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Standard Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions[1]

This standard is issued under the fixed designation C1045; 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 provides the user with a uniform procedure for calculating the thermal transmission properties of a material or system from data generated by steady state, one dimensional test methods used to determine heat flux and surface temperatures. This practice is intended to eliminate the need for similar calculation sections in Test Methods C177, C335, C518, C1033, C1114 and C1363 and Practices C1043 and C1044 by permitting use of these standard calculation forms by reference.

1.2 The thermal transmission properties described include: thermal conductance, thermal resistance, apparent thermal conductivity, apparent thermal resistivity, surface conductance, surface resistance, and overall thermal resistance or transmittance.

1.3 This practice provides the method for developing the apparent thermal conductivity as a function of temperature relationship for a specimen from data generated by standard test methods at small or large temperature differences. This relationship can be used to characterize material for comparison to material specifications and for use in calculation programs such as Practice C680.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 This practice includes a discussion of the definitions and underlying assumptions for the calculation of thermal transmission properties. Tests to detect deviations from these assumptions are described. This practice also considers the complicating effects of uncertainties due to the measurement processes and material variability. See Section 7.

1.6 This practice is not intended to cover all possible aspects of thermal properties data base development. For new materials, the user should investigate the variations in thermal properties seen in similar materials. The information contained in Section 7, the Appendix and the technical papers listed in the References section of this practice may be helpful in determining whether the material under study has thermal properties that can be described by equations using this practice. Some examples where this method has limited application include: (*1*) the onset of convection in insulation as described in Reference (**1**); (*2*) while a phase change ~~of~~ is taking place in one of the insulation ~~system components such as a blowing gas in foam;~~ components causing an unsteady-state condition; and (*3*) the influence of heat flow direction and temperature difference changes for reflective insulations.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C168 Terminology Relating to Thermal Insulation

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

C335 Test Method for Steady-State Heat Transfer Properties of Pipe Insulation

C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

C680 Practice for Estimate of the Heat Gain or Loss and the Surface Temperatures of Insulated Flat, Cylindrical, and Spherical Systems by Use of Computer Programs

C1033 Test Method for Steady-State Heat Transfer Properties of Pipe Insulation Installed Vertically (Withdrawn 2003)[3]

[1] This practice is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

C1043 Practice for Guarded-Hot-Plate Design Using Circular Line-Heat Sources
C1044 Practice for Using a Guarded-Hot-Plate Apparatus or Thin-Heater Apparatus in the Single-Sided Mode
C1058 Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation
C1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus
C1199 Test Method for Measuring the Steady-State Thermal Transmittance of Fenestration Systems Using Hot Box Methods
C1363 Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

3. Terminology

3.1 *Definitions*— The definitions and terminology of this practice are intended to be consistent with Terminology C168. However, because exact definitions are critical to the use of this practice, the following equations are defined here for use in the calculations section of this practice.

3.2 *Symbols*—The symbols, terms and units used in this practice are the following:

A = specimen area normal to heat flux direction, m^2,
C = thermal conductance, $W/(m^2 \cdot K)$,
h_c = surface heat transfer coefficient, cold side, $W/(m^2 \cdot K)$,
h_h = surface heat transfer coefficient, hot side, $W/(m^2 \cdot K)$,
L = thickness of a slab in heat transfer direction, *m*,
L_p = metering area length in the axial direction, *m*,
q = one-dimensional heat flux (time rate of heat flow through metering area divided by the apparatus metering area A), W/m^2,
Q = time rate of one-dimensional heat flow through the metering area of the test apparatus, W,
r = thermal resistivity, $K \cdot m/K$,
r_a = apparent thermal resistivity, $K \cdot m/K$,
r_{in} = inside radius of a hollow cylinder, m,
r_{out} = outside radius of a hollow cylinder, m,
R = thermal resistance, $m^2 \cdot K/W$,
R_c = surface thermal resistance, cold side, $m^2 \cdot K/W$,
R_h = surface thermal resistance, hot side, $m^2 \cdot K/W$,
R_u = overall thermal resistance, $m^2 \cdot K/W$,
T = temperature, K,
T_1 = area-weighted air temperature 75 mm or more from the hot side surface, K,
T_2 = area-weighted air temperature 75 mm or more from the cold side surface, K,
T_c = area-weighted temperature of the specimen cold surface, K,
T_h = area-weighted temperature of specimen hot surface, K,
T_{in} = temperature at the inner radius, K,
T_m = specimen mean temperature, average of two opposite surface temperatures, $(T_h + T_c)/2$, K,
T_{out} = temperature at the outer radius, K,
ΔT = temperature difference, K,
$\Delta T_{a\text{-}a}$ = temperature difference, air to air, $(T_1 - T_2)$, K,
$\Delta T_{s\text{-}s}$ = temperature difference, surface to surface, $(T_h - T_c)$, K,
U = thermal transmittance, $W/(m^2 \cdot K)$, and
x = linear dimension in the heat flow direction, m,
λ = thermal conductivity, $W/(m \cdot K)$,
λ_a = apparent thermal conductivity, $W/(m \cdot K)$,
$\lambda(T)$ = functional relationship between thermal conductivity and temperature, $W/(m \cdot K)$,
λ_{exp} = experimental thermal conductivity, $W/(m \cdot K)$,
λ_m = mean thermal conductivity, averaged with respect to temperature from T_c to T_h, $W/(m \cdot K)$, (see sections 6.4.1 and Appendix X3).

NOTE 1—Subscripts *h* and *c* are used to differentiate between hot side and cold side surfaces.

3.3 *Thermal Transmission Property Equations:*

3.3.1 *Thermal Resistance, R*, is defined in Terminology C168. It is not necessarily a unique function of temperature or material, but is rather a property determined by the specific thickness of the specimen and by the specific set of hot-side and cold-side temperatures used to measure the thermal resistance.

$$R = \frac{A\,(T_h - T_c)}{Q} \tag{1}$$

3.3.2 *Thermal Conductance, C:*

$$C = \frac{Q}{A\,(T_h - T_c)} = \frac{1}{R} \tag{2}$$

NOTE 2—Thermal resistance, *R*, and the corresponding thermal conductance, *C*, are reciprocals; that is, their product is unity. These terms apply to specific bodies or constructions as used, either homogeneous or heterogeneous, between two specified isothermal surfaces.

3.3.3 Eq 1, Eq 2, Eq 3, Eq 5and Eq 7-13 are for rectangular coordinate systems only. Similar equations for resistance, etc. can be developed for a cylindrical coordinate system providing the difference in areas is considered. (See Eq 4 and Eq 6.) In practice, for cylindrical systems such as piping runs, the thermal resistance shall be based upon the pipe external surface area since that area does not change with different insulation thickness

3.3.4 *Apparent–Thermal conductivity,* λ_a, is defined in Terminology C168.

Rectangular coordinates:

$$\lambda_a = \frac{Q\,L}{A\,(T_h - T_c)} \tag{3}$$

Cylindrical coordinates:

$$\lambda_a = \frac{Q \ln(r_{out}/r_{in})}{2\pi L_p\,(T_{in} - T_{out})} \tag{4}$$

3.3.5 *Apparent Thermal Resistivity,* r_a, is defined in Terminology C168.

Rectangular Coordinates:

$$r_a = \frac{A\,(T_h - T_c)}{Q\,L} = \frac{1}{\lambda_a} \tag{5}$$

Cylindrical Coordinates:

$$r_a = \frac{2\pi L_p\,(T_{in} - T_{out})}{Q \ln(r_{out}/r_{in})} = \frac{1}{\lambda_a} \tag{6}$$

NOTE 3—The apparent thermal resistivity, r_a, and the corresponding thermal conductivity, λ_a, are reciprocals, that is, their product is unity. These terms apply to specific materials tested between two specified isothermal surfaces. For this practice, materials are considered homogeneous when the value of the thermal conductivity or thermal resistivity is not significantly affected by variations in the thickness or area of the sample within the normally used range of those variables.

3.4 *Transmission Property Equations for Convective Boundary Conditions:*

3.4.1 *Surface Thermal Resistance,* R_i, the quantity determined by the temperature difference at steady-state between an isothermal surface and its surrounding air that induces a unit heat flow rate per unit area to or from the surface. Typically, this parameter includes the combined effects of conduction, convection, and radiation. Surface resistances are calculated as follows:

$$R_h = \frac{A\,(T_1 - T_h)}{Q} \tag{7}$$

$$R_c = \frac{A\,(T_c - T_2)}{Q} \tag{8}$$

3.4.2 *Surface Heat Transfer Coefficient,* h_i, is often called the film coefficient. These coefficients are calculated as follows:

$$h_h = \frac{Q}{A\,(T_1 - T_h)} = \frac{1}{R_h} \tag{9}$$

$$h_c = \frac{Q}{A\,(T_c - T_2)} = \frac{1}{R_c} \tag{10}$$

NOTE 4—The surface heat transfer coefficient, h_i, and the corresponding surface thermal resistance, R_i, are reciprocals, that is, their product is unity. These properties are measured at a specific set of ambient conditions and are therefore only correct for the specified conditions of the test.

3.4.3 *Overall Thermal Resistance,* R_u—The quantity determined by the temperature difference, at steady-state, between the air temperatures on the two sides of a body or assembly that induces a unit time rate of heat flow per unit area through the body. It is the sum of the resistance of the body or assembly and of the two surface resistances and may be calculated as follows:

$$R_u = \frac{A\,(T_1 - T_2)}{Q} \tag{11}$$

$$= R_c + R + R_h$$

3.4.4 *Thermal Transmittance, U* (sometimes called overall coefficient of thermal transfer), is calculated as follows:

$$U = \frac{Q}{A\,(T_1 - T_2)} = \frac{1}{R_u} \quad (12)$$

The transmittance can be calculated from the thermal conductance and the surface coefficients as follows:

$$1/U = (1/h_h) + (1/C) + (1/h_c) \quad (13)$$

NOTE 5—Thermal transmittance, U, and the corresponding overall thermal resistance, R_u, are reciprocals; that is, their product is unity. These properties are measured at a specific set of ambient conditions and are therefore only correct for the specified conditions of the test.

4. Significance and Use

4.1 ASTM thermal test method descriptions are complex because of added apparatus details necessary to ensure accurate results. As a result, many users find it difficult to locate the data reduction details necessary to reduce the data obtained from these tests. This practice is designed to be referenced in the thermal test methods, thus allowing those test methods to concentrate on experimental details rather than data reduction.

4.2 This practice is intended to provide the user with a uniform procedure for calculating the thermal transmission properties of a material or system from standard test methods used to determine heat flux and surface temperatures. This practice is intended to eliminate the need for similar calculation sections in the ASTM Test Methods (C177, C335, C518, C1033, C1114, C1199, and C1363) by permitting use of these standard calculation forms by reference.

4.3 This practice provides the method for developing the thermal conductivity as a function of temperature for a specimen from data taken at small or large temperature differences. This relationship can be used to characterize material for comparison to material specifications and for use in calculations programs such as Practice C680.

4.4 Two general solutions to the problem of establishing thermal transmission properties for application to end-use conditions are outlined in Practice C1058. (Practice C1058 should be reviewed prior to use of this practice.) One is to measure each product at each end-use condition. This solution is rather straightforward, but burdensome, and needs no other elaboration. The second is to measure each product over the entire temperature range of application conditions and to use these data to establish the thermal transmission property dependencies at the various end-use conditions. One advantage of the second approach is that once these dependencies have been established, they serve as the basis for estimating the performance for a given product at other conditions. **Warning—** The use of a thermal conductivity curve developed in Section 6 must be limited to a temperature range that does not extend beyond the range of highest and lowest test surface temperatures in the test data set used to generate the curve.

5. Determination of Thermal Transmission Properties for a Specific Set of Temperature Conditions

5.1 Choose the thermal test parameter (λ or *r, R* or *C, U* or R_u) to be calculated from the test results. List any additional information required by that calculation i.e. heat flux, temperatures, dimensions. Recall that the selected test parameter might limit the selection of the thermal test method used in 5.2.

5.2 Select the appropriate test method that provides the thermal test data required to determine the thermal transmission property of interest for the sample material being studied. (See referenced papers and Appendix X1 for help with this determination.

5.3 Using that test method, determine the required steady-state heat flux and temperature data at the selected test condition.

NOTE 6—The calculation of specific thermal transmission properties requires that: (*1*) the thermal insulation specimen is homogeneous, as defined in Terminology C168 or, as a minimum, appears uniform across the test area; (*2*) the measurements are taken only after steady-state has been established; (*3*) the heat flows in a direction normal to the isothermal surfaces of the specimen; (*4*) the rate of flow of heat is known; (*5*) the specimen dimensions, that is, heat flow path length parallel to heat flow, and area perpendicular to heat flow, are known; and (*6*) both specimen surface temperatures (and equivalently, the temperature difference across the specimen) are known; and in the case of a hot box systems test, both air curtain temperatures must be known.

5.4 Calculate the thermal property using the data gathered in 5.2 and 5.3, and the appropriate equation in 3.3 or 3.4 above. The user of this practice is responsible for insuring that the input data from the tests conducted are consistent with the defined properties of the test parameter prior to parameter calculation. A review of the information in Section 7 will help in this evaluation. For example, data must be examined for consistency in such areas as heat flow stability, heat flow orientation, metering area, geometry limits, surface temperature definition and others.

5.5 Using the data from the test as described in 5.3, determine the test mean temperature for the thermal property of 5.4 using Eq 14:

$$T_m = (T_h + T_c)/2 \quad (14)$$

NOTE 7—The thermal transmission properties determined in 5.4 are applicable only for the conditions of the test. Further analysis is required using data from multiple tests if the relationship for the thermal transmission property variation with temperature is to be determined. If this relationship is required, the analysis to be followed is presented in Section 6.

5.6 *An Example: Computation of Thermal Conductivity Measured in a Two-Sided Guarded Hot Plate:*

5.6.1 For a guarded hot plate apparatus in the normal, double-sided mode of operation, the heat developed in the metered area heater passes through two specimens. To reflect this fact, Eq 3 for the operational definition of the mean thermal conductivity of the pair of specimens must be modified to read:

$$\lambda_{exp} = \frac{Q}{A\left[(\Delta T_{s-s}/L)_1 + (\Delta T_{s-s}/L)_2\right]} \tag{15}$$

where:

$(\Delta/T_{s-s}/L)_1$ = the ratio of surface-to-surface temperature difference to thickness for Specimen 1. A similar expression is used for Specimen 2.

5.6.2 In many experimental situations, the two temperature differences are very nearly equal (within well under 1 %), and the two thicknesses are also nearly equal (within 1 %), so that Eq 15 may be well approximated by a simpler form:

$$\lambda_{exp} = \frac{Q\ L_{average}}{2A\ \Delta T_{average}} \tag{16}$$

where:

$\Delta T_{average}$ = the mean temperature difference, $((\Delta T_{s\text{-}s})_1 + (\Delta\ T_{s\text{-}s})_2)/2$,
$L_{average}$ = $(L_1+L_2)/2$ is the mean of the two specimen thicknesses, and
$2\ A$ = occurs because the metered power flows out through two surfaces of the metered area for this apparatus. For clarity in later discussions, use of this simpler form, Eq 16, will be assumed.

NOTE 8—The mean thermal conductivity, λ_m, is usually not the same as the thermal conductivity, $\lambda\ (T_m)$, at the mean temperature T_m. The mean thermal conductivity, λ_m, and the thermal conductivity at the mean temperature, $\lambda\ (T_m)$, are equal only in the special case where $\lambda\ (T)$ is a constant or linear function of temperature (**2**); that is, when there is no curvature (nonlinearity) in the conductivity-temperature relation. In all other cases, the conductivity, λ_{exp}, as determined by Eq 3 is not simply a function of mean temperature, but depends on the values of both T_h and T_c. This is the reason the experimental value, λ_{exp}, of thermal conductivity for a large temperature difference is not, in general, the same as that for a small difference at the same mean temperature. The discrepancy between the mean thermal conductivity and the thermal conductivity at the mean temperature increases as ΔT increases. Treatment of these differences is discussed in Section 6.

5.6.3 When ΔT is so large that the mean (experimental) thermal conductivity differs from the thermal conductivity at the mean specimen temperature by more than 1 %, the derived thermal conductivity (Eq 3) shall be identified as a mean value, λ_m, over the range from T_c to T_h. For example, for the insulation material presented in X3.4, the 1 % limit is exceeded for temperature differences greater than 125 K at a temperature of 475 K. Reference (**2**) describes a method for establishing the actual λ versus T dependency from mean thermal conductivity measurements. Proofs of the above statements, along with some illustrative examples, are given in Appendix X3.

6. Determination of the Thermal Conductivity Relationship for a Temperature Range

6.1 Consult Practice C1058 for the selection of appropriate test temperatures. Using the appropriate test method of interest, determine the steady-state heat flux and temperature data for each test covering the temperature range of interest.

6.2 *When Temperature Differences are Small*—The use of Eq 3 or Eq 4 is valid for determining the thermal conductivity versus temperature only if the temperature difference between the hot and cold surfaces is small. For the purpose of this practice, experience with most insulation materials at temperatures above ambient shows that the maximum $\Delta\ T$ should be 25 K or 5 % of the mean temperature (K), whichever is greater. At temperatures below ambient, the temperature difference should be less than 10 percent of the absolute mean temperature. (See Reference (**2**)). The procedure given in section 6.2.1 is followed only when these temperature difference conditions are met. The procedure of section 6.3 is valid for all test data reduction.

NOTE 9—One exception to this temperature difference conditions is testing of insulation materials exhibiting inflection points due to the change of state of insulating gases. For these materials, testing shall be conducted with sufficiently small temperature differences and at closely spaced mean temperatures. The selection of test temperatures will depend on the vapor pressure versus temperature relationship of the gases involved and the ability of the test apparatus to provide accurate measurements at low temperature differences. Another exception occurs with the onset of convection within the specimen. At this point, the thermal conductivity of the specimen is no longer defined at these conditions and the thermal parameter of choice to be calculated is either thermal resistance or thermal conductance.

6.2.1 The quantities on the right-hand side of Eq 3 are known for each data point; from these quantities $\lambda(T)$ may be calculated if ΔT is sufficiently small (see 6.2), for normal insulation applications. The value of $\lambda\ (T)$ so obtained is an approximation, its accuracy depends on the curvature (non-linearity) of the thermal conductivity-temperature relationship (**2**). It is conventional to associate the value of λ_{exp} obtained from Eq 16 with the mean temperature T_m at the given data point. For data obtained at a number of mean temperatures, a functional dependence of λ with T may be obtained, with functional coefficients to be determined from the data. In order to apply a least squares fit to the data, the number of data points shall be greater than the number of coefficients in the function to obtain the functional dependence of the thermal conductivity $\lambda\ T$ on temperature, T. The accuracy of the coefficients thus obtained depend not only on the experimental imprecision, but also on the extent to which the thermal conductivity-temperature relationship departs from the true relationship over the temperature range defined by the isothermal boundaries of the specimen during the tests.

6.3 *Computation of Thermal Conductivity When Temperature Differences are Large*—The following sections apply to all testing results and are specifically required when the temperature difference exceeds the limits stated in 6.2. This situation typically occurs during measurements of thermal transmission in pipe insulation, Test Method C335, but may also occur with measurements using other apparatus. Eq 17 and 18 are developed in Appendix X2, but are presented here for continuity of this practice.

6.3.1 The dependence of λ on T for flat-slab geometry is:

$$\lambda_{\mathrm{m}} = \frac{1}{\Delta T}\int_{T_c}^{T_h} \lambda(T)\ \delta T$$

or;

$$\lambda_{\mathrm{m}} = QL/[2A\ (T_h - T_c)] \tag{17}$$

The quantities T_h, T_c, Q, and $(L/2A)$ on the right-hand side are known for each data point obtained by the user.

6.3.2 The dependence of λ on T for cylindrical geometry is:

$$\lambda_{\mathrm{m}} = \frac{1}{\Delta T}\int_{T_{out}}^{T_{in}} \lambda(T)\ \delta T$$

or;

$$\lambda_{\mathrm{m}} = \frac{Q\ln(r_{out}/r_{in})}{2\pi L_p\,(T_{in} - T_{out})} \tag{18}$$

The quantities T_{in},T_{out},Q, $1n\ (r_{out}/r_{in})$ and $2\pi\ L_p$ on the right-hand side, are known for each data point obtained by the user.

6.4 *Thermal Conductivity Integral (TCI) Method*—To obtain the dependence of thermal conductivity on temperature from Eq 17 or Eq 18, a specific functional dependence to represent the conductivity-temperature relation must first be chosen. This Practice recommends that the functional form of the describing equation closely describe the physical phenomena governing the heat transfer through the sample. In addition, this functional form must be continuous over the temperature range of use. This will avoid potential problems during data fitting and integration. (See Note 10.) While not absolutely necessary, choosing the physically correct equation form can provide better understanding of the physical forces governing the heat flow behavior. After the form of the thermal conductivity equation is chosen, steps 6.4.1 – 6.4.3 are followed to determine the coefficients for that equation.

6.4.1 Integrate the selected thermal conductivity function with respect to temperature. For example, if the selected function $\lambda(T)$ were a polynomial function of the form

$$\lambda(T) = a_o + a_n T^n + a_m T^m, \tag{19}$$

then, from Eq 18, the temperature-averaged thermal conductivity would be:

$$\lambda_{\mathrm{m}} = a_o + \frac{a_n\,(T_h^{n+1} - T_c^{n+1})}{(n+1)\,(T_h - T_c)} + \frac{a_{\mathrm{m}}\,(T_h^{\mathrm{m}+1} - T_c^{\mathrm{m}+1})}{(\mathrm{m}+1)\,(T_h - T_c)} \tag{20}$$

6.4.2 By means of any standard least-squares fitting routine, the right-hand side of Eq 20 is fitted against the values of experimental thermal conductivity, λ_{exp}. This fit determines the coefficients (a_o,a_n,a_m) for the selected n and m in the thermal conductivity function, Eq 19 in this case.

6.4.3 Use the coefficients obtained in 6.4.2 to describe the assumed thermal conductivity function, Eq 19. Each data point is then conventionally plotted at the corresponding mean specimen temperature. When the function is plotted, it may not pass exactly through the data points. This is because each data point represents mean conductivity, λ_{m}, and this is not equal to the value of the thermal conductivity, $\lambda\ (T_{\mathrm{m}})$, at the mean temperature. The offset between a data point and the fitted curve depends on the size of test ΔT and on the nonlinearity of the thermal conductivity function.

NOTE 10—Many equation forms other than Eq 19 can be used to represent the thermal conductivity function. If possible, the equation chosen to represent the thermal conductivity versus temperature relationship should be easily integrated with respect to temperature. However, in some instances it may be desirable to choose a form for $\lambda(T)$ that is not easily integrated. Such equations may be found to fit the data over a much wider range of temperature. Also, the user is not restricted to the use of polynomial equations to represent $\lambda(T)$, but only to equation forms that can be integrated either analytically or numerically. In cases where direct integration is not possible, one can carry out the same procedure using numerical integration.

6.5 *TCI Method—A Summary*—The thermal conductivity integral method of analysis is summarized in the following steps:

6.5.1 Measure several sets of λ_{exp}, T_h, and T_c over a range of temperatures.

6.5.2 Select a functional form for $\lambda(\ T)$ as in Eq 19, and integrate it with respect to temperature to obtain the equivalent of Eq 20.

6.5.3 Perform a least-squares fit to the experimental data of the integral of the functional form obtained in 6.5.2 to obtain the best values of the coefficients.

6.5.4 Use these coefficients to complete the $\lambda(T)$ equation as defined in 6.5.2. Remember that the thermal conductivity equation derived herein is good only over the range of temperatures encompassed by the test data. Extrapolation of the test results to a temperature range not covered by the data is not acceptable.

7. Consideration of Test Result Significance

7.1 A final step in the analysis and reporting of test results requires that the data be reviewed for significance and accuracy. It is not the intent of this practice to cover all aspects of the strategy of experimental design, but only to identify areas of concern.