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

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

2. Terminology

2.1 *Descriptions of Terms:*

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

2.1.2 *comparative instrumentation*—a system that uses electrode assemblies, associated electronics, and known standards to measure a thermoelectric response from a test specimen. 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 metal 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 of the junction between the two. 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 calibrated by placing standards of 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 tested 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 test system and the controls of the instrument are adjusted to obtain a voltage (or arbitrary unit) reading(s). The test is then continued by inserting the pieces to be sorted into the test system, and observing the instrument reading(s).

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

3.2 In both instruments, the range of the instrument response must be adjusted during calibration so that any anticipated deviation from the known standard(s) will be recognized as within the required acceptance limits.

3.3 The testing process may consist of manual insertion of one piece after another into the test 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

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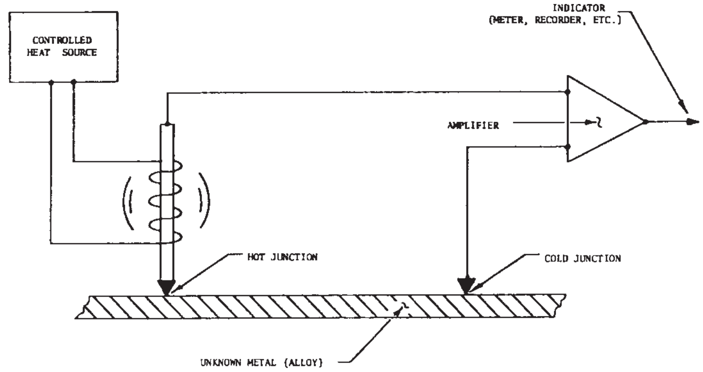

FIG. 1 Typical Circuit Used in Thermoelectric Metal Sorting Instruments

the relation of the thermoelectric voltages with regard to composition, condition, and structure or processing, or both.

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 test electrode and the tested part and the accuracy with which the temperature is held constant during the measuring period. The surface of the test materials and of both electrodes must be kept free of extraneous materials such as surface oxide, dirt, paint, or other foreign material.

5. Interferences

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

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

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

5.1.3 Contaminates that will electrically insulate material (under test), such as rust, grease, oil, mill scale; or surface coatings such as paint, plastic, etc., must be removed to ensure contact between the material under test and the electrodes of the testing device.

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

5.1.5 The geometry and mass of the standard and test 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 Interferences 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 Test 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 test specimens may be used to automate the particular application.

7. Procedure

7.1 *Known Calibration 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 *Calibration and 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 calibration and standardization procedure are governed by the properties of the sample requiring separation.

7.2.2 Test 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 test results.

7.2.4.2 Improper functioning of the system is suspected.

7.2.4.3 Ambient conditions change or are suspected of influencing test 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 Calibrate and standardize in accordance with the manufacturer's recommendations.

7.3.5 Position the electrodes on the test piece.

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 an 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 test results may be meaningless.

7.4.2 Thermoelectric sorting is best used for repetitive tests of material *identical* in composition, and in metallurgical structure.

7.4.3 Interpretation of data depends upon the degree to which the test materials compare with either established test 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 test 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 test 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 the thermoelectric test has been performed.

9. Keywords

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

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