

The American Society of Mechanical Engineers

SAFETY STANDARD FOR PRESSURE VESSELS FOR HUMAN OCCUPANCY IN-SERVICE GUIDELINES FOR PVHO ACRYLIC WINDOWS

AN AMERICAN NATIONAL STANDARD

ASME PVHO-2-2003

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FOREWORD

In 1998 a PVHO Task Group was formed to investigate the need for In-Service Rules and Guidelines for Pressure Vessels for Human Occupancy. Simultaneously a Sub Task Group was formed to investigate the issue of acrylic window design life versus service life. The design life is based on the PVHO window being exposed to the MAWP, at the maximum rated temperature, for the maximum number of (design) cycles, in an outdoor weathering environment. The majority of PVHOs are not operated to such extremes, and service life may indeed be longer than design life. Conversely, if a window is not properly cared for (i.e., becomes exposed, either operationally or nonoperationally, to other detrimental factors which are not, and cannot be, factored into the design life), then the actual service life could be much shorter than the design life. Thus, the recommendation was made that design life and service life be addressed as two different subjects. In 1999 the In-Service Task Group became a PVHO subcommittee, with the most immediate task being the establishment of in-service criteria for PVHO windows and viewports.

This Standard provides the necessary in-service criteria to supplement Section 2 (Viewports) of ASME PVHO-1, which applies to new construction only. By comparison, this Standard applies to all PVHO-1 acrylic windows, regardless of their date of manufacture. This Standard consists of both Technical Criteria and Guidelines. They are intended to provide guidance to the User and/or the Jurisdictional Authority in regard to the establishment of potential Service Life, and the necessary care, inspection, and repair during that Service Life—depending on the actual service conditions to which the PVHO and windows have been, or will be, exposed.

Finally, this Standard was prepared as a "stand alone" document. All Forms additional to those normally supplied with the window in accordance with PVHO-1, which may be necessary throughout the service life of the window, are provided herein. Similarly, all necessary PVHO-1 technical data applicable to service, and repair (if required) are also provided in this Standard.

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SAFETY STANDARD FOR PRESSURE VESSELS FOR HUMAN OCCUPANCY: IN-SERVICE GUIDELINES FOR PVHO ACRYLIC WINDOWS

1 SCOPE

(a) This Standard provides technical criteria and guidelines for the in-service inspection, care, repair or replacement, testing, and recertification of PVHO acrylic windows in Pressure Vessels for Human Occupancy. It is intended to be used only with acrylic windows designed, constructed, tested, and certified in accordance with the requirements of ASME PVHO-1, Safety Standard for Pressure Vessels for Human Occupancy.

(b) This Standard provides technical criteria for the user to establish the serviceability of a PVHO acrylic window under its specific environmental service conditions. Windows in protected environments as well as those in severe environments are addressed. Judicious use of this Standard will allow the user and/or the jurisdictional authority to determine when a PVHO acrylic window requires replacement.

2 DEFINITIONS

acrylic: methyl methyacrylate plastic possessing physical and mechanical properties shown in Tables 2-3.1 and 2-3.2 of ASME PVHO-1.

adsorption: the uptake of water into the acrylic polymer matrix.

blemish: a small flaw on the surface of the window.

casting: the process of making a window by pouring the acrylic resin into a mold.

casting syrup: the mixture of monomer, polymer, and catalyst used in slurry casting.

chip: a small fracture flaw in the window surface (most typically, the result of impact with a hard object).

crazing: a micro feature (consisting of voided and orientated material formed at crack tips or inclusion particles) that is associated with the fracture and failure of polymers.

cylindrical window chamber: a PVHO consisting of a cylindrical acrylic window that is capped at both ends with metallic bulkheads.

defect: a flaw in the window usually present from the time of manufacture.

detergent: an alkaline solution used for cleaning of windows.

deterioration: a gradual breakdown of the acrylic polymer chain or the general physical condition of the window due to the combined effect of age, cycles, stress, and environmental factors.

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

flaw: any imperfection in the acrylic present from manufacture or service that affects the cosmetic or structural adequacy of the window.

high-pressure face: the side of the window exposed to the highest pressure.

low-pressure face: the side of the window exposed to the lowest pressure.

lubricant: any substance used to lessen friction between parts; compatibility with acrylic and the supporting structures limits the available compounds (and in some PVHO applications, also oxygen compatibility).

marine system: a chamber or chamber system used in a marine environment.

MAWP: maximum allowable working pressure.

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

monomer: small molecule with high chemical reactivity, capable of linking up with itself to produce polymers, or with similar molecules to make co-polymers.

polishing: the action of removing minute irregularities from the surface of the acrylic by application of progressively finer abrasives to the surface by either manual or machine methods to remove all traces of previous scratches resulting in an optically clear surface.

polymer: any of two or more polymeric compounds, especially one with a high molecular weight.

Pressure Vessel for Human Occupancy (PVHO): a pressure vessel that encloses a human being and is within the

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scope of ASME PVHO-1, including but not necessarily limited to the following:

(a) submersibles
(b) diving bells
(c) personnel transfer capsules
(d) decompression chambers
(e) recompression chambers
(f) hyperbaric chambers
(g) high-altitude chambers
(h) medical hyperbaric oxygenation facilities

PVHO Window Design Life: the length of time as defined by Section 2-2.7 of the ASME Safety Standard for Pressure Vessels for Human Occupancy (PVHO-1) that the designer uses for a particular geometry window.

PVHO Window Service Life: the length of time counted from the date of fabrication that an acrylic window may be used in a pressure vessel for human occupancy as determined by the user in accordance with the procedures and rules described in this Standard.

PVHO Qualified Window Fabricator: a window fabricator who maintains a QA system in accordance with the requirements of Section 3, Article 2 of PVHO-1 (or Mandatory Appendix III, herein).

radiation: radiant energy in the X-ray, gamma ray, and alpha ray spectrum.

red tag: to identify a window as not suitable for service.

repair: to rework the window in such a fashion as to make it useable again.

retaining ring: the mechanical part of the window assembly that maintains the window in the proper relationship to the window seat and the cushions and seals.

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

seal: any of several devices (both primary and secondary) used to prevent the escape of the pressurizing medium in a PVHO window system (refer to para. 2-2.11 of ASME PVHO-1 for specific design requirements).

seat: the structural bearing surface support for a PVHO window (refer to para. 2-2.10 of ASME PVHO-1 for specific design requirements).

shall: used to indicate that a provision is mandatory.

should: indicates a provision recommended as good practice, but is not mandatory.

significant dimension: when the dimension of a scratch or other defect exceeds a specified value, and is considered as being present for inspection purposes.

soft goods: O-rings, gaskets, seals, and other elastomer components.

solvent: a liquid capable of absorbing a compound (i.e., acrylic) into solution.

surface: the surfaces used in viewing (not an edge).

testing: material or component exposure to standardized tests to compare acceptability of the material or component properties to established standard values.

ASTM tests: any standardized test procedures developed by the American Society for Testing and Materials to establish material or other properties.

fixture testing: performing the required pressure testing of the window by using a test fixture whose window seat dimensions, retaining ring and seal are identical to that of the PVHO in which it is normally installed.

in-place testing: performing the required pressure testing of a window in the PVHO where it is normally installed, using its actual service seat.

proof testing: pressurization to a pressure greater than the intended service pressure by a factor deemed to provide assurance of adequacy.

hydrostatic: proof testing using water as the pressurizing medium.

pneumatic: proof testing utilizing either air or an inert gas as the pressurizing medium.

testing laboratory: a third party organization established to provide material testing in accordance with ASTM standardized test procedures.

thickness actual: the dimension of the window as a result of the original manufacturing and/or subsequent repair processes.

thickness required: the dimension of the window set forth in para. 2-2.7 of ASME PVHO-1 as necessary and sufficient to provide the desired design life as a function of its geometry and maximum temperature and pressure.

ultraviolet light: radiant energy below the visible light frequency having a detrimental effect on acrylic and other polymer materials.

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

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

window designer: the party who stipulates which portions of Section 2 of ASME PVHO-1 are necessary to fulfill the design requirements for a given geometry, suitable for a maximum number of cycles, to a specific maximum working pressure, and at a specified maximum temperature.

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

window supplier: the party who supplies finished windows with all required certifications to the PVHO manufacturer or user (original and/or replacement).

window user: the party who owns, maintains and/or operates the PVHO.

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window service environment: the ambient conditions of temperature, pressure, and pressurizing medium to which the window is exposed (both operationally and nonoperationally).

protected environment: benign conditions consisting of controlled ambient temperature and minimal exposure to UV radiation, chemicals, and abrasion, which the designer would expect to have minimal effect on the service life of the window (medical chambers are typically operated in a protected environment)

severe environment: any conditions of temperature extremes, pressure, radiation (i.e., UV light), and pressurization medium or contamination that the designer would anticipate to shorten the service life of the window (marine systems are typically, but not necessarily, operated in a severe environment)

X-ray: an electromagnetic wave of short wavelength, which causes deterioration of the acrylic polymer chain.

3 REFERENCES

ASME PVHO-1–2002, Safety Standard for Pressure Vessels for Human Occupancy (referred to hereinafter as simply PVHO-1)

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ASTM D 638-98, Standard Test Method for Tensile Properties of Plastics

ASTM D 695-96, Standard Test Method for Compressive Properties of Rigid Plastics

ASTM D 790-98, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

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

4 RESPONSIBILITIES AND JURISDICTIONAL CONSIDERATIONS

4.1 Window Designer's Responsibility

It is the window designer's responsibility to determine the window design requirements. The window designer shall define manufacturing tolerances, and shall certify that the window design complies with the requirements of Section 2 of PVHO-1 (i.e., completion of the applicable PVHO-1 window design certification form).

4.2 Window Fabricator's Responsibility

The window fabricator shall manufacture the window in accordance with the designer's drawings and specifications and PVHO-1. The fabricator shall be responsible for completion of all PVHO-1 certification forms applicable to the manufacture, and comply with the data retention requirements of PVHO-1.

4.3 Window User's Responsibility

The window user shall provide the designer with information regarding the service conditions that the window may encounter during its service life. The user shall protect the window from service life hazards, and ensure that the window is used within its design limitations. It is the user, and not the Designer or Fabricator, who is responsible for determination of the safe service life in accordance with the technical criteria and guidelines herein. The user is responsible to retain all documentation for each window and shall establish a program of periodic window inspection to determine the need for repair or replacement in accordance with Sections 7 through 9 and Mandatory Appendix I.

4.4 Jurisdictional Considerations

The operation of each PVHO is typically governed under specific rules of the jurisdiction in which it is operated. (Examples include, but are not necessarily limited to State, FDA, and USCG). This safety standard is intended to complement the jurisdictional requirements (i.e., to provide guidance to both users and jurisdictional authorities in regard to in-service requirements for PVHO acrylic windows). The responsibility for compliance with jurisdictional in-service requirements, which may become invoked as a result of the technical criteria and guidelines as set forth herein, lies with the user.

4.5 Quality Assurance

The specific rules governing the window fabricator quality program during original window manufacture are detailed in PVHO-1. Quality assurance of the window in-service is no less important. The user is responsible to

(a) retain all original forms

(b) implement a formal in-service window inspection program

(c) retain all maintenance inspection forms and all window repair forms, as applicable, throughout each window's service life

Repair of severely damaged windows shall be performed by a PVHO-1 qualified window fabricator in accordance with the requirements of Mandatory Appendix III, herein.

5 FACTORS AFFECTING SERVICE LIFE

Temperature extremes, exposure to UV light, X-rays, and many chemicals are all detrimental to the longevity of windows. Specific attention should be given to limiting the window's exposure to detrimental environmental factors wherever possible.

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5.1 Physical Abuse Factors

Physical abuse from dropping, impacts with foreign objects, excessive heat from lights, or scratches from cleaning with too coarse a cleaning cloth are all damaging to windows.[1]

Windows should either be removed or adequately protected prior to grit blasting and coating of the chamber surface near the window.

5.2 Temperature Abuse Factors

5.2.1 Heat Sources. Various activities around a PVHO can provide heat sources that can damage the window. Powder-coating systems and other heat curing of coatings on vessel surfaces shall not be attempted without first removing the window from its mounting. Lighting fixtures can cause overheating of the adjacent face of the window and shall not be used if there is a chance that the temperature at the window face may exceed the window's maximum temperature rating.

5.2.2 Improper Operation of Lighting Equipment. Where applicable, light pipes shall NOT be operated with light bulbs of a wattage greater than the rated capacity of the lighting system, faulty temperature sensors, or with the cooling fan inoperative or disabled. Under no circumstances shall the surface of the acrylic, due to the use of a lighting system, be permitted to exceed the window's maximum temperature rating.

5.3 Chemical Abuse Factors

Windows are sensitive to liquids and chemical vapors. Users shall confirm, by testing if necessary, that any liquid solution, cleaner, or vapor that comes in contact with the window will not cause degradation of the acrylic. See Mandatory Appendix V for a partial list of harmful substances and acceptable products.

5.4 Radiation Exposure

PVHO acrylic material can be severely damaged by long term exposure to UV radiation and X-rays. As UV radiation primarily affects the surface, and does not penetrate deeply into the plastic, the designer and/or user may want to consider using separate acrylic covers to protect the window surface by absorbing most of the UV radiation before it reaches the window installed in the PVHO. A minimum thickness of 0.25 in. (6 mm) is recommended. Such covers however, are not effective against X-rays, which will penetrate not only the cover, but also the entire body of the PVHO window.

5.5 Cycles as Related to Above Factors

The user should also be aware that subjecting the window to a high number of pressure cycles (or extended sustained pressurizations) at or near the maximum design pressure, also affect the window's service life. That is, stressors are both pressure and environment related, with cumulative affect.

5.6 Additional Service Factors

Water adsorption (and/or the repeated wetting and drying) of acrylic plastic can be detrimental to the physical properties at the surfaces of the windows.

6 HANDLING OF PVHO WINDOWS

The following general provisions apply to the handling of PVHO windows:

(a) Always use care in handling the windows.

(b) Do not use solvents when cleaning the window.

(c) Do not expose to solvent- based paints or thinners.

(d) Do not expose to temperatures above 150°F (65°C).

(e) Do not expose to high radiation (above four Megarads).

(f) Minimize exposure to sunlight and other UV light sources.

(g) Inspect windows before every operation.

(h) Use only the gasket, seal and/or O-ring size and material specified on drawings.

(i) Ensure seals and gaskets are properly installed using adhesive sealants or lubricants compatible with acrylic window material.

(j) Do not operate at temperatures or pressures above the design temperature or design pressure.

(k) Keep protective cover on windows whenever possible.

(l) Never over torque the window retaining fasteners.

6.1 Cleaning and Polishing

6.1.1 Correct Methods. Windows may be cleaned to restore optical quality or clarity as the need arises. The window should only be wiped with a soft rag or cloth (or a very soft type of paper towel) wetted with warm water and an acceptable cleaning agent. As any use of power tools requires annealing, cleaning and/or polishing by hand is the only acceptable in-service method. The recommended agent to clean windows is a detergent in solution in warm water not exceeding 120°F (49°C). Aliphatic naphtha or hexane are also acceptable, but only if the temperature of the window surface does not exceed 100°F (38°C).

After cleaning, window surfaces may be polished with compounds specifically endorsed by the manufacturer for polishing of acrylic. These compounds are also used for removing small scratches from the surface. See Mandatory Appendix V for a partial listing of acceptable cleaning products and polishing compounds.

6.1.2 Incorrect Methods. Solvents shall not be used for cleaning windows. If used on the seats, extreme care shall be taken to assure that drying/evaporation of the

[1] This can include use of some common paper towels.

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solvent is complete, prior to window installation. Mandatory Appendix V provides a list of harmful substances.

Power polishing shall not be performed unless the window is subsequently annealed and pressure tested, per the requirements set forth in Mandatory Appendix IV.

6.2 Window Storage

An unused acrylic window may be stored for up to ten years from the date of fabrication without the storage time counting toward the service life provided the window is stored under conditions meeting the following requirements:

(a) The window is stored at a temperature not exceeding 125°F (52°C).

(b) The window is protected from exposure to direct or indirect sunlight.

(c) The window is protected from wetting and drying.

(d) The window is protected from exposure to harmful chemicals (both liquid or gaseous).

(e) Windows shall be stored flat and must not be stacked; that is, not on their edges, or with any weight bearing on them.

(f) The date storage begins is the date of manufacture; thus, the date of installation shall be recorded, and retained as a permanent record.

(g) Any storage time in excess of ten years shall be included, day for day, in the service life of the window.

7 INSPECTION OF PVHO WINDOWS AND VIEWPORTS

There shall be (as a minimum), three types of inspections:

(a) window — operational

(b) window — maintenance

(c) viewport seat and seal

The objective of the window inspections is the detection of flaws (i.e., crazing, discoloration, cracks, chips, scratches, gouges, burns, or pits) that may reduce the structural adequacy of the window. If flaws are detected, their size, location, and population shall be recorded and compared to the limits listed in Tables I-1, I-2, I-3, and I-4 of Mandatory Appendix I. If any of these visible defects exceed the stated limits, the PVHO window and/or system shall be taken out of service until the window has been repaired in accordance with the requirements set forth herein, or replaced with a new PVHO window.

7.1 Types of Inspection

The differences between various inspections required by this Standard are the extent and the thoroughness of the inspection required. Regardless of the type of inspection being performed, sufficient lighting is quite important. For inspections, a strong hand-held light should be moved to various angles as necessary to highlight the presence or absence of crazing, cracks, or scratches.

7.1.1 Operational Window Inspection. This type of inspection is continuous during the life of the window and shall be part of any pre-operational procedures the user institutes to establish the safety and serviceability of the PVHO system. Window surfaces readily visible from inside and/or outside the PVHO are examined. Although the bearing and/or sealing surfaces may not be readily visible, as a minimum this does allow for both the high and low pressure surfaces to be fully examined.

The visible surfaces shall be inspected in sufficient detail to detect all flaws of critical severity that require immediate removal of the window or PVHO from service. Inspection for the presence of crazing, cracks, discoloration, blisters, scratches, and pits shall be made during the operational inspections.

7.1.2 Window Maintenance Inspection. This type of inspection is to be performed at periodic intervals. It is more comprehensive than operational inspections and may possibly require removal of the window to satisfy the user or his agent that no hidden damage is present. During this type of inspection, all the surfaces (and edges) described in Table I-1 (of Mandatory Appendix I) are to be inspected to the criteria set forth in Tables I-2 through I-4 of Mandatory Appendix I. Special optical devices, such as prisms, optical measuring devices and coherent fiber bundles are very useful for this purpose. At this time minor cosmetic repairs may be appropriate.

In addition to the requirements set forth in para. 7.2, maintenance inspections should also be performed on windows in PVHOs that have been out of service for 18 months or longer, prior to putting the PVHO back into service.

Written records of the results of maintenance inspections shall be retained throughout the service life of each window. The minimum data to be recorded shall consist of the forms as provided in Mandatory Appendix I. Other additional data may consist of photographic documentation, schematics, etc., as well as any non-remedial cosmetic actions taken regardless of the window's acceptability.

Maintenance inspections should be performed and documented by either a PVHO Qualified Window Fabricator or an inspector meeting the qualifications set forth in para. 7.6. For windows whose service life is in excess of the design life, this becomes a mandatory requirement (versus recommendation only).

7.1.3 Seat and Seal Inspection. In addition to the requirements of Table 7.1.3, this type of inspection applies when

(a) a window has been removed for maintenance inspection or repair, or

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(b) a new replacement window is being installed

At this time all related viewport components should be checked for conformance to design drawings and for serviceability of the assembly. The inspection of the viewport seat and seals shall confirm the integrity of the existing seals; and shall also confirm that the condition of the window bearing surface has not deteriorated.

7.1.4 Reinstallation of PVHO Windows

NOTE: Extreme care shall be exercised during removal and reinstallation of flat disc and double bevel disc windows to ensure they are reinstalled in the original orientation with regard to the high-pressure face and low-pressure face.

Before installation of new windows or reinstallation of existing windows, the condition of the bearing surfaces of the window frames shall be inspected, and renewed as necessary. Gaskets and seals shall be examined, and if deemed necessary, new gaskets and seals shall be used.

The window cavity seat in the flange shall be thoroughly cleaned. The seats for all windows with conical bearing surfaces shall be thoroughly coated with an acceptable lubricant (see Mandatory Appendix V) prior to placement of the window inside the cavity, enabling the lubricated surfaces to act as secondary seals.

7.1.5 Additional Viewport Refurbishment Considerations

(a) Adhesives. Adhesives, when necessary to bond neoprene or cork gaskets or cushions to the metal window seat surface, shall be compatible with the acrylic window. A partial list of compatible products is found in Mandatory Appendix V.

(b) Lubricants. It is the responsibility of the user to determine, by testing if necessary, that greases and other lubricants used are compatible with both Acrylic and the pressurizing medium, and do not present a hazard to the occupants. See Mandatory Appendix V for a partial list of Acrylic compatible products. In the case of chambers which are pressurized with oxygen, the user shall also assure that the lubricant used is rated as being oxygen compatible.

(c) Fasteners. The user should also be aware of the quality and condition of the fasteners. When necessary, they should be replaced by identical items.

7.2 Inspection Intervals

7.2.1 Operational Inspections. Windows in service shall be inspected visually before each pressurization (internal or external as applicable). For windows that are pressurized more than once per day, the operational inspection need be done only before the first pressurization on that particular day. For windows with wetted surfaces, the inspection of both surfaces may be performed from the dry surface unless a flaw is detected on the wetted surface. That is, all flaws detected (regardless of surface) shall be measured to determine the depth of the flaw.

Table 7.1.3 Maximum Intervals for Seat/Seal Inspection and Refurbishment

Type	Maximum Interval
Cylindircal window chambers	Completely refurbish at 10-year intervals regardless of usage
Medical (all other types)	Completely refurbish at expiration of the extended service life and inspect one viewport assembly every 10 years
Marine intermittent submersion	Completely refurbish at 10-year intervals regardless of usage and inspect one viewport assembly at each dry-docking for performance of major maintenance (or window testing) [Note (1)]
Marine continuous submersion	Completely refurbish at expiration of extended service life and inspect one viewport assembly at each dry-docking for performance of major maintenance (or window testing) [Note (1)]

NOTE:
(1) Inspection of seat/seal more frequently than 3-year intervals is not deemed necessary if the periodicity of dry-docking for maintenance (or other) purposes is actually more frequent.

7.2.2 Maintenance Inspections. The user is responsible to establish a written procedure setting forth a formal schedule for window maintenance inspection. This scheduling shall take into account the service environment, and also whether or not the service life is less than, or greater than, its design life.

The intervals shown in **bold** in Table 7.2.2 are the maximum acceptable for both protected and severe environments, also taking into account whether or not the service life has exceeded the design life. As only the maximum recommended intervals are shown, common sense and prudence are required. For example, a marine system maintained within a UV protected environment (versus being stored outdoors) might be deemed as less than severe. Conversely, a medical chamber that is used on a continual daily basis should be inspected at more frequent intervals. Regardless, the user is responsible for establishing a formal schedule, and complying with it.

7.2.3 Seat and Seal Inspections. The periodicity of Seat/Seal Inspection is independent of the relationship of the window's service life as compared to design life. Maximum recommended intervals for viewport seat/seal inspections are provided in Table 7.1.3. Although further apart than maintenance inspections, a formalized schedule that takes into account the service environment should be implemented.

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Table 7.2.2 Maximum Intervals for Window Maintenance Inspections

Actual Service Duration and/or Cycles	Protected	Typical	Severe Service
Less than design life	36 months	24 months	18 months
Greater than design life	24 months	18 months	12 months

GENERAL NOTES:

(a) Because of the critical adjustments of tie rods, cylindrical window chambers should not normally be disassembled on a periodic basis for performance of maintenance inspections.

(b) The cyclic design life of windows per PVHO-1 Case 4 is as determined by the Case.

7.3 Limitations on Service Life

The service life of windows in a PVHO operated in a *protected service environment* may be extended beyond the design life on the basis of visual inspections alone. However, no window may remain in service for more than 10 years or 5,000 cycles beyond its design life, unless one or more windows from that PVHO are tested in accordance with Section 10. (The exception is cylindrical window chambers, which may be operated for up to an additional 10,000 cycles maximum, prior to replacement.)

The service life of windows in a PVHO operated in a *severe service environment* may not be extended beyond the design life on the basis of visual inspections alone. Any service life duration extension beyond the design life shall be justified by the test procedures of Section 10.

The maximum service life duration extensions per each mechanical property test based on the procedures of Section 10 may not exceed 10 years (or the equivalent number of cycles). There is no limit however, on the number of additional extensions that may subsequently be applied to the service life of windows in the same vessel based on subsequent mechanical property tests.

Under no circumstance shall a window found to be in need of repair, be permitted further use without making the needed repair. Similarly, under no circumstance shall a window found to be non-repairable be permitted to be used again. These limitations shall be strictly adhered to, regardless of how short the actual service duration and/or number of accumulated cycles may have been at the time of the subject inspection.

NOTES:

(1) Storage in accordance with para. 6.2 does not contribute to service life, except as noted.

(2) For windows in accordance with PVHO-1 Case 4, the cyclic life is as determined by that Case.

7.4 Instrumentation and Tools

The primary inspection tools are commercially available devices such as rulers, micrometers, vernier calipers, optical comparators, polariscopes, high intensity lights, radius gages, flatness gages, and dial indicators for measuring the properties of flaws (diameter and depth of pits, the depth of scratches, and gouges, and the penetration of cracks below the surface of the window).

Both mechanical and optical devices can measure the properties of flaws (depth of pits, scratches, and gouges); but only optical devices can measure the depth of flaws and the penetration of cracks. The depth of pits, scratches and gouges, as well as penetration of cracks into the acrylic surface less than 0.05 in. in depth can be measured nondestructively using a ×-100 magnification optical depth micrometer with 0.0001 resolution.

The depth of pits, scratches, and gouges deeper than 0.05 in. can be measured with a depth micrometer equipped with a pointed rod, or dial indicator depth gages equipped with a pointed rod.

Mechanical tapes and rulers calibrated in $\frac{1}{64}$ of an inch or millimeters are useful for measurements of sizes of chips on the window's sharp edge surfaces.

7.5 Documentation and Record Retention

All window maintenance inspection results and findings shall be documented using the forms in Mandatory Appendix I. All records including the original PVHO-1 documentation package, the maintenance inspection reports, and all repair-related forms set forth in this Standard (plus any additional documentation that the cognizant jurisdictional authority may require) shall be retained by the user for the duration of the window's service life, plus 1 year.

7.6 Competency of Inspectors

The following is recommended for maintenance inspections in general, and in particular for windows whose service life is in excess of their design life.

7.6.1 Training of Inspectors. Training of inspectors is the responsibility of the user, or the third party inspection organization acting on behalf of the user. A formal training program should be used in the training of inspection personnel.

(a) Training Programs. Inspection personnel shall have competent knowledge of Section 2 of PVHO-1, and this Standard. The inspection personnel should have practical training and competency in the use of measuring instruments. The training program should provide adequate exposure to the principles of quality control and quality assurance documentation to allow the inspection personnel to perform the inspections required and document those inspections in accordance with this Standard. The training program shall prepare inspection personnel to properly identify various window conditions, and the acceptance criteria and required actions as detailed in this Standard.

(b) Testing Requirements. Upon completion of training, inspection personnel should be formally tested for competency and understanding of Section 2 of PVHO-1, and this Standard. The test(s) and results shall be maintained

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for the duration of the inspector's employment. Where the maintenance inspections are performed by the user, such data should also be retained for the duration of the service life of the windows inspected. Regardless of who performs the inspection, it is the responsibility of the inspector's employer to determine if and when periodic retesting of inspection personnel is required.

7.6.2 Certification of Inspectors and Use of Third Parties. Certification of inspection personnel is the responsibility of the user, or the third party agent of the user. When a third party is engaged as the window inspection agency, the user is responsible for selection of a competent organization.

8 CATEGORIES OF DAMAGE

8.1 Superficial (Does Not Require Action)

Damage or a scratch that is superficial in nature (i.e., affecting only the optical clarity of the window and/or is below the significant dimensions set forth in Tables I-2 through I-4 of Mandatory Appendix I) shall require no action on the part of the user other than the logging of the condition on the inspection documents at the time of the discovery of the condition, and continued monitoring thereafter.

8.2 Significant (Requires Action)

Damage that is not superficial (i.e., exceeds the significant dimensions set forth in Tables I-2 through I-4 of Mandatory Appendix I) shall require the window to be Red-Tagged, and action on the part of the user to either repair or replace the window shall be undertaken. Logging of the condition on the inspection documents at the time of the discovery of the condition shall be made.

8.3 Nonrepairable (Requires Replacement)

Whether or not a window is repairable depends, in part, on the thickness. That is, as indicated in Appendix I, enclosure 1 of PVHO-1 for the window in question, can the repair be accomplished with the final *thickness actual* still equal to, or greater than, the *thickness required*. As the other consideration is cost, it might appear that a window whose service life has already exceeded its design life should simply be discarded.

Replacement windows shall meet the requirements for PVHO windows as described in Section 2 of ASME PVHO-1 (i.e., materials, manufacturing processes, quality assurance, material testing, pressure testing, inspection, and certification). Replacement windows shall have all necessary PVHO Certifications (design, manufacture, and pressure test).

9 REPAIR OF DAMAGED PVHO WINDOWS

Windows with minor flaws or blemishes may be repaired by the elimination of the flaw, blemish, or chip. Windows with minor flaws or blemishes may be repaired by hand polishing by the user or his agent. Severely damaged windows shall be repaired only by a party having a quality assurance program which meets the requirements set forth in Mandatory Appendix III.

9.1 Field Repair

Windows with minor flaws or blemishes may be repaired in the field only by hand sanding and polishing. Scratches and/or crazing are removed and the surface is restored to original transparency by manual wet sanding with 240 grit abrasive cloth, followed by progressively finer grits until a clear finish is attained. The recommended series of abrasive cloths is 320; 400; 600; 800; 1,000; 1,200; 2,400; 3,200; 3,600; 8,000; and 12,000. Some polishing grades may be omitted if a minor reduction in surface clarity is acceptable. Windows repaired in this manner do not have to be annealed or pressure tested before being returned to service. Field repairs, however, shall not degrade either the design geometry or the sealing capability of the window.

9.2 Repair of Severely Damaged Windows

Severely damaged windows shall be repaired *only* by a window fabricator who is PVHO qualified in accordance with the requirements of Mandatory Appendix III. Compared to remachining, which may be performed on any window surface, the use of spot casting is restricted to window areas in compression only.

9.3 Thickness Check

After any window repair has been completed, the thickness shall not be less than the required minimum thickness of the window design as stated on the original Window Design Certification. All repairs (regardless of their extent) shall be documented using the applicable portions of the form provided in Mandatory Appendix II, and retained in the documentation package (see para. 7.5).

9.4 Nonconformance

If the post-repair window thickness does not meet the required minimum, the window may be assigned a lower pressure rating by having such lower value entered into the design data package (along with all supporting calculations). It shall not be used in a PVHO having a MAWP greater than that lower value.

9.5 Post-Repair Annealing and Pressure Testing

After completion of any machining, including machine polishing, the window shall be annealed and pressure tested in accordance with the requirements set forth in Mandatory Appendix IV.

10 MECHANICAL PROPERTY TESTING

For PVHOs operated in a protected environment, when service life reaches 10 years or 5,000 cyles beyond

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the design life, one window from the PVHO shall be tested as follows. (The exception is cylindrical window chambers that may be operated for up to an additional 10,000 cycles, maximum.)

For PVHOs operated in a severe service environment, when the service life (based on either time in-service or number of cycles) reaches design life, one or more of the windows from the PVHO shall be tested as follows.

There shall be at least three test coupons for each of the types of tests and locations shown below.

Location	Type	Method
Low-pressure face	Flexural ultimate	ASTM D 790
Window mid-plane	Tensile ultimate	ASTM D 638
Window mid-plane	Flexural ultimate	ASTM D 790
High-pressure face	Flexural ultimate	ASTM D 790

NOTES:

(1) Test coupons from the faces shall include the parent surface material. That surface shall not be refinished and the coupons shall not be annealed. For windows with a 10-year design life, the low-pressure face coupons shall be flexed with the parent surface in tension, and the high-pressure face with the parent surface in compression. For windows with a 20-year design life, both type coupons shall be flexed with the parent material in compression.

(2) The window(s) chosen for testing shall be from a location on the PVHO that is most prone to weathering (i.e., exposure to UV). Similarly, if the PVHO has had some of its windows replaced, the window(s) chosen for testing shall be the oldest and/or those having seen the greatest number of service cycles.

The decision as to which specific window(s) is to be tested should be jointly determined between the user and the local jurisdictional authority.

10.1 Validation of Minimum Acceptable Properties

The mean value of the window mid-plane flexural ultimate strength and the mean value of the tensile ultimate strength shall be equal to or greater than 14,000 psi (96.5 MPa) and 9,000 psi (62.0 MPa), respectively. If either one of those requirements is not fulfilled, then the balance of the windows on the PVHO shall be replaced. Otherwise, evaluation may continue as follows.

NOTE: Computation methods to be used are provided in Mandatory Appendix VI.

10.2 Evaluation of Data for Additional Years of Service Life

The balance of the windows in that PVHO may be extended for an additional 10 years, provided that each of the following conditions is fulfilled:

(a) The mean value plus standard error of the tensile ultimate at the mid-plane is equal to or greater than the value recorded on the original Enclosure 3 of Appendix I of PVHO-1.

(b) The mean value plus the standard error of flexure for the high-pressure face is equal to, or greater, than the mean value of the mid-plane flexure.

(c) The mean value plus the standard error of flexure for the low-pressure face is equal to, or greater than, the mean value of the mid-plane flexure.

If all three conditions are not met, then any additional life extension for the windows in the PVHO should be based on the following extrapolations, which use lower values on the confidence interval (CI) of the high-pressure face and low-pressure face data, in conjunction with the best estimate of the window's original flexure ultimate strength. The additional service life extension based on the extrapolation equations may not exceed 10 years maximum (or 10,000 cycles; see para. 10.3) regardless of the solutions obtained, before having to test another window from the same PVHO. That is, additional service life is the *lowest* value of X calculated by the four extrapolation equations (i.e., the lesser of X_1, X_2, X_3 or X_4), or 10, if all of the solutions are greater than 10.

$$X_1 = [L_{95} - 10{,}000]/[(U_m - L_{95})/Y]$$

$$X_2 = [H_{95} - 10{,}000]/[(U_m - H_{95})/Y]$$

$$X_3 = [L_{99} - 7{,}000]/[(U_m - L_{99})/Y]$$

$$X_4 = [H_{99} - 7{,}000]/[(U_m - H_{99})/Y]$$

H_{95} = lower 95% CI value on HPS flexure (with pressure face in compression)

H_{99} = lower 99% CI value on HPS flexure (with pressure face in compression)

L_{95} = lower 95% CI value on LPS flexure (with pressure face tension)

L_{99} = lower 99% CI value on LPS flexure (with pressure face tension)

U_m = best estimate of original flexure ultimate at window mid-plane, based on actual test data

Y = actual years in-service at the time that the testing is performed

In regard to the last parameter U_m, if the mean value plus the standard error of the ultimate tensile strength at the mid-plane is equal to or greater than the original tensile strength of the window recorded on Enclosure 3 of Appendix I of PVHO-1, then simply let U_m be equal to the mean flexure ultimate value as-tested.

If it is less, then adjust (i.e., increase) the mean value of the flexure ultimate of the mid-plane, U_m in direct proportion to the fractional ratio between the mean value of the tensile strength at mid-plane as compared to the original tensile strength value for the window as recorded on Enclosure 3 of Appendix I of PVHO-1.

10.3 Commensurate Extension of Cyclic Service Life

For each year of additional service life, the cyclic service life should also be extended by 1,000 cycles beyond the number of cycles accumulated prior to testing. That is, the commensurate cyclic service life extension is

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added to the number of cycles that have already accumulated prior to the performance of mechanical testing. See also paras. 10.4(a) through (c).

10.4 Additional Notes to Section 10

(a) For windows in accordance with PVHO-1 Case 4, cyclic fatigue life is as determined by that Case, regardless of any additional service life duration that may result from the mechanical testing of specimens from the representative window in the PVHO.

(b) The stipulation in para. 10.1 that the balance of windows in the PVHO shall be replaced applies only to those whose service life exceeds design life. That is, it does not apply to those windows that may be more recent replacements.

(c) When the balance of windows in the PVHO is granted a service life extension, such extension expires when either the additional time duration is reached, or the additional number of cycles are reached, whichever occurs first. At that time, one or more windows shall again be removed, tested, and evaluated in accordance with the requirements set forth herein. That is, some amount of service life extension is technically justified, when all of the following are true:

(1) mid-plane tensile mean value > 9,000 psi (62.0 MPa)

(2) mid-plane flexure mean value > 14,000 psi (96.5 MPa)

(3) L_{99} and H_{99} > 7,000 psi (48.25 MPa)

(4) L_{95} and H_{95} > 10,000 psi (68.9 MPa)

(d) If one of the test data points appears to be unusually low compared to the others in the same lot, additional coupons may be prepared and tested, with the following provisions. At least two more shall be prepared and tested. The data point in question may only be censored however, if its value lies beyond four standard deviations from the mean, where the mean and standard deviation are based on the population not including that data point. The only exception to this is where the testing circumstances of that particular coupon were clearly abnormal, and the specific reason(s) for that has been documented in writing by the person or party actually performing the testing.

(e) In the event that there is insufficient material to prepare and test additional coupons, the user does have the option of performing additional testing on another window from the same PVHO, and combining both of the data sets, provided that they are from the same original batch and lot of material.

(f) In either case [i.e., paras. 10.4(d) and (e)], the testing of additional coupons may only be perfomed once. That is, an iterative approach is not permitted.

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MANDATORY APPENDIX I
INSPECTION TABLES AND FORMS

Table I-1 Periodic Inspection Requirements

Types of Windows	Surfaces and Edges of Windows					
	High-Pressure Surface (HPS)	Low-Pressure Surface (LPS)	Bearing Surface (BS)	All Other Surfaces	Sharp Edges	Requires Window Removal
Operational Inspections						
All window geometry	Yes	Yes	...	...	...	...
Maintenance Inspections						
Cylinders under internal pressure	Yes	Yes	...	...	...	...
Cylinders under external pressure	Yes	Yes	Yes	Yes	Yes	...
Conical frustums	Yes	Yes	Yes	...	...	...
Double bevel disc	Yes	Yes	Yes	Yes	...	Yes
Spherical sectors with square edge	Yes	Yes	Yes	...	...	...
Spherical sectors with conical edge	Yes	Yes	Yes	...	...	...
Hemispherical with flanges	Yes	Yes	Yes	Yes	Yes	...
Hyper-hemisphere with conical edges	Yes	Yes	Yes	Yes	Yes	...
Nemo shapes	Yes	Yes	Yes	Yes	Yes	...
Plane (flat disc) window seat with O-ring	Yes	Yes	Yes	Yes	Yes	Yes
Plane (flat disc) window seat without O-ring	Yes	Yes	...	...	...	...

GENERAL NOTE: Table I-1 above presents the minimum extent of Operational and Maintenance Inspections. In cases where the window has been removed for the accomplishment of viewport refurbishment (or a choice has been made to remove the window for inspection), then all surfaces/edges shall be inspected in accordance with Tables I-2 though I-4.

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Table I-2 Limits for Blemishes or Flaws on Window Surfaces

Type of Window	Location	Blemish or Flaw		Corrective Action
		Type	Size	
Group A	HPS	Pit	$k > .02t$	Red Tag
Plane (flat disc); conical frustum with $t/D_i < 0.5$; double	HPS	Scratch/gouge	$k > .02t$	Red Tag
bevel discs with $t/D_i < 0.5$; spherical sectors with square	HPS	Crazing	Visible	None
edges; and hemispheres with flanges	HPS	Crazing/cracking	$k > .02t$	Red Tag
	LPS	Pit	$k > .01$	Red Tag
	LPS	Scratch/gouge	$k > .01$	Red Tag
	LPS	Crazing/cracking	$k > .01$	Red Tag
	BS	Pit	$k > .06$	Red Tag
	BS	Scratch/gouge	$k > .06$	Red Tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > .06$	Red Tag
Group B	HPS, LPS, BS	Pit	$k > .03$	Red Tag
Cylinder under internal pressure	HPS, LPS, BS	Scratch/gouge	$k > .01$	Red Tag
	HPS, LPS, BS	Crazing	Visible	None
	HPS, LPS, BS	Crazing/cracking	$k > .01$	Red Tag
Group C	HPS, LPS	Pit	$k > .1t$	Red Tag
Cylinder under internal pressure	HPS, LPS	Scratch/gouge	$k > .06t$	Red Tag
	HPS, LPS	Crazing	Visible	None
	HPS, LPS	Crazing/cracking	$k > .02t$	Red Tag
	BS	Pit	$k > .06t$ (1) $k > .03t$ (2)	Red Tag
	BS	Scratch/gouge	$k > .03t$ (1) $k > .02t$ (2)	Red Tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > .08R_o$ (1) $k > .03t$ (2)	Red Tag
Group D	HPS	Pit	$k > .1t$	Red Tag
Spherical sector with conical edges; nemo windows; and	HPS	Scratch/gouge	$k > .06t$	Red Tag
hyper-hemisphere	HPS	Crazing	Visible	None
	HPS	Crazing/cracking	$k > .02t$	Red Tag
	LPS	Pit	$k > .06t$	Red Tag
	LPS	Scratch/gouge	$k > .02t$	Red Tag
	LPS	Crazing	Visible	None
	LPS	Crazing/cracking	$k > .01t$	Red Tag
	BS	Pit	$k > .06t$	Red Tag
	BS	Scratch/gouge	$k > .03t$	Red Tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > .08R_o$	Red Tag

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Table I-2 Limits for Blemishes or Flaws on Window Surfaces (Cont'd)

Type of Window	Location	Blemish or Flaw		Corrective Action
		Type	Size	
Group E	HPS	Pit	$k > .02t$	Red Tag
Conical frustums with $t/D_i \geq 0.5$ and double beveled	HPS	Scratch/gouge	$k > .02t$	Red Tag
disc with $t/D_i \geq 0.5$	HPS	Crazing	Visible	None
	HPS	Crazing/cracking	$k > .02t$	Red Tag
	LPS	Pit	$k > .01t$	Red Tag
	LPS	Scratch/gouge	$k > .01t$	Red Tag
	LPS	Crazing	Visible	None
	LPS	Crazing/cracking	$k > .01t$	Red Tag
	BS	Pit	$k > .06t$	Red Tag
	BS	Scratch/gouge	$k > .06t$	Red Tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > .06$	Red Tag

GENERAL NOTES:

(a) Red Tag — PVHO should not be pressurized until the window is repaired or replaced.

(b) HPS — High-Pressure Surface
LPS — Low-Pressure Surface
BS — Bearing Surface
k — depth of flaw or blemish, inches
t — thickness of window, in.
R_o — exterior spherical radius, inches
Pit — circular crater without cracks
Scratch/gouge — narrow trench without cracks
Crack — fracture(s) originating at surface
D_i — inside diamter of window, inches (for flat disc = inside diameter of hard bearing surface)

(c) The length of individual scratches/gouges and their location, spacing, or total number do not enter into the definition of critical flaw or blemish size.

(d) The extent of crazing/cracking does not enter into the definition of critical flaw or blemish size.

(e) The diameter of pits, their location and total number do not enter into the definition of critical flaw or blemish size.

(f) Although visible surface crazing per se is not cause for immediate action, if the crazing pattern forms a "closed circle" concentric with the bearing surface, then the window shall be Red-Tagged.

NOTES:

(1) Normal to plane bearing surface.

(2) Normal to cylindrical bearing surface.

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Table I-3 Limits for Blemishes or Flaws on All Other Window Surfaces

Type of Window	Description of Locations Other Than HPS/LPS/BS	Blemish or Flaw		Corrective Action
		Type	Size	
Plane (flat disc) and double bevel disc	Surface normal (i.e., at right angle) to the high and low pressure faces, and bevels if applicable	Pit	$k > .06$	Red Tag
		Scratch/gouge	$k > .03$	Red Tag
		Crazing	Visible	None
		Crazing/cracking	$k > .06$	Red Tag
Double bevel and conical frustrum	Cylindrical surface and/or non-bearing bevel	Pit	$k > .06$	Red Tag
		Scratch/gouge	$k > .03$	Red Tag
		Crazing	Visible	None
		Crazing/cracking	$k > .06$	Red Tag
Hemispheres and spherical sectors with square flanges	Cylindrical surface and the plane non-bearing surface	Pit	$k > .06$	Red Tag
		Scratch/gouge	$k > .03$	Red Tag
		Crazing	Visible	None
		Crazing/cracking	$k > .03$	Red Tag
Spherical sector with conical edges	Bevel	Pit	$k > .125$	Red Tag
NEMO windows and hyper-hemispheres		Scratch/gouge	$k > .06$	Red Tag
		Crazing	Visible	None
Cylinders under external pressure		Crazing/cracking	$k > .03t$	Red Tag
Cylinders under internal pressure	Bevel	Pit	$k > .03$	Red Tag
		Scratch/gouge	$k > .01$	Red Tag
		Crazing	Visible	None
		Crazing/cracking	$k > .01$	Red Tag

GENERAL NOTES:

(a) Red Tag — PVHO should not be pressurized until the window is repaired or replaced.

(b) HPS — High Pressure Surface
LPS — Low Pressure Surface
BS — Bearing Surface
k — depth of flaw or blemish, inches
t — thickness of window, inches
R_o — exterior spherical radius, inches
Pit — circular crater without cracks
Scratch/gouge — narrow trench without cracks
Crack — fracture(s) originating at surface
D_i — inside diamter of window, inches (for flat disc = inside diameter of hard bearing surface)

(c) The length of individual scratches/gouges and their location, spacing, or total number do not enter into the definition of critical flaw or blemish size.

(d) The extent of crazing/cracking does not enter into the definition of critical flaw or blemish size.

(e) The diameter of pits, their location and total number do not enter into the definition of critical flaw or blemish size.

(f) Although visible surface crazing per se is not cause for immediate action, if the crazing pattern forms a "closed circle" concentric with the bearing surface, then the window shall be Red-Tagged.

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Table I-4 Limits on Chipping of Sharp Edges on Windows

Type of Window	Location	d, in.	Corrective Action
Conical frustrum with $t/D_i < .5$	HPE	$> .2t$	Red Tag
	LPE	$> .01D_i$	Red Tag
Conical frustrum with $t/D_i \geq .5$	HPE	$> .2t$	Red Tag
	LPE	$> .02D_i$	Red Tag
Double bevel disc with $t/D_i < .5$	HPE	$> .01D_i$	Red Tag
	LPE	$> .01D_i$	Red Tag
Double bevel disc with $t/D_i \geq .5$	HPE	$> .02D_i$	Red Tag
	LPE	$> .02D_i$	Red Tag
Spherical sector with conical seat	HPE	$> .2t$	Red Tag
	LPE	$> .125$	Red Tag
Hyper-hemisphere	HPE	$> .1t$	Red Tag
	LPE	$> .125$	Red Tag
Nemo window	HPE	$> .1t$	Red Tag
	LPE	$> .125$	Red Tag
Plane (flat disc) window	HPE	$> .03$	Red Tag
	LPE	$> .01D_i$	Red Tag
Spherical sector with square edge	HPE	$> .03$	Red Tag
	LPE	$> .03$	Red Tag
Hemisphere with square flanges	HPE	$> .125$	Red Tag
	LPE	$> .03$	Red Tag
Cylinder under internal pressure	HPE	$> .03$	Red Tag
	LPE	$> .03$	Red Tag
Cylinder under external pressure	HPE	$> .1t$	Red Tag
	LPE	$> .05t$	Red Tag

GENERAL NOTES:

(a) d — greatest projected depth of missing material measured co-planar to the adjacent surface
HPE — High-Pressure Face Edge
LPE — Low-Pressure Face Edge
t — thickness of window, inches
D_i — inside diamter of window, inches (for flat disc = inside diameter of hard bearing surface)

(b) In the event that leakage occurs the window should be replaced regardless of chip depth.

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Window Maintenance Inspection Form

Name of Inspecting Organization: _____

Name of Inspector: _____

Procedure (window removed or inspected in-place): _____

Existing Window Marking: _____ – _____ – PVHO – _____ – _____ – _____

Window Manufacturer: _____

Original Documents Available for Inspector: Yes _____ No _____

Window Cycle Design Life: _____ Cycles

Cycles on Window at Time of Inspection: _____ Cycles

Window Date of Manufacture: dd/mm/yyyy _____ / _____ / _____

Design Life Expires: dd/mm/yyyy _____ / _____ / _____

Window Material Lot No.: _____ Batch No.: _____

Material Manufacturer: _____

Window Drawing No.: _____

Window PVHO Conversion Factor CF: CF = _____ based on _____°F °C (circle one)

Window Assembly Drawing No.: _____

Window Installation Date: dd/mm/yyyy _____ / _____ / _____

Description of the Pressure Vessel: _____

_____

_____

Vessel Marking: SN: _____ NB No. _____

Design Pressure: _____ PSIG

MAWP: _____ PSIG _____°F °C (circle one)

Flaws Present in Window: Yes _____ No _____

If YES, describe in full: _____

_____

_____

Continued Use Acceptable: Yes _____ No _____

Action Required: Repair: Polish and Reinstall
Repair: Send to Fabricator for Rework
Replace: Damage Not Repairable

Seat and Seal Condition (if applicable): Acceptable _____ Needs Replacement _____

Certificate of Compliance

I certify that the statements made in this report are correct and that all the details of this inspection conform to the requirements of PVHO-2 and that I, the undersigned, have inspected the component described in this report on _____, _____ and state to the best of my knowledge and belief the window subject of this report is suitable for continued service.

Signed By: _____ Date: _____

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MANDATORY APPENDIX II
REPAIR REQUIREMENTS AND FORMS

II-1 WINDOW DAMAGE ASSESSMENT

The assessment of damage during Window Maintenance Inspections should be performed by a window fabricator who is PVHO qualified maintaining a Quality Assurance system in accordance with the requirements of Mandatory Appendix III, or an inspector meeting the qualifications set forth in para. 7.6. For windows whose service life is in excess of their design life, this becomes a mandatory requirement. In either case, the criteria to be used for window damage assessment is as specified by Section 8 (Categories of Damage) in accordance with tables provided in Mandatory Appendix I.

The damage to windows, depending on its severity, may be repaired by the user or his authorized agent, or by a PVHO qualified Window Fabricator. Damage to windows is considered slight when it consists solely of surface defects less than 0.020 in. deep, or chips on the window edges less than 0.125 in. wide. Scratches, gouges, crazing, cracks, other imperfections deeper than 0.020 in., and edge chips wider than 0.125 in., are considered to be severe damage.

II-2 SLIGHTLY DAMAGED WINDOW

Slightly damaged windows may be repaired by the user or his authorized agent. Severely damaged windows however, shall be repaired by a window fabricator who is PVHO qualified by having a Quality Assurance Program that is in accordance with the requirements of Mandatory Appendix III.

(a) Slightly damaged windows may be repaired by the user or his authorized agent, provided only hand sanding/polishing techniques are utilized.

(b) The use of power driven tools (disk sanders, buffing wheels, lathes, milling machines, etc.) is not permitted, as that type of repair requires post annealing.

(c) Original window identification marking that has been accidentally removed during repair operations shall be reapplied. The restored identification marking shall have wording identical to the original one which had been removed.

II-3 SEVERLY DAMAGED WINDOW

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

(a) Severely damaged windows shall be repaired by a qualified window fabricator.

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

(c) Written authorization shall be accompanied by the *original* Window Design Certification and the *original* Window Fabrication Certification.

(d) During the repair, the window fabricator may utilize all the fabrication processes customarily employed in the fabrication of new windows in accordance with the requirements of PVHO-1.

II-4 REPAIR REQUIREMENTS FOR SPHERICAL WINDOW

Spherical window damage may be repaired by machining out the damaged acrylic, and then spot casting to repair, provided that all of the following conditions are satisfied.

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

(b) The same batch of casting syrup that was used in doing the spot repairs shall be qualified in accordance with the requirements set forth in Mandatory Appendix IV.

NOTE: In conjunction with the pressure test, this "post-repair" procedure validates the repair procedure for that window.

(c) For repaired spots in spherical sector windows located in areas within 2 deg of the window's edge circumference that are not visible by an observer in the position required for operation, or areas not visible by the PVHO occupants, the following limitations apply:

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

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

(d) For repaired spots in spherical sector windows located in areas outside 2 deg of the window's edge circumference that are visible by an observer in the position required for operation, or areas visible by the PVHO occupants, the following limitations apply:

(1) The area of any repaired spot shall not exceed 0.1% of total (repaired side) window area.

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(2) Only one repaired spot is permitted.

(e) The location and extent of spot casting repairs shall be noted on a sketch attached to the Window Repair Certification.

II-5 ANNEALING SEVERELY DAMAGED WINDOWS

Upon completion of final machine polishing, the window is to be annealed in accordance with Mandatory Appendix IV. After annealing, the repaired window shall be inspected to ensure it meets the requirements of minimum thickness, dimensional tolerance, surface finish, and inclusion limitations applicable to the fabrication of new acrylic windows in accordance with PVHO-1.

II-6 MARKING OF REPAIRED WINDOW

Windows that have been repaired by a qualified window fabricator shall be marked as follows by the window fabricator performing the repair.

(a) The repair identification shall consist of 0.5 in. letters and numbers made with indelible black marker, or 0.125 in. letters and numbers made with epoxy ink on the window's edge. The writing shall not interfere with the ability of the window to seal properly.

(b) The repair identification shall contain the repair logo, fabricator's initials, fabricators serial number of repair, and year performed, as per the example below:

Δ-PS-12-81

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

(c) Original window identification marking that has been accidentally removed during repair operations shall be reapplied. The restored identification marking shall have wording identical to the original one which had been removed.

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

II-7 PRESSURE TEST OF REPAIRED WINDOW

Prior to being placed back into service, all repaired windows shall be pressure-tested in accordance with the requirements set forth in Mandatory Appendix IV.

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Acrylic Window Repair Certification Form for Windows Repaired by the User (or his Authorized Agent)

Window Identification: _____

1. Window Shape (from visual inspection)
   - Conical frustum: _____
   - Double beveled: _____
   - Spherical sector with conical edge: _____
   - Spherical sector with square edge: _____
   - Hemisphere with equatorial flange: _____
   - Flat disk: _____
   - Hyper-hemisphere with conical edge: _____
   - NEMO: _____
   - Cylinder: _____
2. Design Data (from original Window Design Certification)
   - Original Design Certification prepared by: _____
   - Maximum allowable working pressure: _____
   - Maximum design temperature: _____
   - Minimum thickness (calculated t) for above temperature and pressure: _____
3. Original Fabrication Date (from original Window Fabrication Certification)
   - Original fabrication certification prepared by: _____ (Name of preparer)
   - _____ (Name of fabricator)
   - Actual minimum thickness, t: _____
   - Actual inside diameter, D_i: _____
   - Actual outside diameter, D_i: _____
4. Inspection Report Attached: Yes _____ No _____
5. *Repair Instructions*
   - Refinish the following surfaces: High-pressure face: _____
   - Low-pressure face: _____
   - Bearing surfaces: _____
   - Beveled edges: _____
   - Sealing surfaces: _____
   - Repair of the window has been authorized by: _____ (Name of company)
   - _____ (Name of authorized representative)
   - _____ (Signature of authorized representative)
6. Minimum thickness of repaired window: _____

The minimum thickness and/or inside diameter of the Repaired Window meet the minumum requirements: Yes _____ No _____

During repair, original window identification markings were: Left intact _____ Reapplied _____

_____ (Signature of person performing repair)

_____ (Signature of person inspecting repair)

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Acrylic Window Repair Certification Form for Severely Damaged Windows

Window Identification: _____

1. Window Shape (from visual inspection)
   - Conical frustum: _____
   - Double beveled: _____
   - Spherical sector with conical edge: _____
   - Spherical sector with square edge: _____
   - Hemisphere with equatorial flange: _____
   - Flat disk: _____
   - Hyper-hemisphere with conical edge: _____
   - NEMO: _____
   - Cylinder: _____
2. Design Data (from original Window Design Certification)
   - Original Design Certification prepared by: _____
   - Maximum allowable working pressure: _____
   - Maximum design temperature: _____
   - Minimum thickness (calculated t) for above temperature and pressure: _____
3. Original Fabrication Date (from original Window Fabrication Certification)
   - Original fabrication certification prepared by: _____ (Name of preparer)
   - _____ (Name of fabricator)
   - Fabricated according to drawing: _____
   - Identification marking: _____
   - Actual minimum thickness, t: _____
   - Actual inside diameter, D_i: _____
   - Actual outside diameter, D_i: _____
4. Repair Instructions
   - Refinish the following surfaces: High-pressure face: _____
     - Low-pressure face: _____
     - Bearing surfaces: _____
     - Beveled edges: _____
     - Sealing surfaces: _____
   - Spot casting is authorized where appropriate: _____
   - The minimum thickness, t of repaired window shall be: _____
   - The inside diameter, D_i of the repaired window shall be: _____
   - Repair of the window has been authorized by: _____ (Name of company)
   - _____ (Name of authorized representative)
   - _____ (Signature of authorized representative)
5. Repair History
   - The following surfaces were refinished: High-pressure face: _____
     - Low-pressure face: _____
     - Bearing surfaces: _____
     - Beveled edges: _____
   - Spot casting process: Resin used: _____
     - Catalyst used: _____
     - Polymerization technique: _____
     - Material Certification per Mandatory Appendix IV is attached: Yes _____ No _____
     - Sketch of spot casting locations is attached: Yes _____ No _____
   - Minimum thickness of repaired window: _____
   - The minimum thickness and/or inside diameter of the Repaired Window meet the minumum requirements: Yes _____ No _____
   - The repaired window was annealed at _____ for _____ hr
     - Annealing Certification per Mandatory Appendix IV is attached: Yes _____ No _____

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The repaired window was pressure tested at _____ for _____ hr

Pressure Test Certification per Mandatory Appendix IV is attached: Yes _____ No _____

During repair, original window identification markings were: Left intact _____ Removed and reapplied _____

The repair marking applied to the window reads as follows: _____

CERTIFICATION

The refinished surfaces, spot castings, and minimum thickness of the repaired window meet all the requirements of the ***attached original Window Design Certification.***

Authorized representative of window fabricator	Name and address of window fabricator

GENERAL NOTES:

(a) The data for Parts 1 through 4 of this Enclosure are to be provided and certified by the company/individual authorizing the repair of windows.

(b) The repair process information required by Part 5 is to be provided and certified by the window fabricator performing the repair.

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MANDATORY APPENDIX III
QUALITY ASSURANCE PROGRAM FOR REPAIR OF SEVERELY DAMAGED WINDOWS

III-1 GENERAL

This Mandatory Appendix sets forth the requirements for establishing and maintaining Quality Assurance Programs to control the quality of work performed by the repairers of severely damaged windows used in Pressure Vessels for Human Occupancy in accordance with this Standard.

III-2 ORGANIZATION

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

(1) identify problems affecting quality

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

(3) verify implementation of solutions

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

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

III-3 QUALITY ASSURANCE PROGRAM

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

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

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

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

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

III-4 QUALITY ASSURANCE MANUAL

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

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

III-5 DRAWING, DESIGN, AND SPECIFICATION CONTROL

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

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

III-6 PROCUREMENT CONTROL

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

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

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

(1) source evaluation and selection

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

(3) inventory control

(4) material identification

(5) examination of supplied items upon delivery

(d) Procedures for assuring continued compliance with pertinent requirements, including identification of

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procedural revisions, shall be described in the Quality Assurance Manual.

III-7 IDENTIFICATION AND CONTROL OF ITEMS

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

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

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

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

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

III-8 CONTROL OF PROCESSES

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

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

III-9 INSPECTION

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

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

(c) Inspection results shall be documented.

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

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

III-10 TEST CONTROL

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

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

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

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

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

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

III-11 HANDLING, STORAGE, AND SHIPPING

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

III-12 DOCUMENTATION AND STATUS OF TEST ACTIVITIES

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

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

III-13 CORRECTIVE ACTION

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

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

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

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

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

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

III-14 QUALITY ASSURANCE RECORDS

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

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

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

(d) Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and

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disposition shall be established and documented.

(e) Records required for traceability shall be retained for a duration equal to the balance of the windows design life, plus 10 years.

III-15 QUALITY ASSURANCE AUDITS

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

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

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

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

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

III-16 CONFORMITY

A window fabricator who is ISO 9001 Certified is deemed to have an in-place Quality System equivalent to requirements set forth herein (i.e., acceptable for the purposes of this Standard).

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MANDATORY APPENDIX IV
ADDITIONAL WINDOW REPAIR REQUIREMENTS AND FORMS

IV-1 WINDOW REPAIR TEST REQUIREMENTS

A test of the tensile strength of a sample bond between previously cured acrylic window material and the material used to perform spot cast repair shall be made. Samples for the balance of testing shall be taken from an integral part of a separate casting made for that purpose. Where more than one specimen is used in the test procedure, the average of the test values will be used to meet the requirements of the minimum physical properties shown. Samples 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. The test methods are to be as follows.

(a) The test for the tensile strength of a sample bond shall be per ASTM D 638, with the bond face located as close to the center of the gauge length as practical.

(b) Tests for compressive strength of the spot cast material shall be per ASTM D 695.

(c) Tests for the presence of an ultraviolet absorber (ultraviolet transmittance) shall be made using a monochromator having a bandwidth of 10 nm or less, and a photometer having reproducibility of +1% of full scale. Report the value of one specimen ½ in. (12.5 mm) thickness nominal, with both faces polished.

(d) The following procedures are recommended for the measurement of residual Acrylic Monomer. A sample of suitable size shall be obtained and analyzed for unpolymerized methyl methyacrylate and unpolymerized ethyl acrylate monomers using gas liquid chromatographic techniques (as described in Snell and Otto, *Encyclopedia of Industrial Chemical Analysis*, Interscience,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 two. The following (from Cober and Samsel, SPE Transactions, *Gas Chromatograph, A New Tool for Analysis of Plastics*, April 1962, pp. 145-151) is a suitable procedure. 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 ¼ 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-μL 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 to 30 mg of pure monomers in 50 ml of methylene chloride.

Acrylic that does not dissolve shall be analyzed by swelling the plastic and extracting the soluble portion. Place a solid piece of insoluble acrylic about 1 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 methyacrylate and monomeric ethyl acrylate (in accordance with the procedures set forth in the preceding paragraph).

See also Tables IV-1-1, IV-1-2(a), and IV-1-2(b).

All repaired windows shall be annealed after all machining and machine polishing have been completed, hereafter referred to as the final anneal. All annelaing shall take place in a forced air circulation type oven. The final anneal and (any other anneals performed prior to the final anneal) shall be in accordance with Tables IV-1-2(a) and IV-1-2(b). Time and temperature data for all annealing cycles shall be entered into the Annealing Process Certification Form. Also, a copy of the final anneal's time/temperature chart shall be attached.

IV-2 POST-REPAIR PRESSURE TESTING REQUIREMENT

Wherever practical, all repaired windows (regardless of severity) should be pressure-tested prior to being placed back into service. All severely damaged and subsequently repaired windows shall be pressure-tested prior to being placed back into service.

(a) The pressure test may be performed by the window repairer, the user (or his designated agent), or by an independent test laboratory so designated by the window repairer or user.

(b) The pressure test shall take place with the window installed in the PVHO, or in a test fixture whose window seat dimensions, retaining rings, and seals are identical to those of the PVHO.

(c) The window shall be pressurized to design pressure using gas or water, and maintained at that pressure for a period of 1 hr (minimum) to 4 hr (maximum), followed by depressurization at a rate not exceeding 650 psi/minute (4.5 MPa/minute).

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Table IV-1-1 Specified Values of Physical Properties for Spot Casting Repairs (To Be Verified by Testing of Specimens Taken From Test Castings of the Same Slurry Batch Used in Repair)

Test Procedures	Physical Property	Specified Values	
		U.S. Customary	Metric
ASTM D 638	Tensile strength (of sample bond)	≥ 4,500 psi	≥ 31 MPa
ASTM D 695	Compressive:		
	(a) yield strength	≥ 15,000 psi	≥ 103 MPa
	(b) modulus of elasticity	≥ 400,000 psi	≥ 2 760 MPa
Method as described	Ultraviolet (290 nm to 330 nm) light transmittance	≤ 5%	≤ 5%
Method as described	Total residual monomer:		
	(a) methyl methyacrylate	≤ 1.6%	≤ 1.6%
	(b) ethyl acrylate	≤ 1.6%	≤ 1.6%

Table IV-1-2(a) Annealing Schedule for Acrylic Windows Part A: Minimum Heating Times for Elevated Temperature Annealing of Acrylic

Thickness, in. (mm)	Heat Time (hr) for Acrylic Placed in a Forced-Circulation Air Oven Maintained at the Indicated Temperature Within ±5°F (±2.8°C) [Note (1)]			
	≥ 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	16 + 4*x*	17 + 6*x*	18 + 6*x*	22 + 6*x*

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

NOTE:

(1) Where x = each additional inch of thickness over 4.

(d) The temperature of the pressurizing medium during the test shall be at the maximum temperature for which the window is rated, with a tolerance of +0° and −5°F (−2.5°C).

(e) If windows tested in the PVHO leak during the pressure test, the test shall be discontinued, the window shall be removed and fitted out with new seals, and retested. For windows tested in a separate test fixture, the leak shall be remedied in the same manner, otherwise, the test report provided to the user shall include the fact that the seals used were unable to operate properly.

(f) At the 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 PVHO.

IV-3 TEST REJECTION CRITERIA

Presence of crazing, cracks, or permanent deformation that can be seen with the unaided eye (except for the

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Table IV-1-2(b) Annealing Schedule for Acrylic Windows
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)	Cooling Rate, °F/hr (°C/hr)	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

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

correction necessary to achieve 20/20 vision) shall be cause for rejection of the windows. Permanent deformation greater than $0.001D_i$ measured at the center of the window shall also be cause for rejection. Rejection (and cause if applicable) shall be so noted on the test report.

IV-4 ALTERNATIVE TEST

A hydrostatic or pneumatic test in excess of the design pressure may be performed instead, but with all of the following limitations being applicable:

(a) Test pressure shall not exceed 1.5 times design pressure or 20,000 psi (whichever is less).

(b) To prevent inadvertent deformation, the temperature of the window assembly shall be at least 25°F (14°C) [but no more than 35°F (20°C)] *lower* than the design temperature, except for the case of a 50°F (10°C) design temperature, where the temperature during the test shall be in the range of 32°F to 40°F (0°C to 4°C).

IV-5 TEST CERTIFICATION FORM

Upon completion of pressure testing, a pressure testing certification form shall be completed by the party who performed the pressure test.

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Material Testing Certification for Repair by Spot Casting

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

2. Test specimen taken from castings No. _____ in Lot No. _____ of centimeters nominal thickness that have been produced by _____ under the material manufactuer trademark of _____ possess the following physical and chemical properties:

Test Method	Property	Results
ASTM D 638	Tensile strength of sample bond	_____
ASTM D 695	Compressive:	_____
	(a) Yield strength	
	(b) Modulus of elasticity	
Method as set forth in Mandatory Appendix IV	Ultraviolet transmittance [for $\frac{1}{2}$ in. (12 mm) thickness]	_____
Method as set forth in Mandatory Appendix IV	Total residual methyl methycrylate and ethyl acrylate monomers	_____ % _____ %

The experimentally proven properties satisfy the minimum values specified in Table IV-1-1 of the In-Service Safety Standard for Pressure Vessels for Human Occupancy.

_____ _____

Authorized representative of material testing laboratory — Date

_____

Name and address of material testing laboratory

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Annealing Process Certification Form

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 _____ Yes _____ No

Window fabricator has pressure-tested windows _____ Yes _____ No

Window fabricator has completed pressure test Certification _____ Yes _____ No

The window identified above has been repaired in accordance with the repair requirements of this Standard and meets the dimensional requirements applicable to new windows fabricated in accordance with 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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Pressure Testing Certification Form

Window Identification: _____

1. Window Description

   Maximum allowable working pressure: _____

   Maximum design temperature: _____

2. Test arrangement

   Window tested in operational viewport/simulated viewport: _____
   (operational/simulated)

   Operational/simulated viewport Drawing No.: _____

   Window tested according to para. IV-2: _____
   (yes/no)

   Test pressure: _____ psi _____ MPa

   Overpressure ratio (test pressure/maximum allowable working pressure): _____

   Pressurizing medium temperature: _____ °F _____ °C

   Rate of pressurization (average): _____

   Duration of sustained pressurization: _____

3. Test observations (yes/no)

   Leakage: _____

   Permanent Deformation: _____

   Crazing: _____

   Cracking: _____

The acrylic window was pressure tested according to the procedure of para. IV-2 of the In-Service Safety Standard for Pressure Vessels for Human Occupancy (PVHO-2) and was found to perform satisfactorily without any visible permanent deformation, crazing, or cracking.

_____ _____
Pressure test supervisor Date

_____
Name and address of pressure testing laboratory

_____ _____
Authorized representative of window manufacturer (factory window repair) or user (if test performed in-place on an existing PVHO for which the window is intended) Date

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MANDATORY APPENDIX V
PARTIAL LIST OF HARMFUL SUBSTANCES AND ACCEPTABLE PRODUCTS

V-1 SCOPE

This mandatory Appendix provides *partial lists* of cleaners, polishes and lubricants that testing and/or experience, has determined that they are either suitable or unsuitable.

This information is provided as guidance only. Specific products not listed may or may not be acceptable for use with PVHO Acrylic Windows and/or PVHO Service. *It is the user's responsibility to determine the appropriateness of any products prior to actual use.*

V-2 HARMFUL SUBSTANCES

Solvents of any type shall not be used for the cleaning of PVHO windows or their seats. All of the following will cause severe window damage (rendering it nonusable and possibly nonrepairable). *Good practice is to never store any of them in the vicinity of a PVHO.*

(a) Methyl Ethyl Ketone (MEK)
(b) Trichloroethane (TCE)
(c) Acetone
(d) Alcohol
(e) Xylene

V-3 ACCEPTABLE CLEANERS AND POLISHES

For cleaning, the use of detergent in solution in warm water (120°F maximum) is the recommended method. Aliphatic Naphtha or Hexane are acceptable but not preferred. After cleaning, window surfaces may be polished with compounds specifically endorsed by the manufacturer for polishing of acrylic. These compounds may also be used for removing small scratches from the surface. The following is a partial listing of acceptable products.

CAUTION: Do not apply cleaners when windows are hot, otherwise crazing may result.

V-3.1 Cleaners

(a) Windex
(b) Simple Green
(c) Citra-Solv
(d) Mask-Off-Craftics
(e) or equivalent

V-3.2 Polishes

(a) Plastic Polish Mirror Bright MGH-10
(b) Plastic Polish Novus #1, #2, and #3
(c) or equivalent

V-4 ACCEPTABLE LUBRICANTS

When it is necessary to lubricate O-ring seals and/or window cavity seats, the following is a partial list of products that are compatible with acrylic windows:

(a) Apiezon Type H Grease
(b) Dow Corning 3452
(c) Dow Corning #4 Compound
(d) Dow Corning 112 High Performance Lubricant
(e) DuPont Krytox
(f) Cristolube
(g) Parker Super O-Lube
(h) Braycote 601
(i) or equivalent

CAUTION: In the case of chambers that are pressurized with oxygen, the user shall also assure which the lubricant used is rated as being compatible with oxygen.

V-5 ACCEPTABLE SEAL AND GASKET ADHESIVES

When necessary to bond neoprene or cork gaskets to the metal window seat surface, the following is a partial list of adhesives compatible with acrylic windows when fully cured.

(a) Room Temperature Vulcanizing Silicon Rubber Compounds

(1) Dow Corning 3145
(2) Dow Corning 995
(3) Dow Corning 795
(4) Dow Corning 832
(5) or equivalent

Adhesion of the silicon rubber products may be improved by coating the mating surface with Dow Corning 1200 Primer.

(b) Contact Cements

(1) cyanoactylate
(2) 3M Contact Cement 1300
(3) Eclectic Products Polyurethane Plumbers Goop

To provide adequate cure time for the bond, when using the above bonding materials with gaskets, the

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window shall not be installed until the material has become cured in accordance with the manufacturer's recommendation, and should not be pressurized for a period of 24 hr.

(4) or equivalent

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MANDATORY APPENDIX VI
MECHANICAL TESTING COMPUTATIONS AND FORMS

VI-1 STANDARD DEVIATION

(a) Compute the mean (i.e., average) value.

(b) Find the difference betwen the mean value and each individual value.

(c) Square each of those differences.

(d) Sum each of those differences squared.

(e) Divide that sum by the number of samples minus one.

(f) The value just obtained above is called the variance.

(g) The standard deviation is the square root of that value.

VI-2 STANDARD ERROR

Divide the standard deviation by the square root of the number of samples.

VI-3 CONFIDENCE INTERVAL (CI)

Range is mean value ± [(standard error) (*t*)] where the value of *t* depends on number of samples *n*.

95% Interval		99% Interval	
n	*t*	*n*	*t*
2	12.076	2	63.657
3	4.303	3	9.925
4	3.182	4	5.841
5	2.776	5	4.604
6	2.571	6	4.032
7	2.447	7	3.707
8	2.365	8	3.499
9	2.306	9	3.355

VI-4 CRITERIA FOR CENSORING OF SUSPECT DATA

Value lies out side of four Standard Deviations from the Mean, *but first needs to be supplemented by two additional samples with new Standard Deviation being recomputed without the suspect value.* In the example below, another data point that is more than 1,000 psi from that mean might be censored, provided that the additional required samples are tested and it still meets the requirements above.

VI-5 COMPUTATIONAL EXAMPLES

Data = 10,000, 9750, and 9500 psi

Mean = 29,250/3 = 9750 psi

Standard Deviation = square root of 62,500 = 250 psi

Standard Error = $250/(3^{1/2})$ = 144 psi

Lower 95% CI = 9750 – (4.303)(144) = 9130 psi

Variance = $[(250)^2 + (0)^2 + (250)^2]/(3-1)$ = 62,500

VI-6 EVALUATION

As 10,540 psi > 9000 (minimum) and 17,853 psi > 14,000 (minimum), evaluation may proceed. (See Table VI-6.)

As 16,445 psi and 16,910 psi < 17,853, and 10,670 psi < 11,138, the following computations must be performed in order to determine the service life extension for the balance of the windows in that PVHO (if any).

As 10,679 psi < 11,138 must first estimate original mid-body flexture as (11,138/10,540) = (x/17,853)

$$x = U_m = 18{,}866 \text{ psi}$$

(a) HPS Extrapolation. 95% CI to 10,000 psi gives the lowest value for the HPS outside face

(14,794 psi – 10,000 psi)/[(18,866 psi – 14,794 psi)/10] = 11.8 yr

(13,743 psi – 7000 psi)/[(18,866 psi – 13,743 psi)/10] = 13.1 yr

(b) LPS Extrapolation. 99% CI to 7000 psi gives the lowest value for the LPS inside face.

(15,409 psi – 10,000 psi)/[(18,866 psi – 15,409 psi)/10] = 15.6 yr

(13,818 psi – 7000 psi)/[(18,866 psi – 13,818 psi)/10] = 13.5 yr

Normally, the lowest value would be used, except that more than 10 yr additional is not permitted. Thus, the balance of windows in the PVHO may remain in service for another 10 yr, or 10,000 cycles, whichever comes first, provided that they continue to be inspected in accordance with this Standard.

See also Table VI-6.

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Table VI-6 Example Evaluation — Externally Pressurized Manned Submersible After 10 Years of Service

Conditions	Value
Original tensile data	11,138 psi (mean value — recorded on original data sheet)
Tensile mid-plane	10,800 psi 10,420 psi 10,400 psi 10,540 psi (mean); std. error = 130 psi; and mean + std. error = 10,670 psi (vs 11,138)
Flexure mid-plane	18,120 psi 17,930 psi 17,510 psi 17,853 psi (mean)
HPS flexure (with outside surface in compression)	16,540 psi 14,940 psi 16,680 psi 16,040 psi 16,050 psi (mean); std. error = 395 psi; and mean + std. error = 16,445 psi (vs 17,853) [Note (1)]
LPS flexure (with interior surface in tension)	17,130 psi 16,600 psi 16,150 psi 16,627 psi (mean); std. error = 283 psi; and mean + std. error = 16,910 psi (vs 17,853) [Note (2)]

NOTES:
(1) Lower 95% confidence interval = 16,050 psi − (395 psi)(3.182) = 14,794 psi.
Lower 99% confidence interval = 16,050 psi − (395 psi)(5.841) = 13,743 psi.
(2) Lower 95% confidence interval = 16,627 psi − (283 psi)(4.303) = 15,409 psi.
Lower 99% confidence interval = 16,627 psi − (283 psi)(9.925) = 13,818 psi.

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Material Testing Certification for Continued Service Form

Test specimens have been ☐ cut from window or ☐ supplied already cut by _____ .

Test specimens conform to ASTM requirements Yes _____ No _____ (if No explain in space provided below)

Test specimens are original submittal _____ supplementary _____

Test Method	Property	Results
ASTM D 638	Tensile strength at mid-section	1. 2. 3. 4. 5. 6. 7. 8. 9.
ASTM D 790	Flexure strength at mid-section	1. 2. 3. 4. 5. 6. 7. 8. 9.
ASTM D 790	Flexure strength at High-Pressure Face *(tested with the parent material in compression)*	1. 2. 3. 4. 5. 6. 7. 8. 9.
ASTM D 790	Flexure strength at Low-Pressure Face *(tested with the parent material in tension for 10-year window design — or in compression for a 20-year window design)*	1. 2. 3. 4. 5. 6. 7. 8. 9.

Additional Data/Information:

_____ _____

Authorized representative of material testing laboratory Date

_____

Name and address of material testing laboratory

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Material Testing Evaluation for Continued Service Form

Test Window Marking: _____ – _____ – PVHO – _____ – _____ – _____

Original Documents Available: Yes _____ No _____

Window Drawing No.: _____

Window Shape: _____

Design life years: _____

Total service life year-to-date: _____

Design Life Expires: dd/mm/yyyy _____ / _____ / _____

Design life cycles: _____

PVHO-1 Case 4: Yes _____ No _____

Total accumulated cycles-to-date: _____

Description of the Pressure Vessel: _____

Location of test window on PVHO: _____

Vessel Marking: SN _____ NB No. _____

MAWP: _____ PSIG at _____°F °C (circle one)

Mid-section tensile strength: Mean: _____ psi Standard error: _____ psi

Original value from Enclosure 3 of PVHO-1: _____ psi

Mid-section flexure strength: Mean: _____ psi Upward adjusted value (if applicable): _____ psi

Low-pressure face flexure strength: Mean: _____ psi Standard error: _____ psi

Lower value 95% CI: _____ psi Lower value 99% CI: _____ psi

High-pressure face flexure strength: Mean: _____ psi Standard error: _____ psi

Lower value 95% CI: _____ psi Lower value 99% CI: _____ psi

Material Test Certification attached: Yes _____ No _____ Computations attached: Yes _____ No _____

Continue use of the other PVHO windows: Yes _____ No _____

Additional Service Life extension: No. of years _____ No. of cycles _____

Chronological Extension Terminates as of: dd/mm/yyyy _____ / _____ / _____

Cyclic Service Life Extension Terminates at: _____ No. of cycles

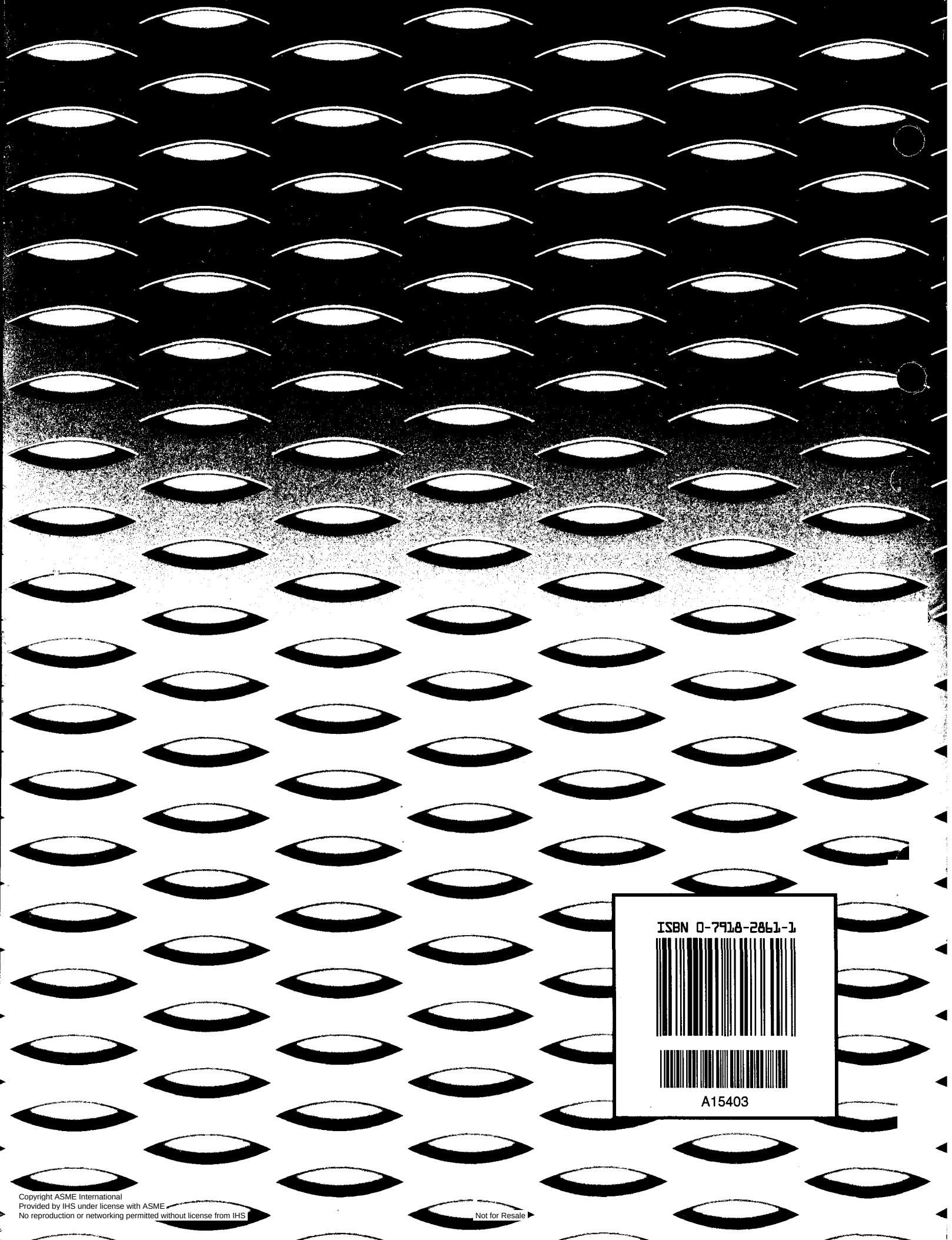
Certificate of Compliance

I certify that the statements made in this report are correct and that all the details of this evaluation conform to the requirements of PVHO-2, para. 10 and that I (the undersigned) have evaluated the test data as provided by Material Test Certification dated _____ and to the best of my knowledge, and the attached computations, the balance of windows in the PVHO are suitable for continued service.

Signed By: _____ Date: _____ Affiliation: _____

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