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# Standard Test Method for Determination of Reference Temperature, $T_o$, for Ferritic Steels in the Transition Range[1]

This standard is issued under the fixed designation E1921; 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.

## 1. Scope

1.1 This test method covers the determination of a reference temperature, $T_o$, which characterizes the fracture toughness of ferritic steels that experience onset of cleavage cracking at elastic, or elastic-plastic $K_{Jc}$ instabilities, or both. The specific types of ferritic steels (3.2.1) covered are those with yield strengths ranging from 275 to 825 MPa (40 to 120 ksi) and weld metals, after stress-relief annealing, that have 10 % or less strength mismatch relative to that of the base metal.

1.2 The specimens covered are fatigue precracked single-edge notched bend bars, SE(B), and standard or disk-shaped compact tension specimens, C(T) or DC(T). A range of specimen sizes with proportional dimensions is recommended. The dimension on which the proportionality is based is specimen thickness.

1.3 Median $K_{Jc}$ values tend to vary with the specimen type at a given test temperature, presumably due to constraint differences among the allowable test specimens in 1.2. The degree of $K_{Jc}$ variability among specimen types is analytically predicted to be a function of the material flow properties (**1**)[2] and decreases with increasing strain hardening capacity for a given yield strength material. This $K_{Jc}$ dependency ultimately leads to discrepancies in calculated $T_o$ values as a function of specimen type for the same material. $T_o$ values obtained from C(T) specimens are expected to be higher than $T_o$ values obtained from SE(B) specimens. Best estimate comparisons of several materials indicate that the average difference between C(T) and SE(B)-derived $T_o$ values is approximately 10°C (**2**). C(T) and SE(B) $T_o$ differences up to 15°C have also been recorded (**3**). However, comparisons of individual, small datasets may not necessarily reveal this average trend. Datasets which contain both C(T) and SE(B) specimens may generate $T_o$ results which fall between the $T_o$ values calculated using solely C(T) or SE(B) specimens. It is therefore strongly recommended that the specimen type be reported along with the derived $T_o$ value in all reporting, analysis, and discussion of results. This recommended reporting is in addition to the requirements in 11.1.1.

1.4 Requirements are set on specimen size and the number of replicate tests that are needed to establish acceptable characterization of $K_{Jc}$ data populations.

1.5 $T_o$ is dependent on loading rate. $T_o$ is evaluated for a quasi-static loading rate range with $0.1 < dK/dt < 2$ MPa√m/s. Slowly loaded specimens ($dK/dt < 0.1$ MPa√m) can be analyzed if environmental effects are known to be negligible. Provision is also made for higher loading rates ($dK/dt > 2$ MPa√m/s) in Annex A1.

1.6 The statistical effects of specimen size on $K_{Jc}$ in the transition range are treated using the weakest-link theory (**4**) applied to a three-parameter Weibull distribution of fracture toughness values. A limit on $K_{Jc}$ values, relative to the specimen size, is specified to ensure high constraint conditions along the crack front at fracture. For some materials, particularly those with low strain hardening, this limit may not be sufficient to ensure that a single-parameter ($K_{Jc}$) adequately describes the crack-front deformation state (**5**).

1.7 Statistical methods are employed to predict the transition toughness curve and specified tolerance bounds for 1T specimens of the material tested. The standard deviation of the data distribution is a function of Weibull slope and median $K_{Jc}$. The procedure for applying this information to the establishment of transition temperature shift determinations and the establishment of tolerance limits is prescribed.

1.8 This test method assumes that the test material is macroscopically homogeneous such that the materials have uniform tensile and toughness properties. The fracture toughness evaluation of nonuniform materials is not amenable to the statistical analysis methods employed in the main body of this test method. Application of the analysis of this test method to an inhomogeneous material will result in an inaccurate estimate of the transition reference value $T_o$ and non-conservative confidence bounds. For example, multipass weldments can create heat-affected and brittle zones with localized properties that are quite different from either the bulk material or weld. Thick section steels also often exhibit some variation in

[1] This test method is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of E08.07 on Fracture Mechanics.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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