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.

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Standard Practice for Thermoelectric Sorting of Electrically Conductive Materials[1]

This standard is issued under the fixed designation E977; 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 the procedure for sorting materials using the thermoelectric method, which is based on the Seebeck effect. The procedure relates to the use of direct- and comparator-type thermoelectric instruments for distinguishing variations in materials which affect the thermoelectric properties of those materials.

1.2 While the practice is most commonly applied to the sorting of metals, it may be applied to other electrically conductive materials.

1.3 Thermoelectric sorting may also be applied to the sorting of materials on the basis of plating thickness, case depth, and hardness.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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. Terminology

2.1 *Descriptions of Terms:*

2.1.1 *acceptance limits*—the thermoelectric response that establishes the group into which the material being examined belongs.

2.1.2 *comparative instrumentation*—a system that uses electrode assemblies (probes), associated electronics, and known standards to measure a thermoelectric response from an electrically-conductive material. This response is compared with that of the reference standard.

2.1.3 *direct instrumentation*—a system that specifically measures and displays the voltage (or an arbitrary unit) generated between the electrodes when they are at different temperatures and in contact with the material.

2.1.4 *electrode*—the conductors used in thermoelectric sorting instruments used to generate the Seebeck effect with the material under test.

2.1.5 *Seebeck effect*—the thermoelectric electromotive force (emf) produced in a circuit connecting two dissimilar conductors at two points of different temperatures. The magnitude of this emf is a function of the chemistry of the materials, surface metallurgical structure, and the temperature at the junctions. See Fig. 1.

3. Summary of Practice

3.1 The two techniques that are primarily used in thermoelectric sorting are direct and comparative instrumentation. In the direct instruments, equipment is standardized by placing materials with known chemistry and metallurgical structure in the test system. The value of the thermoelectric voltage (or arbitrary unit) is read on the scale of an indicator. In the comparative instruments, the thermoelectric response of the test piece is compared with that of a known standard(s) and the response indicates whether the piece is within the acceptance limits.

3.1.1 Both kinds of instrumentation require comparing the pieces to be examined with the known standard(s). Two or more samples representing the acceptance limits may be required.

3.1.2 *Direct Thermoelectric Instrumentation*—A known standard(s) is inserted in the system and the controls of the instrument are adjusted to obtain a voltage (or arbitrary unit) reading(s). The process is then continued by inserting the pieces to be sorted into the system, and observing the instrument reading(s).

3.1.3 *Comparative Instrumentation*—Known standards representing the acceptance limits are inserted into the system. The instrument controls are adjusted for appropriate response. The process is then continued by inserting the pieces to be sorted in the system, and observing the instrument response.

3.2 In both instruments, the range of the instrument response must be adjusted during standardization so that any

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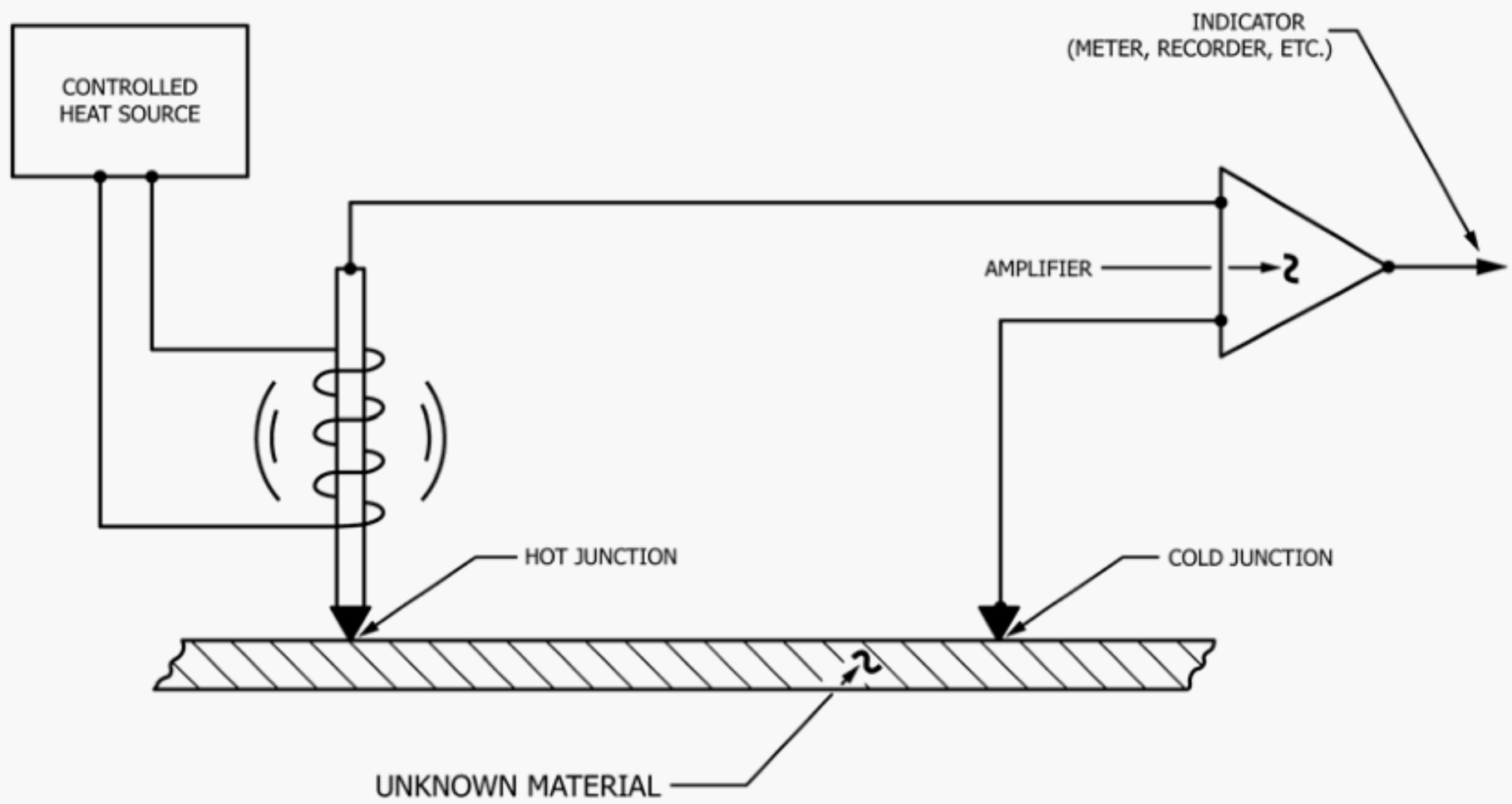

FIG. 1 Typical Circuit Used in Thermoelectric Material Sorting Instruments

anticipated deviation from the known standard(s) will be recognized as within the required acceptance limits.

3.3 The examination process may consist of manual insertion of one piece after another into the system, or an automated feeding and classifying mechanism may be employed.

4. Application

4.1 Thermoelectric techniques provide a method for sorting large quantities of conductive materials. The ability to accomplish satisfactorily these types of separations is dependent upon the relation of the thermoelectric voltages with regard to composition, condition, structure, and processing.

4.2 Comparative instrumentation is used when high-sensitivity testing is required. The advantage of this method is that it reduces internal or external disturbances such as temperature variations of the material or probes, or both.

4.3 The success of an attempted sort will be affected by instrument factors such as electrode composition, electrode temperature differential, and electrode contact.

4.4 The degree of reliability of instrument readings will be affected greatly by the coupling between the electrodes and the part and the accuracy with which the temperature is held constant during the measuring period. The surface of the materials and of both electrodes must be kept free of any insulating materials such as surface oxide, dirt, paint, or other foreign material.

5. Interference

5.1 The specific influence of the following variables must be considered for proper interpretation of the results obtained:

5.1.1 A correlation shall be established so that if the thermoelectric properties of the various groups overlap, auxiliary methods are used for supplementary examination.

5.1.2 In sorting materials, a temperature differential must be used that will result in a well-defined separation of the thermoelectric properties.

5.1.3 Contaminates that will electrically insulate material being examined, such as rust, grease, oil, mill scale; or surface coatings such as paint, plastic, and so forth, must be removed to ensure clean contact between the material and the electrodes of the device.

5.1.4 Extreme temperature differences between the standard(s) and the pieces will alter the emf generated. Known standard(s) should be at the same temperature as the pieces being examined.

5.1.5 The geometry and mass of the standard and part need not be a consideration to permit sorting. Fixturing may be required where the part mass is insufficient to provide an adequate heat sink (for example, thin foil, small-diameter wire, small bearings, etc.).

5.1.6 Interference may be caused by radio frequency produced by devices such as arc welders or radio and radar transmitters. This interference may be observed when the equipment is used in proximity to the above mentioned r-f sources.

5.1.7 If changes in the surface chemistry of the material are brought about due to buildup or depletion of the constituents, the affected surface should be removed by grinding or other means; or a known standard containing the same surface constituents should be used as comparison materials.

6. Apparatus

6.1 *Electronic Apparatus*—The electronic apparatus shall be capable of maintaining a sufficient temperature differential across the electrodes to produce a suitable thermoelectric voltage. Equipment to process this voltage may include any suitable signal-processing devices (d-c amplifiers, null detectors, potentiometers, etc.) and the output may be displayed by meter, scope, recorder, signaling devices, or any suitable combination required for the particular application. A typical circuit is illustrated in Fig. 1.

6.2 Electrodes may be two or more separate electrodes or one multiple electrode probe. They may both contact the same surface of the test sample or different surfaces.

6.3 A mechanical device for feeding and sorting the specimens may be used to automate the particular application.

7. Procedure

7.1 *Known Reference Standards*—Select samples representative of known materials to be sorted that will provide a range of instrument readings representative of the known material group.

7.2 *Standardization:*

7.2.1 The thermoelectric sorting method is primarily one of comparison between pieces. Empirical data and physical tests are used to determine classification. The standardization procedure is governed by the properties of the sample requiring separation. Consult the individual user's manual for specific calibration information

7.2.2 Standardization is governed by the characteristics of the materials to be sorted. In accordance with manufacturer's instructions, adjust the instrument controls so that the readings are representative of the known standard(s) and are within the range of instrument display.

7.2.3 Perform restandardization at the start and finish of each run and at least once during every hour of continuous operation.

7.2.4 Restandardize whenever the following conditions exist:

7.2.4.1 Operator variables that influence examination results.

7.2.4.2 Improper functioning of the system is suspected.

7.2.4.3 Ambient conditions change or are suspected of influencing results.

7.2.5 If restandardization results in a change affecting the sort since the last standardization, retest all material tested since the last standardization.

7.3 *Operation:*

7.3.1 Connect the required test electrode or electrodes to the instrument.

7.3.2 Switch on the instrument and allow it to warm up for at least the length of time recommended by the manufacturer.

7.3.3 Make all necessary setup and control adjustments in accordance with the manufacturer's recommendations.

7.3.4 Standardize in accordance with the manufacturer's recommendations.

7.3.5 Position the electrodes on the piece to be examined.

7.3.6 Observe the instrument output on the indicator.

7.3.7 Sort the piece based on the acceptance limit(s) set.

7.4 *Interpretation of Results:*

7.4.1 The results of any nondestructive testing procedure are based on the comparison of an unknown with a standard. Unless all of the significant interrelationships of material or product properties are understood and measurable for both standard and unknown samples, the results may be meaningless.

7.4.2 Thermoelectric sorting is best used for repetitive examination of materials *identical* in composition and in metallurgical structure.

7.4.3 Interpretation of data depends upon the degree to which the materials compare with either established data or reference materials. Results can often be interpreted by a processing change, such as changes in temperature, composition, or surface condition.

7.4.4 The characteristics of different material(s) in differing conditions may produce identical or similar emf outputs. If any doubt exists about the validity of a sort, a second method or procedure such as changing electrode composition can be used to further define the separation of materials. A chemical spot test, eddy current, or permeability exam using a magnet may also show the effect of other variables.

8. Report

8.1 A written report shall be supplied to the purchaser upon request indicating that a thermoelectric examination has been performed.

9. Keywords

9.1 electrode; electronic device; metal sorting; nondestructive; Seebeck effect; standardization; thermoelectric

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