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400 Commonwealth Dr., Warrendale, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 2750A

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PYROMETRY

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1. SCOPE: This specification covers equipment (temperature sensing elements, instrumentation) and tests (system accuracy, temperature uniformity) required to ensure that parts or raw materials (See 8.1.7) being heat treated are exposed to the temperatures indicated on the controlling and recording instruments. It is applicable to all heat treatment of parts and to final heat treatment of raw material which could affect its fabricability or the properties of parts. Unless otherwise specified herein, it is not applicable to heating, or to intermediate (non-final) heat treatment, or raw material, e.g., for hot working.

1.1 Introduction:

1.1.1 Control and recording of temperature of thermal processing equipment is necessary to ensure that parts or raw material being processed are subjected to the proper temperature. Automatic instruments are utilized (1) to translate the signals from sensors located in the equipment to temperature indications or recordings, and (2) to activate heating or cooling control mechanisms which maintain the desired temperature.

1.1.2 Instruments and sensors are calibrated against test instruments and sensors which are themselves calibrated against chains of standard instruments and sensors linked to the U.S. National Bureau of Standards (NBS). By applying correction factors, determined during calibration of each link of the chain, the deviation of working instrument/sensor measurements from true temperature is reduced to an insignificant level.

1.1.3 Working instrument/sensor systems used for temperature control and recording are tested periodically, while installed, by comparison with test instrument/sensor systems to ensure continuous accuracy of temperature measurements. In addition, periodically, the uniformity of temperature distribution within each piece of equipment is checked to ensure that the readings of working instrument/sensor systems reflect a consistent and acceptable temperature distribution pattern within the equipment.

1.1.4 The minimum frequency requirements for the periodic tests are based upon the type and class of the specific equipment involved. Reduced frequencies are permitted for equipment which has more than one instrument/sensor combination. Reduced frequencies are also permitted for equipment used exclusively for performing certain heat treatments of raw material. Such reductions are based on the fact that (1) the material is tested for conformance to the appropriate specification and (2) the treatments involved only affect the material's fabricability or minor temperature deviations do not significantly affect the final properties of parts.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

2.2.1 ASTM E207 - Thermal EMF Test of Single Thermoelement Materials by Comparison with a Secondary Standard of Similar EMF-Temperature Properties
ASTM E220 - Calibration of Thermocouples by Comparison Techniques

3. TECHNICAL REQUIREMENTS:

3.1 Temperature Sensors and Calibration (See Table 1):

3.1.1 Reference Standard Sensors: Shall be calibrated platinum-platinum plus 10%, or 13%, rhodium thermocouples, or sensors of equivalent accuracy.

3.1.1.1 Calibration: Shall have been performed (1) within five years of use by direct comparison with the standards maintained by the National Bureau of Standards, and (2) at approximately equal intervals of 500 F (280 C) deg or less throughout its range of use, including its minimum and maximum use temperatures.

3.1.1.1.1 Alternatively, in lieu of calibrating individual thermocouples, thermocouples may be made from calibrated rolls. The calibration used shall be the average of NBS calibrations of thermocouples made from both ends and the middle of a pair of single wire rolls. This alternative procedure may not be used if the range of readings exceeds 1°F (0.5°C) at any temperature.

3.1.1.2 Use: Shall be limited to calibration of primary standard sensors.

3.1.2 Primary Standard Sensors (See 8.1.6): Shall be calibrated platinum/platinum plus 10%, or 13%, rhodium thermocouples, or sensors of equivalent accuracy, with a maximum correction factor of ±3°F (±1.5°C) up to 1200°F (650°C) and ±0.25% at higher temperatures.

3.1.2.1 Calibration: Shall have been performed within two years of use by direct comparison with a reference standard sensor, in accordance with a technique which is compatible with ASTM E220 or ASTM E207 procedures, at approximately equal intervals of 500 F (280 C) deg or less throughout its range of use, including its minimum and maximum use temperatures.

3.1.2.2 Use: Shall be limited to calibration of secondary standard sensors, test sensors, load sensors, and working sensors.

3.1.3 Secondary Standard Sensors: Shall be calibrated nonexpendable (See 8.1.3), base metal thermocouples, or sensors of equivalent or greater accuracy.

3.1.3.1 Calibration: Shall have been performed before first use and semi-annually after first use by direct comparison with a primary standard sensor in accordance with a technique which is compatible with, or equivalent to, ASTM E220 or ASTM E207 procedures. Correction factors shall not exceed ±2°F (±1°C) up to 1000°F (540°C) and ±0.4% at higher temperatures except as follows:

3.1.3.1.1 Correction factors for sensors used exclusively in connection with Class 2 equipment (calibrating test, working, and load sensors) may be ±0.4% at temperatures higher than 500°F (260°C).

3.1.3.2 Use: Shall be limited to calibration of test sensors, load sensors, and working sensors.

3.1.4 Test Sensors: Shall be calibrated, expendable (See 8.1.2) or nonexpendable (See 8.1.3), base metal thermocouples, or sensors of equivalent or greater accuracy.

3.1.4.1 Calibration: Shall have been performed before first use and quarterly after first use, except that expendable thermocouples shall be additionally limited to a maximum of ten uses between calibrations. However, in lieu of recalibration, expendable thermocouples from a qualified roll (See 3.1.4.1.2) may be remade by trimming off, and remaking the hot junction. Calibration shall be by direct comparison with a primary or secondary standard sensor in accordance with a technique which is compatible with, or equivalent to, ASTM E220 or ASTM E207 procedures. Correction factors shall not exceed ±2°F (±1°C) up to 1000°F (540°C) and 0.4% at higher temperatures except as follows:

3.1.4.1.1 Correction factors for sensors used exclusively in connection with Class 2 equipment (calibrating working and load sensors, performing system accuracy and temperature uniformity tests) may be ±0.4% at temperatures higher than 500°F (260°C).

3.1.4.1.2 Calibration of Thermocouple Wire Rolls: May be performed, in lieu of calibrating individual thermocouples, by calibrating sample thermocouples from both ends of a dual wire roll or a pair of single wire rolls and demonstrating that correction factors meet the requirements of 3.1.4.1.

3.1.4.1.2.1 If the sample thermocouples read within 2°F (1°C) or 0.2%, whichever is greater, of each other at all temperatures, then thermocouples made from the roll or rolls so qualified may be used.

3.1.4.1.2.2 For thermocouples made from qualified rolls, the calibrations used shall be the average of the calibrations of the sample thermocouples.

3.1.4.2 Use: System accuracy and temperature uniformity tests.

3.1.4.2.1 Reuse of Expendable (See 8.1.2) Thermocouples: Up to ten uses between calibrations is permissible, providing insulation is intact, the wires are not twisted or damaged, and the hot junction is undamaged. Expendable thermocouples which are not re-usable shall be either discarded or salvaged by trimming off the damaged portion, remaking the hot junction if necessary, and recalibrating if not from a qualified roll.

3.1.5 Working Sensors: Shall be calibrated, nonexpendable (See 8.1.3), base metal thermocouples, or sensors of equivalent or greater accuracy. Alternatively, expendable thermocouples may be used but they shall not be reused, i.e., they shall be discarded after a single use.

3.1.5.1 Calibration: Shall have been performed before installation by direct comparison with a primary or secondary standard sensor in accordance with a technique which is compatible with, or equivalent to, ASTM E220 or ASTM E207 proceduress. Deviations from the standard sensor shall not exceed ±1°F (±1°C) up to 1000°F (540°C) and ±0.4% at higher temperature except as follows:

3.1.5.1.1 Deviations for sensors in Class 2 equipment may be ±0.4% at temperatures higher than 500°F (260°C) except they may be ±0.75% if sensors are replaced monthly or more frequently.

3.1.5.1.2 Calibration of Thermocouple Wire Rolls: May be performed in accordance with 3.1.4.1.2 in lieu of calibrating individual thermocouples.

3.1.5.2 Use: Installed in thermal processing equipment for control and recording of temperature, in conjunction with working instruments.

3.1.6 Load Sensors: Shall be calibrated, expendable (See 8.1.2) or nonexpendable (See 8.1.3) thermocouples or sensors of equivalent or greater accuracy.

3.1.6.1 Calibration: Shall have been performed before first use and quarterly after first use, except that expendable thermocouples shall be additionally limited to a maximum of ten uses between calibrations. Calibration shall be by direct comparison with a primary or secondary standard sensor in accordance with a technique which is compatible with, or equivalent to, ASTM E220 or ASTM E207 procedures. Deviations shall not exceed ±2°F (±1°C) or ±0.4%, whichever is greater except deviations of ±0.5% are permissible at temperatures above 2000°F (1095°C).

3.1.6.1.1 When load sensors are used as working sensors to control temperature, calibration shall have been performed before first use and therafter (1) monthly for furnaces used for solution treating or aging of aluminum alloys, and (2) quarterly for other furnaces.

3.1.6.1.2 Calibration of Thermocouple Wire Rolls: May be performed in accordance with 3.1.4.1.2 in lieu of calibrating individual thermocouples.

3.1.6.2 Use: Inclusion in loads for measurement, in conjunction with working instruments, of temperature while in contact with parts or raw material during thermal processing.

3.1.6.2.1 Expendable Thermocouples: May be re-used as specified in 3.1.4.2.1.

3.2 Instrumentation (See Table 1):

3.2.1 Primary Standard Instruments: Shall be calibrated L & N Type K potentiometers, Keithley Instruments Model 181 digital voltmeters, Datron Model 1071 digital voltmeters, or instruments of equivalent accuracy, with a maximum correction factor of ±0.003% of reading.

3.2.1.1 Calibration: Shall have been performed within three years of use against reference resistance standards calibrated by the NBS within the previous three years.

3.2.1.2 Use: Shall be limited to calibration of secondary standard and test instruments.

3.2.2 Reference Standard Cells: Shall be calibrated mercury or cadmium cells of not less than 0.01840 volts.

3.2.2.1 Calibration: Shall have been performed by the NBS within three years of use.

3.2.2.2 Use: Shall be limited to calibration of primary standard cells and standardization of secondary standard and test instruments.

3.2.3 Secondary Standard Instruments: Shall be calibrated L & N Type 8686 potentiometers, or instruments of equivalent accuracy, with a maximum correction factor of ±0.03% of reading.

3.2.3.1 Calibration: Shall have been performed within one year of use against a primary standard instrument or a reference standard cell.

3.2.3.2 Use: Shall be limited to calibration of test instruments.

3.2.4 Primary Standard Cells: Shall be calibrated mercury or cadmium cells of not less than 0.01840 volts.

3.2.4.1 Calibration: Shall have been performed within one year of use against a reference standard cell.

3.2.4.2 Use: Shall be limited to standardization of secondary standard and test instruments.

3.2.5 Test Instruments: Shall be calibrated, portable, potentiometers or digital equipment or instruments of equivalent accuracy; those having scales shall, if used on aluminum solution heat treating or aging furnaces, have scale divisions no greater than 5°F (3°C) or the millivolt equivalent thereof and a readability of at least 0.030 in. per deg F (1.35 mm per deg C); those having scales shall, if used only on other equipment, have scale divisions no greater than 10°F (5°C) or the millivolt equivalent thereof and a readability of at least 0.030 in. per 3 deg F (1.35 mm per 1.5 deg C); digital equipment shall have a readability of 1°F or 1°C; correction factors shall not exceed ±1°F (±0.5°C) or ±0.2%, whichever is greater. To meet the scale readability requirement, it is permissible to (1) scribe intermediate lines between scale divisions (2) sharpen indicator points, and (3) interpolate. As an optional variation, multipoint strip chart recorders and data loggers may be used for temperature uniformity tests providing they meet the above requirements.

TABLE 1

OUTLINE OF SENSORS AND INSTRUMENTS

NOMENCLATURE	DESCRIPTION (1)	CALIBRATION PERIOD	CALIBRATION AGAINST	USE/MAXIMUM CORRECTION FACTOR
Reference standard sensor	Platinum/Platinum -Rhodium	5 years	NBS	Primary standard sensor calibration/None
Primary standard sensor	Platinum/Platinum -Rhodium	2 years	Reference standard	Secondary standard and test sensor calibration(3)
Secondary standard sensor	Base metal (non-expendable)	6 months	Primary standard	Test sensor calibration/ ±2°F (±1°C) or ±0.4%
Test sensor	Base metal (expendable or non-expendable)	3 months (expendable limited to 10 uses)	Primary or secondary standard	System accuracy and temperature temperature uniformity tests/ ±2°F (±1°C) or ±0.4%
Working sensor	Base metal (nonexpendable)	Before installation	Primary or secondary standard	Installation in thermal processing equipmment/±2°F (±1°C) or 0.4%
Load sensor	Base metal (expendable or nonexpendable	3 months (expendable limited 10 uses)	Primary or secondary standard	Insertion in loads of parts or raw material/±2°F (±1°C) or 0.4%
Primary standard instrument	Type K, Keithley 181, Datron 1071	3 years	Reference resistance standards	Secondary standard instrument calibration/±0.003% of reading
Reference standard cell	Mercury or Cadmium	3 years	NBS	Primary standard cell calibration/ None
Secondary sstandard instrument	Type 8686	1 year	Primary standard	Test instrument calibration/ ±0.03% of reading
Primary standard cell	Mercury or Cadmium	1 year	Reference standard	Secondary standard and test instrument standardization/ None
Test instrument	Portable potentiometer	3 months	Primary standard	Working instrument calibration, syatem accuracy and temperature uniformity testa/±1°F (0.5°C) or ±0.2%
Working instrument	Electronic null-balance potentiometer	(2)	Test instrument	Installation on thermal processing equipment ±0.3% range

(1) Sensors and instruments of equivalent accuracy are acceptable.

(2) 1 month for aluminum solution heat treating or aging furnaces, 3 months for other heat treating furnacea, and 6 months for embrittlement relief furnaces, quench batha and refrigeration equipment.

(3) ±3°F (±1.5°C) up to 1100°F (595°C) and ±0.25% at higher temperatures.

3.2.5.1 Calibration: Shall have been performed within three months of use against a primary or secondary standard instrument.

3.2.5.2 Use: System accuracy tests, temperature uniformity tests, and calibration of working instruments.

3.2.6 Working Instruments: Shall be calibrated controlling, recording, or indicating potentiometers of the automatically functioning, electronic null-balance type having a constant voltage unit, or instruments or solid state devices of equivalent or greater accuracy. The deviation or correction factor shall be minimized and shall not exceed ±0.3% of range.

3.2.6.1 Calibration: Shall have been performed against a test instrument within (1) one month of use on furnaces used for solution heat treatment or aging of aluminum alloys, except that a three month period is permissible for computer controlled, self-calibrating instruments, (2) three months of use on furnaces used for other heat treating operations, and (3) six months of use for furnaces used for embrittlement relief treatments, for quench baths, and for refrigeration equipment.

3.2.6.2 Use: Control, indicating, and recording of temperature of thermal processing equipment.

3.3 Thermal Processing (See 8.1.1) Equipment: Furnaces are divided into Classes 1 and 2, depending on the thermal treatments performed in them; they are also divided into Type A and AA for heat treating parts depending on the number of sensors and instruments used, and Type RM for those used exclusively for raw material.

3.3.1 Classification: All equipment used for heat treatment of parts, and some equipment used for heat treatment of raw material, is designated Class 1. Class 2 equipment is that used exclusively for performing Class 2 heat treatments of raw material, (1) those which only affect its fabricability and (2) those whose effects on final properties are not significantly affected by minor deviations outside specified temperature ranges. All other raw material heat treating equipment is designated Class 1.

3.3.1.1 Class 1 heat treatments of raw material include:

3.3.1.1.1 Aluminum Alloys	- Solution heat treating - Aging - High temperature annealing to O1 temper
3.3.1.1.2 Titanium Alloys	- Solution heat treating - Aging
3.3.1.1.3 Corrosion Resistant Steel	- Aging or precipitation hardening grades at 1025°F (550°C) and below
3.3.1.1.4 H-11 Alloy Steel	- Tempering
3.3.1.1.5 Beryllium Copper	- Aging

3.3.1.2 Class 2 heat treatments of raw material include any aging, tempering, solution heat treating, and annealing treatments not designated "Class 1" in 3.3.1.1. Class 2 heat treatments of raw material also include stress relieving, normalizing, normalize and tempering, austenitizing, solution annealing, and subcritical annealing.

3.3.2 Type A Furnaces for Parts: Shall be equipped with at least one working sensor in each zone, attached to a working instrument or instruments, which record(s) and control(s) the temperature. In addition, each zone should have a high limit controller/sensor.

3.3.3 Type AA Furnaces for Parts: Shall be equipped with the minimum required for Type A, plus at least one additional recording working instrument attached to a working or load sensor in each control zone. Additional sensor(s) shall be positioned as close as possible to the hottest and/or coldest locations, based on the last temperature uniformity test. A single multipoint recorder may be used as the additional instrument for several zones in one or more furnaces.

3.3.4 Type RM Furnaces for Raw Materials: Shall be equipped as specified in 3.3.2 or 3.3.3 and shall be used exclusively for heat treatment of raw materials.

3.3.5 Refrigerated Storage Equipment for Aluminum Alloys and Quench Baths: Shall have a suitable temperature control with either a temperature indicator or a working instrument attached to a working sensor. With respect to quench baths, this requirement is only applicable to baths used for heat treatments which include a quenchant temperature (minimum, maximum, or both) requirement.

3.3.6 Embrittlement Relief Furnaces and Subzero Transformation Equipment: Shall be equipped with a working instrument or instruments attached to working sensor(s) to record and control temperature except that a control instrument is not required for dry ice/liquid refrigerators.

3.3.7 Use of Load Sensors: The requirements for recording working instruments in 3.3.2, 3.3.3, 3.3.4 and 3.3.5 are waived when load sensors, whose readings are recorded, are used in contact with parts or raw materials. In such cases, sensors, at least two in each control zone, shall be placed at the locations in the load which are as close as possible to those shown, by the last temperature uniformity test to be the hottest and coolest, and their recorded readings shall become a part of the thermal processing record.

3.3.8 Installation of Working Instruments: Shall (1) avoid conditions detrimental to accuracy and consistency, (2) shall be serviced each time they are calibrated, (3) shall receive an unmodified signal from the sensors except for analog to digital conversions, and (4) shall be sensitive to a change equivalent to 2°F (1°C) or 0.2%, whichever is greater. Lead wires shall not be spliced but connectors, plugs, jacks, and terminal strips are permissible. Recording instruments shall make an accurate, legible mark to indicate the temperature. Chart paper shall not be re-used.

3.3.8.1 Readability of Indicating and Recording Working Instruments: Shall be ±2°F (±1°C) for all heat treating furnaces used for parts except those used only for processes having a temperature tolerance range broader than ±20°F (±10°C). For such furnaces, instrument charts, scales, and indicators shall be readable to ±5°F (±3°C) up to 1799°F (980°C) and ±10°F ((±5°C) at higher temperatures. Readability for raw material furnaces shall be ±5°F (±3°C) for Class 1 and ±10°F (±5°C) for Class 2 furnaces. To meet these requirements, it is permissible to (1) scribe intermediate lines between scale divisions, (2) sharpen indicator points, (3) interpolate, and (4) read the center or edge of recorded lines or dots, whichever corresponds to the indicator reading.

3.4 Tests:

3.4.1 System Accuracy Tests (See Table 2): Shall be performed on the temperature control system (load or working sensor/working instrument combination) in each control zone of each piece of thermal processing equipment. Tests shall also be performed on additional systems which qualify furnaces as Type AA.

3.4.1.1 Frequency: For Class 1 equipment shall be once per week except it may be once per month for control zones having more than one working or load sensor. Frequency for Class 2 equipment shall be every three months after installation.

3.4.1.2 Procedure: The temperature indication of the load sensor or working sensor on the working instrument, at any operating temperature, shall be compared with that indicated on a test instrument by a test sensor placed within 3 in. (75 mm) (Class 1 equipment) or 12 inches (300 mm) (Class 2 equipment) of the load or working sensor. Any difference between the readings (after test sensor and instrument correction factors are applied) shall be recorded.

3.4.1.2.1 If the difference (including any prior adjustment of the working instrument) exceeds 5°F (3°C) for Class 1 or 10°F (6°C) for Class 2 equipment, the cause of the difference shall be determined and repaired or corrected before commencing additional thermal processing. Adjustment of instruments or offsetting set temperatures to alleviate the difference is prohibited.

3.4.1.2.2 In addition, the quality assurance organization responsible for the furnace shall evaluate possible effects of the deviation on raw material and parts processed since the last successful test. The evaluation shall be documented and, where necessary, shall include consultation with metallurgists, engineers, etc. Appropriate corrective action shall be taken and documented.

3.4.1.2.3 If the difference read is less than specified in 3.4.1.2.1, and cause is, wholly or partially, a drift of the working sensor or instrument, the working instrument shall be adjusted, if possible, to compensate for such drift, the amount of adjustment shall be recorded, and 3.4.1.2 shall be repeated. If adjustment of the working instrument is not possible, the difference, if greater than ±2°F (±1°C) if Class 1 or ±5°F (3°C) if Class 2, shall be posted on the instrument and appropriate compensation shall be made by the heat treater.

3.4.1.2.2.1 If the cause is, wholly or partially, movement of the working sensor, from the position it occupied during the previous temperature uniformity test, any compensation for that difference, or portion of the difference, is prohibited. However, it is permissible to reposition the working sensor, returning it to the location it occupied during the previous temperature uniformity test and repeat 3.4.1.2.

TABLE 2

OUTLINE OF SYSTEM ACCURACY TEST FREQUENCIES

Equipment Class	Minimum Number and Type of Sensors in each Control Zone	Mininum Test Frequency
1	1 Working	Weekly
1	1 Working plus 1 (Load or Working	Monthly
2	1 Working	Quarterly

TABLE 3

OUTLINE OF PERIODIC TEMPERATURE UNIFORMITY TEST FREQUENCIES

Usage Code*	Equipment Type**	Class***	Normal Frequency	Conditional Reduced Frequency	(2nd reduction)
1	A	1	Monthly	Quarterly	N/A
1	AA	1	Monthly	Quarterly	N/A
1	RM	1	Monthly	Quarterly	Semi-Annually
2	A	1	Quarterly	Semi-Annually	N/A
2	AA	1	Quarterly	Semi-Annually	N/A
2	RM	1	Quarterly	Semi-Annually	Annually
3	A	1	Semi-Annually	Annually	N/A
3	AA	1	Semi-Annually	Annually	N/A
3	RM	1	Semi-Annually	Annually	Annually
All	All	2	Annually****	-	N/A

*Usage Code:
1. Solution treating or aging of aluminum alloys and aging pH stainless steels at 1025°F (550°C) and below.
2. Solution treating or aging of materials other than aluminum alloys plus austenite conditioning, austenitizing, and tempering.
3. Treatments other than those in 1 and 2.

**A - See 3.3.2
AA - See 3.3.3
RM - Raw Material - See 3.3.4

***See 3.3.1

****Except 5 - 7 months after initial test

3.4.1.2.2.2 Drift of the working sensor shall be determined by attaching it to the test instrument and comparing its reading to that of the test sensor. Drift of the working instrument shall be determined by comparing it against the test instrument.

3.4.1.3 As an alternate to the system accuracy test above, it is permissible to accomplish the same objective by testing the components (working sensor, working instrument) separately and then combining the results.

3.4.2 Temperature Uniformity Tests (See Table 3): Shall be performed, in accordance with the Appendix, on each furnace and each liquid nitrogen, or mechanical, refrigeration unit used for subzero transformation initially (prior to production use or after any repair or adjustment, e.g. to power controls, or baffles, which might have altered the temperature uniformity characteristics) (See 8.1.8) and periodically thereafter. The requirement for initial tests is waived for raw material furnaces which have a history of at least five consecutive successful, first attempt, uniformity tests, in accordance with the Appendix or the appropriate government or industry specification, over at least two years without any major repairs or adjustments.

3.4.2.1 Uniformity Requirements: Unless an equipment temperature uniformity requirement is specified in the applicable material, heat treating, or processing specification, uniformity shall conform to the following:

3.4.2.1.1 For equipment to be used for solution heat treating, high temperature annealing, and aging of aluminum alloys, aging beryllium copper, aging precipitation hardening corrosion resistant steels at 1025°F (540°C) and below, or for tempering H11 steel, deviations from the mean of the temperature range shall not exceed ±10°F (±5°C).

3.4.2.1.2 For equipment to be used for aging precipitation hardening corrosion resistant steels above 1025°F (540°C), deviations from the mean of the temperature range shall not exceed ±15°F (±7°C).

3.4.2.1.3 For all other heat treating processes, deviations from the mean of the temperature range shall not exceed ±25°F (±15°C).

3.4.2.1.4 If any deviation from the set temperature exceeds the applicable limit, the cause of the deviation shall be determined and repaired or corrected and the equipment shall not be used for additional processing until the uniformity test has been performed successfully. Adjustment of instruments or offsetting mean of temperature range to alleviate the deviation is prohibited.

3.4.2.1.4.1 In addition, the quality assurance organization responsible for the furnace shall evaluate possible effects of the deviation on raw material and parts processed since the last successful test. The evaluation shall be documented and, where necessary, shall include consultation with metallurgists, engineers, etc. Appropriate corrective action shall be taken and documented.

3.4.2.2 Initial Test Temperatures: Shall be the highest and lowest temperatures for which the equipment will be used and the following:

3.4.2.2.1 If the highest and lowest temperatures are more than 600 F (335 C) deg apart, additional tests shall be performed at one or more intermediate temperatures so that test temperatures are not more than 600 F (335 C) deg apart.

3.4.2.2.2 Furnaces used for solution heat treating of aluminum alloys shall be tested at the highest and lowest solution heat treating temperatures.

3.4.2.2.3 Furnaces used for aging of aluminum alloys shall be tested at the highest and lowest aging temperatures.

3.4.2.3 Periodic Test Temperatures: Shall be any temperature within each 600 F (335 C) deg or less temperature range, as described in 3.4.2.2.1, 3.4.2.2.2 and 3.4.2.2.3 except that at least once each year, the test shall be performed within 100°F of the maximum temperature of each range. However, the test need not be performed above 2000°F (1095°C) even though the maximum temperature is above 2100°F (1150°C).

3.4.2.4 Periodic Test Frequency: For equipment used for Class 1 heat treatments of raw materials and any heat treatment of parts, shall be (1) monthly for furnaces used for solution heat treatment or aging of aluminum alloys and aging PH stainless steels at 1025°F (550°C) and below, (2) quarterly for solution heat treatment or other aging treatments as well as austenite conditioning, precipitation heat treatment, austenitizing and tempering, and (3) semi-annually for all other furnaces and for liquid nitrogen or mechanical refrigeration units used for subzero transformation except as described in 3.4.2.4.1, 3.4.2.4.2, 3.4.2.4.3 and 3.4.2.4.4. Test frequency for Class 2 equipment shall be annually.

3.4.2.4.1 Test Frequency for Type A Furnaces (See 3.3.2): May be reduced once, by one level, from that required in 3.4.2.4, from monthly to quarterly or quarterly to semi-annually or semi-annually to annually, after completion of six consecutive, successful, first attempt periodic tests providing that a written preventive maintenance plan is established which includes a schedule for replacing working sensors and recording of all maintenance operations.

3.4.2.4.2 Test Frequency for Type AA Furnaces (See 3.3.3): May be reduced once, by one level, from that required in 3.4.2.4, from monthly to quarterly or quarterly to semi-annually or semi-annually to annually, after completion of three consecutive, successful, first attempt periodic tests.

3.4.2.4.3 Test Frequency for Class 1 Raw Material Furnaces: May be reduced one level, from that required in 3.4.2.4, from monthly to quarterly or quarterly to semi-annually or semi-annually to annually for furnaces which have a history of five consecutive, successful, first attempt uniformity tests, in accordance with the Appendix or the appropriate U.S. Government specification, over at least two years. The frequency

3.4.2.4.3 (Continued)

may be reduced two levels, from that required in 3.4.2.4, from monthly to semi-annually or quarterly to annually for furnaces having a history of seven consecutive, successful, first attempt uniformity tests in accordance with the Appendix or the appropriate industry or U.S. Government specification, over at least three years.

3.4.2.4.3.1 Frequency for furnaces employing load sensors may be reduced one level, from that required in 3.4.2.4, from monthly to quarterly or quarterly to semi-annually or semi-annually to annually, after completion of two consecutive successful, first attempt, periodic tests in accordance with the appendix providing that a written preventive maintenance plan is established which includes a schedule for replacing working sensors and recording of all maintenance operations. A second one-level reduction may be made, i.e. from quarterly to semi-annually, or semi-annually to annually, after completion of two or more consecutive, successful, first attempt, periodic tests in accordance with the Appendix.

3.4.2.4.4 Test Frequency for Class 2 Raw Material Furnaces: Shall be annual except that a test shall be performed within 5 - 7 months after the initial test.

3.4.2.4.5 If a reduced frequency, first attempt, periodic test fails to meet the uniformity requirements of the applicable specification, the test frequency shall revert to that of 3.4.2.4 and it shall remain in effect until the furnace is once again qualified for frequency reduction in accordance with 3.4.2.4.1, 3.4.2.4.2, and 3.4.2.4.3 or 3.4.2.4.3.1.

3.4.2.5 Load Condition: Shall be unloaded (racks are permissible), except as specified in 3.4.2.5.1 and 3.4.2.5.2.

3.4.2.5.1 Tests of furnaces used exclusively for heat treatment of heavy loads of parts or raw material may be performed with any load. A load shall be considered heavy if the volume of the parts or raw material exceeds 10% of the volume of a working zone.

3.4.2.5.2 Tests of furnaces used for heat treatment of light or medium loads of parts or raw material, particularly those of alloy/gage combinations which are detrimentally affected by short duration, over-temperature excursions of the furnace (e.g. solution heat treatment of 0.025 in. (0.62 mm) thick 2024 aluminum alloy), shall be performed either without a load, except for racks, or with a load no heavier than the lightest load which will be heat treated.

3.4.2.5.3 A detailed diagram or description, or photograph(s), of any load used and a diagram of test sensor locations shall be included in the test report.

3.5 Records: All calibrations of sensors, standard cells, and instruments, as well as all system accuracy and temperature uniformity tests, diagrams of test sensor locations, including failed tests, shall be kept on file and available for inspection for not less than five years.

3.5.1 Calibration records of sensors, standard cells, and instruments shall include traceability to the NBS.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The processor shall be responsible for performing all required tests and for conformance to all requirements specified herein. He may use his own equipment and personnel or those of any commercial testing organization which has not been designated "unacceptable" by the purchaser. Purchaser reserves the right to witness any of the tests or calibrations specified herein to ensure that processing conforms to the prescribed requirements, but such witnessing shall not hinder operation of the facility.

5. PREPARATION FOR DELIVERY: Not applicable.

6. ACKNOWLEDGMENT: Not applicable.

7. REJECTIONS: Not applicable.

8. NOTES:

8.1 Definitions:

8.1.1 "Thermal Processing" is any process in which metals are exposed to controlled heating, soaking, or cooling. The term normally excludes forging, drying, and heating for hot forming.

8.1.2 "Expendable Thermocouples" are those thermocouples made of fabric-insulated wire. The type of wire is provided in coils or on spools. Insulation usually consists of glass braid, asbestos, or ceramic fiber cloth, or equivalent, on each conductor plus glass braid overall.

8.1.3 "Nonexpendable Thermocouples" are those thermocouples that are not covered with fabric insulations. The following are examples of "nonexpendable thermocouples":

8.1.3.1 Ceramic insulators over bare thermocouple wire, sometimes inserted in an open end or closed end tube for stability and protection.

8.1.3.2 A combination of thermocouple wire, mineral insulations, and a protecting metal sheath compacted into a solid mass of small diameter. The thermocouple thus constructed is protected, flexible and, within the temperature limits of the sheath material, may be used many times without insulation breakdown. This type of thermocouple is available under many trade names.

8.1.4 "Working Zone" is that portion of the enclosed volume of a piece of thermal processing equipment where parts or raw material will be placed for processing. It is usually, but not always, a high percentage of the total enclosed volume.

8.1.5 "Control Zone" is a portion of the working zone of a piece of thermal processing equipment having a separate sensor/instrument/heat input or output mechanism to control its temperature. The number of control zones depends on the design of the equipment. Some large furnaces have only one or two control zones. Some long furnaces have many control zones.

8.1.6 "Correction Factor" is that number of degrees, determined from the most recent calibration, which must be added to, or subtracted from, the temperature reading of a sensor or an instrument or a combination thereof (system) to obtain NBS true temperature. The correction factors of sensors and instruments are usually kept separately and added together algebraically when a combination is used. When a correction factor is expressed as a percent, it means percent of reading.

8.1.6.1 Example of test sensor correction factor of +2°F at 1000°F: During calibration, test sensor reading was 998°F when secondary standard sensor reading was 1000°F. Of course, these readings incorporate consideration of correction factors of the instruments and the secondary standard sensor.

8.1.7 "Heat Treatment of Raw Material" is heat treatment, usually performed by or for a material producer, in accordance with a material specification, which may require, by reference, conformance to a heat treating specification. "Heat treatment of parts" is performed by or for a fabricator in accordance with a drawing, purchase order, fabrication outline, or heat treating specification. "Heat treatment of parts" may include heat treatment, by or for a fabricator, of pieces which resemble raw material.

8.1.7.1 Raw material (e.g. sheet, plate, bar, forgings, castings) is usually destructively tested in accordance with the requirements of a material specification. Parts are produced from raw material, in accordance with the requirements of a drawing, and are usually tested by nondestructive techniques only.

8.1.7.2 Raw material is usually identified by a heat or lot number; parts are usually identified by a part number.

8.1.8 A new initial temperature uniformity test is not required after minor repairs (e.g., replacing bricks) which could not alter temperature uniformity characteristics.