Designation: E 601 – 81 (Reapproved 1997)

Standard Test Method for Comparing EMF Stability of Single-Element Base-Metal Thermocouple Materials in Air[1]

This standard is issued under the fixed designation E 601; 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 test method provides comparison of emf stability of single-element base-metal thermocouple materials in air referenced to platinum at specified constant elevated temperatures.

1.2 Since the useful life of a thermocouple depends on the stability of the emf generated at given temperatures for a required time period, the method includes emf drift measurements with time. The emf is measured against platinum, which may be the platinum leg of the platinum-rhodium/platinum reference thermocouple used to indicate the temperature at the time of taking the emf readings, or an additional platinum reference.

1.3 The total life is included as added information, if required.

NOTE 1—Some thermoelements may show insignificant emf drift while undergoing relatively rapid oxidation. In these cases, failure of the thermoelement may be indicated only by open circuit.

NOTE 2—See ASTM STP470B for recommended upper temperature limits in air.[2]

1.4 *This standard does not purport to address all of the safety concerns, is 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 230 Specification and Temperature Electromotive Force (EMF) Tables for Standardized Thermocouples[3]

E 344 Terminology Relating to Thermometry and Hydrometry[3]

3. Significance and Use

3.1 This test is useful in comparing various alloy thermoelements under the same conditions.

3.2 The relative stability determined by this method is valid only under the specific test conditions and would be affected by changes in the following conditions: (*1*) temperature gradient; (*2*) abundance, velocity, and composition of the air surrounding the test pieces; (*3*) relative inhomogeneity of test thermoelements; (*4*) the relative purity of the platinum.

3.3 This test method in its present form does not include the determination of stability following changes in the operating temperature.

3.4 The reliability of this test method depends on the emf stability of the platinum reference element. For testing the relative emf stability of base-metal thermoelements, it is suggested that a reference element of 99.96 % platinum, or greater, is sufficiently stable to determine a relative significant change in emf of base-metal thermoelements.

3.5 If there is concern that a change in the platinum reference element may have occurred during this test, the procedure described in the appendix may be used to determine such a change.

4. Terminology

4.1 *Definitions*—The definitions given in Terminology E 344 shall apply to this test method.

4.2 *Definitions of Terms Specific to This Standard:*

4.2.1 *emf stability*—the change in emf output expressed in millivolts (or in equivalent degrees), over a period of time.

4.2.2 *total life*—the time required for open circuit to occur in the test thermoelement.

5. Test Specimen

5.1 The test specimen shall be at least 0.8 m (30 in.) long and free of kinks or other defects due to mechanical working.

6. Reference Junction

6.1 The reference junction ends of the test specimens, platinum reference element, if used, and of the platinum-rhodium/platinum reference thermocouple must be maintained at a known constant temperature during the periods of taking

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[1] This test method is under the jurisdiction of ASTM Committee E-20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

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[2] Available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[3] *Annual Book of ASTM Standards*, Vol 14.03.

emf readings. Ice point reference junction baths provide a relatively simple and reliable means for maintaining the reference junction at 0°C (32°F) when proper precautions are exercised in their use.

7. Measuring Junction

7.1 The measuring junction shall consist of a union of the test specimens and platinum reference. The platinum reference may be the platinum leg of the platinum-rhodium/ platinum temperature reference thermocouple.

8. Test Temperature Medium

8.1 The test shall be conducted in a uniformly heated furnace providing an isothermal work zone sufficiently large to maintain all junctions at the same temperature. The zone shall be probed to determine if it meets this requirement. The temperature of the furnace shall be controlled to within ± 10°C (±18°F) of the test temperature.

9. Electromotive Force Indicator

9.1 An instrument that has limits of error of not more than 1 µV at 1000 µV and 12 µV at 50 000 µV shall be used as the means for determining emf in this test.

10. Procedures

10.1 The union shall be prepared by welding, using a procedure proven by experience or by testing to reliably produce mechanically and thermoelectrically stable junctions. The number of test specimens joined to the platinum reference may be as many as the volume of the testing medium permits provided that their thermal conduction does not impair isothermal conditions.

10.2 Weld a platinum-rhodium/platinum reference thermocouple to the test specimen to form a sound junction assembly. An additional platinum wire may be welded to this junction if two measuring instruments are used for the simultaneous reading of temperature (platinum-rhodium/ platinum thermocouple) and specimen emf versus additional platinum leg. Insulate the specimens from each other, except at the junction, and insulate the platinum-rhodium/ platinum thermocouple and the additional platinum leg, if used, from the test specimens with loosely fitting ceramic insulators.

NOTE 3—Insulators used on platinum-rhodium/platinum wires shall be 99.5 % (minimum) aluminum oxide (Al_2O_3). Insulators on base-metal wires can be mullite or equal, except that the insulator nearest the junction should be Al_2O_3.

10.3 Insert the measuring junction end of the assembly into the furnace after the test temperature has been established, so that the junction is near the center of the uniform temperature zone. Avoid distortion of the wire in a zone of temperature gradient. Copper extension wires shall connect the emf-measuring instrument and reference junctions. Take care to ensure that the thermocouple assemblies do not move within the furnace with time in such a manner as to change the gradient along the wires.

10.4 Make the initial emf readings as soon as the system has reached steady-state thermal conditions, especially if recording of early drift is desired. Measure and record the test temperature as indicated by the emf of the platinum-rhodium/platinum reference thermocouple. Measure and record the emf between the platinum reference leg and each of the test specimens while maintaining the test temperature.

10.5 Thermoelectric instability may be reported on the basis of the nominal test temperature ± 10°C (± 18°F) or on the basis of an exact specified temperature.

10.6 If the nominal method is used, compute the true temperature (T_s) from the measured emf of the platinum-rhodium/platinum reference thermocouple, applying only calibration corrections. Determine the emf expected (E_t) for the test combination at that temperature (T_s) from the single-leg tables in Tables E 230. Using these values, calculate the percentage of error by the equation:

$$\% \text{ error} = \frac{E_m - E_t}{E_t} \times 100 \quad (1)$$

where:
E_m = measured emf, and
E_t = table emf for the true temperatures of test.

10.7 If the exact method is used, proceed as follows: since the test temperature may depart ± 10°C (± 18°F) from the specified test temperature, the measured temperature and emf at the time of reading must be corrected to the specified test temperature using the thermoelectric power of the test thermoelement versus Pt 67. For standard thermoelements, the thermoelectric power (α_e) may be obtained from the thermoelement temperature—emf tables in Specification E 230. Using these or other established tables, the emf deviation from the emf at the specified test temperature can be determined and used as the correction. For thermoelements not covered by these or other established tables, the thermoelectric power, α_e, may be determined by taking emf readings 10°C (18°F) below and at the test temperature, dividing the emf difference by the temperature difference. Given the thermoelectric power, the emf of a thermoelement versus platinum may be corrected from the actual test temperature to the specified test temperature by the use of the following equation:

$$E_T = E_T' + \alpha_e (T - T') \quad (2)$$

where:
T = specified test temperature,
T' = actual test temperature,
α_e = thermoelectric power of the thermoelement versus Pt 67 = ($\Delta E/\Delta T$),
E_T = emf versus Pt 67 corrected to specified test temperature, T, and
E_T' = emf versus Pt 67 at actual test temperature, T'.

Example: Assume that a positive Type K thermoelement is tested for stability at a specified temperature of 1000°C. The emf reading is 32.647 mV corresponding to a measured temperature (platinum-rhodium/ platinum thermocouple) of 1005°C. The emf of the thermoelement versus Pt 67 is corrected to 1000°C using Eq 2.

where:

T = 1000°C
T' = 1005°C

where: