Designation: E 1877 – 00

Standard Practice for Calculating Thermal Endurance of Materials from Thermogravimetric Decomposition Data[1]

This standard is issued under the fixed designation E 1877; 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 practice covers additional treatment of the Arrhenius activation energy data determined by Test Method E 1641 to develop a thermal endurance curve and derive a relative thermal index for materials.

1.2 This practice is generally applicable to materials with a well-defined decomposition profile, namely a smooth, continuous mass change with a single maximum rate.

1.3 There is no ISO standard equivalent to this practice.

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:*

E 473 Terminology Relating to Thermal Analysis[2]

E 1142 Terminology Relating to Thermophysical Properties[2]

E 1641 Test Method for Decomposition Kinetics by Thermogravimetry[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *failure*, *n*—change in some chemical, physical, mechanical, electrical or other property of sufficient magnitude to make it unsuitable for a particular use.

3.1.2 *failure temperature* (T_f), *n*—the temperature at which a material fails after a selected time.

3.1.3 *relative thermal index (RTI)*, *n*—a measure of the thermal endurance of a material when compared with that of a control with proven thermal endurance characteristics. The RTI is also considered to be the maximum temperature below which the material resists changes in its properties over a defined period of time. In the absence of comparison data for a control material, a time-to-failure of 60 000 h has been arbitrarily selected for measuring RTI. The RTI is therefore, the failure temperature, T_f, obtained from the thermal endurance curve.

4. Summary of Practice

4.1 The Arrhenius activation energy obtained from Test Method E 1641 is used to construct the thermal endurance curve of a material from which an estimate of lifetime at certain temperatures may be obtained.

5. Significance and Use

5.1 Thermogravimetry provides a rapid method for the determination of the temperature-decomposition profile of a material.

5.2 This practice is useful for quality control, specification acceptance and research.

5.3 This practice shall not be used for product lifetime predications unless a correlation between test results and actual lifetime has been demonstrated. In many cases, multiple mechanisms occur during the decomposition of a material, with one mechanism dominating over one temperature range, and a different mechanism dominating in a different temperature range. Users of this practice are cautioned to demonstrate for their system that any temperature extrapolations are technically sound.

6. Calculation

6.1 The following values obtained by Test Method E 1641 are used to calculate thermal endurance, estimated thermal life and failure temperature.

6.1.1 The following definitions apply to 6.1 and 6.3:

6.1.1.1 E = Arrhenius activation energy (J/mol),

6.1.1.2 R = Universal gas constant (= 8.314 510 J/(mol K)),

6.1.1.3 β = Heating rate (K/min),

6.1.1.4 β` = Heating rate nearest the mid-point of the experimental heating rates (K/min),

6.1.1.5 a = Approximation integral taken from Table 1,

6.1.1.6 α = Constant conversion value,

[1] This practice is under the jurisdiction of Committee E–37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.01 on Test Methods.

Current edition approved March 10, 2000. Published May 2000. Originally published as E 1877 – 97. Last previous edition E 1877 – 97.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

TABLE 1 Numerical Integration Constants

E/RT	*a*
8	5.3699
9	5.8980
10	6.4157
11	6.9276
12	7.4327
13	7.9323
14	8.4273
15	8.9182
16	9.4056
17	9.8900
18	10.3716
19	10.8507
20	11.3277
21	11.8026
22	12.2757
23	12.7471
24	13.2170
25	13.6855
26	14.1527
27	14.6187
28	15.0836
29	15.5474
30	16.0103
31	16.4722
32	16.9333
33	17.3936
34	17.8532
35	18.3120
36	18.7701
37	19.2276
38	19.6845
39	20.1408
40	20.5966
41	21.0519
42	21.5066
43	21.9609
44	22.4148
45	22.8682
46	23.3212
47	23.7738
48	24.2260
49	24.6779
50	25.1294
51	25.5806
52	26.0314
53	26.4820
54	26.9323
55	27.3823
56	27.8319
57	28.2814
58	28.7305
59	29.1794
60	29.6281

6.1.1.7 t_f = Estimated Thermal Life for a given value of α (min),

6.1.1.8 T_c = Temperature for the point of constant conversion for β (K), and

6.1.1.9 T_f = Failure Temperature for a give value of α (K).

NOTE 1—The precision of the calculation in this practice are exponentially dependent on the uncertainty of activation energy value used. Care should be taken to use only the most precise values of *E*.

6.2 Use Eq 1 or Eq 2[3] and trial values of T_f to plot the logarithm of estimated thermal life (t_f) versus reciprocal of T_f as, by example, shown in Fig. 1.

$$\log t_f = E / (2.303\, R\, T_f) + \log [E / (R\, \beta)] - a \qquad (1)$$

$$T_f = E / (2.303\, R\, [\log t_f - \log \{E / (R\, \beta) + a\}]) \qquad (2)$$

6.2.1 To calculate t_f, select the value for the temperature at the constant conversion point (T_c) for a heating rate (β) nearest the mid-point of the experimental heating rates. Use this value, along with the Arrhenius activation energy (E) to calculate the quantity $E/(R\, T_c)$ to select the value in Table 1[4, 5, 6]. Arbitrarily select a number of temperatures in the region of the chosen percent mass loss, indicative of failure, in the mass change curve at the midpoint heating rate. Calculate the logarithm of the thermal life from Eq 1. Plot the thermal endurance curve, as shown in Fig. 1, with thermal life on the ordinate and reciprocal of absolute temperature on the abscissa.

NOTE 2—The values for E and β may be obtained by the procedure described in Test Method E 1641.

6.3 The thermal endurance of two or more materials may be compared by calculating the relative thermal index (RTI) for each material. To compute RTI for each material; select some common thermal life for comparison, a typical value may be 60 000 h (6.8 years), insert that value (in minutes) and the appropriate activation energy for each material into Eq 2 to obtain T_f. This value of temperature is called the "relative thermal index (RTI) at the specified time". Materials with greater resistance to thermal decomposition will have a larger RTI.

7. Report

7.1 Report the following information:

7.1.1 If data other than that generated by Test Method E 1641 is used in these calculations, then include a description of the data source in the report,

7.1.2 Designation of the material under test, including the name of the manufacturer, the lot number, and supposed chemical composition when known, and

7.1.3 The calculated thermal life (t_f) and RTI values.

7.1.4 The specific dated version of this practice that is used.

8. Precision and Bias [7]

8.1 The precision and bias of these calculations depend on the precision and bias of the kinetic data used in them. To provide an example of the precision expected, thermal life was calculated by the procedure in this practice using data for poly(tetrafluoroethylene) from the interlaboratory study conducted to develop the precision and bias statement for Test Method E 1641. Extreme values of thermal life were calculated using an arbitrarily chosen value for temperature of 600 K and the extreme values of E corresponding to the 95 % confidence level from that interlaboratory study. The resulting calculated extreme values were 9 years and 3700 years for this material.

[3] Krizanovsky, L., and Mentlik, V., *J. Therm. Anal., 13*, 1978.

[4] Flynn, J.H., and Wall, L.A., *Polym. Lett., 4*, pp. 323–328, 1966.

[5] Flynn, J.H., *J. Therm. Anal., 27,* pp. 95–102, *1983*.

[6] Toop, D. J., *IEEE Trans. Elec. Insul, EI-6*, pp. 2–12, 1971.

[7] Copies of the references in footnotes 3–6 are on file at ASTM Headquarters. Request RR:E37–1024.