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Aerospace series — Metallic materials — Heat treatment facilities — General requirements

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National foreword

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Foreword

This document (EN 4268:2012) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

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1 Scope

This European Standard covers the general requirements for heat treatment facilities processing semi-finished products and parts in metallic aerospace materials.

It defines the terms used herein and describes the test procedures and requirements for mandatory tests of heat treatment facilities. It also serves as an aid in the surveillance and approval of heat treatment facilities.

This standard applies to all types of heat treatment facilities, including those using direct or indirect heat transfer and liquid or gaseous heating media, with our without circulation, and to vacuum furnaces.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60584-2, *Thermocouples — Part 2: Tolerances* [1)]

3 General

The heat treatment of metallic materials produces specific material properties only if performed within relatively narrow temperature ranges, the respective tolerances of which are specified in the applicable standards. A heat treatment facility can therefore be used for a heat-treating operation only provided its temperature variations over space and time remain within the specified temperature tolerance.

Proper temperature distribution in the heat treatment facility depends on e.g. the type of furnace or bath, the heating medium, the control instruments with their feedback and run-up circuitry, and the rigging and positioning of control sensors.

A suitable recording instrument is needed to properly monitor and document the heat treatment.

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1
temperature uniformity
measure of the temperature variation at various points in the effective working volume after thermal equilibrium has been reached

4.2
effective working volume
for the purposes of the present standard, the effective working volume is the working zone of the heat treatment facility in which temperatures run within the specified maximum temperature variation and which is available for the intended heat treatment

1) Published by International **Commission Electrotechnique Internationale** http://www.iec.ch/ (CENELEC EN 60584-2).

4.3
maximum temperature variation
maximum temperature variation indicates how much the temperatures at different points in the effective working volume are allowed to vary from the working temperature after thermal equilibrium has been reached

4.4
category classification
depending on their technical characteristics, heat treatment furnaces or baths are classified into 4 categories A, B, C, D of different maximum temperature variation (see Table 1)

4.5
thermal equilibrium
thermal equilibrium is reached when following the temperature rise phase no validly recorded temperature varies by more than 20 % of the maximum allowable temperature variation in the effective working volume for the duration of one closed-loop oscillation

4.6
temperature setting
feature permitting analog or digital reproducible selection of the facility temperature set-point

4.7
correction factor
this is the correction applied to the set-point to achieve the specified working temperature

4.8
working temperature
temperature to which the heat treatment facility is brought for a certain heat treatment

4.9
working temperature range
range extending from the lowest to the highest working temperature at which the heat treatment facility is to be operated

Note 1 to entry: A code number identifies the maximum allowable working temperature.

4.10
test temperature
agreed temperature at which the reference measurement is to be made or the temperature uniformity to be demonstrated

4.11
temperature sensors
temperature-sensing elements for the various measuring, control and recording functions

4.12
recording sensor
temperature-sensing element of a chain of validly indicating and recording instruments

4.13
approval
for the purposes of the present standard, approval is the formal release of a facility for production heat treatment

Note 1 to entry: It is granted if compliance with the requirements of the present standard has been demonstrated by acceptance testing.

5 Heat treatment facility requirements

5.1 General

Heat treatment facilities shall be capable of satisfying the requirements of the heat treatment process to be applied.

Heat treatment facilities as defined in Clause 1 shall be approved prior to their release for production heat treatment and shall be subjected to periodic in-service checks. Approval and periodic checks shall be performed by the responsible company quality assurance, facilities support and calibration activities.

Approval and periodic checks shall be in conformance with the requirements of Clause 6.

In the case of safety tests, the competent specialist department shall be consulted. The test results shall be reported by the competent specialist department and filed with the heat treatment facility records.

5.2 Category classification

A heat treatment facility may fall within several categories if designed to operate in different working temperature ranges.

Table 1 — Maximum permissible temperature variation of effective working volume

Code number	Working temperature range °C	Maximum permissible temperature variation °C Category			
		A	B	C	D
03	$\theta \leq 300$	± 7,5	± 5	± 3	–
07	$300 < \theta \leq 700$	± 10	± 7,5	± 5	–
10	$700 < \theta \leq 1\,000$	± 15	± 10	± 7,5	± 5
13	$1\,000 < \theta \leq 1\,300$	± 20	± 15	± 10	± 5

Where a working temperature range of a facility is less than the maximum value given in Table 1, the corresponding code number shall be indicated in the designation as outlined in 5.6.

5.3 Heating media

Heating media shall be selected so as to avoid changes in the material surfaces during the heat treatment operation affecting the operational properties of the parts, unless such changes are allowed or specified in the material standards or design documents. Heating media, especially salts used in heat treatment baths, are liable to change with consumption or due to external influences.

5.4 Quenching equipment and quenchants

The quenching equipment shall be located close enough to the heat treatment facility to permit quenching in accordance with the relevant specifications.

For quenchants, use is made of water, oil, industrial gases, emulsions, air, etc., to achieve the cooling profile needed to develop the required material properties.

5.5 Temperature sensors

5.5.1 General

The temperature sensors for control and recording functions shall operate independently of each other.

The recording sensors shall be located in the effective working volume of the heat treatment facility or shall be positioned at locations representative of the effective working volume.

5.5.2 Temperature sensor accuracy (M)

The accuracy of temperature sensors shall be within the limit deviations as specified in IEC 584-2. The tolerance includes the compensating leads.

The thermocouple tolerance classes are shown in Table 2 versus the various facility categories.

Table 2 — Applicable tolerance classes of temperature sensor (M) in accordance with IEC 60584-2

Code number	Working temperature range °C	Category			
		A	B	C	D
03	$\theta \leq 300$	M = Class 2	M = Class 1	M = Class 1	M = Class 1
07	$300 < \theta \leq 700$				
10	$700 < \theta \leq 1\,000$				
13	$1\,000 < \theta \leq 1\,300$				

5.5.3 Number and distribution of recording sensors

The number of temperature sensors to be used in the effective working volume generally depends on the design and construction of the particular heat treatment facility involved.

The number and distribution of the temperature sensors shall be selected so as to suit the particular facility such that the temperature reading represents an authoritative value for the respective zone monitored (total effective working volume or portion thereof).

The number of recording sensors given in Table 3 is indicated for reference only.

Table 3 — Number of recording sensors (AT)

Code number	Working temperature range °C	Category			
		A	B	C	D
03	$\theta \leq 300$	With one soaking zone	With one soaking zone	With one soaking zone	With one soaking zone
07	$300 < \theta \leq 700$	AT = 1 for each 3 m^3 of effective working volume AT = 4 max.	AT = 1 for each 2 m^3 of effective working volume AT = 6 max.	AT = 1 for each 1 m^3 of effective working volume AT = 12 max.	AT = 1 for each 1 m^3 of effective working volume AT = 12 max.
10	$700 < \theta \leq 1\,000$	With several soaking zones	With several soaking zones	With several soaking zones	With several soaking zones
13	$1\,000 < \theta \leq 1\,300$	Per soaking zone AT = 1	Per soaking zone AT = 1 for each 2 m^3 of effective working volume	Per soaking zone AT = 1 for each 1 m^3 of effective working volume	Per soaking zone AT = 1 for each 1 m^3 of effective working zone

5.6 Designation

The designation of a heat treatment facility shall indicate the category(-ies) and related working temperature range(s) (identified by code number).

A category D heat treatment facility operated in the working temperature range over 1 000 °C to 1 300 °C (code number 13) shall be designated as follows:

Furnace EN 4268 — D 13

A category C heat treatment facility operated within a limited working temperature range of 700 °C to 900 °C (code number 9) shall be designated as follows:

Furnace EN 4268 — C 09

If a heat treatment facility is to be operated in several working temperature ranges with different categories, the relevant category shall be specified for each working temperature range.

EXAMPLE

Furnace EN 4268 — C 07 — B 03

5.7 Temperature setting (W) and indicating accuracy (A)

The accuracy of setting is largely a matter of resolution.

A digital setting (1 digit ≅ 1 °C) will generally give better resolution than an analog setting. This holds true especially in respect of reproducibility.

Analog settings and readings shall give an accuracy of ≥ 0,5 mm.

The most favourable temperature setting for the standard working temperature values shall be apparent from the heat treatment facility records; this applies especially when several controllers are used.

Table 4 shows the temperature setting resolution and indicating accuracy requirements for the different facility categories.

Table 4 — Temperature setting resolution (W) and indicating accuracy (A)

Code number	Working temperature range °C	Category			
		A	B	C	D
03	$\theta \leq 300$	W ≤ 2 °C (analog) A = ± 1 %	W ≤ 1 °C (digital) A = ± 0,5 %	W ≤ 1 °C (digital) A = ± 0,3 %	–
07	$300 < \theta \leq 700$	W ≤ 3 °C (analog) A = ± 1 %	W ≤ 2 °C (digital) A = ± 0,5 %	W ≤ 1 °C (digital) A = ± 0,3 %	–
10	$700 < \theta \leq 1\,000$	W ≤ 5 °C (analog) A = ± 1 %	W ≤ 3 °C (digital) A = ± 0,5 %	W ≤ 2 °C (digital) A = ± 0,3 %	W ≤ 1 °C (digital) A = ± 0,3 %
13	$1\,000 < \theta \leq 1\,300$	W ≤ 5 °C (analog) A = ± 1 %	W ≤ 5 °C (digital) A = ± 0,5 %	W ≤ 3 °C (digital) A = ± 0,3 %	W ≤ 1 °C (digital) A = ± 0 ,3 %

5.8 Accuracy of recorder (R), grade of accuracy (RK), resolution of recording (RA) and rate of paper feed (PV)

The accuracy is summarised in Table 5 according to the working temperature ranges. With digitally indicating and recording instruments, the resolution is 1 °C, or 0,1 °C.

Analog units shall permit readings to be taken within 0,5 mm. This requirement permits calculating the necessary width of the trace.

The rate of paper feed depends on the duration of the heat treatment (WBD).

In keeping therewith, the dot sequence shall be set for a quasi-continuous trace.

Detail requirements are given in Table 5.

Table 5 — Accuracy of recorder (R), grade of accuracy (RK), resolution of recording (RA) and rate of paper feed (PV)

Code number	Working temperature range °C	Category A	Category B	Category C	Category D
03	$\theta \leq 300$	R ≤ ± 2 °C RK = 0,5 RA ≤ 4 °C/mm for WBD ≤ 1 h: PV ≥ 20 mm/h for WBD > 1 h: PV ≥ 10 mm/h	R ≤ ± 1,5 °C RK = 0,3 RA ≤ 3 °C/mm for WBD ≤ 1 h: PV ≥ 30 mm/h for WBD > 1 h: PV ≥ 20 mm/h	R ≤ ± 1 °C RK = 0,2 RA ≤ 2 °C/mm for WBD ≤ 2 h: PV ≥ 40 mm/h for WBD > 2 h: PV ≥ 20 mm/h	–
07	$300 < \theta \leq 700$	R ≤ ± 3 °C RK = 0,5 RA ≤ 6 °C/mm for WBD ≤ 1 h: PV ≥ 20 mm/h for WBD > 1 h: PV ≥ 10 mm/h	R ≤ ± 2 °C RK = 0,3 RA ≤ 4 °C/mm for WBD ≤ 1 h: PV ≥ 30 mm/h for WBD > 1 h: PV ≥ 20 mm/h	R ≤ ± 1,5 °C RK = 0,2 RA ≤ 3 °C/mm for WBD ≤ 2 h: PV ≥ 40 mm/h for WBD > 2 h: PV ≥ 20 mm/h	–
10	$700 < \theta \leq 1\,000$	R ≤ ± 4 °C RK = 0,5 RA ≤ 8 °C/mm for WBD ≤ 1 h: PV ≥ 20 mm/h for WBD > 1 h: PV ≥ 10 mm/h	R ≤ ± 3 °C RK = 0,3 RA ≤ 6 °C/mm for WBD ≤ 1 h: PV ≥ 30 mm/h for WBD > 1 h: PV ≥ 20 mm/h	R ≤ ± 2 °C RK = 0,2 RA ≤ 4 °C/mm for WBD ≤ 2 h: PV ≥ 40 mm/h for WBD > 2 h: PV ≥ 20 mm/h	R ≤ ± 2 °C RK = 0,1 RA ≤ 4 °C/mm for WBD ≤ 2 h: PV ≥ 40 mm/h for WBD > 2 h: PV ≥ 20 mm/h
13	$1\,000 < \theta \leq 1\,300$	R ≤ ± 5 °C RK = 0,5 RA ≤ 10 °C/mm for WBD ≤ 1 h: PV ≥ 20 mm/h for WBD > 1 h: PV ≥ 10 mm/h	R ≤ ± 4 °C RK = 0,3 RA ≤ 8 °C/mm for WBD ≤ 1 h: PV ≥ 30 mm/h for WBD > 1 h: PV ≥ 20 mm/h	R ≤ ± 3 °C RK = 0,2 RA ≤ 6 °C/mm for WBD ≤ 2 h: PV ≥ 40 mm/h for WBD > 2 h: PV ≥ 20 mm/h	R ≤ ± 3 °C RK = 0,1 RA ≤ 6 °C/mm for WBD ≤ 2 h: PV ≥ 40 mm/h for WBD > 2 h: PV ≥ 20 mm/h

6 Tests

6.1 General

The heat treatment facility shall be so designed as to permit performance of the specified tests (e.g. additional lead-ins for temperature sensors, ready accessibility of equipment, concurrent readouts from facility instrumentation and independent test instrumentation).

Testing shall invariably be performed using independent test instruments.

6.2 Test instruments

The accuracy of test instruments shall be at least equivalent to or better than that of the facility working instruments. Test instrument deviations shall be known. Test instruments shall likewise be subjected to periodic checks. The working instruments are calibrated against the test instruments, which are themselves calibrated against chains of standard instruments traceable to standards maintained by internationally recognised standards organisations, responsible for establishing National Standards.

Test instruments shall be checked at a frequency of every 3 months, 6 months or 12 months or as specified by the manufacturer.

In the case of temperature sensors (thermocouples), the frequency also depends on the thermocouple wire diameter, service time, temperature level and heating medium.

6.3 Test frequency

The time interval between tests is governed by so-called “dynamic test frequencies”,

where

k = reduced frequency;

n = normal frequency;

l = extended frequency.

The first test following acceptance, repair, alteration or relocation of the facility shall be made at frequency “k”, tests thereafter at frequency “n”.

If no anomalies are found in three consecutive tests, the frequency requirement may be changed to “l”. When irregularities or deviations are found in operation or use, the frequency shall again revert to “k”.

6.4 Extent of testing

Tests are classified into:

a) Category I — accuracy test;

b) Category II — temperature uniformity test;

c) Category III — instrument test.

Testing required for acceptance or subsequent to relocation:

d) Categories I, II, III.

Testing required upon alteration or repair, depending on the type and extent of the rework:

e) Categories I, II and/or III.

6.5 Test procedures

6.5.1 Accuracy test (V) and test frequency (TV)

Accuracy testing involves checking a heat treatment facility’s chain of validly indicating and recording temperature instruments against a reference chain installed for calibration purposes. The reference sensor shall be located as close as possible to the facility’s recording sensor.

The permissible temperature variations and the test frequencies are shown in Table 6.

Table 6 — Maximum permissible temperature variation in accuracy test (V) and test frequency (TV)

Code number	Working temperature range °C	Category A	Category B	Category C	Category D
03	$\theta \leq 300$	V = ± 4 °C TV: k = 1 month n = 2 months l = 4 months	V = ± 3 °C TV: k = 1/2 month n = 1 month l = 2 months	V = ± 2 °C TV: k = 1 week n = 2 weeks l = 4 weeks	–
07	$300 < \theta \leq 700$	V = ± 5 °C TV: as code number 03	V = ± 3 °C TV: as code number 03	V = ± 3 °C TV: as code number 03	–
10	$700 < \theta \leq 1\,000$	V = ± 8 °C TV: as code number 03	V = ± 5 °C TV: as code number 03	V = ± 4 °C TV: as code number 03	V = ± 3 °C TV: k = 1 week n = 2 weeks l = 4 weeks
13	$1\,000 < \theta \leq 1\,300$	V = ± 9 °C TV: as code number 03	V = ± 6 °C TV: as code number 03	V = ± 5 °C TV: as code number 03	V = ± 3 °C TV: k = 1 week n = 2 weeks l = 4 weeks

6.5.2 Temperature uniformity test and test frequency (TT)

6.5.2.1 General

The temperature uniformity tests shall be performed by means of thermocouples in the heat treatment facility or the heating medium at frequencies as given in Table 7.

The survey can be made optionally with or without production load.

With no production load being present, care shall be taken to ensure that the temperature distribution pattern is affected as little as possible by any support device necessary for the thermocouples.

The temperature measurements shall be taken after the furnace or bath has reached thermal equilibrium. The duration of the measurement shall be selected so that the results provide conclusive evidence of temperature uniformity. Also the time intervals during a measurement shall be selected such that the temperature minimum and maximum, depending on the closed-loop oscillations, are sensed.

Table 7 — Temperature uniformity test frequency (TT)

Code number	Working temperature range °C	Category			
		A	B	C	D
03	$\theta \leq 300$	TT: k = 12 months n = 15 months l = 21 months	TT: k = 9 months n = 12 months l = 18 months	TT: k = 4 months n = 6 months l = 12 months	TT: k = 4 months n = 6 months l = 12 months
07	$300 < \theta \leq 700$				
10	$700 < \theta \leq 1\,000$				
13	$1\,000 < \theta \leq 1\,300$				

6.5.2.2 Furnace temperature uniformity survey

The arrangement of the test locations in the furnace shall be regularly distributed in the effective working volume, as far as possible.

a) Attach the thermocouples to the rack or the production load.

b) Load the rack or production load into the effective working volume.

c) Heat the effective working volume to test temperature and keep the control setting constant thereafter.

d) Start measurement after thermal equilibrium has been reached.

e) Thereafter, record the test locations at intervals of at least two closed-loop oscillations, recording the temperature minimum and maximum.

f) Record and read the temperature on an independent recorder.

6.5.2.3 Salt bath temperature uniformity survey

The temperature uniformity in salt baths is determined by using a temperature sensor enclosed in a suitable protection tube.

The temperature sensor is held in one position until thermal equilibrium has been reached and a reading made. The temperature sensor shall then be placed in a new location and the procedure shall be repeated until the temperature in all parts of the bath has been determined.

The temperature uniformity survey can optionally also be performed with the test locations arranged on a rack.

6.5.3 Instrument test (PG) and instrument test frequency (TPG)

The tolerances allowed in the calibration of facility-specific measuring, control and recording instruments are as given in Table 5 and Table 4 for (R) and (A), respectively.

The instrument test frequency is given in Table 8.

Table 8 — Instrument test frequency (TPG)

Code number	Working temperature range °C	Category			
		A	B	C	D
03	$\theta \leq 300$	TPG: k = 3 months n = 6 months l = 12 months	TPG: k = 3 months n = 6 months l = 12 months	TPG: k = 3 months n = 6 months l = 12 months	TPG: k = 3 months n = 6 months l = 12 months
07	$300 < \theta \leq 700$				
10	$700 < \theta \leq 1\,000$				
13	$1\,000 < \theta \leq 1\,300$				

7 Test results and documentation

7.1 Evaluation of temperature measurement

The minimum and maximum of the temperature values measured at the individual test locations over the complete period of the test shall be determined.

These values shall be corrected by the known error of the temperature sensor.

7.2 Evaluation of temperature uniformity

The requirements regarding temperature uniformity of the furnace or bath shall be satisfied when the minimum and maximum of the corrected temperature values are less than or equal to the maximum temperature variation for the given test temperature as specified in Table 1.

7.3 Documentation of test results

All category I, II and III test results shall be documented and filed with the furnace records. The correction factor as well as changes thereof shall be mentioned in the records. In addition, a test report shall be established.

Upon approval or retest, a test sticker shall be affixed to the heat treatment facility.

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