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Heat treatment — Control of quality

Traitement thermique — Maîtrise de la qualité

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Foreword

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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).

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

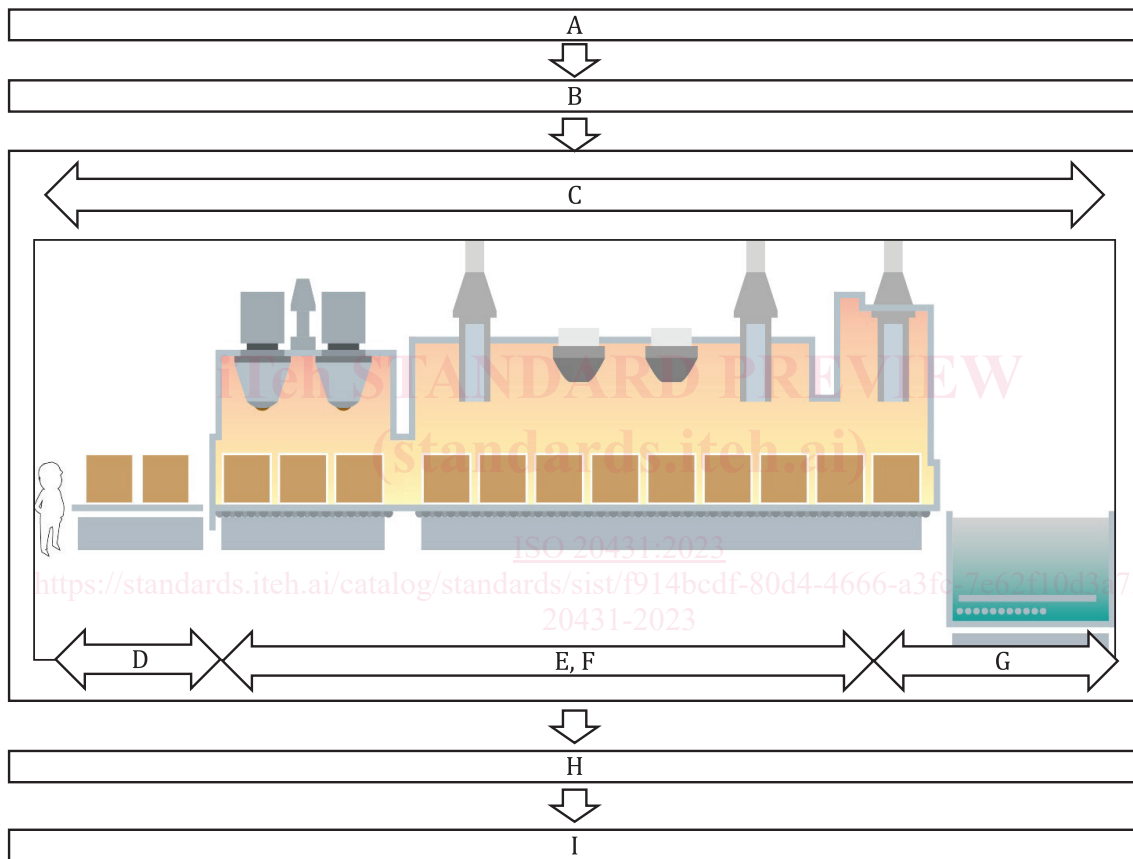
Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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	5.1
CR	Contract Review	5.2.1
HTP	Heat-Treatment Conception	5.2.2
PR	Preparation	5.3
T	Heat-treatment Temperature	5.4.1 to 5.4.3

Table 1 (continued)

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

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_0	N_{100}	N_{20}	N_{50}	N_{80}	N_{100}	
5.1	General organisation of the heat treatment facility								
5.2	Contract review and heat treatment preparation								
5.3	Carrying out the heat treatments:								
5.4		Preparation							
5.5		Control of thermal cycle							
5.6		Control of heat treatment medium							
5.7	Control of cooling								
5.7	Control of product testing								
5.8	Finishing								
Final result (for the entire audit)									

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.

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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).