PART KM
MATERIAL REQUIREMENTS

ARTICLE KM-1
GENERAL REQUIREMENTS

KM-100 MATERIALS PERMITTED

(a) Materials that are to be used under the rules of this Division, except for integral cladding, welding filler metals, weld metal overlay, and protective liner materials (see KD-103), shall conform to a material specification given in Section II, and shall be listed in Tables KM-400-1, KM-400-1M, KM-400-2, KM-400-2M, KM-400-3, KM-400-3M, KM-400-4, or KM-400-4M. The term *material specification* used in this Division shall be the referenced specification in Section II together with the supplemental requirements listed in the User’s Design Specification (see KG-311.7).

(b) Materials that are outside the limits of size and/or thickness stipulated in the title or scope clause of the material specifications given in Section II and permitted by Part KM may be used if the materials are in compliance with the other requirements of the material specification and no size or thickness limitation is specified in this Division. In those specifications in which chemical composition or mechanical properties vary with size or thickness, materials outside the range shall be required to conform to the composition and mechanical properties shown for the nearest specified range.

(c) Except as provided in (1) or (2) below, materials other than those allowed by this Division shall not be used for construction of the pressure-retaining component, including bolting and prestressed inner layer.

(1) Data on other materials may be submitted to and approved by the ASME Boiler and Pressure Vessel Committee in accordance with Section II, Part D, Mandatory Appendix 5.

(2) A vessel or part Manufacturer may certify materials identified with a specification not permitted by this Division, provided the following requirements are satisfied:

(-a) All requirements (including, but not limited to, melting method, melting practice, deoxidation, quality, and heat treatment) of a specification permitted by this Division to which the material is to be certified, including the requirements of this Division, have been demonstrated to have been met.

(-b) A certification that the material was manufactured and tested in accordance with the requirements of the specification to which the material is certified (a Certificate of Compliance), excluding the specific marking requirements, has been furnished to the vessel or part Manufacturer, together with copies of all documents and test reports pertinent to the demonstration of conformance to the requirements of the permitted specification.

(d) The bolt product form, as specified in Tables KM-400-1, KM-400-1M, KM-400-2, KM-400-2M, KM-400-3, or KM-400-3M shall not be used for applications other than bolting (see KM-300).

(e) Pressure vessel closure components, such as threaded bodies and main nuts, that have threaded sections for the purpose of engaging seals and/or retaining end loads may be manufactured from forging or bar product forms listed in Tables KM-400-1, KM-400-1M, KM-400-2, KM-400-2M, KM-400-3, or KM-400-3M, provided that all other qualification and design requirements of this Division are met.

(f) The User shall confirm the coupling of dissimilar metals will have no harmful effect on the corrosion rate or life of the vessel for the service intended (see KG-311.7).

KM-101 CERTIFICATION BY MATERIALS MANUFACTURER

The Materials Manufacturer shall certify that all requirements of the applicable materials specifications in Section II, all special requirements of Part KM which are to be fulfilled by the Materials Manufacturer, and all supplementary material requirements specified by the User’s Design Specification (KG-311) have been complied with. The certification shall consist of a Materials Manufacturer’s material test report showing numerical results of all required tests, and shall certify that all required examinations and repairs have been performed on the laminate materials used for the wrapping of CRPV vessels (see KM-5), and inner layers of covers used on impulsively loaded vessels (see KM-7).
(a) Components or material weighing 1,000 lb (450 kg) or less at the time of heat treatment require at least one tension test and one set of three Charpy V-notch impact test specimens per heat, per heat treatment load.

(b) Components or material weighing between 1,000 lb and 5,000 lb (450 kg and 2 300 kg) at the time of heat treatment require at least one tension test and one set of three Charpy V-notch impact test specimens per component, plate, forging, or test forging [see (d)]. If the component or forging length, excluding test prolongation(s), exceeds 80 in. (2 000 mm), then one set of tests shall be taken at each end and they shall be spaced 180 deg apart. For plate with a length exceeding 80 in. (2 000 mm), one set of tests shall be taken at each end and they shall be removed from diagonally opposite corners.

(c) Components or material weighing over 5,000 lb (2 300 kg) at the time of heat treatment require at least two tension tests and two sets of three Charpy V-notch impact test specimens per component, plate, forging, or test forging [see (d)]. One set of tests shall be taken at each end and they shall be spaced 180 deg apart for a component, forging, or test forging [see (d)], and at diagonally opposite corners for plate. If the component or forging length, excluding test prolongation(s), exceeds 80 in. (2 000 mm), then two sets of tests shall be taken at each end and they shall be spaced 180 deg apart. For plate with a length exceeding 80 in. (2 000 mm), two sets of tests shall be taken at each end and they shall be removed from both corners.

(d) With prior approval of the Manufacturer, test specimens for forgings may be taken from a separate test forging that represents one or more production forgings under the following conditions:

(1) The separate test forging shall be of the same heat of material and shall be subjected to substantially the same reduction and working as the production forgings that it represents.

(2) The separate test forging shall be heat treated in a manner that produces a cooling rate similar to and no faster than the main body of the production forgings that it represents. The holding time at temperature and the heat-treating temperature for the separate forging shall be the same as for the production forgings that it represents.

(3) The separate test forging shall be of the same nominal thickness as the production forgings that it represents.

(4) Test specimen locations shall be as defined in KM-211.

(5) The separate test forging may be used to represent forgings of several thicknesses in lieu of (3) provided the following additional requirements are met:

(a) the separate test forging shall have a weight equal to or greater than the weight of the heaviest forging in the batch to be represented

(b) the separate test forging shall have a thickness equal to or greater than the thickness of the thickest forging in the batch to be represented

**KM-232 TENSILE TEST PROCEDURE**

Tensile testing of all materials except aluminum alloys shall be carried out in accordance with SA-370. Aluminum alloys shall be tested in accordance with ASTM B557.

**KM-233 IMPACT TEST PROCEDURE**

Charpy V-notch impact testing shall be carried out in accordance with SA-370 using the standard 10 mm × 10 mm specimens, except as permitted in KM-212.

**KM-234 CHARPY V-NOTCH IMPACT TEST REQUIREMENTS**

**KM-234.1 Impact Test Temperature.**

(a) The impact test temperature shall not exceed the lower of 70°F (21°C) or the minimum design metal temperature specified in the User’s Design Specification [see KG-311.4(d)] minus the appropriate temperature reduction value specified in Table KM-212, if applicable.

(b) The minimum design metal temperature for pressure-retaining component materials exempted from impact testing by KM-212.1(c), KM-212.2, and KM-212.3(c) shall not be lower than −325°F (−200°C) for fully austenitic stainless steels, or −50°F (−45°C) for other materials.

**KM-234.2 Absorbed Energy Acceptance Criteria.**

(a) Pressure-retaining component materials other than bolting shall meet the minimum Charpy V-notch impact value requirements specified in Table KM-234.2(a) unless exempted by KD-810(f) and KD-931.

(b) Bolting materials shall meet the minimum Charpy V-notch impact value requirements specified in Table KM-234.2(b).

**KM-234.3 Lateral Expansion and Percentage Shear Reporting Requirements.** The lateral expansion and percentage of shear fracture for all impact tests shall be measured in accordance with SA-370 and the results included in the test report.
ARTICLE KM-4
MATERIAL DESIGN DATA

KM-400  CONTENTS OF TABLES OF MATERIAL DESIGN DATA

(a) Vessels fabricated in accordance with the rules of this Division shall be built using the materials listed in the following tables unless specifically exempted by this Division:

(1) Tables KM-400-1 and KM-400-1M
(2) Tables KM-400-2 and KM-400-2M
(3) Tables KM-400-3 and KM-400-3M

The P-Nos. and Group Nos. listed for some of the materials in these tables are for information only. For welded construction in this Division, Section IX, Table QW/QB-422 shall be consulted for P-Nos. and Group Nos.

(b) Limitations on the use of materials are contained in Notes to Tables KM-400-1, KM-400-1M, KM-400-2, KM-400-2M, KM-400-3, and KM-400-3M.

(c) Material property data for all materials that may be used under the rules of this Division are specified in the following tables in Section II, Part D:

(1) Yield Strengths, $S_y$, are specified in Section II, Part D, Subpart I, Table Y-1.
(2) Tensile Strengths, $S_u$, are specified in Section II, Part D, Subpart I, Table U.

(3) Coefficients of thermal expansion are specified in Section II, Part D, Subpart 2, Tables TE-1 and TE-4.
(4) Moduli of elasticity are specified in Section II, Part D, Subpart 2, Tables TM-1 and TM-4.
(5) Coefficients of thermal diffusivity are specified in Section II, Part D, Subpart 2, Table TCD.

(d) With the publication of the 2004 Edition, Section II Part D is published as two separate publications. One publication contains values only in U.S. Customary units and the other contains values only in SI units. The selection of the version to use is dependent on the set of units selected for construction.

(e) Where specifications, grades, classes, and types are referenced, and where the material specification in Section II, Part A or Part B is a dual-unit specification (e.g., SA-516/SA-516M), the design values and rules shall be applicable to either the U.S. Customary version of the material specification or the SI unit version of the material specification. For example, when SA-516M Grade 485 is used in construction, the design values listed for its equivalent SA-516, Grade 70, in either the U.S. Customary or metric, Section II, Part D (as appropriate) shall be used.
The cyclic stress–strain curve of a material (i.e., strain amplitude versus stress amplitude) may be represented by eq. (KM-630.1). The material constants for this model are provided in Table KM-630.1.

\[ \varepsilon_{ta} = \frac{\sigma_0}{E_y} + \left[ \frac{\sigma_0}{K_{CSS}} \right]^{\frac{1}{m_5}} \]  
(KM-630.1)

The hysteresis loop stress–strain curve of a material (i.e., strain range versus stress range) obtained by scaling the cyclic stress–strain curve by a factor of two is represented by eq. (KM-630.2). The material constants provided in Table KM-630 are also used in this equation.

\[ \varepsilon_{ta} = \frac{\sigma_Y}{E_y} + 2 \left[ \frac{\sigma_Y}{2K_{CSS}} \right]^{\frac{1}{m_5}} \]  
(KM-630.2)

### Table KM-620
Tabular Values for Coefficients

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Temperature, °F</th>
<th>( m_2 )</th>
<th>( m_3 )</th>
<th>( m_5 )</th>
<th>( m_6 )</th>
<th>( \epsilon_{p} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferritic steel [Note (1)]</td>
<td>480°C (900°F)</td>
<td>0.60 (1.00 - ( R ))</td>
<td>2 ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>2.2</td>
<td>2.0 E-5</td>
</tr>
<tr>
<td>Austenitic stainless steel and nickel-based alloys</td>
<td>480°C (900°F)</td>
<td>0.75 (1.00 - ( R ))</td>
<td>3 ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>0.6</td>
<td>2.0 E-5</td>
</tr>
<tr>
<td>Duplex stainless steel</td>
<td>540°C (1,000°F)</td>
<td>0.70 (0.95 - ( R ))</td>
<td>2 ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>2.2</td>
<td>2.0 E-5</td>
</tr>
<tr>
<td>Precipitation hardening, nickel based</td>
<td>540°C (1,000°F)</td>
<td>1.09 (0.93 - ( R ))</td>
<td>ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>2.2</td>
<td>2.0 E-5</td>
</tr>
<tr>
<td>Aluminum</td>
<td>120°C (250°F)</td>
<td>0.52 (0.98 - ( R ))</td>
<td>1.3 ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>2.2</td>
<td>5.0 E-6</td>
</tr>
<tr>
<td>Copper</td>
<td>65°C (150°F)</td>
<td>0.50 (1.00 - ( R ))</td>
<td>2 ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>2.2</td>
<td>5.0 E-6</td>
</tr>
<tr>
<td>Titanium and zirconium</td>
<td>260°C (500°F)</td>
<td>0.50 (0.98 - ( R ))</td>
<td>1.3 ln [1 + (1/100)]</td>
<td>ln [100/(100 - ( R ))]</td>
<td>2.2</td>
<td>2.0 E-5</td>
</tr>
</tbody>
</table>

**NOTE:**
(1) Ferritic steel includes carbon, low alloy, and alloy steels, and ferritic, martensitic, and iron-based age-hardening stainless steels.
Step 5. If time point \(m^t\) is a peak in the stress histogram, determine the component stress range between time point \(m^t\) and the next valley in the stress histogram. If time point \(m^t\) is a valley, determine the component stress range between time point \(m^t\) and the next peak. Designate the next time point as \(n^t\), and the stress components as \(n^\sigma_{ij}\). Calculate the stress component ranges and the von Mises equivalent stress range between time points \(m^t\) and \(n^t\).

\[
\Delta \sigma_{ij}^{\text{range}} = \frac{1}{\sqrt{2}} \left[ (\Delta \sigma_{11}^{m^t} - \Delta \sigma_{22}^{m^t})^2 + (\Delta \sigma_{22}^{m^t} - \Delta \sigma_{33}^{m^t})^2 + (\Delta \sigma_{33}^{m^t} - \Delta \sigma_{11}^{m^t})^2 + 6(\Delta \sigma_{12}^{m^t} + \Delta \sigma_{23}^{m^t} + \Delta \sigma_{31}^{m^t}) \right]^{0.5}
\]

Step 6. Repeat Step 5 for the current point, \(m^t\), and the time point of the next peak or valley in the sequence of the stress histogram. Repeat this process for every remaining time point in the stress histogram.

Step 7. Determine the maximum von Mises equivalent stress range obtained in Step 5 and record the time points \(m^t\) and \(n^t\) that define the start and end points of the \(k\)th cycle.

Step 8. Determine the event or events to which the time points \(m^t\) and \(n^t\) belong and record their specified number of repetitions as \(m^N\) and \(n^N\), respectively.

Step 9. Determine the number of repetitions of the \(k\)th cycle.

(a) If \(m^N < n^N\), delete the time point \(m^t\) from those considered in Step 4 and reduce the number of repetitions at time point \(n^t\) from \(n^N\) to \((n^N - m^N)\).

(b) If \(m^N > n^N\), delete the time point \(n^t\) from those considered in Step 4 and reduce the number of repetitions at time point \(m^t\) from \(m^N\) to \((m^N - n^N)\).

(c) If \(m^N = n^N\), delete both time points \(m^t\) and \(n^t\) from those considered in Step 4.

Step 10. Return to Step 4 and repeat Steps 4 through 10 until no more time points with stress reversals remain.

Step 11. Using the data recorded for the counted cycles, perform fatigue assessment in accordance with this Article.