CASTI

Metals Black Book™

European Ferrous Data

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Second Edition on CD-ROM™

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Dedication

CASTI Metals Black Book™ - European Ferrous Data is dedicated to my mother, Mary Bringas, and her parents, my grandparents, Luigi and Regina Zorzit; whose dream they shared of having their son and grandson become an engineer, and my honour to have accomplished their dream.

Additionally this book is dedicated to the memory of my first metallurgy teacher, Mr. George Chirgwin, W.D. Lowe Technical School, Windsor, Ontario. Not only did Mr. Chirgwin encourage me to study metallurgy, but his unique way of teaching influenced me to also teach the wondrous science of metals.

John E. Bringas, P.Eng.
Edmonton, Alberta

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CASTI Metals Black Book™ - European Ferrous Data, First Edition, is the fourth book published in the *CASTI Metals Data Book Series*™. It contains almost 800 pages with more than 600,000 pieces of practical metals data. Since accurate data entry of more than 600,000 numbers and letters is contingent on normal human error, we extend our apologies for any errors that may have occurred. However, should you find errors, we encourage you to inform us so that we may keep our commitment to the continuing quality of the *CASTI Metals Data Book Series*™.

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Chapter 1

EUROPEAN STANDARD STEEL DESIGNATION SYSTEM

European Standardization of Iron and Steel

History

Common markets demand common standards. This time-honoured concept continues to be reaffirmed. When the European Coal and Steel Community (ECSC) was founded in 1951, its administrative body quickly discovered that before the ECSC Treaty could be ratified internationally, the relevant terminology had to be standardized first. For instance, Article 60 of the Treaty requires that steel manufacturers publish their price lists and conditions of sale for their products. At first glance, not a difficult requirement to comply with. It soon became apparent, however, that products of the same type were not comparable, as they were being produced in accordance with different national technical delivery conditions. As a result, the Coordinating Commission for the Nomenclature of Iron and Steel Products (COCOR) was created two years after the foundation of ECSC.

Each member country of ECSC was entitled to send a delegation to COCOR, consisting of a representative of that country's national standards committee, as well as steel manufacturers and users. In turn, COCOR formed working groups comprising representatives of the national standards committees who were to deal with specific steel types and products.

In the course of the next 30 years, COCOR and its working groups compiled a comprehensive body of standards on steel that not only included terminology standards, but also the EURONORMs, harmonized standards on dimensions, quality and testing of steel. Nevertheless, ECSC member countries were not obliged to adopt the EURONORMs since, in many cases, different specifications were still in force at the national level.

At about the same time (the beginning of the 1960s), the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) were established by the national standards bodies within the European Economic Committee (EEC) and the European Free Trade Association (EFTA). Still today, the member countries of CEN and CENELEC are obliged to adopt the European Standards (ENs) published by these two organizations as national standards.

In its Council Resolution of 7 May 1985, the European Community put forth a 'new approach to the technical harmonization of standards' stating that future EC Directives are to be restricted to 'essential safety requirements'. These minimum requirements are to be implemented at the national level by the European national standards bodies.

In response to this 'New Approach', the responsibility for the standardization of iron and steel was given to the newly-established European Committee for Iron and Steel Standardization (ECISS).

Organization and Procedures of ECISS

ECISS is not an independent legal entity, but rather an associated body of CEN. This means that the financial support provided by the European Commission and EFTA is received through CEN.

ECISS members are mainly representatives of the iron and steel standards committees from EU and EFTA national standards bodies. Supported by CEN's Central Secretariat (CS), COCOR continues to serve in an advisory capacity.

The former EURONORM committees are now entitled 'Technical Committees' (TC), but they have retained their original functions. Tables 1 and 2 list the various TCs, together with their functions and organization.

One of the former principle activities of ECISS was the adoption of EURONORMs as ENs; unlike the procedure in the past, member countries are now required to adopt these standards – unchanged – at the national level. Today, the major responsibility of ECISS is the development of European Standards on iron and steel products. Table 3 gives an overview of the ECISS procedure for preparing new steel standards. This procedure differs from that for the preparation of EURONORMs in a number of ways:

by a number which is the specified minimum yield strength in N/mm^2 for the smallest thickness range, while in rail steels the R is followed by the specified minimum tensile strength in N/mm^2. An example is given below.

- EN 10025 S185, where the S identifies this material to be a structural steel and 185 specifies the minimum yield strength in N/mm^2.

Steel Names - Group 2

Group 2 steel names are used for steels which are designated according to their chemical composition, and are further divided into four sub-groups depending on alloy content. The first sub-group consists of non alloy steels (except high speed steels) with an average manganese content less than 1 percent. These have names consisting of the letter C followed by a number which is 100 times the specified average percentage carbon content.

The second sub-group includes non alloy steels with an average manganese content equal to or greater than 1 percent, non alloy free-cutting steels, and alloy steels (except high speed steels) where the content by weight of every alloy element is less than 5 percent. For this sub-group, the name consists of a number which is 100 times the specified average percentage carbon content, followed by chemical symbols representing the alloy elements that characterize the steel (in decreasing order of the values of their contents), followed by numbers indicating the values of contents of alloy elements. These latter numbers represent, respectively, the average percentage content of the element indicated, multiplied by a factor which depends on the element, as shown in Table 1.3.

Table 1.3 Alloying Element Factors for Steels

Element	Factor
Cr, Co, Mn, Ni, Si, W	4
Al, Be, Cu, Mo, Nb, Pb, Ta, Ti, V, Zr	10
Ce, N, P, S	100
B	1000

The numbers referring to the different elements are rounded to the nearest integer and separated by hyphens. An example is given as follows.

- EN 10028 Part 2, 13CrMo4-5
  nominally contains 0.13% C, 1% Cr, and 0.5% Mo.

The third sub-group of steel names based on chemical composition applies to alloy steels (except high speed steels) where the content by weight of at least one alloy element is greater than 5 percent. For this category, the name begins with the letter X, followed by a number which is 100 times the specified average percentage carbon content, followed by chemical symbols representing the alloying elements that characterize the steel (in decreasing order of the values of their contents), followed by numbers indicating the values of contents of these alloy elements. Here the number represent, respectively, the average percentage content of the element indicated, rounded to the nearest integer and separated by hyphens. An example is given as follows.

- EN 10088 Part 1, X2CrNi18-9
  nominally contains 0.02% C, 18% Cr, and 9% Ni.

The fourth and final sub-group of steel names based on chemical composition refers to high speed steels. Here the name consists of the letters HS followed by numbers indicating the values of percentage contents of alloy elements indicated in the order tungsten, molybdenum, vanadium, cobalt. Each number represents the average percentage content of the respective element, rounded to the nearest integer, with the numbers referring to the different elements separated by hyphens.

For both Group 1 (specified by application and properties) and Group 2 (specified by composition) steels, if the name as described above is preceded by the letter G then the steel is specified to be a casting.

Steel Numbers

EN 10027 Part 2 describes the system used for assigning steel numbers, which are complementary to the steel names described above. The number consists of a fixed number of digits and is hence more suitable than the name for data processing purposes. The number is of the form 1.XXXX, where the 1. refers to steel; other numbers may be allocated in the future to other industrial materials if this numbering system is expanded. The first two digits following the "1." give the steel group number. Examples for assigning these two digits are shown in Table 1.4. It can be seen that for this purpose, steels are divided into non alloy and alloy steels, with subdivisions into base steels, quality steels and special steels, as defined in the following.

Table 1.4 Examples of Steel Numbers

Non alloy steel		
Base steel	1.00XX - base steels	
Quality steels	1.01XX - general structural steels with $R_m < 500$ N/mm^2	
Special steels	1.11XX - structural, pressure vessel and engineering steels with C < 0.50%	
Alloy steels		
Quality steels	1.08XX - steels with special physical properties	
Special steels		
	Tool steels	1.23XX - Cr-Mo, Cr-Mo-V or Mo-V steels
	Miscelaneous steels	1.35XX - bearing steels
	Stainless and heat resisting steels	1.46XX - chemical resistant and high temperature Ni alloys
	Structural, pressure vessel and engineering steels	1.51XX - Mn-Si or Mn-Cr steels

The final digits in the steel number are assigned sequentially. At present only two digits are used, but provision is made for expansion to a system using four digits in the future if required by an increase in the number of steel grades.

Definition and Classification of Steels - EN 10020

Non Alloy Steels

Steel is the most important group of engineering materials in use today. Steel is defined by EN 10020, Definition and Classification of Steel, as:

> "a material which contains by weight more iron than any other single element, having a carbon content generally less than 2% and containing other elements. A limited number of chromium steels may contain more than 2% of carbon, but 2% is the usual dividing line between steel and casti iron."

The terms *base steels*, *quality steels* and *special steels* as used in the second and third digits of the steel number in EN 10027-2 are quality classes defined by main property or application characteristics. However,

Chapter

2

INTRODUCTION TO THE METALLURGY OF FERROUS MATERIALS

Introduction

The expression *ferrous materials* is used to mean the metallic element iron and the entire range of iron-based metallic alloys. There are a great many different ferrous materials, but they can be divided into three basic categories, namely wrought iron, steel and cast iron.

Wrought iron, which is no longer commercially produced, is a relatively pure iron containing non-metallic slag inclusions. Modern wrought iron products are actually made of low carbon steel.

Steels are iron-based alloys whose most important component element next to iron itself is carbon. The carbon contents of steels are low, usually below 1%, but the presence and amount of carbon in the steel have a major effect on its behavior in service. By far the most common type of steel is plain carbon steel, i.e. steel containing only iron and carbon plus small amounts of manganese and, usually, silicon or aluminum. The manganese, silicon and aluminum are added to compensate for the presence of the impurities sulfur, oxygen and nitrogen. Another important type of steel, the alloy steels, contain in addition to the above-mentioned elements, significant quantities of such elements as chromium, nickel and molybdenum, which distinguishes them from plain carbon steels. A specialized range of alloy steels, known as stainless steels, contain a minimum of 11.5% chromium. Tool steels, the final type to be considered here, are specialized carbon or alloy steels which are capable of functioning under the demanding service conditions associated with the working and shaping of metallic and non-metallic materials into desired forms. Some steel is used in the form of steel castings, but most steel objects are mechanically worked into their final forms and are thus categorized as wrought products.

Cast irons contain much higher carbon and silicon levels than steels, typically 3-5% carbon and 1-3% silicon. These comprise another category of ferrous materials, which are intended to be cast from the liquid state to the final desired shape.

Ferrous alloys dominate the world of construction materials. Their widespread applications are the result of a broad range of desirable material properties combined with favorable economics. Iron is the least expensive of all the metals and the second most abundant in nature.

This chapter supplies an introduction to the metallurgical aspects of ferrous materials, especially steels. Subsequent chapters provide data on many aspects of various ferrous materials. More details relating to the metallurgy of particular products are discussed in introductions to the sections on Carbon and Alloy Steels, Cast Steels, Cast Irons, Tool Steels and Stainless Steels.

Historical Aspects

Iron is one of the seven metals of antiquity, and is associated with the Roman god Mars and the planet of the same name. The first iron to have been used by humanity was probably meteoritic iron; this is readily identifiable because the so-called 'iron' meteorites are in fact iron-nickel alloys containing an average of about 8% nickel. Objects made from meteoritic iron are found among the archaeological artifacts left by many ancient cultures worldwide. Meteoritic iron, the metal from the sky, was used for utilitarian, decorative and ornamental purposes, and in some cases for objects with ceremonial functions.

However, most of the iron found in the archaeological record has been smelted from ores of iron, and the existence of this early material has led to the designation "Iron Age" for a particular stage of the evolution of societies, which began during the second millennium B.C. The first instances of iron smelting are not known, but it is possible that the earliest smelted iron was an inadvertent by-product of copper smelting operations. Here it was sometimes necessary to add iron oxide to the smelting furnace charge as a flux in order to lower the melting temperature of the silicate slag. Overly reducing conditions in the copper smelting furnace could have led to the subsequent reduction of metallic iron from the slag. Certainly smelted iron was in use by about 2000 B.C. and was relatively widespread by 1000 B.C. The original form in which smelted iron was used was wrought iron, a heterogeneous mixture of iron with silicate slag. Wrought iron was produced in bloomery furnaces by the solid state reduction of iron ore to metal, well below the melting temperature of iron. The product of this smelting operation was a bloom,

Heat Treating of Steel - The Effects of Carbon Content and Cooling Rate

The heat treating of steel normally begins with heating into the austentite temperature range and allowing the pre-existing microstructure to transform fully to austenite as required by the phase diagram. This austenitizing process may be carried out in any one of a number of atmospheres including air, inert gas, vacuum or molten salt. The hot austenitic steel is then cooled at some rate ranging from rapid (e.g. thousands of degrees per second by quenching in chilled brine) to slow (e.g. as little as a few degrees per hour by furnace cooling in a hot furnace which is allowed to cool with the steel inside). It is important to remember that the cooling rate is normally not uniform throughout the cross-section of the steel object, particularly at rapid cooling rates. The inside of a thick section can only cool by conducting its heat to the surface, where it is removed into the cooling medium; this is always a relatively slow process. The consequence is that if a thick section of steel is quenched, its surface undergoes a much higher cooling rate than its center, and therefore the surface and the center can have different microstructures and properties. Furthermore there will be residual stresses in the material associated with this situation. These effects can be beneficial or detrimental to the application of the material. However in the following discussion such complications will be avoided by considering only the cooling of a thin section, where it can be assumed that the cooling rate is constant throughout the cross-section.

During cooling the austenite becomes unstable, as predicted by the phase diagram, and decomposes or transforms to form a different microstructure, the characteristics of which depend on the austenitization conditions, the carbon content and the cooling rate. There are also effects due to the presence of other alloying elements as discussed below.

A description will first be given of the effects of slow cooling of hypoeutectoid (e.g. 0.4%C) steel from the temperature range where austenite is stable. Note that a finite austenitization time is required to dissolve all pre-existing carbides and to take all carbon into solid solution; this time depends on the thickness of the steel part and is frequently specified as one hour per inch of thickness. The higher the austenitizing temperature above the A_3 temperature (which for this 0.4%C steel is about 820°C or 1504°F), and the longer the time at the austenitizing temperature, the larger the austenite grain size will become. This austenite grain growth has detrimental effects on mechanical properties, so austenitization is generally carried out no more than 60°C (110°F) above the A_3 temperature.

removing the steel from the furnace and allowing it to cool in the ambient atmosphere. Still higher cooling rates are obtained by quenching the steel, i.e. by removing it from the furnace and immediately immersing it in a cold medium with particular heat transfer characteristics. Common examples, listed in order of increasing cooling rate, include oil quenching, water quenching and brine (salt water) quenching. Alternatively a wide range of chemicals (typically polymers) is available which when added to water permit cooling rates to be controlled over a range from slower than water to faster. Quench media may be subjected to various degrees of agitation, which increases the cooling rate and permits more uniform cooling. A standard scale used to quantify cooling rate is the index of quench severity (called the H value), which has the value 1.0 for still water, as compared to as little as 0.25 for still oil and as much as 5.0 for agitated brine. In general it is desirable to utilize the minimum cooling rate necessary to achieve the desired microstructure, as more rapid cooling increases the magnitude of the residual stresses left in the quenched component, with consequent increased probability of distortion or cracking (quench cracking).

Several effects of increased cooling rate on the formation of ferrite-pearlite microstructures have already been alluded to, namely the different morphologies of proeutectoid ferrite, and the increasing fineness of the pearlite. However if cooling rates are increased still further, the limited time available during cooling is insufficient to permit the atom diffusion which is necessary for pearlite to form. As a result, microstructural constituents other than pearlite form when the austenite, which has become unstable below the A_1 temperature, transforms. These transformation products, including bainite and martensite, are non-equilibrium constituents which are therefore not present on the (equilibrium) phase diagram. Their formation occurs by processes which rely only partially (bainite), or alternatively not at all (martensite), on the diffusion of atoms. Thus martensite and bainite are able to form even at rapid cooling rates.

Bainite Formation

Bainite is a constituent which forms from austenite in a temperature range below about 535°C (1000°F) and above a critical temperature (the M_s temperature, discussed below) which depends on carbon content and is about 275°C (525°F) for eutectoid steel. Bainite forms together with pearlite in steels which are cooled somewhat too rapidly to permit full transformation to pearlite. Bainite is, like pearlite, a mixture of ferrite and iron carbide, but its morphology is different from that of pearlite, as its formation involves both atomic diffusion and a diffusionless shuffle of atoms referred to as shear. This latter characteristic enables bainite to

form at cooling rates faster than the maximum at which pearlite can form. Furthermore the details of bainite formation depend strongly on the temperature at which the austenite transforms. At transformation temperatures in the upper part of the bainite formation range, upper bainite is formed. This is a rather feathery-appearing microstructural constituent, in contrast to lower bainite which forms at lower temperatures and is finer and more lenticular (lens-shaped). The distinction between upper and lower bainite is significant, and they can differ appreciably in mechanical properties. For the most part, a steel with a bainitic microstructure is harder, stronger and tougher at low temperatures than steels with ferrite-pearlite or fully pearlitic microstructures and equivalent carbon content. Unfortunately it can be extremely difficult to distinguish a steel microstructure as upper or lower bainite using the optical microscope, or to distinguish upper bainite from fine pearlite or lower bainite from martensite, a phase which will be discussed at length below. Examination using the electron microscope is needed to fully characterize bainites.

Martensite Formation

If austenite can be cooled to a sufficiently low temperature, for example by cooling very rapidly, its diffusion-controlled transformation to ferrite, pearlite or even bainite will not be possible. Instead, the austenite becomes so unstable that it is able to change its crystal structure by a diffusionless shearing transformation which moves blocks of atoms by small distances simultaneously. The transformation product is then *martensite*, a metastable phase which, like bainite, does not appear on the phase diagram since it does not exist under equilibrium conditions. The martensite structure is basically the result of the steel's attempt to transform from austenite (fcc) to ferrite (bcc), a process which is prevented by the presence in the austenite of a large amount of carbon, an amount far above the very low solubility limit of carbon in ferrite. This large supersaturation of carbon prevents a true bcc structure from forming so that the martensite is therefore a compromise structure. It can be thought of as a bcc structure which is highly distorted to accommodate the presence of the excessive amounts of carbon which are trapped at interstitial sites within the martensite structure. As a result, martensite possesses a crystal structure which is body-centered but not cubic; it is rather a body-centered tetragonal (bct) structure as shown in Fig. 2.9.

increase their strengths (by increasing the amount of carbide present) and hardenabilities, while ductility, toughness, workability, weldability and machinability are reduced.

Manganese is normally present in all commercial steels. It combines with sulfur impurities to form particles of manganese sulfide (or iron-manganese sulfide), thereby avoiding the possibility of the formation of the detrimental iron sulfide phase (iron sulfides are brittle, and furthermore they melt at low temperatures causing the steel to be hot short). Manganese is an austenite stabilizer and it is not a strong carbide former. It contributes to strength by solution strengthening the ferrite and refining the pearlite. Another major role of manganese is in strongly increasing hardenability, especially when present in amounts greater than 0.8%. It also acts a deoxidizer, and oxygen is frequently present in its sulfides which are then referred to as oxysulfides.

Manganese contents much in excess of 2% tend to severely embrittle steel, however high carbon austenitic steels containing about 12%Mn display toughness combined with a high work-hardening rate, which make them useful industrial alloys for wear resistant applications, especially when the wear is accompanied by impact loading. These alloys, known as Hadfield's Manganese Steels, find applications in the mining industry (e.g. jaw crushers) and in severe service rail applications.

Silicon is present in all steels in minor amounts. It is a ferrite stabilizer, and is not a carbide former, but dissolves in the ferrite. Its major role is as a deoxidizer, since it combines readily with dissolved oxygen in molten steel to form silicates. This removes the possibility of porosity (blow holes) upon subsequent solidification, ensuring the production of dense sound steel. In cast irons the presence of silicon promotes graphite formation and provides resistance to attack by corrosive acids.

Silicon is added to steels designed for electrical and magnetic applications such as motors and transformers since it reduces eddy current losses in alternating current magnetization. It is also added to nickel-chromium-manganese steels where it increases strength and toughness. It increases hardenability especially in high carbon steels, and improves the castability of steels.

Sulfur is almost always a deleterious impurity in steels. It segregates strongly in steel castings and ingots, and degrades surface quality. It tends to combine with iron to form iron sulfides which are hard and have low melting points, hence they cause cracking during both hot and cold working. Thus the presence of sulfur in steel must be compensated for by additions of manganese or other strong sulfide-forming elements such as

to martensite. The advantage of martempering is that the martensite formation occurs during the relatively slow air cooling rather than during a rapid quench, thus the severe temperature gradients which are responsible for the high residual stresses in conventionally quenched martensite are eliminated.

Surface Hardening

For wear-resistance and other specialized applications it can be desirable to have a steel with a high hardness layer (case) on the surface of a high toughness base material (core). This can be accomplished with or without the case and core having different chemical compositions. If the chemical compositions of the case and core are the same, heat treatment is carried out so as to obtain different case and core microstructures. Typically, a high toughness core is first obtained by normalizing or quenching and tempering. This material is then subjected to localized intense surface heating so that only the surface layer becomes hot enough to form austenite, and the steel is then cooled rapidly so that the case transforms to martensite without the core having been markedly affected. The surface heating techniques include the direct impingement of a flame (*flame hardening*), surface heating by a high-frequency induction coil (*induction hardening*) or heating by high intensity light sources. Alternatively, laser beams can be used, especially for hardening of localized surface regions (*laser hardening*).

Processes in which the chemical composition of the surface is changed in order to permit the surface to be given a high hardness are known collectively as *case-hardening* processes. These involve the addition of either or both of the elements carbon and nitrogen, leading to the specific processes carburizing, nitriding and carbonitriding. The processes themselves involve the diffusion of carbon and/or nitrogen into the surface of the steel at high temperature.

In *carburizing* and *carbonitriding*, the material is subjected to a quench after the surface composition is changed so that a surface layer of martensite is formed in the high carbon, high hardenability surface while the low carbon, low hardenability case transforms to a tougher ferrite-pearlite microstructure. Carburizing has the advantage over the previously described surface hardening heat treatments in that the hardness of martensite is directly related to its carbon content, so carburizing provides a harder surface layer.

Several different industrial processes are utilized for these purposes. *Pack carburizing* consists of sealing the steel in a box along with carbonaceous solids and heating externally to permit carbon to diffuse

The ASTM grain size number corresponds to a certain number of grains per unit area of the image at the specified magnification, as shown in Table 2.1.

Table 2.1 ASTM No, Grains/in^2, grains/mm^2

ASTM No.	Grains/in^2 at 100X	grains/mm^2 at 1X
0	0.5	8
1	1	16
2	2	31
3	4	62
4	8	124
5	16	248
6	32	496
7	64	992
8	128	1980
9	256	3970
10	512	7940
11	1024	15,870
12	2048	31,700

The relationships between the grain size number and the number of grains per unit area are given by the expressions:

$$N=2^{(n-1)}$$

where N= number of grains per square inch at 100X magnification, and n = ASTM grain size number, or, for SI units, and

$$N = 2^{(n+3)}$$

where N = number of grains per square millimeter (at 1X magnification), and n = ASTM grain size number (BS4490:1969).

In the Planimetric (Jeffries') Procedure a known area is inscribed in the observed field, and the grains within this area (minimum 50) are counted (including half the number of grains which intersect the perimeter of the field) and multiplied by Jeffries' multiplier. The product is the number of grains per square millimeter.

The Intercept Method has two procedures, the lineal (Heyn) procedure and the circular procedure. Both involve placing a grid pattern on the field of observation, and counting the number of grains at each grid intercept within a selected area.

Chapter 3

WROUGHT NON ALLOY & ALLOY STEEL METALLURGY

Non alloy and alloy steels are classified in a wide variety of ways within CEN specifications. Most common is designation by steel names and principal symbols as in EN 10027-1, and by steel numbers as in EN 10027-2. Additionally, steel definitions and classifications can be found in EN 10020, whereas the definition of steel products are found in EN 10079. Other bases for classification include the manufacturing method (e.g. basic oxygen furnace or electric furnace), the finishing method (hot rolling, cold rolling, etc.), the product form (bar, sheet, etc.), the deoxidation practice (rimmed, capped, semi-killed, killed), the microstructure (ferritic, pearlitic, martensitic), the heat treatment (annealed, normalized, quenched and tempered). Details describing the CEN metal designation systems are given in Chapter 1.

Non Alloy Steels

In this discussion, non alloy steels will be considered in four categories, namely low carbon steels (sheet, and heat treatable steels of low carbon content 0.10 to 0.30%C), medium carbon steels (0.30 to 0.60%C) and high carbon steels (more than 0.60%C). These categories correspond approximately to divisions into non-heat treatable (the low carbon steels) and heat treatable (the higher carbon steels) categories, referring to their abilities to respond to quench and temper heat treatments. Non alloy steels represent well over three quarters of steel production.

These steels can be further divided in groups by the amount of deoxidation they receive during the last stage of the steelmaking process, since liquid steel in the steelmaking furnace typically contains 400 to 800 ppm of oxygen. Deoxidation is performed by adding into the ladle measured amounts of ferromanganese, ferrosilicon and/or aluminum. The four deoxidation groups of carbon steel are: rimmed steel, capped steel, semi-killed steel, and fully-killed steel.

Chapter 4

CAST STEEL METALLURGY

Steel castings are produced by allowing molten steel to solidify in molds which are appropriately formed so that the solidified steel has a desired shape. Molds suitable for steel castings can be made from metal, ceramic, graphite, or any of a wide variety of types of sand, the choice of mold material being determined by the size, intricacy, surface finish and dimensional accuracy of the casting as well as cost. Castings are made in approximately the same steel compositions that are available as wrought products, and the properties can be expected to be similar, although the mechanical properties of castings are generally less directional. Castings are however susceptible to internal defects and surface imperfections, which can have a potentially serious effect on service performance.

In general, castings are made using fully-killed steel, most often aluminum-killed. Steel castings normally have sulfur and phosphorus limits of 0.06% and 0.05% respectively, slightly higher than those of wrought steels, and they also contain 0.30 to 0.65% silicon and 0.50 to 1.0% manganese. Steel castings are heat treated in much the same manner as are wrought products.

Castings are available in low, medium and high carbon steel as well as in low alloy steel. Low carbon cast steels typically contain between 0.16 and 0.19%C, and are typically either annealed or normalized after casting to refine the structure and relieve residual stresses. Some are quenched and tempered, and some are carburized for wear resistance. Free machining grades contain 0.08 to 0.30% sulfur. Applications include automotive and railway castings as well as furnace components and castings for electrical and magnetic equipment.

Medium carbon grades (0.20 to 0.50%C) are the most commonly produced cast steels. These are heat treated, typically by normalizing and tempering, to produce the desired mechanical properties, but this heat treatment also serves to relieve internal stresses and to refine the microstructure. Alternatively, quench and temper treatments can be used for maximum mechanical properties.

High carbon cast steels are most often heat treated by full annealing, but can be normalized and tempered or oil quenched and tempered.

Low alloy cast steels are utilized when higher strength requirements must be met, but there are other reasons why alloy steels are selected, including improved hardenability, wear resistance, impact resistance, machinability, strength at high or low temperatures, and resistance to oxidation or corrosion. Low alloy cast steels find applications in machine tools, steam turbines, valves and fittings, and in the transportation, excavating and chemical process industries.

Steel castings are produced in sizes varying from a few ounces to hundreds of tons. While only about two percent of total steel production is in the form of castings, many objects can be made much more readily by casting than by other processes such as mechanical working. This is true, for example, of turbine shells and diaphragms, valve bodies, exhaust manifolds and pump casings.

Chapter 5

CAST IRON METALLURGY

Cast irons are ferrous alloys which contain carbon contents in the 2-5% range, well above the normal carbon contents of steels. The other critical alloying element in cast irons is silicon, which is present at concentrations between 1 and 3%. Further alloying elements can be added as required to control specific properties such as resistance to abrasion, wear and corrosion. Like steels, perhaps to an even greater extent, the microstructures and properties of cast irons are determined not only by composition but also by the specific processing conditions which include the solidification process, the solidification rate, the cooling rate in the solid state, and the subsequent heat treating schedules.

The main applications of cast irons arise from a combination of their relatively low cost and wide ranges of properties. Their relatively low melting temperatures compared to steel permit lower cost casting processes and their compositions are such that sound and intricate castings can be obtained. Six basic types of cast iron are produced, namely grey cast iron (grey iron), white cast iron (white iron), ductile (nodular) cast iron, malleable cast iron, compacted graphite cast iron and high alloy cast iron. These cannot be clearly distinguished solely on the basis of chemical composition, since the thermal processing is at least as important as the composition in determining the type of cast iron produced. This is illustrated in Fig. 5.1, which shows the ranges of silicon and iron content for the first four types.

One feature of cast irons which is not encountered to a significant extent in steels is the presence of graphite in the microstructure. In carbon steels the carbon is mainly in the form of cementite (iron carbide) with only a small amount in solution in the ferrite. However, in cast irons (other than white iron) some or all of the carbon is in elemental form as graphite, the balance being mainly as iron carbide. The presence of particular alloying elements in iron stabilizes graphite at the expense of iron carbide, the most important of these graphite stabilizers being silicon and carbon (other less common ones include nickel, aluminum, copper, titanium and zirconium). Thus the higher the silicon and carbon

contents, the more likely it is that graphite will form during a given heat treatment. Long holding time at high temperature and slow cooling also favor graphite formation, whereas more rapid cooling and the presence of such elements as manganese, sulfur and chromium stabilize the cementite phase at the expense of graphite (as do molybdenum, tungsten and vanadium). It is clear that a combination of chemical composition and thermal treatment determines the balance between graphite and carbide in a given cast iron.

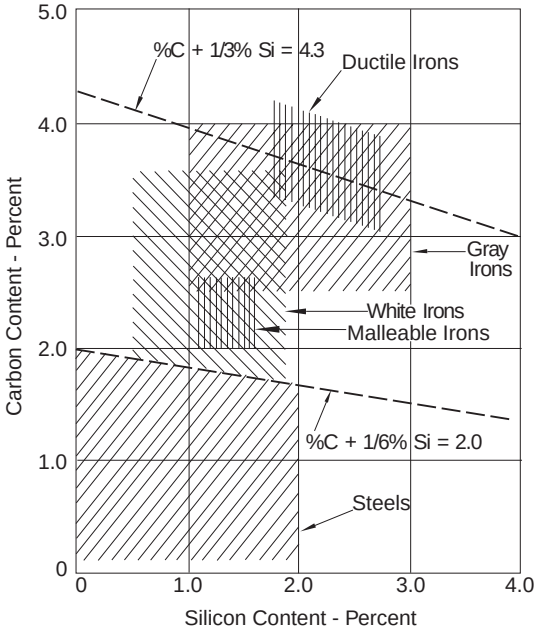


Figure 5.1 Showing the silicon and iron content of cast irons.

In Chapter 1 of this book attention was given to explaining equilibrium phase diagrams and their use in predicting the microstructures which would be present in an alloy of given composition which had been slowly cooled. Thus Fig. 2.4 might be expected to be useful for slowly cooled cast irons, however the presence of silicon modifies the situation in a number of important respects. One effect of silicon is to cause equilibrium eutectic solidification to occur over a narrow range of temperatures, unlike the case in the Fe-Fe_3C system where it occurs at one fixed temperature. In a similar manner it causes the eutectoid point of the Fe-Fe_3C system to become a narrow range of temperatures. This is shown in Fig. 5.2, which is an equilibrium phase diagram for the Fe-C system at a constant silicon content of 2%. The important region of this diagram for cast irons is the 2-5% carbon region, and here the most striking feature is the presence of

Grey iron is normally used in the as-cast condition, but occasionally is stress relieved or annealed. Grey irons are heat treatable by oil quenching and tempering although this is not normal practice.

Grey iron is a very versatile material as a result of not only its favorable economics but also its range of properties and is classified according to EN 1561. It has good strength in compression, where the presence of the graphite flakes does not cause premature failure as is the case in tension. On average, a grey iron with a tensile strength of approximately 140 N/mm^2 will have a compressive strength of about 550 N/mm^2. Grey iron has good capability to damp vibrations and sound as a result of the presence of the graphite flakes which attenuate elastic waves in the iron structure. The graphite flakes also act as chip breakers, lubricants and oil reservoirs giving grey cast iron excellent machinability as well as the ability to resist sliding friction and galling. Its fluidity in the liquid state permits it to be cast to intricate shapes including thin sections.

Grey iron finds countless applications in many industries, including the automotive and machine tool industries and in general engineering use. Low strength grades are commonly used as brake drums and clutch plates as well as ingot molds, taking advantage of their superior resistance to heat checking. Low strength grey iron is also used in machine tools and other components subject to vibrations, as the lower strength material is more effective in damping vibrations. Furthermore both the machinability and the ability to be cast in thin sections are better in the lower strength classes. Properties which increase with increasing strength class include not only strength but also stiffness, wear resistance and the ability to be machined to a fine finish. Higher strength grey iron castings are used for heavy duty diesel engine blocks, heads and cylinder liners, gearboxes, pistons and flywheels.

White Iron

White irons contain no graphite; here virtually all the carbon is in the form of the hard brittle iron carbide, Fe_3C. The solidification process in these (hypoeutectic) irons begins with the formation of primary austenite, followed by the eutectic solidification reaction to form ledeburite, the lamellar austenite-cementite eutectic constituent. This process can be assisted by the use of inoculants, the carbide stabilizing elements tellurium, bismuth and sometimes vanadium.

After solidification the cooling austenite rejects carbon as the solubility of carbon falls along the A_{cm} line; this carbon is taken up by growth of the eutectic cementite. Then, in the eutectoid temperature range the remaining austenite transforms to ferrite and cementite, normally by

Ductile Iron

Ductile Iron is also commonly known as *nodular cast iron, spheroidal graphite cast iron* and in Britain as *spherulitic graphite (SG) iron* although the accepted international term is ductile iron. Specifications include EN 1563 - Spheroidal Graphite Cast Irons and EN 1564 - Austempered Ductile Cast Iron. This material contains graphite in the form of spheroids, rather than in the flake form which is present in grey irons. It is not the presence of graphite but its flake morphology which is responsible for the brittleness and low tensile strength of grey iron, whereas many of the beneficial effects that graphite imparts are not strongly dependent on its morphology, and are maintained in ductile iron. Thus ductile iron has a good range of yield strength, ductility, toughness and hot workability as well as excellent fluidity, castability, machinability and wear resistance. It combines the processing advantages of grey cast iron with the engineering advantages of steel. As a result ductile iron has found a steadily increasing range of applications, notably in the automotive, railroad and agricultural industries, since it was introduced in the late 1940s.

Ductile iron has composition similar to that of the higher carbon grey irons but with low levels of sulfur and phosphorus. The reason why graphite forms as flakes in grey iron is that impurities, notably sulfur and oxygen, poison the growth of graphite in the liquid iron. The graphite would normally grow as spheroids but this poisoning inhibits the growth on particular planes in the graphite crystals so that they are forced to grow as flakes. In order to produce ductile iron, not only is the impurity content kept low but also the liquid iron is treated with small amounts of magnesium or cerium just prior to casting. These elements tie up the sulfur and oxygen in the liquid iron and prevent them from poisoning the graphite growth. The result is that graphite forms with a spheroidal (nodular) morphology. The amount of nodularizing inoculant, typically a nickel-magnesium alloy, which is added to the liquid iron is carefully controlled. It is desirable that the liquid iron take up a small amount of residual magnesium in excess of that required to tie up all the sulfur. The amount of magnesium inoculant required is thus:

$$Mg_{added} = \frac{0.75S_{in} + Mg_{residual}}{\eta}$$

where S_{in} is the initial sulfur level and η is the fractional recovery of magnesium in the particular inoculation process used. The optimum amount of residual magnesium required for the formation of spheroidal graphite is 0.03-0.05%, the precise value depending on cooling rate (less

Chapter 6

METALLURICAL TERMS DEFINITIONS & GLOSSARY

English/French Definitions

A

A_1 temperature. The eutectoid temperature of a steel.
température A_1. La température eutectoïde d'un acier.

A_2 temperature. Curie temperature, where bcc iron upon reaching this temperature, 1420°F (770°C), becomes nonmagnetic.
température A_2. La température de Curie, température à laquelle le fer bcc, lorsqu'atteignant cette température, 1420°F (770°C), devient non magnétique.

A_3 temperature. The temperature at which proeutectoid ferrite begins to separate from austenite under conditions of slow cooling.
température A_3. La température à laquelle la ferrite proeutectoïde commence à se séparer de l'austénite sous des conditions de refroidissement lent.

A_{cm} temperature. The temperature at which proeutectoid cementite begins to separate from austenite under conditions of slow cooling.
température A_{cm}. La température à laquelle la cémentite proeutectoïde commence à se séparer de l'austénite sous des conditions de refroidissement lent.

abrasion. The process of grinding or wearing away using abrasives.
abrasion. Le procédé consistant à moudre ou à user en utilisant des abrasifs.

abrasive. A substance capable of grinding away another material.

procédé Waloon. Un procédé ancien à deux soles de fabrication du fer corroyé par raffinage de la fonte de moulage. La conversion propre était effectuée dans un four à sole appelé affinerie; le re-chauffage pour le forgeage était effectué dans un second four à sole appelé chaferie.

weld. A union made by welding.
soudure. Un joint fait par soudage.

weld bead. A deposit of filler metal from a single welding pass.
cordon de soudure. Un dépôt de métal d'apport en une passe unique de soudage.

weldability. Suitability of a metal for welding under specific conditions.
soudabilité. Aptitude d'un métal à être soudé sous des conditions spécifiques.

welding. Joining two or more pieces of material by applying heat or pressure, or both, with or without filler metal, to produce a localized union through fusion or recrystallization across the interface.
soudage. Joindre deux ou plusieurs pièces de matériau en appliquant de la chaleur ou de la pression, ou les deux, avec ou sans métal d'apport, produisant un joint localisé par la fusion ou la recristallisation à travers l'interface.

wetting agent. A surface-active agent that produces wetting by decreasing the cohesion within the liquid.
agent mouillant. Un agent à action de surface qui produit le mouillage en diminuant la cohésion à l'intérieur du liquide.

Widmanstatten structure. A structure characterized by a geometric pattern resulting from the formation of a new phase on certain crystallographic planes in the parent phase. The orientation of the lattice in the new phase is related crystallographically to the orientation of the lattice in the parent phase.
structure de Widmannstätten. Une structure caractérisée par un motif géométrique résultant de la formation d'une nouvelle phase sur certains plans cristallographiques de la phase parente. L'orientation du réseau de la nouvelle phase est reliée cristallographiquement à l'orientation du réseau de la phase parente.

wootz. A carbon steel containing 1 to 1.6% C produced by melting a bloomery iron or an inhomogeneous steel with charcoal in a crucible. The process originated in India as early as the 3rd century A.D.

GLOSSARY / LEXIQUE / LÉXICO / WÖRTERVERZEICHNIS			
ENGLISH	**FRENCH**	**SPANISH**	**GERMAN**
A_1 temperature	température A_1	temperatura A_1	A_1 Temperatur
A_2 temperature	température A_2	temperatura A_2	A_2 Temperatur
A_3 temperature	température A_3	temperatura A_3	A_3 Temperatur
A_{cm} temperature	température A_{cm}	temperatura A_{cm}	A_{cm} Temperatur
abrasion	abrasion	abrasión	Schleifwirkung; Abnutzung
abrasive	abrasif	abrasivo	Schleifmittel; Abriebeigenschaften
age hardening	durcissement par vieillissement	endurecimiento por envejecimiento	Aushärtung; Vergütung
aging	vieillissement	envejecimiento	Alterung
allotriomorph	allotriomorphe	allotriomorfico	Allotriomorph
allotropy	allotropie	allotropía	Allotropie
alloy	alliage	aleación	Legierung
alloy steel	acier allié	acero aleado	legierter Stahl
alloying element	élément d'alliage	elemento de aleación	Legierungselement
angstrom unit (A)	unité angström (Å)	unidad angstrom (Å)	Ångström (Å)
annealing	recuit	recocido	Glühen
annealing twin	macle de recuit	macla por recocido	Rekristallisationszwilling
arc welding	soudage à l'arc	soldadura por arco	Lichtbogenschweißen
artifact	artefact	artefacto	künstlich
austempering	trempe étagée bainitique	atemperación escalonada (tratamiento con transformación isotérmica de austenita a bainita)	Zwischenstufen-Vergütung
austenite	austénite	austenita	Austenit
austenitic grain size	grosseur de grain austénitique	dimensión de grano austenítico	Austenitkorngröße
austenitizing	austénitisation	austenización	Austenitisieren
autoradiograph	autoradiographie	autorradiografía	Autoradiographie

GLOSSARY / LEXIQUE / LÉXICO / WÖRTERVERZEICHNIS			
ENGLISH	**FRENCH**	**SPANISH**	**GERMAN**
autotempering	auto-revenu	autorevenido	Autoanlaßen
bainite	bainite	bainita	Bainit
bamboo grain structure	structure de grain en bambou	estructura de grano de bambú	Bambus Kornstruktur
banding	bande	bandas	Zeilenbildung
billet	billette (ou larget)	palanquilla	Walzblock; Barren; Knüppel
blister steel	acier comportant des soufflures (ou “pailles”)	acero ampollado	Zement[ations]stahl
bloom	bloom (brame)	bloom; desbaste	Vorblock; Schmiedeblock; Blume
bloomery	bloomerie	planta para fabricar desbastes	Rennherd
box annealing	recuit en caisse	recocido en caja	Kistenglühen
braze welding	soudo-brasage	soldadura con metal amarillo	Schweißlötung
brazing	brasage	soldadura amarilla	Löten; Hartlöten
brittle fracture	rupture fragile	fractura frágil	Sprödbruch
brittleness	fragilité	fragilidad	Sprödigkeit
buffer	tampon	regulador; amortiguador	Pufferschicht
burning	brûlure	quemado	Verbrennung
capped steel	acier coiffé	acero efervescente	gedeckelter Stahl
carbide	carbure	carburo	Carbid
carbon equivalent (for rating of weldability)	équivalent carbone (pour estimer la soudabilité)	carbono equivalente	Kohlenstoffäquivalent (für Schweißbarkeit Schätzung)
carbon potential	potentiel carbone	potencial de carbono	Kohlenstoffpegel, C-Pegel
carbon restoration	traitement de recarburation	tratamiento de recementación	Wiederaufkohlung
carbon steel	acier au carbone	acero al carbono	unlegierter Stahl
carbonitriding	carbonitruration	carbonitruración	Karbonitrieren
carburizing	cémentation	cementación; carburación	Aufkohlen
case	couche superficielle traitée	capa superficial	Einsatz[härte]schicht

LÉXICO / GLOSSARY / LEXIQUE / WÖRTERVERZEICHNIS			
SPANISH	**ENGLISH**	**FRENCH**	**GERMAN**
idiomorfo	idiomorph	idiomorphe	idiomorph
impresión de azufre	sulfur print	empreinte de soufre (empreinte Baumann	Baumannabdruck
impurezas	impurities	impuretés	Unreinheit; Verunreinigung
inclusión	inclusion	inclusion	Einschluß
intercristalina	intercrystalline	intercristalline	interkristallin
intracristalina	intracrystalline	intragranulaire	intrakristallin
intracristalina	transgranular	intragranulaire	Transkristallin
limite de fluencia superior	upper yield stress	limite supérieure d'élasticité	obere Streckgrenze
laminación	rolling	laminage	Walzen; Rollen
laminación transversal	cross rolling	laminage avec cylindres obliques	schrägwalzen
laminado controlado	controlled rolling	laminage contrôlé	Regelrollen
laminado de endurecimiento	temper rolling	laminage de revenu	Nachwalzen; Dressieren
laminado en paquete	pack rolling	laminage en paquet	Paketwalzen
licuación; segregación	liquation	liquation	Seigerung
licuefacción de los límites de los granos	grain-boundary liquation	liquation de joint de grain	Korngrenzenangriff; Korngrenzeseigerung
límite aparente de elasticidad	yield point	limite d'écoulement	Fliesspunkt
límite de elasticidad	elastic limit	limite d'élasticité	Elastizitätsgrenze
línea de deslizamiento	slip line	ligne de glissement	Gleitlinie
línea de líquido	liquidus	liquidus	Liquidus
líneas de fluencia; líneas de Piobert-Lüders; líneas de flujo	flow lines	lignes d'écoulement (lignes de Piobert-Lüders)	Fließlinien; Schlieren
líneas o bandas de Lüder	Luder's lines or bands	lignes ou bandes de Lüder	Fließfiguren; Fließlinien; Lüderssche Linien
lingote	ingot	lingot	Blockmetall; Massel

Chapter 7

EUROPEAN (EN) FERROUS SPECIFICATION DESIGNATIONS AND TITLES

SPECIFICATION	TITLE
EN 39:2001	Loose steel tubes for tube and coupler scaffolds. Technical delivery conditions
	Tubes libres en acier pour échafaudages à tubes et raccords - Conditions techniques de livraison
	Systemunabhängige Stahlrohre für die Verwendung in Trag- und Arbeitsgerüsten - Technische Lieferbedingungen
EN ISO 377:1997	Steel and steel products - Location and preparation of samples and test pieces for mechanical testing (ISO 377:1997)
	Acier et produits en acier - Position et préparation des échantillons et éprouvettes pour essais mécaniques (ISO 377:1997)
	Stahl und Stahlerzeugnisse - Lage und Vorbereitung von Probenabschnitten und Proben für mechanische Prüfungen (ISO 377:1997)
EN 523:1997	Steel strip sheaths for prestressing tendons - Terminology, requirements, quality control
	Gaines en feuillard d'acier pour câbles de précontrainte - Terminologie, prescriptions, contrôle de qualité
	Hüllrohre aus Bandstahl für Spannglieder - Begriffe, Anforderungen, Güteüberwachung
EN 524-1:1997	Steel strip sheaths for prestressing tendons - Test methods - Part 1: Determination of shape and dimensions
	Gaines en feuillard d'acier pour câbles de précontrainte - Méthodes d'essai - Partie 1: Détermination de la forme et des dimensions
	Hüllrohre aus Bandstahl für Spannglieder - Prüfverfahren - Teil 1: Ermittlung der Formen und Maße
EN 524-2:1997	Steel strip sheaths for prestressing tendons - Test methods - Part 2: Determination of flexural behaviour
	Gaines en feuillard d'acier pour câbles de précontrainte - Méthodes d'essai - Partie 2: Détermination du comportement à la flexion
	Hüllrohre aus Bandstahl für Spannglieder - Prüfverfahren - Teil 2: Bestimmung des Biegeverhaltens
EN 524-3:1997	Steel strip sheaths for prestressing tendons - Test methods - Part 3: To-and-fro bending test
	Gaines en feuillard d'acier pour câbles de précontrainte - Méthodes d'essai - Partie 3: Essai de flexion dans les deux sens
	Hüllrohre aus Bandstahl für Spannglieder - Prüfverfahren - Teil 3: Hin- und Herbiegeversuch
EN 524-4:1997	Steel strip sheaths for prestressing tendons - Test methods - Part 4: Determination of lateral load resistance
EN 524-5:1997	Steel strip sheaths for prestressing tendons - Test methods - Part 5: Determination of tensile load resistance
	Gaines en feuillard d'acier pour câbles de précontrainte - Méthodes d'essai - Partie 5: Détermination de la résistance à la traction
	Hüllrohre aus Bandstahl für Spannglieder - Prüfverfahren - Teil 5: Bestimmung der Zugbelastbarkeit
EN 524-6:1997	Steel strip sheaths for prestressing tendons - Test methods - Part 6: Determination of leaktightness (Determination of water loss)
	Gaines en feuillard d'acier pour câbles de précontrainte - Méthodes d'essai - Partie 6: Détermination de l'étanchéité (Détermination des pertes en eau)
	Hüllrohre aus Bandstahl für Spannglieder - Prüfverfahren - Teil 6: Bestimmung der Dichtheit (Bestimmung des Wasserverlustes)

SPECIFICATION	TITLE (Continued)
EN ISO 945:1994	Cast iron - Designation of microstructure of graphite (ISO 945:1975)
	Fonte - Désignation de la microstructure du graphite (ISO 945:1975)
	Gußeisen - Bestimmung der Mikrostruktur von Graphit (ISO 945:1975)
ENV 1090-2:1998	Execution of steel structures - Part 2: Supplementary rules for cold formed thin gauge components and sheeting
	Exécution des structures en acier - Partie 2: Règles supplémentaires pour les bacs nervurés et les éléments minces formés à froid
	Ausführung von Tragwerken aus Stahl - Teil 2: Ergänzende Regeln für kaltgeformte dünnwandige Bauteile und Bleche
EN 1371-1:1997	Founding - Liquid penetrant inspection - Part 1: Sand, gravity die and low pressure die castings
	Fonderie - Contrôle par ressuage - Partie 1: Pièces moulées au sable, en coquille, par gravité et basse pression
	Gießereiwesen - Eindringprüfung - Teil 1: Sand-, Schwerkraftkokillen- und Niederdruckkokillengußstücke
EN 1371-2:1998	Founding - Liquid penetrant inspection - Part 2: Investment castings
	Fonderie - Contrôle par ressuage - Partie 2: Pièces en moulage de précision (cire perdue)
	Gießereiwesen - Eindringprüfung - Teil 2: Feingußstücke
EN 1559-3:1997	Founding - Technical conditions of delivery - Part 3: Additional requirements for iron castings
	Fonderie - Conditions techniques de fourniture - Partie 3: Spécifications complémentaires pour les pièces moulées en fonte
	Gießereiwesen - Technische Lieferbedingungen - Teil 3: Zusätzliche Anforderungen an Eisengußstücke
EN 1560:1997	Founding - Designation system for cast iron - Material symbols and material numbers
	Fonderie - Système de désignation pour la fonte - Désignation symbolique et numérique
	Gießereiwesen - Bezeichnungssystem für Gußeisen - Werkstoffkurzzeichen und Werkstoffnummern
EN 1561:1997	Founding - Grey cast irons
	Fonderie - Fonte à graphite lamellaire
	Gießereiwesen - Gußeisen mit Lamellengraphit
EN 1562:1997	Founding - Malleable cast irons
	Fonderie - Fonte malléable
	Gießereiwesen - Temperguß
EN 1563:1997	Founding - Spheroidal graphite cast irons
	Fonderie - Fonte à graphite sphéroïdal
	Gießereiwesen - Gußeisen mit Kugelgraphit

SPECIFICATION	TITLE (Continued)
EN 10223-2:1997	Steel wire and wire products for fences - Part 2: Hexagonal steel wire netting for agricultural, insulation, and fencing purposes
	Fils et produits tréfilés en acier pour clôtures - Partie 2: Grillage à mailles hexagonales, en acier, utilisé dans l'agriculture, l'isolation et les clôtures
	Stahldraht und Drahterzeugnisse für Zäune - Teil 2: Stahldrahtgeflecht mit sechseckigen Maschen für landwirtschaftliche Zwecke, Isolierungen und Zäune
EN 10223-3:1997	Steel wire and wire products for fences - Part 3: Hexagonal steel wire netting for engineering purposes
	Fils et produits tréfilés en acier pour clôtures - Partie 3: Grillage à mailles hexagonales, en acier, pour applications industrielles
	Stahldraht und Drahterzeugnisse für Zäune - Teil 3: Stahldrahtgeflecht mit sechseckigen Maschen für bauwirtschaftliche Zwecke
EN 10223-4:1998	Steel wire and wire products for fences - Part 4: Steel wire welded mesh fencing
	Fils et produits tréfilés en acier pour clôtures et grillages - Partie 4: Grillage en acier soudé
	Stahldraht und Erzeugnisse aus Stahldraht für Zäune - Teil 4: Geschweißte Gitter aus Stahldraht für Zäune
EN 10223-5:1998	Steel wire and wire products for fences - Part 5: Steel wire woven hinged joint and knotted mesh fencing
	Fils et produits tréfilés en acier pour clôtures et grillages - Partie 5: Grillage noué en acier pour le bétail
	Stahldraht und Erzeugnisse aus Stahldraht für Zäune - Teil 5: Gelenk- und Knotengitter aus Stahldraht für Zäune
EN 10223-6:1998	Steel wire and wire products for fences - Part 6: Steel wire chain link fencing
	Fils et produits tréfilés en acier pour clôtures et grillages - Partie 6: Grillage à simple torsion
	Stahldraht und Erzeugnisse aus Stahldraht für Zäune - Teil 6: Stahldrahtgeflecht mit viereckigen Maschen
EN 10228-2:1998	Non-destructive testing of steel forgings - Part 2: Penetrant testing
	Essais non destructifs des pièces forgées en acier - Partie 2: Contrôle par ressuage
	Zerstörungsfreie Prüfung von Schmiedestücken aus Stahl - Teil 2: Eindringprüfung
EN 10228-3:1998	Non-destructive testing of steel forgings - Part 3: Ultrasonic testing of ferritic or martensitic steel forgings
	Essais non destructifs des pièces forgées en acier - Partie 3: Contrôle par ultrasons des pièces forgées en aciers ferritiques et martensitiques
	Zerstörungsfreie Prüfung von Schmiedestücken aus Stahl - Teil 3: Ultraschallprüfung von Schmiedestücken aus ferritischem oder martensitischem Stahl
EN 10229:1998	Evaluation of resistance of steel products to hydrogen induced cracking (HIC)
	Evaluation de la résistance des produits en acier à la fissuration induite par l'hydrogène (HIC)
	Bewertung der Beständigkeit von Stahlerzeugnissen gegen wasserstoffinduzierte Rißbildung (HIC)

Chapter 8

CAST IRONS

EN 1562 – MECHANICAL PROPERTIES OF BLACKHEART MALLEABLE CAST IRONS						
Material Name	**Material Number**	**Nominal Diameter of Test Piece[a], mm**	**Tensile Strength, Min., N/mm^2**	**% Elongation, Min.**	**0.2% Proof Stress, Min. N/mm^2**	**Brinell Hardness[c], HB**
EN-GJMB-300-6[b]	EN-JM1110[b]	12 or 15	300	6	---	150 max.
EN-GJMB-350-10	EN-JM1130	12 or 15	350	10	200	150 max.
EN-GJMB-450-6	EN-JM1140	12 or 15	450	6	270	150-200
EN-GJMB-500-5	EN-JM1150	12 or 15	500	5	300	165-215
EN-GJMB-550-4	EN-JM1160	12 or 15	550	4	340	180-230
EN-GJMB-600-3	EN-JM1170	12 or 15	600	3	390	195-245
EN-GJMB-650-2	EN-JM1180	12 or 15	650	2	430	210-260
EN-GJMB-700-2	EN-JM1190	12 or 15	700	2	530	240-290
EN-GJMB-800-1	EN-JM1200	12 or 15	800	1	600	270-320

a. Where a 6 mm diameter test piece is representative of the relevant wall thickness of a casting, this size of the test piece may be used by agreement between the manufacturer and the purchaser at the time of acceptance of the order. The minimum properties given in this table shall apply.
b. Material intended particularly for applications in which pressure tightness is more important than a high degree of strength and ductility.
c. For information only.

EN 1562 – MECHANICAL PROPERTIES OF WHITEHEART MALLEABLE CAST IRONS[d]						
Material Name	**Material Number**	**Nominal Diameter of Test Piece, mm**	**Tensile Strength, Min., N/mm^2**	**% Elongation, Min.**	**0.2% Proof Stress, Min. N/mm^2**	**Brinell Hardness[c], HB**
EN-GJMW-**350-4**	EN-JM1010	6	270	10	a	230
		9	310	5	---	
		12	**350**	**4**	---	
		15	360	3	---	
EN-GJMW-**360-12**[b]	EN-JM1020[b]	6	280	16	a	200
		9	320	15	170	

EN 1562 – MECHANICAL PROPERTIES OF WHITEHEART MALLEABLE CAST IRONS[d] (Continued)						
Material Name	**Material Number**	**Nominal Diameter of Test Piece, mm**	**Tensile Strength, Min., N/mm²**	**% Elongation, Min.**	**0.2% Proof Stress, Min. N/mm²**	**Brinell Hardness[c], HB**
EN-GJMW-**360-12**[b]	EN-JM1020[b]	**12**	**360**	**12**	**190**	200
		15	370	7	200	
EN-GJMW-**400-5**	EN-JM1030	6	300	12	a	220
		9	360	8	200	
		12	**400**	**5**	**220**	
		15	420	4	230	
EN-GJMW-**450-7**	EN-JM1040	6	330	12	a	220
		9	400	10	230	
		12	**450**	**7**	**260**	
		15	480	4	280	
EN-GJMW-**550-4**	EN-JM1050	6	---	---	a	250
		9	490	5	310	
		12	**550**	**4**	**340**	
		15	570	3	350	

a. Because of the difficulty in determining the proof stress of small test pieces, the values and the method of measurement shall be agreed between the manufacturer and the purchaser at the time of acceptance of order.
b. Material most suitable for welding.
c. For information only; maximums.
d. The figures given in bold indicate the minimum tensile strength and minimum % elongation to which the symbol of the grade is related, and the preferred nominal diameter of the test piece and the corresponding minimum 0.2% proof stress.

EN 1564 – MECHANICAL PROPERTIES OF AUSTEMPERED DUCTILE CAST IRONS[a, b, c]					
Material Name	**Material Number**	**Tensile Strength, Min., N/mm^2**	**0.2% Proof Stress, Min., N/mm^2**	**% Elongation, Min.**	**Brinell Hardness, HB**
EN-GJS-800-8	EN-JS1100	800	500	8	260-320
EN-GJS-1000-5	EN-JS1110	1000	700	5	300-360
EN-GJS-1200-2	EN-JS1120	1200	850	2	340-440
EN-GJS-1400-1	EN-JS1130	1400	1100	1	380-480

a. Properties measured on test pieces machined from separately cast samples.

b. The values for these materials apply to castings cast in sand moulds of comparable thermal diffusivity. Subject to amendments to be agreed upon in the order, they can apply to castings obtained by alternative methods.

c. Whatever the method used for obtaining the castings, the grades are based on the mechanical properties measured on test pieces taken from samples separately cast in a sand mould or a mould of comparable thermal diffusivity.

Chapter 9

CASTINGS: NON ALLOY & ALLOY STEELS

EN 10213-2 – CHEMICAL COMPOSITION OF CARBON AND ALLOY STEEL CASTINGS FOR PRESSURE PURPOSES (Continued)

Steel Name	Steel Number	C	Mn	Si	P	S	Cr	Ni	Mo	V	Others
G17CrMo5-5	1.7357	0.15 - 0.20	0.50 - 1.00	0.60	0.020	0.020[a]	1.00 - 1.50	---	0.45 - 0.65	---	---
G17CrMo9-10	1.7379	0.13 - 0.20	0.50 - 0.90	0.60	0.020	0.020[a]	2.00 - 2.50	---	0.90 - 1.20	---	---
G12MoCrV5-2	1.7720	0.10 - 0.15	0.40 - 0.70	0.45	0.030	0.020[a]	0.30 - 0.50	---	0.40 - 0.60	0.22 - 0.30	Sn 0.025
G17CrMoV5-10	1.7706	0.15 - 0.20	0.50 - 0.90	0.60	0.020	0.015	1.20 - 1.50	---	0.90 - 1.10	0.20 - 0.30	Sn 0.025
GX15CrMo5	1.7365	0.12 - 0.19	0.50 - 0.80	0.80	0.025	0.025	4.00 - 6.00	---	0.45 - 0.65	---	---

a. For castings of ruling thickness < 28 mm, 0.030% S is permitted.

b. For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum content will be permitted up to maximum of 1.40%.
Cast analysis, single values are maximums.

EN 10213-2 – MECHANICAL PROPERTIES OF CARBON AND ALLOY STEEL CASTINGS FOR PRESSURE PURPOSES AT ROOM TEMPERATURE

Steel Name	Steel Number	Heat Treatment Symbol	Thickness, Max., mm	Yield Strength, Min., MPa	Tensile Strength, Min., MPa	% El., Min.	Impact, KV, Min., J
GP240GR	1.0621	+ N	100	240	420 – 600	22	27
GP240GH	1.0619	+ N	100	240	420 – 600	22	27
		+ QT	100	240	420 – 600	22	40
GP280GH	1.0625	+ N	100	280	480 – 640	22	27
		+ QT	100	280	480 – 640	22	35
G20Mo5	1.5419	+ QT	100	245	440 – 590	22	27
G17CrMo5-5	1.7357	+ QT	100	315	490 – 690	20	27
G17CrMo9-10	1.7379	+ QT	150	400	590 – 740	18	40
G12MoCrV5-2	1.7720	+ QT	100	295	510 – 660	17	27
G17CrMoV5-10	1.7706	+ QT	150	440	590 – 780	15	27
GX15CrMo5	1.7365	+ QT	150	420	630 – 760	16	27

Chapter 10

STRUCTURAL STEELS: NON ALLOY & ALLOY STEELS

EN 10210-1 – CHEMICAL COMPOSITION OF HOT FINISHED STRUCTURAL HOLLOW SECTIONS OF NON-ALLOY STEELS – LADLE ANALYSIS FOR PRODUCT THICKNESS ≤ 65 mm

Steel Name	Steel Number	Type of Deoxidation[a]	Sub-Group[b]	C		Mn	Si	P	S	N[c, d]
				≤ 40 mm	> 40 ≤ 65 mm					
S235JRH	1.0039	FN	BS	0.17	0.20	1.40	---	0.045	0.045	0.009
S275J0H	1.0149	FN	QS	0.20	0.22	1.50	---	0.040	0.040	0.009
S275J2H	1.0138	FF	QS	0.20	0.22	1.50	---	0.035	0.035	---
S355J0H	1.0547	FN	QS	0.22	0.22	1.60	0.55	0.040	0.040	0.009
S355J2H	1.0576	FF	QS	0.22	0.22	1.60	0.55	0.035	0.035	---

a. The deoxidation methods are designated as follows: FN – Rimming steel not permitted. FF – Fully killed steel containing nitrogen binding elements in amounts sufficient to bind available nitrogen (e.g. min. 0.020% total Al, or 0.015% soluble Al).

b. BS: base steel, QS: quality steel

c. It is permissible to exceed the specified values provided that for each increase of 0.001% N, the P maximum content will be reduced by 0.005%, the N content of the ladle analysis, however, shall not be more than 0.012%.

d. The maximum value for nitrogen does not apply if the chemical composition shows a minimum total Al content of 0.020% with a minimum Al/N ratio of 2:1, or if sufficient other N-binding elements are present. The N-binding elements shall be recorded in the Inspection Document. Single values are maximum, unless otherwise specified.

EN 10210-1 – PERMISSIBLE DEVIATIONS OF THE PRODUCT ANALYSIS FROM THE SPECIFIED LIMITS OF LADLE ANALYSIS

C[a]	Mn		Si	P		S		Cr	Ni	Mo	N	Cu	Nb	Ti	V	Al Total
	Non-alloy	Fine grain		Non-alloy	Fine grain	Non-alloy	Fine grain									
Permissible maximum content in the ladle analysis, %																
≤ 0.20 > 0.20	≤ 1.60	≤ 1.70	≤ 0.60	≤ 0.045	≤ 0.035	≤ 0.045	≤ 0.030	≤ 0.30	≤ 0.80	≤ 0.10	≤ 0.025	≤ 0.35 0.35 < Cu ≤ 0.70	≤ 0.060	≤ 0.03	≤ 0.20	≥ 0.020
Permissible deviation of product analysis from specified limits of ladle analysis, %																
+ 0.02 + 0.03	+ 0.10	- 0.05 + 0.10	+ 0.05	+ 0.010	+ 0.005	+ 0.010	+ 0.005	+ 0.05	+ 0.05	+ 0.03	+ 0.002	+ 0.04 + 0.07	+ 0.010	+ 0.01	+ 0.02	- 0.005

a. For S235JRH for thicknesses ≤ 16 mm, the permissible deviation = 0.04% C, and for thicknesses > 16 ≤ 40 mm, the permissible deviation = 0.05% C.

EN 10219-1 – MECHANICAL PROPERTIES OF COLD FORMED STRUCTURAL HOLLOW SECTIONS OF FINE GRAIN STEELS IN THICKNESSES ≤ 40 mm[a] – FEEDSTOCK MATERIAL CONDITION M (THERMOMECHANICALLY ROLLED)							
Steel Name	**Steel Number**	**Yield Strength, Min., N/mm², Nominal Thickness, mm**		**Tensile Strength, N/mm² Nominal Thickness ≤ 40 mm**	**% Elongation[b, c], Min. Nominal Thickness ≤ 40 mm**	**Impact Properties**	
		≤ 16	**> 16 ≤ 40**			**Test °T, °C**	**Impact Energy[d], Min., Avg., J**
S275MH	1.8843	275	265	360 – 510	24	- 20	40
S275MLH	1.8844	275	265	360 – 510	24	- 50	27
S355MH	1.8845	355	345	450 – 610	22	- 20	40
S355MLH	1.8846	355	345	450 – 610	22	- 50	27
S420MH	1.8847	420	400	500 – 660	19	- 20	40
S420MLH	1.8848	420	400	500 – 660	19	- 50	27
S460NH	1.8849	460	440	550 – 720	17	- 20	40
S460NLH	1.8850	460	440	550 – 720	17	- 50	27

a. Only circular hollow sections available in thicknesses over 24 mm.
b. For section sizes ≤ 60 mm and equivalent round and rectangular sections, the minimum value for elongation is 17% for all thicknesses.
c. For thicknesses less than 3 mm, a gauge length of 80 mm or 50 mm shall be used (see EN 10219-1, paragraph 8.2.3.1); the values of percentage elongation to be achieved shall be agreed between the purchaser and the manufacturer at the time of enquiry and order. See EN 10219-1, paragraph 9.2.1.
d. Impact properties for standard test pieces. For impact properties for reduced section test pieces, see EN 10219-1, paragraph 6.7.2.

Chapter 11

GENERAL PURPOSE STEELS: NON ALLOY STEELS

EN 10130 - CHEMICAL COMPOSITIONS OF COLD ROLLED LOW CARBON STEEL FLAT PRODUCTS FOR COLD FORMING							
Steel Name	**Steel Number**	**C**	**Mn**	**Si**	**P**	**S**	**Others**
FeP01/DC01	1.0330	0.12	0.60	---	0.045	0.045	---
FeP03/DC03	1.0347	0.10	0.45	---	0.035	0.035	---
FeP04/DC04	1.0338	0.08	0.40	---	0.030	0.030	---
FeP05/DC05	1.0312	0.06	0.35	---	0.025	0.025	---
FeP06/DC06	1.0873	0.02	0.25	---	0.020	0.020	Ti 0.30 or Nb[a]

a. C + N must be fixed completely.

Single values are maximums, unless otherwise specified.

EN 10139 - CHEMICAL COMPOSITION OF UNCOATED MILD STEEL NARROW STRIP FOR COLD FORMING						
Steel Name	**Steel Number**	**C**	**Mn**	**P**	**S**	**Ti**
DC01	1.0330	0.12[a]	0.60[a]	0.045	0.045	---
DC03	1.0347	0.10	0.45	0.035	0.035	---
DC04	1.0338	0.08	0.40	0.030	0.030	---
DC05	1.0312	0.06	0.35	0.025	0.025	---
CD06	1.0873	0.02	0.25	0.020	0.020	0.3[b]

a. For grade DC01 in the delivery condition C690, the C and the Mn contents may be exceeded.

b. Titanium may be replaced by niobium. Carbon and nitrogen shall be fully fixed.

EN 10139 – MECHANICAL PROPERTIES OF UNCOATED MILD STEEL NARROW STRIP FOR COLD FORMING

Steel Name	Steel Number	Delivery Condition	Symbol	Yield Strength[e], N/mm²	Tensile Strength, N/mm²	% Elongation, Min.			Hardness[h], HV
						A80	A50	L_o 5.65$\sqrt{S_o}$	
DC01	1.0330	Annealed	A	---	270-390	28	30	32	105 max.
		Skin passed	LC	280[a, d] max.	270-410[d]	28[b, d]	30[b, d]	32[b, d]	115[d] max.
		Work hardened	C290	200-380	290-430	18	20	24	95-125
			C340	250 min.	340-490	---	---	---	105-155
			C390	310 min.	390-540	---	---	---	117-172
			C440	360 min.	440-590	---	---	---	135-185
			C490	420 min.	490-640	---	---	---	155-200
			C590	520 min.	590-740	---	---	---	185-225
			C690	630 min.	690 min.	---	---	---	215 min.
DC03	1.0347	Annealed	A	---	270-370	34	36	37	100 max.
		Skin passed	LC	240[a, d] max.	270-370[d]	34[b, d]	36[b, d]	37[b, d]	110[d] max.
		Work hardened	C290	210-355	290-390	22	24	26	95-117
			C340	240 min.	340-440	---	---	---	105-130
			C390	330 min.	390-490	---	---	---	117-155
			C440	380 min.	440-540	---	---	---	135-172
			C490	440 min.	490-590	---	---	---	155-185
			C590	540 min.	590 min.	---	---	---	185 min.
DC04	1.0338	Annealed	A	---	270-350	38	40	40	95 max.
		Skin passed	LC	210[a, c, d] max.	270-350[d]	38[b, d]	40[b, d]	40	105[d] max.
		Work hardened	C290	220-325	290-390	24	26	28	95-117
			C340	240 min.	340-440	---	---	---	105-130
			C390	350 min.	390-490	---	---	---	117-155
			C440	400 min.	440-540	---	---	---	135-172

Chapter 12

SPECIAL PURPOSE STEELS: NON ALLOY & ALLOY STEELS

EN 10083-1 – CHEMICAL COMPOSITION OF QUENCHED AND TEMPERED STEELS – SPECIAL STEELS[a, b, c, d] (Continued)										
Steel Name	**Steel Number**	**C[e]**	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Cr + Mo + Ni[e]**
41Cr4	1.7035	0.38-0.45	0.60-0.90	0.40	0.035	0.035	---	0.90-1.20	---	---
41CrS4	1.7039					0.020-0.040				
25CrMo4	1.7218	0.22-0.29	0.60-0.90	0.40	0.035	0.035	---	0.90-1.20	0.15-0.30	---
25CrMoS4	1.7213					0.020-0.040				
34CrMo4	1.7220	0.30-0.37	0.60-0.90	0.40	0.035	0.035	---	0.90-1.20	0.15-0.30	---
34CrMoS4	1.7226					0.020-0.040				
42CrMo4	1.7225	0.38-0.45	0.60-0.90	0.40	0.035	0.035	---	0.90-1.20	0.15-0.30	---
42CrMoS4	1.7227					0.020-0.040				
50CrMo4	1.7228	0.46-0.54	0.50-0.80	0.40	0.035	0.035	---	0.90-1.20	0.15-0.30	---
36CrNiMo4	1.6511	0.32-0.40	0.50-0.80	0.40	0.035	0.035	0.90-1.20	0.90-1.20	0.15-0.30	---
34CrNiMo6	1.6582	0.30-0.38	0.50-0.80	0.40	0.035	0.035	1.30-1.70	1.30-1.70	0.15-0.30	---
30CrNiMo8	1.6580	0.26-0.34	0.30-0.60	0.40	0.035	0.035	1.80-2.20	1.80-2.20	0.30-0.50	---
36NiCrMo16	1.6773	0.32-0.39	0.30-0.60	0.40	0.030	0.025	3.60-4.10	1.60-2.00	0.25-0.45	---
51CrV4[f]	1.8159	0.47-0.55	0.70-1.10	0.40	0.035	0.035	---	0.90-1.20	---	---

a. Elements not quoted should not be added intentionally to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions should be taken to prevent the addition from scrap or other material used in the manufacture of such elements which affect the hardenability, mechanical properties and applicability.

b. Single values are maximums.

c. Steel with improved machinability as a result of the addition of lead or higher sulfur contents, depending on the manufacturing process up to around 0.100% S (including controlled sulfide and oxide formation [e.g. Ca treatment]) may be supplied on request.

d. Where requirements are made on hardenability (see Table 10083-1-Hardness (HRC) for Quenched and Tempered Steels with Normal Hardness Requirements and Table 10083-1-Hardness (HRC) for Unalloyed Quenched and Tempered Steels with Restricted Hardenability), slight deviations from the limits for the cast analysis are permissible, except for the elements carbon (see footnote e), phosphorus and sulfur.

e. If unalloyed steels including Grade 28Mn6 are ordered without hardenability requirements (symbols +H, +HH, +HL) or without requirements on the mechanical properties in the quenched and tempered or normalized condition, a restriction in the carbon range to 0.05% and/or of the total sum of the elements Cr, Mo and Ni to ≤ 0.45% may be agreed at the time of ordering.

f. Vanadium 0.10 – 0.25%.

EN 10083-1 – MECHANICAL PROPERTIES OF QUENCHED AND TEMPERED STEELS – SPECIAL STEELS[a, b] (Continued)

Steel Name	Steel Number	Mechanical Properties for the Ruling Section (see EN 10083-1) with a Diameter (d) or, for Flat Products, with a Thickness (t) of									
		100 mm < d ≤ 160 mm or 60 mm < t ≤ 100 mm					160 mm < d ≤ 250 mm or 100 mm < t ≤ 160 mm				
		R_e, N/mm^2	R_m, N/mm^2	A, %	Z, %	KV, J	R_e, N/mm^2	R_m, N/mm^2	A, %	Z, %	KV, J
37Cr4 37CrS4	1.7034 1.7038	---	---	---	---	---	---	---	---	---	---
41Cr4 41CrS4	1.7035 1.7039	---	---	---	---	---	---	---	---	---	---
25CrMo4 25CrMoS4	1.7218 1.7213	400	650-800	16	60	45	---	---	---	---	---
34CrMo4 34CrMoS4	1.7220 1.7226	500	750-900	15	55	45	450	700-850	15	60	45
42CrMo4 42CrMoS4	1.7225 1.7227	550	800-950	13	50	35	500	750-900	14	55	35
50CrMo4	1.7228	650	850-1000	13	50	30[d]	550	800-950	13	50	30[d]
36CrNiMo4	1.6511	600	800-950	13	60	45	550	750-900	14	60	45
34CrNiMo6	1.6582	700	900-1100	12	55	45	600	800-950	13	55	45
30CrNiMo8	1.6580	800	1000-1200	11	50	45	700	900-1100	12	50	45
36NiCrMo16	1.6773	800	1000-1200	11	50	45	800	1000-1200	11	50	45
51CrV4	1.8159	650	850-1000	13	50	30[d]	600	800-950	13	50	30[d]

a. R_e: Upper yield stress or, if no yield phenomenon occurs, 0.2% proof stress. R_m: Tensile strength. A: Percentage elongation after fracture.
Z: Reduction in cross section on fracture.
KV: Impact strength of longitudinal Charpy V-notch test pieces (average of 3 individual values; no individual value shall be lower than 70% of the minimum average value).
Single values are minimums.

b. Specifying the dimensional limits does not mean that quenching and tempering can give a martensitic structure through to the specified sample taking point. The depth of hardness results from the end quenching curves. See EN 10083-1 for more details.

c. Applies to diameters up to 63 mm or thicknesses up to 35 mm.

d. Provisional values.

EN 10137-3 – CHEMICAL COMPOSITION[a] OF PLATES AND WIDE FLATS MADE OF HIGH YIELD STRENGTH STRUCTURAL STEEL – PRECIPITATION HARDENED STEELS

Grade	Quality	C	Mn	Si	P	S	Cr	Ni	Mo	N	Cu	Nb	Ti	V	Zr
All Grades	(no symbol)	0.03-1.12	0.30-1.80	0.50	0.025	0.015	0.3	2	0.5	0.015	2	0.060	0.10	0.10	0.080
	L	0.03-1.12	0.30-1.80	0.50	0.020	0.010	0.3	2	0.5	0.015	2	0.060	0.10	0.10	0.080

a. Single values are maximum; ladle analysis.

EN 10137-3 – MECHANICAL PROPERTIES OF PLATES AND WIDE FLATS MADE OF HIGH YIELD STRENGTH STRUCTURAL STEEL – PRECIPITATION HARDENED STEELS

Steel Name	Steel Number	Yield Strength, Min., N/mm^2, for Nominal Thickness, mm		Tensile Strength, N/mm^2	% Elongation, Min.
		≥ 3 ≤ 50	> 50 ≤ 70		
S500A	1.8980	500	480	600-770	17
S500AL	1.8990	500	480	600-770	17
S550A	1.8991	550	530	650-820	16
S550AL	1.8992	550	530	650-820	16
S620A	1.8993	620	580	710-880	15
S620AL	1.8994	620	580	710-880	15
S690A	1.8995	690	650	760-930	14
S690AL	1.8996	690	650	760-930	14

EN 10137-3 – LONGITUDINAL IMPACT PROPERTIES OF PLATES AND WIDE FLATS MADE OF HIGH YIELD STRENGTH STRUCTURAL STEEL – PRECIPITATION HARDENED STEELS

Steel Name	Steel Number	Longitudinal V-Notch, Min., J, Test Temperature,°C		
		0	- 20	- 40
S500A	1.8980	55	40	---
S550A	1.8991	55	40	---
S620A	1.8993	55	40	---
S690A	1.8995	55	40	---
S500AL	1.8990	65	50	40
S550AL	1.8992	65	50	40
S620AL	1.8994	65	50	40
S690AL	1.8996	65	50	40

EN 10137-3 – TRANSVERSE IMPACT PROPERTIES OF PLATES AND WIDE FLATS MADE OF HIGH YIELD STRENGTH STRUCTURAL STEEL – PRECIPITATION HARDENED STEELS

Steel Name	Steel Number	Transverse V-Notch, Min., J, Test Temperature,°C		
		0	- 20	- 40
S500A	1.8980	35	30	---
S550A	1.8991	35	30	---
S620A	1.8993	35	30	---
S690A	1.8995	35	30	---
S500AL	1.8990	40	35	30
S550AL	1.8992	40	35	30
S620AL	1.8994	40	35	30
S690AL	1.8996	40	35	30

Chapter 13

FREE-CUTTING STEELS

EN 10087 – CHEMICAL COMPOSITION OF FREE-CUTTING STEELS, SEMI-FINISHED PRODUCTS, HOT-ROLLED BARS AND RODS[a, b]							
Steel Name	**Steel Number**	**C**	**Mn**	**Si**	**P**	**S**	**Pb**
Steels Not Intended For Heat Treatment							
11SMn30	1.0715	≤ 0.14	0.90-1.30	0.05[c]	0.11	0.27-0.33	---
11SMnPb30	1.0718	≤ 0.14	0.90-1.30	0.05	0.11	0.27-0.33	0.20-0.35
11SMn37	1.0736	≤ 0.14	1.00-1.50	0.05[c]	0.11	0.34-0.40	---
11SMnPb37	1.0737	≤ 0.14	1.00-1.50	0.05	0.11	0.34-0.40	0.20-0.35
Case-Hardening Steels							
10S20	1.0721	0.07-0.13	0.70-1.10	0.40	0.06	0.15-0.25	---
10SPb20	1.0722	0.07-0.13	0.70-1.10	0.40	0.06	0.15-0.25	0.20-0.35
15SMn13	1.0725	0.12-0.18	0.90-1.30	0.40	0.06	0.08-0.18	---
Direct-Hardening Steels							
35S20	1.0726	0.32-0.39	0.70-1.10	0.40	0.06	0.15-0.25	---
35SPb20	1.0756	0.32-0.39	0.70-1.10	0.40	0.06	0.15-0.25	0.15-0.35
36SMn14	1.0764	0.32-0.39	1.30-1.70	0.40	0.06	0.10-0.18	---
36SMnPb14	1.0765	0.32-0.39	1.30-1.70	0.40	0.06	0.10-0.18	0.15-0.35
38SMn28	1.0760	0.35-0.40	1.20-1.50	0.40	0.06	0.24-0.33	---
38SMnPb28	1.0761	0.35-0.40	1.20-1.50	0.40	0.06	0.24-0.33	0.15-0.35
44SMn28	1.0762	0.40-0.48	1.30-1.70	0.40	0.06	0.24-0.33	---
44SMnPb28	1.0763	0.40-0.48	1.30-1.70	0.40	0.06	0.24-0.33	0.15-0.35
46S20	1.0727	0.42-0.50	0.70-1.10	0.40	0.06	0.15-0.25	---
46SPb20	1.0757	0.42-0.50	0.70-1.10	0.40	0.06	0.15-0.25	0.15-0.35

a. Elements not quoted in this table shall not be intentionally added to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat. However, elements such as Te, Bi, etc. may only be added by the manufacturer for improving the machinability, if this has been agreed at the time of enquiry and order. Applicable to cast analysis.

b. Single values are maximums.

c. If, by metallurgical techniques, the formation of special oxides is guaranteed, a Si-content of 0.10% to 0.40% can be agreed.

EN 10087 – MECHANICAL PROPERTIES OF FREE-CUTTING STEELS, SEMI-FINISHED PRODUCTS, HOT-ROLLED BARS AND RODS				
Steel Name	**Steel Number**	**Diameter, d, mm**	**Hardness[a, b], HB**	**Tensile Strength[a, c], N/mm^2**
In the Untreated Condition Not Intended for Heat Treatment				
11SMn30 11SMnPb30 11SMn37 11SMnPb37	1.0715 1.0718 1.0736 1.0737	5 ≤ d ≤ 10	---	380-570
		10 < d ≤ 16	---	380-570
		16 < d ≤ 40	112-169	380-570
		40 < d ≤ 63	109-169	370-570
		63 < d ≤ 100	107-154	360-520
Case Hardened Free-Cutting Steels in the Untreated Condition				
10S20 10SPb20	1.0721 1.0722	5 ≤ d ≤ 10	---	360-530
		10 < d ≤ 16	---	360-530
		16 < d ≤ 40	107-156	360-530
		40 < d ≤ 63	107-156	360-530
		63 < d ≤ 100	105-146	350-490
15SMn13	1.0725	5 ≤ d ≤ 10	---	430-610
		10 < d ≤ 16	---	430-600
		16 < d ≤ 40	128-178	430-600
		40 < d ≤ 63	128-172	430-580
		63 < d ≤ 100	125-160	420-540

a. In cases of dispute, the tensile strength values are deciding.
b. The hardness values are given for information only.
c. For flats, a minimum tensile strength of 340 N/mm^2 applies.

Chapter 14

FORGINGS: NON ALLOY & ALLOY STEELS

EN 10222-4 – CHEMICAL COMPOSITION OF STEEL FORGINGS FOR PRESSURE PURPOSES – WELDABLE FINE-GRAIN STEELS WITH HIGH PROOF STRENGTH[a]

Steel Name	Steel Number	C	Mn	Si	P	S	Cr	Ni	Mo	Others	CE
P285NH	1.0477	0.18	0.60-1.40	0.40	0.025	0.015	0.30	0.30	0.08	0.020 N, 0.20 Cu, 0.03 Nb, 0.05 V, 0.05 Nb+V	0.41
P285QH	1.0478										
P355NH	1.0565	0.20	0.90-1.65	0.10-0.50	0.025	0.015	0.30	0.30	0.08	0.020 N, 0.20 Cu, 0.05 Nb, 0.10 V, 0.12 Nb+V	0.47
P355QH	1.0571										
P420NH	1.8932	0.20	1.00-1.70	0.10-0.60	0.025	0.015	0.30	1.00	0.10	0.020 N, 0.20 Cu, 0.05 Nb, 0.20 V, 0.22 Nb+V	0.51
P420QH	1.8936										

a. Cast analysis, with total aluminium 0.020-0.060% for each steel. Minimum aluminium level need not apply when Nb, V, Ti are used to control N content.

b. Elements not listed in this table shall not be intentionally added to the steel without the approval of the purchaser, except for finishing the cast. All appropriate measures shall be taken to prevent the addition from scrap or other materials used in steelmaking of these elements which may adversely affect the mechanical properties and useability.

EN 10222-4 – MECHANICAL PROPERTIES OF STEEL FORGINGS FOR PRESSURE PURPOSES – WELDABLE FINE-GRAIN STEELS WITH HIGH PROOF STRENGTH[a]

Steel Name	Steel Number	Thickness of the Ruling Section[b] t_R, mm	Yield Strength[c], Min. R_{eH}, N/mm^2	Tensile Strength R_m, N/mm^2	% Elongation[d], Min.	
					l	t, tr
P285NH P285QH	1.0477 1.0478	$t_R \leq 16$	285	390-510	24	23
		$16 < t_R \leq 35$	285	390-510	24	23
		$35 < t_R \leq 70$	265	390-510	24	23
		$70 < t_R \leq 100$	245	370-510	22	21
		$100 < t_R \leq 250$	225	370-510	22	21
		$250 < t_R \leq 400$	205	370-510	22	21

Chapter 15

PRESSURE VESSEL STEELS: NON ALLOY & ALLOY STEELS

EN 10028-2 – FORMER STEEL GRADES IN DIN 17155 (1983)		
Steel Grade as Specified in EN 10028, Part 2	**Equivalent Steel Grade as Specified in DIN 17155, October 1983 Edition**	**Material Number**
P235GH	H I	1.0345
P265GH	H II	1.0425
P295GH	17 Mn 4	1.0481
P355GH	19 Mn 6	1.0473
16Mo3	15 Mo 3	1.5415
13CrMo4-5	13 CrMo 4 4	1.7335
10CrMo9-10	10 CrMo 9 10	1.7380
11CrMo9-10	---	1.7383

EN 10028-2 – CHEMICAL COMPOSITION OF FLAT PRODUCTS MADE FROM STEEL FOR PRESSURE PURPOSES – NON-ALLOY AND ALLOY STEELS WITH SPECIFIED ELEVATED TEMPERATURE PROPERTIES

Steel Name	Steel Number	C	Mn	Si	P	S	Cr	Ni	Mo	Others
P235GH	1.0345	0.16	0.40-1.20	0.35	0.030	0.025	0.30	0.30	0.08	Al 0.20[a], Cu 0.03, Nb 010, Ti 0.03, V 0.02[b]
P265GH	1.0425	0.20	0.50-1.40	0.40	0.030	0.025	0.30	0.30	0.08	Al 0.20[a], Cu 0.03, Nb 010, Ti 0.03, V 0.02[b]
P295GH	1.0481	0.08-0.20	0.90-1.50	0.40	0.030	0.025	0.30	0.30	0.08	Al 0.20[a], Cu 0.03, Nb 010, Ti 0.03, V 0.02[b]
P355GH	1.0473	0.10-0.22	1.00-1.70	0.60	0.030	0.025	0.30	0.30	0.08	Al 0.20[a], Cu 0.03, Nb 010, Ti 0.03, V 0.02[b]
16Mo3	1.5415	0.12-0.20	0.40-0.90	0.35	0.030	0.025	0.30	0.30	0.25-0.35	Cu 0.30
13CrMo4-5	1.7335	0.08-0.18	0.40-1.00	0.35	0.030	0.025	0.70-1.15	---	0.40-0.60	Cu 0.30
10CrMo9-10	1.7380	0.08-0.14	0.40-0.80	0.50	0.030	0.025	2.00-2.50	---	0.90-1.10	Cu 0.30
11CrMo9-10	1.7383	0.08-0.15	0.40-0.80	0.50	0.030	0.025	2.00-2.50	---	0.90-1.10	Cu 0.30

a. Total aluminum, minimum.

b. $Cr + Cu + Mo + Ni \leq 0.70$.

Single values are maximums, unless otherwise specified.

EN 10028-5 – IMPACT PROPERTIES OF FLAT PRODUCTS MADE FROM STEEL FOR PRESSURE PURPOSES – WELDABLE FINE GRAIN STEELS THERMOMECHNICALLY ROLLED					
Steel Name Series	**Impact Energy Values[a], KV, in J at Test Temperatures in °C Transverse V-Notched Test Pieces**				
	-50	**-40**	**-20**	**0**	**+20**
P ... M	---	---	27	40	60
P ... ML1	---	27	40	60	---
P … ML2	27	40	60	80	---

a. For undersize test pieces, see EN 10028-1 paragraph 8.4.3. Single values are minimums, unless otherwise specified.

EN 10028-6 – CHEMICAL COMPOSITION OF FLAT PRODUCTS MADE FROM STEEL FOR PRESSURE PURPOSES – WELDABLE FINE GRAIN STEELS QUENCHED AND TEMPERED[a, b]													
Steel Name	**Steel Number**	**C**	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Nb[c]**	**Ti[c]**	**V[c]**	**Zr[c]**
P355Q	1.8866	0.16	1.50	0.40	0.025	0.015	0.30	0.50	0.25	0.05	0.03	0.06	0.05
P355QH	1.8867	0.16	1.50	0.40	0.025	0.015	0.30	0.50	0.25	0.05	0.03	0.06	0.05
P355QL1	1.8868	0.16	1.50	0.40	0.020	0.010	0.30	0.50	0.25	0.05	0.03	0.06	0.05
P355QL2	1.8869	0.16	1.50	0.40	0.020	0.010	0.30	0.50	0.25	0.05	0.03	0.06	0.05
P460Q	1.8870	0.18	1.70	0.50	0.025	0.015	0.50	1.00	0.50	0.05	0.03	0.08	0.05
P460QH	1.8871	0.18	1.70	0.50	0.025	0.015	0.50	1.00	0.50	0.05	0.03	0.08	0.05
P460QL1	1.8872	0.18	1.70	0.50	0.020	0.010	0.50	1.00	0.50	0.05	0.03	0.08	0.05
P460QL2	1.8864	0.18	1.70	0.50	0.020	0.010	0.50	1.00	0.50	0.05	0.03	0.08	0.05
P500Q	1.8873	0.18	1.70	0.60	0.025	0.015	1.00	1.50	0.70	0.05	0.05	0.08	0.15
P500QH	1.8874	0.18	1.70	0.60	0.025	0.015	1.00	1.50	0.70	0.05	0.05	0.08	0.15
P500QL1	1.8875	0.18	1.70	0.60	0.020	0.010	1.00	1.50	0.70	0.05	0.05	0.08	0.15
P500QL2	1.8865	0.18	1.70	0.60	0.020	0.010	1.00	1.50	0.70	0.05	0.05	0.08	0.15
P690Q	1.8879	0.20	1.70	0.80	0.025	0.015	1.50	2.50	0.70	0.06	0.05	0.12	0.15

EN 10028-6 – CHEMICAL COMPOSITION OF FLAT PRODUCTS MADE FROM STEEL FOR PRESSURE PURPOSES – WELDABLE FINE GRAIN STEELS QUENCHED AND TEMPERED[a, b] (Continued)

Steel Name	Steel Number	C	Mn	Si	P	S	Cr	Ni	Mo	Nb[c]	Ti[c]	V[c]	Zr[c]
P690QH	1.8880	0.20	1.70	0.80	0.025	0.015	1.50	2.50	0.70	0.06	0.05	0.12	0.15
P690QL1	1.8881	0.20	1.70	0.80	0.020	0.010	1.50	2.50	0.70	0.06	0.05	0.12	0.15
P690QL2	1.8888	0.20	1.70	0.80	0.020	0.010	1.50	2.50	0.70	0.06	0.05	0.12	0.15

a. Elements not listed in this table shall not be intentionally added to the steel without the agreement of the purchaser except for finishing the cast. All appropriate measures shall be taken to prevent the addition from scrap and other materials used in steelmaking of these elements which may adversely affect the mechanical properties and usability.

b. Other limits: N 0.015, B 0.0050, Cu 0.50.

c. The percentage of grain refining elements shall be at least 0.015%.

Single values are maximums, unless otherwise specified.

EN 10028-6 – PERMISSIBLE DEVIATIONS OF THE PRODUCT ANALYSIS FROM THE SPECIFIED LIMITS OF THE CAST ANALYSIS

C	Mn	Si	P	S	Cr	Ni	Mo	N	B	Cu	Nb	Ti	V	Zr	Al (Total)
Cast Analysis Limit, %															
≤ 0.20	≤ 1.70	≤ 0.80	≤ 0.025	≤ 0.015 ≤ 0.020	≤ 1.50	≤ 2.50	≤ 0.70	≤ 0.015	≤ 0.005	≤ 0.30	≤ 0.06	≤ 0.05	≤ 0.12	≤ 0.15	≥ 0.018
Limit Deviations in the Product Analysis, %															
+ 0.02	+ 0.10	+ 0.05	+ 0.005	+ 0.003 + 0.005	+ 0.10	+ 0.10	+ 0.04	+ 0.002	+ 0.0005	+ 0.05	+ 0.01	+ 0.01	+ 0.01	+ 0.01	- 0.005

Chapter 16

PIPE: NON ALLOY & ALLOY STEELS

EN 10208-1 – STEEL GRADES COMPARED TO ANSI/API 5L		
Steel Name	**Steel Number**	**ANSI/API 5L Steel Designation**
L210GA	1.0319	A
L235GA	1.0458	---
L245GA	1.0459	B
L290GA	1.0483	X 42
L360GA	1.0499	X 52

EN 10208-2 – CLASSIFICATION OF STEEL PIPES FOR COMBUSTIBLE FLUIDS (CLASS B)			
Heat Treatment Condition	**Class (EN 10020)**	**Name**	**Number**
Normalized or normalizing formed	Non-alloy quality steel	L245NB	1.0457
		L290NB	1.0484
		L360NB	1.0582
	Alloy special steel	L415NB	1.8972
Quenched and tempered	Alloy special steel	L360QB	1.8948
		L415QB	1.8947
		L450QB	1.8952
		L485QB	1.8955
		L555QB	1.8957
Thermomechanically rolled	Non-alloy quality steel	L245MB	1.0418
		L290MB	1.0429
		L360MB	1.0578
	Alloy special steel	L415MB	1.8973
		L450MB	1.8975
		L485MB	1.8977
		L555MB	1.8978

EN 10208-2 – IMPACT PROPERTIES[a] OF STEEL PIPES FOR COMBUSTIBLE FLUIDS (CLASS B)

Steel Name	Steel Number	Charpy V-Notch Impact Test[d] Minimum impact energy in J for outside diameters ≤ 1430 mm and wall thicknesses ≤ 25 mm[b] Transverse to the pipe axis (longitudinal to the pipe axis in angular brackets)[c] Pipe body (pipe outside diameter D in mm)								
		≤ 510	> 510 ≤ 610	> 610 ≤ 720	> 720 ≤ 820	> 820 ≤ 920	> 920 ≤ 1020	> 1020 ≤ 1120	> 1120 ≤ 1220	> 1220 ≤ 1430
L245NB	1.0457	40 (30) [60 (45)]			40 (30)					40 (30)
L245MB	1.0418									
L290NB	1.0484									42 (32)
L290MB	1.0429									
L360NB	1.0582									
L360QB	1.8948									
L360MB	1.0578									
L415NB	1.8972				40 (30)	41 (31)	44 (33)	46 (35)	48 (36)	51 (38)
L415QB	1.8947									
L415MB	1.8973									
L450QB	1.8952	40 (30) [60 (45)]		41 (31) [62 (47)]	43 (32)	46 (35)	48 (36)	51 (38)	53 (40)	57 (43)
L450MB	1.8975									
L485QB	1.8955	46 (35) [69 (52)]	50 (38) [75 (56)]	55 (41) [83 (62)]	58 (44)	62 (47)	65 (49)	68 (51)	71 (53)	77 (58)
L485MB	1.8977									
L555QB	1.8957	61 (46) [92 (69)]	68 (51) [102 (77)]	76 (57) [114 (86)]	83 (62)	90 (68)	96 (72)	102 (77)	108 (81)	120 (90)
L555MB	1.8978									

a. Requirements for Charpy V-notch impact test at 0°C for a safety factor of 1.4.

b. The values apply for standard test pieces. For subsize test pieces, see EN 10208-2, paragraph 8.2.3.3.2. The specified values without brackets are the minimum average values for three tests; minimum individual values (75% of the average values) are indicated in round brackets. The impact requirements do not apply for the heat affected zone (HAZ). For outside diameters > 1430 mm and/or wall thicknesses > 25 mm values shall be agreed.

c. The test pieces shall be taken transverse to the pipe axis as long as minimum subsize test pieces with a width of ≥ 5 mm are still obtainable without flattening.

d. Drop weight tear test to be carried out by agreement for pipes with an outside diameter > 500 mm, a wall thickness > 8 mm and a specified yield strength > 360 N/mm^2.

Chapter 17

TOOL STEELS

EN ISO 4957 – CHEMICAL COMPOSITION OF ALLOY COLD-WORK TOOL STEELS[a, b]								
Steel Name	**C**	**Mn**	**Si**	**Cr**	**Mo**	**Ni**	**V**	**W**
105V	1.00-1.10	0.10-0.40	0.10-0.30	---	---	---	0.10-0.20	---
50WCrV8	0.45-0.55	0.15-0.45	0.70-1.00	0.90-1.20	---	---	0.10-0.20	1.70-2.20
60WCrV8	0.55-0.65	0.15-0.45	0.70-1.00	0.90-1.20	---	---	0.10-0.20	1.70-2.20
102Cr6	0.95-1.10	0.25-0.45	0.15-0.35	1.35-1.65	---	---	---	---
21MnCr5	0.18-0.24	1.10-1.40	0.15-0.35	1.00-1.30	---	---	---	---
70MnMoCr8	0.65-0.75	1.80-2.50	0.10-0.50	0.90-1.20	0.90-1.40	---	---	---
90MnCrV8	0.85-0.95	1.80-2.20	0.10-0.40	0.20-0.50	---	---	0.05-0.20	---
95MnWCr5	0.90-1.00	1.05-1.35	0.10-0.40	0.40-0.65	---	---	0.05-0.20	0.40-0.70
X100CrMoV5	0.95-1.05	0.40-0.80	0.10-0.40	4.80-5.50	0.90-1.20	---	0.15-0.35	---
X153CrMoV12	1.45-1.60	0.20-0.60	0.10-0.60	11.00-13.00	0.70-1.00	---	0.70-1.00	---
X210Cr12	1.90-2.20	0.20-0.60	0.10-0.60	11.00-13.00	---	---	---	---
X210CrW12	2.00-2.30	0.30-0.60	0.10-0.40	11.00-13.00	---	---	---	0.60-0.80
35CrMo7	0.30-0.40	0.60-1.00	0.30-0.70	1.50-2.00	0.35-0.55	---	---	---
40CrMnNiMo8-6-4[c]	0.35-0.45	1.30-1.60	0.20-0.40	1.80-2.10	0.15-0.25	0.90-1.20[c]	---	---
45NiCrMo16	0.40-0.50	0.20-0.50	0.10-0.40	1.20-1.50	0.15-0.35	3.80-4.30	---	---
X40Cr14[d]	0.36-0.42	≤ 1.00	≤ 1.00	12.50-14.50	---	---	---	---
X38CrMo16[c]	0.33-0.45	≤ 1.50	≤ 1.00	15.50-17.50	0.80-1.30	≤ 1.00	---	---

a. Elements not quoted in this table shall not be intentionally added to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition from scrap or other materials used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

b. For all steels: phosphorus ≤ 0.030% and sulfur ≤ 0.030% (see, however, footnote c).

c. By agreement, sulfur may be increased to between 0.050% and 0.100% and Ni may be omitted.

d. This steel may also be supplied in the pre-heated condition with a hardness of approximately 300 HB.

Chapter 18

CASTINGS: STAINLESS STEELS

EN 10213-2 – MECHANICAL PROPERTIES OF STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES AT ELEVATED TEMPERATURE

Steel Name	Steel Number	Heat Treatment Symbol	Yield Strength, (0.2% offset), Min., MPa							
			100°C	200°C	300°C	350°C	400°C	450°C	500°C	550°C
GX8CrNi12	1.4107	+ QT1	---	275	265	---	255	---	---	---
		+ QT2	---	410	390	---	370	---	---	---
GX4CrNi13-4	1.4317	+ QT	515	485	455	440	---	---	---	---
GX23CrMoV12-1	1.4931	+ QT	---	450	430	410	390	370	340	290
GX4CrNiMo16-5-1	1.4405	+ QT	515	485	455	---	---	---	---	---

EN 10213-4 – CREEP RESISTANCE OF AUSTENITIC AND AUSTENITIC-FERRITIC STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES[a]

Steel Name	Steel Number	Time, h	550°C		600°C		650°C		700°C	
			10 000	100 000	10 000	10 0000	10 000	100 000	10 000	100 000
GX5CrNi19-10	1.4308	Rupture Stress, MPa	147	124	110	83	73	52	47	---
GX5CrNiNb19-11	1.4552	Rupture Stress, MPa	246	192	156	124	109	80	73	---
GX5CrNiMo19-11-2	1.4408	Rupture Stress, MPa	194	160	148	113	103	66	60	42

a. Mean values, ruptures stress, MPa.

EN 10213-2 – TYPICAL CREEP PROPERTIES OF STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES AT ELEVATED TEMPERATURE[a, b]

Steel Name	Steel Number	Temperature	400°C			450°C			500°C		
		Time, h	10 000	100 000	200 000	10 000	100 000	200 000	10 000	100 000	200 000
GX23CrMoV12-1	1.4931	σ_r	504	426	394	383	309	279	269	207	187
		σ_{Al}	---	---	---	305	259	239	216	172	153

a. σ_r : Rupture stress MPa; σ_{Al} : 1% creep stress MPa.

b. Informative only, not mandatory.

EN 10213-1 – TYPICAL PHYSICAL PROPERTIES OF STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES[a]									
Steel Name	**Steel Number**	**Density kg/dm³ 20°C**	**Mean Thermal Expansion 10^{-6} K^{-1} from 20°C to**			**Thermal Conductivity W/(m.K) at**		**Specific Heat J/(kg.K) 20°C**	**Magnetic Properties**
			100°C	**300°C**	**500°C**	**50°C**	**100°C**		
GX8CrNi12	1.4107	7.7	10.5	11.5	12.3	26	27	460	Magnetic
GX4CrNi13-4	1.4317	7.7	10.5	11	12	26	27	460	Magnetic
GX3CrNi13-4	1.6982	7.7	10.5	11	12	26	27	460	Magnetic
GX23CrMoV12-1	1.4931	7.7	---	---	---	---	---	460	Magnetic
GX4CrNiMo16-5-1	1.4405	7.8	10.8	11.5	12	17	18	460	Magnetic
GX2CrNi19-11	1.4309	7.88	16.8	17.9	18.6	15.2	16.5	530	Non to slight magnetic
GX5CrNi19-11	1.4308	7.88	16.8	17.9	18.6	15.2	16.5	530	Non to slight magnetic
GX5CrNiNb19-11	1.4552	7.88	16.8	17.9	18.6	15.2	16.5	530	Non to slight magnetic
GX2CrNiMo19-11-2	1.4409	7.9	15.8	17	17.7	14.5	15.8	530	Slight magnetic
GX5CrNiMo19-11-2	1.4408	7.9	15.8	17	17.7	14.5	15.8	530	Slight magnetic
GX5CrNiMoNb19-11-2	1.4581	7.9	15.8	17	17.7	14.5	15.8	530	Slight magnetic
GX2NiCrMo28-20-2	1.4458	8.0	14.5	16.2	17	16	17	500	Slight magnetic
GX2CrNiMoN22-5-3	1.4470	7.7	13	14	---	18	18	450	Appreciably magnetic
GX3CrNiMoCuN25-6-3-3	1.4517	7.7	13	14	---	17	18	450	Appreciably magnetic
GX2CrNiMoN26-7-4	1.4469	7.7	13	14	---	17	18	450	Appreciably magnetic

a. Informative only, not mandatory.

EN 10213-3 – CHEMICAL COMPOSITION OF STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES FOR USE AT LOW TEMPERATURES[a]									
Steel Name	**Steel Number**	**C**	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Mo**
GX3CrNi13-4	1.6982	0.05	1.00	1.00	0.035	0.015	12.00 – 13.50	3.50 – 5.00	0.70

a. Cast analysis, single values are maximums.

EN 10213-3 – MECHANICAL PROPERTIES OF STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES FOR USE AT LOW TEMPERATURES								
Steel Name	Steel Number	Symbol[a]	Thickness, Max., mm,	Yield Strength, Min. MPa	Tensile Strength, MPa	% El., Min.	Impact, KV, Min.	
							J	°C
GX3CrNi13-4	1.6982	+ QT	300	500	700 - 900	15	27	-120

a. + Q = quenching in water except for GX3CrNi13-4 (quenching in air). + T = tempering.

EN 10213-3 – HEAT TREATMENT OF STAINLESS STEEL CASTINGS FOR PRESSURE PURPOSES FOR USE AT LOW TEMPERATURES				
Steel Name	Steel Number	Heat Treatment, °C		
		Symbol[a]	Quenching	Tempering
GX3CrNi13-4	1.6982	+ QT	1000 – 1050	670 – 690 + 590 – 620

a. + Q = quenching in water except for GX3CrNi13-4 (quenching in air). + T = tempering.

Chapter 19

WROUGHT PRODUCTS: STAINLESS STEELS

EN 10088 – CHEMICAL COMPOSITION OF FERRITIC STAINLESS STEELS[a, b]								
Steel Name	**Steel Number**	**C**	**Mn**	**Si**	**Cr**	**Ni**	**Mo**	**Others**
X2CrNi12	1.4003	0.030	1.50	1.00	10.50-12.50	0.30-1.00	---	N ≤ 0.030
X2CrTi12	1.4512	0.030	1.00	1.00	10.50-12.50	---	---	Ti 6x(C+N) ≤ 0.60
X6CrNiTi12	1.4516	0.080	1.50	0.70	10.50-12.50	0.50-1.50	---	Ti 0.05-0.35
X6Cr13[c]	1.4000	0.080	1.00	1.00	12.00-14.00	---	---	---
X6CrAl13[c]	1.4002	0.080	1.00	1.00	12.00-14.00	---	---	Al 0.10-0.30
X2CrTi17	1.4520	0.025	0.50	0.50	16.00-18.00	---	---	N ≤ 0.015 , Ti 0.30-0.60
X6Cr17[c]	1.4016	0.080	1.00	1.00	16.00-18.00	---	---	---
X3CrTi17[c]	1.4510	0.050	1.00	1.00	16.00-18.00	---	---	Ti 4x(C+N)+0.15 ≤ 0.80[d]
X3CrNb17	1.4511	0.050	1.00	1.00	16.00-18.00	---	---	Nb 12xC ≤ 1.00
X6CrMo17-1[c]	1.4113	0.080	1.00	1.00	16.00-18.00	---	0.90-1.40	---
X6CrMoS17	1.4105	0.080	1.50	1.00	16.00-18.00	---	0.20-0.60	S 0.15-0.35
X2CrMoTi17-1	1.4513	0.025	1.00	1.00	16.00-18.00	---	1.00-1.50	N ≤ 0.015, Ti 0.30-0.60
X2CrMoTi18-2	1.4521	0.025	1.00	1.00	17.00-20.00	---	1.80-2.50	N ≤ 0.030, Ti 4x(C+N)+0.15 ≤ 0.80[d]
X2CrMoTiS18-2	1.4523	0.030	0.50	1.00	17.50-19.00	---	2.00-2.50	S 0.15-0.35, (C+N) ≤ 0.040, Ti 0.30-0.85
X6CrNi17-1	1.4017	0.080	1.00	1.00	16.00-18.00	1.20-1.60	---	---
X6CrMoNb17-1	1.4526	0.080	1.00	1.00	16.00-18.00	---	0.90-1.40	N ≤ 0.040, Nb 7x(C+N)+0.10 ≤ 1.00
X2CrNbZr17	1.4590	0.030	1.00	1.00	16.00-17.50	---	---	Zr ≥ 7x(C+N)+0.15, Nb 0.35-0.55
X2CrAlTi18-2	1.4605	0.030	1.00	1.00	17.00-18.00	---	---	Al 1.70-2.10, Ti 4x(C+N)+0.15 ≤ 0.80[d]
X2CrTiNb18	1.4509	0.030	1.00	1.00	17.50-18.50	---	---	Nb 9xC+0.30 ≤ 1.00, Ti 0.10-0.60
X2CrMoTi29-4	1.4592	0.025	1.00	1.00	28.00-30.00	---	3.50-4.50	N ≤ 0.045, 4x(C+N)+0.15 ≤ 0.80[d]

a. Chemical compositions apply for all product forms including ingots and semi-finished materials.

b. P is 0.040% for all alloys except X2CrMoTi29-4 that contains 0.030% P; S is ≤ 0.015% for all alloys except X6CrMoS17 and X2CrMoTiS18-2 that contain 0.15-0.35% S and X2CrMoTi29-4 that contains ≤ 0.010% S.

c. For bars, rods, sections and the relevant semi-finished products, a maximum content of 0.030% S applies. For any product to be machined, a controlled sulfur content of 0.015 to 0.030% is recommended and permitted.

d. The stabilization may be made by use of titanium or niobium or zirconium. Single values are maximums, unless otherwise specified.

EN 10088-2 - MECHANICAL PROPERTIES AT AMBIENT TEMPERATURE OF MARTENSITIC STAINLESS STEELS IN THE HEAT TREATED CONDITION – SHEET, PLATE AND STRIP FOR GENERAL PURPOSES

Steel Name	Steel Number	Product Form	Max. Size mm	HTC[a]	Max Hardness[b]		Proof Stress $R_{p0.2}$ - N/mm²	Tensile Strength R_m - N/mm²	%El[c]
					Rockwell	HV or HB			
X12Cr13	1.4006	Cold Rolled Strip	6	A	90 HRB	200	---	600 max	20
		Hot Rolled Strip	12	A	90 HRB	200	---	600 max	20
		Hot Rolled Plate[d]	75	QT550	---		400	550-750	15
				QT650			450	650-850	12
X20Cr13	1.4021	Cold Rolled Strip	3	QT	44-50 HRC	440-530	---	---	---
		Cold Rolled Strip	6	A	95 HRB	225	---	700 max	15
		Hot Rolled Strip	12	A	95 HRB	225	---	700 max	15
		Hot Rolled Plate[d]	75	QT650	---		450	650-850	12
				QT750			550	750-950	10
X30Cr13	1.4028	Cold Rolled Strip	3	QT	45-51 HRC	450-550	---	---	---
		Cold Rolled Strip	6	A	97 HRB	235	---	740 max	15
		Hot Rolled Strip	12	A	97 HRB	235 HV	---	740 max	15
		Hot Rolled Plate[d]	75	QT800	---		600	800-1000	10
X39Cr13	1.4031	Cold Rolled Strip	3	QT	47-53 HRC	480-580	---	---	---
		Cold Rolled Strip	6	A	98 HRB	240	---	760 max	12
		Hot Rolled Strip	12	A	98 HRB	240	---	760 max	12
X46Cr13	1.4034	Cold Rolled Strip	6	A	99 HRB	245	---	780 max	12
		Hot Rolled Strip	12	A	99 HRB	245	---	780 max	12
X50CrMoV15	1.4116	Cold Rolled Strip	6	A	100 HRB	280	---	850 max	12
		Hot Rolled Strip	12	A	100 HRB	280	---	850 max	12
X39CrMo17-1	1.4122	Cold Rolled Strip	3	QT	47-53 HRC	480-580	---	---	---
		Cold Rolled Strip	6	A	100 HRB	280	---	900 max	12
		Hot Rolled Strip	12	A	100 HRB	280	---	900 max	12
X3CrNiMo13-4	1.4313	Hot Rolled Plate	75	QT780	---		650	780-980	14
		Hot Rolled Plate	75	QT900			800	900-1100	11

EN 10088-3 – MECHANICAL PROPERTIES AT AMBIENT TEMPERATURE OF AUSTENITIC STAINLESS STEELS IN THE SOLUTION ANNEALED CONDITION[a] FOR GENERAL PURPOSE SEMI-FINISHED PRODUCTS, BARS, RODS, AND SECTIONS (Continued)

Steel Name	Steel Number	Thickness d, mm	Hardness HB[b, c] Max.	Yield Strength, N/mm²		Tensile Strength[c, d] N/mm²	% El.[c,d] Min.		Impact Energy, (ISO-V), KV, Min., J		Resistance to Intergranular Corrosion[e]	
				0.2% Proof[d] Min.	1% Proof[d] Min.		L	T	L	T	In the As-Delivered Condition	In the Sensitized Condition
Special Grades												
X6CrNiNb18-10	1.4550	d ≤ 160	230	205	240	510-740	40	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X6CrNiMoNb17-12-2	1.4580	d ≤ 160	230	215	250	510-740	35	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X2CrNiMo18-15-4	1.4438	d ≤ 160	215	200	235	500-700	40	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X1CrNiSi18-5-4	1.4361	d ≤ 160	230	210	240	530-730	40	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X3CrNiCu19-9-2	1.4560	d ≤ 160	215	175	---	450-650	45	---	---	---	Yes	Yes
X6CrNiCuS18-9-2	1.4570	d ≤ 160	215	185	220	500-710	35	---	---	---	No	No
X3CrNiCuMo17-11-3-2	1.4578	d ≤ 160	215	175	---	450-650	45	---	---	---	Yes	Yes
X1NiCrMoCu31-27-4	1.4563	d ≤ 160	230	220	250	500-750	35	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X1CrNiMoCuN25-25-5	1.4537	d ≤ 160	250	300	340	600-800	35	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X1CrNiMoCuN20-18-7	1.4547	d ≤ 160	260	300	340	650-850	35	---	100	---	Yes	Yes
		160 < d ≤ 250					---	30	---	60		
X1NiCrMoCuN25-20-7	1.4529	d ≤ 160	250	300	340	650-850	40	---	100	---	Yes	Yes
		160 < d ≤ 250					---	35	---	60		

Chapter 20

DIN STEEL NAMES, STEEL NUMBERS, RELATED SPECIFICATIONS, AND TITLES

DIN STEEL NAMES			
Steel Name	**Steel Number**	**Specifications**	**Title**
A 0	1.0874	DIN 41301	Magnetic Sheet for Transformers
A 2	1.0875	DIN 41301	Magnetic Sheet for Transformers
A 3	1.0876	DIN 41301	Magnetic Sheet for Transformers
AlNiCo 3/5p	1.3711	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 5/6p	1.3713	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 7/8p	1.3715	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 9/5	1.3728	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 12/6	1.3743	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 18/9	1.3756	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 26/6	1.3760	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 30/10	1.3758	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 30/14	1.3765	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 35/5	1.3761	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 44/5	1.3757	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 52/6	1.3759	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
AlNiCo 60/11	1.3763	DIN 17410	Materials for Permanent Magnets; Technical Delivery Conditions
B420N	1.0428	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
B500G1	1.0464	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
B500G2	1.0465	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
B500G3	1.0466	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
B500H	1.0439	EN 10080	Steel for the Reinforcement of Concrete; Weldable Ribbed Reinforcing Steel B 500; Technical Delivery Conditions for Bars, Coils, and Welded Fabrics*
B500N	1.0438	EN 10080	Steel for the Reinforcement of Concrete; Weldable Ribbed Reinforcing Steel B 500; Technical Delivery Conditions for Bars, Coils, and Welded Fabrics*
		DIN 488-1	Reinforcing Steel; Grades, Properties and Marking

DIN STEEL NAMES (Continued)			
Steel Name	**Steel Number**	**Specifications**	**Title**
BSt 420 S	1.0428	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
BSt 500 G	1.0464	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
BSt 500 M	1.0466	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
BSt 500 P	1.0465	DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
BSt 500 S	1.0438	EN 10080	Steel for the Reinforcement of Concrete; Weldable Ribbed Reinforcing Steel B 500; Technical Delivery Conditions for Bars, Coils, and Welded Fabrics*
		DIN 488-1	Reinforcing Steel; Grades, Properties and Marking
C2D1	1.1185	EN 10016-3	Unalloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 3: Specific Requirements for Rimmed and Rimmed Substitute Low Carbon Steel Rod*
C3D1	1.1187	EN 10016-3	Unalloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 3: Specific Requirements for Rimmed and Rimmed Substitute Low Carbon Steel Rod*
C3D2	1.1110	EN 10016-4	Unalloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 4: Specific Requirements for Rod for Special Applications*
C4C	1.0303	DIN 1654-2	Cold Heading and Cold Extruding Steel; Technical Delivery Conditions for Killed Unalloyed Steel Not Intended for Heat Treatment
C4D	1.0300	EN 10016-2	Non Alloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 2: Specific Requirements for General Purpose Rod*
C4D1	1.1188	EN 10016-3	Unalloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 3: Specific Requirements for Rimmed and Rimmed Substitute Low Carbon Steel Rod*
C 5	1.0878	DIN 41301	Magnetic Sheet for Transformers
C5D2	1.1111	EN 10016-4	Unalloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 4: Specific Requirements for Rod for Special Applications*
C7C	1.0213	DIN 1654-2	Cold Heading and Cold Extruding Steel; Technical Delivery Conditions for Killed Unalloyed Steel Not Intended for Heat Treatment
C7D	1.0313	EN 10016-2	Non Alloyed Steel Wire Rod for Drawing and/or Cold Rolling. Part 2: Specific Requirements for General Purpose Rod*

DIN STEEL NAMES (Continued)

Steel Name	Steel Number	Specifications	Title
StW 24	1.0335	EN 10111	Continuously Hot Rolled Low Carbon Steel Sheet and Strip for Cold Bending; Technical Delivery Conditions*
T 50	1.0371	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T 52	1.0372	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T 57	1.0375	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T 61	1.0377	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T 65	1.0378	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T550	1.0373	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T580	1.0382	EN 31951	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Chromium Oxide Coated Steel*
T620	1.0374	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T660	1.0376	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
T690	1.0383	EN 31951	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Chromium Oxide Coated Steel*
TH50	1.0371	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel
TH52	1.0372	EN 10205	Cold Reduced Blackplate in Coil Form for the Production of Tinplate or Electrolytic Chromium/Oxide Coated Steel

DIN STEEL NAMES (Continued)

Steel Name	Steel Number	Specifications	Title
TStE 355	1.0566	EN 10028-3	Flat Products made from Steel for Pressure Purposes. Part 3: Weldable Fine Grain Steels Normalized
		DIN 17103	Weldable Fine-Grain Steel Forgings; Technical Delivery Conditions
		DIN 17123	Welded Circular Fine-Grain Steel Tubes for Structural Steelwork; Technical Delivery Conditions
		DIN 17124	Seamless Circular Fine-Grain Steel Tubes for Structural Steelwork; Technical Delivery Conditions
		DIN 17125	Square and Rectangular Fine-Grain Steel Tubes (Hollow Sections) for Structural Steelwork; Technical Delivery Conditions
		DIN 17178	Welded Circular Fine-Grain Steel Tubes Subject to Special Requirements; Technical Delivery Conditions
		DIN 17179	Seamless Circular Fine-Grain Steel Tubes Subject to Special Requirements; Technical Delivery Conditions
		W 081	Mechanical Properties of Weldable Fine-Grain Normalized Structural Steel to DIN 17102 for Product Widths Above 100 mm to Below 250 mm
TStE 380	1.8910	DIN 17102	Weldable Normalized Fine-Grain Structural Steel; Technical Delivery Conditions for Plate Strip Wide Flats Sections and Bars
TStE 420	1.8912	EN 10113-2	Hot-Rolled Products in Weldable Fine-Grain Structural Steels. Part 2: Delivery Conditions for Normalized/Normalized Rolled Steels
		DIN 17102	Weldable Normalized Fine-Grain Structural Steel; Technical Delivery Conditions for Plate Strip Wide Flats Sections and Bars
		DIN 17103	Weldable Fine-Grain Steel Forgings; Technical Delivery Conditions
		DIN 17119	Welded Cold Worked Square and Rectangular Steel Tubes (Hollow Sections) for Structural Steelwork; Technical Delivery Conditions
		DIN 17123	Welded Circular Fine-Grain Steel Tubes for Structural Steelwork; Technical Delivery Conditions

Chapter 21

CORRESPONDING FORMER NATIONAL DESIGNATIONS

CORRESPONDING FORMER NATIONAL DESIGNATIONS							
EN 10113-1:1993		HOT-ROLLED PRODUCTS IN WELDABLE FINE GRAIN STRUCTURAL STEELS - GENERAL DELIVERY CONDITIONS PRODUITS LAMINÉS À CHAUD EN ACIERS DE CONSTRUCTION SOUDABLES À GRAINS FINS - CONDITIONS GÉNÉRALES DE LIVRAISON WARMGEWALZTE ERZEUGNISSE AUS SCHWEIßGEEIGNETEN FEINKORNBAUSTÄHLEN - ALLGEMEINE LIEFERBEDINGUNGEN					
Steel Name	**Steel Number**	**Equivalent Former Designation Used In**					
		EU 113-72	**Germany**	**France**	**United Kingdom**	**Italy**	**Sweden**
S275N	1.0490	FeE 275 KGN	StE 285	---	---	FeE 275 KGN	---
S275NL	1.0491	FeE 275 KTN	TStE 285	---	40 EE	FeE 275 KTN	---
S355N	1.0545	FeE 355 KGN	StE 355	E 355 R	---	FeE 355 KGN	2134-01
S355NL	1.0546	FeE 355 KTN	TStE 355	E 355 FP	50 EE	FeE 355 KTN	2135-01
S420N	1.8902	FeE 420 KGN	StE 420	E 420 R	---	---	---
S420NL	1.8912	FeE 420 KTN	TStE 420	E 420 FP	---	---	---
S460N	1.8901	FeE 460 KGN	StE 460	E 460 R	---	FeE 460 KGN	---
S460NL	1.8903	FeE 460 KTN	TStE 460	E 460 FP	55 EE	FeE 460 KTN	---
S275M	1.8818	FeE 275 KGTM	---	---	---	FeE 275 KGTM	---
S275ML	1.8819	FeE 275 KTTM	---	---	---	FeE 275 KTTM	---
S355M	1.8823	FeE 355 KGTM	StE 355 TM	---	---	FeE 355 KGTM	---
S355ML	1.8834	FeE 355 KTTM	TStE 355 TM	---	---	FeE 355 KTTM	---
S420M	1.8825	FeE 420 KGTM	StE 420 TM	---	---	---	---
S420ML	1.8836	FeE 420 KTTM	TStE 420 TM	---	---	---	---
S460M	1.8827	FeE 460 KGTM	StE 460 TM	---	---	FeE 460 KGTM	---
S460ML	1.8838	FeE 460 KTTM	TStE 460 TM	---	---	FeE 460 KTTM	---

CORRESPONDING FORMER NATIONAL DESIGNATIONS

EN 10111:1998	**CONTINUOUSLY HOT-ROLLED LOW CARBON STEEL SHEET AND STRIP FOR COLD FORMING - TECHNICAL DELIVERY CONDITIONS**
	BANDES ET TÔLES LAMINÉES À CHAUD EN CONTINU, EN ACIER DOUX POUR EMBOUTISSAGE OU PLIAGE À FROID - CONDITIONS TECHNIQUES DE LIVRAISON
	KONTINUIERLICH WARMGEWALZTES BAND UND BLECH AUS WEICHEN STÄHLEN ZUM KALTUMFORMEN - TECHNISCHE LIEFERBEDINGUNGEN

Steel Name	Steel Number	Designation Following EU 111.77	Corresponding Previous Designations Used In				
			Germany DIN 1614	France NF A 36 301	United Kingdom BS 1449	Spain UNE 36-086	Italy UNI 5867
DD 11	1.0332	FeP11	StW22	1C	HR3	AP11	FeP11
DD 12	1.0398	FeP12	RRStW23	---	---	---	---
DD 13	1.0335	FeP13	StW24	3C	HR1	AP13	FeP13
DD 14	1.0389	---	---	3CT	---	---	---

CORRESPONDING FORMER NATIONAL DESIGNATIONS

EN 10025:1990/A1:1993	**HOT ROLLED PRODUCTS OF NON-ALLOY STRUCTURAL STEELS - TECHNICAL DELIVERY CONDITIONS (INCLUDES AMENDMENT A1:1993)**
	PRODUITS LAMINÉS À CHAUD EN ACIERS DE CONSTRUCTION NON ALLIÉS - CONDITIONS TECHNIQUES DE LIVRAISON (INCLUT L'AMENDEMENT A1:1993)
	WARMGEWALZTE ERZEUGNISSE AUS UNLEGIERTEN BAUSTÄHLEN - TECHNISCHE LIEFERBEDINGUNGEN (ENTHÄLT ÄNDERUNG A1:1993)

Steel Name	Steel Number	Designation According to EN 10025-1990	Equivalent Former Designations Used In					
			Germany	France	United Kingdom	Spain	Italy	Belgium
S185	1.0035	Fe 310-0	St 33	A 33	---	A 310-0	Fe 320	A 320
S235JR	1.0037	Fe 360 B	St 37-2	E 24-2	---	---	Fe 360 B	AE 235-B
S235JRG1	1.0036	Fe 360 BFU	USt 37-2	---	---	AE 235 B-FU	---	---

CORRESPONDING FORMER NATIONAL DESIGNATIONS (Continued)					
EN 10248-1:1995		HOT ROLLED SHEET PILING OF NON ALLOY STEELS - TECHNICAL DELIVERY CONDITIONS PALPLANCHES LAMINÉES À CHAUD EN ACIERS NON ALLIÉS - CONDITIONS TECHNIQUES DE LIVRAISON WARMGEWALZTE SPUNDBOHLEN AUS LEGIERTEN STÄHLEN - TECHNISCHE LIEFERBEDINGUNGEN			
Steel Name	Steel Number	Equivalent Former Designations			
		Germany	France	United Kingdom	Belgium
S355GP	1.0083	StSp S	E360SP	50 A	PAE360
S390GP	1.0522	---	E390SP	---	PAE390
S430GP	1.0523	---	E430SP	---	PAE420

CORRESPONDING FORMER NATIONAL DESIGNATIONS										
EN 10083-1:1991 + A1:1996		QUENCHED AND TEMPERED STEELS - TECHNICAL DELIVERY CONDITIONS FOR SPECIAL STEELS (INCLUDES AMENDMENT A1:1996) ACIERS POUR TREMPE ET REVENU - CONDITIONS TECHNIQUES DE LIVRAISON DES ACIERS SPÉCIAUX (INCLUT L'AMENDEMENT A1:1996) VERGÜTUNGSSTÄHLE - TECHNISCHE LIEFERBEDINGUNGEN FÜR EDELSTÄHLE (ENTHÄLT ÄNDERUNG A1:1996)								
Steel Name	Steel Number	ISO 683-1: 1987[a]	Germany[a]		Finland	France	United Kingdom[a]	Spain		Sweden SS-Steel
			Steel Name	Steel Number				Steel Name	Steel Number	
C22E	1.1151	---	(Ck22)	(1.1151)	---	[XC 18]	(070M20)	---	---	---
C22R	1.1149	---	(Cm22)	(1.1149)	---	[XC 81 u]	---	---	---	---
C25E	1.1158	(C 25 E4)	Ck25	1.1158	---	[XC 25]	(070M26)	C25K	F1120	---
C25R	1.1163	(C 25 M2)	Cm25	1.1163	---	[XC 25 u]	---	C25K-1	(F1125)	---
C30E	1.1178	(C 30 E4)	Ck30	1.1178	---	[XC 32]	(080M30)	---	---	---
C30R	1.1179	(C 30 M2)	Cm30	1.1179	---	[XC 32 u]	---	---	---	---
C35E	1.1181	(C 35 E4)	Ck35	1.1181	C35	[XC 38 H1]	(080M36)	C35K	F1130	1572
C35R	1.1180	(C 35 M2)	Cm35	1.1180	---	[XC 38 H1 u]	---	C35K-1	(F1135)	---

CORRESPONDING FORMER NATIONAL DESIGNATIONS					
EN 10155:1993		STRUCTURAL STEELS WITH IMPROVED ATMOSPHERIC CORROSION RESISTANCE - TECHNICAL DELIVERY CONDITIONS ACIERS DE CONSTRUCTION À RÉSISTANCE AMÉLIORÉE À LA CORROSION ATMOSPHÉRIQUE - CONDITIONS TECHNIQUES DE LIVRAISON WETTERFESTE BAUSTÄHLE - TECHNISCHE LIEFERBEDINGUNGEN			
Steel Name	Steel Number	Designation According to EU 155-80	Equivalent Former Designations		
			Germany	France	United Kingdom
S235J0W	1.8958	Fe 360 C Kl	---	E 24 W 3	---
S235J2W	1.8961	Fe 360 D Kl	WTSt 37-3	E 24 W 4	---
S355J0WP	1.8945	Fe 510 C 1 Kl	---	E 36 WA 3	WR 50 A
S355J2WP	1.8946	Fe 510 D 1 Kl	---	E 36 WA 4	---
S355J0W	1.8959	Fe 510 C 2 Kl	---	E 36 WB 3	WR 50 B
S355J2G1W	1.8963	Fe 510 D 2 Kl	WTSt 52-3	E 36 WB 4	WR 50 C
S355J2G2W	1.8965	---	---	---	---
S355K2G1W	1.8966	---	---	---	---
S355K2G2W	1.8967	---	---	---	---

CORRESPONDING FORMER NATIONAL DESIGNATIONS					
EN 10248-1:1995		HOT ROLLED SHEET PILING OF NON ALLOY STEELS - TECHNICAL DELIVERY CONDITIONS PALPLANCHES LAMINÉES À CHAUD EN ACIERS NON ALLIÉS - CONDITIONS TECHNIQUES DE LIVRAISON WARMGEWALZTE SPUNDBOHLEN AUS LEGIERTEN STÄHLEN - TECHNISCHE LIEFERBEDINGUNGEN			
Steel Name	Steel Number	Equivalent Former Designations			
		Germany	France	United Kingdom	Belgium
S240GP	1.0021	StSp 37	E240SP	40 A	PAE250
S270GP	1.0023	StSp 45	E270SP	43 A	PAE270
S320GP	1.0046	---	E320SP	---	PAE320

Chapter 22

EURONORMS WITH CORRESPONDING NATIONAL STANDARDS

EURONORMS WITH CORRESPONDING NATIONAL STANDARDS

EURONORM	Germany DIN	France NF	United Kingdom BS	Spain UNE	Italy UNI	Belgium NBN	Portugal NP	Sweden SS	Austria M	Norway NS
5	50 133	A 03-154	427	7-423	1955	A 11-107	---	---	---	---
17	59 110	A 45 051	---	36-089	5598	524	330	---	---	---
18	---	A 03 111	1449/1	36-300	EU 18	A 03-001	2451	11 01 20	---	10 005
			1501	36-400				11 01 05		10 006
			1502							
			4360							
19	1025 T 5	A 45 205	---	36-526	5398	533	2116	21 27 40	3262	---
21	17 010	A 03-115	1449	36-007	EU 21	A 02-001	---	11 00 01	---	---
	50 049	---	---	---	---	---	---	21 93 01	---	---
24	1025 T 1	A 45 210	4	36-521	5679	632-01	---	21 27 25	3261	911
	1026	---	---	36-522	5680	---	---	21 27 35	---	---
48	1016	A 46 100	1449	36-553	6685	---	---	---	DIN 1016	---
49	---	---	---	---	---	---	---	ISO 4288	---	---
53	1025 T2	A 45 201	4	36-527	5397	633	2117	21 27 50	---	1907
	1025 T3			36-528				21 27 51		1908
	1025 T4			36-529				21 27 52		
54	1026	A 45 007	4	36-525	EU 54	A 24-204	338	---	3260	---
55	1024	A 45 008[a]	4	36-533	EU 55	A 24-205	337	21 27 20	---	1905
56	1028	A 45 009[a]	4848	36-531	EU 56	A 24-201	335	21 27 11	3246	1903
57	1029	A 45 010[a]	4848	36-532	EU 57	A 34-202	336	21 21 12	3247	1904
58	1017 T1	A 45 005[a]	4360	36-543	EU 58	A 34-201	---	21 21 50	3230	1902
59	1014 T1	A 45 004[a]	4360	36-542	EU 59	A 34-202	333 + 334	21 27 25	3226	1901
60	1013 T1	A 45 003[a]	4360	36-541	EU 60	A 34-203	331	21 25 02	3221	1900
61	1015	A 45 006[a]	970	36-547	7061	A 24-204	---	---	3237/3228	---

EURONORMS WITH CORRESPONDING NATIONAL STANDARDS (Continued)

EURONORM	Germany DIN	France NF	United Kingdom BS	Spain UNE	Italy UNI	Belgium NBN	Portugal NP	Sweden SS	Austria M	Norway NS
				07-278						
65	59 130	A 45 075[a]	3111	36-546	7356	A 24-206	---	---	3223	---
66	1018	---	---	---	6630	---	---	---	---	---
67	1019	A 45 011	4848	36-548	EU 67	A 24-203	---	21 11 70	---	6034
79	---	A 40 001	6562	36-501	7272	A 01-102	---	01 66 01	---	---
91	59 200	A 46 012	4360	---	EU 91	A 43-301	---	21 21 50	3231	---
103	50 601	A 04 102	4490	7-280	3245	A 14-101	1787	---	---	---
					EU103					
131	1541	---	1449	36-563	---	A 43-401	---	21 12 10	---	---
160	SEL 072-77	A 04 305	5996	36-100	EU 160	---	---	11 42 01	---	---
					5329			21 91 14	---	---
162	17 118	A 37 101	2994	36-570	7344	A 02-002	---	---	3316	---
	59 413	---	---	---	---	---	---	---	---	---
168	---	A 03 116	1501	36-800	EU 168	---	---	11 00 12	---	---
			1502							
			4360							
			6363							
186	---	A 04 306	---	---	---	---	---	---	---	---
ECSC IC 2	SEW 088	A 36 000	5135	---	---	---	---	06 40 25	---	---

a. Tolerances are specified in NF A 45 001 and NF A 45 101

Chapter 23

INTERNATIONAL CROSS REFERENCES:

CARBON & ALLOY STEELS

23.1 Carbon Steels for General Use (Continued)

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	**Name**	**Number**	**Specification**	**Grade**	**UNS #**	**Specification**	**Symbol**	**Specification**	**Name**
10016-2:1994	C20D	s1.0414	A 29/A 29M-99	1020	G10200	G 4051 (1979)	S 20 C	---	---
10016-4:1994	C20D2	1.1137		1021	G10210		S 20 CK	---	---
10083-1:1991	2 C 22	---		1022	G10220	---	---	---	---
	3 C 22	---	A 108-99	1020	G10200	---	---	---	---
10083-2:1991	1 C 22	1.0402		1022	G10220	---	---	---	---
---	---	---	A 576-90	1020	G10200	---	---	---	---
---	---	---		1021	G10210	---	---	---	---
---	---	---		1022	G10220	---	---	---	---
---	---	---	J403 AUG95	1020	G10200	---	---	---	---
---	---	---		1021	G10210	---	---	---	---
---	---	---		1022	G10220	---	---	---	---
---	---	---	A 29/A 29M-99	1023	---	G 4051 (1979)	S 22 C	---	---
---	---	---	A 576-90	1023	G10230	---	---	---	---
---	---	---	J403 AUG95	1023	G10230	---	---	---	---
10016-2:1994	C26D	1.0415	A 29/A 29M-99	1025	G10250	G 4051 (1979)	S 25 C	683-1:1987	C 25
10016-4:1994	C26D2	1.1139		1026	G10260	---	---		C 25 E 4
10083-1:1991	2 C 25	---	A 108-99	1025	G10250	---	---		C 25 M 2
	3 C 25	---	A 576-90	1025	G10250	---	---	---	---
10083-2:1991	1 C 25	---		1026	G10260	---	---	---	---
---	---	---	J403 AUG95	1025	G10250	---	---	---	---
---	---	---		1026	G10260	---	---	---	---

23.1 Carbon Steels for General Use (Continued)

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	**Name**	**Number**	**Specification**	**Grade**	**UNS #**	**Specification**	**Symbol**	**Specification**	**Name**
10016-2:1994	C80D	1.0622	A 29/A 29M-99	1078	G10780	---	---	---	---
	C82D	1.0626	A 576-90	1078	G10780	---	---	---	---
10016-4:1994	C80D2	1.1255	J403 AUG95	1078	G10780	---	---	---	---
	C82D2	1.1262	---	---	---	---	---	---	---
10016-2:1994	C86D	1.0616	A 29/A 29M-99	1080	G10800	---	---	---	---
10016-4:1994	C86D2	1.1265	A 576-90	1080	G10800	---	---	---	---
---	---	---	J403 AUG95	1080	G10800	---	---	---	---
10016-2:1994	C88D	1.0628	A 29/A 29M-99	1084	G10840	---	---	---	---
10016-4:1994	C88D2	1.1272		1086	G10860	---	---	---	---
---	---	---	A 576-90	1084	G10840	---	---	---	---
---	---	---	J403 AUG95	1086	G10860	---	---	---	---
10016-2:1994	C92D	1.0618	A 29/A 29M-99	1090	G10900	---	---	---	---
10016-4:1994	C92D2	1.1282	A 576-90	1090	G10900	---	---	---	---
---	---	---	J403 AUG95	1090	G10900	---	---	---	---
10016-4:1994	C98D2	1.1283	A 29/A 29M-99	1095	G10950	---	---	---	---
---	---	---	A 108-99	1095	G10950	---	---	---	---
---	---	---	A 576-90	1095	G10950	---	---	---	---
---	---	---	J403 AUG95	1095	G10950	---	---	---	---

Chapter 24

INTERNATIONAL CROSS REFERENCES:

CASTINGS

24.1 Cast Carbon Steels

24.1.1 Cast Carbon Steel for General and Structural Applications

USA – SAE/ASTM			Japan - JIS		International - ISO		Germany - DIN		France - AFNOR		UK – BSI BS	
Spec	**Grade**	**UNS #**	**Spec**	**Symbol**	**Spec**	**Name**	**Spec**	**Name**	**Spec**	**Name**	**Spec**	**Grade**
---	---	---	G 5101:1991	SC 360	---	---	1681:1985	GS-38 1.0420	---	---	---	---
A 27/A 27M-95 (2000)	U-60-30	J02500	G 5101:1991	SC 410	3755:1991	200-400	---	---	NF A 32-054:1994	GE230	3100:1991 AMD.1:1992	A1
	60-30	J03000	G 5102:1991	SCW 410		200-400W	---	---		G16Mn5	---	---
A 27/A 27M-95 (2000)	65-35	J03001	G 5101:1991	SC 450	3755:1991	230-450	1681:1985	GS-45 1.0446	---	---	---	---
A 958-00	SC 1020 Cl. 65/35	---	G 5102:1991	SCW 450		230-450W	---	---	---	---	---	---
	SC 1025 Cl. 65/35	---	---	---	---	---	---	---	---	---	---	---
	SC 1030 Cl. 65/35	---	---	---	---	---	---	---	---	---	---	---
A 27/A 27M-95 (2000)	70-36	J03501	G 5101:1991	SC 480	3755:1991	270-480	---	---	NF A 32-054:1994	GE280	3100:1991 AMD.1:1992	A2
	70-40	J02501	G 5102:1991	SCW 480		270-480W	---	---	---	---	---	---
A 958-00	SC 1020 Cl. 70/36	---	---	---	---	---	---	---	---	---	---	---
	SC 1025 Cl. 70/36	---	---	---	---	---	---	---	---	---	---	---
	SC 1030 Cl. 70/36	---	---	---	---	---	---	---	---	---	---	---
	SC 1040 Cl. 70/36	---	---	---	---	---	---	---	---	---	---	---

24.3 Cast Alloy Steels

24.3.2. Cast Alloy Steels for Pressure Purposes at High Temperatures

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Spec	**Name**	**Number**	**Spec**	**Grade**	**UNS #**	**Spec**	**Symbol**	**Spec**	**Name**
10213-2:1996	G20Mo5	1.5419	A 217/A 217M-99	WC1	J12524	G 5151:1991	SCPH 11	4991:1994	C28H
10213-2:1996	G17CrMo5-5	1.7357	A 217/A 217M-99	WC6	J12072	G 5151:1991	SCPH 21	4991:1994	C32H
10213-2:1996	G17CrMoV5-10	1.7706	A 389/A 389M-93 (1998)	C24	J12092	G 5151:1991	SCPH 23	4991:1994	C35BH
10213-2:1996	G17CrMo9-10	1.7379	A 217/A 217M-99	WC9	J21890	G 5151:1991	SCPH 32	4991:1994	C34AH
---	---	---	A 487/A487M-93 (1998)	8 Cl. ABC	J22091	---	---		C34BH
10213-2:1996	GX15CrMo5	1.7365	A 217/A 217M-99	C5	J42045	G 5151:1991	SCPH 61	4991:1994	C37H
---	---	---	A 217/A 217M-99	C12	J82090	---	---	4991:1994	C38H

24.3.3 Cast Alloy Steels for Pressure Purposes at Low Temperatures

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Spec	**Name**	**Number**	**Spec**	**Grade**	**UNS #**	**Spec**	**Symbol**	**Spec**	**Name**
10213-3:1996	G18Mo5	1.5422	A 352/A 352M-93 (1998)	LC1	J12522	G 5152:1991	SCPL 11	---	---
10213-3:1996	G9Ni10	1.5636	A 757/A 757M-00	B2N, B2Q	J22501	G 5152:1991	SCPL 21	---	---
---	---	---	A 352/A 352M-93 (1998)	LC2	J22500	---	---	---	---
10213-3:1996	G9Ni14	1.5638	A 757/A 757M-00	B3N, B3Q	J31500	G 5152:1991	SCPL 31	4991:1994	C43L
---	---	---	A 352/A 352M-93 (1998)	LC3	J31550	---	---	---	---
10213-3:1996	G17NiCrMo13-6	1.6781	A 352/A 352M-93 (1998)	LC2-1	J42215	---	---	4991:1994	C43E2aL
---	---	---	A 757/A 757M-00	E3N	J42065	---	---		C43E2bL

Chapter 25

INTERNATIONAL CROSS REFERENCES:

FORGINGS

25.2 Alloy Steel Forgings

25.2.2 Alloy Steel Forgings for Piping, Pressure Vessel and Components

25.2.2.1 Mo Alloy Steel

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	Steel Name	Steel Number	Specification	Grade	UNS Number	Specification	Symbol	Specification	Steel Name
10222-2:1999	16Mo3	1.5415	A 182/A 182M-00	F 1	K12822	G 3203:1988	SFVA F 1	9327-2:1999	16Mo3
---	---	---	A 336/A 336M-99	F1	K12520	---	---	---	---

25.2.2.2 ½Cr-½Mo Alloy Steels

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	Steel Name	Steel Number	Specification	Grade	UNS Number	Specification	Symbol	Specification	Steel Name
---	---	---	A 182/A 182M-00	F 2	K12122	G 3203:1988	SFVA F 2	---	---

25.2.2.3 1Cr-½Mo Alloy Steels

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	Steel Name	Steel Number	Specification	Grade	UNS Number	Specification	Symbol	Specification	Steel Name
10222-2:1999	13CrMo4-5	1.7335	A 182/A 182M-00	F 12, Cl 2	K11564	G 3203:1988	SFVA F 12	9327-2:1999	14CrMo4-5
---	---	---	A 336/A 336M-99	F12	K11564	---	---	---	---

25.3 Stainless Steel Forgings

25.3.3 Austenitic Stainless Steel Forgings

European Union - CEN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	Steel Name	Steel Number	Specification	Grade	UNS Number	Specification	Symbol	Specification	Steel Name
10222-5:1999	X5CrNi18-10	1.4301	A 182/A 182M-00	F 304	S30400	G 3214:1991	SUS F 304	9327-5:1999	X5CrNi18-9
10250-4:1999	X5CrNi18-10	1.4301	---	---	---	---	---	---	---
10250-4:1999	X2CrNi18-9	1.4307	A 182/A 182M-00	F 304L	S30403	G 3214:1991	SUS F 304L	9327-5:1999	X2CrNi18-10
	X2CrNi19-11	1.4306	---	---	---	---	---	---	---
10222-5:1999	X2CrNi18-9	1.4307	---	---	---	---	---	---	---
10222-5:1999	X6CrNi18-10	1.4948	A 182/A 182M-00	F 304H	S30409	G 3214:1991	SUS F 304H	9327-5:1999	X7CrNi18-9
---	---	---	A 182/A 182M-00	F 304N	S30451	G 3214:1991	SUS F 304N	---	---
10222-5:1999	X2CrNiN18-10	1.4311	A 182/A 182M-00	F 304LN	S30453	G 3214:1991	SUS F 304LN	9327-5:1999	X2CrNiN18-10
10250-4:1999	X2CrNiN18-10	1.4311	---	---	---	---	---	---	---
---	---	---	A 182/A 182M-00	F 310	S31000	G 3214:1991	SUS F 310	9327-5:1999	X6CrNi25-21
---	---	---	---	F310H	S31009	---	---	9327-5:1999	---
10250-4:1999	X5CrNiMo17-12-2	1.4401	A 182/A 182M-00	F 316	S31600	G 3214:1991	SUS 316	9327-5:1999	X5CrNiMo17-12
	X3CrNiMo17-13-3	1.4436	---	---	---	---	---		X5CrNiMo17-13
10222-5:1999	X5CrNiMo17-12-2	1.4401	---	---	---	---	---	---	---
	X3CrNiMo17-13-3	1.4436	---	---	---	---	---	---	---
10222-5:1999	X2CrNiMo17-12-2	1.4404	A 182/A 182M-00	F 316L	S31603	G 3214:1991	SUS F 316L	9327-5:1999	X2CrNiMo17-12
	X2CrNiMo17-12-3	1.4432	---	---	---	---	---		X2CrNiMo17-13
	X2CrNiMo18-14-3	1.4435	---	---	---	---	---	---	---
10250-4:1999	X2CrNiMo17-12-2	1.4404	---	---	---	---	---	---	---
	X2CrNiMo18-14-3	1.4435	---	---	---	---	---	---	---

Chapter 26

INTERNATIONAL CROSS REFERENCES:

WROUGHT STAINLESS STEELS

26.1 Stainless Steels: Plate, Sheet and Strip

26.1.1 Martensitic Stainless Steels

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	Steel Name	Steel Number	Specification	Grade	UNS Number	Specification	Symbol	Specification	Steel Name
---	---	---	A 176-99	403	S40300	G 4304:1999	SUS403	---	---
---	---	---	---	---	---	G 4305:1999	SUS403	---	---
---	---	---	---	---	---	G 4312:1991	SUS403	---	---
10088-2:1995	X6Cr13	1.4000	---	---	---	G 4304:1999	SUS410S	4955:1994	X6Cr13
---	---	---	---	---	---	G 4305:1999	SUS410S	---	---
10088-2:1995	X20Cr13	1.4021	A 176-99	420	S42000	G 4304:1999	SUS420J1	---	---
---	---	---	---	---	---	G 4305:1999	SUS420J1	---	---
10088-2:1995	X30Cr13	1.4028	---	---	---	G 4304:1999	SUS420J2	---	---
---	---	---	---	---	---	G 4305:1999	SUS420J2	---	---

26.2 Stainless Steels: Bar

26.2.3 Austenitic Stainless Steels (Continued)

European Union - EN			USA – SAE/ASTM			Japan - JIS		International - ISO	
Specification	Steel Name	Steel Number	Specification	Grade	UNS Number	Specification	Symbol	Specification	Steel Name
---	---	---	A 276-00	309S	S30908	G 4303:1998	SUS309S	4955:1994	X6CrNi23-14
---	---	---	---	---	---	G 4311:1991	SUS309S	---	---
---	---	---	---	---	---	G 4318:1998	SUS309S	---	---
---	---	---	A 276-00	310S	S31008	G 4303:1998	SUS310S	---	---
---	---	---	---	---	---	G 4311:1991	SUS310S	---	---
---	---	---	---	---	---	G 4318:1998	SUS310S	---	---
10088-3:1995	X5CrNiMo17-12-2	1.4401	A 276-00	316	S31600	G 4303:1998	SUS316	---	---
	X3CrNiMo17-13-3	1.4436	---	---	---	G 4311:1991	SUS316	---	---
---	---	---	---	---	---	G 4318:1998	SUS316	---	---
10088-3:1995	X2CrNiMo17-12-2	1.4404	A 276-00	316L	S31603	G 4303:1998	SUS316L	---	---
	X2CrNiMo17-12-3	1.4432	---	---	---	G 4318:1998	SUS316L	---	---
	X2CrNiMo18-14-3	1.4435	---	---	---	---	---	---	---
---	---	---	A 276-00	316N	S31651	G 4303:1998	SUS316N	---	---
10088-3:1995	X2CrNiMoN17-11-2	1.4406	A 276-00	316LN	S31653	G 4303:1998	SUS316LN	---	---
---	X2CrNiMoN17-13-3	1.4429	---	---	---	---	---	---	---
10088-3:1995	X6CrNiMoTi17-12-2	1.4571	A 276-00	316Ti	S31635	G 4303:1998	SUS316Ti	---	---
---	---	---	---	---	---	G 4311:1991	SUS316Ti	---	---
---	---	---	A 276-00	317	S31700	G 4303:1998	SUS317	---	---
---	---	---	---	---	---	G 4311:1991	SUS317	---	---

Appendix 1

HARDNESS CONVERSION TABLES

APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS[a, b]

Rockwell C 150 kgf Diamond HRC	Vickers HV	Brinell 3000 kgf 10mm ball HB	Knoop 500 gf HK	Rockwell A 60 kgf Diamond HRA	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
					15 kgf Diamond HR15N	30 kgf Diamond HR30N	45 kgf Diamond HR45N	
68	940	---	920	85.6	93.2	84.4	75.4	---
67	900	---	895	85.0	92.9	83.6	74.2	---
66	865	---	870	84.5	92.5	82.8	73.3	---
65	832	739[d]	846	83.9	92.2	81.9	72.0	---
64	800	722[d]	822	83.4	91.8	81.1	71.0	---
63	772	706[d]	799	82.8	91.4	80.1	69.9	---
62	746	688[d]	776	82.3	91.1	79.3	68.8	---
61	720	670[d]	754	81.8	90.7	78.4	67.7	---
60	697	654[d]	732	81.2	90.2	77.5	66.6	---
59	674	634[d]	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)

APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS[a, b] (Continued)

Rockwell C 150 kgf Diamond HRC	Vickers HV	Brinell 3000 kgf 10mm ball HB	Knoop 500 gf HK	Rockwell A 60 kgf Diamond HRA	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
					15 kgf Diamond HR15N	30 kgf Diamond HR30N	45 kgf Diamond HR45N	
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)

APPROXIMATE HARDNESS NUMBERS FOR AUSTENITIC STEELS[a] (Continued)

Rockwell C 150 kgf, Diamond HRC	Rockwell A 60 kgf, Diamond HRA	Rockwell Superficial Hardness		
		15 kgf, Diamond HR15N	30 kgf, Diamond HR30N	45 kgf, Diamond HR45N
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

a. All relative hardness values in this table are averages of tests on various metals whose different properties prevent establishment of exact mathematical conversions. These values are consistent with ASTM A 370-91 for austenitic steels. It is recommended that ASTM standards A 370, E 140, E 10, E 18, E 92, E 110 and E 384, involving hardness tests on metals, be reviewed prior to interpreting hardness conversion values.

Appendix

2

SI UNIT CONVERSIONS

METRIC CONVERSION FACTORS					
To Convert From	**To**	**Multiply By**	**To Convert From**	**To**	**Multiply By**
Angle			**Mass per unit length**		
degree	rad	1.745 329 E -02	lb/ft	kg/m	1.488 164 E + 00
Area			lb/ft	kg/m	1.785 797 E + 01
$in.^2$	mm^2	6.451 600 E + 02	**Mass per unit time**		
$in.^2$	cm^2	6.451 600 E + 00	lb/h	kg/s	1.259 979 E - 04
$in.^2$	m^2	6.451 600 E - 04	lb/min	kg/s	7.559 873 E - 03
ft^2	m^2	9.290 304 E - 02	lb/s	kg/s	4.535 924 E - 01
Bending moment or torque			**Mass per unit volume (includes density)**		
lbf - in.	N - m	1.129 848 E - 01	g/cm^3	kg/m^3	1.000 000 E + 03
lbf - ft	N - m	1.355 818 E + 00	lb/ft^3	g/cm^3	1.601 846 E - 02
kgf - m	N - m	9.806 650 E + 00	lb/ft^3	kg/m^3	1.601 846 E + 01
ozf - in.	N - m	7.061 552 E - 03	$lb/in.^3$	g/cm^3	2.767 990 E + 01
Bending moment or torque per unit length			$lb/in.^3$	kg/m^3	2.767 990 E + 04
lbf - in./in.	N - m/m	4.448 222 E + 00	**Power**		
lbf - ft/in.	N - m/m	5.337 866 E + 01	Btu/s	kW	1.055 056 E + 00
Corrosion rate			Btu/min	kW	1.758 426 E - 02
mils/yr	mm/yr	2.540 000 E - 02	Btu/h	W	2.928 751 E - 01
mils/yr	µ/yr	2.540 000 E + 01	erg/s	W	1.000 000 E - 07
Current density			ft - lbf/s	W	1.355 818 E + 00
$A/in.^2$	A/cm^2	1.550 003 E - 01	ft - lbf/min	W	2.259 697 E - 02
$A/in.^2$	A/mm^2	1.550 003 E - 03	ft - lbf/h	W	3.766 161 E - 04
A/ft^2	A/m^2	1.076 400 E + 01	hp (550 ft - lbf/s)	kW	7.456 999 E - 01
Electricity and magnetism			hp (electric)	kW	7.460 000 E - 01
gauss	T	1.000 000 E - 04			

METRIC CONVERSION FACTORS (Continued)					
To Convert From	**To**	**Multiply By**	**To Convert From**	**To**	**Multiply By**
Electricity and magnetism (Continued)			**Power density**		
maxwell	μWb	1.000 000 E - 02	$W/in.^2$	W/m^2	1.550 003 E + 03
mho	S	1.000 000 E + 00	**Pressure (fluid)**		
Oersted	A/m	7.957 700 E + 01	atm (standard)	Pa	1.013 250 E + 05
Ω - cm	Ω - m	1.000 000 E - 02	bar	Pa	1.000 000 E + 05
Ω circular - mil/ft	μΩ - m	1.662 426 E - 03	in. Hg (32°F)	Pa	3.386 380 E + 03
Energy (impact other)			in. Hg (60°F)	Pa	3.376 850 E + 03
ft - lbf	J	1.355 818 E + 00	$lbf/in.^2$ (psi)	Pa	6.894 757 E + 03
Btu (thermochemical)	J	1.054 350 E + 03	torr (mm Hg, 0°C)	Pa	1.333 220 E + 02
cal (thermochemical)	J	4.184 000 E + 00	**Specific heat**		
kW - h	J	3.600 000 E + 06	Btu/lb - °F	J/kg - K	4.186 800 E + 03
W - h	J	3.600 000 E + 03	cal/g - °C	J/kg - K	4.186 800 E + 03
Flow rate			**Stress (force per unit area)**		
ft^3/h	L/min	4.719 475 E - 01	$tonf/in.^2$ (tsi)	MPa	1.378 951 E + 01
ft^3/min	L/min	2.831 000 E + 01	kgf/mm^2	MPa	9.806 650 E + 00
gal/h	L/min	6.309 020 E - 02	ksi	MPa	6.894 757 E + 00
gal/min	L/min	3.785 412 E + 00	$lbf/in.^2$ (psi)	MPa	6.894 757 E - 03
Force			MN/m^2	MPa	1.000 000 E + 00
lbf	N	4.448 222 E + 00	**Temperature**		
kip (1000 lbf)	N	4.448 222 E + 03	°F	°C	5/9 (°F - 32)
tonf	kN	8.896 443 E + 00	R	K	5/9
kgf	N	9.806 650 E + 00	**Temperature interval**		
			°F	°C	5/9
Force per unit length			**Thermal conductivity**		
lbf/ft	N/m	1.459 390 E + 01	Btu - in./s - ft^2 - °F	W/m - K	5.192 204 E + 02
lbf/in.	N/m	1.751 268 E + 02	Btu/ft - h - °F	W/m - K	1.730 735 E + 00

METRIC CONVERSION FACTORS (Continued)					
To Convert From	**To**	**Multiply By**	**To Convert From**	**To**	**Multiply By**
Fracture toughness			**Thermal conductivity (Continued)**		
ksi √in.	MPa √m	1.098 800 E + 00	Btu - in./h . ft^2 - °F	W/m - K	1.442 279 E - 01
Heat content			cal/cm - s - °C	W/m - K	4.184 000 E + 02
Btu/lb	kJ/kg	2.326 000 E + 00	**Thermal expansion**		
cal/g	kJ/kg	4.186 800 E + 00	in./in. - °C	m/m - K	1.000 000 E + 00
Heat input			in./in. - °F	m/m - K	1.800 000 E + 00
J/in.	J/m	3.937 008 E + 01	**Velocity**		
kJ/in.	kJ/m	3.937 008 E + 01	ft/h	m/s	8.466 667 E - 05
Length			ft/min	m/s	5.080 000 E - 03
A	nm	1.000 000 E - 01	ft/s	m/s	3.048 000 E - 01
µin.	µm	2.540 000 E - 02	in./s	m/s	2.540 000 E - 02
mil	µm	2.540 000 E + 01	km/h	m/s	2.777 778 E - 01
in.	mm	2.540 000 E + 01	mph	km/h	1.609 344 E + 00
in.	cm	2.540 000 E + 00	**Velocity of rotation**		
ft	m	3.048 000 E - 01	rev/min (rpm)	rad/s	1.047 164 E - 01
yd	m	9.144 000 E -01	rev/s	rad/s	6.283 185 E + 00
mile	km	1.609 300 E + 00	**Viscosity**		
Mass			poise	Pa - s	1.000 000 E - 01
oz	kg	2.834 952 E - 02	stokes	m^2/s	1.000 000 E - 04
lb	kg	4.535 924 E - 01	ft^2/s	m^2/s	9.290 304 E - 02
ton (short 2000 lb)	kg	9.071 847 E + 02	in.^{2}/s	mm^2/s	6.451 600 E + 02
ton (short 2000 lb)	kg x 10^3	9.071 847 E - 01	**Volume**		
ton (long 2240 lb)	kg	1.016 047 E + 03	in.^{3}	m^3	1.638 706 E - 05
kg x 10^3 = 1 metric ton			ft^3	m^3	2.831 685 E - 02
			fluid oz	m^3	2.957 353 E - 05

METRIC CONVERSION FACTORS (Continued)					
To Convert From	**To**	**Multiply By**	**To Convert From**	**To**	**Multiply By**
Mass per unit area			**Volume (Continued)**		
oz/in.^{2}	kg/m^2	4.395 000 E + 01	gal (U.S. liquid)	m^3	3.785 412 E - 03
oz/ft^2	kg/m^2	3.051 517 E - 01	**Volume per unit time**		
oz/yd^2	kg/m^2	3.390 575 E - 02	ft^3/min	m^3/s	4.719 474 E - 04
lb/ft^2	kg/m^2	4.882 428 E + 00	ft^3/s	m^3/s	2.831 685 E - 02
			in.^{3}/min	m^3/s	2.731 177 E - 07
			Wavelength		
			A	nm	1.000 000 E - 01

THE GREEK ALPHABET		
Α, α - Alpha	Ι, ι - Iota	Ρ, ρ - Rho
Β, β - Beta	Κ, κ - Kappa	Σ, σ - Sigma
Γ, γ - Gamma	Λ, λ - Lambda	Τ, τ - Tau
Δ, δ - Delta	Μ, μ - Mu	Υ, υ - Upsilon
Ε, ε - Epsilon	Ν, ν - Nu	Φ, ϕ - Phi
Ζ, ξ - Zeta	Ξ, ξ - Xi	Χ, χ - Chi
Η, η - Eta	Ο, ο - Omicron	Ψ, ψ - Psi
Θ, θ - Theta	Π, π - Pi	Ω, ϖ - Omega

SI PREFIXES			
Prefix	**Symbol**	**Exponential Expression**	**Multiplication Factor**
exa	E	10^{18}	1 000 000 000 000 000 000
peta	P	10^{15}	1 000 000 000 000 000
tera	T	10^{12}	1 000 000 000 000
giga	G	10^{9}	1 000 000 000
mega	M	10^{6}	1 000 000
kilo	k	10^{3}	1 000
hecto	h	10^{2}	100
deka	da	10^{1}	10
Base Unit	---	10^{0}	1
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	µ	10^{-6}	0.000 001
nano	n	10^{-9}	0.000 000 001
pico	p	10^{-12}	0.000 000 000 001
femto	f	10^{-15}	0.000 000 000 000 001
atto	a	10^{-18}	0.000 000 000 000 000 001

Appendix

3

DECIMAL EQUIVALENTS OF FRACTIONS, SHEET METAL GAGE CONVERSIONS, AND WIRE GAGE CONVERSIONS

DECIMAL EQUIVALENT OF FRACTIONS		
Fraction (in.)	**Decimal (in.)**	**Millimeter (mm)**
1/64	0.015 625	0.396 875
1/32	0.031 250	0.793 750
3/64	0.046 875	1.190 625
1/16	0.062 500	1.587 500
5/64	0.078 125	1.984 375
3/32	0.093 750	2.381 250
7/64	0.109 375	2.778 125
1/8	0.125 000	3.175 000
9/64	0.140 625	3.571 875
5/32	0.156 250	3.968 750
11/64	0.171 875	4.365 625
3/16	0.187 500	4.762 500
13/64	0.203 125	5.159 375
7/32	0.218 750	5.556 250
15/64	0.234 375	5.953 125
1/4	0.250 000	6.350 000
17/64	0.265 625	6.746 875
9/32	0.281 250	7.143 750
19/64	0.296 875	7.540 625
15/16	0.312 500	7.937 500
21/64	0.328 125	8.334 375
11/32	0.343 750	8.731 250
23/64	0.359 375	9.128 125
3/8	0.375 000	9.525 000
25/64	0.390 625	9.921 875
13/32	0.406 250	10.318 750
27/64	0.421 875	10.715 625

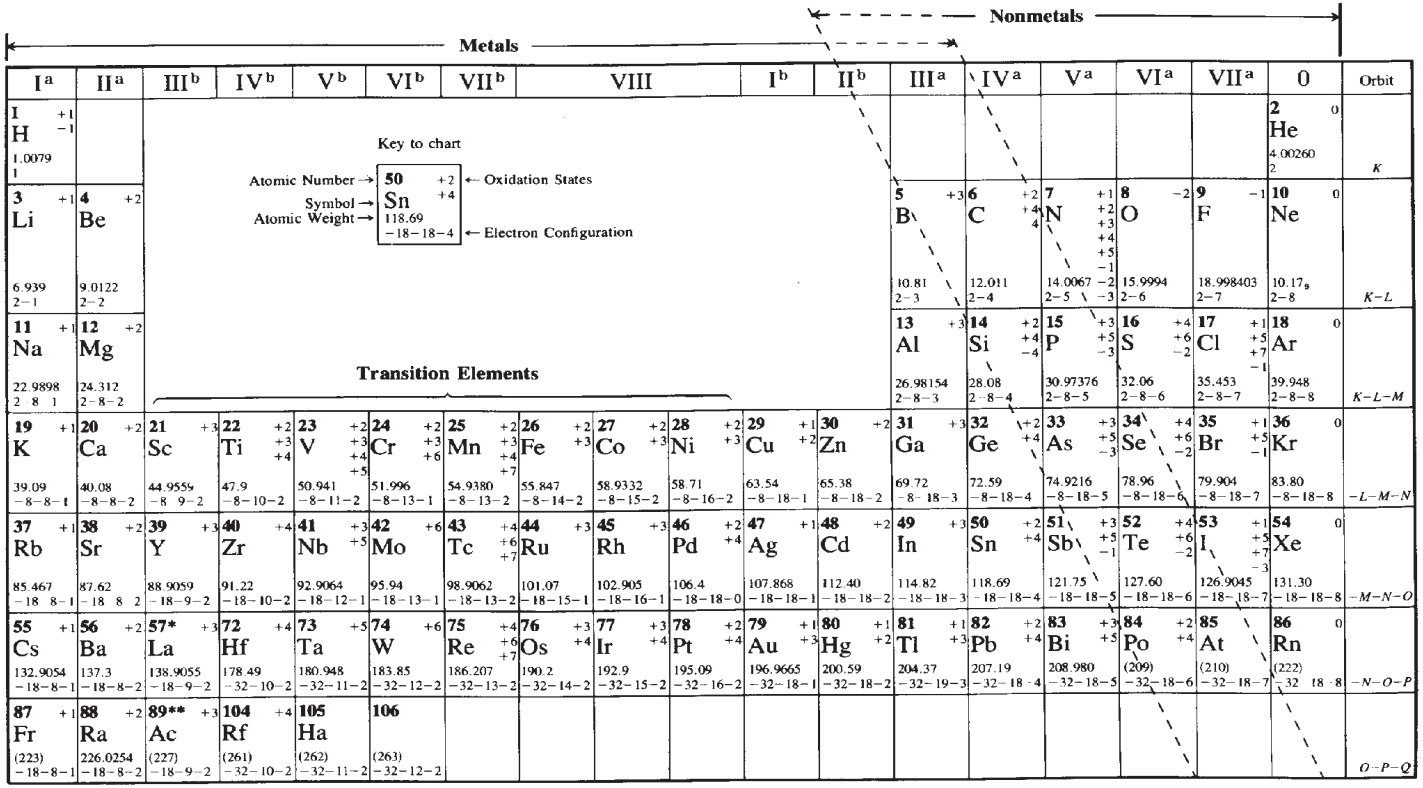
DECIMAL EQUIVALENT OF FRACTIONS (Continued)

Fraction (in.)	Decimal (in.)	Millimeter (mm)
7/16	0.437 500	11.112 500
29/64	0.453 125	11.509 375
15/32	0.468 750	11.906 250
31/64	0.484 375	12.303 125
1/2	0.500 000	12.700 000
33/64	0.515 625	13.096 875
17/32	0.531 250	13.493 750
35/64	0.546 875	13.890 625
9/16	0.562 500	14.287 500
37/64	0.578 125	14.684 375
19/32	0.593 750	15.081 250
39/64	0.609 375	15.478 125
5/8	0.625 000	15.875 000
41/64	0.640 625	16.271 875
21/32	0.656 250	16.668 750
43/64	0.671 875	17.065 625
11/16	0.687 500	17.462 500
45/64	0.703 125	17.859 375
23/32	0.718 750	18.256 250
47/64	0.734 375	18.653 125
3/4	0.750 000	19.050 000
49/64	0.765 625	19.446 875
25/32	0.781 250	19.843 750
51/64	0.796 875	20.240 625
13/16	0.812 500	20.637 500
27/32	0.843 750	21.431 250
53/64	0.828 125	21.034 375

Appendix
4

PERIODIC TABLE

Periodic Table of the Elements



Appendix

5

PHYSICAL PROPERTIES:

THE ELEMENTS

PHYSICAL PROPERTIES OF THE ELEMENTS

Element	Sym.	Atomic No.	Atomic Wt.	Electrons In Shell							Melting Pt. °C	Boiling Pt. °C	Density[a]	Val.[b]
				K	L	M	N	O	P	Q				
Actinium	Ac	89	227	2	8	18	32	18	9	2	1600	---	---	---
Aluminum	Al	13	26.98	2	8	3	---	---	---	---	660.2	2060	s 2.699	3+
Americium	Am	95	241	2	8	18	32	24	9	2	---	---	---	---
Antimony	Sb	51	121.8	2	8	18	18	5	---	---	630.5	1440	s 6.62	5+
Argon	Ar	18	39.95	2	8	8	---	---	---	---	-189.4	-185.8	g 1.784 L 1.40 s 1.65	Inert
Arsenic	As	33	74.92	2	8	18	5	---	---	---	814 (36 atm.)	610	s 5.73	3+ 5+
Astatine	At	85	210	2	8	18	32	18	7	---	---	---	---	---
Barium	Ba	56	137.3	2	8	18	18	8	2	---	704	1640	s 3.5	2+
Berkelium	Bk	97	249	2	8	18	32	26	9	2	---	---	---	---
Beryllium	Be	4	9.01	2	2	---	---	---	---	---	1350	1530	s 1.85	2+
Bismuth	Bi	93	209.0	2	8	18	32	18	5	---	271.3	1420	s 9.80	---
Boron	B	5	10.81	2	3	---	---	---	---	---	2300	2550	s 2.3	3+
Bromine	Br	35	79.91	2	8	15	7	---	---	---	-7.2	19.0	s 3.12	
Cadmium	Cd	48	112.4	2	8	18	18	2	---	---	320.9	765	s 8.65	2+
Calcium	Ca	20	40.08	2	8	8	2	---	---	---	850	1440	s 1.55	2+
Californium	Cf	98	252	2	8	18	32	27	9	2	---	---	---	---
Carbon	C	6	12.01	2	4	---	---	---	---	---	~3500	4200(?)	s 3. 51	4+
Cesium	Cs	55	132.9	2	8	18	18	8	1	---	28	690	s 1.9	1+
Chlorine	Cl	17	35.45	2	8	7	---	---	---	---	-101	-34.7	g 3.214 L 1.557 s 1.9	1-
Chromium	Cr	24	52.00	2	8	13	1	---	---	---	1890	2500	s 7.19	3+
Cobalt	Co	27	58.93	2	8	15	2	---	---	---	1495	2900	s 8.9	2+

Appendix

6

CASTI ENGINEERING AND SCIENTIFIC WEB PORTAL - SELECTED LINKS

The *CASTI* Group of Companies has launched an information-packed Engineering and Scientific Web Portal containing thousands of technical web site links in a fully searchable database and grouped within specific categories. This web portal also contains many links to free engineering software and technical articles. We invite you to visit our engineering and scientific web portal at http://www.casti.ca.

Engineering Associations	
Canada	
AETTN - Association of Engineering Technicians and Technologists of Newfoundland	http://www.netfx.iom.net/aettn
APEGBC - Association of Professional Engineers and Geoscientists of British Columbia	http://www.apeg.bc.ca
APEGGA - Association of Professional Engineers, Geologists, and Geophysicists of Alberta	http://www.apegga.com
APEGM - Association of Professional Engineers and Geoscientists of Manitoba	http://www.apegm.mb.ca
APEGN - Association of Professional Engineers and Geologists of Newfoundland	http://www.apegn.nf.ca/
APEGNB - Association of Professional Engineers and Geoscientists of NewBrunswick	http://www.apegnb.com
APEGS - Association of Professional Engineers and Geoscientists of Saskatchewan	http://www.apegs.sk.ca
APENS - Association of Professional Engineers of Nova Scotia	http://www.apens.ns.ca
APEPEI - Association of Professional Engineers of Prince Edward Island	http://www.apepei.com
APEY - Association of Professional Engineers of Yukon	http://www.apey.yk.ca
ASET - Alberta Society of Engineering Technologists	http://www.aset.ab.ca
ASTTBC - Applied Science Technologists and Technicians of British Columbia	http://www.asttbc.org
CCPE - Canadian Council of Professional Engineers	http://www.ccpe.ca
CCTT - Canadian Council of Technicians and Technologists	http://www.cctt.ca
CTTAM - Certified Technicians and Technologists Association of Manitoba	http://www.cttam.com
NAPEGG - Association of Professional Engineers, Geologists and Geophysicists of the Northwest Territories (representing NWT and Nunavut Territory)	http://www.napegg.nt.ca
OACETT - Ontario Association of Certified Engineering Technicians and Technologists	http://www.oacett.org
OIQ - Ordre des ingénieurs du Québec	http://www.oiq.qc.ca
OTPQ - Ordre des Technologues Professionnels du Québec	http://www.otpq.qc.ca
PEO - Professional Engineers Ontario	http://www.peo.on.ca
SASTT - Saskatchewan Applied Science Technologists and Technicians	http://www.sastt.sk.ca
SCETTNS - Society of Certified Engineering Technicians and Technologists of Nova Scotia	http://www.scettns.ns.ca/
United States - National	
ABET - Accreditation Board for Engineering and Technology	http://www.abet.org
APC - American Plastics Council	http://www.plasticsresource.com

Engineering Associations (Continued)	
United States - National (Continued)	
EIA - Electronic Industries Association	http://www.eia.org
NAS - National Academy of Engineering	http://www.nas.edu/
National Science Foundation	http://www.nsf.gov/
NCEES - National Council of Examiners for Engineering and Surveying	http://www.ncees.org/
NICET - National Institute for Certification in Engineering Technology	http://www.nicet.org/
NSPE - National Society of Professional Engineers	http://www.nspe.org/
SEMA - Specialty Equipment Market Association	http://www.sema.org
US Army Corps of Engineers	http://www.hq.usace.army.mil/hqhome/
United States - State	
ASPE - Alabama Society of Professional Engineers	http://www.aspe-al.com
AZSPE - Arizona Society of Professional Engineers	http://www.azspe.org
CEC - Consulting Engineers Council of Ohio	http://www.cecohio.org
CEPP - Connecticut Engineers in Private Practice	http://www.ctengineers.org
CSPE - California Society of Professional Engineers	http://www.cspe.com
DCSPE - District of Columbia Society of Professional Engineers	http://www.free-4u.com/district_of_columbia_society_of_professional_engineers.htm
FES - Florida Engineering Society	http://www.fleng.org
GSPE - Georgia Society of Professional Engineers	http://www.gspe.org
HSPE - Hawaii Society of Professional Engineers	http://www.eng.hawaii.edu/~hspe
IES - Iowa Engineering Society	http://www.iaengr.org
ISPE - Idaho Society of Professional Engineers	http://home.rmci.net/ispe
ISPE - Illinois Society of Professional Engineers	http://www.ilspe.com/
KCE - Kansas Consulting Engineers	http://www.kce.org
KEC - Kentucky Engineering Center	http://www.kyengcenter.org/
MES - Mississippi Engineering Society	http://www.msengsoc.org
MnSPE - Minnesota Society of Professional Engineers	http://www.mnspe.org
MSPE - Maryland Society of Professional Engineers	http://www.mdspe.org/

Engineering Associations (Continued)	
United States - State (Continued)	
MSPE - Michigan Society of Professional Engineers	http://www.voyager.net/mspe/
MSPE - Missouri Society of Professional Engineers	http://www.mspe.org
NeSPE - Nebraska Society of Professional Engineers	http://www.nespe.org
NHSPE - New Hampshire Society of Professional Engineers	http://www.nhspe.org
NJSPE - New Jersey Society of Professional Engineers	http://www.njspe.org
NMSPE - New Mexico Society of Professional Engineers	http://www.swcp.com/~nmspe
NYSSPE - New York State Society of Professional Engineers	http://www.nysspe.org
OSPE - Oklahoma Society of Professional Engineers	http://www.ospe.org
PEC - Professional Engineers of Colorado	http://www.qadas.com/pec
PENC - Professional Engineers of North Carolina	http://www.penc.org
PEO - Professional Engineers of Oregon	http://www.pro-engineers-oregon.org
PSPE - Pennsylvania Society of Professional Engineers	http://www.pspe.org
SCSPE - South Carolina Society of Professional Engineers	http://www.scspe.org
SDES - South Dakota Engineering Society	http://www.sdes.org
TSPE - Tennessee Society of Professional Engineers	http://www.tnspe.org
TSPE - Texas Society of Professional Engineers	http://www.tspe.org
USPE - Utah Society of Professional Engineers	http://www.inovion.com/~jamesski/USPE/
VSPE - Vermont Society of Professional Engineers	http://www.geocities.com/capecanaveral/4625/index.html
VSPE - Virginia Society of Professional Engineers	http://www.us.net/vspe
WSPE - Wisconsin Society of Professional Engineers	http://www.wspe.org
Other	
ENGC - Engineering Council (UK)	http://www.engc.org
ENGVA - European Natural Gas Vehicle Association	http://www.engva.org

Government	
Canada - Federal	
Geological Survey of Canada	http://www.nrcan.gc.ca/gsc
National Energy Board	http://www.neb.gc.ca
Natural Resources Canada	http://www.nrcan.gc.ca
Canada - Provincial	
Alberta Boilers Safety Association	http://www.albertaboilers.com
Alberta Environment	http://www.gov.ab.ca/env
Alberta Energy and Utilities Board	http://www.eub.gov.ab.ca
BC Ministry of Energy and Mines	http://www.gov.bc.ca/em
BC Oil and Gas Commission	http://www.ogc.gov.bc.ca
Manitoba Industry, Trade and Mines - Mineral Resources Division	http://www.gov.mb.ca/itm/mrd
Natural Resources Conservation Board	http://www.gov.ab.ca/nrcb
New Brunswick Safety Code Services	http://www.gnb.ca/PS-SP/english/indexe.shtml
Nova Scotia Department of Enviroment and Labour - Public Safety Division	http://www.gov.ns.ca/enla/psafe
Saskatchewan Energy and Mines	http://www.gov.sk.ca/enermine
Yukon Department of Energy, Mines and Resources	http://www.emr.gov.yk.ca
Yukon Geoology Program	http://www.geology.gov.yk.ca
United States - National	
National Petroleum Technology Office	http://www.npto.doe.gov
U.S. Department of the Interior	http://www.doi.gov/bureaus.html
U.S. Department of Energy	http://www.energy.gov
U.S. Energy Information Administration	http://www.eia.doe.gov
U.S. Environmental Protection Agency	http://www.epa.gov

Government (Continued)	
United States - State	
Alabama State Oil and Gas Board	http://www.ogb.state.al.us
Alaska Oil & Gas Conservation Commission	http://www.state.ak.us/local/akpages/ADMIN/ogc/homeogc.htm
California Energy Commission	http://www.energy.ca.gov
Colorado Oil & Gas Conservation Commission	http://oil-gas.state.co.us/
Indiana State Boiler and Pressure Vessel Safety Division	http://www.ai.org/sema/osbc_boiler.html
Kansas Geological Survey	http://www.kgs.ukans.edu
Louisiana Department of Natural Resources	http://www.dnr.state.la.us/index.ssi
Louisiana State Fire Marshall Boiler Division	http://www.dps.state.la.us/sfm/index.htm
Maryland Bureau of Mines	http://www.mde.state.md.us/wma/minebur/index.html
Minnesota Code Administration and Boiler Inspection Services	http://www.doli.state.mn.us/code.html
Montana Bureau of Mines and Geology	http://www.mbmg.mtech.edu
Nebraska State Boiler Inspection Program	http://www.dol.state.ne.us/nwd/center.cfm?pricat=2&subcat=2c&action=boiler
Nevada Bureau of Mines and Geology	http://www.nbmg.unr.edu
New Mexico Bureau of Geology and Mineral Resources	http://geoinfo.nmt.edu
New Mexico Oil Conservation Division	http://www.emnrd.state.nm.us/ocd
North Carolina Geological Survey	http://www.geology.enr.state.nc.us/
North Carolina State Department of Labor Boiler Safety Bureau	http://www.dol.state.nc.us/boiler.htm
North Dakota State Boiler Inspection Program	http://www.state.nd.us/ndins/deptprog/boiler.html
Oklahoma Energy Resources Board	http://www.oerb.com
Oklahoma Marginal Well Commission	http://www.state.ok.us/~marginal
Oregon State Boiler Program	http://www.cbs.state.or.us/bcd/sws/boilerhome.htm
Texas State Boiler Law	http://www.license.state.tx.us/boilers/blrlaw.htm
Texas, Railroad Commission of Texas	http://www.rrc.state.tx.us
Utah State Safety Division	http://www.ind-com.state.ut.us/Safety_Division/safety_division.htm
Wyoming Oil & Gas Conservation Commission	http://wogcc.state.wy.us

Industry Associations	
Boiler and Pressure Vessels	
ABSA - Alberta Boilers Safety Association	http://www.albertaboilers.com
PVRC - Pressure Vessel Research Council	http://www.forengineers.org/pvrc/index.htm
VMA - Valve Manufacturers Association of America	http://www.vma.org
Construction	
AEM - Association of Equipment Manufacturers	http://www.aem.org
CCA - Canadian Construction Association	http://www.cca-acc.com
CCPA - Canadian Concrete Pipe Association	http://www.ccpa.com
CII - Construction Industry Institute	http://construction-institute.org
DCA - Distribution Contractors Association	http://www.dca-online.org
MCAA - Mechanical Contractors Association of America	http://www.mcaa.org
NASTT - North American Society for Trenchless Technology	http://www.nastt.org
NUCA - National Utility Contractors Association	http://www.nuca.com
NUCA - National Utility Contractors Association	http://www.nuca.com
OAA - Ontario Association of Architects	http://www.oaa.on.ca
OAHI - Ontario Associations of Home Inspectors	http://www.oahi.com
PLCA - Pipe Line Contractors Association	http://www.plca.org
RMPCA - Rocky Mountain Pipeline Contractors Association	http://www.rmpca.com
Engineering and Science	
AAES - American Association of Engineering Societies	http://www.aaes.org
ACEC - American Council of Engineering Companies	http://www.acec.org
AIChE - American Institute of Chemical Engineers	http://www.aiche.org
Alberta Synchrotron Institute	http://alpha.asi.ualberta.com/MainPage.htm
Association of Engineers and Architects in Israel	http://www.engineers.org.il
ASAE - American Society of Agricultural Engineers	http://www.asae.org
Bureau International des Poids et Mesures	http://www.bipm.org
CEN - Canadian Engineering Network	http://www.transenco.com

Industry Associations (Continued)	
Engineering and Science (Continued)	
CEO - Consulting Engineers of Ontario	http://www.ceo.on.ca
CTI - Cooling Technology Institute	http://www.cti.org
Electric Power Research Institute	http://www.epri.com
IACET - International Association of Continuing Education and Training	http://www.iacet.org
IEEE - Institute of Electrical and Electronics Engineers	http://www.ieee.org
IES - Institute of Environmental Sciences	http://www.bangor.ac.uk/ies/ies.html
IIE - Institute of Industrial Engineers	http://www.iienet.org
ISI - Institute of Scientific Information	http://www.isinet.com
Israel Association for Automatic Control	http://www.technion.ac.il/~iaac
Israel Association for Computational Methods in Mechanics	http://www.iacmm.org.il
Israel Institute of Chemical Engineers	http://www.iiche.org.il
Israeli Society for Medical and Biological Engineering	http://www.eng.tau.ac.il/eng/associations/ISMBE
ITI - Information Technology Institute	http://www.iti.com
NAPE - National Association of Power Engineers	http://www.powerengineers.com
NEIC - National Engineering Information Council	http://www.asee.org/neic
NGVC - Natural Gas Vehicle Coalition	http://www.ngvc.org
RIA - Robotic Industries Association	http://www.robotics.org
Metals and Materials	
AA - Aluminum Association, Inc.	http://www.aluminum.org
AAEC - Asia Aluminum Extrusion Council	http://asia-aec.org
ACI - American Concrete Institute	http://www.aci-int.net
AISE - Association of Iron and Steel Engineers	http://www.aise.org
AISI - American Iron and Steel Institute	http://www.steel.org
BIMRMU - Brockhouse Institute for Materials Research, McMaster University	http://www.science.mcmaster.ca/bimr/general.html
CD - Corrosion Doctors	http://corrosion-doctors.org
CDA - Copper Development Association	http://www.copper.org

Industry Associations (Continued)	
Metals and Materials (Continued)	
CIMM - Canadian Institute for Mining and Metallurgy	http://www.cim.org
CISA - Casting Industry Suppliers Association	http://www.cisa.org
CMI - Cast Metals Institute	http://www.castmetals.com
Corrosion Source	http://www.corrosionsource.com
CSPA - Canadian Steel Producers Association	http://www.canadiansteel.ca
DDC - Diecasting Development Council	http://www.diecasting.org/ddc
DIMG - Ductile Iron Marketing Group	http://www.ductile.org/dimg
FIRST - Foundry Industry Recycling Starts Today	http://www.foundryrecycling.org
ICI - Investment Casting Institute	http://www.investmentcasting.org
ICRI - Iron Casting Research Institute	http://www.ironcasting.org
IISI - International Iron & Steel Institute	http://www.worldsteel.org
ILSR - Institute for Local Self-Reliance	http://www.ilsr.org
IMA - International Molybdenum Association	http://www.imoa.org.uk
IMechE - The Institution of Mechanical Engineers	http://www.imeche.org
IoM - Institute of Materials	http://www.instmat.co.uk
ITA - International Titanium Association	http://www.titanium.org
MTI - Materials Technology Institute of the Chemical Process Industries	http://www.mti-link.org
NADCA - North American Die Casting Association	http://www.diecasting.org
NAPCA - National Association of Pipe Coating Applicators	http://www.napca.com
NASS - National Association of Steel Stockholders	http://www.nass.org.uk/index.htm
NiDI - Nickel Development Institute	http://www.nidi.org
NFFS - Non-Ferrous Founders' Society	http://www.nffs.org
SBI - Swedish Institute of Steel Construction	http://www.algonet.se/~sbi
SFSA - Steel Founders' Society of America	http://www.sfsa.org
SMA - Steel Manufacturers Association	http://steelnet.org/sma/index.html
SRI - Steel Recycling Institute	http://www.recycle-steel.org

Industry Associations (Continued)	
Metals and Materials (Continued)	
SSPC - Steel Structures Painting Council	http://www.sspc.org
Oil and Gas	
AAPG - American Association of Petroleum Geologists	http://www.aapg.org
AGA - American Gas Association	http://www.aga.com
APGA - American Public Gas Association	http://www.apga.org
API - American Petroleum Institute	http://www.api.org
CAODC - Canadian Association of Oil Well Drilling Contractors	http://www.caodc.ca
CAPL - Canadian Association of Petroleum Landmen	http://www.landman.ca
CAPP - Canadian Association of Petroleum Producers	http://www.capp.ca
CEPA - Canadian Energy Pipeline Association	http://www.cepa.com
CGA - Canadian Gas Association	http://www.cga.ca
CGPSA - Canadian Gas Processors Suppliers Association	http://www.cgpsa.com
CHOA - Canadian Heavy Oil Association	http://www.choa.ab.ca
CPSC - Canadian Petroleum Safety Council	http://www.psc.ca
GMRC - Gas Machinery Research Council	http://www.gmrc.org
GPA - Gas Processors Association	http://gasprocessors.com
IADC - International Association of Drilling Contractors	http://www.iadc.org
IGT - Institute of Gas Technology	http://www.igt.org
IP - Institute of Petroleum	http://www.petroleum.co.uk
IPAA - Independent Petroleum Association of America	http://www.ipaa.org
MEA - Midwest Energy Association	http://midwestenergy.org
NGSA - Natural Gas Supply Association	http://ngsa.org
NOIA - The National Ocean Industries Association	http://www.noia.org
NPC - National Petroleum Council	http://www.npc.org
NPGA - National Propane Gas Association	http://www.npga.org
PA - PETROassist.com	http://www.petroassist.com

Industry Associations (Continued)	
Oil and Gas (Continued)	
PCF - Petroleum Communication Foundation	http://www.pcf.ab.ca
PPDM - Public Petroleum Data Model	http://www.ppdm.org
PSAC - Petroleum Services Association of Canada	http://www.psac.ca
PTTC - Petroleum Technology Transfer Council	http://www.pttc.org
SEGA - Southeastern Gas Association	http://www.segas.org
SEPAC - Small Explorers and Producers Association of Canada	http://www.sepac.ca
WSPA - Western States Petroleum Association	http://www.wspa.org
Standards and Quality	
AMRA - Automatic Meter Reading Association	http://www.amra-intl.org
CSA International	http://www.csa-international.org
EECS - Electrical Equipment Certification Service	http://www.hse.gov.uk/eecs
MECS - Mining Equipment Certification Service	http://www.hse.gov.uk/eecs/eecsmecs.htm
MSS - Manufacturers Standardization Society of the Valve and Fittings Industry Inc.	http://www.mss-hq.com/
IPQ - Instituto Português da Qualidade	http://www.ipq.pt/
NIST - National Institute of Standards and Technology	http://www.nist.gov/welcome.html
NNI - Netherlands Normalisatie	http://www.nni.nl/
SMRP - Society for Maintenance and Reliability Professionals	http://www.smrp.org/
SSPC - The Society for Protective Coatings	http://www.sspc.org/
USM - Standards and Metrology Institute (Slovenija)	http://www.usm.mzt.si/
Welding	
EWI - Edison Welding Institute	http://www.ewi.org/
HIWT - Hobart Institute of Welding Technology	http://www.welding.org/
PEWI - E O Paton Electric Welding Institute	http://www.stcu.kiev.ua/paton/
RWMA - Resistance Welder Manufacturers' Association	http://www.rwma.org/
TWI - The Welding Institute	http://www.twi.co.uk/

Industry Associations (Continued)	
Welding (Continued)	
WRC - Welding Research Council	http://www.forengineers.org/wrc

Metals Producers	
Nonferrous	
Alcan Aluminium Corporation	http://www.alcan.com
Alcoa Inc.	http://www.alcoa.com
AlcoTec Wire Corporation	http://www.alcotec.com
Brush Wellman Inc.	http://www.brushwellman.com
Coastal Aluminum Rolling Mills Inc.	http://www.coastalum.com
Columbia Falls Aluminum Company	http://www.cfaluminum.com
Deutsche Nickel AG	http://www.deutsche-nickel.de
Hydro Raufoss Automotive, N.A.	http://www.hydro.com
IMCO Recycling Inc.	http://www.imcorecycling.com
Kaiser Aluminum & Chemical Corp.	http://www.kaiseral.com
KB Alloys Inc.	http://www.kballoys.com
Magnesium Alloy Corp	http://www.magnesiumalloy.ca
Milward Alloys Inc.	http://www.milward.com
Minalex Corporation	http://www.minlex.com
Noranda Aluminum Inc.	http://www.noranda.ca
Northwest Aluminum Company	http://www.nwaluminum.com
Ormet Corporation	http://www.ormet.com
Precision Coil, Inc.	http://www.precisioncoil.com
Ritchey Metals Company Inc.	http://www.ritcheymetals.com/
Scepter Inc.	http://www.scepterinc.com
Shieldalloy Metallurgical Corp.	http://www.metallurg.com
Southwire Co.	http://www.southwire.com

Metals Producers (Continued)	
Nonferrous (Continued)	
United Aluminum Corp	http://www.unitedaluminum.com
Valimet Inc.	http://www.valimet.com
Wabash Alloys	http://www.wabashalloys.com
Stainless Steel and Nickel Alloy Producers	
Allegheny Technologies Incorporated	http://www.alleghenytechnologies.com
Inco Limited	http://www.incoltd.com
Inco Special Products	http://www.incospp.com
Krupp Thyssen Nirosta GmbH	http://www.nirosta.de
Krupp VDM GmbH	http://www.kruppvdm.de
LTV Steel	http://www.ltvsteel.com
Rolled Alloys	http://www.rolledalloys.com
Sandvik Steel	http://www.steel.sandvik.com
Special Metals Corporation	http://www.specialmetals.com
Sumitomo Metal Industries	http://www.sumikin.co.jp
Steel and Steel Alloy Producers	
A. Finkl & Sons Company	http://www.finkl.com
ACME Metals Incorporated	http://www.acme-metals.com
AK Steel Corporation	http://www.aksteel.com
Algoma Steel Inc.	http://www.algoma.com
Allegheny Ludlum	http://www.alleghenyludlum.com
Allvac	http://www.allvac.com
Altos Hornos de Mexico, S.A. de C.V.	http://www.ahmsa.com
Ameristeel	http://www.ameristeel.com
Atlas Specialty Steels	http://www.atlassteels.com
Bayou Steel	http://www.bayousteel.com
Berg Steel Pipe Corporation	http://www.bergpipe.com

Metals Producers (Continued)	
Steel and Steel Alloy Producers (Continued)	
Beta Steel Corporation	http://www.betasteelcorp.com/
Bethlehem Steel Corporation	http://www.bethsteel.com
Birmingham Steel	http://www.birminghamsteel.com
California Steel Industries, Inc.	http://www.californiasteel.com
Cargill Steel	http://www.cargillsteel.com
Carpenter Technology Corporation	http://www.cartech.com
Chaparral Steel	http://www.chaparralsteel.com
Chicago Heights Steel	http://www.steelnet.org/chsteel
Citisteel USA, Inc.	http://www.citisteel.com
Cleveland-Cliffs Inc.	http://www.cleveland-cliffs.com
CMC Steel Group	http://www.cmcsg.com
Connecticut Steel	http://www.ctsteelco.com
Copper Development Organization	http://www.copper.org
Co-Steel Raritan	http://www.costeel.com
Deacero, S.A. de C.V.	http://www.deacero.com
Dofasco Inc.	http://www.dofasco.ca
Electralloy	http://www.electralloy.com
G.O. Carlson, Inc.	http://www.gocarlson.com
Gallatin Steel Company	http://www.gallatinsteel.com
Geneva Steel	http://www.geneva.com
Georgetown Steel	http://www.gscrods.com
Granite City Pickling & Warehousing	http://www.gcpw.com
Grupo Villacero	http://www.villacero.com
Harsco Corporation	http://www.harsco.com
Huntco Steel Inc	http://www.huntcosteel.com
Hylsamex, S. A. de C.V.	http://www.hylsamex.com

Metals Producers (Continued)	
Steel and Steel Alloy Producers (Continued)	
IPSCO Inc.	http://www.ipsco.com
Ispat Inland Inc. (Formerly Inland Steel Industries, Inc.)	http://www.inland.com
Ispat International	http://www.ispat.com
Ispat Mexicana, S.A. deIspat Mexicana, S.A. de C.V.	http://www.ispat.co.uk
J&L Specialty Steel, Inc.	http://www.jlspecialty.com
J&L Structural Inc.	http://www.jlstructural.com
Krupp VDM GmbH	http://www.kruppvdm.de/Index.ASP
Marion Steel Co.	http://www.marionsteel.com
McDonald Steel	http://www.mcdonaldsteel.com
Mexinox S.A. de C.V.	http://www.mexinox.com.mx
National Steel Corporation	http://www.nationalsteel.com
North Star Steel	http://www.cargillsteel.com/divisions/nss/nss_index.shtml
Nucor	http://www.nucor.com
Precision Specialty Metals, Inc.	http://www.psm-inc.com
Republic Technologies International	http://www.repsteel.com
Rouge Industries, Inc.	http://www.rougesteel.com
Sandmeyer Steel Company	http://www.sandmeyersteel.com
Sheffield Steel Corp.	http://www.sheffieldsteel.com
Shenango Incorporated	http://www.shenango.com
Slater Steel-Fort Wayne SpecialtyAlloys Div.	http://www.slater.com
Special Metals Corporation	http://www.specialmetals.com
Stelco Inc.	http://www.stelco.com
Sumitomo Metal Industries	http://www.sumitomometals.co.jp/e
Techalloy Company, Inc.	http://www.techalloy.com
The Timken Company	http://www.timken.com
Thyssen Inc., NA	http://www.tincna.com

Metals Producers (Continued)	
Steel and Steel Alloy Producers (Continued)	
United States Steel Corporation	http://www.ussteel.com
USS-POSCO Industries	http://www.uss-posco.com
WCI Steel, Inc.	http://www.wcisteel.com
Weirton Steel Corporation	http://www.weirton.com
Wheeling-Pittsburgh Steel Corporation	http://www.wpsc.com

National Standards Bodies	
AENOR - Asociación Espanola de Normalización y Certificación	http://www.aenor.es
AFNOR - Association Française de Normalisation	http://www.afnor.fr
ANSI - American National Standards Institute	http://www.ansi.org
ASTM - American Society for Testing and Materials	http://www.astm.org
BSI - British Standards Institute	http://www.bsi-global.com
CEN - Comité Européen de Normalisation (European Committee For Standardization)	http://www.cenorm.be
CSA - Canadian Standards Association	http://www.csa.ca
CSNI - Czech Republic	http://www.csni.cz
DIN - Deutsches Institut fur Normung	http://www.din.de
DS - Dansk Standard	http://www.ds.dk
DSP - US Military Defence Standardization Program	http://www.dsp.dla.mil/
ELOT - Hellenic Organization for Standardization	http://www.elot.gr
ETSI - European Telecommunications Standards Institute	http://www.etsi.fr
IBN - Institut Belge De Normalisation	http://www.ibn.be
IPQ - Instituto Português da Qualidade	http://www.ipq.pt
ISO - International Organization for Standardization	http://www.iso.org
IST - Icelandic Standards	http://www.stri.is
JISC - Japanese Industrial Standards Committee	http://www.jisc.go.jp

National Standards Bodies (Continued)	
JSA - Japanese Standards Association	http://www.jsa.or.jp
NIST - National Institute of Standards and Technology	http://www.nist.gov/welcome.html
NNI - Netherlands Normalisatie Instituut	http://www.nni.nl
NORSOK - Norsk Sokkels Konkuranseposisjon (Norway)	http://www.nts.no
NSAI - National Standards Authority of Ireland	http://www.nsai.ie
NSF - Norges Standardiseringsforbund (Norway)	http://www.standard.no
NTS - Norsk Teknologisenter	http://www.nts.no
ON - Österreichisches Normungsinstitut (Austrian Standards Institute)	http://www.on-norm.at
SA - Standards Australia	http://www.standards.com.au
SASO - Saudi Arabian Standards Organisation	http://www.saso.org
SCC - Standards Council of Canada	http://www.scc.ca
SFS - Suomen Standardisoimisliitto r.y. (Findland)	http://www.sfs.fi
SIRIM - Berhad (Malaysia)	http://www.sirim.my
SIS - Standardiseringen i Sverige	http://www.sis.se
SNV - Swiss Association for Standardization	http://www.snv.ch
SNZ - Standards New Zealand	http://www.standards.co.nz
SPRING - Standards, Productivity and Innovation for Growth (Singapore)	http://www.spring.gov.sg
UNI - Ente Nazionale Italiano di Unificazione	http://www.unicei.it

Scientific Data and Units	
Materials	
Crystal Lattice Structures - Institut Laue-Langevin	http://www.ill.fr/dif/3D-crystals
Crystal Lattice Structures - US Naval Research Laboratory	http://cst-www.nrl.navy.mil/lattice
Material Physics Theory - US Naval Research Laboratory	http://cst-www.nrl.navy.mil/gallery
Material Properties - Apache Point Observatory	http://www.apo.nmsu.edu/Telescopes/SDSS/eng.papers/19950926_ConversionFactors/19950926_MProperties.html
Material Properties - Crucible Materials Corporation	http://www.crucibleservice.com

Scientific Data and Units (Continued)	
Materials (Continued)	
Material Properties for Composites - MIL-17	http://www.mil17.org
Material Properties - Ferro Ceramic Grinding Inc.	http://www.ferroceramic.com/tables/t_01.htm
Material Properties - MatWeb	http://www.matls.com/search/SearchProperty.asp
Material Properties - Plastics USA	http://www.plasticsusa.com/matchar.html
Material Properties- Swedish Ceramics Institute	http://www.keram.se/ke00007.htm
Material Properties, Periodic Table - Atlantic Equipment Engineers	http://www.micronmetals.com
Material Properties, Unit Conversion, Periodic Table, Formulas - eFunda (Engineering Fundamentals)	http://www.efunda.com
Material Properties, Unit Conversion, Periodic Table - Metal Suppliers Online	http://www.suppliersonline.com/research
Material Properties, Unit Conversion, Periodic Table - Principle Metals Online	http://www.principalmetals.com
Material Properties, Unit Conversion, Thermodynamics Data - MAYA	http://www.mayahtt.com/tmwiz/default.htm
Materials Properties Databases - CINDAS (Purdue University)	http://mpho.www.ecn.purdue.edu/MPHO/CRDA_Handbooks
Material Properties Databases - NIST	http://www.nist.gov/srd/materials.htm
Mechanical Properties - Online Metals	http://www.onlinemetals.com/property_search.cfm?step=1
Metalurgical Data, Glossary, Unit Conversion - Timken	http://www.timken.com/timken_ols/steel/handbook
Metalurgical Data, Periodic Table, Unit Conversion - All Metals & Forge	http://www.steelforge.com/infoservices/infoservices.asp
Phase Diagrams - Georgia Tech ASM/TMS Joint Student Chapter	http://cyberbuzz.gatech.edu/asm_tms/phase_diagrams
Phase Diagrams - Scientific Group Thermodata Europe	http://klara.met.kth.se/pd
Plastics - Material Selection Guides	http://www.endura.com
Surfaces of Materials Database - National Institute of Standards and Technology	http://www.nist.gov/srd/surface.htm
Thermoplastic Material Selection Guide - Actech Inc.	http://www.actech-inc.com/engmrgt.htm
Unit Conversion, Periodic Table, and other Scientific References - PhysLink.com	http://www.physlink.com/Reference/Index.cfm

Scientific Data and Units (Continued)	
Periodic Tables	
All Metals & Forge	http://www.steelforge.com/infoservices/infoservices.asp
Metal Suppliers Online	http://www.suppliersonline.com/research
Atlantic Equipment Engineers	http://www.micronmetals.com
eFunda	http://www.efunda.com
Principle Metals Online	http://www.principalmetals.com
PhysLink.com	http://www.physlink.com/Reference/PeriodicTable.cfm
Web Elements	http://www.webelements.com
Physics	
Atomic and Molecular Physics Databases - NIST	http://www.nist.gov/srd/phys.htm
Ionization, Nuclear Physics, and Condensed Matter Data - NIST	http://physics.nist.gov/PhysRefData/contents-misc.html
Molecular Spectroscopic Data - NIST	http://physics.nist.gov/PhysRefData/contents-mol.html
Physical Constants - NIST	http://physics.nist.gov/cuu/Constants/index.html
Physical Reference Data - NIST	http://physics.nist.gov/PhysRefData/contents.html
X-Ray and Gamma-Ray Data – NIST	http://physics.nist.gov/PhysRefData/contents-xray.html
X-ray Data - Berkeley Laboratories	http://www-cxro.lbl.gov/optical_constants
Units of Measurement	
Definitions, Conversions - The Foot Rule	http://www.omnis.demon.co.uk
Definitions, Conversions, History - Bureau International des Poids et Mesures (BIPM)	http://www.bipm.fr
Definitions, Conversions, History - Centre for Innovation in Mathematics Teaching	http://www.ex.ac.uk/cimt/dictunit/dictunit.htm
Definitions, Conversions, History - Center for Mathematics and Science Education	http://www.unc.edu/~rowlett/units/index.html
Definitions, Conversions, History of English Weights and Measures	http://home.clara.net/brianp
Definitions, Conversions, History of International System of Units (SI) - NIST	http://physics.nist.gov/cuu/Units/index.html
Legal Information on Weights, Measures, and Standard Time - Cornell University	http://www.law.cornell.edu/uscode/15/ch6.html

Scientific Data and Units (Continued)	
Units of Measurement - Uncertainty	
Essentials of Expressing Measurement Uncertainty - NIST	http://physics.nist.gov/cuu/Uncertainty/index.html
European Co-operation for Accreditation - Expressions of the Uncertainty of Measurements in Calibration	http://www.european-accreditation.org/documents.html#EA4
Expression of Uncertainty in Measurement - Teknologisk Institut	http://www.gum.dk
Guide to the Expression of Uncertainty in Measurement - Metrodata GmbH	http://www.metrodata.de
Uncertainty Analyzer Software - QUAMETEC Corp.'s	http://www.quametec.com/UA.htm

Standards Associations, Societies and Boards	
A-Pex International (Japan)	http://www.a-pex.co.jp
A2LA - American Association for Laboratory Accreditation	http://www.a2la2.net
ABINEE - Brazilian Electrical & Electronic Equipment Industry Association	http://www.abinee.org.br
ABNT - Associacion Brasileira de Normas Technicas	http://www.abnt.org.br
ABS - American Bureau of Shipping	http://www.eagle.org
ACIL - American Council of Independent Laboratories	http://www.acil.org
MTL-ACTS Testing Labs	http://www.mtl-acts.com
ADLNB - Association of Designated Laboratories & Notified Bodies(Telecom)	http://www.adlnb.com
ANCE - Asociacion Nacional de Normalizacion y Certificacion del Sector Electrico (Mexico - in Spanish)	http://rtn.net.mx/ance
APAVE - (France)	http://www.apave.com
ASME - American Society of Mechanical Engineers	http://www.asme.org
ASSE - American Society of Safety Engineers	http://www.asse.org
ASTM - American Society for Testing and Materials	http://www.astm.org
BEAB - British Electrotechnical Approvals Board	http://www.beab.co.uk
BEC - Belgian Electrotechnical Committee	http://www.bec-ceb.be
BIS - Bureau of Indian Standards	http://www.bis.org.in
BMSI - Bureau of Standards, Metrology and Inspection (Taiwan)	http://www.bsmi.gov.tw/english/e_n_hpg.htm

Standards Associations, Societies and Boards (Continued)	
CANENA - Council for Harmonization of Electrotechnical Standardization of the Nations of the Americas	http://www.canena.org
CCIC - China National Import and Export Commodities Inspection Corp.	http://www.ccic.com
CCL - Communication Certification Laboratory	http://www.cclab.com
CCPS - Center for Chemical Process Safety	http://www.aiche.org/ccps
CDRH - Center for Devices and Radiological Health (FDA)	http://www.fda.gov/cdrh/index.html
CEPEL - Centro de Pequisas de Energia Electrica (Brazil)	http://www.cepel.br
CESI - China Electronic Standardization Institute	http://www.cesi.ac.cn
CPSC - US Consumer Product Safety Commission	http://www.cpsc.gov
CSBTS - China State Bureau of Technical Supervision	http://www.csbts.cn.net/english/index.htm
CSA - Canadian Standards Association International	http://www.csa-international.org
CSCE - Canadian Society for Civil Engineering	http://www.csce.ca
DZNM - State Office for Standardization and Metrology (Croatia)	http://www.dznm.hr
ECMA - European Organization for Standardizing Information & Communication Systems	http://www.ecma.ch
EFTA - European Free Trade Association	http://www.efta.int/structure/main/index.html
ENEC - European Norms Electrical Certification	http://www.enec.com
ETSI - European Telecommunications Standards Institute	http://www.etsi.fr
Europort - Standards Publication Source	http://www.europort.com
FONDONORMA - Standards and Certification Organization (Venezuela)	http://www.fondonorma.org.ve
NETC - National Electronics Testing Centre (Ireland)	http://www.netc.ie
Global Engineering Documents	http://www.global.ihs.com
Gosstandart of Russia - State Committee of the Russion Federation for Standardization and Metrology	http://www.gost.ru
HART Communication Foundation	http://www.hartcomm.org
Hydraulic Institute	http://www.pumps.org
IAEI - International Association of Electrical Inspectors	http://www.iaei.org

Standards Associations, Societies and Boards (Continued)	
IEC - International Electrotechnical Commission	http://www.iec.ch
IECEE - International Electrotechnical Commission of Electrical Equipment	http://www.iecee.org
IETF - The Internet Engineering Task Force	http://www.ietf.org
IHS - Information Handling Services	http://www.ihs.com/
IMQ - Instituto Italiano Del Marchio Di Qualita' (Italy)	http://www.imq.it
INEN - Instituto Ecuatoriano de Normalizacion (Ecuador)	http://www.inen.gov.ec
INN - Instituto Nacional de Normalización (Chile)	http://www.inn.cl
IPQ - Instituto Português da Qualidade (Portugal)	http://www.ipq.pt
IPT - Instituto de Pequisas Technologicas (Brazilian Test Lab)	http://www.ipt.br
IRAM - Instituto Argentino de Normalización (Argentinea)	http://www.iram.com.ar
ISA - Intrumentation, Systems and Automation Society	http://www.isa.org
ISO - International Standards Organization	http://www.iso.ch
IST - Icelandic Standards (Iceland)	http://www.stri.is
ITIC - Information Technology Industry Council	http://www.itic.org
JIS - Japan Industrial Standards Committee	http://www.jisc.org
KEBS - Kenya Bureau of Standards	http://www.kebs.org
LIA - Laser Institute of America	http://www.laserinstitute.org/safety_bulletin/lsib/index.htm
MSHA - Mine Safety and Health Administration	http://www.msha.gov
MSS - Manufacturers Standardization Society of the Valve and Fittings Industry Inc.	http://www.mss-hq.com
MSZT - Magyar Szabványügyi Testület (Hungary)	http://www.mszt.hu
NACLA - National Cooperation for Laboratory Accreditation	http://www.nacla.net
NBIC - National Board of Boiler and Pressure Vessel Inspectors	http://www.nationalboard.org
NEC - Mike Holt's NEC Internet Connection	http://www.mikeholt.com
NEC - Newton's International Electrical Journal (NEC and related matters)	http://www.electrician.com
NEMA - National Electrical Manufacturer's Association	http://www.nema.org
NESF - National Electrical Safety Foundation (U.S.)	http://www.nesf.org

Standards Associations, Societies and Boards (Continued)	
NFPA - National Fire Protection Association	http://www.nfpa.org
NHTSA - National Highway Transportation Safety Agency (U.S.)	http://www.nhtsa.dot.gov
NIST - National Institute of Standards & Technology (Website)	http://www.nist.gov
NLSI - National Lightning Safety Institute	http://www.lightningsafety.com
NPL - National Physical Laboratory (U.K.)	http://www.npl.co.uk
NRTL - Nationally Recognized Testing Labs (includes scope of recognitions)	http://www.osha-slc.gov/dts/otpca/nrtl/index.html
NSAI - National Standards Authority of Ireland	http://www.nsai.ie
NSC - National Safety Council	http://www.nsc.org
NSF - Norges Standiseringsforbund (Norway)	http://www.standard.no
NSSN - National Standards System Network	http://www.nssn.org
NTSSS - North Texas System Safety Society	http://www.flash.net/~rcade
OSHA - Occupational Safety and Health Administration	http://www.osha.gov
PTB - Physikalisch Technische Bundesanstalt (Germany)	http://www.ptb.de
SABS - South African Bureau of Standards	http://www.sabs.co.za
SAQI - State Administration of Import and Export Commodity Inspection of the P.R.C. (China)	http://www.ciq.gov.cn
SCC - Standards Council of Canada	http://www.scc.ca
SEE - Service de l'Energie de l'Etat (Luxembourg)	http://www.etat.lu/SEE
SEMI - Semiconductor Equipment and Materials International	http://www.semi.org
SES - Standards Engineering Society	http://ses-standards.org
SESKO - Finnish Electrotechnical Standards Association (Findland)	http://www.sesko.fi/english.htm
SEV - Swiss Electrotechnical Association	http://www.sev.ch
SFS - Suomen Standardisoimisliitto r.y. (Findland)	http://www.sfs.fi
SII - Standards Institution of Israel	http://www.iso.co.il/sii
SIRIM - Berhad (Malaysia)	http://www.sirim.my
SMIS - Standards & Metrology Institute of Slovenia	http://www.usm.mzt.si
SNV - Schweizerische Normen Vereinigung (Switzerland)	http://www.snv.ch

Standards Associations, Societies and Boards (Continued)	
SP - Swedish National Testing & Research Institute	http://www.sp.se
SPRING - Standards, Productivity and Innovation for Growth (Singapore)	http://www.spring.gov.sg
SSS - System Safety Society	http://www.system-safety.org
STAMEQ - Directorate for Standards and Quality (Vietnam)	http://www.tcvn.gov.vn
Standards Australia	http://www.standards.com.au
FICORA - Finnish Communications Regulatory Authority (Finland)	http://www.ficora.fi
TISI - Thai Industrial Standards Institute	http://www.tisi.go.th/
TÜV America	http://www.tuvam.com
UBS - Uganda Bureau of Standards	http://www.unbs.org
UNI - Italian National Standards Body	http://www.unicei.it
UTE - Union technique de l'Electricite (France)	http://www.ute-fr.com
VDE - Verband Der Elektrotechnik Elektronik Informationstechnik e.V. (Germany)	http://www.vde.com
VNIIS - All-Russian Scientific and Research Institute for Certification of GOSSTANDARDT of Russia	http://www.vniis.ru
WSSN - World Standards Services Network	http://www.wssn.net

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