ARTICLE KG-5
ADDITIONAL GENERAL REQUIREMENTS FOR COMPOSITE REINFORCED PRESSURE VESSELS (CRPV)

KG-500 GENERAL REQUIREMENTS

The following Article provides additional general requirements for the manufacture of Composite Reinforced Pressure Vessels (CRPV).

KG-510 SCOPE

This construction method uses a laminate of continuous unidirectional filaments of a specified glass or carbon fiber with a specified resin that is circumferentially wound in a systematic manner under controlled tension over a cylindrical metallic layer and cured in place. Openings are not permitted in the laminate. Metallic ends and nozzles complete the construction; see Section X, Mandatory Appendix 10, Figures 10-200-2-1, 10-200-2-2, and 10-200-3.3.

KG-511 METALLIC LAYER

The outside diameter of the metallic layer in the reinforced area shall not exceed 60 in. (1.52 m). The thickness of the metallic layer shall not be less than 0.25 in. (6 mm).

KG-512 SERVICE LIFE

Service life for CRPV constructed under the rules of this Division shall be limited to twenty years from the date of manufacture as noted on Form CRPV-1A.

KG-513 APPLICATION SPECIFIC TESTS AND OTHER REQUIREMENTS

This Division does not include requirements or rules for tests that may be appropriate for certain applications (e.g., fire tests, drop tests, projectile impact tests). For some applications, it may be necessary to consider additional conditions such as exposure to fire and projectile impact damage.

KG-514 UPPER LIMIT OF DESIGN PRESSURE

The internal design pressure for CRPV shall not be greater than 15,000 psi (103 MPa).

KG-515 SERVICE PRESSURE AND WORKING PRESSURE

In some standards and regulations used in ambient temperature compressed gas transport service, the term "service pressure" is used to indicate the pressure in the vessel at a temperature of 68°F (20°C). In other standards and regulations, the term "working pressure" is used with the same definition. In these standards and regulations it is generally allowable for the service or working pressure to be exceeded as the gas is heated beyond 68°F (20°C). For support service conditions and the working pressure shall be the maximum expected pressure at a temperature of 68°F (20°C). The service pressure or the working pressure or both shall be defined in the User's Design Specification. The working pressure, service pressure, or the expected pressure due to heating during filling or atmospheric heating shall not exceed the design pressure of the vessel at the design temperature.

KG-516 PROTECTIVE LAYER

Additional requirements regarding specification of a protective layer for the CRPV in the User's Design Specification can be found in Section X, Mandatory Appendix 10, 10-200-3.

KG-517 REQUIREMENTS FOR CYCLIC PRESSURE QUALIFICATION TEST

In addition to the total number of operating cycles during the life of the CRPV, the User's Design Specification shall state if the temperature of the intended service will be controlled. If the intent is to control the temperature of service, the number of cycles colder than 30°F (0°C), the number of cycles between 30°F (0°C) and 110°F (45°C), and the number of cycles warmer than 110°F (45°C) shall be noted. If the service will be in ambient conditions with no intent to control the temperature, there is no requirement to report the number of cycles in the aforementioned temperature ranges.

KG-518 LAMINATE TENSILE STRENGTH AND ELASTIC MODULUS

The User's Design Specification shall state the required minimum tensile strength and the nominal elastic modulus for the laminate in the maximum property direction (parallel to the fiber direction).
KG-520 SUPPLEMENTAL GENERAL REQUIREMENTS FOR CRPV

KG-521 REQUIREMENTS FOR CRPV USED IN TRANSPORT SERVICE

(a) CRPV used in transport service shall conform to the regulatory requirements specific to the application in addition to this Division. Government regulatory agencies and other jurisdictions issue rules that may require compliance with additional Codes and Standards.

(b) CRPV may be installed in ships, barges, container frames, rail cars, over-the-road trucks, and other craft, provided prior written agreement with the local jurisdictional authority is established covering operation and maintenance control for a specific service and where this operation and maintenance control is retained during the life of the CRPV by the User who prepares, or causes to be prepared, the User’s Design Specification. See KG-310.

(c) CRPVs to be used in transport service as described above may be constructed and stamped within the scope of this Division as specified with the following additional provisions:

(1) The User’s Design Specification shall include the requirements that provide for operation and maintenance control for the CRPV.

(2) For vessels to be used in transport service, the User’s Design Specification shall specify the service pressure or the working pressure or both for the vessel (see KG-515).

(3) The Manufacturer’s Data Report, as described in KS-300, shall include under “Remarks” one of the following statements:

(a) “Constructed for transport service for use in (name of local jurisdictional authority in this space).”

(b) “Constructed for service according to the requirements of (regulatory agency or additional code(s) in this space).”

(4) The loads on the CRPV imposed by the conditions of transport, including accident loads, relocation of the CRPV between sites, and cyclic loading and discharge shall be considered as part of KD-110.

(5) The CRPV shall not be used as structural support members in the transport vehicle or vessel structure.

KG-522 SUPPLEMENTARY MANUFACTURER’S RESPONSIBILITIES

Additional supplementary Manufacturer’s requirements are found in Section X, Mandatory Appendix 10, 10-200.4.
ARTICLE KD-13
ADDITIONAL DESIGN REQUIREMENTS FOR COMPOSITE REINFORCED PRESSURE VESSELS (CRPV)

KD-1300 SCOPE

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

KD-1310 GENERAL

(a) Rules for calculating the static and dynamic strength for CRPV made of a metallic layer with a circumferentially wrapped fiber reinforced plastic layer are given in subsequent paragraphs. The loads resulting from transportation, the regulatory requirements and all vibratory, dynamic, and gravity loads shall be included in the CRPV design.

(b) The circumferential stresses generated in both the metallic layer and the laminate are used to resist circumferential loads due to internal pressure. Longitudinal stresses in the metallic layer alone shall be used to resist axial loads due to internal pressure, thermal expansion, and all other longitudinal loads. The longitudinal strength, perpendicular to the fiber winding directions, of the laminate shall be used in the design calculations other than to ensure sufficient strength exists for the transfer of applicable external loads to the metallic layer.

(c) Plastic analysis in accordance with KD-230 and the additional requirements of this Division shall be used to analyze the CRPV. The composite (over wrap) layer shall be assumed to be linear elastic with nominal modulus and minimum strength properties as specified in the Manufacturer’s Laminate Procedure Specification (see Section X, Mandatory Appendix 10, 10-300.9).

(d) The design cycle calculations shall be done in accordance with the fracture mechanics principles of Article KD-4. In the analysis of welded joints, the favorable combination of misalignment, weld geometry and weld geometry shall be considered.

(e) In determining the stress distribution in the two layers, the appropriate elastic modulus for each layer, at the maximum operating temperature, shall be used. Radial strain compatibility between the layers is achieved when the laminate is applied wet and intimate contact is established between the layers. When intimate contact between the two layers is not achieved or other strain incompatibilities exist, the effect on the stress distribution shall be considered. Changes in the stress distribution in the two layers as a result of temperature changes and differences in the coefficients of thermal expansion shall be considered.

(f) Residual stresses, in the form of a precompression in the metallic layer and a pretension in the laminate layer, are generated during the hydrostatic test. These stresses shall be taken into account in determining the residual and operating stress distributions.

(g) Any relaxation in the residual stress distribution due to long-term creep at operating temperature, or short-term creep at elevated temperatures, shall be considered and the limits shown in (h) shall be adjusted accordingly.

(h) For vessels to be installed at a fixed location, the maximum circumferential stress at any location in the laminate shall not exceed 36% of the tensile strength of the glass fiber laminate and 40% of the carbon fiber laminate at the operating pressure as defined in the Manufacturer’s Laminate Procedure Specification (see Section X, Mandatory Appendix 10, 10-300.9). For vessels to be used in transport service, the maximum circumferential stress at any location in the laminate shall not exceed 36% of the tensile strength of the glass fiber laminate and 40% of the carbon fiber laminate pressure as defined in the Manufacturer’s Laminate Procedure Specification (see Section X, Mandatory Appendix 10, 10-300.9). For both fixed and transport service, the maximum circumferential stress at any location in the laminate shall not exceed 67% of the tensile strength of the laminate under the hydrostatic test load. The Manufacturer’s Design Document shall document the basis for selection of the specified pressure range for the hydrostatic test.

(i) The calculated burst pressure of the liner alone shall be equal to or greater than the design pressure of the vessel. The calculation shall be done using the minimum specified values of yield and tensile strength. Strain hardening shall be considered.

(j) The calculation of stresses shall consider the least favorable effects of geometric irregularities (e.g., out-of-roundness), weld peaking, reinforcement, and offsets as well as mismatches of Categories A and B welds. See KF-1211.
KD-1311 LAMINATE PROCEDURE SPECIFICATION

The Laminate Procedure Specification shall be included in the Manufacturer's Design Report. See Section X, Mandatory Appendix 10, 10-402.

KD-1312 MAXIMUM DESIGN TEMPERATURE

The Maximum Design Temperature of the laminate shall be the same as or higher than the Maximum Design Temperature of the CRPV as specified in the User's Design Specification. The Maximum Design Temperature of the CRPV shall not exceed 150°F (66°C). The Maximum Design Temperature of the laminate is defined as 35°F (19°C) below the glass transition temperature, Tg, or the maximum use temperature of the resin, whichever is lower, and shall be documented in the Laminate Procedure Specification. The maximum use temperature of the resin shall exceed the test temperatures as specified in Section X, Mandatory Appendix 10, 10-300.

KD-1313 MINIMUM DESIGN TEMPERATURE

The Minimum Design Temperature to which a CRPV may be constructed shall not be colder than −65°F (−54°C).

KD-1314 CRPV SUPPORTS

CRPV supports shall be designed to function without damaging the CRPV considering all loads resulting from transportation and operation. Supports shall be welded on the heads only or use laminate stops. Laminate stops shall consist of material built up or applied on the outer surface of the laminate that provides a load-bearing surface, perpendicular to the CRPV surface that will transfer external loads to the CRPV. If laminate stops are used, the shear strength of the laminate shall be adequate to resist the longitudinal static and dynamic loads.

KD-1315 LONGITUDINAL REINFORCEMENT

For the service conditions specified by the User's Design Specification, the designer shall consider the need for longitudinal reinforcement of the laminate to prevent laminate cracking under operating or test conditions.