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Heat treatment of ferrous materials

Terminology

DIN 17 014 Part 1

Wärmebehandlung von Eisenwerkstoffen; Begriffe

Supersedes March 1975 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Contents

1 Scope and field of application

This standard establishes the major concepts associated with the heat treatment of ferrous materials. It is intended to ensure that a standard terminology reflecting the state of the art can be used in production planning, heat treatment practice and in technical publications.

Clause 2 defines concepts relating to methods of heat treatment, heat treatment procedures and the evaluation and assessment of results of heat treatment, while clause 3 defines relevant metallurgical concepts. The standard also includes, in clause 4, an alphabetical index of all terms used in clauses 2 and 3 and, in clause 5, a list of terms arranged according to subject groups.

Concepts used in the definitions, which are printed in boldface, are themselves defined in clause 2 or 3.

2 Concepts relating to heat treatment

Ageing

1) Modification in the properties of a metal at ambient temperature or at temperatures close to it due to the migration of interstitial elements.
2) Heating of a solution treated ferrous product one or more times to (a) specified temperature(s), and **soaking** at this (these) temperature(s) followed by **cooling** at an appropriate rate.

Ageing by heating

See 'ageing' (2).

Aluminizing

Thermochemical treatment applied to a ferrous product with the object of producing surface enrichment in aluminium.

Annealing

Heat treatment consisting of **full heating** to a specified temperature, **soaking** and **cooling**, under conditions such that, after return to ambient temperature, the metal will be in a structural state closer to that of equilibrium.

Note. As this definition is very general, it is advisable to specify the aim of the treatment more precisely by using a term like 'recovery' or 'spheroidizing'.

Artificial ageing

See **'stabilizing'**.

Ausforming

Thermomechanical treatment of high alloy steels for quenching and tempering consisting of plastically deforming the **metastable austenite** under conditions such that no **recrystallization** occurs and it is transformed into **martensite** and/or **bainite** in subsequent **cooling**; see also **'thermomechanical treatment'**.

Austempering

Treatment comprising of **austenitizing** followed by **quenching** at a temperature, generally above M_s, at a rate fast enough to avoid transformation into pearlite and **soaking** at this temperature to ensure as complete a transformation of **austenite** into **bainite** as possible.

Subsequent **cooling** to ambient temperature is not at any specific rate.

Austenitizing

Operation during which the ferrous product is brought to a temperature such that the **matrix** becomes austenitic. Treatment with the product in the $(\alpha + \gamma)$ range is termed 'partial austenitizing'.

Note. The term 'incomplete austenitizing' is used if the transformation of ferrite into austenite is incomplete.

Austenitizing temperature

Temperature at which a ferrous product is held during **austenitizing**. This corresponds to the highest temperature in the case of multiple-stage austenitizing.

Austenitizing time

Time interval between the beginning and end of **soaking** at **austenitizing temperature**.

Baking

Heat treatment in order to release hydrogen occluded in a ferrous product without modifying its structure.

Note. This treatment is carried out, for instance, after electrolytic plating or pickling.

Blank carburizing

Treatment of a ferrous product under conditions reproducing the **thermal cycle** of **carburizing** in the absence of a carburizing medium.

Note. This treatment makes it possible to assess the effect of the thermal cycle of carburizing on the properties of a ferrous product.

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Blank nitriding

Treatment of a ferrous product under conditions reproducing the **thermal cycle of nitriding** in the absence of a nitriding medium.

Note. This treatment makes it possible to assess the effect of the thermal cycle of nitriding on the properties of a ferrous product.

Blueing

Heat treatment in an oxidizing **medium**, to produce a very thin film of blue-coloured oxide on the polished surface of a ferrous product.

Boriding

Thermochemical treatment which is applied to a ferrous product to obtain surface enrichment in boron by forming a layer of boride.

Note. It is recommended that the medium used for boriding be indicated, e.g. for boriding in powder: 'powder boriding'; for boriding with paste: 'paste boriding'.

Bright annealing

Annealing in which the metallic surface finish is maintained.

Burning

Irreversible change in the structure and thus the properties brought about by the onset of fusion at the **grain boundaries** as a consequence of incorrect heat treatment.

Burnishing

Thermochemical treatment in an oxidizing **medium**, to produce a very thin film of dark oxide on a metallic surface.

Carbon activity, a_c

Ratio of the carbon vapour pressure, p_c (e.g. in **austenite** of specific carbon concentration), to the vapour pressure of pure carbon (graphite), p_c^o, in the condition under consideration.

Carbon availability

Quantity of carbon, in g, given off by one m^3 gas in the normal condition at a specified temperature at the surface of the ferrous product, when the **carbon potential** drops from 1,0 % to 0,9 %.

Carbon content characteristic

Carbon content as a function of the distance from a **reference point** in a ferrous product. This may be represented graphically in the form of a carbon gradient curve.

Carbonitriding

Thermochemical treatment that is applied to a ferrous product above A_1 to obtain surface enrichment in carbon and nitrogen, both elements then being in **solid solution** in the **austenite**.

Carbon potential, C_p

Carbon content, stated as a percentage of carbon by mass, taken up by a sample of pure iron within the solubility range of **austenite** at a specific temperature in equilibrium with a surrounding **medium**.

Carbon transition index

Carbon quantity, related to the difference between **carbon potential** and surface carbon content penetrating into the surface of the ferrous product from the carburizing medium per unit of time and area.

Carburization

Surface enrichment in carbon of a ferrous product.

Carburizing

Thermochemical treatment that is applied to a ferrous product in the austenitic state to obtain a surface enrichment in carbon, which then, normally is in **solid solution** in the **austenite**.

Note. It is recommended that the medium used for carburizing be indicated, e.g. for carburizing in gas: 'gas carburizing'; for carburizing in powder: 'solid carburizing'.

Case depth

Vertical distance between the surface of a ferrous product and a limit characterizing the thickness of the layer enriched in carbon. This limit is to be expressed by indicating the agreed carbon content, e.g. $At_{0,35}$.

Note. For the total case depth, this limit will correspond to the carbon content of the unaltered base metal.

Case hardening

Treatment consisting of **carburizing** or **carbonitriding** followed by **quench hardening**.

Chromizing

Thermochemical treatment that is applied to a ferrous product to obtain surface enrichment in chromium.

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

Complete decarburization

See **'decarburization'**.

Compound layer

Layer formed immediately on the surface of a product during a **thermochemical treatment** made up of one (or more) chemical compound(s) and from the diffused element(s) and certain elements from the base metal, e.g. the nitride layer formed during nitriding, the boride layer formed during boriding, and the chromium carbide layer formed during the chromizing of high-carbon steel. The layer thickness shall be determined as specified in DIN 50 950.

Continuous-cooling-transformation diagram (CCT diagram)

Set of curves drawn in a semilogarithmic coordinate system defining, for each **cooling characteristic**, the beginning and end of the formation of austenite.

Note. This generally includes information regarding the transformation products and their proportions, and the hardness of the structure measured at ambient temperature, for each **cooling curve**.

Cooling

Reducing the temperature of a ferrous product in one or several steps.

Note. The term 'cooling' should only be used if cooling takes place in still air, while the term 'quenching' should be used for higher cooling rates.

Cooling characteristic

Temperature as a function of time at a given point on a ferrous product, from the beginning to the end of the cooling process.

Cooling conditions

Conditions under which a ferrous product is cooled, e.g. type and temperature of the **cooling medium.**

Cooling curve

Graphical representation of the **cooling characteristic.**

Cooling medium

See **'medium'.**

Cooling rate

Change in temperature as a function of time during cooling.

A distinction is made between:

a) an instantaneous rate, relating to a given temperature;

b) an average rate, relating to a given temperature interval.

Cooling schedule

Schedule specified for the **cooling characteristic.**

Cooling temperature

Temperature at the beginning of the cooling process.

Cooling time

Time interval between the beginning and end of the cooling process or between two characteristic points on the **cooling characteristic.**

Note. It is always necessary to specify for which point on the ferrous product the cooling characteristic is considered.

Crack

Fissure produced in a ferrous product by the immediate or deferred effects of **heating** or **cooling.**

Note. The relationship with the operation concerned may be indicated by means of terms such as 'heating crack', 'quench hardening crack'.

Critical cooling characteristic

Cooling characteristic that will just produce the required austenite transformation.

Note: The term should be qualified by indicating the required transformation structure, e.g. critical cooling characteristic to form martensite or critical cooling characteristic to form pearlite.

Critical cooling rate

Cooling rate corresponding to the **critical cooling characteristic.**

Decarburization

Depletion of carbon from the surface layer of a ferrous product. This depletion may be either partial (**partial decarburization**) or nominally complete (**complete decarburization**).

Decarburizing

Thermochemical treatment intended to remove carbon.

Depth of decarburization

Vertical distance between the surface of a ferrous product and a limit, which is to be agreed, characterizing the thickness of the layer depleted in carbon (see DIN 50 192).

Depth of hardening

Vertical distance between the surface of a quench hardened ferrous product and a limit value, which is to be agreed, characterizing the thickness of the hardened layer.

Depth of nitriding

Vertical distance between the surface of a ferrous product and a limit characterizing the thickness of the layer enriched in nitrogen. The limit shall be specified. When this limit is a hardness level, the term **'effective case depth after nitriding'** is used.

Depth of nitrocarburizing

Vertical distance between the surface of a ferrous product and a limit characterizing the thickness of the layer enriched in nitrogen. The limit shall be specified. When this limit is a hardness level, the term **'effective case depth after nitriding'** is used.

Depth of transformation

Specified depth from the surface of a product, to which the material is quench hardened. The depth of transformation is generally characterized by the **depth of hardening.**

Destabilization of retained austenite

Change in the condition of **retained austenite** as a result of **tempering,** which allows it to transform into martensite during **cooling.**

Diffusion treatment

Heat treatment or operation intended to cause the diffusion towards the interior of the ferrous product of elements previously introduced into the surface to excessive amounts (to be carried out after **carburizing, boriding, nitriding,** for example).

Diffusion zone

Surface layer formed during a **thermochemical treatment** containing, in **solid solution** or where appropriate, partially precipitated, the element(s) introduced during the treatment. The content of these elements diminishes continuously as the base metal is approached.

Note. The precipitates in the diffusion zone can be nitrides, carbides, etc.

Direct hardening

Quenching of a ferrous product immediately following a treatment carried out in the **austenite** temperature range.

Note. Direct hardening may be carried out, for instance, after thermochemical treatment or after hot forming.

Donor medium

See **'medium'.**

Double quench hardening

Two successive quench hardening treatments, generally carried out from different temperatures.

Note. In the case of carburized products, the first quench hardening can be obtained by direct quenching, the second being carried out from a lower temperature.

Effective case depth after carburizing

Vertical distance between the surface of a case hardened ferrous product and the position where the Vickers hardness is generally 550 HV 1 (see DIN 50 190 Part 1).

Effective case depth after nitriding

Depth of nitriding defined by reference to a limit hardness level (see DIN 50 190 Part 3).

Effective case depth after surface hardening

Vertical distance between the surface of a surface hardened ferrous product and the position where the Vickers hardness, generally measured as HV 1, is 80% of the minimum surface hardness required (see DIN 50 190 Part 2).

Electron beam hardening

See 'impulse hardening'.

Equivalent ruling section

Diameter, d, of a cylinder (with length exceeding 3 d) of the same material, such that the cooling rate in its centre would be identical to the slowest cooling rate recorded for the ferrous product considered, for the same cooling conditions.

If the equivalent ruling section is based on different conditions, these conditions shall be indicated precisely.

Note. The equivalent ruling section is not identical with the equivalent diameter as defined in appendix A of DIN 17 200, March 1987 edition.

First-stage heating

Heating of a ferrous product bringing its surface to the specified temperature; see also 'full heating'.

First-stage heating time

Time interval between the beginning and end of first-stage heating.

Flame hardening

See 'surface hardening'.

Full heating

Heating of a ferrous product until the required temperature has been reached throughout. It comprises first-stage heating and second-stage heating.

Grain coarsening

Annealing of hypoeutectoid steels at a temperature between 1050 and 1300 °C for a soaking period sufficient to produce grain growth.

Grain refining

Heat treatment with the object of refining a ferrous product, or making its grain size more uniform, by heating it at a temperature slightly above Ac_3 (Ac_1 for hypereutectoid steels), but without prolonged soaking at this temperature, followed by cooling at a suitable rate.

Graphitization

Precipitation of carbon in the form of graphite.

Graphitizing

Heat treatment with the aim of causing precipitation of the carbon in the form of graphite, e.g. in the case of cast iron.

Hardenability

Capacity of a steel to transform into martensite and/or bainite after austenitizing.

Hardenability is generally characterized, assuming defined hardening conditions, by the change in hardness as a function of the distance from a quenched surface of the ferrous product.

Note. The Jominy test (see DIN 50 191) is a standardized test that serves to determine this change.

Hardening beginning at hot forming temperature

See 'heat treatment beginning at hot forming temperature'.

Hardness characteristic

Hardness as a function of the distance from a reference point in a ferrous product. This may be represented graphically in the form of the (standardized) Jominy curve or other hardness gradient curves.

Heating

Increase in the temperature of a ferrous product in one or more steps.

A distinction is made between fist-stage heating, second-stage heating and full heating.

Note. It is recommended that the heating medium used be indicated.

Heating characteristic

Temperature as a function of time at a given point on a ferrous product, from the beginning to the end of the heating process.

Heating conditions

Conditions under which a ferrous product is heated, e.g. type of heating medium.

Heating curve

Graphical representation of the heating characteristic.

Heating medium

See 'medium'.

Heating rate

Change in temperature as a function of time during heating.

A distinction is made between:

a) an instantaneous rate, relating to a given temperature;

b) an average rate, relating to a given temperature interval.

Heating schedule

Schedule specified for the heating characteristic.

Heating-up time

Time interval between the beginning and end of the heating process or between two specified points of the heating characteristic.

Note. The point in the ferrous product to which this characteristic relates shall be stated.

Heat treatment

Series of operations in the course of which a ferrous product is totally or partially exposed to thermal cycles, to cause a change in its properties and/or structure.

The chemical composition of the metal may possibly be modified during these operations (see 'thermochemical treatment').

Heat treatment beginning at hot forming temperature

Controlled cooling of a ferrous product directly following a heat treatment carried out at suitable temperatures with the aim of achieving required properties.

It is recommended that the heating process be specified more precisely by referring to the procedure used or the aim of the treatment, e.g. 'quench hardening beginning at hot forming temperature', 'treating to condition BY'.

Heat treatment time

Time interval between the beginning and end of a heat treatment process.

Holding time

Interval between introduction of a product into the furnace and its removal.

Homogenizing

Annealing at sufficiently high temperature involving sufficiently long soaking to reduce, by diffusion, local differences in chemical composition (due to segregation).

Impulse hardening

See 'rapid hardening'.

Impulse heating

Method of heating a ferrous product by short repeated bursts of energy, giving rise to a local increase in temperature.

Various sources of energy may be used, such as condenser discharge, lasers, electron beams.

Induction hardening

See 'surface hardening'.

Internal oxidation

Precipitation of oxides near the surface of a ferrous product, formed by oxygen diffusing from the surface.

Interrupted quenching

Quenching interrupted before the ferrous product and the quenching medium have reached thermal equilibrium.

Irreversible temper embrittlement
(also termed '300 °C embrittlement')

Embrittlement of steel which can occur during soaking or similar thermal cycles at about 300 °C.

Isoforming

See 'thermomechanical treatment'.

Isothermal annealing

Isothermal transformation consisting of austenitizing followed by cooling to a temperature in the pearlite phase, and soaking to give full transformation of the austenite into ferrite/pearlite or cementite/pearlite.

Isothermal transformation

Heat treatment involving austenitizing and cooling to an appropriate temperature and soaking at this temperature until the desired degree of transformation is achieved. Subsequent cooling to ambient temperature is not at any specified rate. A distinction is made between 'isothermal annealing' and 'austempering'.

Note. The required thermal cycle can be read from the relevant TTT diagram.

Jominy test

Standardized test (see DIN 50 191) which consists in austenitizing a steel test piece and then quenching it at one end by means of a jet of water. The change in hardness measured on a ground strip of the outer layer of the test piece as a function of the distance from the quenched end (Jominy curve) characterizes the hardenability of the steel.

Limiting characteristic

Term used instead of 'limit value' when a criterion other than a property, e.g. a structure, is used to determine the thickness of a layer the condition of which differs from that of the core material.

Limit value

Reference value used to define the thickness of a surface layer which has undergone a change in one or more of its properties, e.g. hardness, as a result of heat treatment.

Local heat treatment

Heat treatment limited to part of a ferrous product; see DIN 6773 Parts 2 to 5.

Malleablizing

Heat treatment on white cast iron to obtain a malleable cast iron by decarburization or by graphitization.

Note. Malleable cast iron treated in a decarburizing atmosphere is termed 'white-heart malleable cast iron' and malleable cast iron treated in a neutral atmosphere and thus graphitized, 'black-heart cast iron'.

Martempering

Heat treatment involving austenitizing followed by quenching to a temperature about M_s at a rate fast enough to avoid the formation of ferrite, pearlite or bainite, and soaking for long enough to ensure that the temperature of the product is uniform throughout, with subsequent cooling, usually in air, so that martensite is formed almost simultaneously throughout.

Maraging

Treatment of some alloy steels with very low carbon contents, consisting of solution annealing with the aim of producing homogenous martensite, followed by ageing, to increase hardness by causing precipitation of one or more intermetallic phases in the matrix.

Maximum achievable hardness

Maximum hardness achievable in a material by quench hardening under ideal conditions.

Medium

Environment in which the metal is placed during heat treatment.

The medium can be solid, liquid or gaseous, its efficacy in heat treatment essentially depending on its calorific properties (heating medium, cooling medium) and its thermochemical properties (oxidizing medium, decarburizing medium, etc.).

Note. A gaseous medium is often termed an 'atmosphere'.

The media used for thermochemical treatment are termed 'donor media'.

Multiple-stage carburizing

Carburizing in two or more successive steps with differing carbon potentials.

Multiple-stage nitriding

Nitriding treatment with at least one modification in the nitriding conditions (temperature and/or gas composition, etc., such as in the Floe process).

Nitriding

Thermochemical treatment that is applied to a ferrous product in order to produce surface enrichment in nitrogen. (Depending on the conditions of nitriding and the material composition, this treatment produces a **diffussion zone** or a **diffusion zone** and a **compound layer**.)

Note. It is recommended that the medium used for nitriding be indicated, e.g. for nitriding in gas: 'gas nitriding'; for nitriding in plasma: 'plasma nitriding'.

Nitrocarburizing

Thermochemical treatment that is applied to a ferrous product to produce surface enrichment in nitrogen and carbon forming a **compund layer** and a **diffusion zone**, the **diffusion zone** beneath this **compound layer** being enriched mainly in nitrogen.

Note. It is recommended that the medium used for nitrocarburizing be indicated, e.g. for nitrocarburizing in a salt bath: 'salt bath nitrocarburizing'; for nitrocarburizing in gas: 'gas nitrocarburizing'.

Nitrogen content characteristic

Nitrogen content as a function of the distance from a reference point in a ferrous product. This may be represented graphically in the form of a nitrogen gradient curve.

Normalizing

Heat treatment consisting of **austenitizing** at temperatures about 50 °C above Ac_3, followed by **cooling in still air**.

Normalizing forming

See **'thermomechanical treatment'**.

Operation

Each of the elementary actions within a **heat treatment cycle**.

Overcarburizing

Carburizing continuing beyond the desired carbon content, which leads to an unacceptably large content of **retained austenite** and/or carbide precipitations.

Overheating

Excessive grain growth caused by **heating** to too high a temperature.

Grain growth in transformable **steels** can be reversed by means of a suitable **heat treatment**. In the case of non-transformable **steels**, this may be achieved only by means of hot forming.

Oversoaking

Excessive grain growth caused by excessive **soaking**.

Grain growth in transformable **steels** can be reversed by means of a suitable **heat treatment**. In the case of non-transformable **steels**, this may be achieved only by means of hot forming.

Oxynitriding

Thermochemical treatment that is applied to a ferrous product to produce surface enrichment in nitrogen and oxygen forming a **compound layer** containing these elements and a **diffusion zone**, the **diffusion zone** beneath this **compound layer** being enriched mainly in nitrogen.

Partial austenitizing

See **'austenitizing'**.

Partial decarburization

See **'decarburization'**.

Patenting

Heat treatment of wire or strip, consisting of **austenitizing** followed by **cooling** under conditions suitable for producing the structures appropriate for subsequent wire drawing or rolling.

A distinction is made between:

a) continuous patenting, when the unwound product passes continuously through the cooling medium;

b) batch patenting, when the product is immersed in the cooling medium in the form of a coil or bundle.

Note. It is recommended that the medium used for patenting be indicated, e.g. 'air patenting', 'lead bath patenting', 'salt bath patenting', 'fluidized bed patenting'.

Precipitation hardened state

Hardening (i.e. a condition of increased hardness) of a ferrous product caused by precipitation of one or more **phases** from a supersaturated **solid solution**.

Precipitation hardening treatment

Heat treatment comprising **solution treatment** followed by **ageing**.

Note. Precipitation hardening from the martensitic phase is termed 'maraging'.

Preheating

Heating with subsequent **soaking** at one or more temperatures below the scheduled maximum temperature.

Quench hardened state

Hardening (i.e. a condition of increased hardness) of a ferrous product obtained by the **quench hardening treatment**. A distinction is made between **'depth of transformation'** and **'through hardened state'**.

Quench hardening temperature

Temperature from which the ferrous product is cooled in the **quench hardening treatment**.

Quench hardening treatment

Heat treatment involving **austenitization** followed by **cooling** under conditions such that the **austenite** transforms more or less completely into **martensite** and possibly into **bainite**.

Quenching

Cooling of a ferrous product more rapidly than in still air.

Note. It is recommended that the cooling medium be indicated, e.g. for quenching in water: 'water quenching'; for quenching in oil: 'oil quenching'.

The term 'self-quenching' is used where quenching is the result of thermal conduction into the unheated parts of the product.

Quenching and tempering

Quench hardening with subsequent **tempering**, generally above 550 °C, to achieve a desired combination of mechanical properties, particularly where it is required to improve the ductility as compared with the quench hardened state.

Quenching capacity

Ability of a **cooling medium** enabling a particular **cooling schedule** to be realized.

Quenching temperature

Temperature at the beginning of a quenching process.

Note. The term 'hardening temperature' is also used in conjunction with quenching from the austenitizing temperature.

Quenching time

See **'cooling time'**.

Rapid hardening

Quench hardening involving a very short **austenitizing** time and thus higher temperatures than usual.

Here, **quench hardening** is usually effected by thermal conduction into the unheated parts of the ferrous product (**self-quenching**).

If the **heating** process is not continuous but in short pulses, the term **'impulse hardening'** is used.

Note. Various sources of energy, such as condenser discharge, lasers or electron beams, may be used, it being recommended to state which source is to be used. These energy sources may generally also be used for surface hardening.

Recarburizing

Thermochemical treatment with the intention of restoring the carbon content in the surface of a ferrous product which has been decarburized by a previous treatment.

Recovery

Annealing of a work-hardened ferrous product to cause at least partial recovery of its physical or mechanical properties without apparent modification of its structure.

This treatment is carried out at a temperature below that of **recrystallizing**.

Recrystallizing

Annealing treatment intended to cause new grains to develop by nucleation and growth in a work-hardened metal, without a change in phase.

Reversible temper embrittlement
(also termed **'500 °C embrittlement'**)

Embrittlement during **tempering** which affects some grades of steels for quenching and tempering by **soaking** at about 450 to 525 °C or during slow **cooling** through this temperature range.

Note. This type of embrittlement is evidenced by an increase in the transition temperature on the impact strength/temperature curve. It may be corrected or prevented by heating to temperatures above 550 °C followed by rapid cooling.

Secondary hardening

Increase in hardness as a result of **tempering** due to precipitations and/or the formation of **martensite** or **bainite** from the **retained austenite** of quench hardened ferrous products.

Second-stage heating

Heating of a ferrous product until a specified temperature on the surface has been reached; see also **'full heating'**.

Self-quenching

Quenching of a part of a ferrous product that has been heated, by thermal conduction into the unheated parts.

Sherardizing

Thermochemical treatment that is applied to a ferrous product to produce surface enrichment in zinc.

Siliconizing

Thermochemical treatment that is applied to a ferrous product to obtain surface enrichment in silicon.

Single hardening

Single **hardening** operation after prior **carburizing** and **cooling** to ambient temperature.

The term 'single hardening with isothermal transformation' is used if isothermal transformation occurs after **carburizing**.

Soaking

The part of a **thermal cycle** during which the temperature is held constant.

It is necessary to specify whether the temperature concerned is, for example, that of the furnace, that of the surface of the product, that of the whole section of the product or that of any other particular point on the product.

Soaking time

Time interval between the beginning and end of **soaking** at a specified temperature (soaking temperature).

Softening

Heat treatment with the object of reducing the hardness of a ferrous product to a given level.

Note. 'Softening' should not be confused with **'spheroidizing'**.

Solution treatment

Heat treatment intended to dissolve previously precipitated constituents and retain them in solid solution by suitably rapid **cooling** (supersaturated **solid solution**).

Spheroidization

Change in the form of precipitations, e.g. **carbides** (lamellar cementite), changing to approximately spherical form.

Spheroidizing

Annealing with the aim of causing **spheroidization** of the precipitated **carbides**, generally involving prolonged **soaking** at a temperature in the region of Ae_1, possibly with oscillations around this temperature.

Stabilizing

Heat treatment intended to prevent subsequent dimensional or structural changes in a ferrous product.

Stabilizing annealing

Annealing intended to restore the corrosion resistance of stabilized austenitic steels in heat-affected zones caused by welding.

Step quenching

Quenching by soaking the ferrous product in a **medium** at a specified temperature until thermal equilibrium is reached.

Stress relieving

Annealing intended to reduce the intrinsic stresses without substantial modification to the structure and the mechanical properties.

Sub-zero treatment

Treatment carried out after **quench hardening** to transform the **retained austenite** into martensite and consisting of **cooling** to a temperature below ambient.

Sulfidizing

Thermochemical treatment that is applied to a ferrous product to produce surface enrichment in nitrogen, oxygen and sulfur by forming a **compound layer** and a **diffusion zone**, the **diffusion zone** beneath this **compound layer** being enriched mainly in nitrogen.

Surface hardening

Quench hardening treatment with **austenitizing** restricted to the surface layer.

Note. It is recommended that the treatment be characterized by specifying the type of heating process used, e.g. 'flame hardening', 'induction hardening', 'electron beam hardening', 'laser hardening'.

Tempering

Heating a quench hardened ferrous product one or more times to a specific temperature ($< Ac_1$), and **soaking** at this temperature, followed by **cooling** at an appropriate rate.

Note. Hardness is generally reduced by tempering, but it may be increased if **secondary hardening** occurs.

The term 'auto-tempering' is used to describe a tempering effect already occurring during cooling from austenitizing temperature.

Tempering diagram

Graphical representation of the relationship between mechanical properties of a ferrous product and **tempering temperature** for a given **tempering time**.

Tempering parameter

Parameter characterizing the relationship between **tempering temperature** and **tempering time**.

Tempering temperature

Temperature at which a ferrous product is soaked during **tempering**.

Tempering time

Time interval between the beginning and end of **soaking** at **tempering temperature**.

Thermal cycle

Change in temperature as a function of time during **heat treatment**.

Thermochemical treatment

Heat treatment carried out in a **medium** such as to produce a change in the chemical composition of the base metal by exchange with the **medium**, this change, in most cases, being limited to the surface layer of a ferrous product.

Thermomechanical forming

See '**thermomechanical treatment**'.

Thermomechanical treatment

Operation in which both temperature and forming process are controlled over time to obtain a specific material condition, and thus specific material properties.

A distinction is made between the following:

a) processes involving complete **recrystallization** of the **austenite**, e.g. normalizing forming;

b) processes not involving substantial **recrystallization** of the **austenite**, e.g. **ausforming**, isoforming, thermomechanical forming.

The material condition which may be achieved using these methods cannot be achieved through **heat treatment** alone, and is not repeatable.

Note. See in this respect *Stahl-Eisen-Werkstoffblatt* (Iron and steel materials sheet) 082.

Through hardened state

Quench hardened state extending to the core of a product. The through hardened state is characterized by a suitably selected **limit characteristic** of the **depth of hardening**.

Time-temperature-austenitization diagram for continuous heating

Set of curves drawn in a semilogarithmic coordinate system defining, for each **heating characteristic**, the beginning and end of the formation of austenite.

Time-temperature-austenitization diagram for isothermal heating (TTA diagram)

Set of curves drawn in a semilogarithmic coordinate system defining, for each level of temperature, the beginning and end of the formation of austenite under isothermal conditions.

Time-temperature-transformation diagram for isothermal heating (TTT diagram)

Set of curves drawn in a semilogarithmic coordinate system defining, for each level of temperature, the beginning and end of the transformation of austenite under isothermal conditions.

Note. This generally includes information regarding the transformation products and their hardness.

Titanizing

Thermochemical treatment that is applied to a ferrous product to produce surface enrichment in titanium through the formation of a layer of titanium carbide.

Transformation with continuous cooling

Heat treatment involving **austenitizing** and **cooling** under conditions which ensure that the required structure is achieved.

Note. The required thermal cycle can be read from the relevant CCT diagram.

Treatment to condition BY

See '**heat treatment beginning at hot forming temperature**'.

Vanadizing

Thermochemical treatment that is applied to a ferrous product to produce surface enrichment in vanadium through the formation of a layer of vanadium carbide.

3 Concepts relating to metallurgy

Alloy

Product consisting of a metal and one or more elements that are completely dissolved in the metal in the liquid state and are capable of entering into **solid solution** or forming a compound with it.

Austenite

Solid solution of one or several elements in face-centred cubic iron (γ-iron) (also termed **γ-phase**).

Austenitic grain size

The **size of grains** of a **steel** in the domain of stability of the **austenitic** phase.

Note. See DIN 50 601 for determination of the austenitic grain size.

Austenitic steel

Steel with an austenitic structure after **solution treatment** at ambient temperature.

Bainite

Metastable constituent formed by the decomposition of **austenite** in a temperature interval between the temperature at which **pearlite** forms and that at which martensite starts to appear. It consists of grains of supersaturated **ferrite** in which carbon has been finely precipitated in the form of **carbide.**

A distinction is made between:

a) upper **bainite**, which is formed at higher temperatures in the interval described above;

b) lower **bainite**, which is formed at lower temperatures in the interval described above.

Banded structure

Bands parallel to the direction of flow or hot working that appear in a metallographic section and indicate the deformation which the segregated zones of differing chemical compositions have undergone during hot working.

Boride

Compound of boron and one or more metallic elements (e.g. Fe_2B).

Carbide

Compound of carbon and one or more metallic elements (e.g. Fe_3C).

Carbonitride

Compound of carbon, nitrogen and one or more metallic elements.

Cast iron

Ferrous product formed by casting and with a carbon content exceeding 2 % by mass.

The presence of large amounts of carbide-forming elements may modify the lower limit of the carbon content.

Cast steel

Steel that is produced by casting (see DIN 1681, DIN 17 245 and DIN 17 445).

Cementite

Carbide of iron, Fe_3C.

Coalescence of a precipitate

Growth of precipitated particles by diffusion of the constituent elements through the **matrix** of small particles (which disappear) to large particles (which grow in size).

Note. This concept should not be confused with 'spheroidizing'.

Constituent

Single **phases** or a mixture of several **phases** appearing as an individual feature during the metallographic examination of a structure.

Eutectic

Mixture of two or more crystalline **phases** simultaneously precipitated from a melt of specified composition as it solidifies.

Eutectic transformation

Reversible transformation of a melt of eutectic composition on solidification into a mixture of two or more crystalline **phases.**

A melt of iron-carbon alloys will transform into an **austenite** and carbide mixture **(ledeburite).**

Eutectoid

Mixture of two or more crystalline **phases** simultaneously formed from a **solid solution** as it cools.

Eutectoid transformation

Reversible transformation of a **solid solution**, stable at high temperatures, of specific composition, into a mixture of one or more **phases**, stable at a lower temperature.

In a melt of iron-carbon alloys the **austenite** will transform into **ferrite** and **cementite (pearlite).**

Ferrite

Solid solution of one or more elements in **α-iron.**

δ-ferritic steel

Steel, the ferritic content of which is stable up to its melting point.

Ferrous product

A metallic product, the principal constituent of which is iron.

A distinction is made between:

a) **steel;**

b) **cast iron;**

c) **cast steel;**

d) **sintered ferrous products.**

Grain

Crystallite of a polycrystalline structure.

Grain boundary

Interface separating two grains with different crystallographic orientations.

Grain growth

Increase in the **grain size** of a **ferrous product** as a result of **heat treatment** to a temperature generally far above the transformation point Ac_3.

Grain size

Characteristic value of the grain size revealed in a metallographic section.

See DIN 50 601 for determination of the grain size.

Hypereutectoid steel

Steel containing more carbon than the **eutectoid** composition.

Hypoeutectoid steel

Steel containing less carbon than the **eutectoid** composition.

Interstitial solid solution

Solid solution in which the interstices are occupied by solute atoms.

α-iron

Stable state of pure iron at temperatures below 911 °C. Its crystalline structure is body-centred cubic and it is ferromagnetic at temperatures below 768 °C (the Curie point).

γ-iron

Stable state of pure iron between 911 °C and 1392 °C. Its crystalline structure is face-centred cubic and it is paramagnetic.

δ-iron

Stable state of pure iron between 1392 °C and its melting point. Its crystalline structure is body-centred cubic, identical to that of α-iron and it is paramagnetic.

Ledeburite

Eutectic of an iron-carbon alloy, consisting of **austenite** and **cementite**.

Ledeburitic steel

Steel, the carbon content of which corresponds to its eutectic composition.

Low load hardness

Hardness measured under a load of between 1,96 N and 49,1 N.

Malleable cast iron

Ferrous product obtained by malleablizing white-heart cast iron of a given composition (see DIN 1692).

A distinction is made between white-heart and black-heart malleable cast iron (see **'malleablizing'**).

Martensite

Metastable solid solution of a body-centred cubic structure. It is formed by the transformation of **austenite** by a non-diffusional mechanism.

Maraging steel

Steel with a low carbon content, high nickel and/or cobalt content and low contents of other alloying elements, which transforms during **cooling** from the austenitic phase into the martensitic phase, which can be precipitation hardened and has relatively high ductility.

Matrix

Basic structure of a **ferrous product**.

McQuaid-Ehn grain size

Size of the austenite grains formed during **carburizing** under specified conditions.

The McQuaid-Ehn grain size shall only be determined for case-hardening steels (see DIN 50 601).

Metastable

An apparently stable state outside the conditions defined by the equilibrium diagram.

Microhardness

Hardness measured under a load of less than 1,96 N.

Nitride

Compound of nitrogen and one or more metallic elements.

Parent phase

Phase stable at the temperature under consideration, from which another **phase**, which is also stable, is precipitated.

Pearlite

Eutectoid of a **ferrous product**, consisting of **ferrite** and **lamellar cementite (carbide)**.

Peritectic

Structure resulting from a **peritectic transformation**.

Peritectic transformation

Reversible transformation of a melt and a solid **phase** involving the formation of a new crystalline **phase** of peritectic composition.

Phase

Structurally homogenous constituent of a system.

Note. Phases occurring in ferrous products are, for instance, ferrite, austenite, carbide.

Recalescence

The increase in temperature due to the release of heat accompanying the transformation of the **austenite** during the **cooling** process.

Retained austenite

Austenite remaining at ambient temperature after **quench hardening** or **austempering**.

Sensitization

Process through which certain stainless steels are rendered liable to intergranular corrosion.

Note. A sensitizing treatment is used to study the resistance to intergranular corrosion (see DIN 50 914).

Sintered iron

Sintered metal consisting of unalloyed iron, to which neither carbon nor any other alloying element has intentionally been added (see DIN 30 900).

Sintered metal

Metallic material produced by powder metallurgy techniques (see DIN 30 900).

Sintered steel

Sintered metal based on iron, with alloying elements added intentionally (see DIN 30 900).

Solid solution

A homogenous, solid, crystalline **phase** formed by two or more elements.

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.

Stabilization of retained austenite

Phenomenon which prevents the possibility of the transformation of **retained austenite** into **martensite** during **cooling** to a temperature below ambient temperature.

Note. Such stabilization may occur after quench hardening during tempering at comparatively low temperature or during prolonged soaking at ambient temperature.

Steel

Metallic product whose principal element is iron and whose carbon content is not more than 2 % by mass.

The presence of large quantities of carbide-forming elements may modify the upper limit of the carbon content.

Substitutional solid solution

Solid solution in which the solute atoms are substituted for those of the solvent metal.

Transformation range

Temperature range in which the product undergoes a change of phase.

Transformation temperature

Temperature at which a material undergoes a change of phase or at which transformation begins and ends, in cases where the transformation occurs within a temperature range.

The following principal transformation temperatures or points can be distinguished for steels.

Ae_1: equilibrium temperature defining the lower limit of existence of **austenite**.

Ae_3: equilibrium temperature defining the upper limit of existence of **ferrite**.

Ae_m: equilibrium temperature defining the upper limit of existence of **cementite** in a **hypereutectoid steel**.

Ac_1: temperature at which **austenite** begins to form during **heating**.

Ac_3: temperature at which **ferrite** completes its transformation to **austenite** during **heating**.

Ac_m: temperature at which the **cementite** in a **hypereutectoid steel** dissolves into austenite completely during **heating**.

Ar_1: temperature at which **austenite** completes its transformation to **ferrite** or **ferrite** and **cementite** during **cooling**.

Ar_3: temperature at which **ferrite** begins to form during **cooling**.

Ar_m: temperature at which **cementite** begins to form from **austenite** in **hypereutectoid steels** during **cooling**.

M_s: temperature at which the **austenite** begins to transform to **martensite** during **cooling**.

M_f: temperature at which the **austenite** has almost completely transformed to **martensite** during **cooling**.

M_x: temperature at which a specified percentage (x) of the **austenite** has transformed to **martensite** during **cooling**.

Widmannstätten structure

Structure occurring in **hypoeutectoid steels**, which, in micrographic examination, is characterized by an acicular structure of the **ferrite** which is precipitated from the **austenite** in specific crystallographic orientation and is surrounded by **pearlite**.

4 Alphabetical index

The concepts listed in clause 3 are marked with an asterisk (*).

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Depth of hardening
Depth of nitriding
Depth of nitrocarburizing
Depth of transformation
Destabilization of retained austenite
Diffusion treatment
Diffusion zone
Direct hardening
Donor medium
Double quench hardening

Effective case depth after carburizing
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Effective case depth after surface hardening
Electron beam hardening
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Eutectic *
Eutectic transformation *
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Eutectoid transformation *

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Malleable cast iron *
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Operation
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Overheating
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Oxynitriding

Parent phase *
Partial austenitizing
Partial decarburization
Patenting
Pearlite *
Peritectic *

5 Subject groups

In the following, the concepts listed in clauses 2 and 3 are classified according to subject groups.

5.1 Ferrous products

Alloy
Austenitic steel
Cast iron
Cast steel
δ-ferritic steel
Hypereutectoid steel
Hypoeutectoid steel
α-iron
γ-iron
δ-iron
Ledeburitic steel
Malleable cast iron
  Black-heart cast iron
  White-heart cast iron
Maraging steel
Sintered iron
Sintered metal
Sintered steel

5.2 Treatment

Blank treatment
Diffusion treatment
Heat treatment
Holding time
Local heat treatment
Partial austenitizing
Sensitization
Solution treatment
Thermal cycle
Thermochemical treatment
Thermomechanical treatment
Treatment atmosphere
Treatment conditions
Treatment medium
Treatment temperature
Treatment time

5.3 Heating

First-stage heating
Full heating
Impulse heating
Heating characteristic
Heating medium
Heating rate
  Average heating rate
  Intantaneous heating rate
Heating schedule
Heating time
Preheating
Second-stage heating

5.4 Soaking

Soaking temperature
Soaking time

5.5 Cooling and quenching

Air cooling
Cooling characteristic
  Critical cooling characteristic
Cooling medium
Cooling rate
  Average cooling rate
  Critical cooling rate
  Instantaneous cooling rate
Cooling schedule
Cooling temperature
Cooling time
Interrupted quenching
Oil quenching
Quenching capacity
Quenching temperature
Quenching time
Self-quenching
Step quenching
Sub-zero treatment

5.6 Transformation

CCT diagram
Critical cooling characteristic
Critical cooling rate
Eutectic transformation
Eutectoid transformation
Isothermal transformation
Peritectic transformation
Transformation range
Transformation temperature
Transformation time
Transformation with continuous cooling
TTT diagram

5.7 Austenitizing

Austenite
Austenitizing temperature
Austenitizing time
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Time-temperature-austenitization diagram for continuous heating
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5.8 Transformation of the austenite

Air patenting
Ausforming
Austempering
Batch patenting
Continuous patenting

- Depth of transformation
  - Depth of hardening
  - Quench hardened layer
- Effective case depth after surface hardening
- Equivalent diameter
- Equivalent ruling section
- Fluidized bed patenting
- Hardenability
  - Maximum achievable depth of hardening
  - Maximum achievable hardness
- Hardening beginning at hot forming temperature
- Hardness characteristic
- Isothermal annealing
- Jominy test
- Lead bath patenting
- Maraging
- Martempering
- Patenting
- Quench hardening
  - Quench hardening time
- Rapid hardening
  - Impulse hardening
- Resistance patenting
- Retained austenite
- Salt bath patenting
- Sub-zero treatment
- Surface hardening
  - Electron beam hardening
  - Flame hardening
  - Induction hardening
  - Laser beam hardening
- Through hardening

5.9 Tempering

- Auto-tempering
- Destabilizing the retained austenite
- 300 °C embrittlement
- 500 °C embrittlement
- Irreversible temper embrittlement
- Reversible temper embrittlement
- Secondary hardening
- Tempering diagram
- Tempering parameter
- Tempering temperature
- Tempering time

5.10 Quenching and tempering

- Quenching and tempering treatment

5.11 Ageing

- Ageing treatment
- Artificial ageing
- Stabilizing
- Stabilizing the retained austenite

5.12 Precipitation hardening

- Ageing
- Ageing temperature
- Ageing time
- Maraging
- Precipitation hardening treatment
- Sensitizing
- Solution treatment

5.13 Annealing

- Annealing temperature
- Annealing time
- Baking
- Bright annealing
- Grain coarsening
- Grain refining
- Graphitizing
- Homogenizing
- Malleablizing
- Normalizing
- Recovery
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- Spheroidizing
- Stabilizing annealing
- Stress relieving

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- Blueing
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- Boriding temperature
- Boriding time
- Burnishing
- Carbon activity
- Carbon availability
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- Carbonitriding
- Carbonitriding medium
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- Carbon transition index
- Carburizing
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Diffusion treatment
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Effective case depth after carburizing
Effective case depth after nitriding
Nitriding
- Blank nitriding
- Gas nitriding
- Multiple-stage nitriding
- Plasma nitriding

Nitriding medium
Nitriding temperature
Nitriding time
Nitrocarburizing
- Gas nitrocarburizing
- Powder carburizing
- Salt bath nitrocarburizing

Nitrocarburizing medium
Nitrocarburizing temperature
Nitrocarburizing time
Nitrogen content characteristic
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Oxidizing
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Recalescence
Reversible embrittlement
Sensitization
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Standards and other documents referred to

DIN 1681	General purpose cast steel; technical delivery conditions
DIN 1692	Malleable cast iron; concept, properties
DIN 6773 Part 2	Heat treatment of ferrous materials; heat treated parts; representation and indications on drawings; hardening, hardening and tempering, quenching and tempering
DIN 6773 Part 3	Heat treatment of ferrous materials; heat treated parts; representation and indications on drawings; surface hardening
DIN 6773 Part 4	Heat treatment of ferrous materials; heat treated parts; representation and indications on drawings; case hardening
DIN 6773 Part 5	Heat treatment of ferrous materials; heat treated parts; representation and indications on drawings; nitriding
DIN 17 200	Steels for quenching and tempering; technical delivery conditions
DIN 17 245	Ferritic cast steel with elevated temperature strength; technical delivery conditions
DIN 17 445	Stainless cast steel; technical delivery conditions
DIN 30 900	Powder metallurgy terminology; classification, concepts
DIN 50 190 Part 1	Case depth of heat treated parts; determination of effective case depth after carburizing
DIN 50 190 Part 2	Case depth of heat treated parts; determination of effective case depth after surface hardening
DIN 50 190 Part 3	Case depth of heat treated parts; determination of effective case depth after nitriding
DIN 50 191	Hardenability testing of steel by end quenching
DIN 50 192	Determination of depth of decarburizing
DIN 50 601	Metallographic examination; determination of the ferritic or austenitic grain size of steel and ferrous materials
DIN 50 914	Testing stainless steels for resistance to intergranular corrosion; copper sulfate-sulfuric acid method; Strauß test
DIN 50 950	Measurement of coating thickness; microscopic methods for the measurement of coating thickness; metallographic section method

Stahl-Eisen-Werkstoffblatt 082 *Begriffsbestimmungen zur thermomechanischen Behandlung von Stahl* *) (Concepts relating to the thermomechanical treatment of steel)

Previous editions

DIN 17 014: 02.52, 10.59; DIN 17 014 Part 1: 03.75.

Amendment

In comparison with the March 1985 edition, the standard has been brought into line with the state of the art, taking into consideration the specifications of EURONORM 52, 1983 edition.

*) Obtainable from: *Verlag Stahleisen mbH*, Sohnstraße 65, D-4000 Düsseldorf 1.

Explanatory notes *)

The publication of EURONORM 52 – 83 listing a number of concepts new as compared with DIN 17 014 Part 1, March 1975 edition, and consideration of the fact that the new concepts had been agreed internationally, prompted the revision and updating of this standard.

In comparison with the March 1975 edition, the main part of the standard, clause 2, has been extended to cover 60 new concepts, and a further 60 concepts relating to metallurgy have been included for the first time in clause 3.

Although the greater part of the terms and definitions listed in EURONORM 52 has been adopted in this standard, the *Normenausschuß Wärmebehandlungstechnik metallischer Werkstoffe* (Heat Treatment of Metallic Materials Standards Committee) considered it necessary to make changes to form and substance of some definitions or to retain a number of definitions from the previous edition of this standard.

Some concepts dealt with in the March 1975 edition are no longer included in this standard, as they are considered either obsolete or are not used at international level.

The concepts 'cast steel', 'cast iron', 'sintered iron', 'sintered metal' and 'sintered steel' have been included for the first time although they are not established in the EURONORM. The concept 'treatment to condition BY' has been adopted on the request of the *Normenausschuß Schmiedetechnik* (Forging Standards Committee), as it is frequently used by manufacturers and users of forged parts.

International Patent Classification

C 21 D 1/00
C 21 D 3/00
C 21 D 6/00
C 21 D 7/13
C 21 D 8/00
C 21 D 9/52

*) Translator's note. Some information given in these Explanatory notes is only of relevance to the German-language original and has thus been omitted from this translation.