Designation: B 646 – 04

Standard Practice for Fracture Toughness Testing of Aluminum Alloys[1]

This standard is issued under the fixed designation B 646; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 Fracture toughness is a key property for a number of aluminum alloys utilized in aerospace and process industries. Fracture toughness testing is often required for supplier qualification, quality control, and material release purposes. The purpose of this practice is to provide uniform test procedures for the industry, pointing out which current standards are utilized in specific cases, and providing guidelines where no standards exist. This practice provides guidance for testing *(a)* thin products, of thicknesses equivalent to sheet that is ≤0.249 in. (≤6.32 mm), *(b)* intermediate thicknesses of plate, forgings, and extrusions, too thin for valid plane-strain fracture toughness testing but too thick for treatment as sheet, for example, over 0.249 in. (6.32 mm) and up to 1 to 2 in. (25 to 50 mm), dependent upon toughness level, and *(c)* relatively thick products where Test Method E 399 is applicable.

1.2 This practice addresses both direct measurements of fracture toughness and screening tests, the latter recognizing the complexity and expense of making formal fracture toughness measurements on great quantities of production lots.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values in SI units given in parenthesis are provided for information purposes only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

B 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B 645 Practice for Plane-Strain Fracture Toughness Testing of Aluminum Alloys

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

E 338 Test Method of Sharp-Notch Tension Testing of High-Strength Sheet Materials

E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials

E 561 Practice for R-Curve Determination

E 602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens

E 1304 Test Method for Plane-Strain (Chevron Notch) Fracture Toughness of Metallic Materials

E 1823 Terminology Relating to Fatigue and Fracture Testing

3. Terminology

3.1 The terminology and definitions in the referenced documents are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 For purposes of this practice, the following descriptions of terms are applicable in conjunction with Test Method E 561 and use of the compact specimen:

3.2.2 K_{R25}—a value of K_R on the R-curve based on a 25 % secant intercept of the force-crack opening displacement test record from a C(T) specimen and the effective crack length, a_e, at that point that otherwise satisfies the remaining-ligament criterion of Test Method E 561.

3.2.3 K_{Rmax}—a value of K_R on the R-curve based on the maximum force value of the force-crack opening displacement test record from a C(T) specimen and the effective crack length, a_e, at that point that otherwise satisfies the remaining-ligament criterion of Test Method E 561. The K_{Rmax} value is used when the 25 % secant intercept occurs at a point after the maximum force is reached.

3.2.4 K_c—for the purpose of this practice, K_c is the critical stress intensity factor based on the maximum force value of the force-crack opening displacement test record from an M(T) specimen and the effective crack length, a_e, at that point that otherwise satisfies the remaining-ligament criterion of Test Method E 561.

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[1] This practice is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys, and is the direct responsibility of Subcommittee B07.05 on Testing.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

3.2.5 K_{app} (also commonly designated K_{co})—the apparent plane stress fracture toughness based on the original crack length, a_o, and the maximum force value of the force-crack opening displacement test record from an M(T) specimen that otherwise satisfies the remaining-ligament criterion of Test Method E 561.

4. Summary of Practice

4.1 This practice provides guidelines for the selection of tests to evaluate the fracture toughness properties of aluminum alloys, particularly for quality assurance and material release purposes. It also provides supplemental information regarding specimen size selection, analysis, and interpretation of results for the following products and test methods:

4.2 *Fracture Toughness Testing of Thin Products*:

4.2.1 R-Curve testing of middle-crack tension, M(T), specimens in accordance with Test Method E 561.

4.2.2 K_c and K_{app} (K_{co}) testing of M(T) specimens in general accordance with Test Method E 561.

4.3 *Fracture Toughness Testing of Intermediate Thickness Products*:

4.3.1 Testing of compact-tension, C(T), specimens in accordance with Test Method E 399 supplemented with Practice B 645.

4.3.2 Tests on C(T) specimens in accordance with Test Method E 561 using the toughness parameter, KR_{25}.

4.4 *Fracture Toughness Testing of Thick Products*:

4.4.1 Plane-strain fracture testing in accordance with Test Method E 399 supplemented with Practice B 645.

4.5 *Screening Tests*:

4.5.1 Screening tests of thin products using sharply-edge-notched, sheet-type specimens in accordance with Test Method E 338.

4.5.2 Screening tests of both intermediate and relatively thick products using the chevron notch (short-rod or short-bar) in accordance with Test Method E 1304.

4.5.3 Screening tests for a range of thicknesses from about 0.1 in. (2.54 mm) upward using the sharp-notch Charpy test as covered in Test Methods E 23.

4.5.4 Screening tests of thick products using sharply-notched cylindrical specimens in accordance with Test Method E 602.

5. Significance and Use

5.1 This practice is provided to develop and maintain uniformity in practices for the evaluation of the toughness of aluminum alloys, particularly with regard to supplier qualification, quality assurance, and material release to specifications.

5.2 It is emphasized that the use of these procedures will not alter the validity of data determined with specific test methods, but provides guidance in the interpretation of test results (valid or invalid) and guidance in the selection of a reasonable test procedure in those instances where no standard exists today.

6. Selection of Fracture Toughness Test Methods for Specific Products

6.1 Direct measures of fracture toughness are preferred over screening test methods and are highly recommended for supplier qualification and periodic quality control testing. The following measures of fracture toughness and test methods are recommended for these products:

6.2 *Thin Products*—For sheet and other products having a thickness less than 0.250 in. (6.35 mm):

6.2.1 The critical stress intensity factor (K_c) or the apparent fracture toughness (K_{app}) from a middle-cracked tension, M(T), specimen and tested in general accordance with Test Method E 561 as supplemented by this practice in 8.1.

6.2.2 The R-curve measured from a middle-cracked tension, M(T), specimen tested in accordance with Test Method E 561 as supplemented by this practice in 8.2.

6.3 *Thick Products*—For products sufficiently thick to obtain a valid plane strain fracture toughness measurement, K_{Ic}, from C(T) specimens measured in accordance with Test Method E 399 supplemented by Practice B 645 and by this practice in 8.3.

6.4 *Intermediate Thickness Products*—For products having a thickness ≥0.250 in. (≥6.35 mm), but too thin for valid plane-strain fracture toughness testing:

6.4.1 K_Q from compact-tension, C(T), specimens tested in accordance with Test Method E 399 supplemented with Practice B 645 and this practice in 8.3; or

6.4.2 KR_{25} from a compact-tension, C(T) specimen tested in accordance with Test Method E 561 as supplemented by this practice in 8.4.

6.5 *Thin Specimens from Thicker Products*—The methods of 6.2 may also be utilized on thin specimens machined from intermediate thickness or thick products for the purpose of evaluating their fracture toughness under plane stress conditions. These methods may be particularly desirable for products which will be subsequently thinned by machining or other means. Typically, the specimen is machined from the product to a thickness representative of that in the final application.

6.6 *Low Strength Alloy Products*—There are no current standard recommendations for toughness testing of relatively low-strength aluminum alloys which display large-scale yielding even in the presence of extremely large cracks in very thick sections. Such cases must be dealt with individually on a research basis using tests selected from program needs and anticipated design criteria. A typical case for general guidance is given in the literature.[3]

7. Selection of Screening Test Methods for Specific Products

7.1 Screening tests are permitted for high volume, material release testing provided they are allowed by the material specification or by agreement between the purchaser and supplier. The following screening test methods are recommended for these products:

7.2 *Thin Products*—For sheet and other products having a thickness less than 0.250 in. (6.35 mm):

[3] Kaufman, J. G., and Kelsey, R. A., "Fracture Toughness and Fatigue Properties of 5083-0 Plate and 5183 Welds for Liquefied Natural Gas Applications," *Properties of Materials for Liquefied Natural Gas Tankage, ASTM STP 579,* ASTM, 1975, pp. 138–158.

7.2.1 Tension tests of sharply-edge-notched, sheet-type specimens in accordance with Test Method E 338 as supplemented by this practice in 9.1 and 9.2, and the corresponding correlations of such data with the critical stress-intensity factors (K_c) determined in accordance with this practice are recommended.

7.2.2 The sharp-notch Charpy screening test in accordance with Test Methods E 23 as supplemented by this practice in 9.1 and 9.3 may also be applied for correlative purposes for products 0.10 in. (2.54 mm) and thicker.

7.3 *Thick Products*—For products sufficiently thick to obtain a valid plane strain fracture toughness measurement:

7.3.1 Tension tests of sharply-notched, cylindrical specimens in accordance with Test Method E 602 as supplemented by this practice in 9.1 and 9.4 and the associated correlation with plane-strain fracture toughness, K_{Ic}, as determined in accordance with Test Method E 399 and Practice B 645 are recommended. In addition, the following recommended alternative screening tests may be applied:

7.3.2 The chevron notch (short-rod and short-bar) test described in Test Method E 1304 as supplemented by this practice in 9.1 and 9.5.

7.3.3 The sharp-notch Charpy screening test in accordance with Test Methods E 23 as supplemented by this practice in 9.1 and 9.3.

7.4 *Intermediate Thickness Products*—For products having a thickness ≥0.250 in. (≥6.35 mm), but too thin for valid plane-strain fracture toughness testing there is insufficient data to justify strong recommendations for screening test procedures. Presumably, correlation with fracture toughness indices could be made with the results of tests using either chevron-notch (short-rod or short-bar) specimens, sharp-edge-notched, sheet-type specimens, sharply-notched, cylindrical specimens or sharp-notch Charpy specimens.

8. Fracture Toughness Testing Methods and Interpretation

8.1 *K_c and K_{app} (K_{co}) Testing*—Fracture toughness testing to obtain either the critical stress intensity (K_c) or the apparent fracture toughness (K_{app}) shall be performed on M(T) specimens in accordance with Test Method E 561 and the following supplemental requirements. K_{co} is another commonly used designation for the apparent fracture toughness, so all requirements for K_{app} testing are also applicable to K_{co}.

NOTE 1—K_c, K_{app}, and the R-curve may all be obtained from the same test record and specimen. K_c or K_{app} are often preferred for quality assurance or material release purposes because they provide a single value measure of material fracture toughness that can be compared against a minimum specification value. For higher strength, lower toughness alloys where the maximum force is preceded by one or more unstable extensions of the crack, K_{app} is recommended for material release purposes.

8.1.1 The M(T) specimen width, *W*, and original crack length, a_o, shall be in accordance with the material specification and the specimen thickness shall be the full thickness of the product for thin products ≤0.250 in. (≤6.35 mm) in thickness and 0.250 in. (6.35 mm) for thicker products, unless otherwise stated in the material specification. Specimens not of full product thickness shall be excised from the mid-plane of the product unless otherwise stated in the material specification. Recommended widths are W = 16 in. (406 mm) for medium strength, higher toughness products and W = 6.3 in. (160 mm) for high strength, lower toughness products. For very high toughness sheet alloys, W = 30 in. (760 mm) are also sometimes used for supplier qualification. The recommended original crack size is one quarter of the width, *W*; that is $2a_o/W$ = 0.25. In all cases the original crack size, a_o, should be within the range of 0.25 to 0.40*W*, inclusive, allowed in Test Method E 561. If no dimensional requirements are given in the material specification, the nominal specimen size shall be 16 in. (405 mm) wide, with 15 in. (380 mm) being an acceptable minimum width and the initial crack length, $2a_o$ shall be equal to one quarter of the width, *W*; that is, $2a_o/W = 0.25$. For all specimen widths and original crack sizes, the tolerance for the original crack size shall be $+0.0125W - 0W$ or +0.1/−0 in. (+2.5/−0 mm), whichever is greater.

NOTE 2—The values of K_c and K_{app} are dependent upon the interaction of the crack driving force, which is a function of specimen width, *W*, and the crack resistance curve (R-curve). Thus, they are specimen width (as well as thickness) dependent and their values will typically decrease with decreasing specimen width, all other factors being equal. They also depend to a lesser extent on the original crack length, a_o. Therefore, both the specified value and qualification or lot release testing should be based on specimens having the same width and original crack length.

8.1.2 The M(T) specimen shall be machined and precracked in accordance with Test Method E 561. The value of K_{fmax} in the fatigue precracking shall not exceed 15 ksi$\sqrt{\text{in.}}$ (16.5 MPa$\sqrt{\text{m}}$). Fatigue precracking may be omitted only if it can be shown that doing so does not increase the measured value of K_c or K_{app}.

8.1.3 Except when specifically stated in the material specification, testing shall be performed with face stiffeners on the specimen to prevent buckling above or below the center slot.

8.1.4 The K_c value shall be calculated at the maximum force by the use of the secant equation for M(T) specimen given in Test Method E 561. The half crack length used in the *K*-expression shall be the effective half crack length, a_e, at the maximum force point calculated using the compliance expression for M(T) panels in Test Method E 561. If, as sometimes happens, there is considerable crack extension at maximum force, the point at which the force first reaches the maximum shall be used in the crack length calculations.

8.1.5 The K_{app} value shall be calculated at the maximum force by the use of the secant equation for the M(T) specimen given in Test Method E 561. The half crack length used in the *K*-expression shall be the original crack length, a_o.

8.1.6 The net section validity of K_c or K_{app} shall be determined at the maximum force in accordance with Test Method E 561.

8.1.7 Values of K_c or K_{app} calculated under conditions in which the net section stress exceeds 100 % of the tensile yield strength of the material are not suitable for design purposes and do not express the full toughness capability of the material, but they are useful for quality control or lot release; and such value of K_c or K_{app} that equals or exceeds a specified minimum value shall constitute evidence that the material passes the stated specification if the latter is based upon tests of the same or larger width of specimen.

8.2 *R-Curve Testing*—Fracture toughness testing to obtain the R-curve shall be performed on M(T) specimens in accordance with Test Method E 561 and the following supplemental requirements.

NOTE 3—The R-curve provides a complete measure of a material's resistance to slow-stable crack extension and consists of multiple data points (typically ten or more). When the R-curve is used for material release purposes, the release criterion is typically based on minimum specified values of K_R at two or more values of effective crack extension, Δa_e. Use of the R-curve for quality control purposes is suitable only for higher toughness alloys that exhibit stable crack extension and smoothly rising R-curves. For higher strength, lower toughness alloys where the maximum force is preceded by one or more unstable extensions of the crack, use of K_{app} is recommended.

8.2.1 The specimen size, location, and testing requirements for K_c and K_{app} testing in 8.1.1, 8.1.2, and 8.1.3 shall also be used for R-curve testing. For R-curve testing, fatigue precracking is highly recommended. It may be omitted only if it can be shown that doing so does not increase the measured values of K_R at the specified values of Δa_e.

NOTE 4—The R-curve is a function of the material and its thickness but is relatively independent of other geometric factors. However, the amount of valid R-curve obtained (the maximum valid Δa_e) increases with specimen width, W.

8.2.2 For the R-curve, it is recommended that at least 20 pairs of (K_R, Δa_e) pairs be determined from the test record of force versus crack opening displacement in accordance with Test Method E 561. At a minimum, (K_R, Δa_e) pairs shall be calculated using secant offsets having slope decrements of no more than 5 % of the initial linear slope of the test record. The values of K_R corresponding to each secant offset shall be determined using the secant equation for the M(T) specimen in the Test Method E 561. The effective half crack length, a_e, used in the calculation of K_R and Δa_e for each secant offset, shall be determined using the compliance expression for M(T) panels in Test Method E 561.

8.2.3 The net section validity shall be determined for each pair of K_R and Δa_e in accordance with Test Method E 561. Those pairs meeting the validity requirement comprise the valid portion of the R-curve. K_R values in the invalid region where net section yielding has occurred may be higher than valid points that would have been obtained with a larger specimen. However, provided the same specimen or smaller specimen size was used to establish the specification minimums, K_R values in the invalid region that equal or exceeds a specified minimum shall constitute evidence that the material passes the stated specification.

8.2.4 Since minimum K_R values for material release purposes are typically specified at certain values of Δa_e, which do not necessarily coincide with those from the R-curve analysis, linear interpolation between adjacent (K_R, Δa_e) pairs is acceptable as long as there is at least one (K_R, Δa_e) point between each specified value of Δa_e.

8.3 *Plane Strain Fracture Toughness Testing*—Plain strain fracture toughness testing to obtain K_{Ic} or K_Q for material release purposes shall be performed on C(T) specimens in accordance with Test Method E 399 and Practice B 645. For any test result failing to meet the validity requirements for K_{Ic} in Method E 399, the resulting K_Q value is usable for lot release, provided the requirements in Practice B 645 are met. A K_Q meeting these requirements, which meets or exceeds the specified minimum value of K_{Ic}, shall be considered as evidence that the lot meets the requirements of the material specification.

8.4 K_{R25} *Testing*—Fracture toughness testing to obtain the K_{R25} value shall be performed on C(T) specimens in accordance with Test Method E 561 and the following supplemental requirements.

8.4.1 An evaluation of the material should be made to determine the optimum C(T) specimen geometry that will yield a valid K_{R25} result in accordance with Test Method E 561. The optimum geometry (that is, width and original crack length) will depend on the strength, toughness, and thickness of the material. The minimum recommended C(T) specimen width is W = 3 in. (76.2 mm) with a width of W = 4 (102 mm) or larger, preferred. Once the optimum specimen geometry is established, the testing to establish the specification minimums and all future material release tests shall be made utilizing the same specimen geometry. The specimen thickness shall be the full product thickness unless otherwise stated in the material specification.

8.4.2 The C(T) specimen shall be machined and precracked in accordance with Test Method E 561. The value of K_{fmax} in the fatigue precracking shall not exceed 15 ksi$\sqrt{}$in. (16.5 MPa$\sqrt{}$m).

8.4.3 The K_{R25} value shall be calculated from the force corresponding to the 25 % secant offset and the effective crack length, a_e, at that point using the polynomial expression for the C(T) specimen in Test Method E 561. The 25 % secant offset is a line through the origin (as determined by the x-intercept of the initial linear slope of the test record) with a slope 75 % of the initial slope. The 25 % secant force is the force at the intersection of the force-crack opening displacement trace and the 25 % secant offset. The effective crack length at that point is determined from the slope of the 25 % secant offset using the method in Test Method E 561.

8.4.4 If K_{R25} corresponds to a point on the test record at a crack opening displacement beyond the maximum force value, K_{Rmax}, shall be used in place of K_{R25} for comparison with the specification minimum. The K_{Rmax} value shall be calculated from the maximum force and the effective crack length at that point using the polynomial expression for the C(T) specimen in Test Method E 561.

8.4.5 The net section validity of the K_{R25} or K_{Rmax} value shall be determined in accordance with Test Method E 561. Provided there is no evidence of specimen buckling, an invalid K_{R25} or K_{Rmax} value which meets or exceeds the applicable specification value for K_{R25}, based upon tests of specimens of the same geometry, shall be considered as evidence that the lot meets the requirements of the specification.

8.5 *Yield Strength for Validity Determination*—Preferably, the tensile yield strength for calculating certain validity requirements in the above fracture toughness tests should be taken from the same test location as the fracture toughness specimen. However, when this location does not coincide with the requirements for the tension test location in Test Methods B 557, or the material specification is different than Test

Methods B 557, the yield strength from the specimen used to show conformance with the tensile requirements may be used in the calculations.

9. Screening Test Methods and Interpretation

9.1 *General Requirements*:

9.1.1 Screening tests for lot release based on the correlation between a screening test result and a fracture toughness index always have a region of uncertainty, as illustrated in Fig. 1. Screening test values in this region are not suitable for use as acceptance/rejection criteria. In this case, testing with the primary fracture toughness test method is required for lot release purposes.

9.1.2 Data for determining the correlation between an indicator test and the primary toughness test should be collected on a periodic basis and the data should be analyzed regularly to ensure that the correlation and tolerance limits do not change. If a change is detected, new correlation and tolerance limits should be determined.

9.1.3 Screening test specimens shall be centered at the same test location in the product as that required for the primary fracture toughness test specimen. Preferably, the tensile yield strength for calculating the notch yield ratio, NYR (ratio of sharp notch strength to tensile yield strength) in accordance with 9.2 or 9.4 or the validity of the chevron-notch test in 9.5, should be taken from the same test location. However, when this location does not coincide with the requirements for the tension test location in Test Methods B 557, or the material specification if different than Test Methods B 557, the yield strength from the specimen used to show conformance with the tensile requirements may be used in the calculations.

9.2 *Tension Testing of Sharply-Notched, Sheet-Type Specimens*—The notch yield ratio, NYR, from a sharply-notched, sheet-type specimen has been shown to correlate reasonably well with K_c from 16 in. (406 mm) wide M(T) specimens. If a suitable correlation has been established for an alloy/product/temper between NYR and K_c or other fracture indices, NYR may be used as a lot release criterion for that alloy/product/temper.

9.2.1 Testing of sharply-notched, sheet-type specimens shall be performed in accordance with Test Method E 338. The double-edge notched, sheet-type specimen in Fig. 3 of Test Method E 338 is recommended. The specimen shall have the same nominal thickness as the primary fracture toughness specimen.

9.3 *Sharp-Notch Charpy Testing*—Charpy impact tests have long been employed as a measure of the toughness of metals and have been used to predict the plane strain fracture toughness, K_{Ic}. The Charpy energy has also been shown to correlate reasonable well with K_c from 16 in. (406 mm) wide M(T) specimens. If a suitable correlation has been established for an alloy/product/temper between the Charpy energy and K_{Ic} or K_c or other fracture indices, Charpy energy may be used as a lot release criterion for that alloy/product/temper.

9.3.1 Charpy impact testing shall be performed in accordance with Test Method E 23. Various types of notches have been used, including a precrack, but a sharp notch is the most effective. The sharp notch shall have a root radius of <0.001 in. (<0.0254 mm).

9.3.2 Charpy impact testing is limited to product thickness >0.10 in. (>2.54 mm). The Charpy specimen shall have the same nominal thickness as the primary fracture toughness

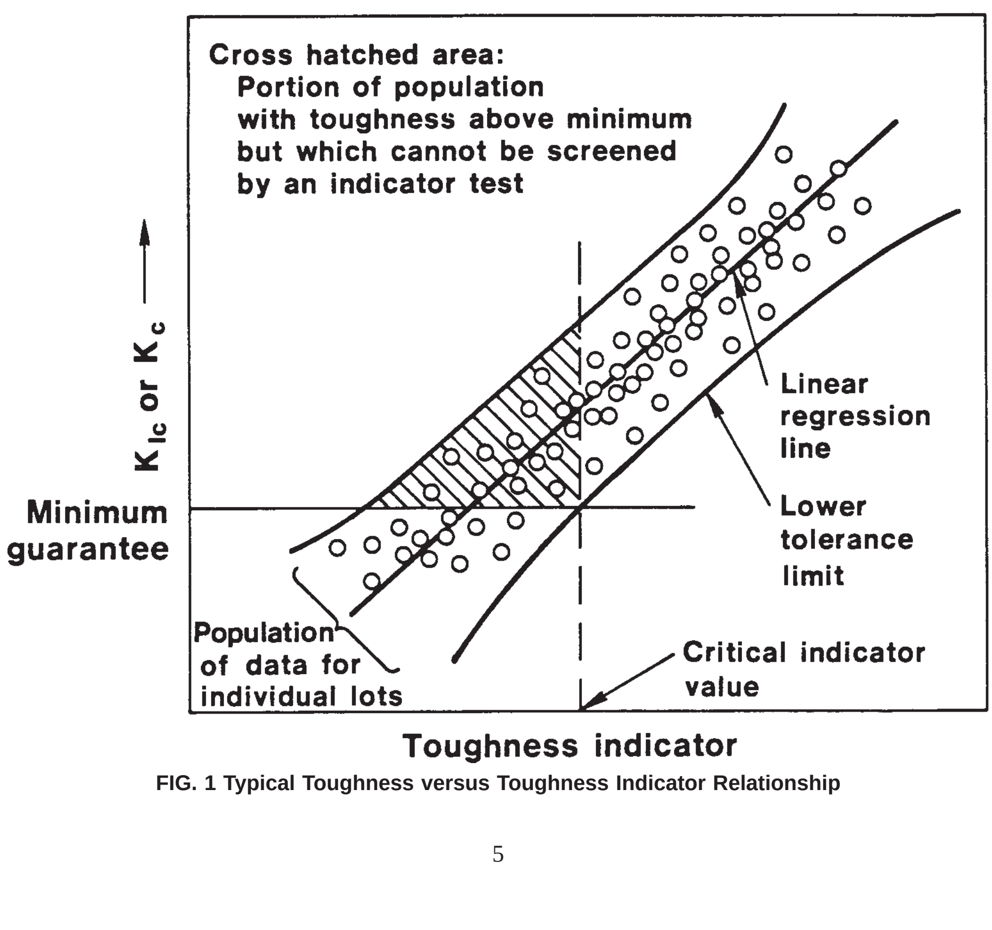

FIG. 1 Typical Toughness versus Toughness Indicator Relationship

specimen up to a thickness of 0.394 in. (10 mm). If the thickness of the primary fracture toughness specimen is >0.394 in. (10 mm), the Charpy specimen shall have a nominal thickness of 0.394 in. (10 mm).

9.3.3 A low capacity impact machine of approximately 25 ft-lbf (33.9 N·m) is recommended with sufficient sensitivity to measure to the nearest 0.01 ft-lbf (0.014 N·m). Machining and maintaining the sharp notch may be most conveniently accomplished on a fly cutter with a single point carbide tool ground to a sharp point.

9.4 *Tension Testing of Sharply-Notched, Cylindrical Specimens*—The notch yield ratio, NYR, from a sharply-notched, cylindrical specimen has been shown to correlate reasonably well with plane strain fracture toughness, K_{Ic}. If a suitable correlation has been established for an alloy/product/temper between NYR and K_{Ic}, NYR may be used as a lot release criterion for that alloy/product/temper. Additional background and guidance on such use is presented in the literature.[4]

9.4.1 Testing of sharply-notched, cylindrical specimens shall be performed in accordance with Test Method E 602.

9.4.2 Both the standard ½-in. (12.5-mm) and 1¹⁄₁₆-in. (27-mm) are permitted. However, whenever product dimensions allow for use of the larger standard specimen, it is recommended, particularly for very tough alloys and tempers, because of its greater sensitivity to fracture toughness at high levels.

9.5 *Chevron Notch (Short Rod or Short Bar) Testing*—The plane-strain (chevron-notch) toughness K_{IvM}, has been shown to correlate reasonably well with the plane strain fracture toughness, K_{Ic}, and if a suitable correlation has been established for an alloy/product/temper between K_{IvM} and K_{Ic}, then K_{IvM} may be used as a lot release criterion for that alloy/product/temper. Additional background and guidance on such use is presented in the literature.[5]

9.5.1 Testing and analysis of short-rod or short-bar specimens to obtain K_{IvM} shall be performed in accordance with Test Method E 1304. The standard chevron notch specimens (short-rod or short-bar specimens 1.00-in. (25.4-mm) in diameter or 1.00-in. (25.4-mm) in width are recommended.

9.5.2 The plane-strain (chevron-notch) toughness, K_{IvM}, may also be used as a direct quantitative measure of fracture toughness[6] when permitted by the material specification or by agreement between the purchaser and supplier. If used for direct measurement of fracture toughness rather than for correlation purposes, fracture toughness minimums for K_{IvM} should be established using the specimens and procedures of Test Method E 1304 as they may differ significantly from minimums for K_{Ic} established using Test Method E 399.

NOTE 5—Test Method E 1304 can be employed as an alternative to Test Method E 399. Two relatively attractive features of the chevron notch test method are fatigue precracking is not required and the small specimen volume.

10. Report

10.1 The test record shall include all information required by the applicable test method(s).

10.2 The complete test record is not normally required for material certification and lot release purposes. Such records are usually retained by the producer for future audits by the purchaser.

10.3 *Rounding*—For the purpose of determining conformance with a specified limit in a material or product specification, the value of the fracture toughness or screening test indices obtained from the applicable test shall be rounded "to the nearest unit" in the last right hand significant digit used in expressing the limiting value in accordance with the rounding method of Practice E 29. For a limit specified as a whole number, all digits shall be considered significant including zeros.

10.4 *Replacement Tests*—The test result from a fracture toughness or screening test specimen may be discarded and a replacement test performed when: *(1)* the specimen was machined incorrectly, *(2)* the test procedure was incorrect, or *(3)* the test machine malfunctioned.

10.5 *Retests of Fracture Toughness Tests*—Retests for direct measures of fracture toughness in Section 8 shall be performed and interpreted in accordance with the applicable material specification or as otherwise agreed upon between the purchaser and supplier. If there is no specific provision for retests, and one or more test results fail to conform with the requirements of the material specification for reasons other than those in 10.4 after rounding in accordance with 10.3, the lot represented by that test result shall be subject to rejection, except as provided below:

10.5.1 For each specimen that failed, test at least two additional specimens at the specified test location from an area in the original sample adjacent to the failing specimen, or

10.5.2 For each specimen that failed, test an additional specimen at the specified location from at least two other samples.

10.5.3 If any retest fails, the lot shall be subject to rejection, except that the lot may be resubmitted for testing provided the producer has reworked the lot, as necessary, to correct the deficiencies.

10.6 *Retests of Screening Tests*—Retests of screening tests in Section 9 are not permitted. If a screening tests result falls below the critical indicator value as illustrated in Fig. 1, testing with the primary fracture toughness test method is required for material release purposes.

11. Keywords

11.1 aluminum alloys; fracture toughness; plane strain; plane stress; quality assurance; screening tests

[4] Jones, M. H., et al., "Sharply Notched Cylindrical Tension Specimen for Screening Plane-Strain Fracture Toughness," *Developments in Fracture Mechanics Test Methods Standardization, ASTM STP 632*, ASTM, 1977, pp. 115–152.

[5] Bray, J. W., "Use of Chevron Notch Short Bar Test to Guarantee Fracture Toughness for Lot-Release in Aluminum Alloys," *Chevron-Notch Fracture Test Experience: Metals and Non-Metals, ASTM STP 1172*, ASTM, 1992, pp. 131–143.

[6] Rolfe, S. T. and Novak, S. R. "Review of Developments in Plane Strain Fracture Toughness Testing," *ASTM STP 463*, ASTM, Sept. 1970, pp. 124–159.

SUMMARY OF CHANGES

Committee B07 has identified the location of selected changes to this standard since the last revision (B 646 – 03).

(1) Separated recommendations and requirements for test method selection (Sections 6 and 7) from recommendations and requirements for testing and interpretation (Sections 8 and 9).
(2) Added information on K_{app} testing (3.2.5, 8.1, and subparas.).
(3) Added additional M(T) specimen sizes (8.1.1).
(4) Added information on use of R-curve test for quality control purposes (8.2 and subparas.).
(5) Added maximum allowable K_{fmax} for fatigue precracking (8.1.2 and 8.4.2).
(6) Added minimum recommended width for KR_{25} testing (8.4.1).
(7) Added Section 10 on reporting, replacement testing and retesting.