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Standard Guide for Testing Sheathed Thermocouples Prior to, During, and After Installation[1]

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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 to life-threatening. Often, an expensive loss of equipment, product, or operating time will result. The user should weigh the potential consequences of thermocouple failure when considering what tests should be performed either prior to, during, or after installation.

This standard is a guide for the field testing of thermocouples 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 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 of these conditions may be detected 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.

The user should always remember that a voltage (not a temperature) is measured when a thermocouple is used. Any extraneous voltages that are introduced in the thermocouple circuit will be interpreted as a temperature, resulting in an error in the indicated temperature. Although the extension wires are not usually a part of the sheathed thermocouple, they are a portion of the measuring system and, if the extension wires are improperly installed with incorrectly matched material or polarity, the extension wires can produce voltages that will introduce substantial errors into the temperature measurements. When high accuracy measurements are made with calibrated thermocouples, it is especially important that the extension wires have thermoelectric properties closely matched to those of the thermocouple over the temperature range to which the extension wires are exposed.

1. Scope

1.1 This guide covers methods for users to test metal sheathed thermocouple assemblies, including the extension wires, just prior to, during, and after installation.

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. They are not, generally, applicable to 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 of installed sheathed thermocouple assemblies and to provide benchmark data for determining if the thermocouple assembly is subsequently damaged in operation:

1.3.1 *Loop Resistance*:

1.3.1.1 Thermoelements,

1.3.1.2 Combined extension wires and the thermoelements,

1.3.2 *Insulation Resistance*:

1.3.2.1 Insulation, thermocouple assembly

1.3.2.2 Insulation, thermocouple assembly and extension wires.

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

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:*

E 344 Terminology Relating to Thermometry and Hydrometry[3]

E 780 Test Method for Measuring the Insulation Resistance of Sheathed Thermocouple Material at Room Temperature[3]

E 839 Test Methods of Testing Sheated Thermocouples and Sheathed Thermocouple Material[3]

E 1129/E 1129M Specification for Thermocouple Connectors[3]

E 1684 Specification for Miniature Thermocouple Connectors[3]

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E 344 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*—class 2 junctions are electrically isolated from conductive sheaths and from reference ground and class 1 junctions are electrically connected to conductive sheaths.

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 ceramic insulation within a metal protecting tube, electrically joined at a junction to form a thermocouple, with its associated parts.

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, 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 E 1129/E 1129M and E 1684.

4. Summary of Tests

4.1 *Loop Resistance 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 (for example, at the thermocouple connector) during the installation process.

4.1.2 *Sensing Circuit*—The measurements are 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 connections are secure. The resistance of the extension wires should be determined before they are joined to the thermocouple assembly.

4.2 *Insulation Resistance Measurements*:

4.2.1 *Thermocouple Assembly*—The room temperature insulation resistance of the installed Class 2 thermocouple assembly is compared to the resistance measured before installation to ensure that the sheath and moisture seal has not been damaged or that the thermoelements are not shorted to the sheath during installation.

NOTE 1—This test applies only to thermocouple assemblies with Class 2 thermocouple junctions. Thermocouples with junctions attached to the sheath cannot be tested in this manner.

4.2.2 *Sensing Circuit*—The measurement is to establish that the electrical isolation of the thermocouples with class 2 junctions is not 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 Class 1 thermocouples are used.

4.3 *Seebeck Voltage Measurements*:

4.3.1 *Thermocouple Assembly*—The measurement, dependent on a temperature difference between the measuring junction and the terminal block, is to establish that the thermocouple connector is mated to the thermoelements 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 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 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 help evaluate the cause of failure.

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

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 temperatures accurately. Such assurance derives from proper thermocouple and instrumentation selection and proper placement in the location where 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.

6. General Requirements

6.1 These test procedures presume that the loop resistance and the room temperature insulation resistance of the delivered thermocouples was already found to be appropriate by Test Method E 839 before installation.

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

6.3 The procedures require that the circuit have electrical continuity.

7. Procedure: Loop Resistance Measurements

7.1 *Thermocouple Loop Resistance*—With the thermocouple disconnected from the extensions and temperature measuring instruments, 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 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. Because any Seebeck voltage from the thermocouple will affect the measured resistance, two resistance measurements must be made, with the second measurement at reversed polarity from the first measurement. The average of the two measurements is the thermocouple loop resistance.

NOTE 2—**CAUTION**: Ohmmeters operate by measuring a voltage produced by passing a 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. The purpose of averaging loop resistance measurements in forward and reverse directions is to eliminate the effect of the Seebeck voltage on the resistance measurements. If, however, a thermocouple with a low loop resistance is measured while it is installed in a high temperature zone, the Seebeck voltage from the thermocouple may then be greater than the voltage produced by the ohmmeter, resulting in a measured negative voltage at the ohmmeter (see 7.1.3). Some digital multimetres do not indicate a negative resistance and thus averaging both forward and reverse resistances as positive will result in an erroneous resistance measurement.

7.1.1 If accurate resistance measurements are to be made, measure the ohmmeter lead resistance. If the ohmmeter lead resistance is significant (>0.1 %), compared to the thermocouple loop resistance, subtract the ohmmeter lead resistance from all subsequent measurements of the thermocouple loop resistance.

NOTE 3—The installed thermocouples will often be at a different temperature than when they were measured before installation. The different temperature will produce a different loop resistance which should not be interpreted as a thermocouple defect.

7.1.2 If several thermocouples of the same type are installed in the same location and in the same thermal environment, compare the resistance per unit length, for the group before and after installation. See Note 3. Suspect damage has occurred in a given thermocouple if the measured before-and-after difference of resistance per unit length is significantly (>10 %) different than the before-and-after difference of resistance per unit length of its companion thermocouples.

NOTE 4—If the loop resistance is greatly different 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. If, for example, the thermocouple connector was rotated in relation to the sheath during installation, the thermoelements could have been broken or shorted at the connector and might be repairable.

7.1.3 An alternative method to determine the loop resistance of a thermocouple at elevated temperatures is to shunt the thermocouple at the connector prongs with a switchable variable resistor. Measure the open-switch thermocouple Seebeck voltage between the connector prongs with a high impedance voltmeter capable of measuring 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 test. Close the switch and adjust the resistance of the variable resistor until the closed-switch measured voltage is ½ that of the open-switch Seebeck voltage (at which time the variable resistor has the same resistance as the thermocouple loop). The variable resistor is then removed from the circuit and its resistance measured directly with an ohmmeter. This method avoids the complication of the Seebeck voltage that is referred to in Note 2.

NOTE 5—At elevated (>800°C) temperatures the insulation resistance of a thermocouple with a class 2 junction may be so low that significant electrical shunting may occur either between the thermoelements or the thermoelement and the sheath. In that case neither of the loop resistance measurements nor the temperature measurements will produce an accurate result. The insulation resistance of a thermocouple with a class 2 junction at elevated temperature should be measured (see 8.3) before any other measurements are made.

7.2 *Sensing Circuit Loop Resistance*—With the extension wires disconnected from the temperature indicating instrument but connected to the thermocouple assembly, measure the loop resistance of the combined thermocouple assembly and the extension wires using 7.1 to at least establish the continuity of the combined extension wires and thermocouple assembly. If accurate measurements are desired, subtract the thermocouple assembly resistance measured in 7.1.2 or 7.1.3 from the combined resistance to find the resistance of the extension

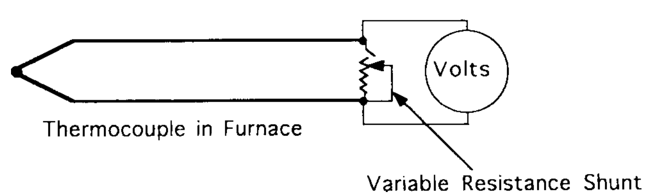

FIG. 1 An Alternative Method to Measure Loop Resistance