

Specification for

Temperature control in the heat treatment of metals

Contrôle de la température de traitement
thermique des métaux — Spécifications

Temperaturregelung bei der Wärmebehandlung
von Metallen

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Foreword

This British Standard has been prepared under the direction of the Aerospace Standards Policy Committee. It is the first revision of BS M 54, which was originally published in 1982 and is now withdrawn.

In this revision, the requirements have been reviewed in the light of operating experience. No major changes have been introduced and the principles remain the same. However, detailed modifications have been introduced and, where necessary, reinforced to reflect current technological trends and to allow maximum commonality with similar documents produced by other industries and international organizations.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Specification

1 Scope

This British Standard specifies the requirements for the measurement and control of temperature during the heat treatment of metals and parts used in aerospace construction, in furnaces¹⁾, ovens or baths.

It does not deal with other aspects of heat treatment operations that may affect the finished product, e.g. soaking time, furnace atmosphere and quenching rate. Furthermore, it is not intended for application to heating for the sole purpose of assisting mechanical deformation or other immediate processes which do not affect the final properties of the material.

NOTE. The titles of the publications referred to in this standard are listed on the inside back page.

2 Definitions

For the purposes of this British Standard, the following definitions apply.

2.1 heat treatment

Heating operations that are applied to obtain specified properties or condition in the material.

2.2 category A heat treatment

Heat treatment where precise control of temperature is essential to ensure development of specific mechanical properties and/or metallographic structure.

2.3 category B heat treatment

Heat treatment where a wider temperature range can be tolerated without impairment of ability to achieve the required mechanical properties and/or metallographic structure.

2.4 effective working volume

That part of the furnace in which the temperature is to be maintained within specified tolerance limits.

2.5 manufacturer

The firm responsible for the heat treatment of materials or parts in the condition in which they are consigned to the purchaser.

2.6 repeatability of temperature measurement

The ability of a temperature measuring system to reproduce consistently the measurement of temperature.

2.7 bias of temperature measurement

The consistent deviation of a temperature measurement system.

2.8 master thermocouple

A thermocouple whose calibration is traceable to a national standard and is used within specified limits. (See 6.4.)

2.9 secondary master thermocouple

A thermocouple that is calibrated against a master thermocouple and is capable of operation within specified limits.

NOTE. Secondary master thermocouples are normally used for the calibration of reference thermocouples where the life of a master thermocouple needs to be preserved. (See 6.4.)

2.10 reference thermocouple

A thermocouple that is calibrated against a master or secondary master thermocouple and is capable of operation within specified limits.

NOTE. Reference thermocouples are normally used to perform furnace surveys and regular checks on furnace pyrometry. (See 6.3.)

3 General

3.1 The temperature of the furnace shall be controlled in such a manner that the temperatures of the charge or the effective working volume shall comply with 3.2 or 3.3, whichever is applicable.

3.2 Where a particular heat treatment temperature with a tolerance is specified in the material specification or order, this shall be strictly observed. Where the specified temperature tolerance is less than or equal to that given in table 1 for category A heat treatment, the heat treatment shall be regarded as category A. Where the specified temperature tolerance is greater, the heat treatment shall be regarded as category B.

Table 1. Heat treatment categories

Temperature	Maximum temperature tolerance of charge or effective working volume	
	Category A heat treatment	Category B heat treatment
°C	°C	°C
< 750	±5	±10
≥ 750	±10	±15

3.3 Where no heat treatment temperature is specified, or where a temperature maximum, minimum, or range is given, the required heat treatment temperature shall be determined by the manufacturer and shall be included in the work instructions for the operation. The tolerance on this selected temperature shall be as given in the material specification or on the order. Where no temperature tolerance is specified, the tolerances given in table 1, category B, shall be applied.

3.4 A record of all heat treatment operations shall be maintained (see clause 8) and the temperature shall be recorded during the process. All such temperature records shall be annotated so that the temperature against time record can be correlated with the work treated.

¹⁾ The word 'furnace' throughout the text of this standard, except where specifically stated, includes furnaces, ovens and baths.

4 Pyrometric equipment

4.1 Each furnace shall, as a minimum, be provided with the following pyrometric equipment.

- (a) An independent control instrument and temperature sensor so that the furnace temperature can be automatically controlled. Where zoned furnaces are used, separate temperature sensors and controllers shall be used for each zone.
- (b) A visual display and recording instrument coupled with a temperature sensor so that the temperature of the effective working volume can be measured. Where zoned furnaces are used, separate temperature sensors shall be provided for each zone. Where multi-point recorders are used, each temperature record shall be clearly identifiable to the relevant temperature sensor.
- (c) An over-temperature instrument coupled with a temperature sensor capable of operating an audible or visual alarm and, where practicable, capable of shutting down the heating source when there is a failure of the controller to cut out at a pre-set temperature. Where zoned furnaces are used, separate over-temperature instruments and temperature sensors shall be used for each temperature zone.

NOTE 1. An integrated system which satisfies the above requirements (a), (b) and (c) may be used.

NOTE 2. In this context, a zone is the volume of furnace under the heat control of one controller and one heating circuit.

4.2 Equipment based on the use of thermocouples shall normally be used for the measurement and control of heat treatment operations. For calibrations, furnace surveys and routine furnace checks, equipment based on the use of thermocouples, shall be used. Operational temperatures of thermocouples shall be in accordance with BS 1041 : Part 4.

NOTE. For temperatures above 1250 °C other instruments may be used, provided they maintain the required control of the process.

4.3 Analogue temperature recording instruments for furnaces used in category A heat treatments shall have a scale spacing, at the operating temperature, as shown in table 2.

Temperature indicating/recording instrument: total indicating range	Maximum temperature increment per mm of scale	Maximum interval between scale divisions
°C	°C	°C
< 750	4	10
≥ 750	7	10

5 Furnace surveys

5.1 Before new furnaces are used for production heat treatment, they shall be surveyed using reference thermocouples and instruments (see 6.3 and 6.5) for temperature variation and adequacy of control. Where it is impossible to use the method of surveying as defined in this standard due to the design of the furnace (e.g. continuous furnaces and vacuum furnaces), an alternative method shall be defined by the manufacturer.

5.2 Furnaces shall be surveyed as follows

- (a) Furnaces used for category A heat treatments shall be surveyed with at least one reference thermocouple for each 0.75 m³ of effective working volume, with a minimum of five thermocouples. Thermocouples shall be distributed evenly within the required effective working volume.

NOTE. For furnaces greater than 18 m³, surveys may be carried out with a total of 24 thermocouples, irrespective of volume.

- (b) Furnaces used for category B heat treatments shall be surveyed with at least one thermocouple for each 1 m³ of effective working volume, with a minimum of five thermocouples. Thermocouples shall be distributed evenly within the required effective working volume.

NOTE. For furnaces greater than 12 m³, surveys may be carried out with a total of 12 thermocouples, irrespective of volume.

- (c) Bath-type furnaces for both category A and B heat treatments below 1000 °C shall either be surveyed in accordance with (a) or (b) as appropriate, or at a minimum of nine evenly distributed locations within the bath to demonstrate temperature uniformity.

NOTE. A single reference thermocouple which is moved in the bath to these locations may be used for this purpose. When checking for overshoot, this test couple should be close to the heat source.

5.3 The initial survey, and any survey after major repair, shall be performed at the maximum and minimum temperature range for which the furnace is likely to be used, and at intermediate temperatures not more than 200 °C apart. Subsequent surveys shall be performed at the maximum and minimum temperatures of the normal operating range and at temperatures not more than 400 °C apart.

5.4 To establish the stabilized temperature pattern, temperature readings shall be taken at intervals, where practicable, not exceeding 2 min and for sufficient time, not less than 30 min after attainment of the required temperature, and without alteration of the set point temperature.

The maximum variation in temperature throughout the effective working volume of the furnace shall not exceed the temperature tolerances specified in 3.2 or 3.3. There shall be no overshoot of temperature beyond these tolerances.

NOTE. Metallic heat sinks on survey sensors may be used if they represent, or are smaller than, the smallest charge in terms of section thickness.

5.5 For furnaces used for category A heat treatments, the survey shall be repeated at intervals not exceeding 6 months, except where it can be demonstrated that the tolerances specified in 3.2 and 3.3 can be maintained; in which case the frequency of the survey may be reduced to intervals not exceeding 12 months. For furnaces used for category B heat treatments the survey shall be repeated at intervals not exceeding 12 months.

NOTE 1. Where the furnace is provided with an equivalent number of evenly distributed temperature indicators as specified in 5.2, only a limited survey to check for adequacy of control and freedom from excessive variation need be carried out.

5.6 A full survey shall be carried out after any repair or modification to the furnace that may affect temperature control and uniformity, or whenever doubt exists as to the furnace efficiency or accuracy of temperature readings.

6 Calibration

6.1 General

6.1.1 Calibration of thermocouples, control and indicating instruments shall be carried out with equipment whose calibration is traceable to national standards.

6.1.2 Thermocouples shall be manufactured and used in accordance with BS 1041 : Part 4.

NOTE. Particular attention is drawn to the effects of temperature gradients and depths of immersion on the output electromotive force (e.m.f.) of a thermocouple when one or both of the wires become heterogeneous. For these reasons, if a thermocouple has been in service in one location for some time it is preferable to check it in situ. Removal to another separate calibration furnace may lead to erroneous calibration unless the test conditions for depth of immersion and temperature gradient are identical with previous service conditions.

6.2 Thermocouples for use in production furnaces and baths

The accuracy of thermocouples used in production furnaces shall be such that they comply with the temperature requirements of 7.2.2.

6.3 Reference thermocouples

6.3.1 Reference thermocouples, together with any necessary compensating leads, shall be initially calibrated against a master, or secondary master, thermocouple. Where the reference thermocouple is to be used over a temperature range, calibration shall be at temperatures or a temperature appropriate to their use. Calibration temperatures

shall be within 75 °C of the maximum and minimum use temperature and at approximately 250 °C intervals between these extremes. The maximum correction that shall be applied to a reference thermocouple system for temperature bias shall not exceed ± 3 °C or ± 0.75 % of the temperature being measured, whichever is the greater.

6.3.2 For thermocouples used only for furnace surveys, as an alternative to calibrating individual thermocouples, wire purchased and certified to class 1 (class 2 for type B) of BS 4937 : Part 20 shall be calibrated by checking one thermocouple from each reel.

6.3.3 Reference thermocouples of the rare metal type shall be calibrated at intervals not exceeding 12 months. Reference thermocouples of the base metal type for use at temperatures below 600 °C shall be calibrated at intervals not exceeding 6 months, and for use at temperatures of above 600 °C shall after 6 months be renewed or re-calibrated and subject to further calibration at intervals not exceeding 3 months. It is recommended that the maximum temperature at which nickel-chromium/nickel-aluminium thermocouples are used for reference is 1100 °C, but if used above this temperature, they shall be calibrated each time before use.

NOTE. At lower temperatures the deterioration of such thermocouples is slower, but the wires gradually lose their homogeneity, and accuracy then becomes dependent on temperature gradient and depth of immersion. It is for these reasons that the more stable platinum/platinum-rhodium thermocouples or previously unused nickel-chromium/nickel-aluminium thermocouples are normally used for reference purposes.

6.4 Master thermocouples

6.4.1 Master thermocouples shall be of the platinum/platinum-rhodium type. They shall be calibrated, together with any compensating leads, at sufficient temperatures throughout the working range to ensure that, when used with an indicator of the required accuracy, the repeatability of temperature measurement is within ± 1.5 °C. The maximum correction to a master thermocouple for bias shall not exceed ± 2 °C.

6.4.2 Master thermocouples shall be calibrated at intervals not exceeding 12 months.

6.4.3 Secondary master thermocouples shall be calibrated against a master thermocouple at intervals not exceeding 12 months and shall comply with 6.4.1.

6.5 Temperature measuring instruments

6.5.1 Instruments for use with reference or master thermocouples shall be of such accuracy that they do not introduce an error of more than ± 0.25 % of full scale range.

6.5.2 Instruments for use with reference thermocouples shall be calibrated at intervals not exceeding 6 months. Instruments for use with master thermocouples shall be calibrated at intervals not exceeding 12 months.

6.5.3 Temperature indicators and recorders for use with production furnaces shall be calibrated against independent reference voltages across the operating range of the furnace at intervals not exceeding 6 months. The instrument error shall not exceed ± 2.5 °C or ± 0.5 % of the selected calibration temperature, whichever is the greater.

7 Routine checks on furnace instrumentation

7.1 Daily checks

When in use, the instrumentation shall be checked daily to ensure that it is working correctly. Such checks shall include, as a minimum, the following:

- (a) alignment of recording chart and correct chart speed setting;
- (b) correct functioning of chart marking mechanism;
- (c) correlation of set point to recorded temperature.

7.2 Weekly and other checks

7.2.1 When in use, checks shall be made on the correct functioning of the over-temperature device and either:

- (a) at least one production thermocouple/recorder combination in each furnace shall be checked at intervals not exceeding 1 week against a reference thermocouple and instrument. The reference thermocouple shall be located close to the recorder thermocouple in the furnace which shall be at normal operating temperature(s) with a representative load in position.

or

- (b) Where a furnace is provided with a number of evenly distributed recording thermocouples equivalent to that specified in 5.2 which are checked against each other, the check shall be performed at intervals not exceeding 3 months. The temperature pattern established at the time of the last survey shall be maintained within the limits specified in 7.2.2.

7.2.2 The discrepancy between the indicated temperature and the temperature as determined by the reference system shall not exceed 0.5 % of the temperature in degrees celsius being measured or 2 °C whichever is the greater, after the necessary temperature correction for the reference thermocouple system has been made.

8 Records

The following information shall be maintained and be available for examination:

- (a) details and date of calibration of thermocouples and associated instruments;
- (b) results and date of furnace temperature surveys;
- (c) results and date of weekly checks;
- (d) heat treatment records.

Publications referred to

- BS 1041 Temperature measurement
 Part 4 Thermocouples
- BS 4937 International thermocouple reference tables
 Part 20 Specification for thermocouple tolerances

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Committees responsible for this British Standard

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