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Ferrous materials — Heat treatments — Vocabulary

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Foreword

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This document was prepared by Technical Committee ISO/TC 17, *Steel,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459/SC 12, *General issues,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 4885:2018), which has been technically revised.

The main changes are as follows:

— the list of terms has been restructured and classified into 9 categories: general, annealing and normalizing, quenching, tempering and partitioning, ageing, surface heat treatment, thermochemical treatment, structure, defects;

— 66 new terms have been added, such as “continuous austenitization diagram”, “expanded austenite”, “partitioning”, “total thickness of surface hardening depth”, etc.;

— 9 terms have been deleted, such as “acicular structure”, “ferritic steel”, “quenching temperature”, etc.;

— 4 terms have been integrated, namely “baking/ hydrogen removal annealing”, “continuous-cooling-transformation diagram/CCT diagram”;

— 3 terms have been divided into 6 new terms, namely “blank nitriding/ blank nitrocarburizing”, “overheating/ oversoaking”, “sub-zero treatment/ cryogenic treatment (former deep freezing)”;

— 39 terms have been added synonyms, such as “cooling function/ cooling curve”, “blackening/ blacking”, “transformation temperature/ critical point”, etc.

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

Ferrous materials — Heat treatments — Vocabulary

1 Scope

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

Annex A provides an alphabetical list of terms defined in this document, as well as their equivalents in French, German, Russian, 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 terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms

3.1.1
accelerated cooling
method of cooling in the rolling process and which aims at conditioning the crystal structure of steels and improving the mechanical properties by means of rolling followed by cooling down through the temperature range for transformation with a greater speed than that of air-cooling

Note 1 to entry: This does not include the cooling method for quenching which merely cools rapidly on a rolling line using the accelerated cooling equipment.

Note 2 to entry: Cooling for equipment protection, capability compensation of cooling bed, etc are not included in the accelerated cooling because they do not affect mechanical properties of steel.

Note 3 to entry: Accelerated cooling is frequently used for tubes, forgings and thick plates.

3.1.2
austenitizing
heating (3.1.37) a ferrous material above A_1 or A_3 temperature and *soaking* (3.1.57) for enough time to form partial or complete austenite

Note 1 to entry: Complete austenitizing takes place above A_3 temperature, while partial austenitizing takes place between A_1 and A_{cm} temperatures.

Note 2 to entry: The minimum temperature and the length of the soaking time required depend on the steel composition, the initial microstructure and the heating conditions used.

3.1.3
austenitizing temperature
temperature at which the ferrous material is maintained during *austenitizing* (3.1.2)

3.1.4
bake hardening steel
steel with the ability to gain an increase of yield strength after a plastic pre-strain and a subsequent *heat treatment* (3.1.35)

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* (3.1.35) and a good dent resistance.

Note 2 to entry: The usual industrial paint processes are in the region of 170 °C for 20 min.

3.1.5
cast iron
alloy of iron, carbon and silicon where the carbon content is approximately more than 2 %

3.1.6
characteristic cooling curve
diagram showing the variations of cooling rate in the core of a specimen with temperature

Note 1 to entry: Characteristic cooling curve reflects the cooling capacity of a specimen in a cooling medium at different temperatures.

3.1.7
controlled atmosphere
furnace atmosphere (3.1.31) of which composition can be controlled for the purpose of oxidation or reduction, carburization or decarburization

Note 1 to entry: The main purpose of controlled atmosphere is to effectively carry out thermo-chemical treatment, such as carburizing and carbonitriding, and to prevent oxidation or decarburization of ferrous materials during heating.

3.1.8
controlled atmosphere heat treatment
heat treatment carried out in a controlled atmosphere to prevent oxidation and decarburization, or allow carburizing (nitriding) as required

Note 1 to entry: Heat treatment in a protective atmosphere or inert gas is also called protective atmosphere heat treatment.

3.1.9
controlled cooling
cooling according to the predetermined cooling schedule during heat treatment

3.1.10
controlled rolling
rolling process where rolling temperature and reduction are controlled to achieve enhanced mechanical properties

EXAMPLE *Normalizing rolling* (3.1.51), *thermomechanical rolling* (3.1.64).

Note 1 to entry: Controlled rolling is used for fine grain ferritic steels and for dual-phase steel for obtaining fine-grain structure.

3.1.11
cooling
decreasing of the temperature of a hot ferrous material, either continuously, discontinuously, gradually, in one or more steps or interrupted

Note 1 to entry: The medium in which cooling takes place should be specified, e.g. air, oil, water, etc. See also *quenching* (3.3.21).

3.1.12
cooling conditions
cooling schedules
condition(s) (temperature and kind of cooling medium, relative movements, agitation, etc.) under which the *cooling* (3.1.11) of the ferrous material takes place

3.1.13
cooling function
cooling curve
temperature change at a defined point of a ferrous material or in a furnace load as a function of time during cooling

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

3.1.14
cooling rate
variation in temperature as a function of time during *cooling* (3.1.11)

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 or time.

3.1.15
cooling time
cooling duration
interval of time separating two characteristic temperatures of the *cooling function* (3.1.13)

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

3.1.16
critical cooling
cooling necessary to avoid transformation to an undesired microstructure

Note 1 to entry: The cooling course can be characterized by the gradient of temperature or of the *cooling rate* (3.1.14) in general or at given temperatures or times.

3.1.17
critical cooling rate
rate corresponding to the *critical cooling* (3.1.16)

3.1.18
critical diameter
diameter, *d*, of a cylinder with a length ≥ 3 *d*, having a structure of a volume fraction of 50 % of *martensite* (3.8.22) at the centre after *quench hardening* (3.3.19) with defined conditions

3.1.19
decomposition of austenite
decomposition of austenite into *ferrite* (3.8.11) and *pearlite* (3.8.26) or into ferrite and *cementite* (3.8.8) or into *bainite* (3.8.5) with decreasing temperature

3.1.20
differential heating
heating that generates temperature gradient in a ferrous material purposely

3.1.21
endogas
gas mixture produced by incomplete combustion of hydrocarbons

Note 1 to entry: Composition of endogas is usually: by using methane, about a volume fraction of 20 % of carbon monoxide, about a volume fraction of 41 % of hydrogen and residual nitrogen; by using propane, about a volume fraction of 24 % of carbon monoxide, about a volume fraction of 31 % hydrogen and residual nitrogen; by using vaporised methanol with a volume fraction of 60 % of methanol and 40 % of nitrogen, resulting in a volume fraction of 20 % of carbon monoxide, 40 % of hydrogen and residual nitrogen.

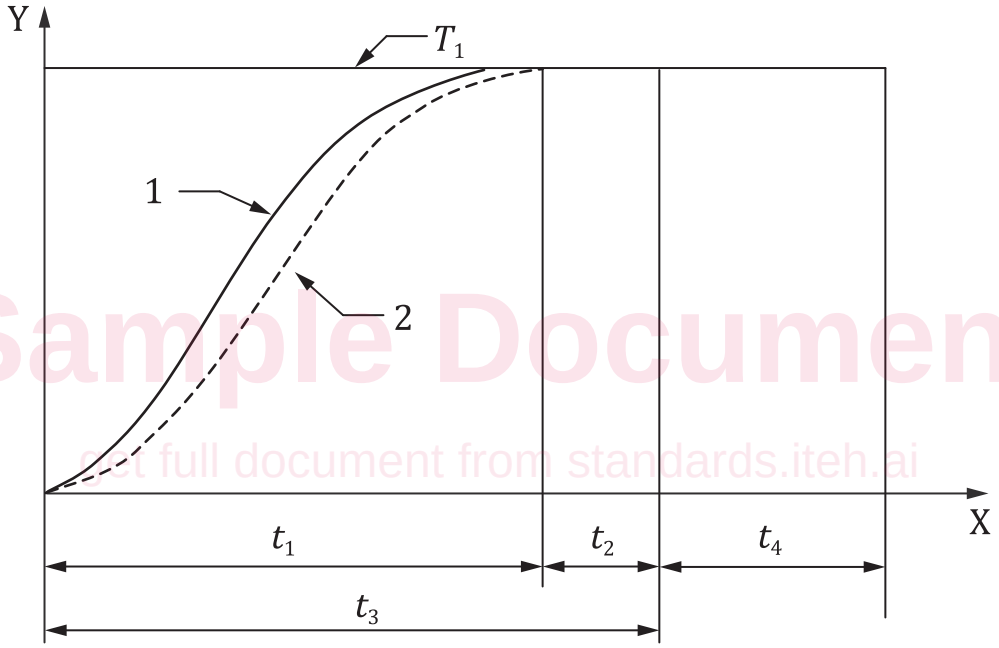
Note 2 to entry: The endogas is used as a basic or carrier gas. *Carbon level* (3.7.9) of the ferrous material is usual about a mass fraction of 0,4 %. For higher carbon levels of the ferrous material, it is necessary to add a gas to donate carbon, e.g. for carburizing.

3.1.22
endothermic atmosphere
furnace atmosphere (3.1.31) produced endothermically and with a carbon potential capable of being matched to the carbon content of the ferrous material under *heat treatment* (3.1.35) in order to reduce, increase or maintain the *carbon level* (3.7.9) at the surface of the ferrous material

Note 1 to entry: Endothermic means that heat energy is transferred to the atmosphere.

3.1.23
equalization
second stage of *heating* (3.1.37) of a ferrous material whereby the required temperature is obtained at the surface throughout its section

Note 1 to entry: See Figure 1.



Key

Y	temperature, T
X	time, t
1	heating curve of surface
2	heating curve of core
T_1	austenitizing or quenching temperature
t_1	heating up time
t_2	equalization time
t_3	heating time
t_4	soaking time

Figure 1 — Schematic representation of heating during an austenitizing treatment

3.1.24
equilibrium diagram
graphical representation of the temperature and composition limits of phase fields in an alloy system

3.1.25
equivalent diameter
equivalent diameter of cooling rate
ruling section
diameter, *d*, of a cylinder of the same steel (of length ≥ 3 *d*) in which the *cooling rate* (3.1.14) in the core is identical to the slowest cooling rate recorded in the considered ferrous workpiece with an irregular shape, under the same *cooling conditions* (3.1.12)

Note 1 to entry: The determination of the equivalent diameter is described in ISO 683-1[1] and ISO 683-2[2].

3.1.26
eutectoid transformation
reversible transformation of *austenite* (3.8.4) into *pearlite* (3.8.26) (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.

3.1.27
exogas
gas mixture produced by complete combustion of hydrocarbons

Note 1 to entry: Composition of exogas is usually a volume fraction of 6,8 % to 10 % of carbon dioxide, 2,4 % to 7,4 % of carbon monoxide, 2,5 % to 9,5 % of hydrogen, small amounts of oxygen, water vapor, residual nitrogen.

Note 2 to entry: Exogas is used to protect ferrous material surfaces from oxidation and has a decarburizing effect.

3.1.28
exothermic atmosphere
furnace atmosphere (3.1.31) produced exothermically and controlled not oxidizing the ferrous material

Note 1 to entry: Exothermic means that heat energy is transferred from the atmosphere.

3.1.29
ferrous material
metals and alloys with iron as the principal element

Note 1 to entry: Ferrous materials include products and workpieces of steel and cast iron.

3.1.30
fluidized bed
heat treatment (3.1.35) medium made by a ceramic powder fluidized by a gas into a furnace heated from the outside

Note 1 to entry: The fluidizing gas can be inert to protect the surface of heat-treated ferrous materials or a reactive gas for a *thermochemical treatment* (3.7.54) such as *carburizing* (3.7.13).

3.1.31
furnace atmosphere
gaseous filling of a furnace, used for *heat treatment* (3.1.35)

Note 1 to entry: Gaseous filling can be pure gas or gas mixture. The atmosphere can be inert or reactive.

Note 2 to entry: The purpose of furnace atmospheres is to prevent *oxidation* (3.9.11) or *decarburization* (3.9.2) or to be the carrier or reactive gas in a *thermochemical treatment* (3.7.54).

3.1.32
heat conduction
spontaneous heat flow from a body at a higher temperature to a body at a lower temperature and/or within a ferrous material with locally different temperatures, e.g. between surface and core

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

3.1.33
heat convection
transfer of heat from one place to another by movement of fluids

Note 1 to entry: Convection is usually the dominant form of heat transfer in liquids and gases.

Note 2 to entry: Heat convection during *quenching* (3.3.21) can be single phase [as in *gas quenching* (3.3.7)] or dual phase [as in water quenching with water and *vapor film* (3.3.29) at the same time]. Usually, single-phase convection has a lower heat transfer than dual-phase convection.

3.1.34
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.

3.1.35
heat treatment
series of operations in the course of which a solid *ferrous material* (3.1.29) is totally or partially exposed to *thermal cycles* (3.1.62) to bring about a change in its properties and/or structure

Note 1 to entry: The chemical composition of the *ferrous material* (3.1.29) can be modified during these operations. See *thermochemical treatment* (3.7.54).

3.1.36
heat treatment cycle
entire heat treatment process involving heating, soaking and cooling

3.1.37
heating
increasing of the temperature of a ferrous material, either continuously, discontinuously or gradually, in one or more steps

Note 1 to entry: The medium in which heating takes place should be specified, e.g. in protective atmosphere, inert gas, noble gas, vacuum, air, etc.

3.1.38
heating conditions
heating schedules
condition(s) (temperature, time and method of heating, etc.) under which the *heating* (3.1.37) of the ferrous material takes place

3.1.39
heating function
heating curve
temperature change at a defined point of a ferrous material or in a furnace load as a function of time during *heating* (3.1.37).

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

3.1.40
heating rate
variation in temperature as a function of time during *heating* (3.1.37)

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 or time.

3.1.41
heating time
heating duration
interval of time separating two characteristic temperatures of the *heating function* (3.1.39)

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

Note 2 to entry: Heating time is the sum of heating up time and equalization time.

3.1.42
heating up time
time for the surface of a ferrous material to reach the specified temperature during heating

3.1.43
high energy beam heat treatment
heat treatment using different high power density energy sources, such as laser, electron beam or plasma, to heat ferrous materials

3.1.44
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.

3.1.45
hypereutectoid steel
steel containing more carbon than the eutectoid composition

3.1.46
hypoeutectoid steel
steel containing less carbon than the eutectoid composition

3.1.47
ideal critical diameter
diameter of a cylinder having a structure of a volume fraction of 50 % of martensite at the centre after cooling in a medium with ideal condition of *quenching intensity* (3.3.22)

3.1.48
impulse heating
method of *heating* (3.1.37) 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.

3.1.49
induction heat treatment
heat treatment using electromagnetic induction to generate eddy current within a ferrous material to heat the ferrous material

3.1.50
isoforming
thermomechanical control process (3.1.63) of steel consisting of plastic deformation carried out during the transformation of *austenite* (3.8.4) to *pearlite* (3.8.26)

3.1.51
normalizing rolling
controlled rolling (3.1.10) 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* (3.2.17), such that the specified mechanical properties are still met in the event of any subsequent normalizing

3.1.52
plasma heat treatment
ion bombardment heat treatment
glow discharge heat treatment
heat treatment using glow discharge generated between a ferrous material (as cathode) and anode in a specific atmosphere with pressure lower than 0,1 MPa

Note 1 to entry: The pressure is usually 10^{-1} Pa to 10^{-3} Pa.

3.1.53
preheating
heating of a ferrous material with one or more temperature levels and suitable soaking time until the desired heat treatment temperature is reached

3.1.54
protective atmosphere
protective gas
gas to avoid the change of composition of the surface layer of ferrous materials during *heat treatment* (3.1.35), usually used to produce a protective *furnace atmosphere* (3.1.31)

Note 1 to entry: Protective gas is usually used to avoid *oxidation* (3.9.11) or *decarburization* (3.9.2).

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.

3.1.55
recovery
change in structure and properties from *annealing* (3.2.1) a cold-worked ferrous material associated with residual stress removal and strain-free region formation

Note 1 to entry: Recovery is carried out at a temperature below that of *recrystallizing* (3.1.56).

Note 2 to entry: Recovery is due to dislocation climb and glide produced by the movement of vacancies and atoms.

3.1.56
recrystallization
change in structure and properties from *annealing* (3.2.1) a cold-worked ferrous material associated with frequent formation of new fine grains

Note 1 to entry: *Grain growth* (3.8.17) can occur in the ferrous material under critical degree of deformation.

Note 2 to entry: Recrystallization usually decreases strength and increases ductility.

3.1.57
soaking
part of the *thermal cycle* (3.1.62) 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 ferrous material, the core or any other particular point on the ferrous material or on the furnace load.

3.1.58
spheroidal graphite iron
cast iron (3.1.5) containing 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 other rare earth elements that influence the formation of graphite spheres

Note 2 to entry: Usually nodular cast iron will be heat treated, e.g. *austempering* (3.3.3), *normalizing* (3.2.17), *quenching andtempering* (3.4.3).

3.1.59
stabilization of retained austenite
phenomenon which reduces or prevents the possibility of the transformation of *retained austenite* (3.8.31) into *martensite* (3.8.22) during *cooling* (3.1.11) to a temperature below ambient temperature

Note 1 to entry: This stabilization occurs during low temperature tempering or holding at ambient temperature after *quenching* (3.3.21).

3.1.60
stabilizing
heat treatment (3.1.35) of a ferrous material intended to prevent subsequent geometrical, dimensional, microstructural and property changes with time

Note 1 to entry: Generally, stabilizing itself can cause those changes to occur, which at a later date would be undesirable.

3.1.61
steel
ferrous material with iron as the principal element and carbon content not more than a mass fraction of 2 %

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* (3.1.35) and for alloyed steels is defined by ISO 4948-1[3] and ISO 4948-2[4].

3.1.62
thermal cycle
variation of temperature as a function of time during *heat treatment* (3.1.35)

3.1.63
thermomechanical control process
TMCP
hot forming (3.1.44) process in which the final deformation is carried out in a certain temperature range followed by air cooling or accelerated cooling

Note 1 to entry: Leading to a material condition with certain properties which can not be achieved or repeated by *heat treatment* (3.1.35) alone, thermomechanical control process can include *tempering* (3.4.8), including *self-tempering* (3.4.7) but excluding *direct quenching* (3.3.5), *quenching and tempering* (3.4.3).

Note 2 to entry: The target of thermomechanical control process is to produce a fine grain, tough and high tensile structure which can not be achieved or repeated by *heat treatment* (3.1.35) alone and improve weldability and formability of a steel product.

3.1.64
thermomechanical rolling
TMR
rolling process in which the final deformation is carried out in a certain temperature range leading to a material condition with certain properties which cannot be achieved or repeated by heat treatment alone

Note 1 to entry: Subsequent heating above 580 °C can lower the strength values. If temperature above 580 °C is needed reference should be made to the supplier.

Note 2 to entry: Thermomechanical rolling leading to the delivery condition TMCP can include processes with an increasing cooling rate with or without *tempering* (3.4.8) including *self-tempering* (3.4.7) but excluding direct quenching and quenching and tempering.

Note 3 to entry: In some publications, TMR is also considered as a process of TMCP.

3.1.65
thermo-mechanical heat treatment
coupled heat treatment by combining plastic deformation and thermal heat treatment to improve mechanical properties of a ferrous material

Note 1 to entry: Thermo-mechanical treatment includes *hot forming* (3.1.44), *controlled rolling* (3.1.10), etc.

3.1.66
through heating
method of heating that enables the whole workpiece to reach a uniform temperature

3.1.67
transformation diagram
presentation of *austenite* (3.8.4) transformation of ferrous materials in dependence on time and temperature for a given steel composition

Note 1 to entry: Set of curves can be drawn in a semi-logarithmic coordinate system with temperature as function of logarithmic time which define, for each level of temperature, the phase transformation of austenite as beginning and the transformation to other *phases* (3.8.27) as ending.

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

Note 3 to entry: There is distinction between transformation diagrams in relation to the heating and soaking period called *time-temperature austenitization diagram (TTA diagram)* (3.1.67.1) and diagrams in relation to the cooling period called *time temperature transformation diagram (TTT diagram)* (3.1.67.4).

3.1.67.1
time-temperature austenitization diagram
TTA diagram
diagram which presents austenitization of the initial structure of ferrous material in dependence on time and temperature for a given steel composition and initial microstructure

Note 1 to entry: There is distinction between *isothermal austenitization diagrams* (3.1.67.2) and time-temperature austenitization diagrams.

Note 2 to entry: Set of curves can be drawn in a semi-logarithmic coordinate system with logarithmic time/temperature coordinates which define, for each level of temperature, the phase transformation of *ferrite* (3.8.11), *pearlite* (3.8.26), carbide as beginning and the transformation to *austenite* (3.8.4) as ending.

3.1.67.2
isothermal austenitization diagram
IA diagram
diagram which presents transformation of an initial microstructure to austenite at a given temperature in dependence on time

Note 1 to entry: For a given temperature, the graph is read from left to right following the horizontal temperature line to find out the required time for transforming each component of the microstructure as beginning and the achieved austenite microstructure as ending.

Note 2 to entry: Differences in the initial microstructure can modify the diagram.

3.1.67.3
continuous austenitization diagram
diagram which presents transformation of an initial microstructure to austenite at a given heating rate in dependence on time

Note 1 to entry: Set of curves for different heating rates can be drawn in a semi-logarithmic coordinate system with logarithmic time/temperature coordinate.

Note 2 to entry: For a given heating rate along the curve, the time and temperature of begin and end of the change of each component of the initial structure and the austenitic structure can be obtained.

Note 3 to entry: Differences in the initial microstructure can modify the diagram.

3.1.67.4
time-temperature-transformation diagram
TTT diagram
isothermal transformation diagram
IT diagram
diagram which presents isothermal transformation of *undercooled austenite* (3.8.39)

Note 1 to entry: TTT-diagrams can be used to determine the volume fraction of each *phase* (3.8.27) and its hardness after the transformation.

3.1.67.5
continuous-cooling-transformation diagram
CCT diagram
diagram which presents continuous cooling transformation of *austenite* (3.8.4)

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

3.1.68
transformation point
transformation temperature between one microstructures to another

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.

3.1.69
transformation range
interval of temperature within which a ferrous product undergoes a change of *phase* (3.8.27)

3.1.70
transformation temperature
critical point
temperature at which a change of *phase* (3.8.27) 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* (3.8.4);

— A_3, equilibrium temperature defining the upper limit of existence of *ferrite* (3.8.11);

— A_{cm}, equilibrium temperature defining the upper limit of existence of *cementite* (3.8.8) in *hypereutectoid steels* (3.1.45);

— M_s, temperature at which the austenite begins to transform into *martensite* (3.8.22) during cooling;

— M_f, temperature at which the austenite has almost completely transformed into martensite during cooling;

— M_x, temperature at which a volume fraction of x % of the austenite has transformed into martensite during cooling.

3.1.71
ultrafast cooling
method of cooling which is carried out mainly in the quenching process of thin plates and which aims at obtaining finer microstructure of steels and improving the mechanical properties by means of high pressure water cooling with a much greater speed than that of water-cooling

3.1.72
vacuum heat treatment
heat treatment in a vacuum environment with pressure below 0,1 MPa

Note 1 to entry: The pressure is usually 1×10^{-1} Pa to 1×10^{-3} Pa.