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Ferrous materials — Heat treatments — Vocabulary

Matériaux ferreux — Traitements thermiques — Vocabulaire

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Foreword

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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.

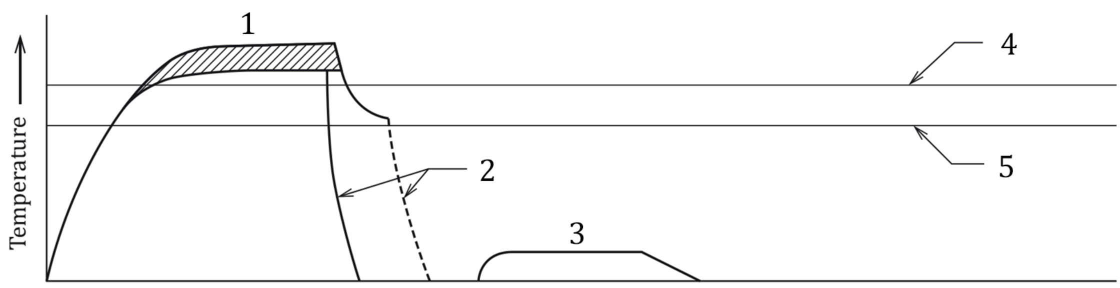
3.36
carburizing
DEPRECATED: cementation
thermochemical treatment (3.207) which is applied to a workpiece in the austenitic state, to obtain a surface enrichment in carbon, which is in solid solution in the *austenite* (3.12)

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

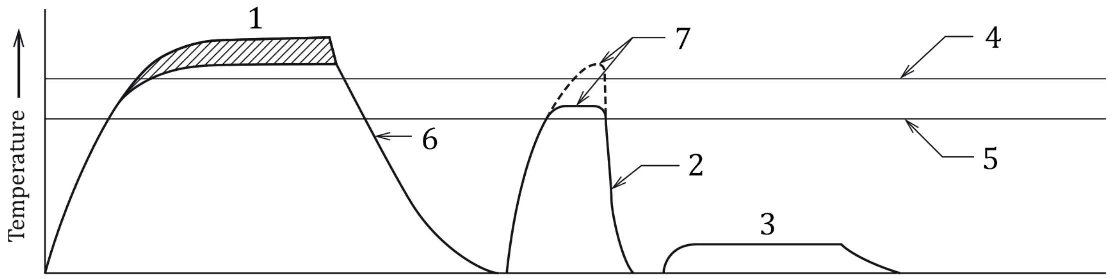
Note 2 to entry: The medium in which carburizing takes place should be specified, e.g. gas, pack, etc.

3.37
case hardening
treatment consisting of *carburizing* (3.36) or *carbonitriding* (3.35) followed by *quench hardening* (3.167)

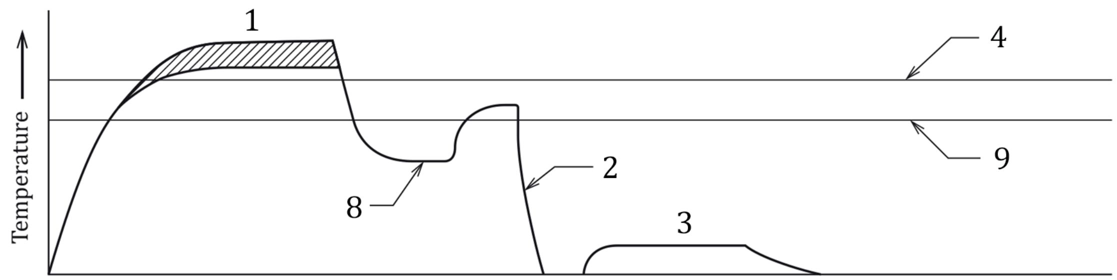
Note 1 to entry: See Figure 1.



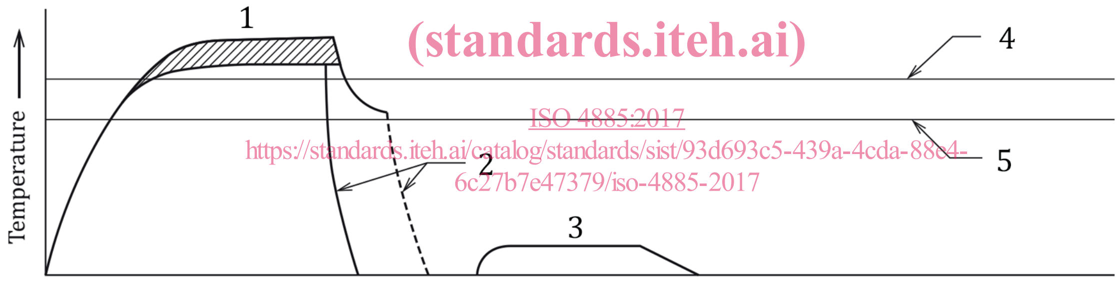
a) Direct-hardening treatment



b) Single-quench hardening treatment



c) Quench-hardening treatment with isothermal transformation



d) Double-quench hardening treatment

Key

1 carburizing, carbonitriding
2 quenching
3 tempering
4 Ac_3 core
5 Ac_3 surface
6 cooling
7 quench-hardening treatment
8 isothermal transformation
9 Ac_3 surface after carburizing

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 Fe_3C

Note 1 to entry: See Table 1.

Table 1 — Iron-carbon (Fe-C) phases

Phase	Crystal structure	Properties	Typical hardness
Ferrite, α	bcc	soft, tough, magnetic	60 HBW to 90 HBW
Austenite, γ	fcc	fair strength, non-magnetic	150 HBW (1,5 % C)
Cementite, Fe_3C	rombic	hard, brittle chemical composition	820 HBW
Pearlite with coarse lamellas (0,4 µm)	α + Fe_3C, lamellar	combination of tough ferrite and hard cementite	200 HBW
Pearlite with fine lamellas (0,1 µm)	α + Fe_3C, lamellar	harder than pearlite with coarse lamellas	400 HBW
Spheroidite	α + globular Fe_3C	soft	120 HBW to 230 HBW, depending on carbon and alloy content
Upper bainite	precipitations of Fe_3C on surface of α	properties such as pearlite with fine lamellas	400 HBW
Lower bainite	precipitations of Fe_3C inside of α	strength near martensite, but tougher than tempered martensite	600 HBW
Martensite, α', non-tempered	bcc, slightly tetragonic	hard, brittle	250 HV to 950 HV, depending on carbon content
Martensite, α', 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 ≥3 *d*, 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.