Designation: ~~E2253 – 11~~ E2253 – 16

Standard Test Method for
Temperature and Enthalpy Measurement Validation of Differential Scanning Calorimeters[1]

This standard is issued under the fixed designation E2253; 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~~ Scope*

1.1 This test method provides procedures for validating temperature and enthalpy measurements of differential scanning calorimeters (DSC) and analytical methods based upon the measurement of temperature or enthalpy (or heat), or both, by DSC. Performance parameters determined include temperature and calorimetric repeatability (precision), detection limit, quantitation limit, linearity, and bias. This test method is applicable to exothermic events.

1.2 Validation of apparatus performance and analytical methods is requested or required for quality initiatives or where results may be used for legal purposes.

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

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]
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E473 Terminology Relating to Thermal Analysis and Rheology
E967 Test Method for Temperature Calibration of Differential Scanning Calorimeters and Differential Thermal Analyzers
E968 Practice for Heat Flow Calibration of Differential Scanning Calorimeters
E1142 Terminology Relating to Thermophysical Properties
E1860 Test Method for Elapsed Time Calibration of Thermal Analyzers
E1970 Practice for Statistical Treatment of Thermoanalytical Data
E2161 Terminology Relating to Performance Validation in Thermal Analysis and Rheology
2.2 *FDA Publications:*[3]
Q2B Validation of Analytical Procedures Methodology, 62 FR 27464, May 19, 1997

3. Terminology

3.1 Technical terms used in this standard are defined in Practice E177 and in Terminologies E473, E1142, and E2161 including *analyte, detection limit, differential scanning calorimetry, enthalpy, extrapolated onset value (temperature), linearity, mean, precision, quantitation limit, relative standard deviation, repeatability, standard deviation, thermal curve*, and *validation*.

4. Summary of Test Method

4.1 Temperature and time are the primary independent parameters and heat flow is the primary dependent experimental parameter provided by DSC. Integration of heat flow, as a function of time, yields enthalpy (heat).
4.1.1 Time, measured by the DSC apparatus, shall conform to better than 0.1 % verified by Test Method E1860 and reported.

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[1] This test method is under the jurisdiction of ASTM Committee E37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.10 on Fundamental, Statistical and Mechanical Properties.
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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] Available from Food and Drug Administration (FDA), 10903 New Hampshire Ave., Silver Spring, MD 20993-0002, http://www.fda.gov.

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

4.1.2 Temperature is directly measured by a temperature sensor that is an integral part of the differential scanning calorimetry apparatus.

4.1.3 Heat flow, a measured value, is validated by its integration over time to obtain the desired calorimetric (enthalpic) information of interest.

4.2 Calorimetric validation of a differential scanning calorimetric apparatus at a single temperature is performed using the indium metal melt as an analyte.

4.3 Validation of a DSC method based upon enthalpic measurement may be performed using the test specimen as the analyte.

4.4 The enthalpy of three (or more) specimens (nominally representing the maximum, midpoint and minimum of the range of the test method) are measured in triplicate (or more). A fourth blank specimen, containing no analyte, is also measured in triplicate.

Note 1—Repeatability is determined by performing a sufficient number of determinations to calculate statistically valid estimates of the standard deviation or relative standard deviation of the measurement.

4.4.1 Calorimetric linearity and bias are determined from the best-fit (linear regression) straight-line correlation of the results from measurements of the three (or more) specimens.

4.4.2 Calorimetric detection limit and quantitation limit are determined from the standard deviation of the blank determination.

4.4.3 Calorimetric repeatability is determined from the repeatability measurement of the three (or more) specimens.

4.5 The temperature validation of a differential scanning calorimetric apparatus is performed at three temperatures using indium, bismuth, and zinc metal melts as an analyte (see Section 7).

4.5.1 The melting temperature of three (or more) materials representing the maximum, midpoint, and minimum of the temperature range of the test method are measured in triplicate (or more) (see Note 1).

4.5.2 Temperature linearity and bias are determined from the best-fit (linear regression) straight-line correlation of the results from the temperature measurements at the three (or more) temperatures.

4.5.3 Temperature repeatability, detection limit and quantitation limit are determined from the standard deviation of the replicate temperature measurements.

5. Significance and Use

5.1 This test method may be used to determine and validate the performance of a particular DSC apparatus.

5.2 This test method may be used to determine and validate the performance of a particular method based upon a DSC temperature and enthalpic measurement, or both.

5.3 This test method may be used to determine the repeatability of a particular apparatus, operator, or laboratory.

5.4 This test method may be used for specification and regulatory compliance purposes.

6. Apparatus

6.1 *Differential Scanning Calorimeter (DSC)*—The essential instrumentation required to provide the minimum differential scanning calorimetric capability for this test method includes:

6.1.1 *DSC Test Chamber,* composed of:

6.1.1.1 *Furnace(s),* to provide uniform controlled heating or cooling of a specimen and reference to a constant temperature or at a constant rate within the applicable temperature range of the test method.

6.1.1.2 *Temperature Sensor,* to provide an indication of the specimen temperature to readability required.

6.1.1.3 *Differential Sensor,* to detect a heat flow difference between the specimen and reference.

6.1.1.4 A means of sustaining a test chamber environment of an inert purge gas at a rate of 10 to 50 mL/min ± 10 %.

Note 2—Typically, 99+ % pure nitrogen (or other inert gas, such as argon or helium) is employed when oxidation in air is a concern. Unless the effects of moisture are to be studied, the use of a dry purge gas is recommended, especially for operation at subambient temperatures.

6.1.2 *Temperature Controller,* capable of executing a specific temperature program by operating the furnace(s) between selected temperature limits at a rate of temperature change constant to ±1 % or at an isothermal temperature constant to ±0.5°C.

6.1.3 *Data Collection Device,* to provide a means of acquiring, storing, and displaying measured or calculated signals, or both. The minimum output signals required for differential scanning calorimetry are heat flow, temperature, and time.

6.1.4 *Containers,* (pans, crucibles, vials, lids, closures, seals, etc.) that are inert to the specimen and reference materials and that are of suitable structural shape and integrity to contain the specimen and reference in accordance with the specific requirements of the test method.

6.2 *Balance,* of 100 mg or greater capacity to weigh specimens and containers to ±1 μg.

Note 3—A balance of this high precision is required so that weighing imprecision is not part of the overall method imprecision.

7. Reagents and Materials

7.1 *Indium (In) Metal,* 99.99+ % purity, preferably a certified reference material for which the melting temperature and enthalpy of fusion are known.

7.2 *Bismuth (Bi) Metal,* 99.99+ % purity, preferably a certified reference material for which the melting temperature is known.

7.3 *Zinc (Zn) Metal,* 99.99+ % purity, preferably a certified reference material for which the melting temperature is known.

8. Calibration and Standardization

8.1 After turning the power on, allow the instrument to equilibrate for at least one hour prior to any measurements.

8.2 Perform any cleaning and calibration procedures described by the manufacturer in the apparatus Operator's Manual.

8.3 If not previously established, perform temperature and heat flow calibrations according to ~~Practices~~ Test Method E967 and Practice E968 respectively, using the same purge gas, purge gas flow rate and heating rate (here ~~10 °C~~10°C/min~~/min~~) to be used for validation experiments.

8.4 If not previously established, obtain the instrument's elapsed time conformance using Test Method E1860.

9. Procedure for Determining Calorimetric Repeatability, Detection Limit, Quantitation Limit, Linearity, and Bias

9.1 This process involves characterizing, in triplicate, a blank and three (or more) test specimens taken to represent the low, medium and high extremes of the range over which performance is to be validated.

NOTE 4—The details of this procedure are written using indium as an analyte. For validation of an enthalpic method, test specimens representing the range of that method shall be used, and steps 9.2 to 9.7 replaced with the enthalpic method procedure.

9.2 Prepare three (or more) indium test specimens covering the enthalpy or mass range of the tests. Nominal mass values might be 1, 10, and 20 mg. Measure the mass of each of these specimens to the nearest 1 µg and record as M_{min}, M_{mid}, and M_{max}. Enclose each test specimen within clean specimen containers and lids. Also prepare a blank specimen that contains no analyte but otherwise is similar to the specimens prepared above.

NOTE 5—Most thermoanalytical methods cover 1.5 to 2 decades of range. The mass values selected should be approximately equally distributed over the anticipated range. Other masses and mass ranges may be used but shall be reported.

9.3 Load the largest specimen into the instrument chamber, purge the chamber with dry nitrogen (or other inert gas) at a flow rate of 10 to 50 mL/min ± 10 % throughout the experiment. An empty sample specimen container is loaded in the reference position.

9.4 Erase any thermal history in the test specimen by heating the specimen to ~~180 °C,~~180°C, then cool at ~~5 °C~~5°C/min~~/min~~ to ~~120 °C.~~120°C. The thermal curve need not be recorded.

9.5 Equilibrate at ~~120 °C~~120°C for one minute.

9.6 Heat the test specimen at ~~10 °C~~10°C/min~~/min~~ through the indium melting transition to ~~180 °C~~180°C and record the thermal curve.

NOTE 6—Other heating rates may be used but shall be reported.

9.7 Cool the test specimen to ~~120° C~~120°C at 5°C/min, then cool to ambient temperature at any convenient rate. The thermal curve need not be recorded.

9.8 Construct a baseline for the melting endotherm by selecting a point on the curve immediately before and another immediately after the endotherm. Record the temperatures of these two points as T_1 and T_2. Construct a linear baseline between the two points (see Fig. 1).

9.9 Integrate, as a function of time, the heat flow described by the constructed baseline and the melting endotherm. Record this value as enthalpy ($\Delta Q_{max}(1)$, in mJ).

9.10 Repeat steps 9.3 through 9.9 for the medium mass test specimen from step 9.2. Use the same integration limits (T_1 and T_2) determined in step 9.8. Record this value as enthalpy ($\Delta Q_{mid}(1)$, in mJ).

NOTE 7—Loading and unloading of the specimen is required to determine analytical repeatability. If only instrumental repeatability is being determined, the specimen may be left in place between determinations.

9.11 Repeat steps 9.3 through 9.9 for the small mass test specimen from step 9.2. Use the same integration limits (T_1 and T_2) determined in step 9.8. Record this value as enthalpy ($\Delta Q_{min}(1)$, in mJ).

9.12 Repeat steps 9.3 through 9.9 for the blank test specimen from step 9.2. Use the same integration limits (T_1 and T_2) determined in step 9.8 (see Fig. 2). Record this value as enthalpy ($\Delta Q_o(1)$, in mJ).

NOTE 8—Observe and record the sign of the value for ΔQ_o. It may be positive or negative.

9.13 Repeat steps 9.5 through 9.9 two more times for the large mass specimen. Remove the specimen from the DSC sample chamber and reload it between each determination. Record these values as enthalpy ($\Delta Q_{max}(2)$ and $\Delta Q_{max}(3)$, in mJ).

9.14 Repeat steps 9.5 through 9.9 two more times for the medium mass specimen. Remove the specimen from the DSC sample chamber and reload it between each determination. Record these values as enthalpy ($\Delta Q_{mid}(2)$ and $\Delta Q_{mid}(3)$, in mJ).

9.15 Repeat steps 9.5 through 9.9 two more times for the low mass specimen. Remove the specimen from the DSC sample chamber and reload it between each determination. Record these values as enthalpy ($\Delta Q_{min}(2)$ and $\Delta Q_{min}(3)$, in mJ).
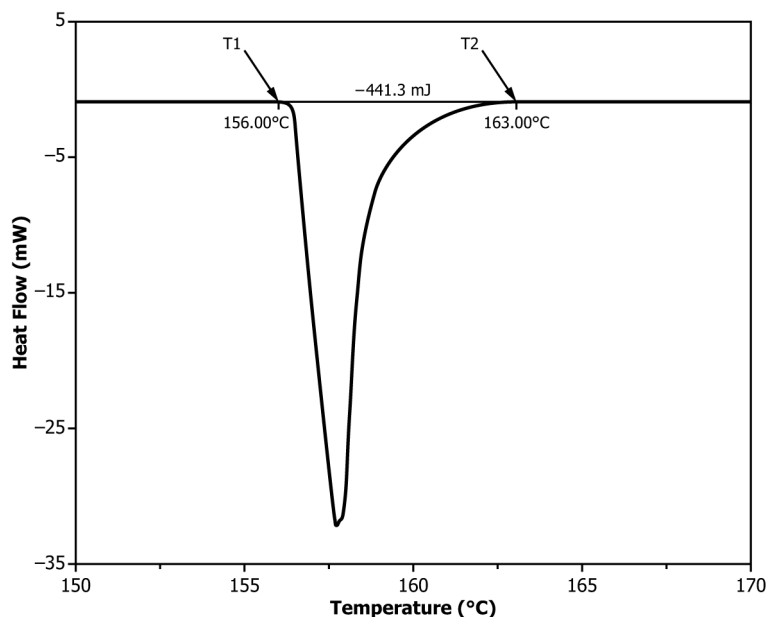
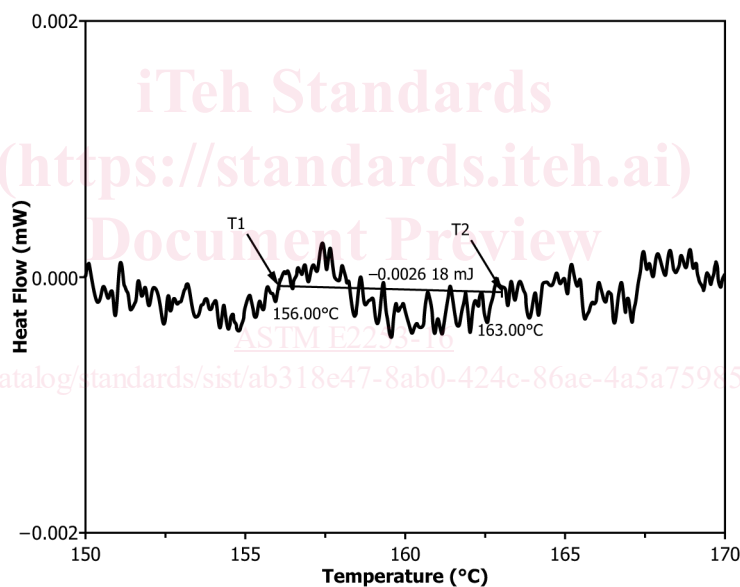**FIG. 1 Integration of Large Indium Melting Endotherm**

FIG. 2 Integration of Baseline

9.16 Repeat steps 9.5 through 9.9 two more times for the blank specimen. Remove the specimen from the DSC sample chamber and reload it between each determination. Record these values as enthalpy ($\Delta Q_o(2)$ and $\Delta Q_o(3)$, in mJ).

9.17 Calculate the mean (Q), standard deviation (s) and relative standard deviation (RSD) for the enthalpy from the replicate determinations made on each of the three mass specimens (see Practice E1970). Record these values as Q_{max}, Q_{mid}, Q_{min}, s_{max}, s_{mid}, s_{min}, and RSD_{max}, RSD_{mid}, and RSD_{min}, respectively. Calculate the mean and standard deviation for the enthalpy determination of the blank. Record these values as Q_o and s_o respectively.

9.18 Using the standard deviation for the enthalpy of the blank (s_o) from step 9.17, determine the instrument detection limit (DL) and quantitation limit (QL) as in calculations 11.2 and 11.3. Report DL and QL.

9.19 Calculate the pooled relative standard deviation for the enthalpy of fusion from the RSD_{max}, RSD_{mid}, and RSD_{min}, obtained in step 9.17 (see Practice E1970). Report this value as the Calorimetric Repeatability value (r).

9.20 Using the three (or more) mass values from step 9.2 as the independent (X) values and the three (or more) mean enthalpy values from step 9.17 as the dependent (Y) values, determine the least square (linear regression) best fit values for the slope (m) in mJ mg^{-1}, and intercept (b) in mJ (see Practice E1970).

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