**PVHO Case 11**

**Use of Nonmetallic Expansion Joint**

Approval Date: August 13, 2007
Reaffirmation Date: February 15, 2024

**Inquiry:** Under what conditions may a ring-reinforced elastomer expansion joint be used as a diving system component in construction under the rules of PVHO-1–2012?

**Reply:** It is the opinion of the Committee that a ring-reinforced elastomer expansion joint may be constructed under the requirements of PVHO-1–2012 as a diving system component, and be marked as a PVHO-1 pressure vessel part in accordance with PVHO-1–2012, when the requirements of PVHO-1–2012, with the exceptions in the paragraphs below, have been met.

1 GENERAL

1.1 Requirements

(a) The maximum allowable working pressure (MAWP) is 80 psig (0.55 MPa).

(b) The expansion joint will conform to the following configuration, shape, and dimensions: single wide arch unfilled elastomer expansion joint, 30 in. (762 mm) internal diameter, 12 in. (305 mm) overall length; flange-end connections in accordance with ASME B16.1, Class 125, standard expansion joint flanges.

(c) No windows or penetrators are permitted.

(d) The expansion joint serves as a transit (i.e., trunk/tunnel) between other pressure vessels and can permit passage for only one occupant at a time.

(e) The temperature design limits are 0°F to 110°F (−17.8°C to 43.3°C) operational, and 0°F to 150°F (−17.8°C to 65.6°C) nonoperational.

(f) The design and service life is 5 yr from date of manufacture.

(g) The design number of pressure cycles is 1,250.

(h) The design number of displacement fatigue cycles is 50,000.

(i) The minimum ratio of proof pressure to rated pressure (MAWP) is 6:1.

(j) In-service use shall be ventilated with breathing-quality air.

(k) The expansion joint shall only be used in a system that is pressure relieved in accordance with PVHO-1–2012, subsection 1-8.

(l) The maximum flange-to-flange relative displacement is shown in Table 11-1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Movement Capability From Neutral Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial compression</td>
<td>0.434 in.</td>
</tr>
<tr>
<td>Axial extension</td>
<td>0.936 in.</td>
</tr>
<tr>
<td>Lateral deflection</td>
<td>0.452 in.</td>
</tr>
<tr>
<td>Angular deflection</td>
<td>1.207 deg</td>
</tr>
<tr>
<td>Torsional rotation</td>
<td>0.116 deg</td>
</tr>
</tbody>
</table>

GENERAL NOTE: Movements are defined in the FSA Technical Handbook.

1.2 Standards

The expansion joint shall meet all requirements of ASTM F1123-87, Standard Specification for Non-Metallic Expansion Joints; the Fluid Sealing Association (FSA) Technical Handbook, Non-Metallic Expansion Joints and Flexible Connectors, sixth edition; and the requirements as specified herein.

2 MATERIALS

All of the materials shall be used in combination to meet the performance requirements of this Code Case. A Process Control Procedure in accordance with para. 5.7 shall identify how the materials are to be used and in what specific quantities.

All materials shall be verified by the purchaser/owner/user and/or by an independent third-party agency designated by them. All materials used in the manufacture of the expansion joint shall be supplied with documentation certifying that each lot used in the manufacture of the expansion joint meets those properties listed. In lieu of the requirements of PVHO-1–2012, subsection 1-6, the requirements in the following paragraphs shall apply. Materials shall conform to the following standards.

2.1 Commercial-Grade Fluoroelastomer

Compound: THD-VT75-10

Material: Fluoroelastomer compound

Temperature Limitations: Typical maximum usable temperature of 392°F (200°C)
Test Requirements:

Physical Properties per ASTM D412

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile at break, psi</td>
<td>700</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Physical Properties per ASTM D224

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durometer Shore “A”</td>
<td>65</td>
<td>75</td>
</tr>
</tbody>
</table>

Aged Physical Properties per ASTM D573

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile at break, psi</td>
<td>1,250</td>
<td>N/A</td>
</tr>
</tbody>
</table>

2.2 Neoprene N4614

Material: Neoprene N4614

Temperature Limitations: Typical maximum usable temperature of 212°F (100°C)

Test Requirements:

Physical Properties per ASTM D412

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate elongation, %</td>
<td>650</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Physical Properties per ASTM D224

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durometer Shore “A”</td>
<td>35</td>
<td>45</td>
</tr>
</tbody>
</table>

Shelf Life: Neoprene N4614 shall be used within 6 weeks after it is calendered

2.3 Neoprene N5157

Material: Neoprene N5157

Temperature Limitations: Typical maximum usable temperature of 212°F (100°C)

Test Requirements:

Physical Properties per ASTM D412

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate elongation, %</td>
<td>475</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Physical Properties per ASTM D224

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durometer Shore “A”</td>
<td>80 ± 5</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Shelf Life: Neoprene N5157 shall be used within 6 weeks after it is calendered

2.4 Neoprene N8017

Material: Neoprene N8017

Temperature Limitations: Typical maximum usable temperature of 212°F (100°C)

Test Requirements:

Physical Properties per ASTM D412

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile at break, psi</td>
<td>1,450</td>
<td>N/A</td>
</tr>
<tr>
<td>Ultimate elongation, %</td>
<td>100</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Physical Properties per ASTM D224

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durometer Shore “A”</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

Shelf Life: Neoprene N8017 shall be used within 6 weeks after it is calendered

2.5 Neoprene N4957

Material: Neoprene N4957

Temperature Limitations: Typical maximum usable temperature of 212°F (100°C)

Test Requirements:

Physical Properties per ASTM D412

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile at break, psi</td>
<td>1,200</td>
<td>N/A</td>
</tr>
<tr>
<td>Ultimate elongation, %</td>
<td>500</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Physical Properties per ASTM D224

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durometer Shore “A”</td>
<td>45</td>
<td>55</td>
</tr>
</tbody>
</table>

Aged Physical Properties per ASTM D573

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile at break, psi</td>
<td>960</td>
<td>N/A</td>
</tr>
<tr>
<td>Ultimate elongation, %</td>
<td>325</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Flame Resistance per MIL-E-15330D (SH)

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afterglow, sec</td>
<td>N/A</td>
<td>4</td>
</tr>
</tbody>
</table>

Shelf Life: Neoprene N4957 shall be used within 6 weeks after it is calendered

2.6 Polyester DD1500

Material: Polyester DD1500

Temperature Limitations: Typical maximum usable temperature of 350°F (176°C)

Test Requirements:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread count, epi, warp</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Tensile (denier): warp</td>
<td>44</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Shelf Life: Polyester DD1500 shall be used within 6 weeks after it is calendered

2.7 Polyester DD1200

Material: Polyester DD1200

Temperature Limitations: Typical maximum usable temperature of 400°F (204°C)
Test Requirements:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread count, epi, warp</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Tensile (denier): warp</td>
<td>500</td>
<td>N/A</td>
</tr>
</tbody>
</table>

2.8 Flange Tie-Down, Steel Cord JZ #5

Material: Steel tire cord

Temperature Limitations: Typical maximum usable temperature of 250°F (121°C)

Test Requirements:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread count, epi</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Adhesion, lb</td>
<td>15</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Physical Properties:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile at break, lb per</td>
<td>71</td>
<td>N/A</td>
</tr>
<tr>
<td>1-in. strip</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.9 Body Rings

Material Properties: ASME SA-695 Grade 40, minimum yield strength 60,000 psi (413.8 MPa)

Ring Sizes: $\frac{3}{8}$ in. (16 mm) thickness diameter body ring with $31\frac{3}{16}$ in. (808 mm) ring diameter, 2 each per expansion joint; $\frac{3}{4}$ in. (19 mm) thickness diameter body ring with $31\frac{3}{16}$ in. (811 mm) ring diameter, 2 each per expansion joint

3 DESIGN AND MANUFACTURE

3.1 Design

The expansion joint shall be designed in accordance with the requirements of ASTM F1123-87, Standard Specification for Non-Metallic Expansion Joints, and the FSA Technical Handbook, Non-Metallic Expansion Joints and Flexible Connectors, sixth edition. There shall be no window(s), penetrations, or piping associated with this design. The end flanges shall have internal reinforced flanges as an integral part of the shell, and the fluoroelastomer shall be sealed to the internal surface of the expansion joint.

3.2 Requirements

In lieu of the requirements of PVHO-1–2012, subsection 1-7, the following design and fabrication requirements shall apply:

(a) A detailed stress analysis of the metallic portion shall be performed by a Professional Engineer registered in one or more U.S. states or the provinces of Canada, or licensed by any other country that has equivalent licensing procedures, who is experienced in composite pressure vessel design and construction.

(b) A design analysis shall be performed that considers the effects of aging and all applicable environmental considerations (both operational and nonoperational), the effects of minimum and maximum temperatures, time under pressure, cyclic movements, and long-term storage between usages.

3.3 Design Certification

Conformance of the design of the expansion joint to the requirements of PVHO-1–2012 shall be established by one of the two following procedures:

(a) A Professional Engineer registered in one or more U.S. states or the provinces of Canada, or licensed by any other country that has equivalent licensing procedures, who is experienced in composite pressure vessel design, shall certify that the expansion joint was designed either by him or under his direct supervision, or that he has thoroughly reviewed a design prepared by others, and that to the best of his knowledge, the expansion joint complies with PVHO-1–2012 as modified by this Case.

(b) The design of the expansion joint shall be reviewed by an independent third-party agency competent in PVHO systems, and such organization shall provide a certificate verifying that the expansion joint complies with PVHO-1–2012 as modified by this Case.

3.4 Manufacture

The expansion joint shall be manufactured in accordance with a detailed process control plan. The process control plan shall clearly define the details of the manufacturing steps necessary to fabricate the expansion joint and shall document the fabrication process.


The steel ring portion of the expansion joint shall be welded in accordance with the weld procedures, procedure qualifications, and welder qualifications outlined in Section IX of the ASME Boiler and Pressure Vessel Code (the Code).

Nondestructive examination of the ring welds shall be 100% radiograph inspection, in accordance with Section V, Nondestructive Examination, of the ASME Code.

4 TESTING

All tests shall be witnessed by the purchaser/owner/user and/or by an independent third-party agency designated by them. In lieu of the requirements of PVHO-1–2012, paras. 1-7.7 and 1-7.8, the following requirements shall apply.
4.1 Prototype Testing

(a) A proof pressure test shall be performed on at least three completely assembled expansion joints of the same design, shape, and form. If a failure of the vessel occurs under proof pressure testing, the failure shall occur above a pressure equal to or greater than 6 times the rated pressure. Failure shall be defined as a rupture in the body or flange of the expansion joint causing a loss in pressure.

(b) A cyclic pressure/deformation test of at least one completely assembled expansion joint shall be conducted for a minimum of 4,500 cycles. This test shall qualify the expansion joint for 1,250 cycles; 50% of the test cycles shall be performed at the minimum temperature (0°F, −18°C), and 50% of the test cycles shall be performed at the maximum temperature (110°F, 43°C). The test shall include pressurization from zero to the rated pressure and back to zero. The cycle rate time shall be established by conducting cycle testing for 10 cycles at maximum and minimum test temperatures and pressures. The test shall confirm the time required for the expansion joint to stabilize at both the high- and low-pressure values of the cycle test. The pressure hold times shall be either 1.5 times the stabilization time or 1 min, whichever is greater. Failure is defined as a rupture in the body or flange of the expansion joint causing a loss in pressure.

(c) A movement fatigue test of at least one completely assembled expansion joint shall be conducted for a minimum of 50,000 movement cycles. The test shall include a movement fatigue test at the MAWP, and shall include testing at both the maximum and minimum temperatures during the testing; 80% of the movement cycles shall be tested at normal room temperature (65°F to 75°F, 18°C to 23°C), 10% of the movement cycles shall be tested at the minimum temperature (0°F, −18°C), and 10% of the movement cycles shall be tested at the maximum temperature (110°F, 43°C). The fatigue test shall be conducted with the maximum expansion joint movements in a concurrent fashion. Failure is defined as a rupture in the body or flange of the expansion joint, causing a loss in pressure. Movement cycles shall be as defined in the FSA Technical Handbook of Non-Metallic Expansion Joints, sixth edition, Chapter III, Section J.

(d) A creep test of one completely assembled expansion joint shall be conducted at maximum operational temperature in accordance with subsection 1-10 of ASME PVHO-1–2012, with a 12-hr storage period. Failure shall be defined as a loss in pressure.

(e) An off-gas test of one completely assembled expansion joint shall be conducted at maximum operational temperature in accordance with subsection 1-10 of ASME PVHO-1–2012, with a 12-hr storage period. The dilution effect of the entire PVHO assembly shall be considered. The dilution volume of the PVHO assembly consists of the expansion joint and any additional volumes that cannot be isolated. An independent third-party agency shall be employed to ensure that the test results are less than the established limits.

4.2 Production Testing

(a) Every expansion joint shall be subjected to a hydrostatic test at a pressure of 1.5 times the rated pressure and held for a period of 1 hr without leakage.

(b) Every expansion joint shall be inspected for damage to the sealing areas and shall be subjected to a dimensional check. Any permanent change shall be grounds for rejection.

(c) Every expansion joint shall be subjected to an off-gas test as stated in para. 4.1(e).

5 QUALITY ASSURANCE PROGRAM

5.1 General

A documented Quality Assurance Plan (QAP) shall be developed for the design and manufacture of the expansion joint. The QAP shall be reviewed and approved by the purchaser. This section describes the requirements for the content of the QAP. In addition to the QAP, quality assurance shall meet the requirements of Section 3 of ASME PVHO-1–2012, Quality Assurance for PVHO Manufacturers.

5.2 Organization

The QAP shall describe the organizational structure, with responsibilities, authorities, and lines of communication clearly delineated. Persons shown in the QAP to be responsible for verifying the expansion joint quality shall have the authority and organizational freedom to:

(a) identify problems affecting quality
(b) initiate, recommend, or provide solutions to quality problems, through designated channels
(c) verify implementation of solution
(d) control further processing, delivery, or assembly of a nonconforming item, deficiency, or unsatisfactory condition until proper corrective action has been taken

5.3 Design Control

A methodical process shall be used to develop and control the expansion joint design, which includes:

(a) a process for design inputs and review
(b) a requirement for formal design review
(c) a process for product configuration management and change control
5.4 Document Control
The QAP shall describe the manufacturer's measures for ensuring that design output documents are correctly translated into manufacturing specifications, drawings, procedures, and shop/lab instructions. Considerations shall be made for reviews and approvals, including those of the purchaser.

The manufacturer shall include the procedure for ensuring distribution of appropriate documents to the working areas in a timely fashion and the process for ensuring nonuse of obsolete documents.

5.5 Procurement Control
The QAP shall include the controls necessary to ensure that applicable requirements are included in procurement documents. The manufacturer shall describe the basis for source evaluation and selection and the method of objective evaluation of the quality of furnished materials, items, and services upon receipt.

5.6 Material Control
The QAP shall describe the identification applied to material and items upon receipt and shall show that this identification shall remain until the material or item is incorporated into the expansion joint. Identification shall be such that the manufacturer's personnel can easily determine quality status, material or item type, specification, lot or part as appropriate, and job number.

All material properties of production units shall meet or exceed the actual material properties of the prototype test articles.

5.7 Process Control
The QAP shall include a Process Control Procedure that will record the identification of materials and items incorporated into the expansion joint and each chronological step in its manufacture, including inspection and test steps. The Process Control Procedure shall contain periodic operator and inspector signature points so that product status can be readily determined.

The manufacturer shall identify critical manufacturing activities and ensure that they are accomplished by appropriately trained and qualified personnel. Inspection points shall follow the activities in the process control plan.

5.8 Inspection Control
The QAP shall include the measures used by the manufacturer to ensure that inspections are reliable. These measures shall include

(a) proper qualification of inspection personnel
(b) calibration of inspection instrumentation
(c) incorporation of acceptance criteria into inspection points in the Process Control Procedure
(d) assurance that inspections are performed by persons other than those performing or supervising work
(e) documentation of all inspections

5.9 Test Control
The QAP shall describe the measures used to ensure that tests (including lab tests) are performed consistently and reliably. The following requirements shall be met:

(a) Tests shall be performed in accordance with written instructions stipulating acceptance criteria.
(b) Test results shall be documented.
(c) Examination, measurement, and testing equipment used for activities affecting quality shall be controlled, calibrated, and adjusted at specified periods to maintain required accuracy.
(d) Tests shall be performed by trained and qualified personnel.
(e) Tests shall be verified by persons other than those performing or supervising the test.

5.10 Control of Measuring Test and Inspection Equipment
The QAP shall describe the equipment used in inspections and tests and the measures used to ensure appropriate accuracy. Appropriate equipment shall be calibrated, and the calibration shall be traceable to standards where they exist. Where such standards do not exist, the equipment manufacturer's recommendations shall be followed.

5.11 Control of Nonconforming Items/Materials
The QAP shall describe the measures used by the manufacturer to control materials or items that are found to be discrepant to prevent their inadvertent use. Nonconforming materials/items shall be identified. The discrepant condition(s) shall be documented. The process for determining, documenting, and verifying corrective action shall be described, including the involvement of the purchaser.

5.12 Quality Assurance Records
The QAP shall provide for quality assurance records as follows:

(a) Records shall be specified, compiled, and maintained to furnish documentary evidence that services, materials, and completed expansion joints meet this and applicable referenced standards.
(b) Records shall be legible, identifiable, and retrievable.
(c) Records shall be protected against damage, deterioration, or loss.
(d) Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.
(e) Records required for traceability shall be retained for a minimum of 12 yr.

5.13 Standard Repair Planning
The QAP shall describe methods for repairing discrepancies that are expected to occur during the expansion joint manufacture.
5.14 Quality Assurance Overview by an Independent Third Party

An independent third-party agency shall be employed to ensure that all expansion joints intended to be classified under this Case are designed and manufactured to the requirements of PVHO-1–2012 and this Case. This includes, but is not restricted to, the following:

(a) The expansion joint is designed in accordance with PVHO-1–2012 and this Case.

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

(c) The materials used in construction of the expansion joint comply with approved procedures by qualified operators, as required by PVHO-1–2012 and this Case.

(d) All manufacturing operations are conducted in accordance with approved procedures by qualified operators, as required in PVHO-1–2012 and this Case.

(e) All defects are acceptably repaired.

(f) All prototype and production testing has been performed and witnessed as required by PVHO-1–2012 and this Case.

(g) The expansion joint is marked in accordance with PVHO-1–2012 and this Case.

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

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

6 MARKING

(a) The PVHO shall be marked with a neoprene nameplate containing the data stated in subsection 1-9 of PVHO-1–2012. The nameplate shall be permanently vulcanized into the expansion joint at the completion of the manufacturing process.

(b) PVHO-1 Case 11 Form, Manufacturer’s Data Report for Pressure Vessels for Human Occupancy, shall be completed to certify that each expansion joint meets the requirements of PVHO-1–2012 and this Case.
1. Manufactured and certified by

2. Manufactured for

3. Vessel identification (manufacturer's serial no.) (year built)

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

5. Manufactured for a maximum allowable working pressure of 80 psi, a maximum working temperature of °F, and a hydrostatic test pressure of psi (internal).

6. Design analysis conducted by

7. Manufacturing Process Control Plan (manufacturing no.) (date) (completed by)

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**THIRD-PARTY CERTIFICATION**

(User’s Design Specification on file at)

(Manufacturer’s Design Report on file at)

(Prototype test program attested by)

(Quality Assurance Plan reviewed by)

(Fabrication documentation reviewed by)

(Production testing witnessed by)

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**CERTIFICATION OF COMPLIANCE**

We certify that the statements made in this report are correct and that all details of the design, material, construction, and workmanship and marking of this vessel conform to the ASME Safety Standard for Pressure Vessels for Human Occupancy (PVHO-1) and PVHO Case 11.

Date ______________________ Signed ______________________

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