Designation: ~~E1350 – 07~~ E1350 – 13

Standard Guide for Testing Sheathed Thermocouples, Thermocouples Assemblies, and Connecting Wires Prior to, and After Installation or Service[1]

This standard is issued under the fixed designation E1350; 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.

INTRODUCTION

Thermocouples are widely used in industry and provide reliable service when used within their specified temperature range. However, if thermocouples fail in service the consequences can range from ~~negligible~~insignificant to life-threatening. Often, ~~an expensive~~a costly loss of equipment, product, or operating time will result. The user should weigh the potential consequences of thermocouple failure when considering ~~what~~which tests should be performed either prior to, during, or after installation.

This standard is a guide for the field testing of thermocouples, thermocouple assemblies, and their connecting wires to ensure that they were not damaged during storage, installation, or use rather than being a guide for acceptance testing of thermocouples as delivered from the vendor. The test methods range from ~~the most~~ basic tests to ~~assure~~ verify that the thermocouple was properly installed to ~~simple~~ tests necessary for failure analysis. Thermocouple tests such as homogeneity, capacitance, and loop-current step-response require elaborate equipment and sophisticated analysis and are not included in this guide.

Faulty installation practices and in-service operation beyond prescribed limits are frequently the cause of failure in properly made sheathed thermocouples. Many of the most common ~~forms~~types of these ~~conditions~~ application errors may be ~~detected~~identified through use of the test methods described in this document. For further information, the reader is directed to MNL 12, Manual on the Use of Thermocouples in Temperature Measurement,[2] which is an excellent reference document on metal sheathed thermocouples.

1. Scope

1.1 This guide covers methods for users to test metal sheathed thermocouple assemblies, including the extension ~~wires,~~wires just prior ~~to,~~to and after installation or some period of service.

1.2 The tests are intended to ensure that the thermocouple assemblies have not been damaged during storage or installation, to ensure that the extension wires have been attached to connectors and terminals with the correct polarity, and to provide benchmark data for later reference when testing to assess possible damage of the thermocouple assembly after operation. Some of these tests may not be appropriate for thermocouples that have been exposed to temperatures higher than the recommended limits for the particular type.

1.3 The tests described herein include methods to measure the following ~~variables~~characteristics of installed sheathed thermocouple assemblies and to provide benchmark data for determining if the thermocouple assembly ~~is~~ has been subsequently damaged in operation:

1.3.1 *Loop Resistance:*

1.3.1.1 Thermoelements,

1.3.1.2 Combined extension wires and ~~the thermoelements,~~ thermoelements.

[1] This guide is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

Current edition approved ~~May 1, 2007~~June 1, 2013. Published ~~June 2007~~July 2013. Originally approved in 1991. Last previous edition approved in ~~2001~~2007 as ~~E1350 – 97 (2001).~~E1350 – 07. DOI: ~~10.1520/E1350-07.~~10.1520/E1350-13.

[2] *Manual on the Use of Thermocouples in Temperature Measurement*, MNL 12, ASTM. Available from ASTM International, www.astm.org.

1.3.2 *Insulation Resistance:*
1.3.2.1 Insulation, thermocouple assembly,
1.3.2.2 Insulation, thermocouple assembly and extension wires.
1.3.3 *Seebeck Voltage:*
1.3.3.1 Thermoelements,
1.3.3.2 Combined extension wires and thermocouple assembly.

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:*[3]

E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples
E344 Terminology Relating to Thermometry and Hydrometry
E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples
E780 Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Thermocouple Cable at Room Temperature
E839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable
E1129/E1129M Specification for Thermocouple Connectors
E1684 Specification for Miniature Thermocouple Connectors
E2181/E2181M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable
MNL 12 Manual on the Use of Thermocouples in Temperature Measurement

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 shall apply to this guide.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *extension wires, n*—pair of wires having temperature-emf characteristics that match the thermocouple temperature-emf characteristics over a specified temperature range.

3.2.2 *junction class, n*—Style U junctions are electrically isolated from conductive sheaths and from reference ground and Style G junctions are electrically connected to conductive sheaths.[4]

3.2.3 *sensing circuit, n*—the combination of the thermoelements and extension wires, but excluding active signal conditioning components such as reference junction compensators, amplifiers, and transmitters.

3.2.4 *sheathed-thermocouple assembly, n*—an assembly consisting of two thermoelements ~~in~~within ceramic insulation contained within a metal ~~protecting tube,~~protective sheath, electrically joined at a junction to form a thermocouple, with its associated parts.

[3] 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.

[4] Historically ~~reffered~~referred to as class 1 and class 2 junctions.

3.2.4.1 *Discussion*—

An assembly may include associated parts such as a terminal block and a connection head. The metal protecting tube, or sheath, has a moisture seal at the reference junction end. Usually the metal sheath is welded closed at the measuring end. ~~If, however,~~However, if the thermocouple has an exposed junction, it must have an effective moisture seal at the measuring end as well as at the reference junction end.

3.2.5 *terminal block, n*—a terminal device for mechanical connection of thermoelements and extension wires or for the connection of extension wires to each other or to instruments.

3.2.6 *thermocouple connector, n*—a quick-connect plug and jack in which the electrically connecting components have temperature-emf characteristics matching the extension wires or thermoelements they are intended to connect.

3.2.6.1 *Discussion*—

The temperature-emf characteristics of the connector parts will match the extension wires or the thermoelements only over a specified temperature range. Thermocouple connectors are described in Specifications E1129/E1129M and E1684.

4. Summary of Tests

4.1 *Loop Resistance ~~Measurements :~~ Measurements:*

4.1.1 *Thermocouple*—The electrical loop resistance is compared to the resistance measured before installation to ensure that the thermoelements have not been broken or ~~shorted to each other~~ been short circuited (for example, at the thermocouple connector) during the installation process.

4.1.2 *Sensing Circuit*—The measurements ~~are~~ may be used to establish the loop resistance of the combined thermocouple assembly and extension wires and to ensure that the extension wires are not shorted and that all connections are secure. The resistance of the extension wires should be ~~determined~~ measured separately before they are ~~joined~~connected to the thermocouple assembly.

4.2 *Insulation Resistance ~~Measurements :~~ Measurements:*

4.2.1 *Thermocouple Assembly*—The room temperature insulation resistance of the installed Style U thermocouple assembly is compared to the resistance measured before installation to ensure that the sheath and moisture seal ~~has~~have not been damaged ~~or~~and that the thermoelements ~~are~~were not shorted to the sheath during installation.

NOTE 1—This test applies only to thermocouple assemblies with Style U thermocouple junctions. Thermocouples ~~with junctions attached to the sheath~~ having Style G junctions cannot be tested in this manner.

4.2.2 *Sensing Circuit*—The measurement is to establish that the electrical isolation of the Style U thermocouples ~~is~~has not been degraded by the extension circuit.

4.2.3 *Extension Wires*—The measurement is to establish that the extension wires are continuous and not shorted to each other, or to any other component, including earth ground. This is a necessary measurement when Style G thermocouples are ~~used.~~tested.

4.3 *Seebeck Voltage ~~Measurements :~~ Measurements:*

4.3.1 *Thermocouple Assembly*—The measurement, dependent on a temperature difference between the measuring junction and the terminal block, is to ~~establish~~verify that the thermocouple connector is mated to the ~~thermoelements~~thermocouple with ~~the~~ proper polarity.

4.3.2 *Sensing Circuit*—The measurement, dependent on a temperature difference between the measuring junction and the terminating hardware, is to ~~establish~~verify that ~~the~~ correct polarity has been maintained in connecting the extension wires to the thermocouple.

5. Significance and Use

5.1 These test procedures ~~ensure~~confirm and document that the thermocouple assembly was not damaged prior to or during the installation process and that the extension wires are properly connected.

5.2 The test procedures should be used when thermocouple assemblies are first installed in their working environment.

5.3 In the event of subsequent thermocouple failure, these procedures will provide benchmark data to verify failure and ~~to~~may help ~~evaluate~~ to identify the cause of failure.

5.4 The usefulness and purpose of the applicable tests will be found within each category.

5.5 These tests are not meant to ensure that the thermocouple assembly will ~~indicate~~measure temperatures accurately. Such assurance ~~derives~~ is derived from proper thermocouple and instrumentation selection and proper placement in the location ~~where~~ at which the temperature is to be measured. For further information, the reader is directed to MNL 12, Manual on the Use of the Thermocouples in Temperature Measurement[2] which is an excellent reference document on metal sheathed ~~thermocouples.~~thermocouple uses.

6. Apparatus

6.1 *~~Resistance Measuring~~ Digital ~~Meter~~Ohm-meter or Multi-meter,* a ~~digital~~ direct current resistance measurement ~~device~~instrument having a measuring range from ~~0 Ohms to 1 megohms and a resolution of better than 1KΩ.~~zero ohms to at least 1 megohm with a resolution less than 1kilohm.

6.2 *Megohmeter or Megohm ~~B Ridge ,~~ Bridge,* with ranges from 5×10^4 ~~Ω~~ ohm to 10^{12} ~~Ω~~ ohm with an accuracy of better than ±10.0 % of the measured ~~test~~ resistance and a test voltage ~~of~~ selectable between 50 ~~to 500 VDC depending on the outside diameter of the sheathed thermocouple material.~~ and 500 dc volts (VDC).

6.3 *Heat Source,* for example, a small propane type torch or an electric heat gun.

7. General Requirements

7.1 ~~These~~ The following test procedures ~~presume~~assume that the loop resistance and ~~the~~ room temperature insulation resistance of the delivered ~~thermocouples was~~thermocouple were already found to be ~~appropriate~~acceptable by Test Method E839 ~~before~~ prior to installation.

7.2 All thermocouple assemblies to be tested should be identified by a serial number or by some other type of unique identifier traceable to pre-installation tests and to a manufacturer's production run.

7.3 ~~The~~These procedures require that ~~the circuit~~all circuits have electrical continuity.

7.4 For all connections the color codes and material composition of the extension wires should be appropriate for the particular thermocouple type being ~~used.~~tested. See Specification E230 for standard thermocouple type color ~~coding.~~codes.

8. Procedure: Loop Resistance Measurements

8.1 *Thermocouple Loop Resistance*—With the thermocouple disconnected from ~~the extensions~~ its extension wires and temperature measuring ~~instruments,~~instrument, measure the loop resistance at the plug connector pins or at the terminal block. The ~~most~~ basic measurement is simply to establish circuit continuity. For accurate loop resistance measurements to establish benchmark data and to ~~assure~~ensure that the thermoelements are not shorted to each other (for example, at the thermocouple ~~connector assembly) an ohmmeter capable of measuring the indicated resistance to at least 0.1 Ω must be used.~~ connector) use a digital ohmmeter able to measure resistance with a resolution smaller than 0.1 ohm. Because any Seebeck voltage ~~from~~ generated by the thermocouple will affect the ~~measured resistance,~~ resistance value measured, two resistance measurements ~~must~~shall be made, with the second measurement ~~at~~ taken with reversed polarity from the ~~first measurement.~~ first. The average of the two measurements is the ~~thermocouple~~ thermocouple's true loop resistance. **Warning—**~~Ohmmeters operate~~Ohm-meters function by measuring ~~a~~the voltage produced by passing a small DC current through the ~~measured resistance. If the thermocouple is in a temperature gradient so that the measuring and reference junctions are at different temperatures, the Seebeck voltage from the thermocouple will add to or subtract from the voltage measured by the ohmmeter.~~unknown resistance. ~~The purpose of averaging~~ If the thermocouple is in a temperature gradient zone such that the measuring and reference junctions are at different temperatures, the thermocouple's Seebeck voltage will add to or subtract from the voltage measured by the ohm-meter. The objective of averaging the loop resistance measurements in forward and reverse ~~directions~~polarities is to eliminate the effect of the ~~Seebeck voltage on the resistance measurements. If, however,~~ thermocouple's Seebeck voltage. However, if a thermocouple with ~~a~~ low loop resistance is ~~measured~~tested while it is installed in a high temperature zone, the Seebeck voltage ~~from the thermocouple may then~~ may be greater than the voltage produced by the ~~ohmmeter,~~ohm-meter, resulting in a ~~measured~~ negative voltage at the ~~ohmmeter~~ ohm-meter's terminals (see 8.1.3). Some digital ~~multi-metres do~~multimeters may not indicate ~~a~~ negative resistance and thus averaging ~~both~~the forward and reverse ~~resistances as positive~~ polarity measurements will result in an erroneous loop resistance measurement.

8.1.1 If very accurate resistance measurements are ~~to be made,~~ required, measure the ~~ohmmeter~~ ohm-meter's test lead resistance. If the ~~ohmmeter~~ohm-meter's lead resistance is significant (>0.1 %), ~~compared to~~ of the ~~thermocouple~~thermocouple's loop ~~resistance,~~resistance), subtract the ~~ohmmeter~~ ohm-meter's test lead resistance from all subsequent measurements of the ~~thermocouple~~thermocouple's loop resistance.

NOTE 2—~~The~~An installed ~~thermocouples~~thermocouple will often be at a different temperature than when ~~they were measured~~it was tested before installation. The different temperature will ~~produce~~ result in a different loop resistance that should not be interpreted as a thermocouple defect.

8.1.2 If several thermocouples of the same type are installed ~~in~~near the same location and in the same thermal environment, compare the resistance per unit length, for all thermocouples in the group before and after installation. ~~See~~Damage ~~Note 2. Suspect damage has occurred~~ may be suspected in a given thermocouple if ~~the measured before-and-after difference of~~ its resistance per unit length is significantly (>10 %) different ~~than the before-and-after difference~~ from the before and after installation readings of resistance per unit length of its companion ~~thermocouples.~~thermocouples in the group.

NOTE 3—~~If the~~ A loop resistance ~~is greatly different~~ measurement, taken after the thermocouple assembly has been ~~installed (that is, particularly if the resistance shows open circuit or near zero), then the thermocouple must be replaced or repaired.~~ installed, which differs significantly from the initial loop resistance measurement will require replacement or repair of the thermocouple. If, for example, the thermocouple connector was rotated in relation to the sheath during installation, the thermoelements ~~could~~might have been broken or shorted at the connector and ~~might~~may be repairable.

8.1.3 An alternative method which may be used to determine the loop resistance of a thermocouple at ~~elevated temperatures is~~ which is in service is to shunt the thermocouple at ~~the~~its connector ~~prongs~~pins with a variable resistor. Measure the ~~open-switch thermocouple~~ thermocouple's open circuit Seebeck voltage between the connector ~~prongs~~pins with a high impedance voltmeter capable of measuring accurately in the microvolt range (see Fig. 1). The ~~measuring junction must be at constant temperature and the connector prongs must remain at the same terminal temperature during this~~temperature of the thermocouple's measuring junction and the connector's pins must remain stable during the test. Close the switch and adjust the resistance of the variable resistor until the ~~closed-switch measured~~closed circuit voltage is ½ that of the ~~open-switch~~ open circuit Seebeck voltage ~~(at which time~~ (this will occur when the variable resistor has the same resistance as the ~~thermocouple~~thermocouple's loop). The variable

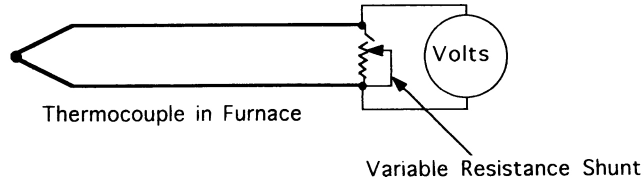

FIG. 1 An Alternative Method to Measure Loop Resistance