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**Ferrous materials — Heat treatments  
— Vocabulary**

*Matériaux ferreux — Traitements thermiques — Vocabulaire*

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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 documents 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)).

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This document was prepared by Technical Committee ISO/TC 17, *Steel*.

This second edition cancels and replaces the first edition (ISO 4885:1996), which has been technically revised.

# Ferrous materials — Heat treatments — Vocabulary

## 1 Scope

This document defines important terms used in the heat treatment of ferrous materials.

NOTE The term ferrous materials include products and workpieces of steel and cast iron.

[Annex A](#) provides an alphabetical list of terms defined in this document, as well as their equivalents in French, German, Chinese and Japanese.

[Table 1](#) shows the various iron-carbon (Fe-C) phases.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

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

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

### 3.1

#### **acicular structure**

structure which appears in the form of needles in a micrograph

### 3.2

#### **activity**

effective concentration of species under non-ideal (e.g. concentrated) conditions; for *heat treatment* ([3.108](#)), this means the effective concentration of carbon or nitrogen (or both) in heat treatment media and in ferrous materials

Note 1 to entry: Ratio of the vapour pressure of a gas (usually carbon or nitrogen) in a given state (e.g. in *austenite* ([3.12](#)) of specific carbon/nitrogen concentration) to the vapour pressure of the pure gas, as a reference state, at the same temperature.

### 3.3

#### **ageing**

change in the properties of steels depending on time and temperature after hot working or *heat treatment* ([3.108](#)) or after cold-working operation due to the migration of interstitial elements

Note 1 to entry: The ageing phenomenon can lead to higher strength and lower ductility.

Note 2 to entry: The ageing can be accelerated either by cold forming and/or subsequent *heating* ([3.109](#)) to moderate temperatures (e.g. 250 °C) and soaking (e.g. for 1 h) to create the ageing effects.

### 3.4

#### **air-hardening steel**

DEPRECATED: self-hardening steel

steel, the *hardenability* ([3.103](#)) of which is such that *cooling* ([3.45](#)) in air produces a martensitic structure in objects of considerable size

### 3.5

#### **alpha iron**

stable state of pure iron at temperatures below 911 °C

Note 1 to entry: The crystalline structure of an alpha iron is body-centred cubic.

Note 2 to entry: Alpha iron is ferromagnetic at temperatures below 768 °C (the Curie point).

### 3.6

#### **alpha mixed crystal**

iron with body-centred cubic lattice structure with alloying elements in interstitially or substitutively solution

Note 1 to entry: The material science for alpha mixed crystal is ferritic.

Note 2 to entry: Alpha mixed crystal is ferromagnetic.

### 3.7

#### **aluminizing**

DEPRECATED: calorizing

*surface treatment into and on a workpiece* ([3.201](#)) relating to aluminium

### 3.8

#### **annealing**

*heat treatment* ([3.108](#)) consisting of *heating* ([3.109](#)) and soaking at a suitable temperature followed by *cooling* ([3.45](#)) under conditions such that, after return to ambient temperature, the metal will be in a structural state closer to that of equilibrium

Note 1 to entry: Since this definition is very general, it is advisable to use an expression specifying the aim of the treatment. See *bright annealing* ([3.29](#)), *full annealing* ([3.89](#)), *softening/soft annealing* ([3.186](#)), *inter-critical annealing* ([3.122](#)), *isothermal annealing* ([3.127](#)) and subcritical annealing.

### 3.9

#### **ausferrite**

fine-grained mixture of *ferrite* ([3.85](#)) and stabilized *austenite* ([3.12](#)) which should lead to high hardness and ductility of austempered ductile cast iron (ADI)

### 3.10

#### **ausforming**

*thermomechanical treatment* ([3.207](#)) of a workpiece which consists of plastically deforming the metastable *austenite* ([3.12](#)) before subjecting it to the martensitic and/or bainitic transformation

### 3.11

#### **austempering**

isothermal heat treatment for producing bainitic (see [3.17](#) and [3.18](#)) or ausferritic (see [3.9](#)) structure of a workpiece

Note 1 to entry: The final *cooling* ([3.45](#)) to ambient temperature is not at a specific rate.

### 3.12

#### **austenite**

solid solution of one or more elements in *gamma iron* ([3.91](#))

Note 1 to entry: See also [Table 1](#).

### 3.13

#### **austenitic steel**

steel structure which is austenitic at ambient temperature

Note 1 to entry: Cast austenitic steels can contain up to about 20 % of *ferrite* ([3.85](#)).

**3.14****austenitizing**

*heating* (3.109) a workpiece to *austenitizing temperature* (3.15) and holding at this, so that the microstructure is predominantly austenitic

Note 1 to entry: The amount of the minimum required temperature results from the heat speed and the steel composition. The holding period depends on the heating conditions used.

**3.15****austenitizing temperature**

temperature at which the workpiece is maintained during austenitization

**3.16****auto-tempering**

self-tempering

tempering undergone by *martensite* (3.137) during *quenching* (3.168) or subsequent *cooling* (3.45)

**3.17****bainite**

microstructure resulting from the transformation of *austenite* (3.12) at temperatures above *martensite* (3.137) start temperature ( $M_s$ ) and outside the *pearlite* (3.155) range consisting of ferrite laths and carbides which are dispersed either inside the ferrite laths (lower bainite) or between the ferrite laths (upper bainite)

Note 1 to entry: See also Table 1.

**3.18****bainitizing**

*austenitizing* (3.14) and *quenching* (3.168) to a temperature above  $M_s$  and isothermal soaking to ensure a transformation of the *austenite* (3.12) to *bainite* (3.17)

**3.19****bake hardening steel**

steel with the ability to gain an increase of yield strength after a plastic pre-strain and a subsequent *heat treatment* (3.108) in the usual industrial paint processes (in the region of 170 °C for 20 min)

Note 1 to entry: These steels have a good suitability for cold forming and present a high resistance to plastic straining (which is increased on finished parts during heat treatment) and a good dent resistance.

**3.20****baking**

*heat treatment* (3.108) permitting the release of hydrogen absorbed in a ferrous product without modifying its structure

Note 1 to entry: The treatment is generally carried out following an electrolytic plating or pickling, or a welding operation.

**3.21****banded structure**

lines of constituents of the microstructure caused by *segregation* (3.179) during solidification

**3.22****blacking**

operation carried out in an oxidizing medium at a temperature such that the polished surface of a workpiece becomes covered with a thin, continuous, adherent film of dark-coloured oxide (see 3.151)

**3.23****black nitriding**

*nitriding* (3.143) followed by *oxidation* (3.150) of the steel surface

Note 1 to entry: After *nitrocarburizing* (3.144), *blacking* (3.22) will improve the corrosion resistance and the surface properties

**3.24**

**blank nitriding**

blank nitrocarburizing

simulation treatment which consists of reproducing the thermal cycle of *nitriding* (3.143)/*nitrocarburizing* (3.144) without the nitriding/nitrocarburizing medium

Note 1 to entry: This treatment makes it possible to assess the metallurgical consequences of the thermal cycle of nitriding/nitrocarburizing.

**3.25**

**batch annealing**

box annealing

process in which strip is annealed in tight coil form, within a protective atmosphere, for a predetermined time-temperature cycle

**3.26**

**blueing**

treatment carried out in an oxidizing medium (see 3.152) at a temperature such that the bright surface of a workpiece becomes covered with a thin, continuous, adherent film of blue-coloured oxide

Note 1 to entry: If the blueing is carried out in superheated water vapour, it is also called steam treatment.

**3.27**

**boost-diffuse carburizing**

carburizing carried out in two or more successive stages and/or different temperatures with different carbon potentials

**3.28**

**boriding**

*thermochemical treatment* (3.207) of a workpiece to enrich the surface of a workpiece with boron

Note 1 to entry: The medium in which boriding takes place should be specified, e.g. pack boriding, paste boriding, etc.

**3.29**

**bright annealing**

*annealing* (3.8) in a medium preventing the *oxidation* (3.150) of the surface and keeps the original surface quality

**3.30**

**burning**

irreversible change in the structure and properties brought about by the onset of melting at the grain boundaries and surface

**3.31**

**carbon activity**

effective concentration of carbon under non-ideal (e.g. concentrated) conditions; for *heat treatment* (3.108), this means the effective concentration of carbon in heat treatment media and in ferrous materials.

**3.32**

**carbon mass transfer coefficient**

coefficient of the mass of carbon transfer from the carburizing medium into steel (per unit surface area and time)

Note 1 to entry: Also defined as the mass of carbon transferred from the carburizing medium into the steel, per unit surface area per second, for a unit difference between the carbon potential and actual surface carbon content.



**3.33****carbon level**

carbon content in percent of mass in an austenitized probe of pure iron at a given temperature in the equilibrium with the carburizing medium

Note 1 to entry: The “carbon level” has been defined for practical use, because the carbon potential of steels cannot be measured directly in carburizing media; see Reference [13].

**3.34****carbon profile**

carbon content depending on the distance from the surface

**3.35****carbonitriding**

*thermochemical treatment* (3.207) to enrich the surface layer with carbon and nitrogen

Note 1 to entry: The elements are in solid solution in the *austenite* (3.12), usually the carbonitrided workpiece undergoes *quench hardening* (3.167) (immediately or later).

Note 2 to entry: Carbonitriding is a *carburizing* (3.36) process.

Note 3 to entry: The medium in which carbonitriding takes place should be specified, e.g. gas, salt bath, etc.

**3.36****carburizing**

DEPRECATED: cementation

*thermochemical treatment* (3.207) which is applied to a workpiece in the austenitic state, to obtain a surface enrichment in carbon, which is in solid solution in the *austenite* (3.12)

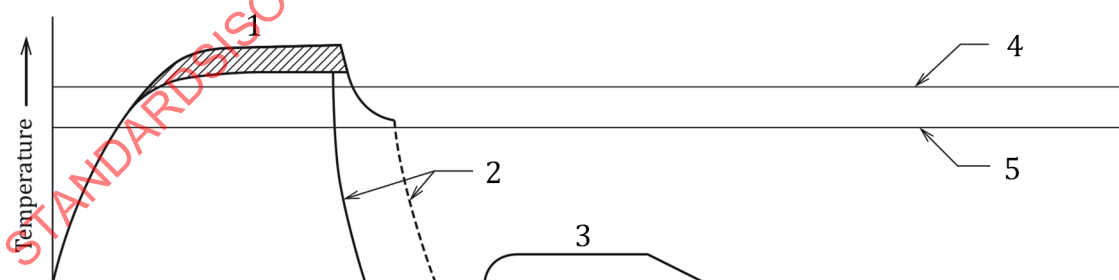
Note 1 to entry: The carburized workpiece undergoes *quench hardening* (3.167) (immediately or later).

Note 2 to entry: The medium in which carburizing takes place should be specified, e.g. gas, pack, etc.

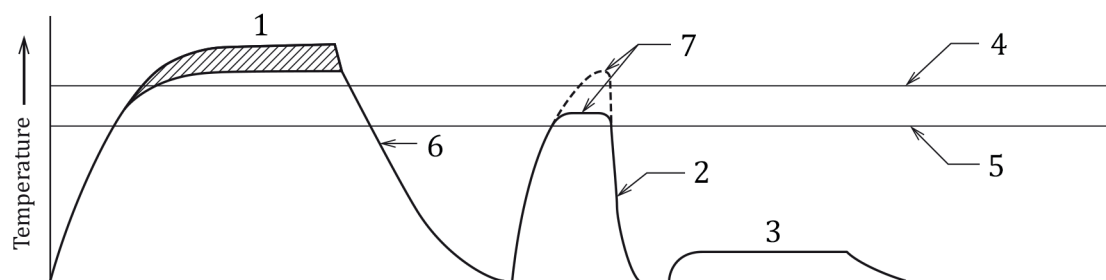
**3.37****case hardening**

treatment consisting of *carburizing* (3.36) or *carbonitriding* (3.35) followed by *quench hardening* (3.167)

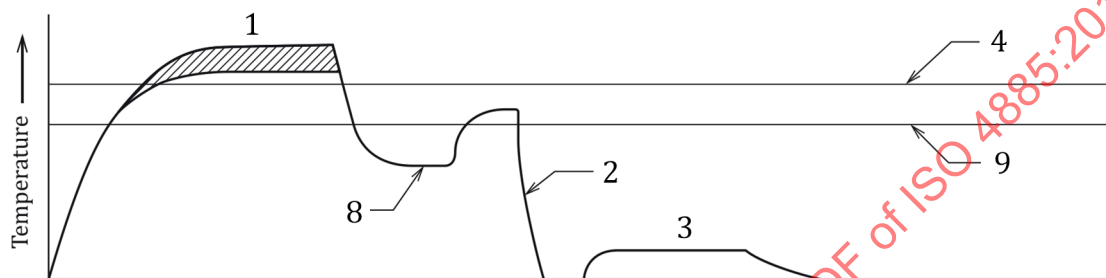
Note 1 to entry: See Figure 1.



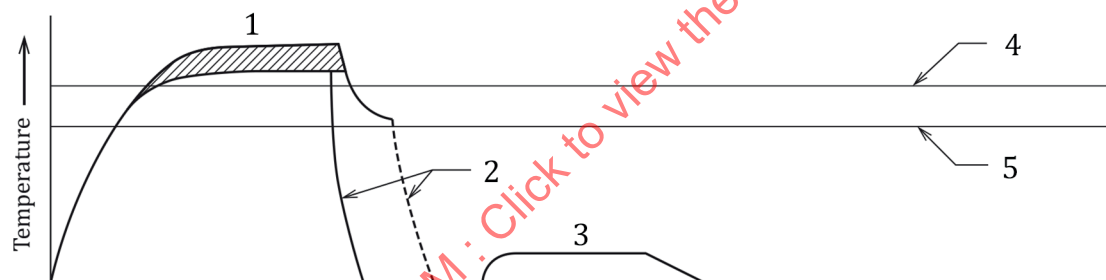
a) Direct-hardening treatment



b) Single-quench hardening treatment



c) Quench-hardening treatment with isothermal transformation



d) Double-quench hardening treatment

**Key**

- |                               |                                      |
|-------------------------------|--------------------------------------|
| 1 carburizing, carbonitriding | 6 cooling                            |
| 2 quenching                   | 7 quench-hardening treatment         |
| 3 tempering                   | 8 isothermal transformation          |
| 4 $A_{c3}$ core               | 9 $A_{c3}$ surface after carburizing |
| 5 $A_{c3}$ surface            |                                      |

**Figure 1 — Schematic representation of the possible thermal cycles of various case-hardening treatments**

**3.38**

**cast iron**

alloy of iron, carbon and silicon where the carbon content is approximately more than 2 %

**3.39****cementite**

iron carbide with the formula  $\text{Fe}_3\text{C}$

Note 1 to entry: See [Table 1](#).

**Table 1 — Iron-carbon (Fe-C) phases**

Phase	Crystal structure	Properties	Typical hardness
Ferrite, $\alpha$	bcc	soft, tough, magnetic	60 HBW to 90 HBW
Austenite, $\gamma$	fcc	fair strength, non-magnetic	150 HBW (1,5 % C)
Cementite, $\text{Fe}_3\text{C}$	rombic	hard, brittle chemical composition	820 HBW
Pearlite with coarse lamellas (0,4 $\mu\text{m}$ )	$\alpha + \text{Fe}_3\text{C}$ , lamellar	combination of tough ferrite and hard cementite	200 HBW
Pearlite with fine lamellas (0,1 $\mu\text{m}$ )	$\alpha + \text{Fe}_3\text{C}$ , lamellar	harder than pearlite with coarse lamellas	400 HBW
Spheroidite	$\alpha + \text{globular Fe}_3\text{C}$	soft	120 HBW to 230 HBW, depending on carbon and alloy content
Upper bainite	precipitations of $\text{Fe}_3\text{C}$ on surface of $\alpha$	properties such as pearlite with fine lamellas	400 HBW
Lower bainite	precipitations of $\text{Fe}_3\text{C}$ inside of $\alpha$	strength near martensite, but tougher than tempered martensite	600 HBW
Martensite, $\alpha'$ , non-tempered	bcc, slightly tetragonic	hard, brittle	250 HV to 950 HV, depending on carbon content
Martensite, $\alpha'$ , tempered	bcc, slightly tetragonic	softer and tougher than non-tempered martensite	250 HV to 650 HV, depending on carbon content and tempering temperature

**3.40****chromizing**

surface treatment into and on a workpiece ([3.201](#)) relating to chromium

Note 1 to entry: The surface layer can consist of practically pure chromium (on low-carbon steels) or of chromium carbide (on high-carbon steels).

**3.41****compound layer**

DEPRECATED: white layer

surface layer formed during *thermochemical treatment* ([3.207](#)) and made up of the chemical compounds formed by the element(s) introduced during the treatment and certain elements from the base metal

EXAMPLE The surface layer may consist of the layer of nitrides formed during *nitriding* ([3.143](#)), the layer of borides formed during *boriding* ([3.28](#)), the layer of chromium carbide formed during the *chromizing* ([3.40](#)) of high-carbon steel.

Note 1 to entry: In English, the term “white layer” is improperly used to designate this layer on nitrided and nitrocarburized ferrous products.

**3.42****continuous annealing**

process in which strip is annealed by moving continuously through an oven within a protective atmosphere

**3.43**

**continuous-cooling transformation diagram**

CCT diagram

see [3.210.2](#)

**3.44**

**controlled rolling**

rolling process where rolling temperature and reduction are controlled to achieve enhanced mechanical properties, e.g. normalizing rolling, thermomechanical rolling

Note 1 to entry: Controlled rolling is used for fine-grain *ferritic steels* ([3.86](#)) and for dual-phase steel for obtaining fine-grain structure.

**3.45**

**cooling**

reduction (or operation to reduce) of the temperature of a hot workpiece continuous, discontinuous, gradually or interrupted

Note 1 to entry: The medium in which cooling takes place should be specified, e.g. in furnace, air, oil, water. See also *quenching* ([3.168](#)).

**3.46**

**cooling condition**

condition(s) (temperature and kind of cooling medium, relative movements, agitation, etc.) under which the *cooling* ([3.45](#)) of the workpiece takes place

**3.47**

**cooling function**

reduction of the temperature as a function of time of a determined point of a workpiece

Note 1 to entry: This function could be shown as a graph or written in a mathematical form.

**3.48**

**cooling rate**

variation in temperature as a function of time during *cooling* ([3.45](#))

Note 1 to entry: A distinction is made between

- an instantaneous rate corresponding to a specified temperature, and
- an average rate over a defined interval of temperature or time.

**3.49**

**cooling time**

interval of time separating two characteristic temperatures of the *cooling function* ([3.47](#))

Note 1 to entry: It is always necessary to specify precisely what the temperatures are.

**3.50**

**core refining**

process to get a fine grain and a homogenous microstructure in the core, often done by hardening of carburized workpieces

Note 1 to entry: See [Figures 1 b\), c\) and d\)](#).

**3.51**

**critical cooling course**

cooling course to avoid transformation in undesired microstructure

Note 1 to entry: The cooling course can be characterized by the gradient of temperature or of the *cooling rate* ([3.48](#)) in general or at given temperatures or times.

**3.52****critical cooling rate**

cooling rate (3.48) corresponding to the *critical cooling course* (3.51)

**3.53****critical diameter**

diameter ( $d$ ) of a cylinder with a length  $\geq 3d$ , having a structure of 50 % by volume of *martensite* (3.137) after *quench hardening* (3.167) with defined conditions at its centre

**3.54****decarburization**

depletion of carbon from the surface layer of a workpiece

Note 1 to entry: This depletion can be either partial (partial decarburization) or nominally complete (complete decarburization). The sum of the two types of decarburization (partial and complete) is termed total decarburization; see ISO 3887.

**3.55****decarburizing**

*thermochemical treatment* (3.207) intended to produce *decarburization* (3.54) of a workpiece

**3.56****decomposition of austenite**

austenite transformation

decomposition into *ferrite* (3.85) and *pearlite* (3.155) or ferrite and *cementite* (3.39) with decreasing temperature

**3.57****delta iron**

stable state of pure iron between 1 392 °C and its melting point

Note 1 to entry: The crystalline structure of a delta iron is body-centred cubic, identical to that of the *alpha iron* (3.5).

Note 2 to entry: Delta iron is paramagnetic.

**3.58****depth of carburizing**

carburizing depth

distance between the surface of a workpiece and a specified limit characterizing the thickness of the layer enriched in carbon, which means effective case depth

**3.59****depth of decarburization**

decarburization depth

distance between the surface of a workpiece and a limit characterizing the thickness of the layer depleted in carbon

Note 1 to entry: This limit varies according to the type of *decarburization* (3.54) and can be defined by reference to a structural state, a level of hardness or the carbon content of the unaltered base metal (see ISO 3887), or any other specified carbon content.

**3.60****depth of hardening**

distance between the surface of a workpiece and a limit characterizing the penetration of *quench hardening* (3.167)

Note 1 to entry: This limit can be defined starting from a structural state or a level of hardness.

**3.61**

**depth of nitriding**

nitriding depth

distance between the surface of a workpiece and a specified limit characterizing the thickness of the layer enriched in nitrogen

**3.62**

**destabilization of retained austenite**

phenomenon occurring during tempering which allows the *retained austenite* (3.175) to undergo martensitic transformation within a temperature range where it would not previously have been transformed spontaneously

**3.63**

**diffusion**

movement of atoms to new places in ferrous materials

**3.64**

**diffusion annealing**

*heat treatment* (3.108)/*annealing* (3.8) of ferrous products or workpieces to reduce *segregation* (3.179) and promote homogeneity by *diffusion* (3.63)

Note 1 to entry: To reduce segregation of metallic elements in steel making and in bar rolling a process with temperatures between 1 000 °C and 1 300 °C is required.

Note 2 to entry: Reducing segregations of non-metallic alloying elements (such as carbon or sulphur) in workpieces usually would be done at a temperature below 1 000 °C.

**3.65**

**diffusion treatment**

*heat treatment* (3.108) to reduce a very high concentration of elements in the surface layer such as carbon or nitrogen after *carburizing* (3.36) or *nitriding* (3.143)

Note 1 to entry: See also *malleablizing* (3.133), which is also a diffusion treatment.

**3.66**

**diffusion zone**

surface layer formed by a *thermochemical treatment* (3.207) characterized by enrichment of elements such as carbon or nitrogen

Note 1 to entry: The enriched elements such as carbon or nitrogen are in solid solution and/or precipitated such as carbides or nitrides.

Note 2 to entry: The concentration of the enriched elements decreases from surface to the core of a workpiece.

**3.67**

**direct-quench hardening**

*quench hardening* (3.167) of carburized workpieces immediately after *carburizing* (3.36) or *carbonitriding* (3.35)

Note 1 to entry: The direct-quench hardening should be started directly from the carburizing or a lower temperature, adjusted to the surface carbon content.

Note 2 to entry: Direct hardening from hot forging or hot rolling replaces separate *austenitizing* (3.14) and *quenching* (3.168).

Note 3 to entry: See [Figure 1 a](#)).

**3.68**

**direct quenching**

*quenching* (3.168) carried out immediately following hot rolling or hot forging or *solution annealing* (3.188) of stainless steels or after a *thermochemical treatment* (3.207)

**3.69****dislocation**

crystallographic defect or irregularity, within a crystal structure

EXAMPLE There are two primary types, “edge dislocations” and “screw dislocations”.

Note 1 to entry: Cold forming increases the amount of dislocations and results in higher hardness.

**3.70****distortion**

any change in the shape and original dimensions of a ferrous workpiece, occurring during *heat treatment* (3.108)

Note 1 to entry: The causes are manifold including not only the heat treatment process but also the workpiece geometry, steel inhomogeneity and the production conditions.

**3.71****double-quench hardening treatment**

*heat treatment* (3.108) consisting of two successive quench-hardening treatments, generally carried out at different temperatures

Note 1 to entry: In the case of carburized products, the first *quench hardening* (3.167) could be done immediately after *carburizing* (3.36) from carburizing temperature. The second quench hardening could be carried out from a lower temperature adjusted to the carbon content of core.

Note 2 to entry: Double-quench hardening is also used for grain refining.

Note 3 to entry: See [Figure 1 d](#)).

**3.72****effective case depth after carburizing**

case-hardening hardness depth

carburizing depth

perpendicular distance between the surface of a case-hardened workpiece and the point where the hardness has the limit hardness value

Note 1 to entry: This limit should be specified, e.g. for the total case depth, this limit will correspond to the carbon content of the unaltered base metal.

Note 2 to entry: The term case depth is used in relation to any case-hardening or surface-hardening process.

[SOURCE: ISO 18203:2016, 3.1, modified.]

**3.73****effective case depth after nitriding**

nitriding hardness depth

perpendicular distance from the surface of a nitrided or nitrocarburized workpiece to the point where the hardness has the limit hardness value

[SOURCE: ISO 18203:2016, 3.4, modified.]

**3.74****effective case depth after surface hardening**

surface hardening hardness depth

distance between the surface and the point at which the Vickers hardness (HV) is equal to 80 % of the minimum surface hardness required for the workpiece considered

[SOURCE: ISO 18203:2016, 3.5, modified.]

### 3.75

#### **electron beam hardening**

*austenitizing* (3.14) the surface layer of a workpiece by *heating* (3.109) with an electron beam

Note 1 to entry: *Quenching* (3.168) for hardening could be done by external *quenching media* (3.170) or it takes place by self-cooling.

### 3.76

#### **embrittlement**

severe loss of toughness of a material

Note 1 to entry: Steels can be affected by different forms of embrittlement such as blue embrittlement, *temper embrittlement* (3.202), quench-age embrittlement, sigma-phase embrittlement, strain-age embrittlement, thermal embrittlement and low-temperature or cold embrittlement.

### 3.77

#### **endogas**

gas mixture produced by incomplete combustion of hydrocarbons

Note 1 to entry: Endogas has a conventional composition of 20 % by volume to 24 % by volume of carbon monoxide, 31 % by volume to 40 % by volume of hydrogen and residual nitrogen.

Note 2 to entry: A gas with the composition given in the above Note 1 to entry can also be generated synthetically by a mixture of gaseous methanol and nitrogen.

### 3.78

#### **endothermic atmosphere**

furnace atmosphere produced endothermically and with a carbon potential capable of being matched to the carbon content of the ferrous product under *heat treatment* (3.108) in order to reduce, increase or maintain the *carbon level* (3.33) at the surface of the ferrous product

Note 1 to entry: Endothermic means heat energy transfer to the atmosphere.

### 3.79

#### **epsilon carbide**

iron carbide with the approximate formula,  $\text{Fe}_{2-4}\text{C}$

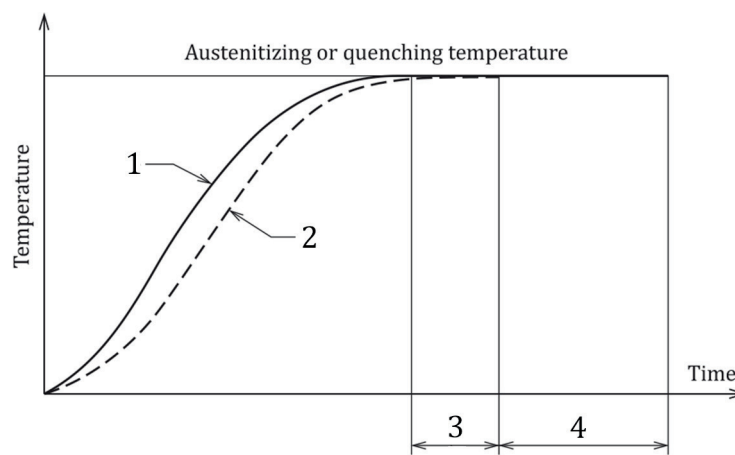
### 3.80

#### **equalization**

second stage of *heating* (3.109) of a workpiece whereby the required temperature at the surface is attained throughout its section

Note 1 to entry: See [Figure 2](#).



**Key**

1 surface  
2 core

3 equalization  
4 soaking

**Figure 2 — Schematic representation of heating during an austenitizing treatment**

**3.81****equilibrium diagram**

graphical representation of the temperature and composition limits of phase fields in an alloy system

**3.82****equivalent diameter**

diameter ( $d$ ) of a cylinder of the same steel (of length  $\geq 3d$ ) in which the *cooling rate* (3.48) at its centre is identical to the slowest cooling rate recorded in the workpiece considered, for the same *cooling conditions* (3.46)

Note 1 to entry: The equivalent diameter is also called the ruling section. The determination of the equivalent diameter is described in ISO 683-1 and ISO 683-2.

**3.83****eutectoid transformation**

reversible transformation of *austenite* (3.12) into *pearlite* (3.155) (ferrite + cementite) that occurs at a constant temperature

Note 1 to entry: Temperature for eutectoid transformation of pure iron is 723 °C. Alloying elements or cooling speed influence this temperature.

**3.84****exothermic atmosphere**

furnace atmosphere produced exothermically and controlled so that it does not oxidize the ferrous product

Note 1 to entry: Exothermic means heat energy transfer from the atmosphere.

**3.85****ferrite**

body-centred cubic lattice structure of iron or steel

Note 1 to entry: See [Table 1](#).

**3.86****ferritic steel**

steel whose structure is ferritic at room temperature

**3.87**

**flame hardening**

surface-hardening treatment where the heat source is a flame

**3.88**

**fluidized bed**

heat treat medium made by a ceramic powder fluidized by a gas into a furnace that will be heated from the outside

Note 1 to entry: The fluidizing gas could be inert to protect the surface of heat-treated workpieces or a reactive gas for a *thermochemical treatment* (3.207) such as *carburizing* (3.36).

**3.89**

**full annealing**

*heat treatment* (3.108) to achieve a spheroidized structure (see 3.190), which includes full or partial *austenitizing* (3.14) followed with slow *cooling* (3.45)

Note 1 to entry: The austenitization of *hypoeutectoid steel* (3.118) ( $C < 0,77\%$ ) takes place above  $A_3$  temperature (the structure is then fully austenitic), however *hypereutectoid steels* (3.117) ( $C > 0,77\%$ ) between  $A_1$  and  $A_m$  temperatures (the structure is partially austenitic).

Note 2 to entry: Full annealing is also called critical annealing.

**3.90**

**furnace atmosphere**

gaseous filling of a furnace, used for *heat treatment* (3.108)

Note 1 to entry: Gaseous filling could be pure gas or gas mixture. The atmosphere can be inert or reactive, and will operate at or below atmospheric pressure.

Note 2 to entry: The purpose of furnace atmospheres is to prevent *oxidation* (3.150) or *decarburization* (3.54) or to be the carrier or reactive gas in a *thermochemical treatment* (3.207).

**3.91**

**gamma iron**

pure iron with face-centred cubic lattice structure

Note 1 to entry: Gamma iron is paramagnetic.

**3.92**

**gamma mixed crystal**

iron with face-centred cubic lattice structure with alloying elements in interstitially or substitutively solution

Note 1 to entry: The material science name for gamma mixed crystal is *austenite* (3.12).

Note 2 to entry: Gamma mixed crystal is paramagnetic.

**3.93**

**gas quenching**

*cooling* (3.45) with gas flow, which means quicker than in resting air

Note 1 to entry: The cooling gas could be pure gas or a gas mixture, i.e. air, air with water spray, inert gas or noble gas.

**3.94**

**grain**

space lattice formed by atoms with regular interstices

Note 1 to entry: The shape of a ferrite grain can be c-b-c.

**3.95****grain boundary**

interface separating two grains with different crystallographic orientations

**3.96****grain coarsening**

*annealing* (3.8) carried out at a temperature well above  $A_3$  for a soaking period sufficient to bring about *grain growth* (3.97)

**3.97****grain growth**

increase in the *grain size* (3.99) of the microstructure as a result of *heating* (3.109) to a high temperature and/or to long soaking time

**3.98****grain refining**

see *core refining* (3.50) and *normalizing* (3.146)

**3.99****grain size**

characteristic size of a *grain* (3.94) revealed in a metallographic section

Note 1 to entry: The nature of the grain should be specified, e.g. austenitic, ferritic, etc.

Note 2 to entry: See ISO 643.

**3.100****graphitic steel**

steel in the structure of which a proportion of the carbon is intentionally precipitated in the form of graphite

**3.101****graphitization**

precipitation of carbon in the form of graphite

**3.102****graphitizing**

*heat treatment* (3.108) applied to *cast irons* (3.38) or *hypereutectoid steels* (3.117) to bring about *graphitization* (3.101)

**3.103****hardenability**

ability of steels to undergo *martensite* (3.137) and/or *bainite* (3.17) transformation

Note 1 to entry: Hardenability is often characterized under defined experimental conditions by the development of hardness as a function of the distance from a quenched surface, e.g. the Jominy curve (see ISO 642). Hardenability can be defined by calculation.

**3.104****hardening temperature**

start temperature for *quenching* (3.168) austenitized, carburized or carbonitrided workpieces to quench-harden them

Note 1 to entry: The hardening temperature can be identical to the *austenitizing temperature* (3.15).

**3.105****heat conduction**

spontaneous heat flow from a body at a higher temperature to a body at a lower temperature

Note 1 to entry: In the absence of external drivers, temperature differences decay over time and the bodies approach to thermal equilibrium.

Note 2 to entry: See Reference [12].

### 3.106

#### heat convection

convection

transfer of heat from one place to another by the movement of fluids

Note 1 to entry: Convection is usually the dominant form of heat transfer in liquids and gases; see Reference [13].

Note 2 to entry: Heat convection during *quenching* (3.168) can be single phase [as in *gas quenching* (3.93)] or dual phase [as in water quenching with water and vapour film at the same time. Usually, single-phase convection has a lower heat transfer than dual-phase convection.

### 3.107

#### heat radiation

thermal radiation

emission of electromagnetic waves from all matter that has a temperature greater than absolute zero

Note 1 to entry: Heat radiation represents a conversion of thermal energy into electromagnetic energy; see Reference [12].

### 3.108

#### heat treatment

series of operations in the course of which a solid ferrous product is totally or partially exposed to thermal cycles to bring about a change in its properties and/or structure

Note 1 to entry: The chemical composition of a ferrous product can possibly be modified during these operations. See *thermochemical treatment* (3.207).

### 3.109

#### heating

increasing the temperature of a workpiece

Note 1 to entry: Heating can be carried out continuously or discontinuously, gradual in one or more steps.

### 3.110

#### heating duration

interval of time separating two defined temperatures of the *heating function* (3.111)

Note 1 to entry: It is always necessary to specify precisely what the temperatures are.

### 3.111

#### heating function

temperature change at a defined point of a workpiece or in a furnace load as a function of time during *heating* (3.109)

Note 1 to entry: The function may be shown as a graph or could be written in a mathematical formula.

### 3.112

#### heating rate

variation in temperature as a function of time during *heating* (3.109)

Note 1 to entry: A distinction is made between

- an instantaneous rate corresponding to a specific temperature, and
- an average rate over a defined interval of temperature.

### 3.113

#### homogenizing

treatment to homogenize a heterogeneous distribution of the chemical composition of ferrous material by a prolonged high-temperature *annealing* (3.8)

**3.114****hot forming**

forming of steel products in a temperature range usually between 780 °C up to 1 300 °C, depending on the chemical composition of the workpiece

Note 1 to entry: Hot forming includes hot rolling, hot forging, hot bending, etc.

Note 2 to entry: Forming between the temperatures of hot forming and cold forming is called warm forming.

**3.115****hydrogen embrittlement**

*embrittlement* (3.76) caused by accumulation of hydrogen atoms and recombination of hydrogen molecules

Note 1 to entry: Hydrogen embrittlement is distinctive at big workpieces and high-strength steels.

Note 2 to entry: It is often the result of unintentional introduction of hydrogen into steel during melting, *hot forming* (3.114), welding or electroplating and increases the risk of cleavage fracture.

**3.116****hydrogen removal annealing**

*annealing* (3.8) below  $A_1$  temperature, the holding time depends on the size of the workpiece and the hydrogen content

Note 1 to entry: In quench-hardened or case-hardened steels, the hydrogen will be removed usually at a tempering temperature of 230 °C up to 300 °C, with some hours of soaking time.

**3.117****hypereutectoid steel**

steel containing more carbon than the eutectoid composition

**3.118****hypoeutectoid steel**

steel containing less carbon than the eutectoid composition

**3.119****impulse hardening**

hardening after impulsively *heating* (3.109) by self-cooling of the workpiece

Note 1 to entry: Treatment is used for surface hardening.

**3.120****impulse heating**

method of *heating* (3.109) by short repeated bursts of energy, giving rise to a local increase in temperature

Note 1 to entry: Various sources of energy can be used, e.g. condenser discharge, lasers, electron beams, etc.

**3.121****induction hardening**

surface hardening where the *austenitizing* (3.14) of the workpiece is made by induction heating

**3.122****inter-critical annealing**

inter-critical treatment

*annealing* (3.8) of a *hypoeutectoid steel* (3.118) involving *heating* (3.109) to and soaking at a temperature between  $A_1$  and  $A_3$ , followed by *cooling* (3.45) adapted to the characteristics required

**3.123****intermetallic compound**

compound of two or more metals possessing physical properties and a crystal structure different from those of the pure metals and their solid solutions

### 3.124

#### **internal oxidation**

occurrence inside heat-treated workpieces by *diffusion* (3.63) of oxygen, caused by precipitation of oxides below the surface

Note 1 to entry: The precipitates could occupy the grain boundaries or are inside of the grains.

### 3.125

#### **interrupted quenching**

*quenching* (3.168) carried out in a medium giving rapid *cooling* (3.45) and interrupted before the workpiece reaches thermal equilibrium with the *quenching medium* (3.170)

Note 1 to entry: This term should not be used to designate *step quenching* (3.196).

### 3.126

#### **isoforming**

*thermomechanical treatment* (3.207) of steel consisting of plastic deformation carried out during the transformation of *austenite* (3.12) to *pearlite* (3.155)

### 3.127

#### **isothermal annealing**

*heat treatment* (3.108) with *austenitizing* (3.14) and interrupted *cooling* (3.45) down to a certain temperature and is held constant until transformation is completed

EXAMPLE Isothermal pearlite transformation or isothermal *bainitizing* (3.18).

Note 1 to entry: This treatment is used for alloyed case-hardening steels in order for pearlitizing to improve the machinability.

### 3.128

#### **Jominy test**

end-quenching test

standardized test for evaluation of *hardenability* (3.103)

Note 1 to entry: For details, see ISO 642.

Note 2 to entry: The Jominy curve can be calculated based on the chemical composition of the steel being tested.

### 3.129

#### **laser beam hardening**

*austenitizing* (3.14) the surface layer of a workpiece by *heating* (3.109) with a laser beam

Note 1 to entry: See *impulse hardening* (3.119) and *impulse heating* (3.120)

Note 2 to entry: *Quenching* (3.168) for hardening could be done by external *quenching media* (3.170) or it takes place by self-cooling.

### 3.130

#### **Ledeburite**

structure of an iron/carbon alloy which results from a eutectic transformation of a melted iron material and consists of *austenite* (3.12) and *cementite* (3.39)

Note 1 to entry: See Table 1.

### 3.131

#### **local hardening**

*quench hardening* (3.167) of a local limited area of a workpiece

**3.132****low-pressure carburizing**

*carburizing* (3.36) carried out in a vacuum furnace at a pressure below atmospheric pressure

Note 1 to entry: Usually, hydrocarbon gases are used to spend the carbon for *diffusion* (3.63) into the steel. Therefore, *internal oxidation* (3.124) can be avoided.

Note 2 to entry: Low-pressure carbonizing is also often called vacuum carburizing.

**3.133****malleablizing**

long-time *annealing* (3.8) at high temperatures to change the structure of white *cast iron* (3.38) to produce malleable cast iron

Note 1 to entry: If the annealing would be done in a *decarburizing* (3.55) atmosphere, the malleable cast iron is called "white malleable cast iron". If the annealing atmosphere will not decarburize elementary carbon is dropped out as graphite, the iron is called black malleable cast iron.

**3.134****maraging**

*heat treatment* (3.108) of *maraging steel* (3.135), consisting of *austenitizing* (3.14) and *solution annealing* (3.188), followed by *quenching* (3.168) to produce *martensite* (3.137) and *ageing* (3.3) for precipitation of intermetallic phases to give the required mechanical properties

**3.135****maraging steel**

steel with specific properties of which can be obtained by *maraging* (3.134)

Note 1 to entry: Typical tensile strength is around 2 000 MPa.

**3.136****martempering**

*heat treatment* (3.108) involving *austenitizing* (3.14) followed by *step quenching* (3.196), at a rate fast enough to avoid the formation of *ferrite* (3.85), *pearlite* (3.155) or *bainite* (3.17), to a temperature slightly above  $M_s$ , and soaking for long enough to ensure that the temperature is uniform but short enough to avoid the formation of bainite

Note 1 to entry: The final *cooling* (3.45), during which *martensite* (3.137) forms practically simultaneously throughout the cross-section, is generally carried out in air.

**3.137****martensite**

*phase* (3.156) formed in carbon containing steels by the *cooling* (3.45) of *austenite* (3.12) at such a high rate that carbon atoms do not have time to diffuse out of the crystal structure in large enough quantities to form *cementite* (3.39) ( $Fe_3C$ )

Note 1 to entry: See [Table 1](#).

Note 2 to entry: Plate martensite is formed in steels generally with a carbon content greater than 0,10 %. Plate martensite is typically hard and brittle.

Note 3 to entry: Lath martensite is formed in steels generally with a carbon content below 0,10 %. The toughness of lath martensite is usually good.

Note 4 to entry: Martensite is a metastable solid solution with a body-centred tetragonal distorted structure.

**3.138****maximum achievable hardness**

maximum value of hardness that can be obtained on a given workpiece by *quench hardening* (3.167), under ideal conditions



**3.139**

**McQuaid-Ehn grain size test**

test to evaluate apparent austenitic *grain size* (3.99) of case-hardening steels

Note 1 to entry: Test results are given as an index from 1 upwards; for more details, see ISO 643.

**3.140**

**medium**

surrounding in which the ferrous workpiece is placed during *heat treatment* (3.108)

Note 1 to entry: The medium can be solid, liquid or gaseous. The kind and the specific properties of the media are important for the heat treatment results.

**3.141**

**metastable**

apparently stable structure outside the conditions defined by the *equilibrium diagram* (3.81)

**3.142**

**nitride**

compound of nitrogen with iron and/or nitride-forming alloying elements in ferrous materials

Note 1 to entry: There are several nitrides, depending on the amount of nitrogen. The most important nitrides in nitrided workpieces are ferrous  $\epsilon$ - and the  $\gamma'$ -nitrides.

**3.143**

**nitriding**

*thermochemical treatment* (3.207) to produce hard surface layers on workpieces containing nitrides, e.g. *oxynitriding* (3.152), gas nitriding, *plasma nitriding* (3.157)

Note 1 to entry: It would be functional to specify the nitriding media, e.g. gas, plasma, oxygen, etc.

**3.144**

**nitrocarburizing**

*thermochemical treatment* (3.207) to produce a hard surface layer on a workpiece containing nitrides and nitrocarbides to form a compound layer and a diffusion layer below it

Note 1 to entry: It would be functional to specify the treatment media used, e.g. salt bath, gas, plasma, etc.

Note 2 to entry: The term nitrocarburizing should be differentiated from *carbonitriding* (3.35), which is a *carburizing* (3.36) process and takes place above  $A_3$  temperature.

**3.145**

**nitrogen profile**

nitrogen content as a function of the distance from the surface

**3.146**

**normalizing**

*heat treatment* (3.108) with the object of refining and eventually making uniform the *grain size* (3.99) of a ferrous product, and comprising *heating* (3.109) it at a temperature slightly above  $A_3$  [ $A_1$  for *hypereutectoid steels* (3.117)], without prolonged soaking at this temperature, followed by *cooling* (3.45) at a suitable rate to a fine ferritic-pearlitic structure

**3.147**

**normalizing forming**

process in which the final deformation is carried out within a certain temperature range, leading to a material condition equivalent to that obtained after *normalizing* (3.146), such that the specified mechanical properties would still be met in the event of any subsequent normalizing



**3.148****overcarburizing**

excess carburizing

carbon enriching of the surface layer could induce carbide precipitations during *carburizing* (3.36) or could lead to a greater content of *retained austenite* (3.175) after *quench hardening* (3.167)

**3.149****overheating**

oversoaking

*heating* (3.109) carried out under temperature conditions for a duration such that excessive *grain growth* (3.97) is produced

Note 1 to entry: A distinction can be made between overheating, which is due to the temperature effect, and oversoaking, which is due to the effect of time. An overheated and oversoaked workpiece can be re-treated by appropriate *heat treatment* (3.108) or by deformation, depending on the nature of the product.

Note 2 to entry: If a partial melting occurs during overheating, the process is irreversible.

**3.150****oxidation**

result of the reaction of oxygen with iron and oxide-forming alloying elements in ferrous materials

Note 1 to entry: Oxide layers grow as temperature and time increase.

Note 2 to entry: Iron has three different oxides, wustite (FeO), magnetite (Fe<sub>3</sub>O<sub>4</sub>) and hematite (Fe<sub>2</sub>O<sub>3</sub>).

Note 3 to entry: There should be a distinction between oxidation as a result of an intentional *oxidizing* (3.151), e.g. during *oxynitriding* (3.152), *blueing* (3.26) or after *nitrocarburizing* (3.144) or an unintentional effect by *carburizing* (3.36) in oxygen containing carburizing media; see *internal oxidation* (3.124).

**3.151****oxidizing**

operation in a medium and at a temperature that the polished surface becomes covered with a thin continuous, adherent film of dark-coloured oxide

Note 1 to entry: After *nitrocarburizing* (3.144), a thin oxide layer will be produced to get higher corrosion resistance.

Note 2 to entry: During *nitriding* (3.143) or nitrocarburizing, oxygen supply could overcome the surface passivation and promote the *diffusion* (3.63) of nitrogen.

**3.152****oxynitriding**

*nitriding* (3.143) carried out in a medium to which a certain quantity of oxygen has been added

**3.153****parent phase**

*phase* (3.156) from which one or more new phases are formed

**3.154****patenting**

*heat treatment* (3.108) consisting of *austenitizing* (3.14) followed by *cooling* (3.45) under conditions suitable for producing the appropriate structures for subsequent wire-drawing or rolling

Note 1 to entry: The cooling medium in which patenting takes place should be specified, e.g. air, salt bath, etc.

Note 2 to entry: The patenting method should be specified with the words “continuous”, if the operation would be carried out continuously on the unwound product or “batch” (discontinuously) if the material would be handled as one load and remains in the form of a coil or bundle during the heat treatment.

**3.155**

**pearlite**

aggregate of *ferrite* (3.85) and *cementite* (3.39) platelets formed by the eutectoid *decomposition of austenite* (3.56) and the simultaneous transformation into ferrite and cementite

Note 1 to entry: See [Table 1](#).

Note 2 to entry: Pearlite usually appears as light microscopic lamellar and consists of lamellas of cementite and ferrite.

**3.156**

**phase**

constituent in the microstructure

Note 1 to entry: In steels, these phases are *ferrite* (3.85), *austenite* (3.12) and *cementite* (3.39).

**3.157**

**plasma nitriding**

*nitriding* (3.143) usually at a pressure below atmospheric pressure and with a plasma support to ionize the nitrogen

**3.158**

**plasma nitrocarburizing**

*nitrocarburizing* (3.144) usually at a pressure below atmospheric pressure and with a plasma support to ionize the nitrogen and the carbon-spending medium

**3.159**

**potential**

partial derivative of the Gibbs free energy with respect to the number of moles of that species

Note 1 to entry: For applications concerning *carburizing* (3.36).

**3.160**

**precipitation growth**

growth of precipitated particles by *diffusion* (3.63) of elements, dissolve smaller particles into larger particles

Note 1 to entry: This term shall not be considered a synonym for *spheroidizing* (3.191).

**3.161**

**precipitation hardening**

hardening of a workpiece caused by the precipitation of one or more compounds from a supersaturated solid solution

Note 1 to entry: See also *secondary hardening* (3.177).

**3.162**

**precipitation hardening treatment**

process of increasing the hardness of metallic materials by precipitating of compounds from a supersaturated solid solution, consisting of *solution annealing* (3.188) to solve specific elements, followed by rapid *cooling* (3.45) to hold the solved elements in supersaturated solution and precipitating special compounds by a tempering treatment

**3.163**

**preheating**

operation consisting of raising the temperature of a workpiece to one or more temperatures, intermediate between the initial and the maximum temperature, and holding it there for a certain time

**3.164****proeutectoid constituent**

product formed from *austenite* (3.12) prior to *eutectoid transformation* (3.83)

Note 1 to entry: In the case of *hypoeutectoid steel* (3.118), the proeutectoid constituent is *ferrite* (3.85). In *hypereutectoid steels* (3.117), the proeutectoid constituent is *cementite* (3.39).

**3.165****protective gas**

gas used to avoid the change of composition of the surface layer of workpieces during *heat treatment* (3.108), usually used to produce a protective furnace atmosphere

Note 1 to entry: Protective gas is usually used to avoid *oxidation* (3.150) or *decarburization* (3.54).

Note 2 to entry: The composition of protective gases depends on the purpose of its use.

Note 3 to entry: Best protection is treatment in vacuum furnaces.

**3.166****quench-hardened layer**

surface layer of a quench-hardened workpiece, the thickness of which is usually defined by the depth of *quench hardening* (3.167)

**3.167****quench hardening**

process of hardening a workpiece, obtained after *austenitizing* (3.14), by *cooling* (3.45) under conditions such that the *austenite* (3.12) transforms more or less completely into *martensite* (3.137) and possibly into *bainite* (3.17)

**3.168****quenching**

operation which consists of *cooling* (3.45) a workpiece more rapidly than in still air

Note 1 to entry: Quenching includes *direct quenching* (3.68).

Note 2 to entry: The use of the term specifying the *cooling conditions* (3.46) is recommended, e.g. water quenching, oil quenching, *step quenching* (3.196), air-blast quenching, etc.

Note 3 to entry: For stainless steels, *solution annealing* (3.188) can be followed by subsequent quenching.

Note 4 to entry: Quenching is also used, instead of slow cooling, to avoid *grain growth* (3.97) of a workpiece with ferritic-pearlitic structure.

**3.169****quenching and tempering**

*quench hardening* (3.167) of workpieces followed by tempering at temperature in the range of about 550 °C up to 650 °C to generate a stage characterized by good combination of hardness and toughness

**3.170****quenching media**

media where *quenching* (3.168) is performed

Note 1 to entry: Quenching media could be a liquid or a gas or a blend gas, e.g. water, oil, nitrogen, hydrogen and salt bath.

**3.171****quenching temperature**

temperature at which *quenching* (3.168) is initiated

Note 1 to entry: See *hardening temperature* (3.104).

**3.172**

**recarburizing**

carbon restoration

*thermochemical treatment* (3.207) intended to restore the carbon content of the surface layer, decarburized during an earlier treatment

**3.173**

**recovery**

*annealing* (3.8) intended to cause at least partial recovery of the physical or mechanical properties of a cold-worked ferrous product without apparent modification of its structure

Note 1 to entry: This treatment is carried out at a temperature below that of *recrystallizing* (3.174).

**3.174**

**recrystallizing**

*annealing* (3.8) to remove strengthening after a cold forming and developing new grains by nucleation without any change in *phase* (3.156)

**3.175**

**retained austenite**

untransformed *austenite* (3.12) remaining, at ambient temperature, after *quench hardening* (3.167)

**3.176**

**scale**

layer which is formed on the surface of a workpiece during *heat treatment* (3.108) in a non-protective atmosphere

Note 1 to entry: Usually, the scale is an oxide scale and can be removed by blasting or pickling.

**3.177**

**secondary hardening**

increasing of the hardness by the tempering of quench-hardened steel caused by precipitation of carbides and transformation of *retained austenite* (3.175) to *martensite* (3.137) and *bainite* (3.17)

Note 1 to entry: Tempering for initiating secondary hardening is often used for tool steels.

Note 2 to entry: The carbon content of the retained austenite is decreasing and the martensite transformation is continuous.

**3.178**

**secondary martensite**

*martensite* (3.137) formed during *secondary hardening* (3.177)

**3.179**

**segregation**

inhomogeneous concentration of elements in steel, e.g. carbon, sulfur and manganese, due to the slow heat transfer during solidification

Note 1 to entry: *Diffusion annealing* (3.64) can decrease the segregation. Modern steelmaking and continuous casting have largely overcome this problem.

**3.180**

**self-quenching**

*quenching* (3.168) of an workpiece

Note 1 to entry: The function presupposes a sufficient relation between the mass of the cold core area and the heated area below the surface.

Note 2 to entry: In case of austenitized hardenable steels the phenomenon can be used to quench-harden a workpiece, see for example 3.129.

### 3.181 sensitization

increase in the sensitivity of stainless steels to intergranular corrosion due to the precipitation of carbides at the grain boundaries

Note 1 to entry: In order to study the resistance to intergranular corrosion, a sensitizing treatment is used (see ISO 3651-2).

### 3.182 sherardizing

*surface treatment into and on a workpiece* (3.201) relating to zinc (zinc diffusion layer)

### 3.183 siliconizing

*surface treatment into and on a workpiece* (3.201) relating to silicones

### 3.184 single-quench hardening treatment

hardening treatment carried out in a single step after *carburizing* (3.36) and *slow cooling* (3.45) to ambient temperature

Note 1 to entry: See [Figure 1 b](#)).

Note 2 to entry: It is recommended to refer to the *hardening temperature* (3.104), e.g. single-quench hardening from surface-hardening temperature or single-quench hardening from core-hardening temperature.

### 3.185 soaking

part of the thermal cycle during which the temperature is held constant

Note 1 to entry: It is necessary to stipulate whether the temperature concerned is that of the surface of the workpiece, the core or any other particular point on the workpiece or on the furnace load.

### 3.186 softening

soft annealing

*heat treatment* (3.108) with the object of reducing the hardness of the ferrous product to a given level

Note 1 to entry: Soft annealing slightly below  $A_1$  is called subcritical annealing.

### 3.187 solid solution

homogeneous, solid, crystalline phase formed by two or more elements, at least one metal

Note 1 to entry: A distinction is made between a substitutional solid solution in which the solute atoms are substituted for those of the solvent and an interstitial solid solution in which the solute atoms are inserted between those of the solvent.

### 3.188 solution annealing

solution treatment

*heat treatment* (3.108) consisting of *austenitizing* (3.14) to a high temperature followed by *cooling* (3.45) sufficiently rapid to avoid new precipitations on return to ambient temperature, e.g. applied to austenitic stainless steels and maraging steels

### 3.189 spheroidal graphite iron

grey cast iron (3.38) with spherical graphite

Note 1 to entry: It differs from the grey cast iron with lamellar graphite in its chemical composition, merely due to the addition of magnesium (from 0,04 % to 0,06 %), cerium and rare earths that influence the formation of graphite spheres

Note 2 to entry: Usually nodular cast iron will be heat treated, e.g. *austempering* (3.11), *normalizing* (3.146), *quenching and tempering* (3.169).

### 3.190

#### **spheroidite**

characteristic soft microstructure consisting of sphere-like globular *cementite* (3.39) particles within a *ferrite* (3.85) matrix

Note 1 to entry: See *spheroidizing* (3.191) and Table 1.

### 3.191

#### **spheroidizing**

*annealing* (3.8) just below the  $A_1$  temperature of steels with long soaking time to bring the carbides in the form of spheroids

Note 1 to entry: See also *precipitate growth* (3.160).

### 3.192

#### **stabilization of retained austenite**

phenomenon which reduces or prevents the possibility of the transformation of *retained austenite* (3.175) into *martensite* (3.137) during *cooling* (3.45) to a temperature below ambient temperature

Note 1 to entry: This stabilization occurs during low temperature tempering or holding at ambient temperature after *quenching* (3.168).

### 3.193

#### **stabilizing**

*heat treatment* (3.108) of a workpiece intended to prevent subsequent dimensional or structural changes with time

Note 1 to entry: Generally, this treatment causes those changes to occur, which at a later date would be undesirable.

### 3.194

#### **stabilizing annealing**

*annealing* (3.8) at around 850 °C with the aim of obtaining precipitation or spheroidization of compounds, e.g. carbides, in stabilized austenitic stainless steels

### 3.195

#### **steel**

ferrous material the principal element of which is iron and the carbon content of which is not more than 2 % of mass

Note 1 to entry: The presence of large quantities of carbide-forming elements can modify the upper limit of the carbon content.

Note 2 to entry: The nomenclature for unalloyed steels suitable for *heat treatment* (3.108) and for alloyed steels is defined by ISO 4948-1 and ISO 4948-2.

### 3.196

#### **step quenching**

*quenching* (3.168) during which *cooling* (3.45) is temporarily interrupted by soaking in a medium at a suitable temperature

Note 1 to entry: This term should not be used to designate *interrupted quenching* (3.125).

### 3.197

#### **stress relieving**

*annealing* (3.8) at temperatures below  $A_1$  to reduce the internal stresses without substantially modifying the structure of a workpiece or ferrous product down to a level, at which internal stresses would be minimized, followed by slow *cooling* (3.45)

**3.198****sub-zero treating**

deep freezing

treatment carried out after *quench hardening* (3.167) or *case hardening* (3.37), consisting of cooling down below room temperature to complete the transformation of *austenite* (3.12) to *martensite* (3.137)

Note 1 to entry: *Retained austenite* (3.175) would transform to martensite or martensite and *bainite* (3.17).

**3.199****sulfidizing**

*surface treatment into and on a workpiece* (3.201) relating to sulfur

**3.200****surface-hardening treatment**

*quench hardening* (3.167) restricted to the surface layer

Note 1 to entry: It is expedient to specify the method of *heating* (3.109), e.g. flame, induction, laser beam, electron beam etc.

Note 2 to entry: The *quenching* (3.168) can occur from outside the workpiece or by *self-quenching* (3.180).

**3.201****surface treatment into and on a workpiece**

*thermochemical treatment* (3.207) intended to import a metallic element or a metalloid into and on a workpiece

Note 1 to entry: Specific treatments for modifying the surface layer are, for example, *case hardening* (3.37), *nitrocarburizing* (3.144), *aluminizing* (3.7), *boriding* (3.28), *chromizing* (3.40), *siliconizing* (3.183), *nitriding* (3.143), *sherardizing* (zinc diffusion coating) (3.182), *sulfidizing* (3.199) and *vanadizing* (3.216).

Note 2 to entry: Specific treatments for coating are hot-dip coating, chemical vapour deposition (CVD) and physical vapour deposition (PVD).

**3.202****temper embrittlement**

*embrittlement* (3.76) which affects certain quenched and tempered steels during tempering at certain temperatures or during slow *cooling* (3.45) through these temperatures

**3.202.1****irreversible temper embrittlement**

blue brittleness

*temper embrittlement* (3.202) that occurs during soaking of certain quenched hardened steels in the temperature range of about 250 °C to 375 °C

Note 1 to entry: It is caused by *segregation* (3.179) and precipitation of carbon and nitrogen on *dislocations* (3.69) and is usually handled by alloying steels with aluminium and titanium.

**3.202.2****reversible temper embrittlement**

*temper embrittlement* (3.202) that occurs during tempering of quench-hardened steels in the temperature range of 450 °C up to 550 °C or after tempering at a higher temperature and during slow *cooling* (3.45) through this range

Note 1 to entry: It is caused by *segregation* (3.179) of trace elements such as Sb, P, As and Sn and is usually avoided by alloying with sufficient amounts of tungsten or molybdenum.

Note 2 to entry: The reversible temper embrittlement reveals itself by a displacement of the transition curve for the impact strength of the base metal towards higher temperatures.

Note 3 to entry: The reversible temper embrittlement can be cured by a second tempering at a temperature above 550 °C followed by rapid cooling.



### 3.203

#### **tempering**

*heat treatment* (3.108) applied to a ferrous product, generally after *quench hardening* (3.167), or another heat treatment to bring the properties to the required level, and consisting of *heating* (3.109) to specific temperatures ( $<A_1$ ) and soaking one or more times, followed by *cooling* (3.45) at an appropriate rate

Note 1 to entry: The tempering treatment could be done one time or more times, especially tool steels should be tempered at least two times.

Note 2 to entry: Depending of the tempering temperature the hardness will be reduced and the toughness will be increased.

Note 3 to entry: Tempering can also, in certain cases, cause an increase in hardness. See *secondary hardening* (3.177).

### 3.204

#### **tempering curve**

tempering diagram

graphical representation of the relationship between mechanical properties and tempering temperature for specified tempering times

### 3.205

#### **thermal crack**

crack or fissures of heat treated workpieces caused by too big differences of internal stresses between surface and core at *heating* (3.109), *cooling* (3.45) or quench-hardening operation

Note 1 to entry: Generally, the term crack is qualified by an indication of the conditions under which the crack appeared, e.g. heating crack, quenching crack, etc.

### 3.206

#### **thermal cycle**

variation of temperature as a function of time during *heat treatment* (3.108)

### 3.207

#### **thermochemical treatment**

*heat treatment* (3.108) in a medium suitably chosen to enrich the surface layer of a workpiece with desired elements such as carbon or nitrogen

Note 1 to entry: The process parameters of the thermochemical treatment can be controlled by instruments and data processing.

Note 2 to entry: The targets of thermomechanical treatments are to produce a fine grain, tough and high tensile structure which cannot be achieved or repeated by heat treatment alone and improved weldability and formability of a steel product.

### 3.208

#### **thermomechanical control process**

TMCP

controlled rolling process in which the final deformation is carried out in a certain temperature range followed by air cooling or controlled cooling

Note 1 to entry: Leading to a material condition with certain properties which cannot be achieved or repeated by *heat treatment* (3.108) alone, thermomechanical rolling can include *tempering* (3.203), including *self-tempering* (3.16) but excluding *direct quenching* (3.68) and *quenching and tempering* (3.169).

### 3.209

#### **through-hardening**

*quench hardening* (3.167) to achieve *martensite* (3.137) forming up to the core of a workpiece

Note 1 to entry: Depending on the geometry of the workpiece, steel used and conditions during the hardening process, it could not always be possible to get a core microstructure only consisting of 100 % martensite.



**3.210****transformation diagram**

presentation of *austenite* (3.12) transformation of ferrous materials in dependence of time and temperature for a given steel composition

Note 1 to entry: Set of curves drawn in a semi-logarithmic coordinate system with logarithmic time/temperature coordinates which define, for each level of temperature, the transformation of austenite as beginning and ending the transformation to other *phases* (3.156).

Note 2 to entry: At the end of transformation, the amount of constituents of the microstructure and the hardness can be read out.

**3.210.1****time-temperature-transformation diagram**

TTT diagram

diagram which presents isothermal transformation of *austenite* (3.12)

Note 1 to entry: TTT diagrams can read out after the end of transformation, the volume-% of each *phase* (3.156) and its hardness.

**3.210.2****continuous-cooling-transformation diagram**

CCT diagram

diagram which presents continuous cooling transformation of *austenite* (3.12)

Note 1 to entry: At the 500 °C line, the cooling parameter,  $\lambda$ , divided by 100 or directly in seconds for the temperature range between 800 °C and 500 °C can be read out.

**3.211****transformation point**

temperature of transformations from one microstructures to another microstructures

Note 1 to entry: The term shall be completed by indication of the kind of the microstructure, e.g. transformation point of the martensitic stage, pearlitic stage etc.

**3.212****transformation range**

interval of temperature within which a product undergoes a change of *phase* (3.156)

**3.213****transformation temperature**

temperature at which a change of *phase* (3.156) occurs and, by extension, at which the transformation begins and ends when the transformation occurs over a range of temperatures

Note 1 to entry: The following principal transformation temperatures can be distinguished in steels:

- $A_1$ , equilibrium temperature defining the lower limit of existence of *austenite* (3.12);
- $A_3$ , equilibrium temperature defining the upper limit of existence of *ferrite* (3.85);
- $A_m$ , equilibrium temperature defining the upper limit of existence of *cementite* (3.39) in *hypereutectoid steels* (3.117);
- $M_s$ , temperature at which the austenite begins to transform into *martensite* (3.137) during *cooling* (3.45);
- $M_f$ , temperature at which the austenite has almost completely transformed into martensite during cooling;
- $M_x$ , temperature at which x vol.-% of the austenite has transformed into martensite during cooling.

**3.214****two-stage nitriding**

*nitriding* (3.143) with at least one change in the nitriding conditions (temperature and/or gas composition), intended to reduce the thickness of the compound layer

**3.215**

**vapour film**

film formed on the piece to be hardened in the first stage of water and oil quenching

**3.216**

**vanadizing**

*surface treatment into and on a workpiece* ([3.201](#)) relating to vanadium

**3.217**

**water emulsion**

polymer solution

*quenching media* ([3.170](#)) which is a mixture of water and polymers

Note 1 to entry: Water emulsion allows slower *cooling rate* ([3.48](#)) than water and helps to avoid cracks and *distortion* ([3.70](#)).

**3.218**

**Widmannstaetten structure**

structure resulting from the formation of a new *phase* ([3.156](#)) along certain crystallographic planes in the parent solid solution

Note 1 to entry: In the case of *hypoeutectoid steel* ([3.118](#)), it appears in a metallographic section in the form of ferrite needles in a *pearlite* ([3.155](#)) background. In the case of *hypereutectoid steels* ([3.117](#)), the needles consist of *cementite* ([3.39](#)).

**3.219**

**work hardening**

strain hardening

strengthening of a metal by deformation

Note 1 to entry: This strengthening occurs because of dislocation movements and dislocation generation within the crystal structure of the material.

Note 2 to entry: Work-hardened structure can be removed by recrystallization heat treatment.

## Annex A (informative)

### Equivalent terms

Table A.1 gives the alphabetical list of terms defined in this document and their equivalents. The following rules have been applied in preparing this table:

- one single equivalent per language has been used for one given term;
- the same equivalents have been used for a term and its synonym.

**Table A.1 — Equivalent terms**

English	Ref. No. <sup>a</sup>	French	German	Chinese	Japanese
<b>A</b>					
acicular structure	<a href="#">3.1</a>	structure aciculaire	Nadelförmiges Gefüge/ Nadeliges Gefüge	针状结构	針状組織
activity	<a href="#">3.2</a>	activité	Aktivität	活度	活量
ageing	<a href="#">3.3</a>	vieillessement	Altern	时效	時効
air hardening steel	<a href="#">3.4</a>	auto-trempant (acier)	Lufthärtender Stahl	空冷淬硬鋼	空冷硬化鋼
alpha iron	<a href="#">3.5</a>	fer $\alpha$	$\alpha$ -Eisen	$\alpha$ 铁	$\alpha$ 鉄
alpha mixed crystal	<a href="#">3.6</a>	avec présence de ferrite	$\alpha$ -Mischkristall	$\alpha$ 固溶体	—
aluminizing	<a href="#">3.7</a>	aluminisation	Aluminieren	渗铝	アルミナイジング
annealing	<a href="#">3.8</a>	recuit	Glühen	退火	焼なまし
ausferrite	<a href="#">3.9</a>	austénite-ferrite (structure)	Ausferrit	奥铁体	オースフェライト
ausforming	<a href="#">3.10</a>	austéniformage	Austenitformhärten	奥氏体形变热处理	オースフォーム処理
austempering	<a href="#">3.11</a>	trempe étagée bainitique	Austempern	等温淬火 贝氏体等温淬火	オーステンパ
austenite	<a href="#">3.12</a>	austénite	Austenit	奥氏体	オーステナイト
austenitic steel	<a href="#">3.13</a>	acier austénitique	Austenitischer Stahl	奥氏体钢	オーステナイト鋼
austenitizing	<a href="#">3.14</a>	austénitisation	Austenitisieren	奥氏体化	オーステナイト化
austenitizing temperature	<a href="#">3.15</a>	température d'austénitisation	Austenitisiertemperatur	奥氏体化温度	オーステナイト化温度
auto-tempering/ self-tempering	<a href="#">3.16</a>	auto-revenu	Selbstanlassen	自回火	オートテンパ
<b>B</b>					
bainite	<a href="#">3.17</a>	bainite	Bainit	贝氏体	ベイナイト
bainitizing	<a href="#">3.18</a>	bainitisation	Bainitisieren	贝氏体化	ベイナイトタイジング
bake hardening steel	<a href="#">3.19</a>	acier à bake hardening	Bake-hardening-Stahl	烘烤硬化钢	塗装焼付硬化型钢
<sup>a</sup> Reference number of the term in this document.					

Table A.1 (continued)

English	Ref. No. <sup>a</sup>	French	German	Chinese	Japanese
baking	<a href="#">3.20</a>	déshydrogénation	Dehydrieren; Wasserstoffentzug Durch Glühen	脱氢处理	ベイキング
banded structure	<a href="#">3.21</a>	bandes (structure de)	Zeilengefüge; Zeilenstruktur	带状组织	しま状組織
blackening	<a href="#">3.22</a>	brunissage	Brünieren	表面氧化处理	黒化
black nitriding	<a href="#">3.23</a>	nitruration noire	(no German equivalent)	渗氮氧化	黒色窒化
blank nitriding	<a href="#">3.24</a>	nitruration à blanc	Blindnitrieren	空白渗氮	ブランク窒化
batch annealing/ box annealing	<a href="#">3.25</a>	recuit base	Haubenglühen	單式退火/ 装箱退火	箱焼なまし
blueing	<a href="#">3.26</a>	bleuissage	Bläuen	发蓝处理	ブルーイング
boost-diffuse carburizing	<a href="#">3.27</a>	cémentation étagée	Mehrstufiges Aufkohlen	加速扩散渗碳	ブースト拡散浸炭
boriding	<a href="#">3.28</a>	boruration	Borieren	渗硼	ボライディング
bright annealing	<a href="#">3.29</a>	recuit blanc	Blankglühen	光亮退火	光輝焼なまし
burning	<a href="#">3.30</a>	brûlure	Verbrennung	过烧	バーニング
<b>C</b>					
carbon activity	<a href="#">3.31</a>	activité du carbone	Kohlenstoffaktivität; C-Aktivität	碳活度	炭素の活量
carbon mass transfer coefficient	<a href="#">3.32</a>	coefficient de transfert du carbone	Kohlenstoffübergangszahl	碳传递系数	炭素の質量移動係数
carbon level	<a href="#">3.33</a>	teneur en carbone	Kohlenstoffpegel	碳含量	カーボンレベル
carbon profile	<a href="#">3.34</a>	courbe de répartition du carbone	Kohlenstoffverlauf	碳含量分布	炭素濃度の変化推移
carbonitriding	<a href="#">3.35</a>	carbonitruration	Carbonitrieren	碳氮共渗	浸炭窒化
carburizing	<a href="#">3.36</a>	cémentation	Aufkohlen	渗碳	浸炭
case hardening	<a href="#">3.37</a>	(no French equivalent)	Einsatzhärten	表面硬化	はだ焼き
cast iron	<a href="#">3.38</a>	fonte	Gusseisen	铸铁	鑄鉄
cementite	<a href="#">3.39</a>	cémentite	Zementit	渗碳体	セメントタイト
chromizing	<a href="#">3.40</a>	chromisation	Chromieren	渗铬	クロマイジング
compound layer	<a href="#">3.41</a>	couche de combinaison	Verbindungsschicht	化合物层	化合物層
continuous annealing	<a href="#">3.42</a>	recuit continu	Kontinuierliches Glühen	连续退火	連続焼なまし、連続焼鈍
continuous-cooling-transformation diagram (CCT diagram)	<a href="#">3.43</a>	diagramme de transformation en refroidissement continu (en conditions anisothermes) (diagramme TRC)	Kontinuierliches Zeit-Temperatur-Umwandlungsschaubild (Kontinuierliches ZTU-Schaubild)	连续冷却转变图(CCT图)	連続冷却変態曲線(CCT線図)
controlled rolling	<a href="#">3.44</a>	laminage contrôlé	Kontrolliertes Walzen	控制轧制	制御圧延
cooling	<a href="#">3.45</a>	refroidissement	Abkühlen	冷却	冷却
cooling conditions	<a href="#">3.46</a>	refroidissement (mode de)	Abkühlbedingungen	冷却条件	冷却
<sup>a</sup> Reference number of the term in this document.					