ARTICLE KF-12
ADDITIONAL FABRICATION REQUIREMENTS FOR COMPOSITE REINFORCED PRESSURE VESSELS (CRPV)

KF-1200 SCOPE

The following Article provides additional fabrication requirements for the Composite Reinforced Pressure Vessels (CRPV) fabricated in accordance with this Division.

KF-1210 WELDING

The surfaces of the external welds and all other welds and surfaces shall be designed, fabricated, and finished in accordance with the requirements of this Division before laminate application.

KF-1211 FINAL WELD FINISH FOR CRPV

Weld surfaces may be left unground inside the CRPV provided a fatigue analysis, including experimental verification, is undertaken for the specific Welding Procedure Specification and Procedure Qualification Record, see KF-1210. The outer surface of the weld shall be finished in accordance with KF-204. Experimental verification shall be accomplished by the pressure cycle tests of CRPV required to qualify and requalify the Laminate Procedure Specification, see Section X, Mandatory Appendix 10, 10-500.2 and 10-600.8, Laminate Procedure Qualification. For the unfinished weld surfaces on the internal surface of the CRPV, the maximum permitted weld reinforcement shall be in accordance with Table KF-1211.

KF-1212 LAMINATE PROCEDURE SPECIFICATION QUALIFICATION

(a) General Requirements. For vessels to be installed at a fixed location, a hydrostatic test to a pressure at least 1.25 times the design pressure shall be performed on each CRPV Prototype Vessel. For vessels to be used in transport service, a hydrostatic test to a pressure at least 1.5 times the service or working pressure, whichever is greater, shall be performed on each CRPV Prototype Vessel. This test may be combined with any hydrostatic pressurization procedure used to provide a prestress in the individual layers, provided the minimum test pressure is reached. This hydrostatic test shall be done after the tests and examinations in Section X, Mandatory Appendix 10, 10-500.3(a) (1), 10-600.3(a) (1), 10-600.3(b), and 10-600.9 but before tests and examinations in (b)(1) and Section X, Mandatory Appendix 10, 10-600.13 through 10-600.16.

(b) Specific Requirements

(1) Volumetric Expansion Tests. Each CRPV Prototype Vessel shall be subjected to a volumetric expansion test using a test fluid that complies with the requirements of KT-320.

(-a) The volume of liquid used to fill the CRPV at atmospheric pressure and temperature shall be compared with that required to fill it at the design pressure and at the same temperature. Care shall be taken to eliminate air pockets to ensure accuracy. The volume of liquid used in each instance shall be determined by any appropriate means, such as a weigh tank that has been calibrated to an accuracy of ±0.2%. The percent expansion shall be subsequently used in the production volumetric expansion test.

(-b) Alternatively, the volumetric expansion may be determined by measuring the overall length of the CRPV and its circumference at 5 ft (1.5 m) intervals along its length, with a minimum of three such determinations being made; all measurements shall be made with instruments that have been calibrated to an accuracy of ±0.05%. These measurements shall be taken with the CRPV filled with liquid at atmospheric pressure and at design pressure, both at the same temperature. The percent volumetric expansion calculated from these measurements shall be subsequently used in the production volumetric expansion test.

(-c) Acceptance criteria shall be in accordance with KT-510(b).

(2) Laminate Acoustic Emission Examination. An acoustic emission examination of the laminate shall be conducted in accordance with Section X, Mandatory Appendix 10, 10-500.3(a)(6). The acoustic emission examination report shall be included in the Qualification Test Report and referenced on Form CRPV-2A.

Table KF-1211
Permitted Weld Reinforcement

<table>
<thead>
<tr>
<th>Weld Thickness, in. (mm)</th>
<th>Max. Reinforcement, in. (mm)</th>
</tr>
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<tbody>
<tr>
<td>1/4 to 1/2 (6.0 to 12.7), incl.</td>
<td>1/8 (3.2)</td>
</tr>
<tr>
<td>Over 1/2 (12.7)</td>
<td>5/32 (4.0)</td>
</tr>
</tbody>
</table>

10-608 and 10-609
10-613 through 10-616.

10-503
10-503(a)(7)

10-503
19-2818
(3) Cyclic Pressure Qualification Test. At least one CRPV Prototype Vessel shall be subjected to a cyclic pressure test in accordance with KD-1260, followed by a hydrostatic qualification pressure test, as follows:

-(a) The vessel to be tested shall have the same diameter and wall thickness as the production vessels, but the length between girth welds may be reduced to no less than \(10\sqrt{Rt}\), where \(R\) is the overall outside radius of the composite vessel and \(t\) is the overall wall thickness.

-(b) The test fluid shall comply with the requirements of KT-320.

-(c) Portions of the cyclic pressure test may be done at different temperatures and pressure ranges. When this is done, the number of test cycles shall be calculated as follows:

**Step 1.** Determine the test temperature, test pressure range, and number of test cycles for the first portion of the test (test cycle 1). The test pressure range shall not be less than the operating pressure range as defined in the User’s Design Specification. The test temperature shall not be warmer than the minimum design metal temperature specified in the User’s Design Specification. The number of test cycles shall not be less than the number calculated using the requirements of KD-1260 based on 10% of the total number of cycles. Designate the number of test cycles \(n_{t1}\).

**Step 2.** Calculate the number of test cycles that would be required if the entire test was done at the test temperature and test pressure range for the first portion of the test using the requirements of KD-1260. Designate the required number of cycles \(N_{t1}\).

**Step 3.** Calculate the fraction of the total cyclic test requirement, \(T_{t1}\), that will be achieved in the first portion of the test as \(T_{t1} = n_{t1}/N_{t1}\).

**Step 4.** Determine the test temperature, test pressure range, and number of test cycles for the second portion of the test (test cycle 2). The test pressure range shall not be less than the operating pressure range as defined in the User’s Design Specification. The test temperature shall not be colder than the design metal temperature specified in the User’s Design Specification. The number of test cycles shall not be less than the number calculated using the requirements of KD-1260 based on the number of operating pressure cycles that will occur at a metal or composite temperature colder than 30°F (0°C) specified in the User’s Design Specification. If no cycles colder than 30°F (0°C) are specified in the User’s Design Specification because the vessel is operating in ambient conditions, the number of test cycles shall be calculated using the requirements of KD-1260 based on 10% of the total number of cycles. Designate the number of test cycles \(n_{t2}\).

**Step 5.** Calculate the fraction of the total cyclic test requirement, \(T_{t2}\), that will be achieved in the second portion of the test as \(T_{t2} = n_{t2}/N_{t2}\).

**Step 6.** Repeat Steps 1 through 3 for each additional portion of the test (test cycles 1 through \(n\)).

**Step 7.** Add the fractions of the total cyclic test requirement for each portion of the test (each test cycle), \(T_R = T_{t1} + T_{t2} + \ldots + T_{tn}\). Adjust the number of cycles to be achieved in each portion of the test until \(T_R\) equals or exceeds 1.0.

(4) Hydrostatic Pressure Qualification Test. The Qualification Test Pressure is a pressure designated by the Manufacturer that shall be at least two times the design pressure for vessels to be installed at a fixed location. For vessels to be used in transport service, the Qualification Test Pressure shall be at least two times the design pressure or 2.5 times the service or working pressure, whichever is greater. This pressure shall be reported in the Qualification Test Report and recorded on Form CRPV-2A. At least one CRPV Prototype Vessel shall be subjected to hydrostatic pressure qualification tests after the cyclic pressure qualification tests as follows:

-(a) The test fluid shall be applied at a uniform rate to the Qualification Test Pressure, so that it is reached in not less than 60 sec and then it shall be held at this pressure for at least 60 sec. No leakage is permitted.

-(b) After the Qualification Test Pressure is held for a minimum of 60 sec the pressure shall be increased at a rate that is not greater than specified in (-a) until burst. The mode(s) of failure shall be characterized and the burst pressure and mode(s) of failure shall be reported in the Qualification Test Report and recorded on Form CRPV-2A.
ARTICLE KE-5
ADDITIONAL EXAMINATION REQUIREMENTS FOR COMPOSITE REINFORCED PRESSURE VESSELS (CRPV)

KE-500 SCOPE

The following Article provides examination requirements for the Composite Reinforced Pressure Vessels (CRPV) manufactured in accordance with this Division.

KE-501 QUALIFICATION OF NONDESTRUCTIVE EXAMINATION PERSONNEL FOR CRPV

(a) The Manufacturer shall certify that each examiner performing acoustic emission testing according to the Division has attended a dedicated training course on the subject, passed a written examination, and has the recommended experience level. The training course shall be appropriate for specific NDT Level II qualification according to Section V, Article 1, T-120(e) or T-120(f).

(b) The manufacturer shall certify that each examiner performing visual tests according to the Division has been qualified to the requirements of Section V, Article 9.

KE-502 WELD EXAMINATION

(a) For Categories A and B welds, the internal surface may not be ground nor examined with magnetic particle or liquid penetrant. The performance of the external ultrasonic examination method of the welds shall be demonstrated using a performance demonstration test block that has been prepared using the welding procedure to be used in production and having similar weld geometry and containing simulated flaws equal to or smaller in size than the initial flaw size in the fracture mechanics calculations. The examination method shall meet the requirements of KE-333.

(b) The external surfaces of all welds shall be examined in accordance with the requirements of this Division before laminate application.

KE-503 ADDITIONAL EXAMINATION REQUIREMENTS FOR CRPV

(a) The Manufacturer completing a CRPV or vessel part shall be responsible for conducting the examinations required by this paragraph.

(b) Each CRPV shall be subjected to the examinations required by this paragraph and shall conform to the specified requirements, with results recorded in Production Test Reports. Examinations detailed in (1) through (4) shall be carried out before the hydrostatic test and the examination in Article KT-5 shall be carried out after the hydrostatic test. The CRPV Production Test Report shall become part of the Manufacturer’s Construction Records.

1. Design Dimensions Examination. CRPV shall be examined for conformance with dimensions and tolerances shown on the design drawings.

2. Repair of Imperfections and Replacement of the Laminate During Construction. Requirements for the repair of imperfections, visual inspection of repaired areas, and replacement of the laminate during construction are found in Section X, Mandatory Appendix 10, 10-400.6, 10-400.7, and 10-500.3(a)(3).

3. Acoustic Emission Examination. An acoustic emission examination in accordance with the requirements of Section V, Article 11 shall be performed on each CRPV in accordance with KF-1212(b)(2). The acoustic emission examination shall not be conducted until all other tests and examinations required by this Division have been conducted. All repairs that are required as a result of the other tests and examinations shall be completed prior to the acoustic emission examination.

4. Metallic Surface Examination After Hydrostatic Test. The requirements of KE-400 do not apply to CRPV as examination of internal surfaces and external surfaces under the laminate are not practical. It shall be demonstrated by a fracture mechanics approach that the minimum detectable flaw size will not grow during the hydrostatic test to a size not accounted for in the analysis, see KF-1210 and KE-502.
ARTICLE KT-5
ADDITIONAL TESTING REQUIREMENTS FOR COMPOSITE REINFORCED PRESSURE VESSELS (CRPV)

KT-500  RESPONSIBILITY

The Manufacturer completing a CRPV or vessel part shall be responsible for conducting the tests required by this Division.

KT-510  TESTING REQUIREMENTS

Each CRPV shall be subjected to the tests required by this paragraph and shall conform to the specified requirements, with results recorded on Production Test Reports.

(a) Hydrostatic Test. For vessels to be installed at a fixed location, a hydrostatic test to a pressure at least 1.25 times the design pressure shall be performed on each CRPV. For vessels to be used in transport service, a hydrostatic test to a pressure at least 1.25 times the design pressure or 1.5 times the service or working pressure, whichever is greater, shall be performed on each CRPV, see KT-310. This test may be combined with any hydrostatic pressurization procedure used to provide a prestress in the individual layers. The hydrostatic test shall be staged with examinations in KE-503(b), before the volumetric expansion test, KF-1212(b)(1). The CRPV Production Test Report shall become part of the Manufacturer’s Construction Records.

(b) Volumetric Expansion Test. A volumetric expansion test shall be performed on every CRPV in accordance with the requirements of the Laminate Procedure Specification Qualification, see KF-1212(b)(1). The results of these tests shall not differ by more than 5% from the values recorded in the original Qualification Test Report and Laminate Procedure Specification after correcting for any variance in material properties.