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**Heat treatment — Control of quality**

*Traitement thermique — Maîtrise de la qualité*

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Reference number  
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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 244, *Industrial furnaces and associated processing equipment*.

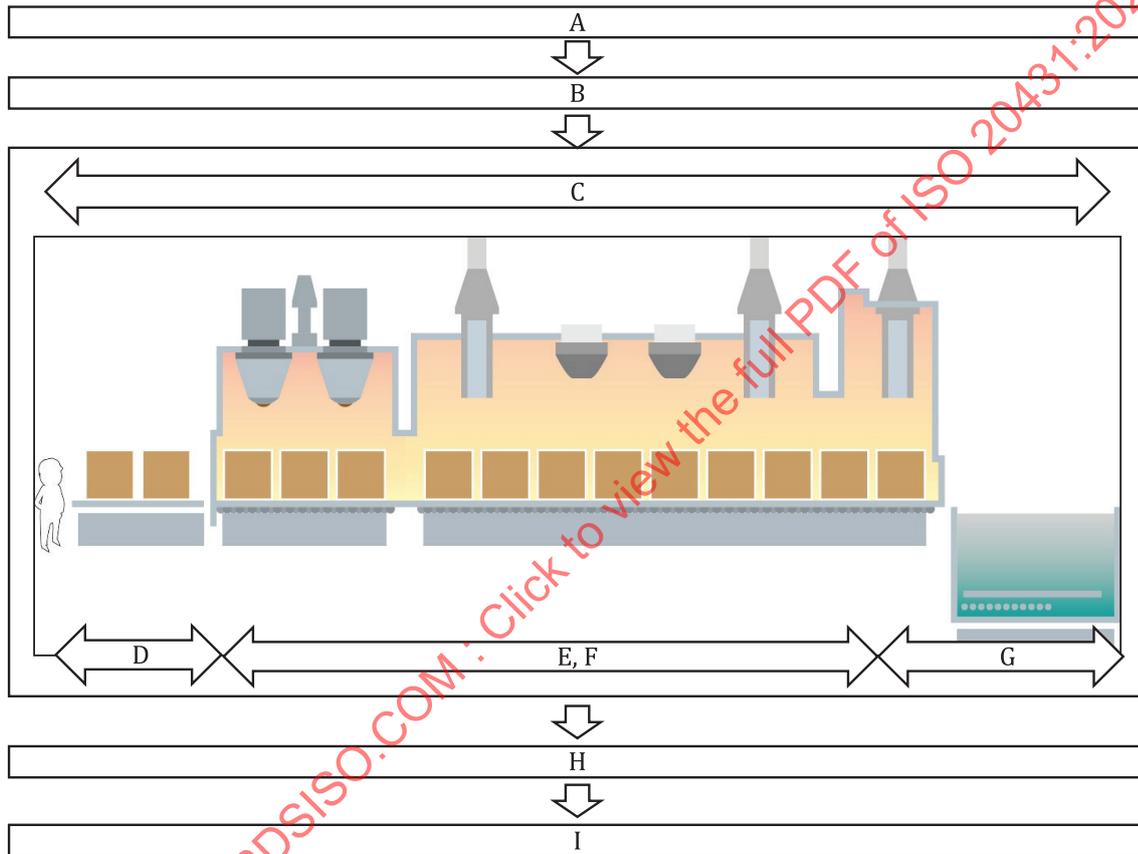
Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document draws a list of best practices in order to ensure quality control in the application of heat treatment. This document is for use with equipment constructed in accordance with International Standards for thermoprocessing equipment. These concepts are also suitable for application with other heat-treatment processes.

This document is a reference for assessment and continuous improvement which is part of the quality management system of a heat-treatment facility.

Figure 1 shows the typical flowchart for a heat-treatment process. The main steps are subject to requirements and recommendations in this document.



**Key**

- |   |   |   |  |
|---|---|---|--|
| A | general organisation of a heat-treatment facility (see 5.1) | F | control of the heat-treatment medium (see 5.5) |
| B | contract review and heat-treatment conception (see 5.2)     | G | control of cooling (see 5.6)                   |
| C | carrying out the heat treatment                             | H | control of product testing (see 5.7)           |
| D | preparation (see 5.3)                                       | I | finishing (see 5.8)                            |
| E | control of the thermal cycle (see 5.4)                      |   |  |

**Figure 1 — Heat-treatment process**

# Heat treatment — Control of quality

## 1 Scope

This document defines the quality requirements and recommendations applicable to heat treatment on mechanical parts intended to be used in the industry (e.g. car manufacturing, aerospace, pipeline systems, civil engineering equipment, earth moving machinery, agricultural equipment, naval industry, energy equipment, tooling, fasteners).

This document provides a reference for quality audit and for the inspection of heat-treatment facilities, whether these are integrated or belonging to subprime contractors. This document can also be used as a basis for discussion and development of specifications.

A description of the equipment calibration and the frequency of the controls is given in [Annex A](#). An example of scoring table is given in [Annex B](#). An example of audit report is given in [Annex C](#). The different measuring chain testing methods (SAT) are presented in [Annex D](#).

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4885, *Ferrous materials — Heat treatments — Vocabulary*

ISO 6506 (all parts), *Metallic materials — Brinell hardness test*

ISO 6507 (all parts), *Metallic materials — Vickers hardness test*

ISO 6508 (all parts), *Metallic materials — Rockwell hardness test*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4885 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1

#### **heat-treatment facility**

set of equipment implementing processes associated with each other used to modify, through a thermal cycle, the physical, mechanical and/or chemical properties of a metallic material

### 3.2

#### **recommendation**

preferred advice and criterion (criteria) providing guidance, but not required to be in accordance with this document

**3.3  
requirement**

criterion (criteria) to be complied with in order to achieve conformity with this document

Note 1 to entry: A requirement not fulfilled can have an impact on the *special characteristic(s)* (3.5) of the final product.

**3.4  
contract review**

systematic procedure carried out in order to identify the *requirements* (3.3) and expectations for the process outputs as expressed in documents and that they may be carried out

Note 1 to entry: Requirements and expectations for the process can be internal (inhouse heat treatment) or external (from customer).

**3.5  
special characteristic**

feature or property of a final product which impacts, contributes, or affects safety or compliance with regulations, fit, function, performance or subsequent processing of product

**3.6  
preproduction quality planning**

process which defines the rules for planning of all the manufacturing steps of a product, from offer review to delivery, in order to meet the customer's *requirements* (3.3)

Note 1 to entry: Preproduction quality planning is well known as advanced production quality planning (APQP) in the automotive industry.

Note 2 to entry: Requirements can be internal (inhouse heat treatment) or external (from customer).

**3.7  
verification**

provision of objective evidence that a given item fulfils specified *requirements* (3.3)

[SOURCE: ISO/IEC Guide 99:2007, 2.44, modified — EXAMPLES and NOTES removed.]

**3.8  
calibration**

set of operations that establishes, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realised by standards

Note 1 to entry: Adapted from ISO/IEC Guide 99:2007, 2.39.

**3.9  
measuring chain**

series of elements of a measuring system constituting a single path of the signal from a sensor to an output element

EXAMPLE A display or recording system.

Note 1 to entry: Each element of the measuring chain is characterised by its metrological properties which are, mainly, the measuring range, the freedom from bias, the reproducibility, the resolution, the drift depending on influence quantities, the drift over time depending on the conditions of use and, as a consequence, the measurement uncertainty.

[SOURCE: ISO/IEC Guide 99:2007, 3.10, modified — Note 1 to entry added and EXAMPLES 1 and 2 replaced by EXAMPLE.]

**3.10  
regulation system**

device(s) composed of sensor(s) which measure(s) a physical characteristic to be monitored and supplying control signals for action to the control system to respect the tolerance threshold

**3.11****monitoring chain**

system composed of monitoring element(s) which transmits a signal (e.g. voltage, current) to a recording system

**3.12****major modification**

modification of the process parameters referenced in the validation file (qualification parts) and which has an impact on the *special characteristic(s)* (3.5) of the final product

**3.13****soak time**

hold time

time increment of the thermal cycle during which the temperature is held constant

Note 1 to entry: The soak time begins when the load TC reaches the minimum temperature of the tolerance. The soak time finishes when the load TC leaves the minimum temperature of the tolerance.

**3.14****responsibilities matrix**

detailed description of designated personnel for key heat-treatment management and supervisory functions including their back-up

**3.15****heat-treatment conception**

phase during which the organization analyses the customer's *requirements* (3.3), assesses whether they are technically feasible and identifies the conditions necessary for a smooth running of its process

Note 1 to entry: This phase includes in particular the results of the feasibility confirmation tests, the tests results under industrial conditions, the development of a recipe, the *verification* (3.7) of capability and any limitations or warnings to be brought to the attention to the customer.

**3.16****heat-treatment plan**

procedure or specification which describes at least the parameters and tolerances of the heat-treatment process, the controls, the equipment *verifications* (3.7) and frequencies

**3.17****electronic record**

any combination of text, graphics, data, audio, pictorial, or other information representation in digital form that is created, modified, maintained, archived, retrieved, or distributed by a computer system

**4 System for assessment and scoring of requirements and recommendations****4.1 General**

The assessment shall focus on the requirements and recommendations listed in [Clause 5](#) and identified according to their nature, in accordance with [Table 1](#).

**Table 1 — Identification of requirements and recommendations**

Requirement or recommendation identifier	Nature of the requirement or recommendation	Subclause in this document
GO	General Organisation	<a href="#">5.1</a>
CR	Contract Review	<a href="#">5.2.1</a>
HTP	Heat-Treatment Conception	<a href="#">5.2.2</a>
PR	Preparation	<a href="#">5.3</a>
T	Heat-treatment Temperature	<a href="#">5.4.1</a> to <a href="#">5.4.3</a>

**Table 1 (continued)**

Requirement or recommendation identifier	Nature of the requirement or recommendation	Subclause in this document
HTT	Heat-Treatment Time	<a href="#">5.4.4</a>
C	atmospheres containing Carbon	<a href="#">5.5.2</a>
N	Nitriding and nitrocarburising atmospheres and derived treatments	<a href="#">5.5.3</a>
SB	Salt Baths	<a href="#">5.5.4</a>
SH	Surface Hardening (quenching after surface heating)	<a href="#">5.5.5</a>
L	Laser hardening	<a href="#">5.5.6</a>
V	Vacuum or low-pressure heat treatment	<a href="#">5.5.7</a>
CEQ	Cooling Equipment	<a href="#">5.6.1</a>
CPM	Cooling Parameters	<a href="#">5.6.2</a>
CP	Control of Product testing	<a href="#">5.7</a>
F	Finishing	<a href="#">5.8</a>

**4.2 General requirements**

To declare the heat-treatment facility in accordance with this document, a quality-management system shall exist which meets the requirements of its customers.

Any subcontracted process shall be assessed in accordance with this document.

NOTE 1 Customers can be internal and external.

NOTE 2 The basic repository used is often completed with other certifications and accreditations, where necessary (e.g. ISO 9001).

**4.3 Scoring of requirements and recommendations**

**4.3.1 General**

Determination of acceptable scores are typically part of the contractor agreement.

**4.3.2 Scoring of requirements**

The requirements shall be scored in accordance with the following criteria:

- a satisfied requirement scores 100;
- a non-satisfied requirement scores 0.

A non-satisfied requirement shall give rise to a systematic action plan.

**4.3.3 Scoring of recommendations**

Recommendations shall be scored according to the criticalities listed in [Table 2](#).

**Table 2 — Scoring of recommendations according to their criticality**

Recommendation criticality	Score
Satisfied recommendation	100
Recommendation partially fulfilled without new corrective action proposed	80
Recommendation partially fulfilled with corrective action proposed	50

Table 2 (continued)

Recommendation criticality	Score
No conformity with corrective action proposed	20

All the requirements and recommendations listed in [Clause 5](#) shall be scored in accordance with criteria in [4.3.2](#) and [4.3.3](#). If a requirement or recommendation is not relevant for the heat-treatment facility under assessment, it shall be scored as "N/A" (not applicable).

If the audit is not completed, the customer and the supplier shall agree to use the final scores according to this document. In this case the requirements and recommendations not seen during the audit shall be scored as "N/A" and shall be documented in the audit report.

The scoring table given in [Table B.1](#), should be used.

All corrective actions and non-satisfied requirements identified should be recorded in a report intended to monitor the continuous improvement of the quality program of the heat treatment facility.

#### 4.4 Assessment of the heat treatment facility

The final assessment of the heat treatment facility shall be carried out in accordance with the following criteria.

- Final score: ratio between the weighted sum of the scores of the requirements and recommendations and the number of the applicable scored requirements and recommendations ( $A$ ).
- Final requirements only score: ratio between the weighted sum of the scores of the requirements and the number of the applicable scored requirements.
- Score depending on the nature of the requirements and recommendations: for each nature of requirements and recommendations, this is the ratio between the sum of the scores of requirements and recommendations and the number of the applicable scored requirements and recommendations ( $N_0$ ,  $N_{20}$ ,  $N_{50}$ ,  $N_{80}$  and  $N_{100}$ ). The calculation of scores by requirement is performed using [Formula \(1\)](#) line by line.

$$S = (B + C + D + E) / A \quad (1)$$

where

- $S$  is the score;
- $B$  is the number  $N_{20}$  of non-conforming recommendations with corrective action proposed multiplied by 20;
- $C$  is the number  $N_{50}$  of recommendations partially fulfilled with corrective action proposed multiplied by 50;
- $D$  is the number  $N_{80}$  of recommendations partially fulfilled without new corrective action proposed multiplied by 80;
- $E$  is the number  $N_{100}$  of satisfied recommendations multiplied by 100;
- $A$  is the number of the applicable scored requirements and recommendations.

NOTE 1 The scores are proportional to the level of quality.

The heat treatment facility shall be assessed using [Table 3](#).

**Table 3 — Heat treatment facility assessment**

Reference	Audit section	A	Requirements		Recommendations				Score
			N <sub>0</sub>	N <sub>100</sub>	N <sub>20</sub>	N <sub>50</sub>	N <sub>80</sub>	N <sub>100</sub>	
<a href="#">5.1</a>	General organisation of the heat treatment facility								
<a href="#">5.2</a>	Contract review and heat treatment preparation								
<a href="#">5.3</a>	Carrying out the heat treatments:								
<a href="#">5.4</a>		Preparation							
<a href="#">5.5</a>		Control of thermal cycle							
<a href="#">5.6</a>		Control of heat treatment medium							
<a href="#">5.7</a>	Control of cooling								
<a href="#">5.7</a>	Control of product testing								
<a href="#">5.8</a>	Finishing								
<b>Final result (for the entire audit)</b>									

Where a minimum score is to be obtained, and/or recommendations are to be fulfilled as requirements, the customer shall inform the supplier with a delay agreed between the two parties or by default two weeks before the audit.

NOTE 2 [Annex C](#) gives an example of assessment and score calculation.

## 5 Requirements and recommendations

### 5.1 General organisation of a heat treatment facility

#### 5.1.1 Documentation (references G01 to G03)

**Requirement G01:** For each heat treatment, preparation or testing process, a heat-treatment plan shall be available for all personnel involved in the use of the heat-treatment equipment. All the steps of the process and the main operating parameters, with their tolerances, shall be specified in this document.

**Requirement G02:** The heat-treatment plan shall specify responses in case of incident and/or emergency situation for the process (e.g. power failure which leads to start or restart an equipment after shutdown, batch allocation and management of suspicious or non-compliant products, cyber-attacks).

**Requirement G03:** Any major modification shall be documented and shall be validated by the customer in the context of formal approval of a production (e.g. type of oil, heat-treatment devices, key process parameters).

#### 5.1.2 Management responsibility (references G04 and G05)

**Requirement G04:** In order to provide proof of their commitment to develop and implement the quality-management system, the managers shall carry out, at least once per year, a review of the performance or managing indicators related to the heat treatment process. This review shall be documented.

**Requirement G05:** The management review shall lead to the implementation of corrective and preventive actions if the objectives have not been reached.

### 5.1.3 Human resources management (references G06 to G010)

**Requirement G06:** A skill qualification matrix shall exist for the personnel allowed to carry out heat-treatment process operations. This matrix shall be up-to-date or its revision shall be planned.

**Requirement G07:** A responsibilities matrix including authorization shall exist ensuring that the main management and supervision tasks are carried out by competent personnel (usual personnel and back-up). This matrix shall be current and available to the management at all times.

**Requirement G08:** The management shall implement suitable training to obtain the necessary skills according to the heat-treatment process. This document shall be available to management at all times or posted on the heat-treatment facility.

**Requirement G09:** The personnel of the heat-treatment facility who could have an impact on the customer product shall have their skills verified periodically. The overall monitoring of assessments and additional trainings needed shall be documented.

**Recommendation G010:** The person as a referent for heat treatment should be a permanent employee whose position and responsibilities should be reflected in the organization chart. This position should be held by a competent person with significant experience whose training and qualifications (in metallography, heat treatment process and equipment) are approved by the company.

NOTE For experience, five years is a typical minimum.

### 5.1.4 Infrastructure and equipment management (references G011 to G025)

**Requirement G011:** The nature and conformity of the products which come into contact with the parts and which are used for heat treatment shall be identified and validated upon receipt.

**Recommendation G012:** The supplier of products in contact with the part should be qualified and evaluated.

**Requirement G013:** A documented preventive maintenance plan shall exist. This plan shall take into account the maintenance actions (failures and incidents), the quality scraps, the results of the initial samples and the operator information.

**Recommendation G014:** Maintenance data should be collected and analysed as part of predictive maintenance program.

**Requirement G015:** The process / alarm data shall be reviewed and authorized by competent personnel before sending the products (related to this process data) to the customer. The product shall be released by quality department or its representative before sending the products to the customer.

**Requirement G016:** A list of critical alarms for product quality shall be drawn through participation of various functions or departments (production, maintenance, etc.).

**Recommendation G017:** Except for digital equipment with controlling and monitoring system, a schedule for checking the alarms critical for product quality should be defined and followed up. The check frequency should be defined depending on the risk assessment.

**Requirement G018:** Acknowledgment (reset) of critical alarms for product quality shall be checked at regular intervals and traced.

**Requirement G019:** The process data, including critical alarms, shall be continuously recorded and preserved.

**Recommendation G020:** The environment, the working conditions (including, e.g. temperature of the air inside the facility, emission of fumes) and the cleanliness of the plant should allow better quality control, improvement and working in safety conditions. Steps can be implemented to assess these criteria (e.g. a cleanliness audit).

**Requirement G021:** A back-up for plant and equipment taking into account all the means necessary to ensure the production shall be implemented.

**Recommendation G022:** The security plan should be tested and validated.

**Requirement G023:** The zones in which parts are retained throughout the heat treatment process shall be identified and documented.

**Recommendation G024:** The zones in which parts are retained throughout the heat-treatment process (e.g. trap points) should be monitored at least during each maintenance operation or at a defined frequency.

**Recommendation G025:** Handling, storage and packaging should not affect the quality of the final product.

### 5.1.5 Internal audit (reference G026 and G027)

**Requirement G026:** A schedule of audits for each process of the heat treatment facility, taking into account the risks, shall be defined and complied with. The audit frequency should be reviewed every year. The audit frequency shall not exceed three years for each process.

**Requirement G027:** The internal auditor for heat-treatment control of quality assessment shall be qualified for this task and referenced in the skill qualification matrix.

### 5.1.6 Control of nonconforming product (references G028 to G036)

**Requirement G028:** A procedure shall be implemented to identify and monitor each batch at each stage in the process. This procedure shall include measures to prevent batch mixing, incorrect heat treatments, risks of contamination of heat-treated batches by non-treated products and shipment of batches on which all tests have not been carried out.

**Requirement G029:** A procedure shall be implemented for the management of suspect or non-conforming products. This procedure shall provide identification and quarantine of suspect or non-conforming products. It shall define the incoming and outgoing flows of suspect or non-conforming products to the non-conforming hold area or the continuation of production.

**Requirement G030:** The quality manager or his/her authorized representative shall approve and document the final release of quarantined parts.

**Recommendation G031:** A procedure specifying the conditions of heat retreatment should be implemented and documented. The conditions for heat retreatment should be validated by the customer. This procedure should specify the documentation to be set and the personnel authorized to define and apply the heat retreatment conditions.

**Requirement G032:** The documentation to be set shall include at least the part number and name, batch number, original furnace number, quantity, rework cause, retreatment process.

**Requirement G033:** The customer shall be advised of the non-conformity of the product except if there is an agreement or if it is specified in the heat-treatment plan.

**Requirement G034:** In case of retreatment on quenching/tempering, operation shall be performed under control.

**Recommendation G035:** If the customer approved the retreatment at the preproduction quality planning or production parts approval process stage, the organization should describe the retreatment process of the parts in the FMECA or specification and in the control plan. In this case, the retreatment may be carried out before notification to the customer. See [5.1.8](#).

**Requirement G036:** The result of retreatment shall be validated, and the release of retreated parts shall be approved by the authorized person appointed by the organization. When recommendation G035 has not been implemented the customer shall approve the outcome.

### 5.1.7 Continuous improvement (references G037 and G038)

**Requirement G037:** A continuous improvement plan for each process or a continuous improvement plan representative of each process shall be implemented and shall define priority actions planned in order to improve quality and performance. The efficiency of the programme shall be demonstrated.

**Requirement G038:** The quality department shall review, process and document customer claims and internal problems through a methodical problem-solving approach.

### 5.1.8 Failure mode, effect and criticality analysis (FMECA) (references G039 to G041)

**Requirement G039:** There shall be a procedure which plans to perform the FMECA of each process of the heat-treatment facility. It shall identify and take account of the special characteristics and require the participation of several functions (production, maintenance, etc.).

**Requirement G040:** When a product/process FMECA(s) is required by the customer, it shall be performed in cooperation with the customer.

**Recommendation G041:** Any modification of each process should lead to a review of the relevant FMECA.

### 5.1.9 Monitoring plan (references G042 to G044)

**Recommendation G042:** A procedure to define and implement monitoring plans should be implemented. This procedure should identify and take into account the special characteristics and include the consistency with the related documentation [work instructions, follow-up sheets, FMECA(s), etc.].

**Recommendation G043:** Monitoring plans should be defined and validated by the customer in accordance with its requirements concerning the process, the parts or the part families.

**Recommendation G044:** Any modification of each process should lead to review the relevant monitoring plan.

### 5.1.10 Preproduction quality planning (reference G045 and G046)

**Recommendation G045:** A preproduction quality planning procedure should be applied at the customer's request and with the customer's participation. This request and the needed information are forwarded by the customer.

**Recommendation G046:** The organization should study the effectiveness of production and control process capacities including the initial-stage equipment rearrangement/relocation, overhaul, mass production and engineering change.

### 5.1.11 Statistics: (references G047 to G049)

**Recommendation G047:** Statistical analysis should be performed using data on special characteristics and/or the heat-treatment process parameters.

**Recommendation G048:** Capability measurements should be carried out in accordance with the prime contractor's requirements or a procedure or ISO 22514-6.

**Recommendation G049:** If the results or other statistical characterisations of the process do not meet the customer's requirements, an action plan should be implemented.

**NOTE** The conventional capability measurement methods are usually not applicable to heat-treatment processes. In these conditions, low capabilities can be measured with these methods; however, these values will not be representative of a malfunction with the heat-treatment process. If the prime contractor requests these measurements, they will be provided for information and will not lead to any specific action plan.

**5.1.12 Controlling monitoring and recording (references G050 to G062)**

**Requirement G050:** The controllers, monitoring and sensors of the critical process parameters shall be connected to a recording system (chart recorder, electronic data recorder or data acquisition system).

**Recommendation G051:** Digital recorders creating electronic records should be used.

**Recommendation G052:** Measures (e.g. procedures, technical documentation of the system) should be taken to ensure the integrity of the records.

**Recommendation G053:** When a system software and playback utilities are used, measures (e.g. procedures, technical documentation of the system) should be taken to provide means of examining and/or compiling the record data.

**Recommendation G054:** The recording system should provide the ability to generate accurate and complete copies of the records in both human-readable and electronic form suitable for inspection, review and copying.

**Requirement G055:** When an electronic recording is used, the system shall be able to provide evidence the record was reviewed – such as by recording an electronic review, or a method of printing the record for a physical marking indicating review.

**Requirement G056:** The system shall support protection, retention and retrieval of accurate records throughout the record retention period or adequate procedure for recording file backup in digital or paper format.

**Recommendation G057:** When an electronic recording is used, the system should provide methods (e.g. passwords) to limit system access to authorized personnel as stated in the documentation.

**Recommendation G058:** The resolution for analogue chart recording instrument should comply with [Table 4](#).

**Table 4 — Resolution for analogue chart recording instrument**

Furnace class	Max. degrees per centimetre of chart paper	Max. chart recording increment
1	11	1
2	33	3
3	33	3
4	55	5
5	55	5
6	77	15

**Requirement G059:** Digital recording instruments shall have a minimum readability of 0,1 °C.

**Recommendation G060:** The timing function for all digital recording instruments and data acquisition systems should be calibrated annually and shall be accurate to ±1 min/h.

NOTE A documented digital synchronization of timing systems to NIST (or international equivalent) via satellite, internet, or telephonic systems periodically (at least monthly) to support a ±1 min/h accuracy is acceptable.

**Requirement G061:** With control, monitoring and recording digital instruments evidence shall be provided, that software revisions are verified to ensure continued compliance with the material or process specification requirements.

**Requirement G062:** If offsets are used, a documented procedure describing maximum offsets and when and how to perform manual and electronic offsets shall be implemented.

## 5.2 Contract review and heat-treatment conception

### 5.2.1 Contract review

#### 5.2.1.1 Modification not taken into account (references CR1 to CRC3)

**Recommendation CR1:** The general heat-treatment standards (ISO, ASTM, etc.) referenced by the customer(s) should be made available, reviewed and updated within a timeframe of less than three months since dates of availability of the regional published standards.

**Requirement CR2:** During the contract review or the offer review, the standards and specifications supplied by the customer(s) shall be taken into account.

**Recommendation CR3:** In case of modification(s) or change(s) to a specification, the customer(s) should be informed of the planned implementation or of the rejection of such modification(s) within two weeks.

#### 5.2.1.2 Mistake in the identification of part batches (reference CR4 and CR5)

**Requirement CR4:** The facility shall ensure that the data entered in the receiving system matches the information on the customer's shipping documents.

**NOTE** A detailed procedure can be implemented to solve any possible discrepancy between the information contained in the shipment documents and the received products.

**Requirement CR5:** The product shall be clearly identified and staged throughout the heat-treatment process and batch(es) traceability and integrity maintained throughout all processes.

### 5.2.2 Heat-treatment conception

#### 5.2.2.1 Heat-treatment planning (references HTP1 and HTP2)

**Requirement HTP1:** All the heat-treatment process phases (preparations, intermediate heat treatments and finishing) shall be defined and documented according to the special characteristics expected for the product.

**Requirement HTP2:** The parameters of the heat-treatment operations (preparations, intermediate heat treatments and finishing) and their tolerances shall be clearly documented and applied.

#### 5.2.2.2 Defective or nonconforming equipment (reference HTP3 and HTP4)

**Recommendation HTP3:** The process and product testing equipment should be checked and calibrated in accordance with the provisions specified in [Table A.1](#).

Equipment items not listed in [Table A.1](#) should be covered by a specific procedure which defines the check and calibration procedures.

**Requirement HTP4:** The heat-treatment plan shall describe the verification procedures of the measuring devices needed before restarting the equipment taking into account different cases and different factors (e.g. time, reason).

## 5.3 Carrying out heat treatments: preparation

### 5.3.1 General

The main steps of heat treatment are the following:

- a preparation phase including surface-preparation phases, batch preparation, etc., depending on the types of heat treatment and the customer's requirements;

- the heat treatment itself, characterised by the requested control of thermal cycle(s) followed by cooling in defined conditions. Several heat treatments can be performed successively;
- possible finishing processes;
- testing during production and/or release checks.

**5.3.2 Load preparation**

**5.3.2.1 Product non-conformity (references PR1 and PR2)**

**Requirement PR1:** The furnace-loading parameters shall be specified, documented and followed up, at least: belt speed, number of parts per load, distribution of the parts on the belt or in the jigs and weight of the load.

**Recommendation PR2:** Alarm and/or Poka-yoke should be implemented to prevent any risk of incorrect loading.

**5.3.2.2 Mixing of parts (reference PR3)**

**Requirement PR3:** Procedures or devices shall be used to prevent part mixing and contamination by inappropriate materials (for instance, check of containers, flow management, blocked parts, etc.).

**5.3.2.3 Degreasing of products (references PR4 to PR7)**

**Recommendation PR4:** Parts before heat treatment should be cleaned to be free of grease or oil.

**Recommendation PR5:** All key process parameters impacting the degreasing should be defined in an internal procedure and regularly checked accordingly.

**Recommendation PR6:** The washing-solution concentration and oil content tests should be carried out once per week, or at a specified interval based on an available and documented experience. A specified interval of washing bath and cleaning tank should be documented.

**Recommendation PR7:** The temperature of the washing solution should be monitored (only if the specified temperature is above the room temperature) by means of a supervision system or, failing that, it should be checked before each use or once per day of use.

**Recommendation PR8:** The chloride content in the washing solutions should be checked at least once every three months or at a different frequency based on an available and documented experience.

**5.3.2.4 Heat treatment**

**Recommendation PR9:** A furnace class should be chosen following the heat-treatment type and the temperature uniformity required. See [Table 5](#).

**Table 5 — Furnace classes uniformity tolerances**

Furnace class	Furnace uniformity (°C)
1	±3
2	±5
3	±8
4	±10
5	±15
6	±30

## 5.4 Carrying out heat treatment: Control of the thermal cycle

### 5.4.1 Temperature drift and heat-treatment temperature error (references T1 to T10)

**Requirement T1:** The furnace(s) shall be equipped with temperature-measuring instruments. The main types of thermocouples used in heat treatment of metals are described in [Table 6](#).

NOTE 1 The temperature is measured by a sensor (usually a temperature sensor) connected to a measuring device which can be a display, a recorder or a controller that allows the temperature to be maintained within a defined range for heat treatment.

**Table 6 — Designation, composition and maximum operating temperature of thermocouples and resistance temperature detector (RTDs)**

Classification	Letter designation	Elements and nominal alloy compositions by weight		Maximum operating temperature (°C) (informative value)
		Positive conductor	Negative conductor	
Noble metal	R	Platinum – 13 % rhodium	Platinum	1 600
	S	Platinum – 10 % rhodium	Platinum	1 600
	B	Platinum – 30 % rhodium	Platinum – 6 % rhodium	1 700
Base metal	J	Iron	Copper - nickel	750
	T	Copper	Copper - nickel	350
	E	Nickel - chromium	Copper - nickel	900
	K	Nickel - chromium	Nickel - aluminium	1 200
	N	Nickel - chromium - silicon	Nickel - silicon	1 200
Refractory	C	Tungsten – 5 % rhenium	Tungsten – 26 % rhenium	2 315
	A	Tungsten – 5 % rhenium	Tungsten – 20 % rhenium	2 500
RTDs	Pt 100	Platinum		-200 / 850

**Requirement T2:** The calibration of the temperature sensor shall comply with the following:

- a primary temperature sensor shall be calibrated by comparing it against a reference standard sensor. A secondary sensor may be created by a calibration against a primary temperature sensor;
- the temperature sensors installed on the furnace (control, temperature high limit, load) shall be calibrated by comparing it against a primary or a secondary temperature sensor;
- the calibration can be implemented on the temperature sensor itself or on the coil of wire from which it is made. In this event, calibration shall be performed at both ends of the coil;
- the temperature sensors should be calibrated before the first use and then replaced following the limit of service. See [Table 7](#);
- the non-expendable noble metal temperature sensors may be recalibrated after reaching the use duration limit. The non-expendable base metal temperature sensors shall not be recalibrated after reaching the use duration limit.

Table 7 — Calibration or change and limit of service

Type of thermocouple	Use	Recalibration or replacement (months)	Maximum number of use	Maximum duration of service (months)
Primary	N/A	36	N/A	N/A
Secondary	N/A	24	N/A	N/A
Non-expendable noble metal	TUS SAT Control High limit temperature	24	N/A	N/A
Non-expendable noble metal	Load	6	N/A	N/A
Non-expendable base metal over 760 °C	TUS SAT Control High limit temperature	12	N/A	N/A
Non-expendable base metal under 760 °C	TUS SAT Control High limit temperature	24	N/A	N/A
Non-expendable base metal over 1 260 °C	Load	N/A	1	N/A
Non-expendable base metal between 1 204 °C and 1 260 °C	Load	N/A	10	3
Non-expendable base metal between 980 °C and 1 204 °C	Load	N/A	90	3
Non-expendable base metal under 980 °C	Load	N/A	180	6
Expendable base metal over 760 °C	Load	N/A	1	N/A
Expendable base metal under 760 °C	Load	N/A	30	3
SAT : Systems Accuracy Tests TUS : Temperature Uniformity Surveys N/A : Not Applicable				

NOTE 2 The minimum frequency can be subject of agreement between the customer and the subcontractor, considering the field of the industry.

NOTE 3 The calibration period begins at first use if the storage period does not exceed the calibration period.

The calibration accuracy of the primary and secondary temperature sensor shall be  $\pm 0,6$  °C or 0,1 % of the range, the largest of both.

The calibration accuracy of the temperature sensors used for SAT, TUS or process control, monitoring and recording shall be  $\pm 1,1$  °C or 0,4 % of the range, the largest of both.

The tolerance on the recalibration and the duration of service is 15 days.

**Requirement T3:** The following headings shall be included in the calibration report of a temperature sensor:

- calibration date;
- source of calibration data;
- identification of the sensor tested;

- identification of the test sensor;
- identification of the test instrument;
- identification of the operator performing the test;
- company having performed the test (if not carried out in-house);
- signature of the calibration company representative (if not carried out in-house);
- nominal test temperature;
- actual test temperatures recorded;
- calibration technique;
- correction factor for each calibration temperature (traceable to national standards);
- indication of test acceptance or failure.

NOTE 3 The usage of the temperature sensor and the conditions under which it is used, determine the rules to be applied for its recalibration and use:

- control and monitoring thermocouples (for display and recording of furnace parameters);
- thermocouples used for systems accuracy tests (SAT) or for temperature uniformity surveys (TUS);
- reference thermocouples, which serve to verify and calibrate the previously mentioned sensors.

**Requirement T4:** The company shall determine and supply the resources to ensure the measurements conformity. The checking of the furnace and of the instruments shall be mentioned in the heat-treatment plan.

**Requirement T5:** The checking frequencies shall be mentioned in the heat-treatment plan in accordance with the furnace use.

**Requirement T6:** The critical process temperature(s) shall be monitored.

**Requirement T7:** The monitoring shall be continuously recorded.

**Requirement T8:** If there is no supervision system (set point alarm and recording), the check of heat-treatment temperatures inside the work zone shall be carried out and documented by signature at least once per heat treatment or a minimum once per two hours.

**Recommendation T9:** For quenched parts heat treated in a continuous belt furnace and when there is no temperature control system in the furnace output zone, a device should be fitted to check the temperature of the parts in the output zone with an alarm set to 25 °C below the working zone temperature.

**Recommendation T10:** Digital controllers and data recording should be used. The digital data should be readable at least for five years.

#### 5.4.2 Measuring equipment error SAT (system accuracy test) (references T11 to T17)

**Requirement T11:** A heat-treatment plan shall be issued and applied. This heat-treatment plan shall take the following into account:

- management of temperature measuring chain;

- management of temperature detectors or sensors such as:
  - thermocouples, platinum-resistance temperature sensors, thermal-profiling systems (on-board system) and infrared pyrometers;
- management of the checking of the temperature controllers and recorders;
- management of thermocouple simulators and reference voltmeter;
- heat-treatment plan for furnace(s) and furnace instrumentation check and for furnace(s) homogeneity check.

**Requirement T12:** The minimum frequency of checks shall comply with [Table 8](#) in accordance with the used methods described in [Annex D](#).

**Table 8 — Check recommendations for measuring chains (sensor, recorder controller)**

Measuring chain	Use	Minimum frequency for methods 1 and 3 (months)	Grace period for methods 1 and 3(days)
Reference chain	Calibration	12	10
Test measuring chain (SAT and TUS)	Calibration	12	10
Control, recording, display measuring chain	Class 1 furnace	1	3
	Class 2 furnace	3	5
	Class 3 furnace	3	5
	Class 4 furnace	6	7
	Class 5 furnace	6	7
	Class 6 furnace	12	10
	Temperature control of quench media tank	12	10
	Temperature control of degreasing equipment	36	15
	Sub-zero equipment	12	10
Infrared pyrometer	12	10	

NOTE 1 The minimum frequency can be subject of agreement between the customer and the subcontractor, considering the field of the industry.

If using the method 2, the frequency shall be 1 month with a grace period of 3 days.

**Requirement T13:** The calculated SAT difference shall be under  $\pm 5$  °C for the methods 1 and 3 (see [Annex D](#)) and  $\pm 1$  °C for the method 2.

NOTE 2 Uncertainties calculation of the measurements allows to adapt the precision of the measurement equipment following the application. Examples of uncertainty calculations are given in CETIM 9Q347<sup>[5]</sup>.

**Requirement T14:** Thermocouples and standard devices used for SAT shall comply with [5.4.1](#).

**Recommendation T15:** Measuring chains should comply with the following:

- control measuring chains (sensor, recorder and controller) installed on the furnace should be checked using one of the three SAT methods described in [Annex D](#);
- reference or test equipment (sensor, recorder, controller and voltmeter) used for SAT and TUS should be calibrated every year;
- reference, test and control measuring chains installed on the furnace should be checked in accordance with the heat-treatment plan.

**Requirement T16:** If the checking of the measuring chain is not correct according to the heat-treatment plan, an action plan shall be achieved.

**Requirement T17:** Calibration and verification of measuring chains shall be recorded in a report indicating as a minimum the data below:

- identification of the sensor tested;
- identification of the test sensor;
- identification of the test instrument;
- date and time of test;
- furnace set point during the test;
- value read on the furnace instrument;
- value read on the test instrument;
- correction factors applied to the test sensor and the test instrument;
- corrected value of the test instrument;
- calculated error of the measuring chain;
- indication of test acceptance or failure;
- identification of the operator performing the test;
- company that realised the SAT (if not carried out in-house);
- signature of the calibration company representative (if not carried out in-house);
- quality department validation.

#### 5.4.3 Temperature uniformity survey (TUS) of furnace (references T18 to T31)

**Requirement T18:** The heat-treatment company shall define and apply a heat-treatment plan performed by pyrometric check or by product dispersion and follow-up check.

**Recommendation T19:** If the checking of the furnace temperature uniformity (mapping) is performed through pyrometric check, it is recommended to carry out the uniformity check, at least the following:

- every year or with the indication of the heat-treatment plan and,
- after the following operations:
  - implementation;
  - relocation of the facility;
  - reduction of the furnace class;
  - any maintenance operation likely to affect the homogeneity of the furnace.

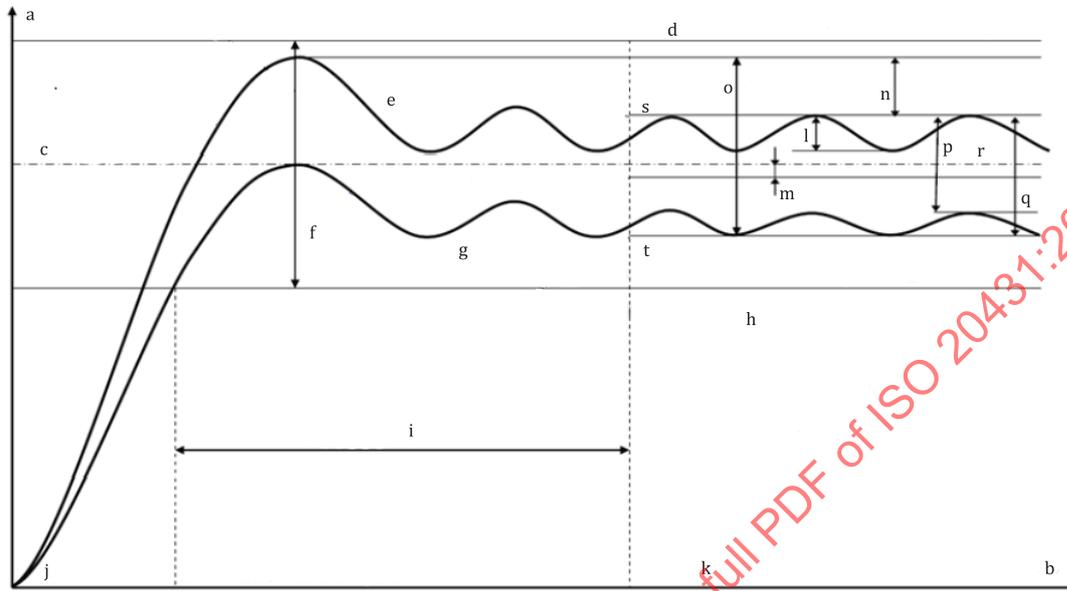
Maintenance operations that affect the furnace temperature uniformity should be documented.

**Requirement T20:** Thermocouples and standard devices used for TUS shall comply with indications of [5.4.1](#).

**Requirement T21:** When a pyrometric check is performed, the temperature uniformity at a given level shall be verified by installing sensors within the work zone of the furnace and ensuring that none of them exceeds the specified limits for the furnace class (see [Table 5](#)).

An adjustment should be made to the measuring instrument (to correct the measurement deviation). Calibrations before and after adjustment shall be recorded on the report in order to monitor any drift of the measuring instruments over time. See [Figure 2](#).

NOTE 1 When heating a load in a furnace, three distinct phases can be observed: the heating period, a transition regime and a steady-state operating regime.



**Key**

- |   |  |   |  |
|---|--|---|--|
| a | temperature  | k | steady-state operating regime                                  |
| b | time   | l | regulation range   |
| c | setpoint temperature   | m | temperature offset   |
| d | upper temperature limit for the furnace class                  | n | overshoot  |
| e | maximum temperature deviation in steady-state operating regime | o | maximum total temperature deviation                            |
| f | furnace class tolerance  | p | maximum temperature deviation in steady-state operating regime |
| g | coldest sensor   | q | temperature uniformity   |
| h | lower temperature limit for the furnace class                  | r | median temperature   |
| i | transition regime  | s | maximum temperature in steady-state operating regime           |
| j | heating period   | t | minimum temperature in steady-state operating regime           |

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**Figure 2 — Heating phases and control**

**Requirement T22:** The work zones of the equipment shall be defined in the heat-treatment plan.

**Requirement T23:** The temperature uniformity survey shall be conducted under steady-state operating conditions. The minimum duration shall be indicated in the heat-treatment plan.

**Requirement T24:** During the transition regime, an overshoot can occur. The overshoot temperature shall not exceed the upper limit set for the furnace class (see [Figure 2](#)).

**Recommendation T25:** The number of sensors used for heat-treatment equipment should comply with the recommendations given in [Tables 9](#) and [10](#).

**Table 9 — Minimum number of sensors for heat-treatment equipment, depending on the useful volume**

Useful volume $V_u$ (m <sup>3</sup> )	Minimum number of sensors	Locations of sensors
$V_u < 0,1$	5	
$0,1 \leq V_u < 8,5$	9	
$8,5 \leq V_u$	9 + 1 sensor per m <sup>3</sup> , with a maximum of 24	

**Table 10 — Minimum number of sensors for a continuous furnace, depending on dimensions**

Furnace dimensions			Minimum number of sensors	Locations of sensors
Height ( $H$ )	Width ( $w$ )	Working section ( $S$ )		
$H \leq 0,3$ m	$w < 2,4$ m	N/A	3	
	$w \geq 2,4$ m	N/A	3 + 1 sensor every 0,6 m for a with beyond 2,4 m	
$H > 0,3$ m	N/A	$S < 0,75$ m <sup>2</sup>	5	
	N/A	$0,75$ m <sup>2</sup> $\leq S < 1,5$ m <sup>2</sup>	7	
	N/A	$1,5$ m <sup>2</sup> $\leq S$	8	

**Requirement T26:** The temperatures chosen for the test shall, as a minimum, encompass the extreme processes temperatures.

NOTE 2 Intermediate temperatures can be defined to ensure that the temperature uniformity is constant over the whole operating temperature range. A furnace can have various uniformity ranges. For example,  $\pm 5$  °C from 500 °C to 650 °C and  $\pm 10$  °C from 650 °C to 900 °C.

**Recommendation T27:** The uniformity check should be performed with a load and an atmosphere representative of the usual condition of use of the furnace and indicated in the heat-treatment plan.

**Requirement T28:** A minimum testing time, generally 30 min, shall be defined from the start of the steady-start operating regime. The testing time shall be indicated in the heat-treatment plan.

**Recommendation T29:** If the check of the furnace uniformity survey (mapping) is performed through pyrometric check, the check report should be drafted in the form of a calibration certificate in accordance with a documentation template or in the form indicated as a minimum the data following:

- furnace reference;
- set point temperature and furnace setting parameters;
- temperature recording;
- instrument reference;
- brand name and model of the calibrated instrument;
- standard used during calibration;
- calibration method (manufacturer's instructions, other);
- required accuracy;
- as found and as left data at calibration point;
- offset as found and as left;
- sensitivity (if verified);
- declaration of test acceptance or failure;
- any limitations or restrictions relating to calibration;
- date of the calibration;
- date of the next calibration;
- authority having performed calibration or verification;
- quality department approval.

**Recommendation T30:** If the check of the furnace temperature uniformity (mapping) is performed through dispersion measurements and product follow-up, the heat-treatment plan specifying the conditions of implementation and validation of the check should be defined and applied.

**Requirement T31:** If the checking of the TUS is not correct according to the heat-treatment plan, an action plan shall be achieved.

#### 5.4.4 Drift of the soak times of the various heat-treatment phases (references HTT1 to HTT2)

**Requirement HTT1:** Procedures shall indicate the method for measuring the soak time of the various heat-treatment phases for each process and indicate the soak time parameters and tolerances.

**Requirement HTT2:** The soak times of the various heat-treatment phases shall be monitored by a set point alarm, followed by a recording or be checked and documented by signature at least once per heat-treatment procedure or twice per work shift.

**NOTE** Usually, a soak time at the heat-treatment temperature is indicated (maximum, minimum soak, or soak time). For some furnaces or equipment, the heat-treatment soak time can be characterised in the form of a particular parameter: feed speed, belt speed, etc.

## 5.5 Mastering of the heat-treatment medium

### 5.5.1 General

The medium in which the heat treatment is carried out can be solid, liquid (salt bath treatment), gaseous or low pressure (vacuum).

**NOTE** During thermochemical treatments, the medium allows the surface to be enriched with one or more chemical elements. At the opposite, in some cases (quenching, annealing, tempering, etc.), it is better that the treatment medium is neutral for the part to be treated.

Solid media are not frequently used and they are covered by particular agreements between the heat-treatment facility and the customer.

### 5.5.2 Control of carbon-containing atmosphere

#### 5.5.2.1 General

The heat treatments concerned are those treatments performed under atmosphere and in which carbon is the main element, e.g. case hardening, carbonitriding and derived heat treatments.

Low-pressure case hardening heat treatments are not concerned.

#### 5.5.2.2 Atmosphere drift (references C1 to C6)

**Requirement C1:** Atmosphere furnaces, atmosphere generators and measurement devices shall be operated by competent operator(s). If the flow is the only checking means, it shall be equipped with a calibrated device used to measure the flow for all fluids and shall be subject to scheduled maintenance.

**Requirement C2:** The different gas flow parameters with tolerances shall be indicated in the heat-treatment plan.

**Recommendation C3:** A means for continuous recording of the carbon content in the heat-treatment atmosphere should be provided. The heat-treatment plan should indicate the nominal value of the carbon content in the atmosphere with the tolerance.

**Recommendation C4:** In a carburising atmosphere, a soot burning programme for the furnaces and generators should be foreseen. Its set up conditions should be documented.

**Requirement C5:** If one (or several) atmosphere generator(s) is (are) used, the temperature and the atmosphere shall be continuously monitored.

**Requirement C6:** The atmosphere in the furnaces shall be monitored by a set point alarm, followed by a recording or checked and documented by signature at least once per heat-treatment procedure or twice per work shift.

#### 5.5.2.3 Drift of measuring equipment (references C7 and C8)

**Recommendation C7:** For annealing, quench hardening, normalising, stress relieving treatments, case hardening or carbonitriding in atmosphere, the carbon content in the heat-treatment atmosphere should be checked at least twice per week, using another checking method (alternative method e.g. oxygen probes or online infrared (IR) gas analysis).

**Recommendation C8:** When the alternative method is no longer correlating with the main method within the prescribed limits, actions should be implemented to restore correlation between the two methods.

#### 5.5.2.4 Presence of unwanted gases (references C9 and C10)

For furnaces with ammonia supply also used to perform heat treatments without ammonia, the following recommendations should apply.

**Recommendation C9:** A device intended to eliminate any risk of accidental introduction of ammonia in the furnace should be mounted. A three-valve ammonia (fail safe valve system) is permitted with one manual and two electrical magnetic valves in series.

**Recommendation C10:** The ammonia should be removed from the furnace prior to performing any heat treatment without ammonia, in accordance with a defined procedure.

#### 5.5.3 Control of nitriding, nitrocarburising and derived heat-treatment atmospheres

For nitriding, the atmosphere drift is taken into account with requirements and recommendations (references N1 to N6).

**Requirement N1:** Atmosphere furnaces and atmosphere generators for which the flow is the only checking means shall be equipped with flowmeters (or equivalent checking devices) for all gases and be subjected to scheduled maintenance. A procedure shall indicate the different flow parameters with tolerances according to the heat-treatment cycle.

**Requirement N2:** If one (or several) atmosphere generator(s) is (are) used, the temperature and the atmosphere shall be continuously monitored.

**Requirement N3:** The atmosphere in the furnaces shall be monitored by a set point alarm according to the tolerance defined in the procedure, followed by a recording or be checked and documented by signature at least once per heat-treatment procedure or twice per work shift.

**Recommendation N4:** During gas nitriding, and if there are no continuous checks with alarm (hydrogen sensor, gas or flow infrared analysis), dissociation of ammonia should be checked at least once per heat-treatment procedure or twice per work shift, and this shall be documented by signature.

**Recommendation N5:** For ferritic nitrocarburizing, and if there are no continuous checks with alarm, the gas mixture should be checked at least once per heat-treatment procedure or twice per work shift, and it shall be documented by signature.

**Recommendation N6:** For gaseous nitriding treatment the nitrogen potential should be monitored, recorded and alarmed.

#### 5.5.4 Control of salt bath and drift of treatment medium

The control of the drift of the heat-treatment medium is taken into account with requirements (references SB1 to SB2).

**Requirement SB1:** For austenitising salt baths, the composition of the bath or the decarburisation of the parts shall be checked before each use of the heat-treatment equipment and at least once per week (e.g. foil).

**Requirement SB2:** For nitriding and nitrocarburizing salt baths, the chemical composition of the bath shall be checked once per week.

#### 5.5.5 Control of operational conditions of surface hardening after induction superficial heating

##### 5.5.5.1 Error on the quenching profile or on the heat treatment characteristics of the product (references SH1 to SH2)

**Recommendation SH1:** The heat-treatment plan should define the different process parameters such as frequency, power, feed speed, cooling spray delay, heating temperature, heating time, inductor speed for continuous heating, as well as nominal values with tolerances and periodic checking.

**Recommendation SH2:** The temperature of the quenching fluid should be monitored by an alarm.

#### 5.5.5.2 Part treatment lead time (reference SH3)

**Recommendation SH3:** A system for managing the inductors and cooling systems should be provided with the following means:

- templates and/or drawings enabling quick manufacturing of spare inductors;
- available spare inductors;
- modification of the inductors after approval from the customer within two weeks.

#### 5.5.5.3 Heat-treatment reproducibility (references SH4 to SH10)

**Recommendation SH4:** The quenching system should be automated, unless otherwise specified and approved by the customer.

**Recommendation SH5:** A heat-treatment plan should define the control of the inductor and the specified interval of exchange.

**Recommendation SH6:** The influent parameters (voltage, current, power, etc.) should be monitored using a supervision device (set point alarm and recording) or documented by signature at least once per heat-treatment procedure or twice per work shift.

**Requirement SH7:** For each start-up, end of production run, pre and post tool change, equipment repair, station alarm (shutdown, malfunction, etc.), metallurgical characteristics shall be checked on one part (induction pattern dimensions, surface hardening depth or total hardening depth, surface and core hardness, microstructural observation). The checking frequency during production shall be defined in a heat-treatment plan.

**Recommendation SH8:** The flow rate of the sprays should be automatically controlled or, failing that, the spraying system should be checked and/or cleaned once per work shift or at documented intervals suited to the risk. An alarm system for quench pressure and flow rate for high and low limit is recommended. In the absence of an alarm system, the quench pressure and the flow should be checked at start-up and at specified intervals.

**Recommendation SH9:** Solids in suspension in the quenching fluid should be checked every three months, or at a different interval based on an available and documented experience. A complete replacement of the quench media and cleaning of the tank at the same intervals satisfies this recommendation.

**Recommendation SH10:** The concentration and/or density of the quenching fluid (polymers, brine and caustic solutions) should be checked daily, or at a specified interval based on available and documented experience.

#### 5.5.6 Laser hardening (references L1 to L4)

**Recommendation L1:** A procedure should define the nominal value and tolerance of key process parameters to monitor, record and alarm (frequency, speed, cycle of the speed if needed, cycle time, amplitude, temperature regulation, etc.).

**Recommendation L2:** A pre-study should define the type of laser to use, the shape of the beam and the major process parameters to apply.

**Recommendation L3:** In case of water-cooling copper bars, the follow-up of water temperature, water flow should be monitored. The gap between bars and the part should be checked regularly according to experience.

**Recommendation L4:** Positioning of the parts thanks to fixturing should ensure the repeatability of the results.

### 5.5.7 Vacuum or low-pressure heat treatment (references V1 to V7)

**Recommendation V1:** The vacuum furnaces for thermochemical heat treatments should be equipped with flowmeters (or equivalent checking devices) for all treatment gases and be subjected to scheduled maintenance. See [Table A.1](#).

**Recommendation V2:** The temperature, the pressure or vacuum and the gas flows should be continuously monitored.

**Recommendation V3:** The time needed to reach the limit vacuum before heating should be monitored with a set point alarm.

**Recommendation V4:** A leakage rate should be done every month, except for aeronautical parts every week.

**Recommendation V5:** The leak test should be lower than 4 Pa/h except for titanium alloys lower than 2 Pa/h.

NOTE 1 Pa is equivalent to 0,01 mbar.

**Recommendation V6:** The dew point of the different gases should be monitored with a set point alarm.

**Recommendation V7:** The characteristics of the electrical power delivered by the bias power supply of plasma furnaces (amperage, voltage, duty cycle) should be monitored with a set point alarm.

## 5.6 Control of cooling

### 5.6.1 Equipment control and heat-treatment reproducibility (references CEQ1 to CEQ3)

**Requirement CEQ1:** All quench tanks shall be equipped with temperature measuring instruments.

**Recommendation CEQ2:** The quenching systems should be equipped with monitoring means or equipment (e.g. control of agitation, temperature level).

**Recommendation CEQ3:** The level, temperature and agitation of the quench tank should be monitored by means of a supervision device (set point alarm and recording) or documented by signature at least once per heat-treatment procedure or twice per work shift.

### 5.6.2 Control of cooling parameters (references CPM1 to CPM12)

**Requirement CPM1:** The quenching time shall be documented.

**Requirement CPM2:** Soak times before tempering or before cold treatment shall be documented.

**Requirement CPM3:** For batch furnaces or pushing type load continuous furnaces, the transfer overtime shall be alarmed.

**Recommendation CPM4:** For batch furnaces or pushing type load continuous furnaces, the transfer time should be monitored by a supervision system.

**Recommendation CPM5:** The quenching media should be checked at a specified interval based on the acquired documented experience according to a specification.

The requirements related to the checks of the quenching fluids depend on the nature of these fluids and are defined in accordance with [Table 11](#).

Table 11 — Types and frequencies of the checks of quenching fluid

Nature of the fluid	Check to be performed	Frequency or periodicity of the check	Requirement or recommendation
Polymers	Polymer concentration	Daily or at different frequencies defined from an available and documented experience	<b>Requirement CPM6</b>
	Solids in suspension	Every six months	<b>Requirement CPM7</b>
Water	Solids in suspension <sup>a</sup> , pH level, chloride content, etc.	Every year or at a different frequency defined from an available and documented experience	<b>Requirement CPM8</b>
Brines	Solids in suspension	Every six months	<b>Recommendation CPM9</b>
	Concentration and/or density	Daily	<b>Recommendation CPM10</b>
Oils	To be defined on the basis of an experience (water content, solids in suspension, viscosity, cooling curve, acid value and flash point)	Every six months	<b>Requirement CPM11</b>
Salts	Analysis of baths and check of contaminants	At least once a year	<b>Requirement CPM12</b>

<sup>a</sup> Mud, paste, soot and rust or metallic particles can be present as solids in suspension.

## 5.7 Control of product

### 5.7.1 Drift of testing means (references CP1 and CP2)

**Requirement CP1:** Product testing equipment shall be checked in accordance with the standards in force and, for equipment listed in [Annex A](#), at the frequencies given in [Table A.1](#).

**Requirement CP2:** Hardness testing equipment shall be checked and calibrated in accordance with the ISO 6506, ISO 6507 and ISO 6508 series and at the frequency defined in [Annex A](#).

### 5.7.2 Non-conforming product (references CP3 to CP5)

**Requirement CP3:** The product shall be tested in accordance with the standards in force or using other defined methods.

**Requirement CP4:** The documents drafted in accordance with the customer's specifications and defining the parameters of the product to be tested and the frequencies of these tests shall be supplied and applied.

**Requirement CP5:** The product data shall be recorded and follow-up.

## 5.8 Finishing process

**Recommendation F1:** The tolerances of use related to the testing of soluble oils used as corrosion inhibitors should be defined according to expiration or life duration and environment protection durability.

**Recommendation F2:** The soluble oil concentration test should be carried out once per week, or at a different frequency based on an available and documented experience.

**Recommendation F3:** The washing solution concentration and oil content tests should be carried out once per week, or at a specified interval based on an available and documented experience. A specified interval of washing bath and cleaning tank should be documented.

**Recommendation F4:** The temperature of the washing solution should be monitored (only if the specified temperature is above the room temperature) by means of a supervision system or, failing that, it should be checked before each use or once per day of use.

**Recommendation F5:** The chloride content in the washing solutions should be checked at least once every three months or at a different frequency based on an available and documented experience.

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## Annex A (normative)

### Equipment calibration and frequency control

When used during the heat-treatment process, the testing or measuring equipment shall be checked in terms of drift control or calibrated according to the specified intervals described in [Table A.1](#).

All requirements in [Table A.1](#) shall be scored according to [4.3.2](#).

In case of a non-conform drift control or calibration or at least every three years the equipment shall be sent to supplier for maintenance.

**Table A.1 — Calibration and drift control or routine check minimum intervals of available measuring equipment related to the process**

Equipment	Drift control or routine check	Calibration	Example of control
Dew-point measuring device	Not required	Calibration once a year (by the supplier or third party or exchanged)	
Gas analyser for CO / CO <sub>2</sub> / CH <sub>4</sub>	Weekly in case of continuous furnace or before each use	Calibration once per year by return to the supplier	Using standard gases
Gas analyser for hydrogen	Weekly in case of continuous furnace or before each use	Calibration once per year by return to the supplier	Using standard gases
Spark emission spectrometer or GDOES	Not applicable	Calibration after a maintenance and according to return of experience	Using certified reference material (CRM) standard
Device for determination of carbon through combustion (chips)	Daily or before each use	Calibration once per year	Using certified reference material (CRM) standard with a defined percentage of carbon
Non-automatic refractometer	Before each use or at least once per day	Calibration after an accident	Zero with distilled water
Oxygen/lambda probe	Test the gauges with an alternative method (e.g. combustion gas analyser, chips). The routine check period should be indicated in the heat-treatment plan.	Calibration once per calendar year with a time frame not exceeding 18 months	Using a standard gas
Gas or liquid mass or Coriolis flow meter	Regular cleaning according to return of experience	Calibration once a year by return to the supplier	
Volume flow meter, rotameter and electrovalve	Checking monthly the good functioning and integrated in the maintenance plan	Calibration once per year or according to the return of experience	
Pressure manometer (overpressure)	Checking twice a year	Calibration every three years for vacuum furnace and/or according to the frequency of use and integrated into the maintenance plan	
Vacuum gauge (primary and secondary vacuum)	Twice per year	Calibration of new or repaired devices or if the drift control is not compliant	For the drift control: verification with a calibrated gauge

Table A.1 (continued)

Equipment	Drift control or routine check	Calibration	Example of control
Water flowmeter for vacuum furnace	Checking quarterly the good functioning and integrated in the maintenance plan	Calibration once per year or according to the return of experience	
Thermocouples for endothermic- and exothermic-atmosphere generator	Not applicable	According to <a href="#">5.4.1</a> and <a href="#">5.4.2</a> Recalibration or replacement once per year	
Rotation direction of turbines and stirrers	Yearly checking and after a major maintenance	Not applicable	Visual checking
Voltmeter and ammeter for the furnace power supply	Quarterly functioning checking	Calibration of voltmeter and ammeter for plasma and low-pressure furnaces once per year	
Level indicator	Quarterly functioning checking	Not applicable	By manual action on the sensor
Belt speed or conveyor speed	Twice a year and/or after maintenance and/or exchange of conveyor parts	Not applicable	
Automatic feeder (weight and vibration given the quantity of parts/meter)	Quarterly or following heat-treatment plan indications	Calibration once a year for the weight	Drift control by checking the number of parts after a controlled time
Overall state of belt or loading jigs or conveyor	Continuously on the fly and implementation of a visual control according to the furnace and the frequency of use with integration of it into the maintenance plan	Not applicable	
Weight measurement	Not applicable	Calibration by the supplier or a third party once per year or if the drift control is not compliant	Calibration using a standard weight

## Annex B (informative)

### Example of scoring table for requirements and recommendations

[Table B.1](#) may be used to score the heat-treatment facility according to [Clause 4](#).

**Table B.1 — Example of scoring table for requirements and recommendations of the heat-treatment facility**

Reference	Assessment						Score
	100	80	50	20	0	N.A.	
Documentation							
Requirement G01							
Requirement G02							
Requirement G03							
Management responsibility							
Requirement G04							
Requirement G05							
Management of human resources							
Requirement G06							
Requirement G07							
Requirement G08							
Requirement G09							
Recommendation G010							
Infrastructure and equipment management							
Requirement G011							
Recommendation G012							
Requirement G013							
Recommendation G014							
Requirement G015							
Requirement G016							
Recommendation G017							
Requirement G018							
Requirement G019							
Recommendation G020							
Requirement G021							
Recommendation G022							
Requirement G023							
Recommendation G024							
Recommendation G025							
Internal audit							
Requirement G026							
Requirement G027							

Table B.1 (continued)

Reference	Assessment						Score
	100	80	50	20	0	N.A.	
Control of non-conforming product							
Requirement G028							
Requirement G029							
Requirement G030							
Recommendation G031							
Requirement G032							
Requirement G033							
Requirement G034							
Recommendation G035							
Requirement G036							
Continuous improvement							
Requirement G037							
Requirement G038							
FMECA							
Requirement G039							
Requirement G040							
Recommendation G041							
Monitoring plan							
Recommendation G042							
Recommendation G043							
Recommendation G044							
Preproduction quality planning							
Recommendation G045							
Recommendation G046							
Statistics							
Recommendation G047							
Recommendation G048							
Recommendation G049							
Controlling, monitoring and recording							
Requirement G050							
Recommendation G051							
Recommendation G052							
Recommendation G053							
Recommendation G054							
Requirement G055							
Requirement G056							
Recommendation G057							
Recommendation G058							
Requirement G059							
Recommendation G060							
Requirement G061							
Requirement G062							

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**Table B.1 (continued)**

Reference	Assessment						Score
	100	80	50	20	0	N.A.	
Contract review							
Recommendation CR1							
Requirement CR2							
Recommendation CR3							
Requirement CR4							
Requirement CR5							
Heat-treatment conception							
Requirement HTP1							
Requirement HTP2							
Recommendation HTP3							
Requirement HTP4							
Load preparation							
Requirement PR1							
Recommendation PR2							
Requirement PR3							
Recommendation PR4							
Recommendation PR5							
Recommendation PR6							
Recommendation PR7							
Recommendation PR8							
Recommendation PR9							
Heat-treatment temperature error							
Requirement T1							
Requirement T2							
Requirement T3							
Recommendation T4							
Requirement T5							
Requirement T6							
Requirement T7							
Requirement T8							
Recommendation T9							
Recommendation T10							
Requirement T11							
Measuring equipment error SAT							
Requirement T12							
Requirement T13							
Requirement T14							
Recommendation T15							
Requirement T16							
Requirement T17							
Requirement T18							
Survey of furnace Temperature Uniformity							

Table B.1 (continued)

Reference	Assessment						Score
	100	80	50	20	0	N.A.	
Recommendation T19							
Requirement T20							
Requirement T21							
Requirement T22							
Requirement T23							
Requirement T24							
Recommendation T25							
Requirement T26							
Recommendation T27							
Requirement T28							
Recommendation T29							
Recommendation T30							
Requirement T31							
Drift of the soak times of the various heat-treatment phases							
Requirement HTT1							
Requirement HTT2							
Atmosphere drift							
Requirement C1							
Requirement C2							
Recommendation C3							
Recommendation C4							
Requirement C5							
Requirement C6							
Recommendation C7							
Recommendation C8							
Recommendation C9							
Recommendation C10							
Control of nitriding, nitrocarburising and derived heat-treatment atmospheres							
Requirement N1							
Requirement N2							
Requirement N3							
Recommendation N4							
Recommendation N5							
Recommendation N6							
Control of salt bath and drift of treatment medium							
Requirement SB1							
Requirement SB2							
Control of operational conditions of surface hardening after induction superficial heating							
Recommendation SH1							
Recommendation SH2							