In cases where the test coupon is not attached to the part being treated, it shall be quenched from the same heat treatment charge and under the same conditions as the part which it represents. It shall be so proportioned that test specimens may be taken from the locations prescribed in (a).

**KM-242 TEMPERING**

**KM-242.1 Attached Test Coupons.** The test coupons shall remain attached to the vessel or vessel component during tempering, except that any thermal buffers may be removed after quenching. After the tempering operation and after removal from the component, the coupon shall be subjected to the same thermal treatment(s), if any, to which the vessel or vessel component will be later subjected. The holding time at temperature shall not be less than that applied to the vessel or vessel component (except that the total time at each temperature may be applied in one heating cycle) and the cooling rate shall not be faster.

**KM-242.2 Separate Test Coupons.** The coupons that are quenched separately, as described in KM-241(b), shall be tempered similarly and simultaneously with the vessel or component which they represent. The conditions for subjecting the test coupons to subsequent thermal treatment(s) shall be as described in KM-242.1.

**KM-243 NUMBER OF TESTS**

One tensile test and one impact test, consisting of three impact test specimens, shall be made on material from coupons representing each lot of material in each vessel or vessel component heat treated. A lot is defined as material from the same heat, heat treated simultaneously and having thicknesses within ±20% or 1/2 in. (13 mm) of nominal thickness, whichever is smaller.

(a) Coupons not containing welds shall meet the complete tensile requirements of the material specification and impact requirements of this Part.

(b) Coupons containing weld metal shall be tested across the weld and shall meet the required mechanical property requirements of the material specification; in addition, the minimum impact requirements shall be met by samples with notches in the weld metal. The form and dimension of the tensile test specimen shall conform to Section IX, Figure QW-462.1(a) or Figure QW-462.1(d). Charpy impact testing shall be in accordance with the requirements of Article KT-2.

**KM-250 SUPPLEMENTARY TOUGHNESS REQUIREMENTS FOR PRESSURE-RETAINING COMPONENT MATERIALS**

Where a fracture mechanics evaluation in accordance with Article KD-4 is to be conducted, a value of $K_{IC}$ is required for the analysis. The designer shall specify the minimum value of $K_{IC}$ required, the number of tests to be performed, and shall indicate which of the following methods are to be used to verify that the material meets this value.

The orientation of the direction of crack propagation for all test coupons shall be the same as the direction of crack propagation expected in the fracture mechanics analysis conducted in accordance with Article KD-4. Variation of fracture toughness through the thickness of a component shall be considered to ensure the toughness used in Article KD-4 is representative of the material at the location being considered.

**KM-251 CHARPY V-NOTCH IMPACT TESTING**

The designer may require that the pressure-retaining component meet minimum Charpy V-notch absorbed energy values that are greater than those specified in KM-234.2 in order to verify compliance with the minimum $K_{IC}$ value. If supplemental impact testing is conducted, it shall be performed in accordance with SA-370 and be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. It shall be the designer’s responsibility to determine and specify the appropriate $K_{IC}$-CVN conversion equation, in compliance with API 579-1/ASME FFS-1, to be used to ascertain the Charpy V-notch acceptance criterion.

**KM-252 CTOD FRACTURE TOUGHNESS TESTING**

The designer may require that CTOD (crack tip opening displacement) testing of the high pressure-retaining component be conducted to determine the critical crack tip opening displacement CTOD or $\delta_{c,ct}$, and to verify compliance with the minimum $K_{IC}$ value. If CTOD testing is required, it shall be performed in accordance with ASTM E1820, and be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. The temperature reduction values given in Table KM-212 do not apply. The equivalent $K_{IC}$ value (or $K_{c,\delta}$) shall be computed from CTOD data using API 579-1/ASME FFS-1, Equation (9F.29).

**KM-253 J-INTEGRAL FRACTURE TOUGHNESS TESTING**

The designer may require that $J$-Integral testing of the pressure-retaining component be conducted to determine the critical value of the $J$-integral or $J_{c,\text{crit}}$, and to verify compliance with the minimum $K_{IC}$ value. If $J$-Integral testing is required, it shall be performed in accordance with ASTM E1820 and shall be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. The temperature reduction values given in Table KM-212 do not apply. The equivalent $K_{IC}$, denoted as $K_{IC}$, shall be computed from $J_{c,\text{crit}}$ using API 579-1/ASME FFS-1, Equation (9F.27).
**KM-254**  
**K_{IC}** FRACTURE TOUGHNESS TESTING  
The designer may, at his option, require that direct $K_{IC}$ testing of the pressure-retaining component be conducted to verify compliance with the specified minimum $K_{IC}$ value. If such testing is required, it shall be performed in accordance with ASTM E399 and shall be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. The temperature reduction values given in Table KM-212 do not apply.

**KM-260** RETESTS  
**KM-261** GENERAL RETEST REQUIREMENTS  
The following retest requirements apply to tension, Charpy V-notch impact, and CTOD, $J$-Integral, and $K_{IC}$ fracture toughness tests.

(a) If any test specimen fails to meet the applicable acceptance criteria for mechanical reasons, such as test equipment malfunction or improper specimen preparation, the results may be discarded and another representative specimen may be substituted.

(b) If any test specimen fails to meet the applicable acceptance criteria for nonmechanical reasons, two representative specimens as close to the original specimen location as possible may be selected for retesting without reheat treatment, provided the failure was not caused by preexisting material defects such as ruptures, flakes, or cracks. Both of these specimens shall meet the applicable acceptance criteria (see KM-262 for Charpy V-notch impact retests).

(c) Only one retesting is permitted. If the material fails the retest, it may be retempered or reheat treated, as necessary.

**KM-262** SPECIAL CHARPY V-NOTCH IMPACT RETEST REQUIREMENTS  
(a) A Charpy V-notch impact retest is permitted if the average absorbed energy value meets the applicable acceptance criteria but the absorbed energy value for one specimen is below the specified minimum for individual specimens. The retesting shall consist of two representative impact specimens removed from a location adjacent to and on either side, if possible, of the original specimen location. Each of the retest specimens shall exhibit an absorbed energy value equal to or greater than the minimum average value.

(b) Only one retesting is permitted. If the material fails the retest, it may be retempered or reheat treated, as necessary.

**KM-270** NOTCH TENSILE TESTING  
PROCEDURE AND ACCEPTANCE CRITERION  
Material listed in Table KM-400-4 (Table KM-400-4M) shall be qualified by the following notch tensile test for T6 or T651 temper:

(a) The Sharp-Notch Strength/Yield Strength Ratio shall be determined using the ASTM E338 or ASTM E602 test method. Specimens shall be cut from a production vessel. Two specimens from a production vessel shall be tested to qualify a single heat of material. The samples shall be obtained from the production vessel after all forming and heat treating is completed.

(b) The geometry of the specimen shall meet the dimensional requirement of ASTM E338, paragraph 6, Figure 3 or ASTM E602, Figure 1. The specimen shall be cut such that the longitudinal axis of the production vessel is parallel to the long axis of the specimen. The following exemptions to the dimensional requirements of the above specimens may be applied:

(1) For ASTM E338 specimen, the test section width less than 2 in. (50 mm) may be used; however, the ratio of the notch depth to specimen net ligament width shall not be less than 0.25. The specimen thickness limitation in the test section need not be satisfied.

(2) For ASTM E602 specimen, the test section diameter less than 0.5 in. (12.5 mm) may be used; however, the ratio of notch depth to the specimen net ligament diameter shall not be less than 0.25.

(c) The tensile test methods in ASTM B557 shall be used in lieu of ASTM E8 where specified in ASTM E338 and ASTM E602.

(d) Sharp-Notch Strength/Yield Strength Ratio shall be not less than 0.9.
(b) In cases where the test coupon is not attached to the part being treated, it shall be quenched from the same heat treatment charge and under the same conditions as the part which it represents. It shall be so proportioned that test specimens may be taken from the locations prescribed in (a).

**KM-242 TEMPERING**

**KM-242.1 Attached Test Coupons.** The test coupons shall remain attached to the vessel or vessel component during tempering, except that any thermal buffers may be removed after quenching. After the tempering operation and after removal from the component, the coupon shall be subjected to the same thermal treatment(s), if any, to which the vessel or vessel component will be later subjected. The holding time at temperature shall not be less than that applied to the vessel or vessel component (except that the total time at each temperature may be applied in one heating cycle) and the cooling rate shall not be faster.

**KM-242.2 Separate Test Coupons.** The coupons that are quenched separately, as described in KM-241(b), shall be tempered similarly and simultaneously with the vessel or component which they represent. The conditions for subjecting the test coupons to subsequent thermal treatment(s) shall be as described in KM-242.1.

**KM-243 NUMBER OF TESTS**

One tensile test and one impact test, consisting of three impact test specimens, shall be made on material from each lot of material in each vessel or vessel component heat treated. A lot is defined as material from the same heat, heat treated simultaneously and having thicknesses within ±20% or 1/2 in. (13 mm) of nominal thickness. The equivalent K\text{IC} value (or K\text{IG}) shall be computed from CTOD data using API 579-1/ASME FFS-1, Equation (9F.29).

(a) Coupons not containing weld metal across the weld and shall meet the required mechanical property requirements of the material specification in addition, the minimum required displacement value determined in Section IX, Figure QW-462.1(a) or Figure QW-462.1(d). Charpy impact testing shall be in accordance with the requirements of Article KT-2.

(b) Coupons containing weld metal across the weld and meet the required mechanical property requirements of the material specification in addition, the minimum required displacement value determined in Section IX, Figure QW-462.1(a) or Figure QW-462.1(d). Charpy impact testing shall be in accordance with the requirements of Article KT-2.

**KM-244 CTOD FRACTURE TOUGHNESS TESTING**

The equivalent K\text{IC} value (or K\text{IG}) shall be computed from CTOD data using API 579-1/ASME FFS-1, Equation (9F.29).

The equivalent K\text{IC} value denoted as K\text{IC} shall be computed from J\text{IC} testing of the pressure-retaining component be conducted to verify compliance with the minimum K\text{IC} value. If J\text{IC} testing is required, it shall be conducted in accordance with ASTM E1820 and be conducted at a temperature beyond the impact test temperature specified in KM-234.1. The designer shall specify the appropriate K\text{IC}-CVN conversion equation in compliance with API 579-1/ASME FFS-1, to be used to ascertain the J\text{IC} acceptance criterion.

**KM-250 SUPPLEMENTARY TOUGHNESS**

Where a fracture mechanics evaluation in accordance with Article KD-4 is to be conducted, a value of K\text{IC} is required for the analysis. The designer shall specify the minimum value of K\text{IC} required, the number of tests to be performed, and shall indicate which of the following methods are to be used to verify that the material meets this value.

The orientation of the direction of crack propagation for all test coupons shall be the same as the direction of crack propagation expected in the fracture mechanics analysis conducted in accordance with Article KD-4. Variation of fracture toughness through the thickness of a component shall be considered to ensure the toughness used in Article KD-4 is representative of the material at the location being considered.

**KM-251 CHARPY V-NOTCH IMPACT TESTING**

The designer may require that the pressure-retaining component meet minimum Charpy V-notch absorbed energy values that are greater than those specified in KM-234.2 in order to verify compliance with the minimum K\text{IC} value. If supplemental impact testing is conducted, it shall be performed in accordance with SA-370 and be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. It shall be the designer’s responsibility to determine and specify the appropriate K\text{IC}-CVN conversion equation, in compliance with API 579-1/ASME FFS-1, to be used to ascertain the Charpy V-notch acceptance criterion.

**KM-252 CTOD FRACTURE TOUGHNESS TESTING**

The designer may require that CTOD (crack tip opening displacement) testing of the high pressure-retaining component be conducted to verify compliance with the minimum K\text{IC} value. If CTOD testing is required, it shall be performed in accordance with ASTM E1820, and be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. The temperature reduction values given in Table KM-212 do not apply. It shall be the designer’s responsibility to determine and specify the appropriate K\text{IC}-CTOD conversion equation, in compliance with API 579-1/ASME FFS-1, to be used to ascertain the CTOD acceptance criterion.

**KM-253 J\text{IC} FRACTURE TOUGHNESS TESTING**

The designer may require that J\text{IC} testing of the pressure-retaining component be conducted to verify compliance with the minimum K\text{IC} value. If J\text{IC} testing is required, it shall be performed in accordance with ASTM E1820 and shall be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. The temperature reduction values given in Table KM-212 do not apply. It shall be the designer’s responsibility to determine and specify the appropriate K\text{IC}-J\text{IC} conversion equation, in compliance with API 579-1/ASME FFS-1, to be used to ascertain the J\text{IC} acceptance criterion.
**KM-254  \( K_{IC} \) FRACTURE TOUGHNESS TESTING**

The designer may, at his option, require that direct \( K_{IC} \) testing of the pressure-retaining component be conducted to verify compliance with the specified minimum \( K_{IC} \) value. If such testing is required, it shall be performed in accordance with ASTM E399 and shall be conducted at a temperature not exceeding the impact test temperature specified in KM-234.1. The temperature reduction values given in Table KM-212 do not apply.

**KM-260 RETESTS**

**KM-261 GENERAL RETEST REQUIREMENTS**

The following retest requirements apply to tension, Charpy V-notch impact, and CTOD, \( J \), and \( K_{IC} \) fracture toughness tests.

(a) If any test specimen fails to meet the applicable acceptance criteria for mechanical reasons, such as test equipment malfunction or improper specimen preparation, the results may be discarded and another representative specimen may be substituted.

(b) If any test specimen fails to meet the applicable acceptance criteria for nonmechanical reasons, two representative specimens as close to the original specimen location as possible may be selected for retesting without reheat treatment, provided the failure was not caused by preexisting material defects such as ruptures, flakes, or cracks. Both of these specimens shall meet the applicable acceptance criteria (see KM-262 for Charpy V-notch impact retests).

(c) Only one retesting is permitted. If the material fails the retest, it may be retempered or reheat treated, as necessary.

**KM-262 SPECIAL CHARPY V-NOTCH IMPACT RETEST REQUIREMENTS**

(a) A Charpy V-notch impact retest is permitted if the average absorbed energy value meets the applicable acceptance criteria but the absorbed energy value for one specimen is below the specified minimum for individual specimens. The retesting shall consist of two representative impact specimens removed from a location adjacent to and on either side, if possible, of the original specimen location. Each of the retest specimens shall exhibit an absorbed energy value equal to or greater than the minimum average value.

(b) Only one retesting is permitted. If the material fails the retest, it may be retempered or reheat treated, as necessary.

**KM-270 NOTCH TENSILE TESTING PROCEDURE AND ACCEPTANCE CRITERION**

Material listed in Table KM-400-4 or Table KM-400-4M shall be qualified by the following notch tensile test for T6 or T651 temper:

(a) The Sharp-Notch Strength/Yield Strength Ratio shall be determined using the ASTM E338 or ASTM E602 test method. Specimens shall be cut from a production vessel, Two specimens from a production vessel shall be tested to qualify a single heat of material. The samples shall be obtained from the production vessel after all forming and heat treating is completed.

(b) The geometry of the specimen shall meet the dimensional requirement of ASTM E338, paragraph 6, Figure 3 or ASTM E602, Figure 1. The specimen shall be cut such that the longitudinal axis of the production vessel is parallel to the long axis of the specimen. The following exemptions to the dimensional requirements of the above specimens may be applied:

1. For ASTM E338 specimen, the test section width less than 2 in. (50 mm) may be used; however, the ratio of the notch depth to specimen net ligament width shall not be less than 0.25. The specimen thickness limitation in the test section need not be satisfied.

2. For ASTM E602 specimen, the test section diameter less than 0.5 in. (12.5 mm) may be used; however, the ratio of notch depth to the specimen net ligament diameter shall not be less than 0.25.

(c) The tensile test methods in ASTM B557 shall be used in lieu of ASTM E8 where specified in ASTM E338 and ASTM E602.

(d) Sharp-Notch Strength/Yield Strength Ratio shall be not less than 0.9.