



Designation: **A991/A991M – 17** **A991/A991M – 22**

## Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products<sup>1</sup>

This standard is issued under the fixed designation A991/A991M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 This test method covers the procedures used to conduct a temperature uniformity survey on a furnace used to heat treat steel products. This method is used to determine the capability of the furnace to meet the permissible temperature variation specified in the applicable product specification, or as agreed to by the purchaser and supplier of heat treat services. Survey documentation requirements, and the procedure used to subsequently establish the furnace working zone, are defined in this test method.

1.2 This test method covers heat treat furnaces in any of the following categories:

1.2.1 Continuous or semi-continuous conveyance furnaces,

1.2.2 Batch furnaces, and

1.2.3 Salt or liquid baths and fluidized beds.

1.3 This test method only applies when specified in the product specification or the purchase order.

1.4 Controlling a heat treatment of steel products using thermocouples attached to the extremities of each load is an alternative to performing a furnace survey. The producer shall adhere to [Annex A1](#).

1.5 By mutual agreement between the purchaser and the supplier of heat treat services, more stringent and/or additional requirements may be specified. The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order as agreed upon by the purchaser and supplier.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 *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.*

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.13 on Mechanical and Chemical Testing and Processing Methods of Steel Products and Processes.

Current edition approved April 15, 2017; April 15, 2022. Published April 2017; May 2022. Originally approved in 1998. Last previous edition approved in 2015 as A991/A991M – 10 (2015); A991/A991M – 17. DOI: 10.1520/A0991\_A0991M-17; 10.1520/A0991\_A0991M-22.

\*A Summary of Changes section appears at the end of this standard



1.8 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. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

E207 Test Method for Thermal EMF Test of Single Thermoelement Materials by Comparison With Reference Thermoelement of Similar EMF-Temperature Properties

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

E230 Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples

### 2.2 SAE Standard:<sup>3</sup>

AMS 2750 Pyrometry

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *batch furnace, n*—heating device in which material may be stationary or oscillating during the processing cycle.

3.1.2 *continuous conveyance furnace, n*—heating device through which material is moved intentionally at a constant rate during the processing cycle.

3.1.3 *extremities, n*—as referring to furnace working zone; outer boundaries in all three dimensions (length, width, and height) of the material being processed.

3.1.4 *operating range, n*—expected range of temperature over which a furnace will be controlled to heat treat steel products.

3.1.5 *primary survey, n*—initial evaluation of the furnace, or an evaluation triggered by the initiation of a major furnace modification.

3.1.6 *secondary survey, n*—evaluation of the furnace triggered by the expiration of a time requirement.

3.1.7 *semi-continuous conveyance furnace, n*—heating device through which material is moved intentionally with a predetermined start-stop-start pattern during the processing cycle.

3.1.8 *working zone, n*—maximum volume and location in the furnace that meet the permissible temperature variation.

## 4. Significance and Use

4.1 Furnaces for heat treatment of steel products are used in many industries, in many ways. Regardless of heat treat furnace type, or processing cycle, it may be necessary for users to know the temperature uniformity in the furnace and whether the material is processed in a zone within the furnace that is capable of meeting the applicable permissible temperature variation requirements.

4.2 The procedures in this test method may be used by those using, manufacturing, and providing calibration service for, heat treat furnaces used to process steel products.

## 5. Furnace Survey Equipment

### 5.1 Thermocouples:

5.1.1 Metal sheathed thermocouples shall be in accordance with Specification E608/E608M.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.



- 5.1.2 The use of extension wires is permitted when compensated connectors, plugs, jacks, and terminal strips are used.
- 5.1.3 Thermocouples made from spool wire shall meet the requirements of AMS 2750.
- 5.1.4 The use of spliced extension wire is prohibited.
- 5.1.5 Thermocouples may be reused if the requirements of AMS 2750 (except Paragraphs 3.1.1.10 and 3.1.1.11 of Rev. D) are met.

5.2 *Calibration:*

- 5.2.1 All reference, primary, secondary, test and working equipment, instrumentation and sensors used in conjunction with this test method shall meet the requirements of calibration defined by Test Methods E207 and E220.
- 5.2.2 Temperature measuring devices shall be calibrated within three months prior to use.
- 5.2.3 Calibration shall be traceable to the National Institute of Standards Technology standards, or equivalent national standards. Calibration to such national standards shall be done at least once every two years.

5.2.4 Calibration shall be within the temperature range to be used in the survey and at intervals not greater than  $200^{\circ}\text{F}$  [ $100^{\circ}\text{C}$ ]/ $200^{\circ}\text{F}$  [ $100^{\circ}\text{C}$ ] for primary and secondary standards.

5.2.5 Correction factors, limits of error, and deviations shall be in accordance with Specification E230.

**6. Requirements**

6.1 *Uniformity Survey Test Conditions:*

6.1.1 The furnace to be surveyed shall be capable of being tested at set point temperature(s) typical for the normal operating range.

6.1.1.1 If the operating range does not exceed a spread of  $300^{\circ}\text{F}$  [ $150^{\circ}\text{C}$ ]/ $300^{\circ}\text{F}$  [ $150^{\circ}\text{C}$ ], the midpoint temperature shall be selected for the survey.

6.1.1.2 If the operating range exceeds a spread of  $300^{\circ}\text{F}$  [ $150^{\circ}\text{C}$ ]/ $300^{\circ}\text{F}$  [ $150^{\circ}\text{C}$ ], survey at the minimum and maximum set point temperature for the normal operating range, except that the maximum temperature need not be higher than  $2000^{\circ}\text{F}$  [ $1100^{\circ}\text{C}$ ].

6.1.2 Either typical or maximum production size and weight furnace loads shall be utilized during the survey. Use of representative material to simulate product during survey is permitted.

6.1.3 The furnace atmosphere and operating conditions shall be representative of those used in production.

6.2 *Frequency of Uniformity Surveys:*

6.2.1 Primary Surveys:

6.2.1.1 A primary survey shall have been performed within twelve months prior to, or run concurrently with, the first production heat treatment to which this test method applies.

6.2.1.2 A primary survey shall have been conducted when a major furnace modification is completed. A major furnace modification includes, but is not limited to, the installation of the following: a different burner type, a new heating element design, a different type of insulation system, and, a different type of temperature controlling device.

6.2.1.3 Replacement of worn parts with similar parts or patching of insulation that does not change the furnace characteristics does not constitute a major furnace modification.

6.2.1.4 The survey shall be conducted within twelve months prior to, or run concurrently with, the first production heat treatment performed after the modification.



### 6.2.2 Secondary Surveys:

6.2.2.1 To maintain conformance with this test method, a secondary survey shall be conducted within twelve months after the primary survey and additional surveys within every twelve month period thereafter.

6.2.2.2 Secondary surveys shall be conducted at a typical furnace set point temperature within the normal operating range. All other conditions described in 6.1 shall apply.

## 7. Procedure

7.1 Survey measuring equipment shall meet the requirements of Section 5.

7.2 Test conditions and test frequency shall be as defined in 6.1 and 6.2, respectively.

7.3 Place thermocouples to monitor time and temperature profiles in the furnace to evaluate the uniformity of the intended working zone. Place them at the outer extremities, the center of the proposed working zone, and in areas of suspected variability in the proposed working zone. Attach survey test sensors to, or set them in the load.

7.4 For proposed working zones less than 12 in. [300 mm] in height, it is acceptable to monitor the center height location, it is not necessary to monitor both the top and bottom of the heating chamber. For proposed working zones greater than, or equal to, 12 in. [300 mm] in height, both top and bottom extremities must be monitored.

### 7.5 Continuous Conveyance and Semi-Continuous Conveyance Furnaces:

7.5.1 Convey test sensors through the furnace. The rate of conveyance shall be representative of normal operating conditions.

7.5.2 The frequency of temperature recordings shall be capable of detecting variations from the test temperature range during the entire conveyance through the furnace.

7.5.3 Several conveyances with the test sensors attached to the steel product, under the same conditions, may be made to ensure that any recurrent temperature profiles are determined at all test locations throughout the furnace.

7.5.4 Alternative surveying techniques are described in 7.7.

### 7.6 Batch and Batch Liquid Media Furnaces:

7.6.1 Take readings starting when the control instrument rises to within  $200^{\circ}\text{F}$  [ $100^{\circ}\text{C}$ ]  $200^{\circ}\text{F}$  [ $100^{\circ}\text{C}$ ] of the set point temperature and continue throughout the hold cycle at the set point temperature.

7.6.2 Take readings at a minimum frequency of 1/10 the normal hold time.

7.6.3 Take the readings frequently enough to detect variations from the test temperature range and to determine the extremes of the recurrent temperature profile, if any.

7.6.4 Alternative surveying techniques are described in 7.7.

7.7 *Alternative Surveying Techniques*—When agreed to by the purchaser and the supplier of heat treat services, alternative surveying techniques may be used to characterize the temperature uniformity of the furnace and subsequently define the size and location of the working zone. Examples of these surveying techniques are listed below.

#### 7.7.1 Statistical Sampling:

7.7.1.1 When it is impossible or impractical to perform the tests outlined in 7.5 and 7.6, it is permissible to substitute an analysis of the resultant mechanical properties of the steel products heat treated in the subject furnace to validate temperature uniformity. Details of this procedure shall be as agreed to between purchaser and supplier.