Fracture Toughness Test Procedure
(ASTM E 399)

1. Select specimen – type and size :

   - compact tension, three point bend, etc.
   - function of – application, material form, ASTM criteria, available stress intensity solutions

2. Machine specimen; measure specimen; prepare notch region for crack observation (low power magnification, e.g., 3X - 10X).

3. Fatigue precrack specimen (fatigue crack length typically > 0.05 in. long).

4. Properly instrument specimen; load to failure, recording load vs. clip-gage-displacement.

5. Measure crack length on broken specimen at five positions across thickness. Calculate crack average length a_{avg}.

6. Analyze load-displacement test record. Draw tangent line, extrapolating initial loading line. Draw 95 % secant line. Determine P_5, P_Q, and P_{max}.

7. Calculate conditional K_Q value, using a_{avg} and P_Q.

8. Check validity of K_Q value using the following criteria :

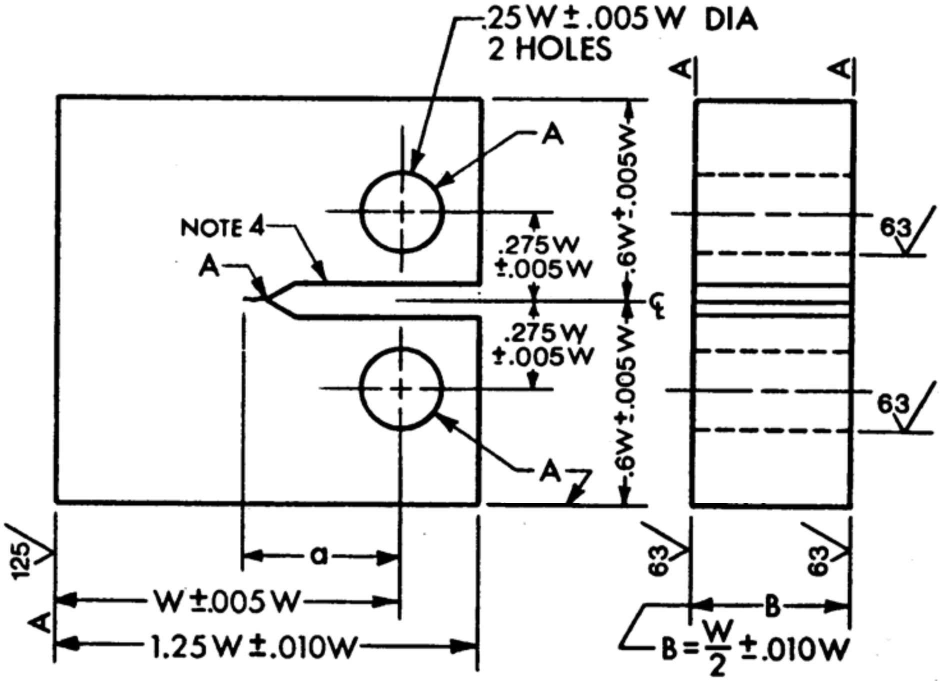
   $a \geq 2.5 (K_Q / \sigma_{ys})^2$

   $B \geq 2.5 (K_Q / \sigma_{ys})^2$

   $(P_{max} / P_Q) \leq 1.10$

   others : precracking loads, precrack length, precrack straightness, etc.

9. If all criteria are met, then the K_Q value is now identified as fracture toughness K_{Ic}.



NOTE 1—*A* surfaces shall be perpendicular and parallel as applicable to within 0.002 *W* TIR.

NOTE 2—The intersection of the crack starter notch tips with the two specimen surfaces shall be equally distant from the top and bottom edges of the specimen within 0.005 *W*.

NOTE 3—Integral or attachable knife edges for clip gage attachment to the crack mouth may be used (see Fig. 5 and Fig. 6).

NOTE 4—For starter notch and fatigue crack configuration see Fig. 7.

FIG. A4.1 Compact Specimen C (T) Standard Proportions and Tolerances

mm) or 0.1 %, whichever is larger, at not less than three positions near the notch location, and record the average value.

A4.4.1.1 For general requirements concerning specimen measurement see 8.2.

A4.4.2 *Compact Specimen Testing*—When assembling the loading train (clevises and their attachments to the tensile machine) care should be taken to minimize eccentricity of loading due to misalignments external to the clevises. To obtain satisfactory alignment keep the centerline of the upper and lower loading rods coincident within 0.03 in. (0.76 mm) during the test and center the specimen with respect to the clevis opening within 0.03 in. (0.76 mm).

A4.4.2.1 Load the compact specimen at such a rate that the rate of increase of stress intensity is within the range 30 to 150 ksi·in.$^{1/2}$/min (0.55 to 2.75 MPa·m$^{1/2}$/s) corresponding to a loading rate for a standard ($W/B = 2$) 1-in. thick specimen between 4500 and 22 500 lbf/min (0.34 to 1.7 kN/s).

A4.4.2.2 For details concerning recording of the test record, see 8.4.

A4.5 Calculations

A4.5.1 For general requirements and procedures in interpretation of the test record see 9.1.

A4.5.2 For a description of the validity requirements in terms of limitations on P_{max}/P_Q and the specimen size requirements see 9.1.2 and 9.1.3.

A4.5.3 *Calculation of K_Q*—For the compact specimen calculate K_Q in units of ksi·in.$^{1/2}$ (MPa·m$^{1/2}$) from the following expression (Note A4.1)

$$K_Q = (P_Q/BW^{1/2})\cdot f(a/W) \quad \text{(A4.1)}$$

where:

$$f(a/W) = \frac{(2 + a/W)(0.886 + 4.64a/W - 13.32a^2/W^2 + 14.72a^3/W^3 - 5.6a^4/W^4)}{(1 - a/W)^{3/2}} \quad \text{(A4.2)}$$

where:

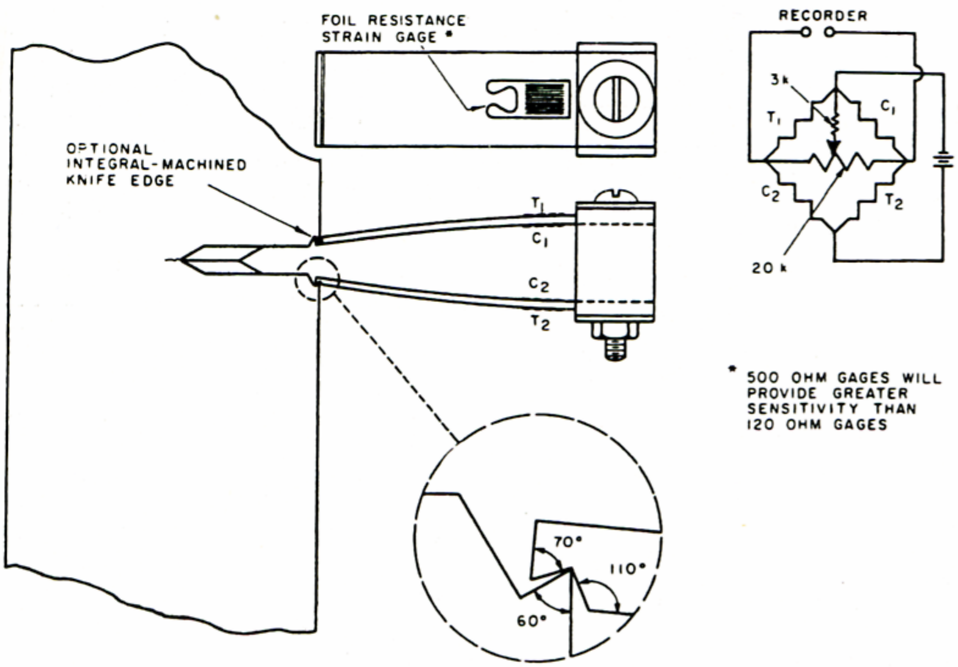
P_Q = load as determined in 9.1.1, klbf (kN),
B = specimen thickness as determined in 8.2.1, in. (cm),
W = specimen width, as determined in A4.4.1, in. (cm), and
a = crack length as determined in 8.2.2 and A4.4.1, in. (cm).

NOTE A4.1—This expression is considered to be accurate within ±0.5 % over the range of a/W from 0.2 to 1 (**12**) (**13**).

A4.5.3.1 To facilitate calculation of K_Q, values of f (a/W) are tabulated below for specific values of a/W.

Compact Specimens

a/W	f(a/W)	a/W	f(a/W)
0.450	8.34	0.500	9.66
0.455	8.46	0.505	9.81
0.460	8.58	0.510	9.96
0.465	8.70	0.515	10.12
0.470	8.83	0.520	10.29
0.475	8.96	0.525	10.45
0.480	9.09	0.530	10.63
0.485	9.23	0.535	10.80
0.490	9.37	0.540	10.98
0.495	9.51	0.545	11.17
		0.550	11.36



NOTE – Gage details are given in the Annex.

FIG. 4 Double–Cantilever Clip-In Displacement Gage Showing Mounting by Means of Integral Knife Edges (Gage Design Details are Given in Annex A1)

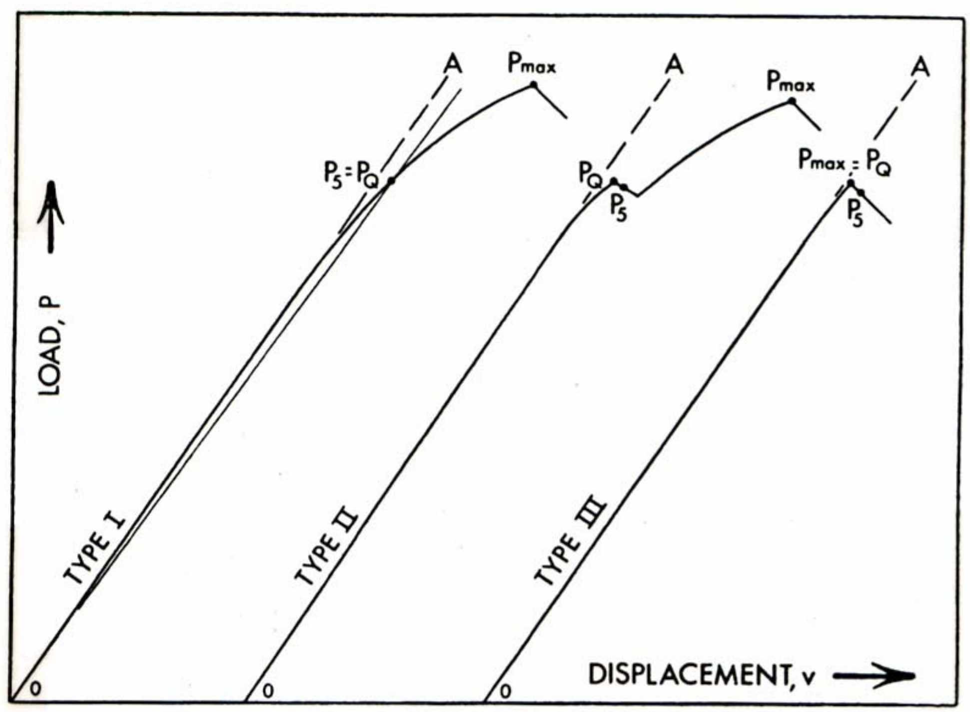


FIG. 8 Principal Types of Load-Displacement Records

Interpretation of results. Once the specimen is broken, the fracture surfaces are examined and the average crack depth (**a**) is carefully measured. The mating fracture surfaces in a compact tension specimen are shown in Figure 9-14.

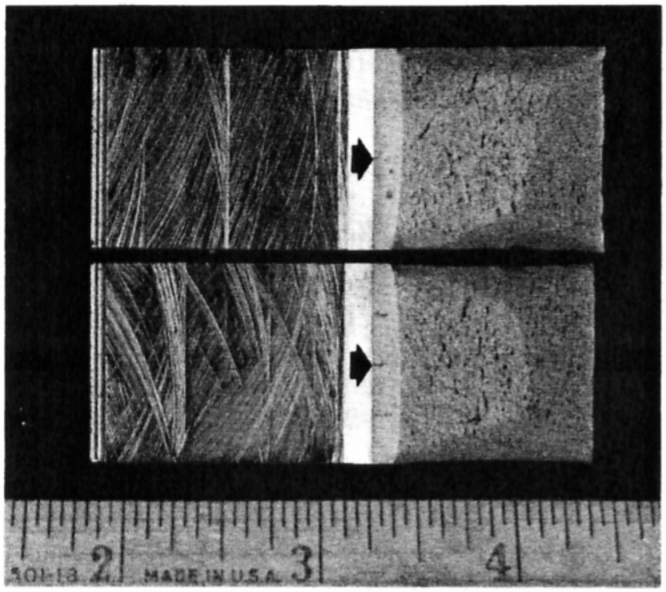


Figure 9-14 Mating halves of fractured compact tension specimen ($B = 1$ in.). This view shows the depth and shape of fatigue precrack (light gray region denoted with arrow).

This figure shows a view of the machined notch and the subsequent cracked portions. The depth of the precrack is measured in three locations, at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ of the thickness (B), as shown in Figure 9-15. The average value of **a** is used in the fracture toughness expression [equation (9-10)]. However, if the difference between any two measurements of **a** exceeds 5% of the average value (indicating a skewed crack front), the test is considered *invalid* according to ASTM Standard E399.

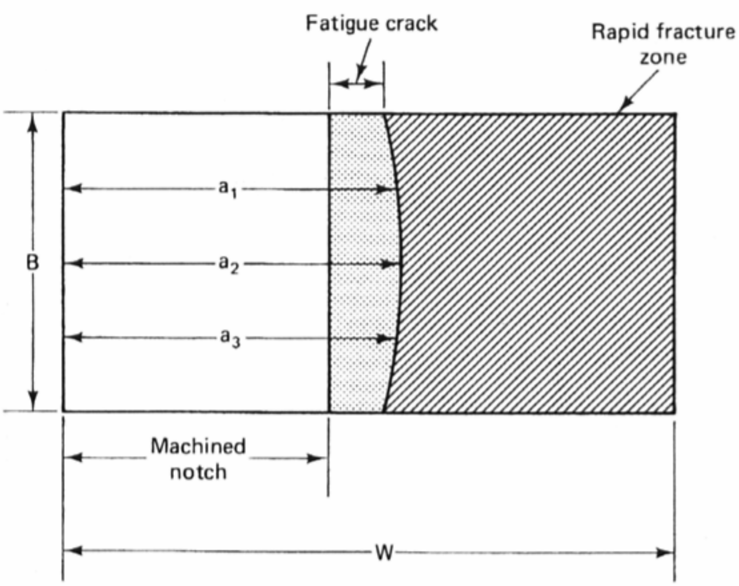


Figure 9-15 Schematic of fracture surface showing various important regions and dimensions.