ASME PVHO-2–2019

(Revision of ASME PVHO-2–2016)

Safety Standard for Pressure Vessels for Human Occupancy: In-Service Guidelines

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2-2019

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ASME PVHO-2–2019
(Revision of ASME PVHO-2–2016)

Safety Standard for Pressure Vessels for Human Occupancy: In-Service Guidelines

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: January 24, 2020

The next edition of this Standard is scheduled for publication in 2022.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Periodically certain actions of the ASME PVHO Committee may be published as Cases. Cases and interpretations are published on the ASME website under the Committee Pages at http://cstools.asme.org/ as they are issued.

Errata to codes and standards may be posted on the ASME website under the Committee Pages to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in codes and standards. Such errata shall be used on the date posted.

The Committee Pages can be found at http://cstools.asme.org/. There is an option available to automatically receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the appropriate Committee Page after selecting "Errata" in the "Publication Information" section.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

ASME is the registered trademark of The American Society of Mechanical Engineers.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not "approve," "rate," or "endorse" any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

No part of this document may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

Copyright © 2020 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All rights reserved
Printed in U.S.A.

CONTENTS

Foreword v

Committee Roster vi

Correspondence With the PVHO Committee ix

Summary of Changes xi

Section 1 **General** 1

1-1 Introduction and Scope 1

1-2 Responsibilities and Jurisdictional Considerations 1

1-3 In-Service Evaluations, Repairs, and Modification of PVHOs 1

1-4 PVHO and PVHO Systems Documentation 2

1-5 Owner's Manual 2

1-6 Maintenance Requirements 3

1-7 Checklists and Logs 3

Section 2 **Viewports** 5

2-1 Responsibilities 5

2-2 Factors Affecting Service Life 5

2-3 Handling of PVHO Windows 6

2-4 Operational and Maintenance Inspections of PVHO Viewports 7

2-5 Categories of Damage 9

2-6 Repair of Damaged PVHO Windows 9

2-7 Mechanical Property Testing 11

2-8 Testing Requirements for Increasing the 40,000-hr Design Life 13

Mandatory Appendices

I Definitions 24

II Reference Standards and Specifications 27

III Quality Assurance Program for Repair of Severely Damaged Windows 28

IV Additional Window Repair Requirements and Forms 31

V Partial List of Harmful Substances and Acceptable Products 38

VI Mechanical Testing Computations and Forms 40

Nonmandatory Appendices

A Checklists and Logs for PVHO Operation 44

B Operation of Submersible Craft 45

Tables

2-4.1-1 Periodic Inspection Requirements 14

2-4.1.1-1 Limits for Blemishes or Flaws on Standard Window Geometry Surfaces 15

2-4.1.1-2 Limits for Blemishes or Flaws on All Other Standard Window Geometry Surfaces 17

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

2-4.1.1-3 Limits on Chipping of Sharp Edges on Standard Window Geometries 18
2-4.3-1 Maximum Intervals for Maintenance Viewport Inspection 18
2-4.3-2 Maximum Intervals for Refurbishment 18
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) 32
IV-1-2(a) Annealing Schedule for Acrylic Windows Part A: Minimum Heating Times for Elevated Temperature Annealing of Acrylic 33
IV-1-2(b) Annealing Schedule for Acrylic Windows Part B: Maximum Cooling Rates for Acrylic Subjected to Elevated Annealing Temperatures 34
VI-6-1 Example Evaluation — Mandatory Appendix VI 41

Forms

VM-1 Viewport Inspection 19
VM-2 Acrylic Window Repair Certification for Severely Damaged Windows 20
VM-3 Acrylic Window Repair Certification for Slightly Damaged Windows Repaired by the User (or the User's Authorized Agent) 22
VT-1 Pressure Testing Report for Increasing Window Service Life Beyond the 40,000-hr Design Life 23
IV-1-1 Material Testing Certification for Repair by Spot Casting 35
IV-1-2 Annealing Process Certification 36
IV-5-1 Pressure Testing Certification 37
VI-1 Material Testing Results for Continued Service 42
VI-2 Material Testing Evaluation for Continued Service 43

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

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 maximum allowable working pressure (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 that 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 ASME 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 ASME PVHO-1, which may be necessary throughout the service life of the window, are provided herein. Similarly, all necessary ASME PVHO-1 technical data applicable to service and repair (if required) are also provided in this Standard.

The 2019 edition of ASME PVHO-2 further develops and clarifies the in-service guidelines for PVHOs. The requirements for in-service pressure testing gauge calibration have been updated. Nonmandatory Appendix A, covering checklists and logs for PVHO operation, has been deleted, and the text under this appendix has been integrated into the general requirements of Section 1. New testing criteria for increasing the 40,000-hr design life of acrylic windows have been incorporated under Section 2. Additionally, new forms have been added, and some of the existing forms have been updated.

Sections on the following topics are in development are in development and may be included in future editions: quality assurance for PVHO manufacturers, piping systems, medical hyperbaric systems, diving systems, and submersibles.

Previous editions of this Standard were issued in 2003, 2012, and 2016. The 2019 edition of this Standard was approved by the American National Standards Institute as an American National Standard on December 4, 2019.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

ASME PRESSURE VESSELS FOR HUMAN OCCUPANCY COMMITTEE

(The following is the roster of the Committee as of February 1, 2019.)

STANDARDS COMMITTEE OFFICERS

G. Wolfe, *Chair*
J. Witney, *Vice Chair*
E. Lawson, *Secretary*

STANDARDS COMMITTEE PERSONNEL

J. E. Crouch, Southwest Research Institute
B. Faircloth, FMS Engineering, LLC
M. A. Frey, Naval Sea Systems Command
T. R. Galloway, Naval Sea Systems Command
B. Kemper, Kemper Engineering Services, LLC
W. Kohnen, Hydrospace Group, Inc.
D. Lawrence, U.S. Coast Guard
E. Lawson, The American Society of Mechanical Engineers
S. Reimers, Reimers Systems, Inc.
G. Richards, Blanson, Ltd.
T. C. Schmidt, Lockheed Martin
K. A. Smith, U.S. Coast Guard
R. C. Smith, Naval Facilities Engineering Command, Ocean Facilities Program
J. Stromer, Triton Submarines
D. Talati, Sechrist Industries, Inc.
R. Thomas, American Bureau of Shipping
M. R. Walters, Oceaneering International, Inc.
J. Witney, Atlantis Submarines International
G. Wolfe, Southwest Research Institute
E. G. Fink, *Delegate*, Fink Engineering Pty., Ltd.
H. Pauli, *Delegate*, Germanischer Lloyd AG
J. S. Selby, *Delegate*, SOS Group Global, Ltd.
L. Cross, *Alternate*, Kemper Engineering Services, LLC
J. P. Hierholzer, *Alternate*, DNV GL
J. K. Martin, *Alternate*, Perry Technologies
P. Selby, *Alternate*, SOS Group Global, Ltd.
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
W. F. Crowley, Jr., *Contributing Member*, Aerospace & Undersea Support Services, LLC
W. Davison, *Contributing Member*, Consultant
G. J. Jacob, *Contributing Member*, Navy Experimental Diving Unit
J. Maison, *Contributing Member*, Adaptive Computer Technology, Inc.
T. Marohl, *Contributing Member*
J. C. Sheffield, *Contributing Member*, International ATMO, Inc.

HONORARY MEMBERS

R. J. Dzikowski
F. T. Gorman
L. G. Malone, Plastic Supply & Fabric, Inc.
R. P. Swanson

SPECIAL PROJECTS TASK GROUP

J. Witney, *Chair*, Atlantis Submarines International
J. E. Crouch, Southwest Research Institute
E. G. Fink, Fink Engineering Pty., Ltd.
M. A. Frey, Naval Sea Systems Command
T. R. Galloway, Naval Sea Systems Command
B. Kemper, Kemper Engineering Services, LLC
W. Kohnen, Hydrospace Group, Inc.
S. Reimers, Reimers Systems, Inc.
G. Richards, Blanson, Ltd.
R. C. Smith, Naval Facilities Engineering Command, Ocean Facilities Program
G. Wolfe, Southwest Research Institute
L. Cross, *Alternate*, Kemper Engineering Services, LLC
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC

TASK GROUP ON TUNNELING

L. Cross, Kemper Engineering Services, LLC
G. L. East, ASI Marine
E. G. Fink, Fink Engineering Pty., Ltd.
J. P. Hierholzer, DNV GL
B. Kemper, Kemper Engineering Services, LLC
W. Kohnen, Hydrospace Group, Inc.
S. Reimers, Reimers Systems, Inc.
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

SUBCOMMITTEE ON DESIGN AND PIPING SYSTEMS

T. C. Schmidt, *Chair*, Lockheed Martin
B. Faircloth, *Vice Chair*, FMS Engineering, LLC
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
G. Bryant, Consultant
W. Davison, Consultant
R. K. Dixit, PCCI, Inc. (Reimers Division)
P. Forte, Woods Hole Oceanographic Institution
M. A. Frey, Naval Sea Systems Command
T. R. Galloway, Naval Sea Systems Command
C. Gaumond, Groupe Medical Gaumond
B. Humberstone, Diving Technical Advisor
G. J. Jacob, Navy Experimental Diving Unit
B. Kemper, Kemper Engineering Services, LLC
S. Reimers, Reimers Systems, Inc.
D. A. Renear, Aqua-Air Industries, Inc.
G. Richards, Blanson, Ltd.
R. Thomas, American Bureau of Shipping
M. R. Walters, Oceaneering International, Inc.
J. S. Selby, *Delegate*, SOS Group Global, Ltd.
L. Cross, *Alternate*, Kemper Engineering Services, LLC
J. K. Martin, *Alternate*, Perry Technologies
J. N. Pollack, *Alternate*, U.S. Navy
P. Selby, *Alternate*, SOS Group Global, Ltd.
R. M. Webb, *Alternate*, Naval Sea Systems Command
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
F. Burman, *Contributing Member*, Divers Alert Network
W. F. Crowley, Jr., *Contributing Member*, Aerospace & Undersea Support Services, LLC
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC

SUBCOMMITTEE ON DIVING SYSTEMS

R. Thomas, *Chair*, American Bureau of Shipping
T. R. Galloway, *Vice Chair*, Naval Sea Systems Command
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
G. Bryant, Consultant
W. F. Crowley, Jr., Aerospace & Undersea Support Services, LLC
G. L. East, ASI Marine
B. Faircloth, FMS Engineering, LLC
B. Humberstone, Diving Technical Advisor
B. Kemper, Kemper Engineering Services, LLC
D. Lawrence, U.S. Coast Guard
J. K. Martin, Perry Technologies
D. A. Renear, Aqua-Air Industries, Inc.
J. S. Selby, SOS Group Global, Ltd.
K. A. Smith, U.S. Coast Guard
M. R. Walters, Oceaneering International, Inc.
E. G. Fink, *Delegate*, Fink Engineering Pty., Ltd.
H. Pauli, *Delegate*, Germanischer Lloyd AG
L. Cross, *Alternate*, Kemper Engineering Services, LLC
T. Gilman, *Alternate*, U.S. Coast Guard
P. Selby, *Alternate*, SOS Group Global, Ltd.
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC
T. Marohl, *Contributing Member*

SUBCOMMITTEE ON GENERAL REQUIREMENTS

M. A. Frey, *Chair*, Naval Sea Systems Command
B. Kemper, *Vice Chair*, Kemper Engineering Services, LLC
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
J. E. Crouch, Southwest Research Institute
T. R. Galloway, Naval Sea Systems Command
S. Reimers, Reimers Systems, Inc.
J. Witney, Atlantis Submarines International
L. Cross, *Alternate*, Kemper Engineering Services, LLC
J. N. Pollack, *Alternate*, U.S. Navy
R. M. Webb, *Alternate*, Naval Sea Systems Command
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
G. J. Jacob, *Contributing Member*, Navy Experimental Diving Unit
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC

SUBCOMMITTEE ON MEDICAL HYPERBARIC SYSTEMS

G. Richards, *Chair*, Blanson, Ltd.
T. Dingman, *Vice Chair*, Healogics
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
F. Burman, Divers Alert Network
L. Cross, Kemper Engineering Services, LLC
W. T. Gurnee, Oxyheal Health Group
S. Reimers, Reimers Systems, Inc.
R. C. Smith, Naval Facilities Engineering Command, Ocean Facilities Program
D. Talati, Sechrist Industries, Inc.
E. G. Fink, *Delegate*, Fink Engineering Pty., Ltd.
H. Pauli, *Delegate*, Germanischer Lloyd AG
B. Kemper, *Alternate*, Kemper Engineering Services, LLC
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
W. Davison, *Contributing Member*, Consultant
K. W. Evans, *Contributing Member*, Perry Baromedical
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC
J. C. Sheffield, *Contributing Member*, International ATMO, Inc.
N. To, *Contributing Member*, U.S. Food and Drug Administration

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

SUBCOMMITTEE ON POST CONSTRUCTION

J. E. Crouch, *Chair*, Southwest Research Institute
R. C. Smith, *Vice Chair*, Naval Facilities Engineering Command, Ocean Facilities Program
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
G. Bryant, Consultant
T. Dingman, Healogics
M. A. Frey, Naval Sea Systems Command
T. R. Galloway, Naval Sea Systems Command
D. R. Hurd, Atlantis Submarines International
B. Kemper, Kemper Engineering Services, LLC
W. Kohnen, Hydrospace Group, Inc.
D. Lawrence, U.S. Coast Guard
J. K. Martin, Perry Technologies
G. Richards, Blanson, Ltd.
D. Talati, Sechrist Industries, Inc.
J. Witney, Atlantis Submarines International
L. Cross, *Alternate*, Kemper Engineering Services, LLC
T. Gilman, *Alternate*, U.S. Coast Guard
J. N. Pollack, *Alternate*, U.S. Navy
R. M. Webb, *Alternate*, Naval Sea Systems Command
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
J. Bell, *Contributing Member*, Fink Engineering Pty., Ltd.
W. F. Crowley, Jr., *Contributing Member*, Aerospace & Undersea Support Services, LLC
W. Davison, *Contributing Member*, Consultant
P. Forte, *Contributing Member*, Woods Hole Oceanographic Institution
B. Humberstone, *Contributing Member*, Diving Technical Advisor
G. J. Jacob, *Contributing Member*, Navy Experimental Diving Unit
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC
J. C. Sheffield, *Contributing Member*, International ATMO, Inc.

SUBCOMMITTEE ON SUBMERSIBLES

R. Thomas, *Chair*, American Bureau of Shipping
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
G. Bryant, Consultant
J. P. Hierholzer, DNV GL
D. R. Hurd, Atlantis Submarines International
B. Kemper, Kemper Engineering Services, LLC
W. Kohnen, Hydrospace Group, Inc.
J. K. Martin, Perry Technologies
K. A. Smith, U.S. Coast Guard
J. Stromer, Triton Submarines
M. R. Walters, Oceaneering International, Inc.
J. Witney, Atlantis Submarines International
H. Pauli, *Delegate*, Germanischer Lloyd AG
L. Cross, *Alternate*, Kemper Engineering Services, LLC
D. Lawrence, *Alternate*, U.S. Coast Guard
W. F. Crowley, Jr., *Contributing Member*, Aerospace & Undersea Support Services, LLC
T. R. Galloway, *Contributing Member*, Naval Sea Systems Command
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC
R. M. Webb, *Contributing Member*, Naval Sea Systems Command

SUBCOMMITTEE ON VIEWPORTS

B. Kemper, *Chair*, Kemper Engineering Services, LLC
J. Witney, *Vice Chair*, Atlantis Submarines International
E. Lawson, *Secretary*, The American Society of Mechanical Engineers
G. Bryant, Consultant
B. Faircloth, FMS Engineering, LLC
D. R. Hurd, Atlantis Submarines International
W. Kohnen, Hydrospace Group, Inc.
D. Lawrence, U.S. Coast Guard
D. A. Renear, Aqua-Air Industries, Inc.
G. Richards, Blanson, Ltd.
R. C. Smith, Naval Facilities Engineering Command, Ocean Facilities Program
J. Stromer, Triton Submarines
D. Talati, Sechrist Industries, Inc.
R. Thomas, American Bureau of Shipping
L. Cross, *Alternate*, Kemper Engineering Services, LLC
J. K. Martin, *Alternate*, Perry Technologies
M. W. Allen, *Contributing Member*, Microbaric Oxygen Systems, LLC
K. K. Kemper, *Contributing Member*, Kemper Engineering Services, LLC

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

CORRESPONDENCE WITH THE PVHO COMMITTEE

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, PVHO Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the PVHO Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the PVHO Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the PVHO Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

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

Attending Committee Meetings. The PVHO Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the PVHO Standards Committee.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

ASME PVHO-2–2019
SUMMARY OF CHANGES

Following approval by the ASME PVHO Committee and ASME, and after public review, ASME PVHO-2–2019 was approved by the American National Standards Institute on December 4, 2019.

ASME PVHO-2–2019 includes the following changes identified by a margin note, **(19)**.

Page	*Location*	*Change*
2	1-3.4	Added
3	1-7	Added, from former Nonmandatory Appendix A
6	2-2.4	Revised
7	2-4.3	Last paragraph revised
8	2-4.8	Last sentence revised
11	2-6.8	Subparagraph (a) revised
13	2-8	Added
15	Table 2-4.1.1-1	(1) Title revised (2) General Note (g) added
17	Table 2-4.1.1-2	(1) Title revised (2) General Note (g) added
18	Table 2-4.1.1-3	(1) Title revised (2) General Note (c) added
19	Form VM-1	Former Form VP-1 redesignated, and “Window service life expended” line deleted
20	Form VM-2	Former Form VP-2 revised in its entirety
22	Form VM-3	Former Form VP-3 revised in its entirety
23	Form VT-1	Added
36	Form IV-1-2	“Window markings” line added
37	Form IV-5-1	“Window Identification” line replaced with “Window markings” line
40	VI-6	First value in third paragraph revised
41	Table VI-6-1	Title revised
42	Form VI-1	(1) Title revised (2) “Window markings” line added (3) “Test specimens are original submittal” line deleted
43	Form VI-2	Revised in its entirety
44	Nonmandatory Appendix A	Text moved to subsection 1-7

SPECIAL NOTE: ASME PVHO-2 Cases are no longer published with the edition.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

INTENTIONALLY LEFT BLANK

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Section 1
General

1-1 INTRODUCTION AND SCOPE

(a) This Standard provides technical requirements and guidelines for the operation and maintenance of PVHOs and PVHO systems that were designed, constructed, tested, and certified in accordance with 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.

1-2 RESPONSIBILITIES AND JURISDICTIONAL CONSIDERATIONS

1-2.1 User's Responsibilities

The PVHO and PVHO systems user shall provide the designer with information regarding the service conditions that the PVHO and PVHO systems may encounter during their service life. The user shall protect the PVHO and its systems from hazards, and ensure they are used within their design limitations. It is the user, and not the designer or fabricator, who is responsible for determining the safe service life in accordance with the technical criteria and guidelines herein. The user is responsible for retaining all documentation for each PVHO and its associated systems, and shall establish a program of periodic inspection to determine the need for repair or replacement of any part, in accordance with the requirements listed in this Standard. For window repair and replacement requirements, refer to Section 2, Viewports.

1-2.2 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, the state, the U.S. Food and Drug Administration, and the U.S. Coast Guard.) 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 the PVHO, acrylic windows, and PVHO systems). 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.

1-3 IN-SERVICE EVALUATIONS, REPAIRS, AND MODIFICATION OF PVHOs

1-3.1 In-Service PVHO Evaluation and Testing

The owner shall be responsible for performing periodical pressure testing of the PVHO pressure boundary, pressurized systems, and PVHO operational systems. Test pressures shall be at maximum operating pressure and not exceed the maximum allowable working pressure of the components/systems being tested. These tests shall be performed and documented at a periodicity established by the user, manufacturer, and/or applicable jurisdiction.

Pressure testing shall be performed on any valve, fitting, and/or piping/tubing that penetrate the PVHO pressure boundary following reassembly or replacement. The test boundary shall include the first stop valve both upstream and downstream of the reassembled or replaced component.

Pressure testing after pressure vessel or piping weld repairs shall be a hydrostatic or pneumatic test and shall follow the applicable pressure vessel or system component code or standard.

New pressure boundary components (i.e., valve, piping, and windows) shall be hydrostatically or pneumatically tested in accordance with the applicable pressure vessel or system component code or standard.

1-3.2 PVHO Windows and Viewports

The owner shall be responsible for ensuring that in-service viewport evaluations, window replacements, and inspections are performed in accordance with this Standard.

(a) PVHO acrylic windows shall be evaluated and, if necessary, repaired per subsections 2-4 through 2-6 of this Standard.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(b) The service life of acrylic windows shall be determined in accordance with para. 2-4.4 and subsection 2-7 of this Standard.

(c) Replacement windows shall meet PVHO design requirements for the viewport.

(d) Viewports in which PVHO acrylic windows are installed shall be evaluated and, if necessary, refurbished per subsection 2-4 of this Standard.

1-3.3 Pressure Boundary (Except for Windows)

When evidence of a flaw is detected or a modification of a PVHO pressure boundary is planned, the owner shall be responsible for ensuring that the PVHO is evaluated and repaired, replaced, or modified in accordance with the requirements of this Standard, applicable codes, and appropriate jurisdictional authorities.

(a) In-service flaw evaluation techniques, such as nondestructive examination, shall be applied to assess the potential impact to the structural integrity against the PVHO's original design specification and code. Alternatively, the PVHO can be evaluated to the current code provided it is applied to the entire PVHO.

(1) PVHOs designed, fabricated, and tested to ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, or certified to ASME PVHO-1 alternative design rules, that show signs of flaws or damage may be evaluated using API 579-1/ASME FFS-1.

(2) PVHOs that are designed and fabricated to ASME PVHO-1 Code Cases shall be evaluated and repaired in accordance with requirements stated in the case.

(b) Pressure boundary repairs shall include a plan and repair and test procedures consistent with the applicable code. Repairs that do not bring the PVHO to the original "as designed" condition are considered a modification.

(1) For PVHOs stamped per ASME BPVC, Section VIII, the National Board Inspection Code (ANSI/NBBI NB-23) provides applicable weld repair and modification procedures.

(2) All other repairs shall be certified by a qualified Professional Engineer or Authorized Inspector to be in compliance with this Standard and applicable code(s).

(c) Pressure boundary modifications shall be performed in accordance with the most recent code regardless of the original year of fabrication. A Professional Engineer shall be responsible for the modification design and compliance with applicable code requirements.

(d) All pressure boundary parts that are replaced shall meet original manufacturer specifications.

(e) All repair, replacement, and modification documentation shall be maintained per subsection 1-4, PVHO and PVHO Systems Documentation.

1-3.4 Pressure Gauge Calibration (19)

Except where the jurisdictional authority requirements are specified, primary gauges that indicate system and chamber pressures or applicable system and diver depths shall be deadweight tested (or calibrated against a master reference gauge) every 12 months (±30 days) or whenever there is a discrepancy greater than 2% of full scale between any two equivalent gauges.

1-4 PVHO AND PVHO SYSTEMS DOCUMENTATION

The owner shall be responsible for maintaining the following documentation for the service life of PVHOs and PVHO systems:

(a) documentation required by ASME PVHO-1, Section 1, General Requirements

(b) documentation generated during inspection, maintenance, repairs, and modifications

(c) documentation related to operational procedures and manuals

1-5 OWNER'S MANUAL

1-5.1 General

An Owner's Manual is required for each PVHO. It shall contain adequate information to safely operate and maintain the PVHO, its systems, and associated equipment. The owner shall be responsible for maintaining the manual.

1-5.2 Component Description

The Owner's Manual shall include the following:

(a) operating procedures that provide sufficient information to operate the equipment in a safe manner, including

(1) an overview of the PVHO and its systems

(2) procedures to operate the PVHO and its systems

(3) emergency procedures

(b) engineering drawings and schematics necessary for the operation and maintenance of PVHO systems.

(c) systems description that includes an overview and functional description of each system.

(d) equipment documentation that includes electrical and mechanical system descriptions, maintenance requirements, and operating instructions for components and equipment used. This may include collection of vendor-supplied data; supplier-recommended maintenance procedures; and designer-, fabricator-, or manufacturer-supplied data.

The manual shall be kept current, documenting system changes, equipment updates, and the addition or deletion of procedures, and including vendor-supplied documentation, and shall meet or exceed the requirements of applicable jurisdictional authorities.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

1-5.3 Storage of Equipment

Documentation shall define storage requirements for the PVHO, its systems and subsystems, and associated equipment. Information to be provided shall include, but not be limited to

(a) maximum and minimum temperature limits

(b) maximum storage time limits, if applicable, for equipment, including windows, batteries, and nonmetallic materials

(c) preservation requirements

(d) for gas storage and hydraulic systems, purging requirements and pressure settings

(e) special considerations for battery systems

(f) maintenance requirements

(g) reactivation considerations

1-6 MAINTENANCE REQUIREMENTS

Paragraph 1-6.1 outlines requirements for the in-service maintenance of the PVHO and its support systems.

1-6.1 General

It is the responsibility of the owner/operator to maintain a maintenance program for each PVHO. A maintenance program provides a formal approach to maintaining the PVHO and its support systems. The maintenance program shall be supported by a maintenance manual that organizes, defines, and formalizes the maintenance and inspection procedures required. The maintenance program shall be designed to allow updates and the addition or deletion of maintenance and inspection procedures. In addition to maintenance and inspection procedures generated by the PVHO designer, fabricator, owner, or operator, or any combination thereof, the program should rely on vendor-supplied documentation. The program shall be designed to meet or exceed the requirements of applicable jurisdictional authorities.

(19) 1-7 CHECKLISTS AND LOGS

Documented checklists, operating logs, and maintenance logs are an essential part of the safe operation of a PVHO.

All components, systems, subsystems, monitors, sensors, etc., of a PVHO shall be demonstrated, and documented, to be functioning in a safe and acceptable manner prior to operating a PVHO.

There are many different types of PVHOs including, but not limited to, diving bells, manned submersibles, saturation systems, and medical chambers. Each type and/or design will have unique operational characteristics and parameters requiring specific checklists, operating logs, maintenance logs, and record keeping.

It is the responsibility of the owner/operator to ensure that adequate checklists, operating logs, and maintenance logs are completed before, during, and following each operation of a PVHO.

No checklists or logs, other than those required by an operator located inside the PVHO, are to remain inside the PVHO during operations.

All checklists and logs shall be completed by a qualified person(s). All checklists and logs must be completely filled out, signed, and dated by the person(s) who completed the task.

1-7.1 Checklists

Before commencing operations, all preoperation checklists, including those for support equipment, shall be reviewed, signed, and dated by the person responsible for the operation of the PVHO, thereby confirming the PVHO and its support equipment are acceptable for the anticipated operational activities.

1-7.1.1 Preoperation Checklists. These are detailed list(s) of systems, subsystems, components, support equipment, control systems, monitors, and indicator systems, both internal and external, that shall be checked for proper function prior to commencing a PVHO operation.

Where applicable, measured values such as, but not limited to, quantities of supplies, including high-pressure air, breathing gases, battery status, consumables, etc., shall be recorded.

1-7.1.2 Post-Operation Checklists. These are detailed list(s) of systems, subsystems, components, support equipment, control systems, monitors, and indicator system that shall be checked at the conclusion of an operation.

1-7.1.3 Prestorage Checklists. If the PVHO is to be shut down for an extended period of time, a detailed checklist shall be prepared to cover storage requirements including items that can be adversely affected during storage.

1-7.2 Operating Logs

This log is a record of the status of systems, subsystems, monitors, sensors, gas supplies, temperatures, and other vital information, including significant communications and events, prior to, during, and upon completion of each operation of a PVHO. The time associated with each entry shall be recorded.

Each cycle of a PVHO shall be recorded, along with the maximum pressure or depth attained, to monitor the number of cycles on the PVHO pressure boundary, its viewports, and its components.

Any discrepancies affecting safety shall be documented on the operating log and appropriate corrective action(s) undertaken.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

The status of the PVHO's normal and emergency life-support systems shall be documented at the beginning of, during, and upon completion of each operation.

1-7.3 Maintenance Logs

This log(s) constitute a record of all repairs, modifications, changes of equipment, equipment removal, or any other routine or nonroutine maintenance performed on the PVHO and support equipment.

This log is a valuable source of information in determining the history and frequency of repairs to any given system over the operational life of a PVHO. For these reasons, it is important to take the time required to fully describe any and all work done on the PVHO or its support equipment in this log.

Each entry shall be signed and dated by the person performing the work.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Section 2
Viewports

2-1 RESPONSIBILITIES

2-1.1 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 (by completing the applicable ASME PVHO-1 window design certification form) that the window design complies with the requirements of Section 2 of ASME PVHO-1.

2-1.2 Window Fabricator's Responsibility

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

2-1.3 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 determining the safe service life in accordance with the technical criteria and guidelines herein. The user is responsible for retaining 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 subsections 2-4 through 2-6.

2-1.4 Quality Assurance

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

(a) retaining all original forms

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

(c) retaining 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.

2-2 FACTORS AFFECTING SERVICE LIFE

2-2.1 General

Temperature extremes and 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.

2-2.2 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[1] are all damaging to windows.

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

2-2.3 Temperature Abuse Factors

2-2.3.1 Heat Sources. External heat sources (e.g., lightning) shall NOT come in contact with or otherwise heat the surface of a window in excess of its maximum design temperature while pressurized.

Under no circumstances, including storage, should an acrylic window be exposed to temperatures in excess of 150°F (65°C).

2-2.3.2 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 an inoperative or disabled cooling fan. 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.

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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(19) ### 2-2.4 Chemical Abuse Factors

It is the user's responsibility to confirm that any liquid, cleaning solution, vapor, or polish that comes in contact with the window will not cause damage to the acrylic. The user should review the Safety Data Sheet (SDS/MSDS) and Mandatory Appendix V for a partial list of harmful substances and acceptable products.

ASTM F484 can be used to assess the potential of any material to cause crazing in acrylic.

2-2.5 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.

2-2.6 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 affects the window's service life. That is, stressors are both pressure and environment related, with cumulative effect.

2-2.7 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.

2-3 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 windows.

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

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

(e) Do not expose the windows to high radiation (above 4 Mrad).

(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 the windows at temperatures or pressures above the design temperature or design pressure.

(k) Keep a protective cover on windows whenever possible.

(l) Never overtorque the window-retaining fasteners.

2-3.1 Cleaning and Polishing

2-3.1.1 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.

2-3.1.2 Incorrect Methods. Solvents shall not be used for cleaning windows. If solvents are used on the seats, extreme care shall be taken to ensure that drying/evaporation of the 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.

2-3.2 Window Storage

An unused acrylic window may be stored for up to 10 yr from the date of fabrication without the storage time counting toward the service life, provided the storage conditions meet 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 and gaseous).

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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2-2019

(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 10 yr shall be included, day for day, in the service life of the window.

2-4 OPERATIONAL AND MAINTENANCE INSPECTIONS OF PVHO VIEWPORTS

2-4.1 General

There shall be (as a minimum) two levels of inspections:

(a) operational viewport inspection (OVI)

(b) maintenance viewport inspection (MVI)

These inspections shall be performed and documented by a qualified person (inspector) familiar with ASME PVHO-2 as required for the inspection being performed.

2-4.1.1 Scope. The objective of these inspections is to examine viewport components and to document signs of damage or deterioration. Inspections shall include the following:

(a) Windows. Inspect for signs of crazing, discoloration, cracks, chips, scratches, gouges, burns, or pits. If flaws are detected, their size, location, and population shall be recorded and compared to the allowable limits listed in Tables 2-4.1.1-1 through 2-4.1.1-3. Windows with defects exceeding these allowable limits shall be taken out of service.

(b) Flanges, Retaining Rings, and Bolts. Inspect for mechanical damage, corrosion, and deformation.

(c) Seats and Seals. Inspect for mechanical damage, corrosion, extrusion, and irregularities.

Regardless of the inspection being performed, sufficient lighting is important. A strong handheld light should be moved to various angles and positions as necessary to highlight the presence or absence of crazing, cracks, or scratches.

2-4.2 Operational Viewport Inspection

Viewport components, including both interior and exterior surfaces, shall be visually examined and inspected for signs of flaws, corrosion, or irregularities. Viewports having one wetted surface may be inspected from the dry surface unless a flaw is detected on the wetted surface, which will require inspection from that surface.

Viewports do not have to be disassembled for this inspection, unless deemed necessary by the inspector to further inspect a flaw of concern and determine if it exceeds allowable limits as set forth in this Standard.

2-4.2.1 Operational Viewport Inspection Schedule. Viewports shall be visually inspected prior to each pressurization of the PVHO.

Viewports that are pressurized more than once per day need only be inspected prior to the first pressurization of that day, unless otherwise deemed necessary.

2-4.3 Maintenance Viewport Inspection (19)

Maintenance viewport inspections shall be performed at periodic intervals. These inspections shall be more comprehensive than operational viewport inspections. For maximum intervals for maintenance viewport inspection, see Table 2-4.3-1.

In addition to inspecting the other viewport components, all window surfaces (and edges) described in Table 2-4.1-1 shall be inspected to the criteria set forth in Tables 2-4.1.1-1 through 2-4.1.1-3. Special optical devices, such as prisms, optical measuring devices, and coherent fiber bundles, are often useful for these inspections.

At the discretion of the inspector, components of a viewport may need to be removed for a more detailed inspection.

When refurbishing viewports (see Table 2-4.3-2), complete removal of the window is required.

PVHO-2 Form VM-1, Viewport Inspection, shall be completed and signed by the inspector. Additional information may include photographs and schematics, and should be retained with the Viewport Inspection form.

Records of the MVI shall be retained throughout the service life of each window.

2-4.3.1 Maintenance Viewport Inspection Schedule. The user is responsible for establishing a procedure and schedule for the maintenance viewport inspection. Scheduling shall take into account the service environment and whether or not the service life of the window is less than or greater than its design life.

Maintenance viewport inspections shall be performed

(a) as a minimum, at intervals shown in Table 2-4.3-1

(b) at refurbishment intervals shown in Table 2-4.3-2

(c) when a window is removed and reinstalled

(d) when a new window is installed

(e) for windows that have been out of service for 18 months or longer

2-4.4 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 yr or 5,000 cycles beyond its design life, unless one or more windows from that PVHO are tested in accordance with subsection 2-7. (The exception is cylindrical window chambers, which may be operated for up to an additional 10,000 cycles max., 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 subsection 2-7.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

The maximum service life duration extensions per each mechanical property test based on the procedures of subsection 2-7 may not exceed 10 yr (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 nonrepairable 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. 2-3.2 does not contribute to service life, except as noted.

(2) For windows in accordance with ASME PVHO-1, para. 2-2.7.9, the cyclic life is as determined by that paragraph.

2-4.5 Reinstallation of PVHO Windows

NOTE: Extreme care shall be exercised during removal and reinstallation of flat disk and double bevel disk 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.

2-4.6 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 that are pressurized with oxygen, the user shall also ensure 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.

2-4.7 Instrumentation and Tools

The primary inspection tools are commercially available devices such as rulers, micrometers, vernier calipers, optical comparators, polariscopes, high-intensity lights, radius gauges, flatness gauges, 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. (1.25 mm) 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. (1.25 mm) can be measured with a depth micrometer equipped with a pointed rod, or a dial-indicator depth gauge equipped with a pointed rod.

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

2-4.8 Documentation and Record Retention (19)

All window maintenance inspection results and findings shall be documented using PVHO-2 Form VM-1. All records, including the original ASME 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.

2-4.9 Qualification of Window Inspectors

Paragraphs 2-4.9.1 and 2-4.9.2 establish window inspector qualifications to perform operation and maintenance inspections, and in particular, for windows whose service life is in excess of their design life. The user is responsible for determining that a window inspector, whether internal or a third-party employee, has met the appropriate inspector's level of qualification as stated herein.

2-4.9.1 Procedure and Levels of Qualification. The user is responsible for establishing in writing and implementing an inspector qualification procedure to ensure PVHO-2 requirements are met during the service life of their PVHO windows. The procedure documents their organization's specific responsibilities and the associated training, testing, and frequency used to requalify

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

and maintain each level of window inspector. In general, window inspectors are qualified to two levels.

(a) Operational Inspector. The operational inspector (OI) performs the operational window inspection. This is a visual inspection performed prior to operation and is normally conducted by operational personnel. OIs require knowledge specific to assigned responsibilities and procedures along with the ability to recognize the variety of window flaws associated with their PVHO application. In the event that a significant flaw is suspected, operations shall not commence until approved by persons having the appropriate qualifications and authority.

(b) Maintenance Inspector. The maintenance inspector (MI) performs the window maintenance inspection and seat and seal inspection. MIs require in-depth knowledge of applicable sections of ASME PVHO-1 and PVHO-2, and skills in examining and assessing corrective actions. The MI should be the qualified person who is called upon when a suspected flaw is detected during an operational window inspection.

2-4.9.2 Use of Third Parties. When third-party window inspectors or trainers are used, the owner/user shall retain the third-party agent documentation and qualifications. The agent shall provide the owner/user with documentation that describes the scope and procedure of their inspection or training and assures that it meets current PVHO standards. The agent shall also retain inspector or trainer qualification records for the term of their employment, plus 3 yr.

2-5 CATEGORIES OF DAMAGE

2-5.1 Superficial (Does Not Require Action)

Damage or a scratch that is superficial in nature (i.e., it affects only the optical clarity of the window and/or is below the significant dimensions set forth in Tables 2-4.1.1-1 through 2-4.1.1-3) 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.

2-5.2 Significant (Requires Action)

Damage that is not superficial (i.e., it exceeds the significant dimensions set forth in Tables 2-4.1.1-1 through 2-4.1.1-3) shall require that the user red tag the window and either repair or replace it. The condition shall be logged on the inspection documents at the time of the discovery of the condition.

2-5.3 Nonrepairable (Requires Replacement)

Whether or not a window is repairable depends, in part, on the thickness; that is, as indicated in ASME PVHO-1 Form VP-2, Acrylic Window Design Certification, 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).

2-6 REPAIR OF DAMAGED PVHO WINDOWS

2-6.1 General

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 that meets the requirements set forth in Mandatory Appendix III.

2-6.2 Window Damage Assessment

The assessment of damage during window maintenance inspections should be performed by a PVHO-Qualified Window Fabricator who maintains a Quality Assurance Program in accordance with the requirements of Mandatory Appendix III, or an inspector meeting the qualifications set forth in para. 2-4.9. The criteria to be used for window damage assessment is as specified by subsection 2-5, Categories of Damage, in accordance with Tables 2-4.1-1 through 2-4.1.1-3.

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 0.02 in. (0.5 mm) deep, or chips on the window edges less than 0.125 in. (3.175 mm) wide. Scratches, gouges, crazing, cracks, other imperfections deeper than 0.02 in. (0.5 mm), and edge chips wider than 0.125 in. (3.175 mm) are considered to be severe damage.

2-6.2.1 Slightly Damaged Windows

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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(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 that had been removed.

2-6.2.1.1 Field Repair of Slightly Damaged Windows. Windows with minor flaws or blemishes may be repaired in the field only by hand sanding and polishing. Scratches and 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.

2-6.2.2 Severely Damaged Windows. 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 ASME PVHO-1.

2-6.2.3 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. All repairs (regardless of extent) shall be documented using PVHO-2 Form VM-2, Acrylic Window Repair Certification for Severely Damaged Windows; the form shall be retained in the documentation package (see para. 2-4.8).

2-6.3 Repair Requirements for Spherical Windows

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.

(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.

2-6.4 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 ASME PVHO-1.

2-6.5 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 PVHO-2 Form VM-3 and retained in the documentation package (see para. 2-4.8).

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

2-6.6 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.

2-6.7 Post-Repair Annealing and Pressure Testing

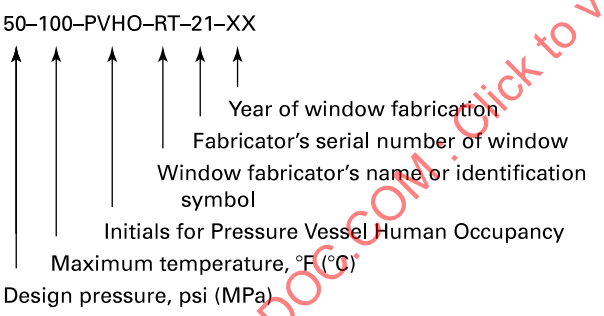
After completion of any machining, including machine polishing, the window shall be annealed and pressure tested in accordance with the requirements set forth in Mandatory Appendix IV.

(19) ### 2-6.8 Marking of Repaired Windows

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

(a) Window markings and the repair identification shall consist of 0.5-in. (12.5-mm) letters and numbers made with indelible black marker or 0.125-in. (3.175-mm) 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.

The identification marking on each window is located on the window's surface as per ASME PVHO-1 and contains the following information:



(b) The repair identification shall contain the repair logo, fabricator's initials, fabricator's 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 that had been removed.

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

2-6.9 Pressure Test of Repaired Windows

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.

2-7 MECHANICAL PROPERTY TESTING

2-7.1 General

For PVHOs operated in a protected environment, when service life reaches 10 yr or 5,000 cycles beyond the design life, one window from the PVHO shall be tested as follows. (The exception is cylindrical window chambers, which may be operated for an additional 10,000 cycles max.)

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 D790
Window midplane	Tensile ultimate	ASTM D638
Window midplane	Flexural ultimate	ASTM D790
High-pressure face	Flexural ultimate	ASTM D790

GENERAL NOTES:

(a) 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-yr 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-yr design life, both type coupons shall be flexed with the parent material in compression.

(b) 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.

2-7.2 Validation of Minimum Acceptable Properties

The mean value of the window midplane 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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

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.

2-7.3 Evaluation of Data for Additional Years of Service Life

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

(a) 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 midplane flexure.

(b) 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 midplane flexure.

If conditions (a) and (b) 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 yr max. (or 10,000 cycles; see para. 2-7.4) 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 extrapolation equations (i.e., the lesser of X_1, X_2, X_3, or X_4), or 10, if the solutions are greater than 10.

X_2 and X_4 need to be computed only if the requirements of (a) are not met. X_1 and X_3 need to be computed only if the requirements of (b) are not met.

$$X_1 = [L_{95} - 10{,}000]/[(U_m - L_{95})/Y]$$
$$X_2 = [H_{95} - 10{,}000]/[(U_m - H_{95})/Y]$$
$$X_3 = [L_{99} - 7{,}000]/[(U_m - L_{99})/Y]$$
$$X_4 = [H_{99} - 7{,}000]/[(U_m - H_{99})/Y]$$

H_{95} = lower 95% CI value on high-pressure surface (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 low-pressure surface (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 midplane, based on actual test data

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

In regard to the parameter U_m, if the mean value plus the standard error of the ultimate tensile strength at the midplane is equal to or greater than the original tensile strength of the window recorded on ASME PVHO-1 Form VP-4, Material Testing Certification for Acrylic, 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 midplane, U_m, in direct proportion to the fractional ratio between the mean value of the tensile strength at midplane as compared to the original tensile strength value for the window as recorded on ASME PVHO-1 Form VP-4, Material Testing Certification for Acrylic.

2-7.4 Commensurate Extension of Cyclic Service Life

For each additional year of 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 added to the number of cycles that have already accumulated prior to the performance of mechanical testing. See also paras. 2-7.5(a) through 2-7.5(c).

2-7.5 Additional Notes to Subsection 2-7

(a) For windows in accordance with ASME PVHO-1, para. 2-2.7.9 requirements, cyclic fatigue life is as determined by that paragraph, 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. 2-7.2 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 is 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) midplane tensile mean value > 9,000 psi (62.0 MPa)

(2) midplane 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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

provisions. At least two more shall be prepared and tested. The data point in question may be censored, however, only 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 the case of either (d) or (e), the testing of additional coupons may be performed only once. That is, an iterative approach is not permitted.

(19) 2-8 TESTING REQUIREMENTS FOR INCREASING THE 40,000-hr DESIGN LIFE

For standard geometry PVHO windows having a design pressure of less than 2,000 psi (13.8 MPa), other than hyperhemispherical and NEMO types, the design total time under pressure can be increased in excess of that stated in ASME PVHO-1 through experimental pressure testing procedures, provided the following procedures and requirements are met and documented using PVHO-2 Form VT-1:

(a) For each window design, at least one window of identical shape, dimensions, and design pressure–temperature rating shall be pressurized to design pressure to determine whether its design total time under pressure may exceed the 40,000-hr limit stated in ASME PVHO-1. The pressure test shall take place with the window installed in a test fixture whose window seat dimensions, retaining ring, and seals are identical to those of the PVHO chamber.

(b) The window shall be pressurized to design pressure with gas or water. The pressurization and depressurization rates are not to exceed 650 psi/min (4.5 MPa/min). At least one complete pressure cycle shall be undertaken every 24 hr.

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

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

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

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

(g) The Pressure Test Supervisor, as noted in Pressure Testing Report AA, shall certify the results of the test. Copies of the test report shall be furnished to the user.

(h) An extension of 1 hr may be granted by the Standard for each two test hours after completion of the first 40,000 hr, up to failure of the test window.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Table 2-4.1-1 Periodic Inspection Requirements

Types of Windows	Surfaces and Edges of Windows					Requires Window Removal
	High-Pressure Surface (HPS)	Low-Pressure Surface (LPS)	Bearing Surface (BS)	All Other Surfaces	Sharp Edges	
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 disk	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	...
Hyperhemisphere with conical edges	Yes	Yes	Yes	Yes	Yes	...
NEMO shapes	Yes	Yes	Yes	Yes	Yes	...
Plane (flat disk) window seat with O-ring	Yes	Yes	Yes	Yes	Yes	Yes
Plane (flat disk) window seat without O-ring	Yes	Yes	...	...	...	...

GENERAL NOTE: This Table 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 and edges shall be inspected in accordance with Tables 2-4.1.1-1 through 2-4.1.1-3.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Table 2-4.1.1-1 Limits for Blemishes or Flaws on Standard Window Geometry Surfaces (19)

Type of Window	Location	Blemish or Flaw		Corrective Action
		Type	Size	
Group A				
Plane (flat disk); conical frustum with $t/D_i < 0.5$; double bevel disks with $t/D_i < 0.5$; spherical sectors with square edges; and hemispheres with flanges	HPS	Pit	$k > 0.02t$	Red tag
	HPS	Scratch/gouge	$k > 0.02t$	Red tag
	HPS	Crazing	Visible	None
	HPS	Crazing/cracking	$k > 0.02t$	Red tag
	LPS	Pit	$k > 0.01$	Red tag
	LPS	Scratch/gouge	$k > 0.01$	Red tag
	LPS	Crazing/cracking	$k > 0.01$	Red tag
	BS	Pit	$k > 0.06$	Red tag
	BS	Scratch/gouge	$k > 0.06$	Red tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > 0.06$	Red tag
Group B				
Cylinder under internal pressure	HPS, LPS, BS	Pit	$k > 0.03$	Red tag
	HPS, LPS, BS	Scratch/gouge	$k > 0.01$	Red tag
	HPS, LPS, BS	Crazing	Visible	None
	HPS, LPS, BS	Crazing/cracking	$k > 0.01$	Red tag
Group C				
Cylinder under external pressure	HPS, LPS	Pit	$k > 0.1t$	Red tag
	HPS, LPS	Scratch/gouge	$k > 0.06t$	Red tag
	HPS, LPS	Crazing	Visible	None
	HPS, LPS	Crazing/cracking	$k > 0.02t$	Red tag
	BS	Pit	$k > 0.06t$ (1) $k > 0.03t$ (2)	Red tag
	BS	Scratch/gouge	$k > 0.03t$ (1) $k > 0.02t$ (2)	Red tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > 0.08R_o$ (1) $k > 0.03t$ (2)	Red tag
Group D				
Spherical sector with conical edges; NEMO windows; and hyper-hemisphere	HPS	Pit	$k > 0.1t$	Red tag
	HPS	Scratch/gouge	$k > 0.06t$	Red tag
	HPS	Crazing	Visible	None
	HPS	Crazing/cracking	$k > 0.02t$	Red tag
	LPS	Pit	$k > 0.06t$	Red tag
	LPS	Scratch/gouge	$k > 0.02t$	Red tag
	LPS	Crazing	Visible	None
	LPS	Crazing/cracking	$k > 0.01t$	Red tag
	BS	Pit	$k > 0.06t$	Red tag
	BS	Scratch/gouge	$k > 0.03t$	Red tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > 0.08R_o$	Red tag

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Table 2-4.1.1-1 Limits for Blemishes or Flaws on Standard Window Geometry Surfaces (Cont'd)

Type of Window	Location	Blemish or Flaw		Corrective Action
		Type	Size	
Group E				
Conical frustums with $t/D_i \geq 0.5$ and double bevel disk with $t/D_i \geq 0.5$	HPS	Pit	$k > 0.02t$	Red tag
	HPS	Scratch/gouge	$k > 0.02t$	Red tag
	HPS	Crazing	Visible	None
	HPS	Crazing/cracking	$k > 0.02t$	Red tag
	LPS	Pit	$k > 0.01t$	Red tag
	LPS	Scratch/gouge	$k > 0.01t$	Red tag
	LPS	Crazing	Visible	None
	LPS	Crazing/cracking	$k > 0.01t$	Red tag
	BS	Pit	$k > 0.06$	Red tag
	BS	Scratch/gouge	$k > 0.06$	Red tag
	BS	Crazing	Visible	None
	BS	Crazing/cracking	$k > 0.06$	Red tag

GENERAL NOTES:

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

(b)
BS = bearing surface
Crack = fracture(s) originating at surface
D_i = inside diameter of window, in. (for flat disk = inside diameter of hard bearing surface)
HPS = high-pressure surface
k = depth of flaw or blemish, in.
LPS = low-pressure surface
Pit = circular crater without cracks
R_o = exterior spherical radius, in.
Scratch/gouge = narrow trench without cracks
t = thickness of window, in.

(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, and 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.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Table 2-4.1.1-2 Limits for Blemishes or Flaws on All Other Standard Window Geometry Surfaces (19)

Type of Window	Description of Locations Other Than HPS/LPS/BS	Blemish or Flaw		Corrective Action
		Type	Size	
Plane (flat disk) and double bevel disk	Surface normal (i.e., at right angle) to the high- and low-pressure faces, and bevels, if applicable	Pit	$k > 0.06$	Red tag
		Scratch/gouge	$k > 0.03$	Red tag
		Crazing	Visible	None
		Crazing/cracking	$k > 0.06$	Red tag
Double bevel and conical frustum	Cylindrical surface and/or nonbearing bevel	Pit	$k > 0.06$	Red tag
		Scratch/gouge	$k > 0.03$	Red tag
		Crazing	Visible	None
		Crazing/cracking	$k > 0.06$	Red tag
Hemispheres and spherical sectors with square flanges	Cylindrical surface and the plane non-bearing surface	Pit	$k > 0.06$	Red tag
		Scratch/gouge	$k > 0.03$	Red tag
		Crazing	Visible	None
		Crazing/cracking	$k > 0.03$	Red tag
Spherical sector with conical edges	Bevel	Pit	$k > 0.125$	Red tag
NEMO windows and hyperhemispheres		Scratch/gouge	$k > 0.06$	Red tag
		Crazing	Visible	None
Cylinders under external pressure		Crazing/cracking	$k > 0.03t$	Red tag
Cylinders under internal pressure	Bevel	Pit	$k > 0.03$	Red tag
		Scratch/gouge	$k > 0.01$	Red tag
		Crazing	Visible	None
		Crazing/cracking	$k > 0.01$	Red tag

GENERAL NOTES:

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

(b)
BS = bearing surface
Crack = fracture(s) originating at surface
HPS = high-pressure surface
k = depth of flaw or blemish, in.
LPS = low-pressure surface
Pit = circular crater without cracks
Scratch/gouge = narrow trench without cracks
t = thickness of window, in.

(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, and 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.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(19) **Table 2-4.1.1-3 Limits on Chipping of Sharp Edges on Standard Window Geometries**

Type of Window	Location	d, in.	Corrective Action
Conical frustum with $t/D_i < 0.5$	HPE	$> 0.2t$	Red tag
	LPE	$> 0.01D_i$	Red tag
Conical frustum with $t/D_i \geq 0.5$	HPE	$> 0.2t$	Red tag
	LPE	$> 0.02D_i$	Red tag
Double bevel disk with $t/D_i < 0.5$	HPE	$> 0.01D_i$	Red tag
	LPE	$> 0.01D_i$	Red tag
Double bevel disk with $t/D_i \geq 0.5$	HPE	$> 0.02D_i$	Red tag
	LPE	$> 0.02D_i$	Red tag
Spherical sector with conical seat	HPE	$> 0.2t$	Red tag
	LPE	> 0.125	Red tag
Hyperhemisphere	HPE	$> 0.1t$	Red tag
	LPE	> 0.125	Red tag
Nemo window	HPE	$> 0.1t$	Red tag
	LPE	> 0.125	Red tag
Plane (flat disk) window	HPE	> 0.03	Red tag
	LPE	$> 0.01D_i$	Red tag
Spherical sector with square edge	HPE	> 0.03	Red tag
	LPE	> 0.03	Red tag
Hemisphere with square flanges	HPE	> 0.125	Red tag
	LPE	> 0.03	Red tag
Cylinder under internal pressure	HPE	> 0.03	Red tag
	LPE	> 0.03	Red tag
Cylinder under external pressure	HPE	$> 0.1t$	Red tag
	LPE	$> 0.05t$	Red tag

GENERAL NOTES:

(a)

d = greatest projected depth of missing material measured coplanar to the adjacent surface

D_i = inside diameter of window, in. (for flat disk = inside diameter of hard bearing surface)

HPE = high-pressure face edge

LPE = low-pressure face edge

t = thickness of window, in.

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

Table 2-4.3-1 Maximum Intervals for Maintenance Viewport Inspection

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) Window removal is not required unless deemed necessary by the inspector.

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

Table 2-4.3-2 Maximum Intervals for Refurbishment

Type	Maximum Interval
Cylindrical window chambers	Completely refurbish at 10-yr intervals regardless of usage
Marine intermittent submersion	Completely refurbish at 10-yr intervals regardless of usage
Marine continuous submersion	Completely refurbish at expiration of extended service life
All other window types	Completely refurbish at expiration of extended service life

GENERAL NOTE: Refurbishment requires a more detailed (hands-on) inspection of the viewport components and requires the complete removal and refurbishment of all viewport components.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(19)

PVHO-2 Form VM-1 Viewport Inspection

Window markings: _____ - _____- PVHO-_____ - _____-_____

Window repair markings: ☐ None Δ - _____ - _____ - _____

Purpose of inspection: ☐ Window inspection ☐ Seat and seal inspection ☐ Both

☐ Other (describe) _____

Vessel markings: Mfg _____ S/N _____

Vessel description: _____

_____

Service environment: ☐ Protected ☐ Typical ☐ Severe

Location of window in PVHO: _____

Facility/Owner (name & address) _____

_____

Inspection Results

Acrylic Window Inspection performed with the window: ☐ Installed ☐ Removed

Are there flaws exceeding PVHO-2 allowable limits? ☐ Yes ☐ No

Comments: _____

Recommended actions: ☐ No action required ☐ Remove from service (repair/replace as appropriate)

Seat and Seal Inspection:

Window Flanges: Is there damage, corrosion, etc.? ☐ Yes ☐ No

Comments: _____

Recommended actions: ☐ No action required ☐ Repair ☐ Replace

Window Seals: Is there damage, excessive wear, etc.? ☐ Yes ☐ No

Comments _____

Recommended actions: ☐ No action required ☐ Repair ☐ Replace

General Comments: _____

_____

_____

_____

Certificate of Compliance

I, _____ (print name), certify that the statements made in this report are correct and that all details of this inspection conform to the requirements of PVHO-2 and that I inspected the components described in this report on ____/_____/_____ (day/month/year) and state to the best of my knowledge and belief that the viewport of this report is ___is not ___suitable for continued service.

Signature of inspector: _____ Date: _____

Name and address of inspection organization: _____

GENERAL NOTE: This form may be reproduced and used without written permission from ASME if used for purposes other than republication.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(19)

PVHO-2 Form VM-2 Acrylic Window Repair Certification for Severely Damaged Windows

Window identification markings: _____ - _____ - PVHO - _____ - _____ - _____

1. Original Fabrication Date (from original Window Fabrication Certification) _____ /_____ /_____
(Month/Day/Year)

Original fabrication certification prepared by: _____
(Name of authorized representative)

_____
(Name of fabricator)

2. Window Shape (from visual inspection)
   - Conical frustum: _____
   - Double beveled: _____
   - Spherical sector with conical edge: _____
   - Spherical sector with square edge: _____
   - Flat disk: _____
   - Hyper hemisphere with conical edge: _____
   - NEMO: _____
   - Cylinder: _____

3. Original Design Data (from original Window Design Certification Form VP-2)
   - Fabricated according to drawing No.: _____
   - Original Design Certification prepared by: _____
   - Maximum design pressure: _____
   - Maximum design temperature: _____
   - For the design temperature and pressure:
     - Minimum thickness (calculated t): _____
     - Minimum inside diameter, D_i: _____
     - Minimum outside diameter, D_o: _____

4. Original Window Dimensions (from original Window Design Certification Form VP-2)
   - Minimum thickness, t: _____
   - Inside diameter, D_i: _____
   - Outside diameter, D_o: _____

5. Repair History
   - Surfaces repaired:
     - High-pressure face: _____
     - Low-pressure face: _____
     - Bearing surfaces: _____
     - Beveled edges: _____
     - Sealing surfaces: _____
   - Spot casting was required: Yes _____ No _____
     - 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 _____
   - The repaired window was annealed at _____ for _____ hr
   - Annealing Certification per Mandatory Appendix IV is attached: Yes _____ No _____

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

PVHO-2 Form VM-2 (Back)

6. Post-Repair
   Actual dimensions:
   Minimum thickness, t: _____
   Inside diameter, D_i: _____
   Outside diameter, D_o: _____

   Minimum thickness and/or inside/outside diameters of the repaired window meet the minimum design requirements: Yes ____ No ____

   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: _____

7. Where the minimum dimensions do NOT meet the minimum design requirements:
   Redo the design calculations in accordance with ASME PVHO-1, Section 2 using actual post-repair dimensions.
   Complete ASME PVHO-1 Form VP-2 using actual repair dimensions (indicate "revised").
   Attach a copy of the above mentioned ASME PVHO-1 Form VP-2 to this report.
   The post-repair design temperature is: _____
   The post-repair design pressure is: _____
   The new post-repair window marking is: _____-_____-PVHO-_____-_____-_____ year.
   (Year must be the same as on the original window marking).

Window was repaired by: _____
(Name of company)

_____
(Name of authorized representative)

_____
(Signature of authorized representative)

Date of window repair: _____ / _____ / _____
(Month/Day/Year)

CERTIFICATION

The refinished surfaces, spot castings, and minimum thickness of the repaired window meet all the requirements of the ***attached 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 form are to be provided and certified by the company/individual authorizing the repair of severely damaged windows.
(b) The repair process information required by Parts 5 and 6 is to be provided and certified by the window fabricator performing the repair.
(c) This form may be reproduced and used without written permission from ASME if used for purposes other than republication.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(19)

PVHO-2 Form VM-3 Acrylic Window Repair Certification for Slightly Damaged Windows Repaired by the User (or the User's Authorized Agent)

Window markings: _____ - _____ - PVHO - _____ - _____ - _____

1. Window Shape (from visual inspection)
   - Conical frustum: _____
   - Double beveled: _____
   - Spherical sector with conical edge: _____
   - Spherical sector with square edge: _____
   - Hemisphere with equatorial flange: _____
   - Flat disk: _____
   - Hyperhemisphere with conical edge: _____
   - NEMO: _____
   - Cylinder: _____
2. Design Data (from original Window Design Certification)
   - Original Design Certification prepared by: _____
   - Design minimum thickness, t: _____
   - Design inside diameter, D_i: _____
   - Design outside diameter, D_o: _____
3. After Repair
   - Actual minimum thickness, t : _____
   - Actual inside diameter, D_i: _____
   - Actual outside diameter, D_o: _____
4. Inspection report attached: Yes _____ No _____
5. Repair performed
   - High-pressure face: _____
   - Low-pressure face: _____
   - Bearing surfaces: _____
   - Beveled edges: _____
   - Sealing surfaces: _____

   Repair of the window performed by: _____
   (Name of company)
   _____
   (Name of authorized representative)
   _____
   (Signature of authorized representative)
6. The minimum thickness and/or inside diameter of the Repaired Window meet the minimum requirements: Yes _____ No _____
7. During repair, original window identification markings were: Left intact _____ Reapplied _____

_____ (Signature of person performing repair)

_____ (Signature of person inspecting repair)

GENERAL NOTE: This form may be reproduced and used without written permission from ASME if used for purposes other than republication.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(19)

PVHO-2 Form VT-1 Pressure Testing Report for Increasing Window Service Life Beyond the 40,000-hr Design Life

Window Drawing No.: _____

Window Identification: _____

Window Design

Maximum allowable working pressure/design pressure _____

Test Arrangement

Window tested in accordance with para. 2.8 _____ (yes/no)

Test Observations

Leakage _____ (yes/no)

Permanent deformation exceeds limits outlined in para. 2.8 _____ (yes/no)

Signs of crazing and/or cracks _____ (yes/no)

Test Results

Total number of hours at design pressure and temperature _____ hr

An extension of 1 hr may be granted for each two test hours, after completion of the first 40,000 hr, up to failure of the window.

Calculations:

Allowable hours per ASME PVHO-1, para. 2-1.2(d)	40, 000	hr
Plus 50% of test hours exceeding 40,000 hr	_____	hr
Total number of allowable hours	_____	hr

The acrylic window was tested according to the procedure of para. 2.8 of this Standard and was found to perform satisfactorily without any visible permanent deformation, crazing, or cracking.

_____ _____

Pressure test supervisor Date

_____

Name and address of testing facility

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

GENERAL NOTE: This form may be reproduced and used without written permission from ASME if used for purposes other than republication.

MANDATORY APPENDIX I
DEFINITIONS

This Appendix contains the definitions for the terms used throughout this Standard.

acrylic: methyl methacrylate plastic possessing physical and mechanical properties shown in Tables 2-3.4-1 and 2-3.4-2 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 haze on the surface of the window made up of a multitude of very fine, hairlike straight or randomly oriented cracks that become clearly visible if illuminated at an angle by a bright light. Crazing is an indication of surface degradation that may be induced thermally, mechanically, or chemically, or by radiation.

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.

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

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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

PVHO Window Design Life: the length of time as defined by para. 2-2.7 of ASME 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.

qualified person: someone who, by possession of a recognized degree, certificate, or professional standing, or who, by knowledge, training, and experience, has successfully demonstrated the ability to perform the assigned duties.

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

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

refurbishment: a documented procedure where a manufactured item is functionally inspected, restored, and tested in accordance with its performance specification.

repair: to rework the window in such a fashion as to make it usable 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 a 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 is 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 (e.g., 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.

hydrostatic: proof testing using water as the pressurizing medium.

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

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

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

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.

third-party inspection agency: an individual or organization, independent of the designer, fabricator, and user, who is qualified through education, test, or experience to perform the inspection.

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 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, that the designer would expect to have minimal effect on the service life of

ASMENORMDOC.COM Click to view the full PDF of ASME PVHO-2 2019

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).

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

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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

MANDATORY APPENDIX II
REFERENCE STANDARDS AND SPECIFICATIONS

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

ANSI/NBBI NB-23, National Board Inspection Code
Publisher: National Board of Boiler and Pressure Vessel Inspectors (NBBI), 1055 Crupper Avenue, Columbus, OH 43229 (www.nationalboard.org)

API 579-1/ASME FFS-1, Fitness-for-Service
ASME Boiler and Pressure Vessel Code
ASME PVHO-1, Safety Standard for Pressure Vessels for Human Occupancy
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ASTM D638-98, Standard Test Method for Tensile Properties of Plastics
ASTM D695-96, Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D790-98, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

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

III-1 GENERAL

This 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 that 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

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(d) Procedures for assuring continued compliance with pertinent requirements, including identification of 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 that have satisfactorily passed required inspections and tests shall be identified.

III-13 CORRECTIVE ACTION

(a) Items, services, or activities that do not conform to specified requirements shall be controlled to ensure 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 disposition shall be established and documented.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

(e) Records required for traceability shall be retained for a duration equal to the balance of the window's design life, plus 10 yr.

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).

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

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. (PVHO-2 Form IV-1-1, Material Testing Certification for Repair by Spot Casting, shall be completed when repair by spot casting is performed.) 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 shall 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 shall be as follows:

(a) The test for the tensile strength of a sample bond shall be per ASTM D638, 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 D695.

(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 methacrylate 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 mg 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 methacrylate 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 annealing shall take place in a forced circulation air-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 PVHO-2 Form IV-1-2, Annealing Process Certification. 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 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.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

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

(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, and the window shall be removed, 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 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 (138 MPa), 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, PVHO-2 Form IV-5-1, Pressure Testing Certification, shall be completed by the party who performed the pressure test.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

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	SI
ASTM D638	Tensile strength (of sample bond)	≥4,500 psi	≥31 MPa
ASTM D695	Compressive:		
	(a) yield strength	≥15,000 psi	≥103 MPa
	(b) modulus of elasticity	≥400,000 psi	≥2760 MPa
Method as described	Ultraviolet (290 nm to 330 nm) light transmittance	≤5%	≤5%
Method as described	Total residual monomer:		
	(a) methyl methacrylate	≤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)			
	≥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 [Note (1)]	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.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

Table IV-1-2(b) Annealing Schedule for Acrylic Windows
Part B: Maximum Cooling Rates for Acrylic Subjected to Elevated Annealing Temperatures

Thickness, in. (mm)	Cooling Rate, °F/hr (°C/h)	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)			
		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.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019

PVHO-2 Form IV-1-1 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 manufacturer trademark of _____ possess the following physical and chemical properties:

Test Method	Property	Results
ASTM D638	Tensile strength of sample bond	_____
ASTM D695	Compressive:	_____
	(a) Yield strength	
	(b) Modulus of elasticity	
Method as set forth in Mandatory Appendix IV	Ultraviolet transmittance [for ½ in. (12 mm) thickness]	_____
Method as set forth in Mandatory Appendix IV	Total residual methyl methacrylate	_____ %
	and ethyl acrylate monomers	_____ %

The experimentally proven properties satisfy the minimum values specified in Table IV-1-1 of ASME PVHO-2, Safety Standard for Pressure Vessels for Human Occupancy: In-Service Guidelines.

_____ _____

Authorized representative of material testing laboratory — Date

_____

Name and address of material testing laboratory

GENERAL NOTE: This form may be reproduced and used without written permission from ASME if used for purposes other than republication.

ASMENORMDOC.COM : Click to view the full PDF of ASME PVHO-2 2019