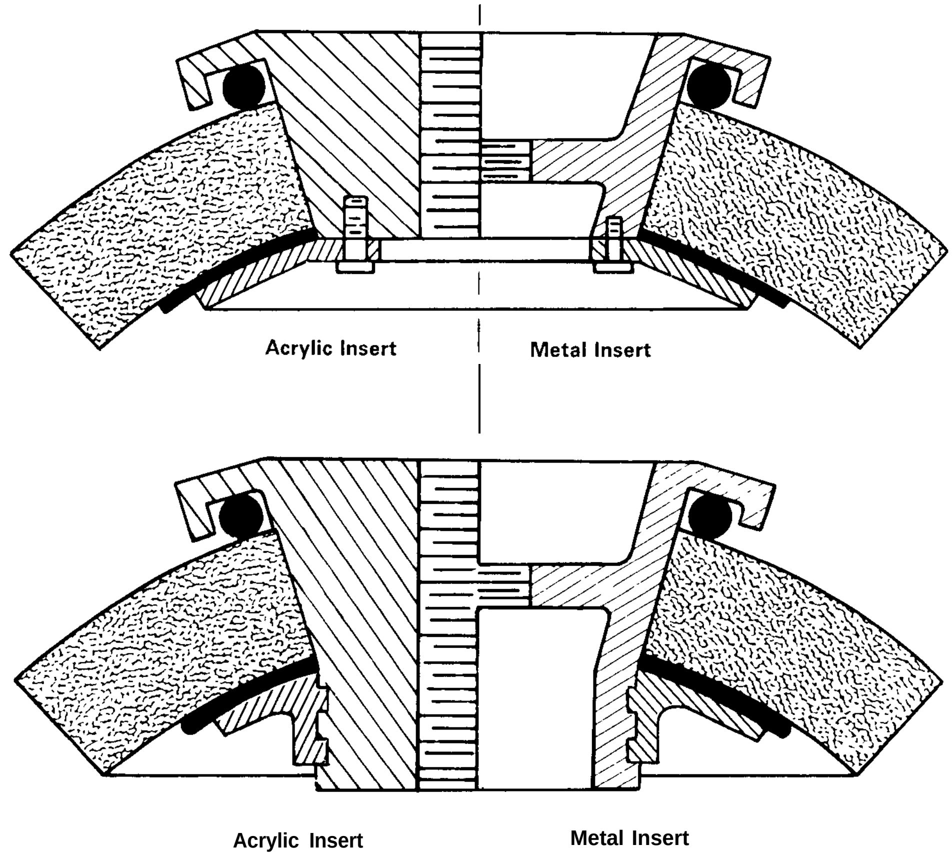


FIG. 2-2.34 RESTRAINTS FOR INSERTS IN ACRYLIC WINDOWS

2-2.14.29 **Each of the certifications shall follow the** procedure described in para. 2-l .7 except that the material certifications for polycarbonate and metallic inserts shall differ from the one specified for acrylic.

(a) For polycarbonate, the supplier shall provide a report listing the results of tests performed according to Table 2-2.7 on coupons cut from the stock used in the fabrication of inserts.

(6) For metal, the supplier shall provide a certified mill test report. The report shall include the results of all the tests as required by the material specifications, including chemical analysis and mechanical tests. In addition, the results of any applicable supplementary tests shall be recorded.

ARTICLE 3 MATERIAL

2-3.1

Windows shall be fabricated only from cast polymethyl methacrylate plastic, hereafter referred to as acrylic.

2-3.2

Laminating several sheets of acrylic to arrive at the desired window thickness is not permitted.

2-3.3

Joining of acrylic castings by bonding is permitted provided the following provisions are met.

(a) The joint shall be subjected only to membrane compressive stresses.

(b) The properties of the bond joint shall meet or exceed those specified in para. 2-3.10.

(c) The joint shall be pressure tight during hydrostatic testing of the window.

2-3.4

The acrylic used for fabrication of windows must satisfy two general requirements.

(a) The casting process used in production of acrylic shall be capable of producing material with the minimum physical properties shown in Table 2-3.1. The manufac-

TABLE 2-3.1 SPECIFIED VALUES OF PHYSICAL PROPERTIES FOR EACH LOT
(To be certified by the manufacturer of material)

Test Procedures	Physical Property	Specified Values: U.S. Customary Unit	Specified Values: Metric Unit
ASTM D 256*	Izod notched impact strength	≥ 0.25 ft-lb/in.-min	≥ 13.3 J/m
ASTM D 542*	Refractive index	1.49 ± 0.01	1.49 ± 0.01
ASTM D 570*	Water absorption, 24 hr	≤ 0.25%	≤ 0.25%
ASTM D 621	Compressive deformation at 4000 psi (27.6 MPa), 122°F (50°C). 24 hr	≤ 0.85%	≤ 0.85%
ASTM D 638*	Tensile:		
	(a) ultimate strength	≥ 9000 psi	≥ 62 MPa
	(b) elongation at break	≥ 2%	≥ 2%
	(c) modulus	≥ 400,000 psi	≥ 2760 MPa
ASTM D 695*	Compressive:		
	(a) Yield strength	≥ 15,000 psi	≥ 103 MPa
	(b) modulus of elasticity	≥ 400,000 psi	≥ 2760 MPa
ASTM D 732*	Shear ultimate strength	≥ 8000 psi	≥ 55 MPa
ASTM D 785*	Rockwell hardness	≥ M scale 90	≥ M scale 90
ASTM D 790*	Flexural ultimate strength	≥ 14,000 psi	≥ 97 MPa
ASTM D 792*	Specific gravity	1.19 ± 0.01	1.19 ± 0.01
ASTM E 308	Ultraviolet (290-330 nm) light transmittance	≤ 5%	≤ 5%
PVHO-1 method, para. 2-3.7(e)	Clarity, visually rated	Must have readability	Must have readability
ASTM D 696	Coefficient of linear thermal expansion at	≤ 10^{-5} (in./in. °F)	≤ 10^{-5} (mm/mm °C)
	“F / °C		
	- 40 / -40	2.9	5.22
	- 20 / -29	3.0	5.40
	0 / -18	3.2	5.76
	+ 20 / - 7	3.4	6.12
	+ 40 / 4	3.7	6.66
	+ 60 / 16	4.0	7.20
	+ 80 / 27	4.3	7.74
	+100 / 38	4.7	8.46
	+120 / 49	5.1	9.18
	+140 / 60	5.4	9.72
ASTM D 648	Deflection temperature of plastics under flexure at 264 psi (1.8 MPa)	≥ 185°F	≥ 85°C
PVHO-1 method, para. 2-3.8	Total residual monomer: (a) methyl methacrylate (b) ethyl acrylate	≤ 1.6%	≤ 1.6%

GENERAL NOTE:
Tests marked with an asterisk require testing of a minimum of two specimens. For others, test a minimum of one specimen. Where applicable, use the sampling procedures described in para. 2-3.7. For other tests, use the sampling procedures described in the appropriate ASTM test methods. Where two specimens are required in the test procedure, the average of the test values will be used to meet the requirements of the minimum physical properties of this Table.

turer of material shall provide certification to the window fabricator that the typical physical properties of the material satisfy the criteria of Table 2-3.1. The material manufacturer's certification shall convey the information in a form equivalent to Appendix A, Enclosure 2. The certification shall identify the material by lot number and shall be marked in such a way that each casting shall be positively identified with the lot number. If the manufacturer is **not** willing to certify that the ***typical physical properties*** of the castings meet the requirements in Table 2-3. I, experimental verification of all properties shown in Table 2-3.1 becomes mandatory.

(b) The acrylic castings from which the windows are produced must meet the ***minimum physical properties*** specified in Table 2-3.2 after the castings have been annealed per para. 2-4.4. The acceptance tests of castings

TABLE 2-3.2 SPECIFIED VALUES OF PHYSICAL PROPERTIES FOR EACH CASTING
(To be verified by testing of specimen from each casting or lot as defined in para. 2-3.5)

Test Procedures	Physical Property	Specified Values	
		U.S. Customary Unit	Metric Unit
ASTM D 638*	Tensile:		
	(a) ultimate strength	≥ 9000 psi	≥ 62 MPa
	(b) elongation at break	≥ 2%	≥ 2%
	(c) modulus of elasticity	≥ 400,000 psi	≥ 2760 MPa
ASTM D 695*	Compressive:		
	(a) yield strength	≥ 15,000 psi	≥ 103 MPa
	(b) modulus of elasticity	≥ 400,000 psi	≥ 2760 MPa
ASTM D 621*	Compressive deformation at 4000 psi (27.6 MPa) and 122°F (50°C), 24 hr	≤ 1.0%	≤ 1.0%
ASTM E 308	Ultraviolet transmittance [for 0.5 in. (12.5 mm) thickness]	≤ 5%	≤ 5%
PVHO-1 method, para. 2-3.7(e)	Visual clarity	Must pass readability test	Must pass readability test
PVHO-1 method, para. 2-3.8	Total residual monomer: (a) methyl methacrylate (b) ethyl acrylate	≤ 1.6%	≤ 1.6%

GENERAL NOTE:
Tests marked with an asterisk require testing of a minimum of two specimens. For others, test a minimum of one specimen. Where applicable, use the sampling procedures described in para. 2-3.7. Where two specimens are required in the test procedure, the average of the test values will be used to meet the requirements of the minimum physical properties of this Table.

shall be conducted for the window fabricator by the manufacturer of acrylic or by an independent materials testing laboratory. The results of the material acceptance tests (specified in Table 2-3.2) for sheet or custom castings shall be certified on a form equivalent to Appendix A, Enclosure 3. This certification shall be provided to the window fabricator and shall become a part of the certification information forwarded to the chamber manufacturer or user.

2-3.5

Acrylic castings shall be supplied in sheet form or as custom castings. All acrylic sheet castings shall have a nominal thickness of ½ in. (12.5 mm) or greater.

For purposes of this Standard, acrylic in the form of custom castings is classified as either Type I or Type 2 castings.

(a) Type I custom castings are defined as being of such thickness and configuration, and produced by such a process as to meet the requirements of Table 2-3.1 without experimental verification. To classify a casting as a Type I custom casting, the manufacturer of acrylic must certify that he has produced castings of similar shape and thickness and of the same material in the past and that such castings have met the requirements of Table 2-3.1.

(b) Type 2 custom castings are defined as being produced in such a thickness or configuration, or by such a process that the manufacturer of acrylic must *experimentally verify* that the acrylic castings possess the minimum physical properties specified in Table 2-3.1. All custom castings failing to meet the requirements of Type I shall be classified as Type 2 custom castings.

2-3.6

Acceptance tests performed according to para. 2-3.4(b) on a single casting can be used not only to certify the particular casting, but also, under special circumstances, to certify an entire lot.

(a) Acceptance tests performed according to para. 2-3.4(b) on one sheet casting chosen at random from a lot of acrylic cast sheets shall serve to certify all sheets of that lot providing that the manufacturer of acrylic shall positively and permanently identify each sheet so certified with a lot number and the designation ASME PVHO-1.

(b) The manufacturer of acrylic sheet castings may certify that a product of a given thickness meets the typical physical properties specified in Table 2-3.1 without identification of lot number. Each casting so certified must have acceptance tests performed on it according to para. 2-3.4(b) and at that time have assigned to it an inventory control identification which shall be affixed to the casting by the window fabricator and utilized in lieu of a lot identification in all ASME PVHO-1 documentation.

(c) Acceptance tests performed according to para. 2-3.4(b) on specimens cut from one Type 1 custom casting, taken at random from a lot of custom castings, shall serve to certify all castings of that lot. The manufacturer shall positively and permanently identify each certified casting with lot number and Safety Standard designation ASME PVHO-1.

(d) Single Type 1 custom castings shall have acceptance tests performed according to paras. 2-3.4(a) and (b) on specimens cut from each casting.

(e) Type 2 custom castings shall have tests performed according to paras. 2-3.4(a) and (b) on specimens cut from each casting to experimentally verify that the acrylic possesses the physical properties specified in both Tables 2-3.1 and 2-3.2. Tests for experimental verification of properties in Table 2-3.1 shall serve also to certify the properties in Table 2-3.2.

2-3.7

Testing of acrylic castings for the physical and optical properties specified in Tables 2-3.1 and 2-3.2 shall follow ASTM methods where applicable. Where possible, samples for testing shall be taken from an integral part of the casting. A test coupon casting may be used to supply material for testing provided the test coupon and window castings meet the lot requirements. Samples for testing are to be cut so that no surface of the test sample is closer to an unfinished cast surface than the normal trim line. Where possible, test samples shall be cut from the central portion of the original casting, e.g., a large casting cut into several windows. The test methods for physical properties specified in Table 2-3.2 shall be as follows.

(a) Tests for tensile properties shall be performed per ASTM D 638, using a testing speed of 0.20 in. (5.0 mm) per min ± 25%.

(b) Tests for compressive properties shall be per ASTM D 695.

(c) Tests for compressive deformation shall be performed per ASTM D 621 Method A, using specimens loaded to 4000 psi (27.6 MPa), and tested at 120°F (50°C). The sample size is a $\frac{1}{2}$ in. (12.5 mm) cube. To test nominal $\frac{1}{2}$ in. (12.5 mm) thick material, machine the specimen in such a manner that the as-cast surfaces serve as the load-bearing surfaces. Do not stack samples to reach $\frac{1}{2}$ in. (12.5 mm) height; instead test a sample, $\frac{1}{2}$ in. x $\frac{1}{2}$ in. (12.5 mm x 12.5 mm) nominal thickness. Nominal thicknesses over $\frac{1}{2}$ in. (12.5 mm) yield standard test specimens. These sampling procedures override those specified in ASTM D 621.

(d) Tests for the presence of an ultraviolet absorber (ultraviolet transmittance) shall be made using a monochromator having a bandwidth of 10 nm or less, a photometer having reproducibility of +1% of full scale, and the practices of ASTM E 308 to measure the spectral transmittance in the 290 to 330 nm wavelength band. Report the value of one specimen of nominal $\frac{1}{2}$ in. (12.5 mm) thickness. Measurements can be made on the casting or on the monomer mix from which the plastic is to be cast. Solid samples shall have two polished faces through which the light passes.

(e) The clarity of a casting shall be visually rated. Clear print of size 7 lines per column inch (25 mm) and 16 characters to the linear inch (25 mm) shall be clearly visible when viewed from a distance of 20 in. (500 mm) through the thickness of the casting with the opposite faces polished.

(f) Since an ASTM standard method is not available for measurement of residual acrylic monomer, the procedure specified in para. 2-3.8 is recommended.

2-3.8

A sample of suitable size shall be obtained and analyzed for unpolymerized methyl methacrylate and unpolymerized ethyl acrylate monomers using gas liquid chromatographic techniques (described in Snell and Otto, *Encyclopedia of Industrial Chemical Analysis*, Interscience Publisher, 1972, Vol. 4, pp. 211-217, and Vol. 16, p. 99, or one giving equivalent results). Samples for testing are to be cut so that the center point of the analyzed piece is no closer to the original edge or surface of the casting than the thickness divided by 2. The following (after Cober and Samsel, SPE Transactions "Gas Chromatograph, A New Tool for Analysis of Plastics," April 1962, pp. 145-151) is a suitable procedure.

(a) The instrument shall be a Beckman GC-2A gas chromatograph with a hydrogen flame detector, or equivalent, and a 6 ft (1.8 m) column of $\frac{1}{4}$ in. (6.0 mm) stainless tubing operated at 212°F (100°C). Pack the column with 25% diethylene glycol adipate polyester (LAC-2-R-446, Cambridge Industries Co.) and 2% phosphoric acid on an 80-100 mesh Celite filter aid. The acrylic to be analyzed shall weigh approximately 2.0 g and shall be dissolved in exactly 50 ml of methylene chloride. Inject a 3 microliter aliquot of the plastic-solvent solution into the gas chromatographic apparatus. Compare the areas of the resulting peaks with the areas produced by the injection of a standard solution. Prepare the standard solution by dissolving 20-30 mg of pure monomers in 50 ml of methylene chloride.

(b) Acrylic which does not dissolve shall be analyzed

by swelling the plastic and extracting the soluble portion. Place a solid piece of insoluble acrylic about l g and 20 ml of methylene chloride in a glass bottle, and place on a shaker for 24 hr. After 24 hr, the fluid portion shall be analyzed for monomeric methyl acrylate and monomeric ethyl acrylate per para. 2-3.5(a).

2-3.9

Windows in excess of 6 in. thickness shall require material testing of two samples from the casting. One sample shall be taken from the surface of the casting. The second sample shall be taken from the interior of the casting at a distance from any surface equal to half the thickness. The properties of each sample shall meet the requirements of Table 2-3.2.

2-3.10

The physical properties of bonds shall meet or exceed the following.

(a) The tensile strength of the bond shall be at least SO% of the parent material strength as established by ASTM D 638 test on five tensile coupons cut from a bond quality control specimen that was bonded at the same time and in the same manner as the acrylic castings intended for actual service.

(6) The significant and critical dimensions of inclusions, as well as the critical spacing between adjacent inclusions, shall not exceed those specified in para. 2-5.4 for a given window shape. The critical size of inclusion population shall not exceed the cross-sectional area of the bonded joint in $cm^2/10$. The critical density of population shall not exceed 2 inclusions per cm^2 of contiguous joint cross-sectional area.

ARTICLE 4 FABRICATION

2-4.1

Windows shall be fabricated only from acrylic castings satisfying the requirements of Section 2, Article 3. This shall be accomplished by the window fabricator through compliance with the following procedures.

(a) The window fabricator shall establish and maintain a current and documented Quality Assurance Program which complies with Section 3, Article 4, of this Standard. The Quality Assurance Program shall be accepted by the PVHO manufacturer and owner/user(s), hereafter referred to as the purchaser(s), prior to fabrication.

(b) All castings used for fabrication of windows shall be marked prominently with letters and/or numbers that are traceable to the material certifications (see Appendix A, Enclosures 2 and 3, and Form PVHO-2).

(c) Each window shall be numbered per para. 2-6.1 and these numbers shall be traceable to the castings from which they were fabricated. This traceability shall be certified on the fabrication data report, which shall provide, in equivalent form, the information shown on Form PVHO-2.

2-4.2

No fabrication process, solvent, cleaner, or coolant that degrades the original physical properties of the acrylic casting shall be used during fabrication.

2-4.3

During the fabrication process, each window shall be identified with identification and fabrication verification documents containing pertinent material and fabrication data.

2-4.4

All window material shall be annealed after all forming, machining, and machine polishing have been completed, hereafter referred to as the *final anneal.* All annealing shall take place in a forced air circulation oven. The final anneal and any other anneals performed prior to the final anneal shall be in accordance with Table 2-4. I. Time and temperature data for all annealing cycles shall be entered into Form PVHO-2. A copy of the final anneal's time/temperature chart shall be attached to Form PVHO-2.

2-4.5

Hand lapping and hand polishing to remove scratches caused by handling may be performed after final annealing.

2-4.6

Each window shall be inspected in accordance with Section 2, Article 5, after the final anneal.

ARTICLE 5 INSPECTION

2-5.1

The quality control inspection shall consist of dimensional and visual checks to assure the finished window meets the dimensional tolerances, material quality, and surface finish requirements specified in Section 2, Arti-

TABLE 2-4.1 ANNEALING SCHEDULE FOR ACRYLIC WINDOWS

Part A - Minimum Heating Times for Elevated Temperature Annealing of Acrylic

	Heat Time [Note (1)], hr. for Acrylic Placed in a Forced-Circulation Air Oven Maintained at the Indicated Temperature Within ± 5°F (2.8°C)			
Thickness, in. (mm)	≥ 230°F (110°C)	212°F (100°C)	195°F (90°C)	185°F (85°C)
0.500 to 0.750, incl. (13 to 19, incl.)	3.5	4	6	11
0.875 to 1.125, incl. (22 to 28, incl.)	4	4½	6½	11½
1.250 to 1.500, incl. (32 to 38, incl.)	6	5	7	12
1.750 (44)	7	5	7	12
2.000 (50)	8	6	8	13
2.250 (57)	9	7	9	14
2.500 (64)	10	9	11	15
3.000 (75)	12	11	12	17
3.250 (82)	13	13	14	17
3.500 (89)	14	13	14	19
3.750 (92)	15	14	16	20
4.000 (100)	16	17	18	22
>4.000	4	6	6	6 (per in. of additional thickness over 4)

Part B - Maximum Cooling Rates for Acrylic Subjected to Elevated Annealing Temperatures

		Time, hr, to Cool Acrylic From the Indicated Annealing Temperature at the Maximum Permissible Rate to the Maximum Allowable Removal Temperature of 120°F (49°C)			
Thickness, in. (mm)	Maximum Cooling Rate, °F/hr (°C/h)	230°F (110°C)	212°F (100°C)	195°F (90°C)	185°F (85°C)
0.500 to 0.750, incl. (13 to 19, incl.)	25 (14)	4.5	3.5	3	2.5
0.875 to 1.125, incl. (22 to 28, incl.)	18 (10)	6	5	4	4
1.250 to 1.500, incl. (32 to 38, incl.)	13 (7.2)	8.5	7	6	5
1.750 (44)	11 (6.1)	10	8.5	7	6
2.000 (50)	10 (5.5)	11	9	7.5	6.5
2.250 (57)	9 (5)	12.5	10	8.5	7.5
2.500 (64)	8 (4.5)	14	11.5	9.5	8.5
3.000 (75)	7 (4)	16	13	11	9.5
3.250 (82)	6 (3.5)	18.5	15	12.5	11
3.500 (89)	6 (3.5)	18.5	15	12.5	11
3.750 (92)	6 (3.5)	18.5	15	12.5	11
4.000 (100)	5 (3)	22	18	15	13
4.000 to 6.000, incl. (100 to 150, incl.)	4 (2)	27.5	23	19	16.5
6.000 to 8.000, incl. (150 to 200, incl.)	3 (1.5)	37	30.5	25	22
8.000 to 10.000, incl. (200 to 250, incl.)	2 (1)	55	45.5	37.5	32.5
10.000 to 12.000, incl. (250 to 300, incl.)	1 (0.5)	110	91	75	65

NOTE:
(1) Includes period of time required to bring part up to annealing temperature, but not cooling time.

cles 2, 3, and 4. Windows that meet the requirements of Section 2, Articles 2, 3, and 4, plus the requirements of this Section shall be accepted. In particular, dimensional measurements shall be made to show compliance with para. 2-2.12.

2-5.2

All dimensional and angular measurements shall be performed at a material temperature of 70 to 75°F (21 to 24°C). For hyperhemisphere, cylindrical, and NEMO type windows, measurements for deviation from true circular form, such as out-of-roundness and sphericity, shall be conducted at least 24 hr after placing the window in the orientation of, and supported in a similar manner to, the intended service. Out-of-roundness measurements of cylindrical windows shall be taken at both ends and at 25%, 50%, and 75% of the window length.

2-5.3

Scratches (or machining marks) on the surfaces of and inclusions in the body of the window shall not be acceptable if they exceed the specified critical dimension, critical spacing, critical size of population, or critical density of population, or are found in a critical location.

2-5.4

The critical dimensions of inclusions, critical spacing, critical size of inclusion population, critical location, and critical density of inclusion population depend on the shape of the window. Only inclusions whose diameter or length exceeds the following specified significant dimension will be considered during a visual inspection; all others will be disregarded.

(a) For spherical sectors with conical edge, hyperhemispheres, NEMO windows, conical frustums with $t/D_i \geq 0.5$, double beveled disks with $t/D_i \geq 0.5$, and cylinders under external pressure loading:

(I) significant dimension: 0.015 in. (0.4 mm);

(2) critical dimension: $0.05t$;

(3) critical size of population: total volume of window in cubic centimeters divided by 10,000;

(4) critical density of population: one inclusion per 16 cm^2 of contiguous volume;

(5) critical spacing between adjacent inclusions: select the larger of the two adjacent inclusions and multiply its diameter by a factor of 2;

(6) critical locations: no inclusions are permitted on or within critical spacing of all of the bearing and sealing surfaces.

(b) For spherical sectors with square edge, hemispheres with equatorial flange, cylinders under internal pressure, conical frustums with $t/D_i < 0.5$, double beveled disks with $t/D_i < 0.5$, and disks:

(I) significant dimension: 0.015 in. (0.4 mm);

(2) critical dimension: 0.030 in. (0.8 mm);

(3) critical size of population: total volume of window in cubic centimeters divided by 10,000;

(4) critical density of population: one inclusion per 16 cm^2 of contiguous volume;

(5) critical spacing between adjacent inclusions: 0.25 in. (6 mm);

(6) critical locations: no inclusions are permitted on or within critical spacing of all of the surfaces.

2-5.5

Critical dimensions of scratches (or machining marks), critical spacing, critical sizes of scratch population, critical locations, and critical densities of scratch population depend on the shape of the window. Only scratches whose depth exceeds the significant dimension will be considered during a visual inspection; all others will be disregarded.

(a) For spherical sectors with conical edge, hyperhemispheres, NEMO windows, conical frustums with $t/D_i \geq 0.5$, double beveled disks with $t/D_i \geq 0.5$, and cylinders under external pressure loading:

(I) significant dimension: 0.01 in. (0.25 mm);

(2) critical dimension: 0.06 in. (1.5 mm);

(3) critical size of population: total length of all scratches in centimeters equals total surface area divided by 1000;

(4) critical density of population: none specified;

(5) critical spacing between scratches: none specified;

(6) critical locations: no scratches are permitted on the bearing and sealing surfaces.

(b) For conical frustums with $t/D_i < 0.5$, double beveled disks with $t/D_i < 0.5$, disks and cylinders under internal pressure:

(I) significant dimension: 0.003 in. (0.08 mm);

(2) critical dimension: 0.06 in. (1.5 mm);

(3) critical size of population: total length of all scratches in centimeters equals total surface area divided by 1000;

(4) critical density of population: none specified;

(5) critical spacing between scratches: none specified;

(6) critical locations: no scratches are allowed on

the bearing and sealing surfaces, on any faces of double beveled disks and cylinders, and on low-pressure faces of conical frustums and disks.

(c) For spherical sectors with square edge, and hemispheres with equatorial flange of acrylic:

(1) significant dimension: 0.003 in. (0.08 mm);

(2) critical dimension: 0.01 in. (0.25 mm);

(3) critical size of population: total length of all scratches in centimeters equals total surface area divided by 1000;

(4) critical density of population: none specified;

(5) critical spacing between scratches: none specified;

(6) critical locations: no scratches are permitted on bearings and sealing surfaces, on low pressure face of spherical sector with square edge, and in the heel and instep areas of flanged hemisphere.

2-5.6

Repairs to new windows which do not meet acceptance criteria shall be performed in accordance with Appendix C.

2-5.7

After the quality control inspection, each acceptable window shall be certified as to fabrication processes, on a fabrication data report. The report shall be made on a form equivalent to Form PVHO-2. This report shall be forwarded to the chamber manufacturer or user as a part of the certification package.

ARTICLE 6 MARKING

2-6.1

Identification of each window with the window fabricator's certification shall be located on the window's seating surface. Identification shall consist of $\frac{1}{2}$ in. (13 mm) letters and numbers made by the window fabricator with an indelible black felt marker, or $\frac{1}{8}$ in. (3.2 mm) letters and numbers applied with epoxy ink. The identification shall contain information per the example shown below.

50–100–PVHO–RT–21–XX

- XX: **Year of window** fabrication
- 21: **Fabricator's serial number** of window
- RT: **Window** fabricator's name or identification symbol
- PVHO: Initials **for Pressure Vessel Human Occupancy**
- 100: **Maximum temperature, °F** (°C)
- 50: Design **pressure, psi** (MPa)

2-6.2

At the time of marking, the window fabricator shall certify the overall fabrication of the window by completing a window certification equivalent to Form PVHO-2. This certification shall indicate revision number of window fabricator's Quality Assurance Program and date accepted by purchaser. Only after completion of Form PVHO-2 shall the window be considered to have met the requirements of this Standard and the window can be marked in accordance with para. 2-6.1. This window certification shall be forwarded to the purchaser or used as part of the window certification package.

2-6.3

The windows are to be marked by the window fabricator with PVHO identification per para. 2-6.1 only if the design, material manufacturer, material testing, and fabrication certifications have been completed and are on file with the window fabricator applying the markings after having met the requirements of para. 2-6.2.

2-6.4

The window may also be marked with additional identifications. The size of letters, method of application, and their location on the window must satisfy the requirements of para. 2-6.1.

2-6.5

Copies of the window certifications and data reports (Form PVHO-2 and Appendix A, Enclosures 1–4) for each window are to be retained by the window fabricator or his agent for a period not less than the design life of the window plus 2 years.

ARTICLE 7 PRESSURE TESTING

2-7.1

Each window shall be pressure tested at least once prior to being accepted for service.

2-7.2

The pressure test shall take place with the window installed in the chamber, or placed within a test fixture whose window seat dimensions, retaining ring, and seals are identical to those of the chamber.

2-7.3

The window shall be pressurized with gas or water until design pressure is reached. The design pressure shall be maintained for a minimum of 1 hr, but not more than 4 hr, followed by depressurization at a maximum rate not to exceed 650 psi/min (4.5 MPa/min).

2-7.4

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 (+O/ –2.5°C). Brief deviations from the above temperature tolerances are allowed, providing that the deviation does not exceed 10°F (5.5°C) and lasts less than 10 min.

2-7.5

Windows that leak during the pressure tests shall be removed, fitted out with new seals, and retested. If, during the retest, the leakage continues, efforts will be made to complete the test by stopping the leak with a temporary seal. The inability of seals to operate properly during the test shall be noted in the test report, which shall be submitted at the conclusion of the pressure test to the chamber manufacturer/user.

2-7.6

At conclusion of 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.

2-7.7

Presence of crazing, cracks, or permanent deformation visible with the unaided eye (except for correction necessary to achieve 20/20 vision) shall be the cause of rejection of the windows and shall be so noted on the test report. Permanent deformation less than 0.0010, in magnitude measured at the center of the window shall not be cause for rejection.

2-7.8

A hydrostatic or pneumatic test in excess of design pressure may be substituted for the mandatory tests of paras. 2-7.3 and 2-7.4. During the hydrostatic or pneumatic test, the pressure shall be maintained for a minimum of 1 hr, but not more than 4 hr. The test pressure shall not exceed 1.5 times the design pressure or 20,000 psi (I 38 MPa), whichever is the lesser value. The temperature of the pressurizing medium during the test shall be at least 25°F (14°C), but no more than 35°F (20°C), lower than the design temperature, except for 50°F (10°C) design temperature, where the temperature during the test shall be in the 32 to 40°F (0 to 4°C) range to prevent permanent deformation of windows tested above design pressure. All the other requirements of the mandatory pressure test specified in paras. 2-7.5 through 2-7.7 shall be retained.

2-7.9

After pressure testing, a pressure test report shall be completed to certify the results of the pressure test. The information shall be reported on a form equivalent to Appendix A, Enclosure 4. The pressure test report shall be forwarded to the chamber user as part of the certification package.

2-7.10

Pressure test records shall be kept on file for at least the design life of the window plus 2 years.

ARTICLE 8 INSTALLATION OF WINDOWS IN CHAMBERS

2-8.1

The window cavity seat in the flange must be thoroughly cleaned. Aliphatic naphtha and hexane are suitable fluids for cleaning.

2-8.2

The window cavity seats for all window shapes possessing conical bearing surfaces shall be thoroughly coated with grease prior to placement of the window inside the window cavity so that the greased surfaces will act as secondary seals. Silicone greases are suitable for this purpose. Other greases must be checked for chemical compatibility with acrylic.

2-8.3

After placement of the window inside the window cavity, the primary elastomeric seal will be placed on the high pressure face of the window, and the retainer tightened until the seal compression reaches the minimum value specified in para. 2-2.1 1.