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Stainless steels

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1. WHAT ARE STAINLESS STEELS?

Stainless steel is an iron-based alloy with a significant chromium content; in many cases, together with chromium, other special chemical elements are intentionally added, such as nickel and molybdenum. The main characteristics of this family of steels is resistance to wet corrosion, or electrochemical corrosion, in aggressive environments such as fresh water, sea water, contaminated water based solutions, acid and base environments, industrial environments, etc. Another important characteristic of this category of steel is the resistance to oxidation at high temperatures, or chemical corrosion, as typically occurs in hot process gases. The typical fields of application for stainless steel are those in the chemical industry, oil industry, foodstuffs and paper manufacturing, the pharmaceutical, biomedical and transport sectors, in off-shore structures, household appliances, and the construction and urban furnishing sectors.

In accordance with the European standard EN 10088, steel is classed as stainless when its chemical composition has a minimum chromium content of 10.5%. However, it should be noted that in virtually all types of stainless steel available on the market, the chromium content is much greater than this value, normally ranging, in the most common cases, from 13% to 18%: this is due to the fact that in practice, a chromium content of at least 12% is needed to obtain satisfactory resistance to corrosion in water based solutions.

The presence of chromium alloy ensures the possibility of creating a very thin layer of oxide (also known as passive film) on the steel surface, mainly made up of chromium oxides and hydroxides Cr_2O_3 and $Cr(OH)_3$: this film is insoluble, compact and adheres well to the substrate thereby protecting the material on which it is formed. The passive film does not only comprise chromium oxides and hydroxides: tests performed using XPS¹ techniques have also revealed the presence of iron and molybdenum (again in the form of oxides and hydroxides) and have shown how nickel tends to accumulate in the interface between the passive film and steel substrate (note the schematic in figure 1).

The film of chromium oxide/hydroxide is extremely thin - just a few nanometres - and transparent to luminous radiation, and therefore gives stainless steel its typical grey-silver metal finish, as clearly seen in cooking utensils, pans, cutlery and metal watch straps.

All the above properties are the consequence of the rapid reaction of the chromium alloy with oxygen in the atmosphere. Oxidation of stainless steel, also known as passivation, occurs naturally and spontaneously in neutral oxidating environments, such as in contact with air. Otherwise, as normally occurs in the processes for manufacturing semi-finished articles, it is induced artificially by the immersion of the semi-finished product

¹ XPS is the acronym for X-ray Photoelectron Spectroscopy. The sample is exposed to a flow of photons, emitted by the X-ray: the interaction of the photons with the material to be investigated lead to the emission of electrons each of which has a specific kinetic energy that depends on the binding energy of the chemical element from which it was emitted. By measuring this kinetic energy of the emitted electrons, it is possible to calculate the binding energies and then the type of chemical elements present in the test material. This technique is also known as ESCA, i.e. Electron Spectroscopy for Chemical Analysis.

in a solution diluted with nitric acid. In this case the protective and stable chromium oxide/hydroxide film that is formed acts as a sealant and creates a barrier between the material and the external environment. In consideration of the above process, in a certain sense the term "stainless" is not appropriate. Steel is, in fact, highly "oxidisable" and as it is in a stable oxide/hydroxide state, it is also highly resistant to corrosion and aggression from the surrounding environment.

The passive film of chromium oxide/hydroxide also has another important property: when scuffed, scratched or mechanically damaged, it spontaneously forms again on the surface of the component, thus immediately restoring protection against any corrosive action (figure 2).

As well as the considerations of general corrosion, the presence of chromium also ensures optimal resistance to localised forms of corrosion such as pitting and crevice.

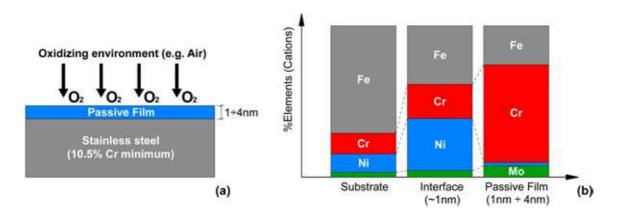


Figure 1 – (a) Mechanism of stainless steel passivation in contact with the atmosphere and (b) schematic of trends of elements present in the passive film, in the interface and in the substrate of a stainless steel grade 18%Cr-14,3%Ni-2,5%Mo [from Olefjord and Elfstrom 1982].



Figure 2 – Mechanical removal of the passive layer and subsequent re-passivation of stainless steels [from Baddoo 1995].

Lastly, given that the chromium oxides that form on the surface of stainless steels are highly stable at temperatures above ambient values, the material is therefore highly resistant to oxidation and corrosion when subject to heat.

Thus in very general terms, it can be concluded that the greater the quantity of chromium in the alloy, the greater the resistance of stainless steel to corrosion. This applies both in conditions of wet corrosion and under the effect of heat oxidation. For this purpose, figure 3 illustrates the trend in the speed of corrosion of iron alloys with various chromium contents, in the presence of water based solutions diluted with nitric acid and sulphuric acid and in conditions of oxidation under heat in air at a temperature of 1000°C.

Note that in the presence of nitric acid, i.e. an oxidising acid that can cause passivation of the chromium, the steel's resistance to corrosion increases in proportion to the increase in chromium content, whereas in the presence of a reducing acid such as sulphuric acid, the speed of corrosion follows a similar trend in reverse. An additional effect of the chromium is that of improving resistance to creep in stainless steels, which for this reason are widely used at temperatures higher than ambient values, in conditions where deterioration is predominantly caused by creep.

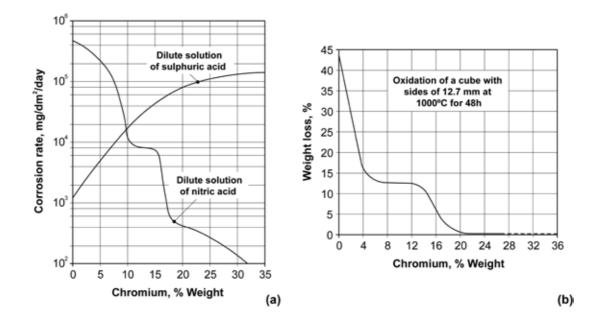


Figure 3 – Speed of corrosion, in terms of weight loss of chromium-iron alloys (a) in water based solutions diluted with nitric acid and sulphuric acid and (b) in conditions of oxidation under heat in air at temperatures of 1000°C [from Verhoeven 2007].

2. STAINLESS STEEL TREE STRUCTURE

Before dealing in detail with the relevant metallurgical and mechanical characteristics, the main types of stainless steel available on the market can be summarised in a simple tree view (see figure 4).

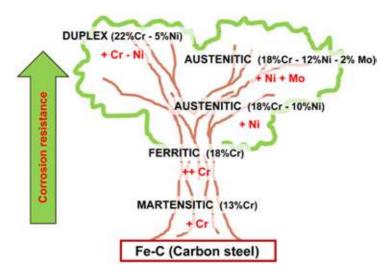


Figure 4 – Schematic of the evolution of stainless steels starting from plain carbon steels: the stainless steel tree structure.

To begin with we consider a common heat-treatable plain steel, such as steel grade C30: to make this steel stainless it is sufficient to add a set content of chromium (~13%) to obtain an initial possible version of stainless steel. This is grade X30Cr13.

A steel with this type of chemical composition can undergo heat treatment (in fact this is a heat-treatable steel) and, after tempering and quenching (hardening), it takes on a tempered martensitic structure at ambient temperature. It also offers the benefit of offering good resistance to corrosion, combined with good mechanical resistance.

With the aim of further increasing corrosion resistance of stainless steel as proposed above, a larger quantity of chromium needs to be added, while the presence of carbon should be reduced. In this case the steel grade obtained will be X6Cr17, with a ferritic structure at ambient temperature, due to the significant presence of chromium, with notable ferrite forming properties. The level of corrosion resistance of the new steel will be greater than that of the X30Cr13 steel; on the contrary the mechanical resistance of the X6Cr17 will be much more limited as no hardening heat treatment will be possible.

To obtain a steel with even greater corrosion resistance than the two grades described above, the addition

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of nickel and molybdenum will be necessary, and possibly a further increase in chromium content. In this case, there are two alternative procedures:

starting with the X6Cr17, nickel could be added to obtain stainless steel grade X5CrNi18-10 or both nickel and molybdenum to obtain the grade X5CrNiMo17-12-2: this will thus obtain an austenitic structure at ambient temperature, due to the austenite stabilising properties of nickel that predominate over the ferrite forming strength of the chromium.

alternatively, again starting with X6Cr17, smaller quantities of nickel can be added, along with greater quantities of chromium, with a set percentage of molybdenum, to obtain the stainless steel grade X2CrNiMoN22-5-3: this solution obtains a mixed (or two-phase) structure of ferrite and austenite.

The four steel grades described above, belonging to various levels of the tree structure of stainless steels illustrated in figure 4, also represent the four main families of stainless steels currently used; these families, all defined on the basis of their microstructure at ambient temperature, are:

martensitic stainless steel (such as X30Cr13),

ferritic stainless steel (such as X6Cr17),

austenitic stainless steel (such as X5CrNi18-10 and X5CrNiMo17-12-2),

austen-ferritic, two-phase or duplex stainless steel (such as X2CrNiMoN22-5-3).

A fifth category can be added to these four, i.e. the family of stainless steels by precipitation hardening: this is not defined by the metallurgical structure of the steel at ambient temperature but rather, as per tradition, by the heat treatment/strengthening mechanism used to produce it (precipitation hardening).

3. METALLURGY OF STAINLESS STEELS

As described in the previous chapter, the four main families of stainless steels are classified on the basis of the microstructure they have at ambient temperature, in other words:

- martensitic stainless steels (with a martensitic microstructure)
- ferritic stainless steels (with a ferritic microstructure)
- austenitic stainless steels (with an austenitic microstructure)
- austen-ferritic stainless steels (with a mixed austenitic and ferritic microstructure)

To understand how it is possible to obtain such diverse microstructures, a thorough analysis is needed of the effect of the alloy elements on the phase diagram of stainless steels: only a careful examination of these phase diagrams will enable a full understanding of how such different structures and properties can be obtained within the same family of materials.

On analysis of the phase diagrams, it must always be taken into account that these diagrams are only valid in balanced conditions, i.e. only when the specified alloy is cooled very gradually in consecutive stages of equilibrium from the melting temperature to the ambient temperature.

3.1 Iron-chromium

The first phase diagram to be considered has to be the Fe-Cr diagram, as it is the very element of chromium that characterises the family of stainless steels, and which gives all types their excellent levels of corrosion resistance. For this purpose, refer to figure 5.

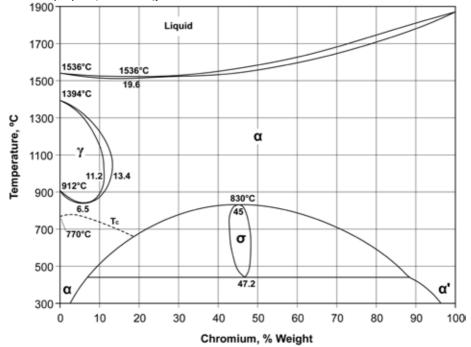


Figure 5 – Fe-Cr phase diagram [from ASM-H.3 1992].

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As chromium is a ferrite forming element, i.e. it aids the expansion of the field of phase α , the Fe-Cr phase diagram highlights the presence of a closed γ field, with upper and lower limits corresponding respectively to 11.2% and 13.4%: this means that if the chromium content exceeds 13.4% the iron-chromium alloy will have a lattice α with a stable ferritic structure² starting from the temperature of alloy solidification through to the ambient temperature. On the contrary, if the chromium content is lower than 13.4%, the standard transformation $\gamma \rightarrow \alpha$ will occur, typical of the Fe-C phase diagram.

While closure of the field γ is caused by the addition of ferrite forming elements such as chromium, aluminium, vanadium, silicon, molybdenum, titanium, niobium or tungsten, the austenitising elements such as nickel, manganese, carbon or nitrogen contribute to expanding the field γ and shifting the limit threshold to the right.

All these factors are critical because, as seen in figure 6, on addition of carbon, nitrogen or nickel to the iron-chromium alloy, the existence field of phase γ expands significantly. This therefore can obtain a stable phase γ at high temperatures (900°C-1000°C) even with chromium contents of more than 13.4%.

These two specific characteristics of the Fe-Cr phase diagram enable an explanation of the existence of two important stainless steel families.

On the one hand, if the chromium content is around 16%-17% and the carbon level is very low (less than 0.1%), there are no structural transformations and the steel structure will be ferritic (the grade of ferritic stainless steels); on the other hand, when the chromium content is around 13% and the carbon level is around 0.2%-0.3%, the alloy undergoes a transformation $\gamma \rightarrow \alpha$ and may achieve the status of martensitic stainless steel.

Another notable characteristics of the Fe-Cr phase diagram is the presence of the phase σ , i.e. an intermetallic compound between the iron and chromium with a tetragonal structure (with a variable chromium content, ranging approximately between 40% and 50%) which is deposited on the grain boundary, achieving optimal levels of hardness and brittleness of the steel. As phase σ is high in chromium content, it tends to significantly worsen corrosion resistance of stainless steels (removing the same element that gives steel its resistance to corrosion): its presence should therefore be avoided at all costs, taking care not to expose the material to temperatures in the range 550°C-850°C for time intervals of 100-1,000 hours. Bear in mind that the specified temperature range (550°C-850°C) applies exclusively to alloys made up of iron and chromium; if other alloy elements are present, such as molybdenum, phase σ may also occur at temperatures up to 980°C. At times the phenomena following formation of phase σ are also termed "embrittlement at 800°C".

² When speaking of stainless steels, the phase α , corresponding to the ferritic structure, is often alternatively referred to as phase δ . The distinction (α and δ) between the two names used to define the same structure (ferrite), is completely conventional: usually the body-centred cubic phase is known as δ if found at a high temperature, while α is used when referring to ambient temperature.

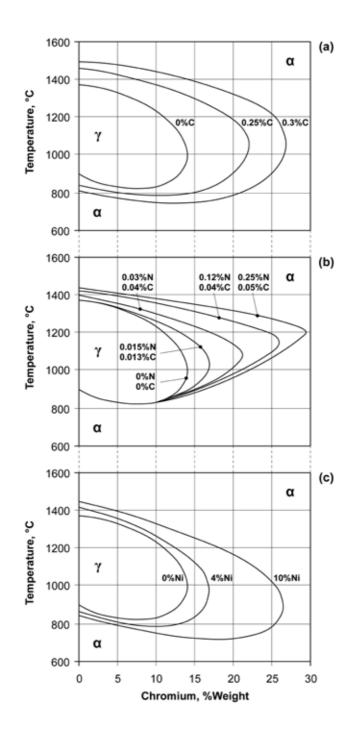


Figure 6 – Effect of adding (a) carbon, (b) nitrogen and (c) nickel on the expansion of the existence field of phase γ in the Fe-Cr phase diagram [from Lacombe et al. 1993].

On the same Fe-Cr phase diagram, there exists phase α' : this phase forms at temperatures ranging from approximately 350°C to 550°C for hold times of varying lengths³. The most critical condition occurs at 475°C, after some tens of minutes, and is hence known as "embrittlement at 475°C".

Phase α' forms within ferrite grains and has a body-centred cubic structure: it is a phase rich in iron and chromium, in line with the steel α matrix, with sub-microscopic dimensions. To all effects and purposes, phase α' is a decomposition/transformation of the ferrite structure, not identifiable by means of standard metallographic analysis or by X-rays, due to the sub-microscopic dimensions and lattice parameters identical to those in phase α^4 .

Phase α' tends to lead to a progressive embrittlement of the steel on increase of the hold time at the critical temperatures, as well as the decline in corrosion resistance properties of the alloy. The phenomenon occurs on alloys with a chromium content of more than 14% with kinetics that increase in proportion to the increase of alloy elements.

3.2 Iron-Nickel

We will now look into the effect of nickel (Fe-Ni phase diagram), i.e. the other alloy element always present in the chemical composition of the two remaining stainless steel families (austenitic stainless steel and austen-ferritic stainless steels).

The nickel affords ductility to the material and extremely high strength, also at cryogenic temperatures; it contributes to the increase in corrosion resistance of stainless steels not so much because it improves stability of the passive film (which is the case of chromium) but rather because it aids repassivation of the steel⁵ and increases corrosion resistance in reducing environments. Just as in the case of chromium, nickel gives stainless steel optimal resistance to oxidation under heat and to creep.

While the effect of chromium is to close the field of phase γ , the action of nickel is to open the field γ up to the ambient temperature and then at the same time close the field α : note this process in the Fe-Ni phase diagram shown in figure 7.

⁵ If the passive film is subject to mechanical scratches or worse, if it is chemically damaged, the presence of nickel aids the film to "reheal", restoring the original corrosion resistance of the material.



³ The formation of phase α' is obtained, according to most authors, by spinodal decomposition, in other words by decomposition of an unstable phase (the original α phase) which gives rise to two separate solid solutions with the same crystalline structure but a different chemical composition (phase α' is the new modified phase α); however a minority maintain that the phase α' forms by nucleation and accretion from phase α .

⁴ Note that the symbol α' is also currently attributed to martensite obtained by cold plastic deformation of austenitic stainless steel following transformation from austenite (see more details below). As the two phases (α' -martensite and α' -ferrite from spinodal decomposition) must not be confused, we have opted in this document to use the term "embrittlement at 475°C" rather than the term α' .

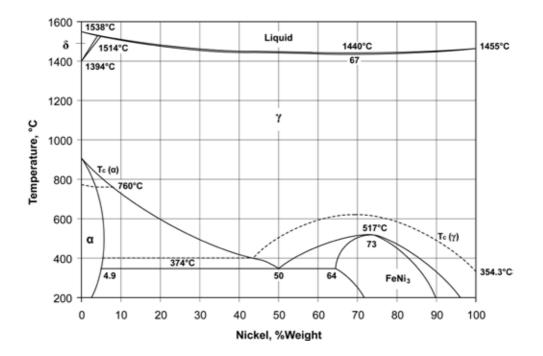


Figure 7 – Fe-Ni phase diagram [from ASM-H.3 1992].

The possibility of having an open field γ (i.e. with a stable γ phase) starting from the solidification temperature through to the ambient temperature, will obtain a completely austenitic structure. The phenomenon is possible as the addition of nickel tends to shift the critical points of transformation $\gamma \rightarrow \alpha$ at very low temperatures: on cooling, the structure is not subject to any transformation, remaining austenitic also at ambient temperature. The Fe-Ni phase diagram also shows the existence of the phase Ni₃Fe, which however is of little practical interest with regard to stainless steels.

While in simple Fe-Ni alloys, around 30% of nickel is needed to have only phase γ at ambient temperature, if around 17% of chromium is added, 8% of nickel is sufficient to obtain a stable austenitic structure: this would explain the existence of austenitic stainless steels with 17%-18% chromium and 10%-12% nickel (see figure 8).

3.3 Iron-Chromium-Nickel

For a better understanding of the phenomena described above, it is worth considering the Fe-Cr-Ni ternary diagram, undoubtedly more significant when describing alloys containing higher percentages of the three alloy elements. However, in consideration of the practical difficulty in plotting ternary diagrams (which in other words would have a three dimensional structure), it is more customary to use a representation in the form of binary sections in which the percentage of one of the three alloy elements is plotted. With regard to

this, refer to the Cr-Ni binary section of the Fe-Cr-Ni ternary diagram, with an iron content of 70% (figure 9), useful when both chromium and nickel are present in the alloy⁶.

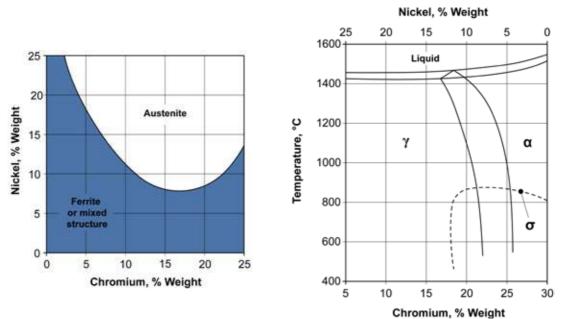


Figure 8 – Effect of nickel on the formation of an austenitic structure in relation to the chromium content in alloys: steels of various chemical compositions with C=0.1% soluble in water from 1100°C [from Peckner and Bernstein 1977].

Figure 9 – Cr-Ni binary section in Fe-Cr-Ni ternary diagram (with Fe = 70%) [from Lippold and Kotecki 2005].

The ternary section shown in figure 9 again highlights the absence of critical points in transformation $\gamma \rightarrow \alpha$. It also explains, in relation to the chromium and nickel contents in the alloy, the existence of exclusively austenitic structures (austenitic stainless steels) or of two-phase austenite and ferrite structures (austenferritic or duplex stainless steels): hypothesising a chromium content of 17%-18% and nickel of 10%-12% an austenitic structure is obtained, while a chromium content of 22%-25% and nickel at 4%-8% an austenferritic structure is obtained.

⁶ To be more precise, note that austenitic chromium-nickel or chromium-nickel-molybdenum stainless steels do not have a completely austenitic structure. On examination of the ternary diagrams, the presence of a small percentage of is always shown (up to 5%): this is normally an advantage as it reduces the steel's susceptibility to the formation of hot cracks during welding.

3.4 Other alloy elements

As well as chromium and nickel, stainless steels also contain other chemical elements that modify both the metallurgical characteristics and the mechanical properties and corrosion resistance of the steel, creating additional and specific properties.

Given all stainless steels are steel, carbon is always present.

Carbon, an austenitising element like nickel, gives steel hardness and mechanical resistance. As carbon has a close affinity with chromium, in stainless steels there is always the tendency to form chromium carbides, such as $Cr_{23}C_6$, particularly detrimental to stainless steel, as it impoverishes the same chemical element that guarantees corrosion resistance. The phenomena of chromium carbide formation occurs at temperatures above ambient values, normally within the range of 450°C to 900°C.

Chromium carbides usually deposit on the grain boundary and leading to a localised, i.e. within the boundary of the grain itself, depletion of chromium: a consequence of this process is that the chemical composition of the metal mass falls below the passivation threshold (10.5% chromium) giving rise to intergranular corrosion, also in only slightly aggressive environments⁷. The entity of corrosion depends both on the quantity of carbide precipitation and the lesser or greater ability of the chromium to spread in the steel lattice: in the crystalline structure of the steel, this causes short or long range depletion of the chromium with differing effects in terms of material deterioration⁸ (see figure 10).

Given the great importance of the issue of chromium carbides, we shall deal with this in more detail below. For now it is sufficient to note that, with the exception of the case in which high mechanical properties are required (such as the case of martensitic stainless steels), this problem is avoided by minimising the carbon content or attempting to neutralise the effect of the latter, by combining it with other chemical elements. After chromium, nickel and carbon, the fourth significant chemical element in stainless steels is molybdenum, another ferritising element.

When added to the alloy, this element significantly increases resistance to corrosion, with particular regard to the phenomena of localised attack, such as the case of pitting and crevice corrosion. Molybdenum also aids heat resistance of stainless steels at least up to medium temperatures; however, at temperatures over 800° C, it tends to form liquid oxides (MoO₃) leading to catastrophic phenomena of selective oxidation. There is then another series of alloy elements often present in stainless steels, but these are of less importance with respect to those above. They are manganese, titanium, niobium, sulphur, nitrogen and copper.

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⁷ The mechanism of deterioration generated by the presence of phase σ is also very similar to what occurs with the formation of chromium carbides, leading to localised depletion of chromium and intergranular corrosion.

⁸ In ferritic stainless steels, the diffusivity of chromium is high, while the depletion of chromium caused by the formation of carbides is long range, starting from the grain boundary; on the contrary in the case of austenitic stainless steels (low chromium diffusivity) chromium depletion remains short range. As a consequence, possible phenomena of intergranular corrosion are much more marked in austenitic stainless steels compared to ferritic stainless steels.

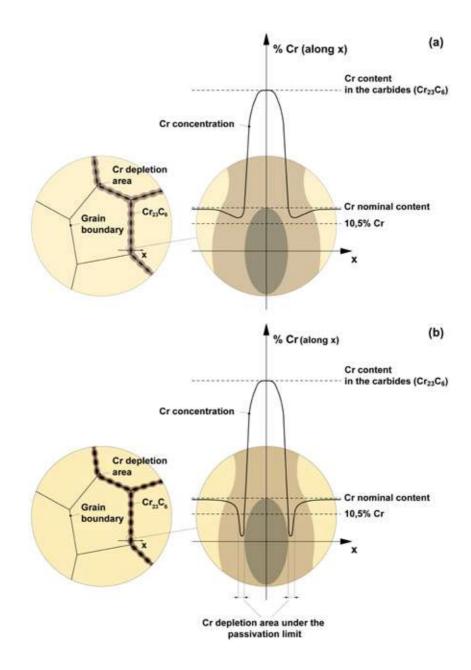


Figure 10 – Trends in chromium concentrations at a grain boundary where chromium carbide precipitation occurs: a) in the case of ferritic stainless steel (high diffusivity of chromium); b) in the case of austenitic stainless steel (low diffusivity of chromium).

Manganese is normally present in stainless steels at percentages lower than 2% as it is used in the steel production phase as a strong de-oxidant⁹; at values greater than 2% it is used as a replacement for nickel due to its austenitising properties. The presence of significant percentages of manganese (>2%) improves the work hardening properties of stainless steel, but reduces its corrosion resistance.

Titanium and niobium are both ferritising elements, and in the case of stainless steels, are known as stabilising elements. These two elements are added in chemical analysis as they have a great affinity with carbon and can form carbides or carbonitrides of titanium or niobium such as MC or $M_x(NC)_y$ (with M=Ti or Nb): this prevents the carbon from alloying with chromium , thus forming chromium carbides and reducing the steel's resistance to corrosion¹⁰.

To improve workability on machine tools (machinability) sulphur can be added to the stainless steels: sulphur forms manganese and/or chromium sulphides that contribute to the breakability of chips during roughing and finishing of the part. However the presence of sulphur has a series of negative implications: it reduces corrosion resistance and the strength/resilience of stainless steel, as well as its plastic deformability under heat and weldability.

Nitrogen, a highly austenitising element, is added to some grades of stainless steel (austenitic and austenferritic) both to increase mechanical strength and to improve localised resistance to corrosion.

Lastly, copper, another austenitising element, is added in small percentages (maximum 1%) to improve ductility (cold plastic deformability) of austenitic stainless steels. However, the presence of copper slightly reduces corrosion resistance, as well as weldability and plastic deformability under heat.

⁹ Silicon is also used in a similar way, as a strong de-oxidant of the metal steel bath.

¹⁰ As an alternative to titanium and niobium, tantalum may also be added, also known as columbium, with similar stabilising effects.

3.5 Schaeffler diagrams and De Long diagrams

Given the great variety of alloy elements that can be found in the chemical composition of stainless steels, it is always important to consider the overall ferritising or austenitising effect of each, to enable a specific definition of the structure of the steel at ambient temperature.

To solve this problem, the use of a more intuitive instrument is needed in place of a phase diagram.

For this purpose, a structure diagram has been drawn up, originally by Schaeffler and subsequently modified by other researchers, which enables the identification, after rapid solidification, of the metallurgical structure of stainless steels at ambient temperatures starting from the alloy elements present in the chemical composition. Although the diagram lacks the solid thermodynamic foundations typical of equilibrium diagrams, it is still very useful for a great number of practical applications (refer to figure 11).

On the X-axis, the Schaeffler diagram shows a summary of the ferritising elements (known as equivalent chromium, Cr_{eq}) while the Y-axis summarises the austenitising elements (known as equivalent nickel, Ni_{eq}). In both cases, each element is weighed with its specific coefficient, set at 1 for the ferritising effect of chromium and for the austenitising effect of nickel.

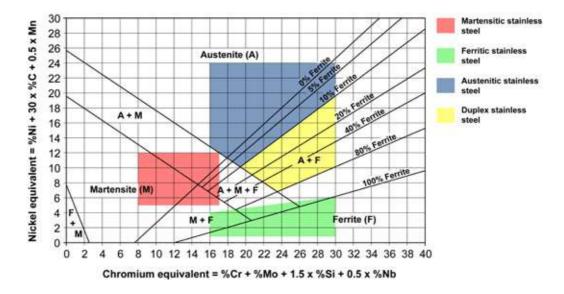


Figure 11 – Schaeffler structural diagram [from Krauss 2005]; highlighting the existence fields of the for main families of stainless steel.

The Schaeffler diagram is divided into four zones that correspond to the four typical microstructures of the above four categories of stainless steel (martensite, ferrite, austenite and austen-ferrite): note the chemical composition of the steel, which enables the identification of the microstructure at ambient temperature and the relative material category.

As can be observed, the Schaeffler diagram does not mention nitrogen among the alloy elements: to remedy this problem, in the 1970s the diagram was amended by De Long, within the austenitic and austen-ferritic fields (figure 12). The need for a more complete diagram with respect to that of Schaeffler arises from the possibility of adding controlled percentages of nitrogen to the alloy during the manufacturing phase: this applies above all to the austenitic and austen-ferritic families of stainless steel, with the aim of increasing hardness and resistance.

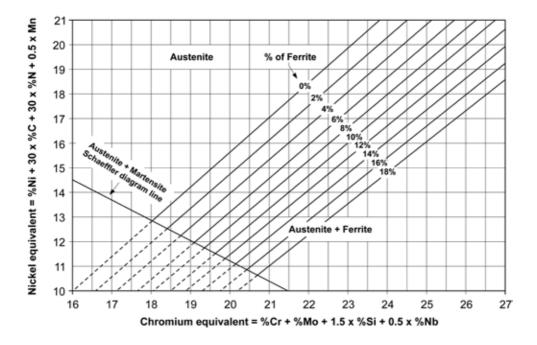


Figure 12 – De Long structural diagram [from Krauss 2005].

Lastly it is worth re-iterating previous observations that both the Schaeffler and the De Long diagrams referred to welding beads, i.e. for alloys cooled rapidly from the melting temperature: these can therefore only provide reliable results in these specific conditions.

However in many cases the two diagrams are used, even if only as a guideline, to evaluate the structures of semi-finished parts in the annealed or soluble state (castings, laminates, forged, drawn etc.)¹¹.

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¹¹ It is worth noting that the Schaeffler diagram must never be used to define the microstructural specifications of steel based on its chemical composition. Although quantity-based data can also be obtained, it mustalways be taken into account that the microstructuresand semi-finished products in stainless steel are always highly influenced by the heat treatment applied, as well as the presence of local irregularities in the chemical composition, obviously in addition to the values of Req and Nieq.

4. STAINLESS STEEL REFERENCE STANDARDS

On a European scale, the reference standard for stainless steels is EN 10088, parts 1 to 5 (in Italy this is implemented with the pre-fix UNI-EN): this standard lists the various types of stainless steel, the relative chemical compositions, the physical and mechanical properties, and heat treatments, also specifying the technical conditions for the supply of flat semi-finished and long semi-finished products.

As well as the European standard, another useful standard is still used, though now "old fashioned", which are the AISI (American Iron and Steel Institute) standards, the last edition of which dates back to the 1990s: this standard, as in the case of all US standards, refers to a method of designation in which each type of stainless steel has a specific progressive number within a specific grade (or class). The AISI standards was then taken over by the ASTM (American Society for Testing and Materials) which quotes its reference in its own standards packages¹².

The AISI standard divides stainless steels into set grades; the most common are the following:

- 200 series: chromium-manganese austenitic stainless steels
- 300 series: chromium-nickel austenitic stainless steels
- 400 series: chromium martensitic and ferritic stainless steels
- 600 series: precipitation hardening stainless steels

While with the normal precautions specific to the case, an approximate correspondence can nevertheless be established between the European standard symbols and the AISI symbols used. As regards the main types of stainless steel (as outlined above), the corresponding AISI types are as follows¹³:

- martensitic stainless steel type X30Cr13 corresponds approximately to type AISI 420,
- ferritic stainless steel type X6Cr17 corresponds approximately to type AISI 430,
- austenitic stainless steel types X5CrNi18-10 and X5CrNiMo17-12-2 correspond approximately to types AISI 304 and AISI 316.

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¹² This is the case, for example, of the standard ASTM A240/A240M entitled "Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications" or the standard ASTM A473 entitled "Standard Specification for Stainless Steel Forgings" which state, together with the UNS designation (Unified Numbering System), the equivalent AISI designation, if this exists.

¹³ In this document, as regards the section on equivalents between the standards, it was decided to use the term "corresponding approximately to" or "similar to" to avoid misleading information and the reader's presumption that the corresponding designations are identical to one another.

5. NOTES ON THE MARKET OF STAINLESS STEELS

Although the production of stainless steels represents just a fraction of the overall production of steel (approx. 2% of all semi-finished products) it nevertheless is of significant importance, both in terms of the high unit value of the marketed product (with a market share of around 15%) and in terms of the fact that the use of stainless steel, in certain specific applications, is an absolute necessity.

Approximately three quarters of the world production of stainless steel is for flat semi-finished articles (sheets, strips, etc.); only one quarter derives from long semi-finished products (bars, rods, wires, profiles etc.).

As a consequence of the market shares described above, the sector for the production of long semi-finished products has a much more flexible response to market demands (with more types and formats available) with respect to the case of flat semi-finished products which tends to be more standardised.

A basic and guideline schematic on how the various families of stainless steel are used is illustrated in figure 13, which makes a distinction between flat and long semi-finished products.

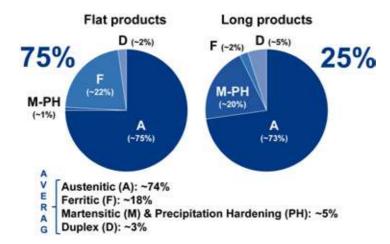


Figure 13 – Guideline schematic of world production/use of stainless steels, divided by flat and long semifinished products.

Among the types of stainless steel most used, the lion's share is certainly taken by the austenitic stainless steel grades, which cover the most substantial applications (flat and long semi-finished products), and consequently this type represents the most significant portion of world stainless steel production. Less used, but no less important, are the ferritic and martensitic stainless steels. The more "niche" type applications regard the austen-ferritic and precipitation hardening stainless steels. The more "niche" type applications the main intended uses of stainless steels are summarised in table 1.

SECTOR AND/OR APPLICATIONS	%
Petrochemical and energy	
(iOn-shore and off-shore plants, oil extraction and production industries, resource and natural gas transport systems, undersea equipment, geothermic, solar and photovoltaic plants, etc.)	12 – 14
Process industries	
(chemical, petrochemical and pharmaceutical industries, transformation and production of semi-finished products and components industries, food industries, pulp and paper industries, water treatment and desalination plants, etc.)	18 – 20
Transport	12 – 14
(Cars, bicycles and motorcycles, heavy goods vehicles, trains, ships and boats etc.)	12 - 14
Building, architecture and urban furnishing	
(Architectural monuments and structures, facades and roofs, flues and chimneys, handrails and railings, escalators and elevators, water distribution pipes, etc.)	16 – 18
Appliances and household items	34 – 36
(Pots, cutlery, washing machines, dishwashers, sinks, taps and general cooking utensils etc.)	54 – 36
Other	~ 3

Table 1 – Main fields of application of stainless steel

Bear in mind that approximately 55% of the stainless steel produced (flat and long semi-finished products) is normally used for the manufacture of durable goods and components – industrial plants, construction and transport – while 45% is used for consumables, above all household appliances and goods.

These two markets differ significantly: while in the first case the final user looks mainly to the metallurgical characteristics of stainless steel used, comparing performance and costs with other materials such as coated steel, aluminium alloys, plastic materials etc., in the case of consumables, the technical specifications pass to second place with respect to the cost of the product and current market conditions.

6. MARTENSITIC STAINLESS STEELS

6.1 Metallurgy

As can be observed in the Schaeffler diagram, the martensitic family of stainless steels is characterised by limited chromium content (normally between 11.5% and 18%) and carbon contents among the highest of the stainless steels most commonly used (generally between 0.1% and 1%).

Chromium, a highly ferritising element, and carbon, an austenitising element, are balanced so that the steel has an austenitic structure at high temperature and a martensitic structure at ambient temperatures after tempering.

It must be pointed out that the presence of a high content of carbon, required to ensure a good level of hardness and mechanical resistance for the steel, also tends to aid the formation of chromium carbides. Consequently martensitic stainless steels are, among all types, the least resistant to corrosion; their field of application in fact is limited to only slightly aggressive environments.

The chemical composition of some of the main types of martensitic stainless steels and relative designation according to EN 10088 are shown in table 2.

Figure 14 illustrates the "metallurgical" logic that has led to the creation of the main types of martensitic stainless steels, starting with X30Cr13 (similar to AISI 420B), the progenitor of this family, and still today widely used in the knife sector.

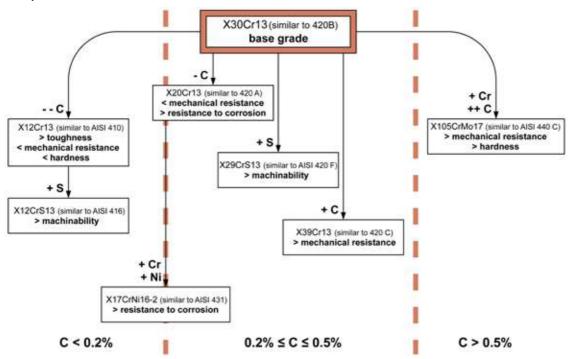


Figure 14 – Schematic of the main types of martensitic stainless steels, starting from X30Cr13 (similar to AISI 420B), progenitor of this family.



EN Designation	%С	%Si	%Mn	4 %	%S	%Cr	Other	AISI approximate correspondence
X12Cr13 (1.4006)	0,08-0,15	≤1,00	≤1,50	≤0,040	≤0,015	11,5-13,5	1	AISI 410
X12Cr513 (1.4005)	0,08-0,15	≤1,00	≤1,50	≤0,040	0,15-0,35	12,0-14,0	2	AISI 416
X20Cr13 (1.4021)	0,16-0,25	≤1,00	≤1,50	≤0,040	≤0,015	12,0-14,0		AISI 420 (420A*)
X30Cr13 (1.4028)	0,26-0,35	≤1,00	≤1,50	≤0,040	≤0,015	12,0-14,0		AISI 420 (420B*)
X39Cr13 (1.4031)	0,36-0,42	≤1,00	≤1,00	≤0,040	≤0,015	12,5-14,5		AISI 420 (420C*)
X29Cr513 (1.4029)	0,25-0,32	≤1,00	≤1,50	≤0,040	0,15-0,25	12,0-13,5	3	AISI 420F
X17CrNi16-2 (1.4057)	0,12-0,22	≤1,00	≤1,50	≤0,040	≤0,015	15,0-17,0	4	AISI 431
X105CrMo17 (1.4125)	0,95-1,20	≤1,00	≤1,00	≤0,040	≤0,015	16,0-18,0	5	AISI 440C
X3CrNiMo13-4 (1.4313)	≤0,050	≤0,70	≤1,50	0†0′0⋝	≤0,015	12,0-14,0	9	-
X4CrNiMo16-5-1 (1.44185)	≤0,060	≤0,70	≤1,50	≤0,040	≤0,015	15,0-17,0	7	
			- -		-			

*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 420B)

Notes:

1: %Ni ≤ 0,75 2: %Mo ≤ 0,60 3: %Mo ≤ 0,60

4: 1,50 ≤ %Ni ≤ 2,50 5: 0,40 ≤ %Mo ≤ 0,80 6: 3,50 ≤ %Ni ≤ 4,50; 0,30 ≤ %Mo ≤ 0,70; %N ³ 0,020 7: 4,00 ≤ %Ni ≤ 6,00; 0,80 ≤ %Mo ≤ 1,50; %N ³ 0,020

Table 2 – Chemical composition of some of the main types of martensitic stainless steels [from EN 10088].

The phase diagrams that can be used as a reference to further understand the metallurgy of martensitic stainless steels are illustrated in figure 15 and figure 16: these envisage the existence of critical points, i.e. the possibility of transformation $\gamma \rightarrow \alpha$, in a similar manner to that which occurs on the classic Fe-C phase diagram. For example, this is what happens when the carbon content is around 0.3%, such as in the case of X30Cr13 (similar to AISI 420B) or when it is around 1% such as in the case of X105CrMo17 (similar to AISI 440C).

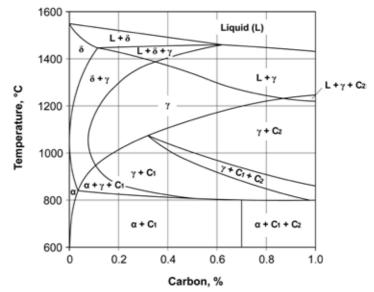


Figure 15 – Binary section Fe-C of Fe-Cr-C ternary diagram with Cr = 13%; C_1 carbides type $(Cr,Fe)_{23}C_6$, C_2 carbides type $(Cr,Fe)_7C_3$ [from Lippold and Kotecki 2005].

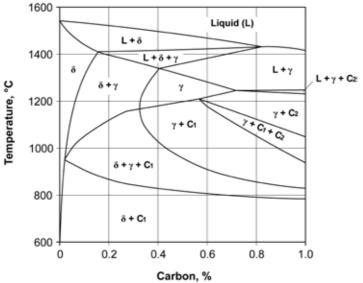


Figure 16 – Binary section Fe-C of Fe-Cr-C ternary diagram with Cr = 17%; C_1 carbides type (Cr,Fe)₂₃ C_6 , C_2 carbides type (Cr,Fe)₇ C_3 [from Lippold and Kotecki 2005].

Therefore when the steel is heated to temperatures above the critical points, the original microstructure transforms completely into austenite plus carbides, to then become martensite plus carbides under the effect of cooling the steel in oil or in air.

Note that the addition of carbon (or nitrogen or nickel) aids expansion of the field of existence of phase γ thereby obtaining a martensitic structure after tempering, also in the case of chromium contents well above 13.4%, the threshold envisaged by the Fe-Cr diagram (refer back to figure 5).

Given the existence of critical points, it is therefore possible to trace the isothermal transformation curves (TTT) and anisothermal curves (CCT) of the austenite: these curves are shown in figure 17 for a martensitic stainless steel grade. As already indicated previously, the presence of stable carbides, both at high and low temperatures, can be explained due to the high carbon content, which aids formation of the carbides.

Also note, given the great quantity of alloy elements present, that the TTT curves and CCT curves shift significantly to the right and downwards, with respect to the temperature-time axes: this greatly aids the hardenability of the steel (martensitic stainless steels are in fact self-hardening steels) but at the same time this may lead to the presence of residual austenite (above all for the types with high carbon content) and the formation of quench cracks.

6.2 Heat treatments

Before using semi-finished products in martensitic stainless steel, they must undergo heat treatment to obtain a structure adequately workable for the machine tools. For this purpose, as in the case of traditional special steels for construction, an annealing process could be performed (complete or isothermal annealing). However, in practice a sub-critical annealing process is used on martensitic stainless steels, i.e. a heat treatment at temperatures from $730^{\circ}C - 830^{\circ}C$ for several hours, followed by gradual cooling in the furnace or air: this obtains a globular pearlite structure characterised by a matrix of phase α with globular carbides. During execution of the heat treatments on martensitic stainless steels, special attention must always be paid to the phenomena of surface decarburisation and that of chromium oxidation under heat, due to the oxygen present in the treatment atmosphere. To remedy this situation, in many cases, users resort to treatment processes in furnaces with a controlled neutral or reducing atmosphere (nitrogen or nitrogen/ hydrogen atmosphere).

The technological process that obtains a component in martensitic stainless steel (such as a power drive shaft for applications in the marine sector) envisages the use of an annealed semi-finished piece; all necessary roughing operations are performed on this part using machine tools to bring it to dimensions close to those of the finished piece, minus an adequate machine allowance.

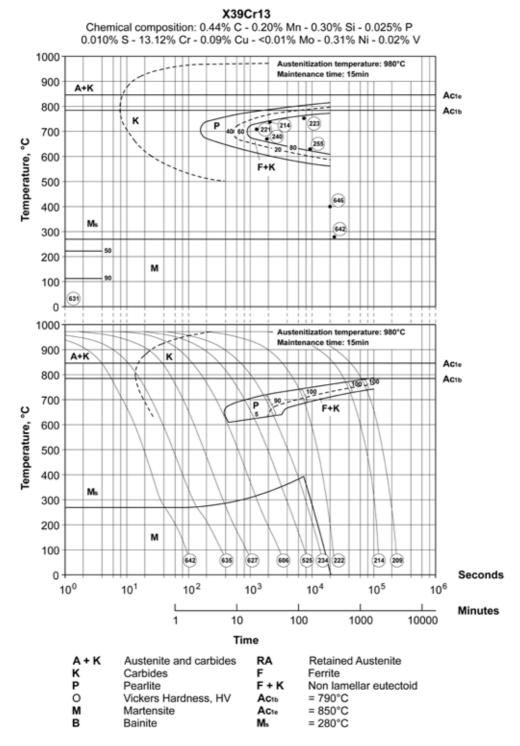
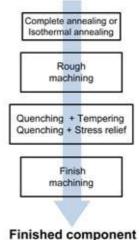


Figure 17 – Isothermal transformation curves (TTT) and anisothermal transformation curves (CCT) for martensitic stainless steel type X39Cr13 (similar to AISI 420C) [from Wever et al. 1954/56/58].

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The semi-finished part, roughed by machine tools, then undergoes the hardening treatment: this gives it the mechanical properties and characteristics of resistance to corrosion, aimed at ensuring optimal behaviour during operation. Lastly the mechanical finishing processes are performed on the machine tools to obtain a semi-finished part with the dimensions and tolerances as required on the finished piece.

A schematic of the technological process required to obtain a component in martensitic stainless steel is shown in figure 18.



Semi-finished products

Figure 18 – Technological process required to obtain a component in martensitic stainless steel.

With regard to the hardening heat treatment of martensitic stainless steels, a number of important factors must be taken into account.

The heating phase during tempering must be managed with care. Martensitic stainless steels, as in the case of all stainless steels, feature very low conductivity: to avoid permanent deformation of parts, or even worse breakage, the heating phase must be controlled (such as stepped heating, with pre-heating to between 550°C and 800°C), especially in the case of large size parts and/or parts with complex geometry.

As regards the subsequent austenitisation phase, a higher temperature must be envisaged with respect to those usually used for common heat-treatable steels: martensitic stainless steels are in fact heated and held at temperatures ranging from 950° C – 1100° C¹⁴. As well as to obtain an austenitic structure, these high temperatures are necessary to aid, as far as possible, solubilisation of any carbides present, thus creating the carbon in a solid solution for hardening of the martensite during the subsequent tempering phase (see figure 19).

¹⁴ On increase of the carbon (and chromium) content, there is a proportional increase in the steel austenitisation temperature.

However, there is an optimal temperature for austenitisation, over which phenomena occur such as grain enlargement, which then predominate the process with a consequent reduction in resistance properties of the steel (see figure 20).

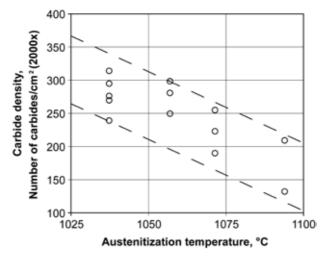


Figure 19 – Effect of the austenitisation temperature on the density of chromium carbides present after tempering on a martensitic stainless steel with 0.65%C - 12.8% Cr - 0.4%Si - 0.65%Mn [from Verhoeven 2007].

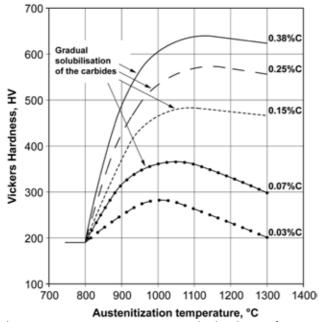


Figure 20 – Effect of the austenitisation temperature on the hardness of a martensitic stainless steel at 13%Cr with increasing carbon content (quenched in oil and then stress relieved at 200°C) [from Lacombe et al. 1993].

The austenitisation temperature of martensitic stainless steels however must not be increased as required: this would increase the risk of enlarging the crystalline grain and the probability of obtaining residual austenite at ambient temperatures, above all in the case of steels with high carbon content (see figure 21).

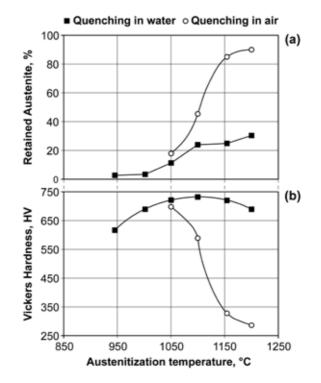


Figure 21 – Effect of the austenitisation temperature and tempering method on the hardness and % of residual austenite in a martensitic stainless steel with 0.4%C - 16% Cr - 0.9%Mo - 0.5%Ni [from Lacombe et al. 1993].

Due to their particular chemical composition, martensitic stainless steels, as previously noted, are self-tempering steels, and even harden by simple air cooling; however very often oil cooling may be envisaged (oil tempering), especially in the case of large to medium size parts, to achieve a uniform microstructure and increase uniformity of response along the resistant section of the component.

The tempering phase, always necessary after hardening treatment, also has a number of special features. Tempering, as mentioned for special construction steels, is performed to reduce brittleness of the fully quenched martensite and to reduce residual tension generated in the part during the tempering treatment. In the case of martensitic stainless steels, tempering is performed at low temperatures (below 400°C) or at high temperatures (over 640°C). Great care is taken to prevent the tempering process from taking place within the temperature range of 450°C to 600°C: this interval is considered critical as it reduces resistance to brittle fractures (a type of temper brittleness) and significantly reduces corrosion resistance (see figure 22).

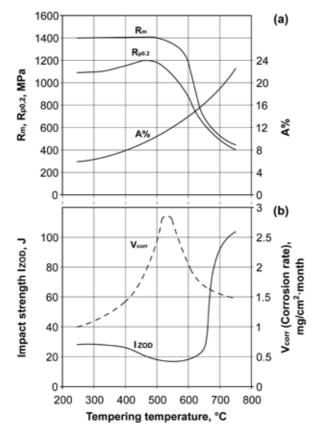


Figure 22 – Effect of tempering temperature on mechanical properties and corrosion resistance of a martensitic stainless steel type X20Cr13 (similar to AISI 420A) [from Sedriks 1996].

By tempering martensitic stainless steels at temperatures below 400°C (in these cases it is known as stress relieving) maximum hardness is obtained, along with the highest values of tensile strength and resistance to corrosion. Even though a certain brittleness remains in the martensitic structure not fully tempered, stress relief is the method envisaged by standards, normally performed on an industrial level on small size components in martensitic stainless steel.

Alternatively tempering can be performed at temperatures over 640°C (up to even a maximum of 750°C): this second case will obtain further strength and resistance to fracturing of the steel (with respect to the case of stress relief at temperatures below 400°C), combined however with a more limited hardness and reduced resistance to corrosion.

The heat treatment methods for some of the most common martensitic stainless steels are summarised table 3.

EN Designation	Annealing Subcritical annealing	Cooling in	Austenitization	Quenching in	Stress Relieving	AISI approximate correspondence
X12Cr13 (1.4006)	820°C-900°C 730°C-790°C	furnace calm air	930°C-1010°C	oil, air	600°C-750°C 150°C-400°C	AISI 410
))))	
X17CrC12 /1 1005)	820°C-900°C	furnace	03000_10100	i.	600°C-750°C	AISL / 16
	730°C-790°C	calm air		UII, all	150°C-400°C	
	840°C-900°C	furnace		.: 	600°C-750°C	(**************************************
	730°C-790°C	calm air	200 C-1020 C	UII, all	150°C-400°C	
	840°C-900°C	furnace	DEDOC 10E08C		600°C-700°C	
A3UULI 3 (1.4U28)	730°C-790°C	calm air	ש- טכטו -ש- טכצ	oli, alf	150°C-400°C	AIN 420 (4206
(1 CUV 1/ CL-JUCA	840°C-900°C	furnace	DENOC 1DENOC		600°C-700°C	
	730°C-790°C	calm air	200 C-1020 C	UII, all	150°C-400°C	AIN 420 (4200)
	840°C-900°C	furnace	DEDOC 10EDOC		600°C-700°C	
(6204.1) 51517678	730°C-790°C	calm air	ש- חכטו -ש- חכצ	UII, alf	150°C-400°C	AIJI 42UF
V176-N1:16 2 (1 4067)	840°C-900°C	furnace	DEDOC 10EDOC		600°C-700°C	
	680°C-790°C	calm air	ר טכטן -ר טכע	UII, all	150°C-400°C	1 CH ICIA
V10EC*N0217 (1 413E)	840°C-900°C	furnace	101005 107005		1500 10000	
	730°C-770°C	calm air		011 , all		
X3CrNiMo13-4 (1.4313)	hot forming**	air	950°C-1050°C	oil, air	600°C-700°C	1
X4CrNiMo16-5-1 (1.4418)	hot forming**	air	950°C-1050°C	oil, air	600°C-700°C	1

*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 420B). **These steels are cooled in air after hot plastic deformation and can be used as such or can be quenched and tempered.

Table 3 – Guideline characteristics of heat treatment on some of the main types of martensitic stainless steels.

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6.3 Physical and mechanical properties

The physical properties of martensitic stainless steels are very similar to those of the common heat-treatable steels, sharing the same martensitic tempered microstructure (see table 4).

The mechanical properties of martensitic stainless steels depend on the heat treatment applied. While in the annealed state, hardness values of around 160-250 HB are obtained, when in the hardened state most martensitic stainless steels have a unit resistance under traction R_m of between 700 MPa and 1700 MPa depending on the chemical composition and tempering conditions; the fatigue limit in air remains around the value $0.45 \cdot R_m$.

Table 5 shows the mechanical properties obtainable for each type of martensitic stainless steel according to the different heat treatment applied.

Brittle fracture also strongly depends on the chemical composition and heat treatment conditions of the steel. In proportion to the increase in carbon content, phosphorous, and the average size of the crystalline grain (i.e. to the increase in austenitisation temperature), the strength of the steel is reduced, while the transition temperature increases.

Figure 23 illustrates the trend of the transition curves for a number of commonly used martensitic stainless steels: note the behaviour virtually identical to that of special heat-treatable steels used frequently in industrial applications.

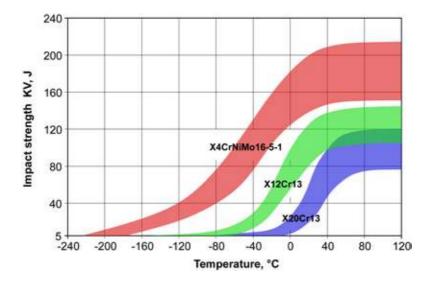


Figure 23 – transition curves for a number of commonly used martensitic stainless steels after quenching and tempering at 650°C.

EN	Mass	Specific heat at 20°C	Electrical resistance at	Thermal	Linear expansio	Linear thermal expansion [10 ^{.6} .K ¹]	Modulo [G	Modulo elastico [GPa]	AISI ·
Designation	[kg/dm³]	[J·kg ⁻¹ ·K ⁻¹]	20°C [W·mm²·m ⁻¹]	[W·m ⁻¹ ·K ⁻¹]	from 20°C to 100°C	from 20°C from 20°C to 100°C to 200°C	to 20°C	to 20°C to 200°C	approximate correspondence
X12Cr13 (1.4006)	۲,۲	460	09'0	30	10,5	11,0	215	205	AISI 410
X12CrS13 (1.4005)	۲,۲	460	0,60	30	10,5	11,0	215	205	AISI 416
X20Cr13 (1.4021)	L'L	460	09'0	30	10,5	11,0	215	205	AISI 420 (420A*)
X30Cr13 (1.4028)	L'L	460	0,65	30	10,5	11,0	215	205	AISI 420 (420B*)
X39Cr13 (1.4031)	L'L	460	0,55	30	10,5	11,0	215	205	AISI 420 (420C*)
X29Cr513 (1.4029)	L'L	460	0,55	30	10,5		215	205	AISI 420F
X17CrNi16-2 (1.4057)	L'L	430	0,70	25	10,0	10,5	215	205	AISI 431
X105CrMo17 (1.4125)	7,7	460	0,80	15	10,4	10,8	215	205	AISI 440C
X3CrNiMo13-4 (1.4313)	L'L	430	0,60	25	10,5	10,9	200	185	
X4CrNiMo16-5-1 (1.4418)	7,7	430	0,80	15	10,3	10,8	200	185	1

*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 420B)

Table 4 – Guideline physical properties of some of the main types of martensitic stainless steels [from EN 10088].

AISI approximate correspondence	B					8					В	AISI 420 (420B*)	C AISI 420 (420C*)	C AISI 420F	()	В			()			
Hardness	160-200 HB		42-46 HRC	40-44 HRC	16-24 HRC	220-260 HB	1	42-46 HRC	40-44 HRC	21-25 HRC	180-220 HB	1	48-52 HRC	45-49 HRC	22-28 HRC	230-270 HB		56-60 HRC	54-58 HRC	16-24 HRC		
A [%]	18-28	12-18	11-16	11-17	18-24	16-26	12-18	11-16	11-17	16-20	14-24	10-16	10-15	10-16	14-18	12-20	8-14	4-8	4-8	18-24		
R _m [MPa]	500-600	650-1000	1350-1500	1250-1400	650-850	550-700	700-1100	1350-1550	1250-1450	750-950	550-700	700-1200	1550-1750	1450-1650	800-1050	650-800	750-1100	1900-2100	1750-1900	650-900		
R _{p0,2} [MPa]	300-400	450-900	1000-1250	950-1150	550-700	350-450	500-900	1050-1300	1000-1200	600-800	350-450	600-1000	1250-1400	1200-1350	650-900	400-550	006-009	1650-1900	1600-1750	550-750		
Metallurgical condition	A	A + CD**	QT 200°C	QT 350°C	QT 650°C	A	A + CD**	QT 200°C	QT 350°C	QT 650°C	A	A + CD**	QT 200°C	QT 350°C	QT 650°C	A	A + CD**	QT 200°C	QT 350°C	Hot formed Q T 650°C		
EN Designation			X12CF13 (1.4006)	#(CN04.1) 61 (J771)#				X2UCF15 (1.4U21) V1776-N136 2 (1.4021)	(/CU4.1) 2-011N17/1V			X30Cr13 (1.4028)	X39Cr13 (1.4031)	X29CrS13 (1.4029)#						X3CrNiMo13-4 (1.4313)		

*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 420B).

A: Annealed

A + CD: Annealed and Cold Drawn
 A + CD: Annealed and Tempered at the indicated temperature
 Te values of the mechanical features in the condition A + CD are variable as they very much depend on the hardening conditions
 # The types with sulphur have a slightly lower elongation to failure that the equivalent types withhout sulphur.

Table 5 – Guideline mechanical properties of some of the main types of martensitic stainless steels.

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6.4 Types and applications

The semi-finished products in martensitic stainless steel commercially available are either annealed or prehardened, predominantly in the form of long products (bars and rods); only in some cases flat semi-finished products are manufactured (strips and sheets), especially for the sector of cutting blades.

The martensitic stainless steels most commonly used in industrial sectors are X30Cr13 (similar to AISI420B¹⁵) and X12Cr13 (similar to AISI 410): among the two, the first will guarantee hardness with a higher carbon content, while the second features increased strength.

These two steels are widely used where high mechanical resistance and wear resistance is required. Corrosion resistance is good, especially in rural environments, fresh water not contaminated by chlorides, in contact with foodgrade substances, or with weak acids (such as organic acids), with petrol products (crude and intermediate) and with oxidating saline solutions (chromates, permanganates, etc.).

These are frequently used for the production of table knives, industrial cutting knives, surgical instruments, rasors, scissors, callipers, machine gun barrels, brake disks for motor vehicles; they are also used in the sector of moulds for plastic materials and for springs.

Another specific use of this steel grade is for the manufacture of power drive shafts in mildly aggressive environments, steam turbine blades or compressor blades, con rods, bushings for pumps and compressors, filters, bathroom fittings, hardware, handles, coins and medals.

Type X29CrS13 (similar to AISI420F) and type X12CrS13 (similar to AISI 416) are the same as the two steel types described above (X30Cr13 and X12Cr13) but with improved machinability due to the significant presence of sulphur (approx. 0.2%). This means that strength is limited, and above all weldability will prove to be very difficult. Furthermore, resistance to corrosion is slightly lower than that of the same steel types without sulphur.

Type X17CrNi16-2 (similar to AISI 431¹⁶) is must more resistant to corrosion with respect to those described above, due to the increased chromium content in the alloy: it also offers increased strength due to the presence of nickel (not present in types X30Cr13 and X12Cr13).

The steel type X17CrNi16-2 is used in particular for shafts on marine engines, propeller shafts, pump parts, hydraulic machinery shafts, valves, turbine blades and wear-resistant components in reforming oil plants. Worth noting here is also type X105CrMo17 (similar to AISI 440C¹⁷): this steel, due to the significant content

¹⁷ Also in this case the AISI standard envisages a low carbon type (AISI 440A with %C 0.60-0.75), medium carbon (AISI 440B with %C 0.75-0.95%) and high carbon content (AISI 440C with %C 0.95-1.20%)

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¹⁵ AISI standards divide type 420 into three sub-groups, of low, medium and high carbon content. Type 420A with an average carbon content of 0.3% and type 420C with an average carbon content of 0.4%: on increase of the carbon content, there is a proportional increase in hardness at the same time sensitivity to carbide formation.

¹⁶ In fact the AISI standard envisages two martensitic stainless steels with nickel contents ranging between 1.25% and 2.5%: AISI 414 and AISI 431. AISI 414 envisages a carbon content of approximately 0.15% while in the case of AISI 431 it is approximately 0.20%. In the case of EN 10088, the type X17CrNi16-2 envisages a carbon content ranging from 0.12% to 0.22%.

of chromium and carbon, offers good resistance to corrosion (comparable with that of type X12Cr13) and, after hardening, ensures excellent durability and resistance to wear; on the contrary fracture toughness is reduced.

This is used to parts resistant to wear, oxidation or to wear and corrosion, such as the production of chains working at high temperatures, special ball bearings and surgical instruments for special applications.

Lastly, the types X3CrNiMo13-4 and X4CrNiMo16-5-1, known also as "super-martensitic", which represent two examples of martensitic stainless steel with a low content of carbon with nickel and molybdenum: these materials, at the end of the manufacturing process (for example downline of hot rolling) offer good mechanical resistance and high strength, even without heat treatment.

Tubular products manufactured using these steels are used in the chemical and oil sector as fluid carriers or as structural elements or, also, for the construction of heat exchangers. These offer optimal resistance to attack in environments rich in H₂S e CO₂, where they can be used without the addition of corrosion inhibitors.

7. FERRITIC STAINLESS STEELS

7.1 Metallurgy

When the chromium content in an alloy reaches values of 17% (or greater) and, at the same time, the presence of carbon is reduced (content below 0.1%), the ferritising effect of the chromium is no longer compensated for by the austenitising action of the carbon and, as envisaged in the Schaeffler diagram, the structure of the stainless steel will be ferritic at ambient temperatures: this is precisely what occurs on steel type X6Cr17 (similar to AISI 430), the progenitor of ferritic stainless steels.

Commercially available ferritic stainless steels however are not limited to just this chemical composition, there are in fact various types, roughly divided into three families, according to the relative chromium content in the alloy.

Figure 24 illustrates the "metallurgic" logic that led to the creation of the main types of ferritic stainless steels present on the market, starting from type X6Cr17, the progenitor of this family; on the other hand, table 6 shows the chemical composition of some of the main types of ferritic stainless steels and the relative designation in accordance with the standard EN 10088.

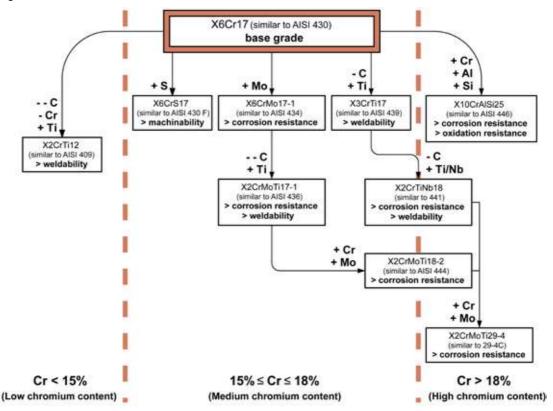


Figure 24 – Schematic of the main types of ferritic stainless steels, starting from X6Cr17 (similar to AISI 430), progenitor of this family.



X2CrTi12 (1.4512) ≤0,03 X6Cr17 (1.4016) ≤0,08 X6CrMAs17 (1.4105) <0.08	≤1,00 ≤1,00							conceptonaciae
	≤1,00 ~1 E0	≤1,00	≤0,040	≤0,015	10,5-12,5		1	AISI 409
_	1	≤1,00	≤0,040	≤0,015	16,0-18,0	1	1	AISI 430
_		≤1,50	≤0,040	0,15-0,35	16,0-18,0	0,20-0,60		AISI 430F
X3CrTi17 (1.4510) ≤0,05	≤1,00	≤1,00	≤0,040	≤0,015	16,0-18,0		2	AISI 439 (430Ti*)
X6CrMo17-1 (1.4113) ≤0,08	≤1,00	≤1,00	≤0,040	≤0,015	16,0-18,0	0,90-1,40		AISI 434
X2CrMoTi17-1 (1.44513) ≤0,025	≤1,00	≤1,00	≤0,040	≤0,015	16,0-18,0	0,80-1,40	S	AISI 436
X2CrMoTi18-2 (1.4521) ≤0,025	≤1,00	≤1,00	≤0,040	≤0,015	17,0-20,0	1,80-2,50	4	AISI 444
X2CrTiNb18 (1.4509) ≤0,03	≤1,00	≤1,00	≤0,040	≤0,015	17,5-18,5		5	441*
X10CrAlSi25 (1.4762) ≤0,12	0,70-1,40	≤1,00	≤0,040	≤0,015	23,0-26,0		9	AISI 446
X2CrMoTi29-4 (1.4592) ≤0,025	≤1,00	≤1,00	≤0,030	≤0,010	28,0-30,0	3,50-4,20	7	29-4C*

* The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 441). 1: $\%Ti = [6 \times (C + N)] - 0.65$ 2: $\%Ti = [4 \times (C + N) - 0.15] - 0.80$ 3: $0.30 \le \%Ti \le 0.60$; $\%N \le 0.020$ 4: $\%Ti = [4 \times (C + N) - 0.15] - 0.80$; $\%N \le 0.030$ 5: $0.10 \le \%Ti \le 0.60$; $[3 \times C + 0.30] \le \%Nb \le 1,00$ 6: $1,20 \le \%AI \le 1,70$; $1,20 \le \%Si \le 1,70$ 7: $\%Ti = [4 \times (C + N) - 0.15] - 0.80$; $\&N \le 0.045$

Table 6 – Chemical composition of some of the main types of ferritic stainless steels [from EN 10088].

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The first family, to which the aforementioned type X6Cr17 belongs, has a chromium content ranging from 15.5% to 18%: this family is the most numerous in terms of the quantity of alloy types present on the market. There are a further two families, one characterised by chromium content ranging from 11.5% to 14.5% (ferritic stainless steels with low chromium content) and the other with a chromium content of more than 18% (known also as "superferritic" stainless steels).

In all three of the above families - with low, medium and high carbon chromium content - other alloy elements may also be present: these include aluminium and silica, aimed at stabilising the ferritic structure and improving resistance to oxidation under heat, molybdenum, necessary to improve corrosion resistance, titanium and niobium, to prevent precipitation of the harmful chromium carbides.

For a more comprehensive understanding of the structure of a general ferritic stainless steel with a high chromium content and very low carbon content, it is necessary to take into account the reference phase diagram. For this purpose, note how the original Fe-Cr diagram (already illustrated in figure 5) is modified, due to the presence of carbon at a percentage of around 0.05% (figure 25).

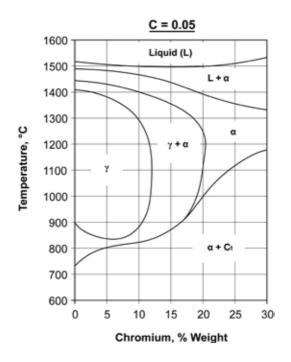


Figure 25 – Fe-Cr binary section of Fe-Cr-C ternary diagram for a steel containing 0.05% carbon; C_1 carbides type (Cr,Fe)₂₃ C_6 [from McGuire 2008].

In the case of ferritic stainless steel type X6Cr17 initial solidification is noted in phase α followed by a two-phase transformation type $\gamma+\alpha$; subsequently, from temperatures of around 900°-950°C through to ambient temperature¹⁸, the steel returns to a single phase state α with a ferrite grain structure.

Therefore if we attempt to temper this steel, for example by heating it to around 800°C to then cool it in water, no particular change in structure would occur and, after cooling, there would be no significant increase in resistance. In fact in the temperature range 20°-900°C there are no critical points to enable austenite \rightarrow martensite transformation: this means that it would not be possible to apply the classic tempering heat treatment to increase the tensile strength of the steel (as otherwise is possible in the case of martensitic stainless steels).

Above 900°-950°C, as observed above, there is a two phase field of ferrite and austenite¹⁹: this is typical of non stabilised ferritic stainless steels with chromium content of 16%-17%.

On the one hand, the presence of small percentages of austenite at high temperatures is positive, in that it avoids excessive enlargement of the crystalline grain during annealing heat treatments.

Nevertheless, on the other hand the existence of austenite at high temperatures should be taken into due consideration due to another additional problem: if rapid cooling is performed immediately after heating at such high temperatures, the austenite could be transformed into martensite, causing problems of intergranular brittleness in the steel.

However, when the ferritic stainless steel contains stabilising elements, such as titanium and niobium, and/or a high content of chromium (more than 18%) or molybdenum (1-2%), its microstructure will be completely ferritic, starting from the melting temperature through to ambient temperature: this significantly improves weldability of these steels with respect to non-stabilised traditional types.

An additional metallurgical problem typical in stainless steels, including ferritic, is related to the precipitation of chromium carbides, type $Cr_{23}C_6$: as is known, this occurs due to the high level of affinity between the chromium and carbon, and can lead to the phenomena of intergranular corrosion in this material.

As the solubility of carbon in the body-centred cubic lattice is significantly limited, the precipitation of chromium carbides in ferritic stainless steels is practically impossible to eliminate. On the other hand, due to the high diffusivity of chromium in the lattice of phase α , the chromium gradients in the vicinity of the ferritic grain boundary are much less pronounced with respect to what occurs in austenitic stainless steels (refer also back to figure 10, and case "a" in particular): as a consequence the problems of intergranular corrosion in ferritic stainless steels, under the effect of carbide precipitation on the grain boundary, are less marked with respect to the same phenomena in austenitic stainless steels.

¹⁹ However, the entity of austenite present at high temperatures in non stabilised ferritic stainless steels is still limited: values remain at a maximum of 20%.



¹⁸ The temperature at which the transition occurs, from a two phase structure $\gamma + \alpha$ to a single phase structure α depends on the chromium content in the alloy. The value specified at 900°-950°C is representative of a steel with chromium content of around 17%. If the chromium content is greater, the temperature would increase proportionally, and vice versa in the case of lower chromium contents.

To eliminate the problem of chromium carbides, it is often necessary to return to the source, i.e. the phase of processing steel in its liquid state: here stabilising elements are added, such as titanium and niobium, in an attempt to minimise the carbon content in the chemical composition of steel. Also, as explained further in the section below, the semi-finished products should also undergo a complete annealing heat treatment before being used.

Again in relation to the phenomena of deterioration due to temperatures, two further problems should be noted in relation to ferritic stainless steels: the formation of phase σ and embrittlement at 475°C.

Due to the harmful effects in terms of corrosion resistance and strength, the problem of the formation of phase σ (Fe-Cr phase) needs to be taken in due consideration exclusively as regards steels with high contents of chromium and molybdenum (superferritic); in these steels, the presence of molybdenum also contributes to additional harmful phases, such as χ and the Laves phase (in both cases, this regards Fe-Cr-Mo phases).

To eliminate any secondary phases present (σ , χ , Laves) the steel should be heated to temperatures of around 1050°C, followed by rapid cooling of the semi-finished product in water: this enables the chromium compounds to be solubilised, thereby preventing re-formation of the latter during cooling.

A typical example of the diagrams that illustrate the formation of carbides and secondary phases on variations in temperature and the time of exposure of the iron-chromium alloy is shown in figure 26.

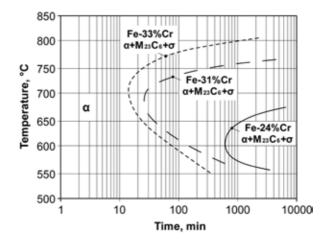


Figure 26 – Time-temperature diagram representing the formation of chromium carbides and phase σ in different Fe-Cr alloys [from Vander Voort 1991].

Embrittlement at 475°C is obviously a far more significant problem with respect to the formation of phase σ : in fact it affects a wider spectrum of ferritic stainless steels, with the only exception of those with a very low carbon content (Cr < 14%).

Also in this case, to be able to describe the phenomenon, time-temperature diagrams can be used, such as that shown in figure 27 or diagrams that illustrate the decline in strength in proportion to the embrittlement temperature according to variations in the exposure time (see figure 28).

The harmful effect of embrittlement at 475°C is eliminated by annealing at a temperature of around 550°-600°C for intervals however that do not lead to the formation of carbides/phase σ ; subsequent cooling must be in air or water.

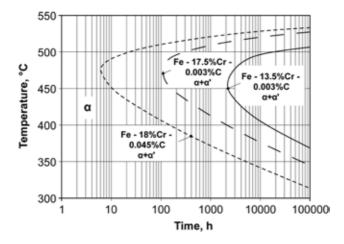


Figure 27 – Time-temperature diagram representing embrittlement at 475°C (spinodal decomposition of phase α in different Fe-Cr alloys [from Grobner 1973].

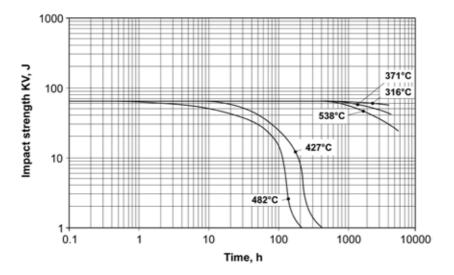


Figure 28 – Trends of strength of ferritic stainless steels with 18% chromium, aged at 316°C, 371°C, 427°C, 482°C e 538°C for progressively increasing time intervals [from Grobner 1973].



7.2 Heat treatments

The only heat treatment possible for the family of ferritic stainless steels is complete annealing or simply annealing: its role is to optimise corrosion resistance of the steel, aiding a uniform distribution of the chromium in the crystalline structure of the semi-finished part²⁰.

Annealing of ferritic stainless steels is performed at different temperatures depending on the chemical composition of the steel treated. Great care is taken in selecting the temperature and hold time, as this family of materials is particularly sensitive to the phenomena of crystalline grain enlargement. Table 7 shows the heat treatment methods to be adopted for the most common types of ferritic stainless steels.

Cooling after annealing is always performed in air for for thin, flat semi-finished parts or for long, small diameter parts; in water for parts with larger sections; otherwise water cooling is compulsory for compositions with a higher content of chromium, to avoid the phenomena of embrittlement at 475°C.

Annealing of ferritic stainless steels also has another important characteristic. If the material to be treated is in the hardened state, the heat treatment would also serve to re-crystallise the microstructure, i.e. to reform new crystalline grains, starting from the original grains that have extended under the effect of cold plastic deformation. In general, these newly formed grains are finer that the original hot formed grains in the semifinished part. This is normally referred to as recrystallisation annealing (figure 29).

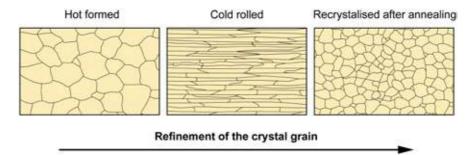


Figure 29 – Effect of recrystallisation annealing on ferritic stainless steels.

Lastly, it must be noted that the semi-finished parts to undergo heat treatment must be cleaned thoroughly to remove all oils, grease or carbon residue; otherwise there is the risk of the phenomena of surface carburisation, a common occurrence in steels with a very low carbon content.

²⁰ The temperatures for ferritic stainless steel annealing do not constitute a risk of solubilisation of any chromium carbides present. Nevertheless, annealing is carried out because, through the diffusion mechanisms, it aids redistribution of the chromium in the metal matrix of the steel. Therefore, even in the vicinity of the carbides, the chromium content will be restored to levels above the passivation threshold, thereby avoiding the typical problems of intergranular corrosion.

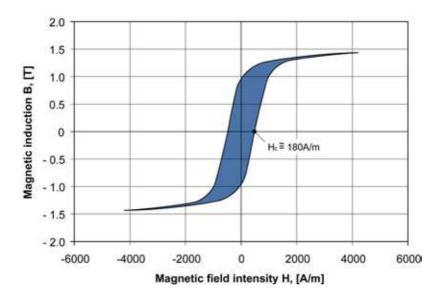
EN Designation	Annealing	Cooling in	AISI approximate correspondence
X2CrTi12 (1.4512)	770°C-850°C	air or water	AISI 409
X6Cr17 (1.4016)	770°C-850°C	air or water	AISI 430
X6CrMoS17 (1.4105)	770°C-850°C	air or water	AISI 430F
X3CrTi17 (1.4510)	770°C-850°C	air or water	AISI 439 (430Ti*)
X6CrMo17-1 (1.4113)	770°C-850°C	air or water	AISI 434
X2CrMoTi17-1 (1.4513)	800°C-880°C	air or water	AISI 436
X2CrMoTi18-2 (1.4521)	800°C-880°C	air or water	AISI 444
X2CrTiNb18 (1.4509)	850°C-930°C	air or water	441*
X10CrAlSi25 (1.4762)	800°C-880°C	air or water	AISI 446
X2CrMoTi29-4 (1.4592)	900°C-1000°C	air or water	29-4C*

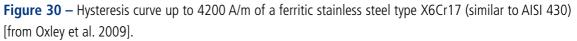
* The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 441). The treatment duration depends on the dimension of the components and, usually, does not exceed 1 continuous hour. **Table 7** – Guideline characteristics of annealing heat treatment on some of the main types of ferritic stainless steels.

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7.3 Physical and mechanical properties

The physical characteristics of some of the most common types of ferritic stainless steels are shown in table 8. An important physical property of ferritic stainless steels, given their special microstructure, is the magnetically soft behaviour, which is enhanced after the annealing heat treatment with prolonged hold intervals (see figure 30).





The resistance properties of ferritic stainless steels are not particularly significant; in fact these steels are made up of uniform ferrite grains and are used in an annealed state. The unitary value of tensile strength R_m ranges between 450 MPa and 600 MPa, according to the chemical composition, with hardness values of 150-220 HB.

Table 9 show the typical mechanical properties for some types of ferritic stainless steels.

As already mentioned, ferritic stainless steels cannot be hardened by means of a quenching heat treatment: the only way to increase mechanical resistance is by means of cold plastic deformation processes, such as cold drawing or rolling, which harden the steel: in this case the unitary value of tensile strength can reach up to 900-1000 MPa (figure 31).

The strength of ferritic stainless steels is highly variable which therefore leads to difficulties in establishing a reference: in general it can be said that the transition temperature increases (and therefore the behaviour worsens) in proportion to the increase of chromium content in the alloy (refer to figure 32).

EN	Mass	Specific heat at	Electrical resistance at	Thermal	Linear expansio	Linear thermal expansion [10 ⁻⁶ ·K ⁻¹]	Modulus d	Modulus of elasticity [GPa]	AISI
Designation	volume [kg/dm³]	[J·kg ⁻¹ ·K ⁻¹]	20°C [W·mm²·m ⁻¹]	[W·m ⁻¹ ·K ⁻¹]	from 20°C to 100°C	from 20°C from 20°C to 100°C to 200°C	to 20°C	to 20°C to 200°C	approximate correspondence
X2CrTi12 (1.4512)	7,7	460	0,60	25	10,5	11,0	220	210	AISI 409
X6Cr17 (1.4016)	7,7	460	0,60	25	10,0	10,0	220	210	AISI 430
X6CrMoS17 (1.4105)	7,7	460	0,70	25	10,0	10,5	220	210	AISI 430F
X3CrTi17 (1.4510)	7,7	460	0,60	25	10,0	10,0	220	210	AISI 439 (430Ti*)
X6CrMo17-1 (1.4113)	7,7	460	0,70	25	10,0	10,5	220	210	AISI 434
X2CrMoTi17-1 (1.4513)	7,7	460	0,70	25	10,0	10,5	220	210	AISI 436
X2CrMoTi18-2 (1.4521)	7,7	430	0,80	23	10,4	10,8	220	210	AISI 444
X2CrTiNb18 (1.4509)	7,7	460	0,60	26	10,0	10,0	220	210	441*
X10CrAlSi25 (1.4762)	7,7	500	1,10	17	1	10,5	220	210	AISI 446
X2CrMoTi29-4 (1.4592)	7,7	440	0,67	17	11,5		220	210	29-4C*

* The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 441).

Table 8 – Guideline physical properties of some of the main types of ferritic stainless steels [from EN 10088].

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EN Designation	Metallurgic condition	R _{p0,2} [MPa]	R _m [MPa]	A [%]	Hardness	AISI approximate correspondence
X2CrTi12 (1.4512)	A	250-350	400-500	27-32	140-180 HB	AISI 409
VEC-17 /1 1016	A	300-400	450-550	25-30	150-200 HB	
	A + CD**	550-850	650-950	5-18		ADU 450
VEC-M-C17 (1 /10E)	A	250-350	450-550	20-25	150-200 HB	A161 430E
	A + CD**	400-700	600-850	5-15		
V3C,T:17 /1 /E 10)	A	250-350	450-550	25-30	150-200 HB	
	A + CD**	500-800	006-009	5-20		
X6CrMo17-1 (1.4113)	A	300-400	480-580	22-28	150-200 HB	AISI 434
X2CrMoTi17-1 (1.4513)	A	250-350	420-520	25-30	140-180 HB	AISI 436
X2CrMoTi18-2 (1.4521)	A	350-450	480-580	25-30	160-220 HB	AISI 444
X2CrTiNb18 (1.4509)	A	250-350	450-550	20-25	150-200 HB	441*
X10CrAlSi25 (1.4762)	A	350-450	550-650	12-18	170-230 HB	AISI 446
X2CrMoTi29-4 (1.4592)	A	450-550	560-660	22-27	150-200 HB	29-4C*

* The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 441). A Annealed A + CD: Annealed and Cold Drawn ** The values of the mechanical features in the condition A + CD are variable as they very much depend on the hardening conditions

Table 9 – Guideline mechanical properties of some of the main types of ferritic stainless steels.

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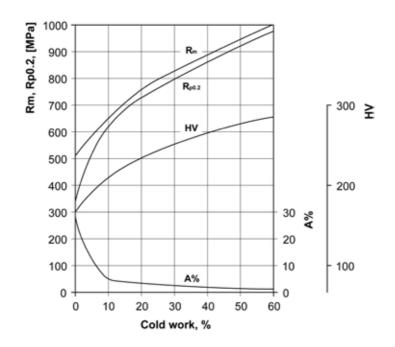


Figure 31 – Effect of hardening on mechanical properties of a ferritic stainless steel type X6Cr17 (similar to AISI 430) [from Lacombe et al. 1993].

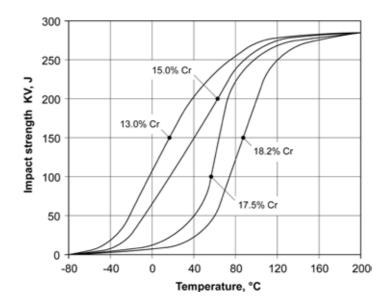
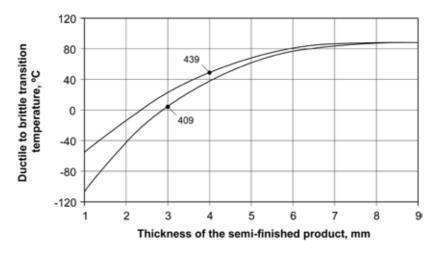
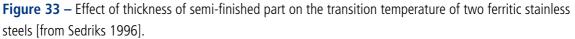


Figure 32 – Effect of chromium content on transition curves of iron-chromium alloys (the carbon content is ~ 0.01) [from Sedriks 1996].



In addition to the chromium content, the resistance to brittle fractures also depends on the combined effect of other metallurgical parameters. The transition temperature increases with the increase in contents of interstitial elements (carbon and nitrogen) and decreases under the effect of a reduction in the average size of the crystalline grain; the thickness of the semi-finished part also has an interesting effect on the brittle fractures of the ferritic stainless steels (see figure 33).





7.4 Types and applications

Semi-finished parts in ferritic stainless steels are available on the market in the annealed state, mainly in the form of sheet steel, strips or sheets; a more limited percentage is also available as long products, such as bars and rods.

The ferritic stainless steels most commonly used in the industrial environment are grades X6Cr17 (similar to AISI 430) and X2CrTi12 (similar to AISI 409).

Steel grade X6Cr17 is a traditional ferritic stainless steel, easily cold plastically deformable and workable by machine tools.

X6Cr17 is mainly produced in the form of steel sheet or strips to be cold formed or pressed, in pipes or extruded bats; it has a good resistance to corrosion, certainly superior to martensitic grades, especially in the presence of nitric acid (up to 90% in water-based solutions in cold conditions, and up to 10% in heat). As regards the above, steel grade X6Cr17 (similar to AISI 430) is used for machine parts in the industry for the production and transformation of nitric acid (tanks, condensers, pipelines, coils, etc.); it is also widely used for cracking and reforming plants in the oil sector, for the production of low cost cutlery, household appliances, decorative elements and furnishing accessories for interiors, coverings for bar counters and tables, and kitchen extractor hoods. It is also used in a number of applications in the cheese/milk dairy

sector and for manufacture of train carriages and buses. Ferritic stainless steel grade X6Cr17 is also used in components operating at temperatures up to 750°-800°C due to its optimal resistance to oxidation under heat.

Grade X6CrMoS17 (similar to AISI 430F) is the same as X6Cr17, but with improved machinability due to the presence of sulphur in the alloy: this steel is used to produce bars and rods (long semi-finished products) mainly used in the sector of solenoid valves²¹ and metal hardware obtained by metal cutting.

The other widely used ferritic stainless steel is X2CrTi12 (similar to AISI 409). This offers less corrosion resistance with respect to the traditional X6Cr17 but increased cold plastic deformability and improved weldability due to the stabilisation of titanium; it also has a lower cost than the X6Cr17.

X2CrTi12 is widely used in the automotive sector for the manufacture of exhausts, catalytic converters and exhaust pipes for cars, lorries and motorcycles: this field of application represents the single most important market for a specific type of stainless steel.

To resolve issues related to material weldability, while conserving the corrosion resistance typical of the transitional grade X6Cr17, the grade X3CrTi17 has been developed, stabilised with titanium and with a carbon content of around 0.025% (similar to AISI 439, also known as 430Ti).

X3CrTi17 is used in similar applications to that of the ferritic stainless steel X6Cr17, at least in all cases where welding is required to make the component. One typical application is in the sector of household appliances: washing machine drums are produced from a strip in X6Cr17 if made by mechanical joining (stapling), or from a strip in X3CrTi17 if produced by welding.

With the aim of increasing corrosion resistance of the traditional X6Cr17, above all in relation to the phenomena of local deterioration, other chemical compositions have also been developed.

In aggressive environments, the ferritic stainless steel X6CrMo17-1 (similar to AISI 434) can be used, in which the presence of molybdenum improves resistance to corrosion due to pitting, or stabilised types X2CrTiNb18 with 18% chromium (known also as 441) and X2CrMoTi17-1 (similar to AISI 436) with the addition of molybdenum.

As well as for exhaust systems in the automotive sector, these steels are also used for internal cladding of buildings, on escalators, lifts and conveyor belts, for drinking water pipelines or as supports for photovoltaic cells.

Ferritic stainless steel grades X2CrMoTi18-2 (similar to AISI 444) and X2CrMoTi29-4 (also known as 29-4C) represent a further improvement in terms of corrosion resistance, due to the addition of high percentages of chromium and molybdenum: these are widely used for heat exchangers, boilers and hot water storage tanks. Lastly, the ferritic stainless steel X10CrAISi25, with a high content of chromium and added silicon and aluminium (more correctly a heat-resistant steel, as defined by the standard EN 10088): this alloy is very

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²¹ In the sector of solenoid valves ferritic stainless steels have been developed with specific chemical compositions containing a percentage of silicon (1-1.5%): this has the specific aim of making the material magnetically soft to improve the action of the mobile core in the solenoid valve itself.

resistant to heats up to 1100°C, both in oxidating and reducing environments and also offers optimal behaviour in sulphurous environments (diesel oil combustion products, sulphur oxides, etc.) in which austenitic stainless steels would offer only poor performance due to the high content of nickel. This type is widely used for the production of ovens and boilers, floors and mufflers, annealing enclosures, crucibles, hydrogeneration plant parts (also with oils rich in sulphur) and superheater pipelines.

8. AUSTENITIC STAINLESS STEELS

8.1 Metallurgy

If the chromium content is increased to at least 17-18% and at the same time nickel is added to a percentage of 8% to 9%, the steel will have an austenitic structure at ambient temperature: this is due to the significant austenitising effect of the nickel that predominates over the ferritising action of the chromium (with regard to this, refer back to the diagram in figure 8 and the Schaeffler diagram in figure 11). As in the other cases, the carbon content is fixed a very low values (C = 0.02-0.06%) to limit the formation of chromium carbides as far as possible.

The combination of chromium and nickel in the alloy obtains a stainless steel with an austenitic structure, i.e. with a face-centred cubic lattice, highly resistant to atmospheric corrosion and water-based solutions²²: this is grade X5CrNi18-10 (similar to AISI 304) progenitor of the family of austenitic chromium-nickel stainless steels.

Added corrosion resistance can be achieved by increasing the nickel content up to 11-12% or adding molybdenum to values of 2-3%: this obtains another widely used stainless steel, i.e. the X5CrNiMo17-12-2 (similar to AISI 316), progenitor of the second family of austenitic stainless steels, i.e. chromium-nickel-molybdenum²³.

There is then a third possibility of obtaining an austenitic stainless steel: this is by replacing the nickel part with manganese²⁴, the element which otherwise would only act as a deoxidant in the alloy. This solution was developed in the 1950s, with the aim of limiting production costs; the progenitor of the family of austenitic stainless steels with chromium-manganese-nickel is the X12CrMnNiN17-7-5 (similar to AISI 201). Austenitic stainless steels with manganese – which here are not taken into consideration – did not have the distribution that was hoped for, perhaps due to the limited resistance to corrosion in contact with water-based solutions, more similar to the behaviour of a ferritic stainless steel type X6Cr17 or that of an austenitic stainless steel with chromium-nickel type X5CrNi18-10.

Figure 34 illustrates the "metallurgical" logic, which led to the creation of two main types of austenitic stainless steels available on the market: one is chromium-nickel stainless steels such as X5CrNi18-10 and the other is the chromium-nickel-molybdenum such as X5CrNi17-12-2 and their respective by-products.

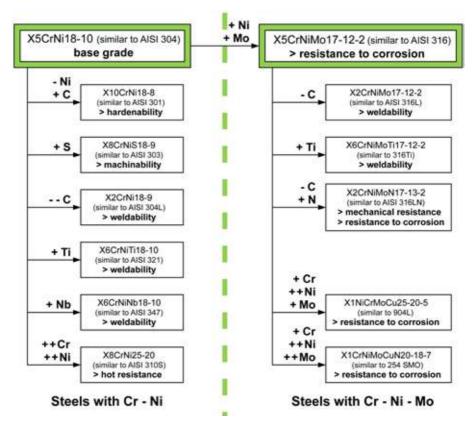
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²² In air and water-based solutions, even partially contaminated by chlorides (generally up to 500ppm of ions Cl⁻) the corrosion resistance of austenitic stainless steel X5CrNi18-10 is superior with respect to martensitic and ferritic types such as X30Cr13 and X6Cr17.

²³ The austenitic chromium-nickel-molybdenum stainless steel X5CrNiMo17-12-2 (similar to AISI 316) is suitable for applications in contact with sea water ($Cl \cong 20,000$ pm = 2%) or with water-based solutions strongly contaminated by chlorides.

²⁴ The alternative to manganese with respect to nickel is based on the austenitising effect that both elements show if added to Fe-C alloys: as the austenitising effect of the manganese is equal to half that of nickel, around 2% of Mn needs to be added for each 1% of replaced Ni.

A further distinction divides these two families into "austenitic" if the nickel content is less than or equal to 20% and "super-austenitic" if greater.



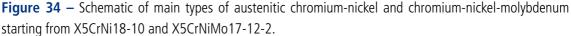


Table 10 shows the chemical composition of some of the most commonly used austenitic stainless steels and relative designation according to the standard EN 10088.

As in the previous cases, also in the case of austenitic stainless steels it is important to refer to a phase diagram for a full understanding of the metallurgical problems of these alloys: figure 35 shows the simplified phase diagram of a steel with 18% chromium and 8% nickel on variation in carbon content.

An undoubtedly significant aspect of the phase diagram of austenitic stainless steels is the absence of critical points, i.e. no transformation $\gamma \rightarrow \alpha$, as can clearly noted on figure 35 following cooling of an alloy with very low carbon content (C = 0.05%). After initial solidification at very high temperatures in phase $\gamma + \delta$, the stainless steel becomes completely austenitic (phase γ) and remains in this state through to ambient temperature, without the inevitable chromium carbides.

EN symbolic designation	%С	%Si	%Mn	%Р	%S	%Cr	%Ni	%Mo	Other	AISI approximate correspondence
X10CrNi18-8 (1.4310)	0,05-0,15	≤2,00	≤2,00	≤0,045	≤0,015	16,0-19,0	6,0-9,5	≤0,80	L	AISI 301
X8CrNiS18-9 (1.4305)	≤0,10	≤1,00	≤2,00	≤0,045	0,15-0,35	17,0-19,0	8,0-10,0		1, 2	AISI 303
X5CrNi18-10 (1.4301)	≤0,07	≤1,00	≤2,00	≤0,045	≤0,015	17,5-19,5	8,0-10,5	ł	~	AISI 304
X2CrNi18-9 (1.4307)	≤0,03	≤1,00	≤2,00	≤0,045	≤0,015	17,5-19,5	8,0-10,5		l	AISI 304L
X6CrNiTi18-10 (1.4541)	≤0,08	≤1,00	≤2,00	≤0,045	≤0,015	17,0-19,0	9,0-12,0	-	З	AISI 321
X6CrNiNb18-10 (1.4550)	≤0,08	≤1,00	≤2,00	≤0,045	≤0,015	17,0-19,0	9,0-12,0	-	4	AISI 347
X8CrNi25-21 (1.4845)	≤0,10	≤1,50	≤2,00	≤0,045	≤0,015	24,0-26,0	19,0-22,0		1	AISI 310S
X5CrNiMo17-12-2 (1.4401)	≤0,07	≤1,00	≤2,00	≤0,045	≤0,015	16,5-18,5	10,0-13,0	2,00-2,50	1	AISI 316
X2CrNiMo17-12-2 (1.4404)	≤0,03	≤1,00	≤2,00	≤0,045	≤0,015	16,5-18,5	10,0-13,0	2,00-2,50	1	AISI 316L
X2CrNiMoN17-13-3 (1.4429)	≤0,03	≤1,00	≤2,00	≤0,045	≤0,015	16,5-18,5	11,0-14,0	2,50-3,00	5	AISI 316LN
X6CrNiMoTi17-12-2 (1.4571)	≤0,08	≤1,00	≤2,00	≤0,045	≤0,015	16,5-18,5	10,5-13,5	2,00-2,50	З	316Ti*
X1NiCrMoCu25-20-5 (1.4539)	≤0,02	≤0,70	≤2,00	≤0,030	≤0,010	19,0-21,0	24,0-26,0	4,00-5,00	9	904 L*
X1CrNiMoCuN20-18-7 (1.4547)	≤0,02	≤0,70	≤1,00	≤0,030	≤0,010	19,5-20,5	17,5-18,5	6,00-7,00	7	254 SMO*

* The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 904 L). 1: $\%N \le 0,11$ 2: $\%Cu \le 1,0$ 3: $\%Ti = 5 \times C - 0,70$ 4: $\%Nb = 10 \times C - 1,00$ 5: %N = 0,12 - 0,226: $\%N \le 0,15$; %Cu = 1,20 - 2,007: %N = 0,18 - 0,25; %Cu = 0,50 - 1,00

Table 10 – Chemical composition of some of the main types of austenitic stainless steels [from EN 10088].

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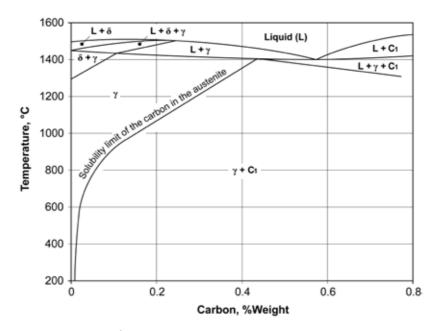


Figure 35 – Fe-C binary section of Fe-Cr-Ni-C quaternary diagram with Cr = 18% and Ni = 8%; C₁ carbides type (Cr,Fe)₂₃C₆ [from Sedriks 1996].

The presence of various austenitising elements, such as carbon, nitrogen, nickel and manganese, have in fact shifted the temperature of austenite transformation into martensite to well below the ambient temperature: this explains the impossibility of performing heat treatments, such as quenching, which can increase the mechanical resistance of austenitic stainless steels.

Another very important aspect, again shown in the diagram of figure 35, is the extremely limited solubility of the carbon in phase γ^{25} : even if the carbon content is kept at very low values (in the case of these steels this is normally %C = 0.04-0.06%), the presence of chromium carbides type (Cr,Fe)₂₃C₆ at ambient temperature is virtually certain.

The phenomena of carbide precipitation, also known as "sensitisation", is quite complex. It occurs at temperatures between 450°C and 900°C and at highly variable exposure times: the most critical conditions are found at around 700°C for time intervals of just a few minutes.

Sensitisation of austenitic stainless steels leads to a decline of chromium in the immediate vicinity of areas where the carbides form, i.e. on the boundaries of the crystalline grains: consequently, the chromium content of the grain boundaries is below the passivation limit of the steel, leading to local deterioration in corrosion resistance and the phenomena of inter-crystalline corrosion, even in only slightly aggressive environments (refer also back to figure 10, case "b").

 $^{^{25}}$ In the case of an austenitic stainless steel with 18% chromium and 8% nickel, the limit of carbon solubility in phase γ is equal to approx. 0.03%.



To remedy the problem of chromium carbides, various interventions have been developed: these are based on the modification to the chemical composition of the steel and appropriate heat treatments.

An initial method of solving this problem is to add titanium or niobium at the time of manufacture: titanium and niobium in fact aid the formation of very stable carbides, thereby preventing the carbon from engaging with the chromium to form chromium carbides (the mechanism of intervention of titanium and niobium is the same as that described in the case of ferritic stainless steels).

In light of these metallurgical considerations, "stabilised" austenitic stainless steels have been developed, such as X6CrNiTi18-10 (similar to AISI 321), X6CrNiNb18-10 (similar to AISI 347) or X6CrNiMoTi17-12-2 (similar to AISI 316Ti): in brief, these are steels identical to X5CrNi18-10 and X5CrNiMo17-12-2 but with the addition of titanium or niobium²⁶. As better explained in the section on heat treatments, the semi-finished products in these types of steel, before being used in operation, should undergo a "stabilisation" heat treatment in order to form the carbides of the stabilising elements (Ti and Nb).

A second method of intervention, in many ways simpler than the first, consists in minimising the carbon content of the steel down to values of around 0.02-0.03%. As a consequence the time required for incubation and the formation of chromium carbides changes from a few minutes to several hours, which practically renders sensitisation of the material negligible.

For a clearer idea of this concept, it is helpful to refer to the isothermal diagram shown in figure 36, specifically drawn up to establish (note the temperature) the minimum time for carbide precipitation: the curves shown on the diagram are also known as "C curves".

As can be seen, the time required to sensitise the steel depends, as well as on the exposure temperature, on the carbon content in the alloy: for example, if the carbon content is 0.08%, the time for carbide precipitation is around one minute, while this can extend to several hours if carbon is reduced to 0.02%.

On the basis of the "C curves" austenitic steels with low carbon content have been developed, such as X2CrNi18-9 (similar to AISI 304L²⁷) or X2CrNiMo17-12-2 (similar to AISI 316L) which are virtually insensitive to the phenomena of chromium carbide precipitation.

²⁶ The analogy between traditional and stabilised stainless steels is not only formal: there is also very little different in terms of corrosion resistance. The only difference lies in the presence of stabilising elements, which in fact inhibit the formation of chromium carbides.

²⁷ The L series in the AISI standards indicates the presence of a very low carbon content, normally C = 0.03%. L stands for low carbon.

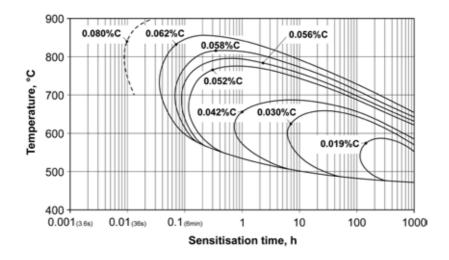


Figure 36 – Time-temperature diagram ("C curve") showing precipitation of chromium carbides on variation of the carbon content, for austenitic stainless steels with 18% chromium and 9% nickel [from McGuire 2008].

Lastly it is worth remembering that there is always another option to avoid the occurrence of inter-granular corrosion. If there are founded reasons to believe that chromium carbide precipitation has occurred in one or more areas of the component, a solubilisation heat treatment can still be performed, at 1040°-1050°C²⁸: this would "dissolve", i.e. solubilise, any carbides present, but this will be dealt with in more detail in the next section.

Again with reference to austenitic stainless steels, there are also metallurgical problems related to the hold times of the material at high temperatures.

As the chromium or chromium-molybdenum contents in these alloys is significant, the possible formation of phase σ , phase χ or the Laves phase must be taken into account: this occurs due to prolonged holding times (more than 100 hours) at temperatures between 550°C and 900°C (see figure 37).

However note that the problem of precipitation of phases rich in chromium or chromium-molybdenum is often secondary to the phenomena of chromium carbide precipitation, which as noted above, occurs at the same temperatures but for much shorter time intervals.

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²⁸ The option of solubilisation also depends on the dimensions of the semi-finished part or component to be treated. Small parts are easily managed while in the case of plant parts or large welded structures, the option of a final heat treatment after all processes is virtually impossible. In these cases the stabilised or low carbon steels should be used.

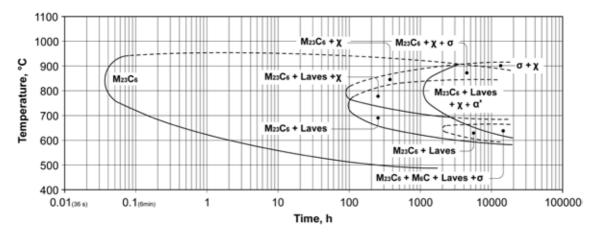


Figure 37 – Time-temperature diagram showing precipitation of phases σ , χ and the Laves phase, and of chromium carbides in an austenitic stainless steel type X5CrNiMo17-12-2 [from Khatak and Baldev 2002].

In austenitic stainless steels other alloy elements are sometimes added, the most common being sulphur, nitrogen and copper.

Sulphur serves to improve machinability of the material under the effect of the formation of iron sulphides and iron-chromium sulphides (as occurs on martensitic and ferritic stainless steels).

It is a different case for nitrogen and copper. While nitrogen is added due to the strongly austenitising capacity and at the same time to improve corrosion resistance and mechanical strength, copper is used because it tends to improve cold plastic deformability of stainless steels.

Lastly, on careful examination of the Schaeffler diagram²⁹ it can be noted how in the case of the common austenitic stainless steels (X5CrNi18-10 and X5CrNiMo17-12-2) at ambient temperature the microstructure may even show a small percentage of ferrite (usually between 1% and 5%): this occurs if the material undergoes rapid cooling from the melting temperature, as in the case during welding operations³⁰. Only by increasing the nickel content (from 12% upwards) and/or adding nitrogen (0.10%-0.25%) is it possible to obtain a completely austenitic structure: this is necessary when the final application requires such a structure, for example in the case of specific corrosive environments (strongly reducing acid solutions) or in nuclear applications (magnetic containment circuits operating at 0°-5°K) or due to specific problems of hot machining.

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²⁹ A similar situation can also be seen on the phase diagram shown in figure 35 where initial solidification is evident, with a two phase structure of $\gamma + \delta$ which can remain in this state if the alloy is rapidly cooled to ambient temperature.

³⁰ The presence of small percentages of ferrite in austenitic stainless steels can, in some cases, also be a positive factor: it can aid material weldability as it reduces the occurrence of hot cracks in the melted area of the welding bead and limits enlargement of the crystalline grain during heat treatments.

8.2 Heat treatments

Austenitic stainless steels, as noted above, do not need to be hardened for heat treatment as in practice their microstructure remains unchanged from the melting temperature through to ambient temperature.

The only feasible heat treatment is solubilisation, also known as negative quenching or austenitic quenching: this treatment is normally performed on semi-finished products and finished products in austenitic stainless steel, downline of the various manufacturing processes.

The treatment is performed at high temperatures (approximately in the range 1000°C to 1100°C), for a sufficient time to ensure homogenisation of the chemical composition of the steel: during the treatment, microstructural irregularities are also eliminated, and above all solubilisation of the chromium carbides is ensured.

Refer to Table 11 for more precise information on the treatment temperatures for the most common austenitic stainless steels.

Before the heat treatment, the parts must be cleaned to remove all residue from previous processes (oil, grease, etc.); in many cases solubilisation is performed in a controlled atmosphere (nitrogen or nitrogen + hydrogen) so that the steel can maintain its typical metal grey shine, avoiding oxidation in air or undesired carburisation effects.

To ensure successful solubilisation, austenitic stainless steels must be cooled rapidly in water, above all if they are particularly thick parts. Cooling must be rapid to avoid deterioration in the uniform composition of the austenite in the stage between 450°C and 900°C as well as to prevent separation of the carbides on the grain boundary, causing local deterioration of chromium³¹. In the case of thin parts, a high pressure flow of nitrogen can also be used, although cooling in water is still preferable³².

On the other hand a special treatment is used on stabilised austenitic stainless steels. In fact in the case of types X6CrNiTi18-10, X6CrNiNb18-10, X6CrNiMoTi17-12-2 stabilisation must be performed after completing solubilisation.

The stabilisation treatment consists in maintaining the steel at temperatures between 850°C and 950°C for times ranging from 1 to 4 hours depending on the dimensions of the semi-finished part. During treatment, there is precipitation of the titanium and niobium carbides which, by fixing the carbon, prevent any from remaining, with the formation of harmful chromium carbides. The subsequent cooling is in air.

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³¹ Take into account that cooling in water does not produce any structural transformation or hardening of the material, as austenitic stainless steels have no critical points: also for this reason the treatment is also known as negative quenching as the hardness at the end of the process is normally less than the initial value.

³² Even if less drastic than water, cooling in nitrogen (combined with treatment in controlled atmosphere) undoubtedly has the advantage of not causing oxidation of the part surface, so that it maintains a pleasant shine: the treatment, in British literature, is known as bright annealing.

EN Designation	Solubilisation	Cooling	Stabilization	AISI approximate correspondence
X10CrNi18-8 (1.4310) X8CrNi518-9 (1.4305) X5CrNi18-10 (1.4301) X2CrNi18-9 (1.4307)	1010°-1120°C	water, air	N	AISI 301 AISI 303 AISI 304 AISI 304 AISI 304L
X6CrNiTi18-10 (1.4541)	955°C-1065°C	water air	ϗϝͶͽϹͺϴϝͶͽϹ	AISI 321
X6CrNiNb18-10 (1.4550)	980°C-1065°C			AISI 347
X8CrNi25-21 (1.4845)		water	No	AISI 310S
X5CrNiMo17-12-2 (1.4401) X2CrNiMo17-12-2 (1.4404) X2CrNiMoN17-13-3 (1.4429)	1020°C-1120°C	water, air	Q	AISI 316 AISI 316L AISI 316LN
X6CrNiMoTi17-12-2 (1.4571)	1020°C-1120°C	water, air	850°C-950°C	316∏*
X1NiCrMoCu25-20-5 (1.4539)	1050°C-1150°C	water, air	No	904 L*
X1CrNiMoCuN20-18-7 (1.4547)	1140°C-1200°C	water, air	No	254 SM0*

*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 904 L).

Table 11 – Guideline characteristics of heat treatments on some of the main types of austenitic stainless steels.

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8.3 Physical and mechanical properties

The physical characteristics of some of the most common austenitic stainless steels are shown in table 12. It should be immediately noted how such characteristics are very particular and strictly depend on the facecentred cubic matrix of the austenite, which is very different from that of ferritic and martensitic stainless steel. The linear heat expansion of austenitic stainless steels, for example, is 50-60% greater than that of ferritic or martensitic stainless steels, as well as the thermal conductivity, which on the contrary is 40-50% lower. These particular properties must be taken into consideration in an industrial context: in the heating and cooling during thermal treatment, the dimensional variation of the stainless steel pieces will be much greater than in common steels, but heat exchange will be much more limited³³.

Again from a point of view of the physical characteristics, it should be noted how austenitic stainless steels have nonmagnetic behaviour, this characteristic makes them well suited to some military applications; finally, please note that as a result of cold plastic deformation operations, the semi-finished products tend to become slightly ferromagnetic.

The mechanical characteristics of austenitic stainless steels are rather limited, due to the high deformability of the austenite matrix. In an annealed condition, these steels provide a tensile strength R_m of 550-650 MPa and a yield stress $R_{p0.2}$ of 220-280 MPa; conversely, the austenitic microstructure has high ductility, with percentage values of elongation at break of 40-50% and hardness of 160-200 HB.

Table 13 reports the resistance properties of the main types of austenitic stainless steel.

The only way to increase the traction resistance of austenitic stainless steels is through hardening: by cold plastic deformation (rolling, drawing etc.) it is possible to obtain a tensile strength R_m of 1500-1800 MPa and yield stress $R_{p0.2}$ of 1300-1600 MPa, much greater values than those that would be obtained using a low carbon common steel (see Figure 38).

This significant increase of tensile characteristics (R_m can triple and $R_{p0.2}$ can increase up to six times compared to its annealed state!) is due to the great hardening capacity of the austenite and the effect of the structural transformation of austenite into martensite, triggered by the mechanical energy transferred to the steel during the cold deformation processes.

Austenitic stainless steels that can be hardened more easily will therefore be those with an unstable austenitic structure, or rather those that are more prone to transformation into martensitic due to mechanically induced deformations. This is typical of stainless steels with low nickel content, as is the case of X10CrNi18-8 (similar to AISI 301); however, steels with a high nitrogen and nickel content are more stable and therefore more difficult to harden, such as for example X8CrNi25-21 (similar to AISI 310S) or X2CrNiMoN17-13-3 (similar to AISI 316LN). To this regard see Figure 39.

³³ In the sector of quality cookware, the issue of the poor conductivity of austenitic stainless steels leads to the need to apply heat diffusing bases (usually in aluminium) to allow for the uniform distribution of heat during cooking.



[kg/dm³] [J.kg ⁻¹ .K ⁻¹] [W 310) 7,9 500 500 301) 7,9 500 500 301) 7,9 500 500 301) 7,9 500 500 301) 7,9 500 500 310) 7,9 500 500 450) 7,9 500 500 4550) 7,9 500 7,9 4401) 8,0 500 7,9 4401 8,0 500 7,9 4401 8,0 500 7,9 1.4429 8,0 500 7,9 1.4571) 8,0 500 7,9 1.4539 8,0 500 7,9 1.4539 8,0 500 7,9 1.4539 8,0 500 7,9	EN	Mass volume	Specific heat at	Electrical resistance at	Thermal conductivity	Linear exp [10	Linear thermal expansion [10 ⁻⁶ ·K ⁻¹]	Modulus o [G	Modulus of elasticity [GPa]	AISI approximate
7,95000,731516,017,02001861867,95000,731516,016,52001861867,95000,731516,016,52001861867,95000,731515,016,016,52001861867,95000,731515,016,016,52001861867,95000,731515,016,016,52001861867,95000,731515,016,016,52001861868,05000,751515,016,016,52001861668,05000,751515,016,016,52001861668,05000,751515,016,016,52001861868,05000,751515,016,016,52001861868,05000,751515,016,016,52001861868,05000,751515,016,016,52001861868,05000,751515,016,016,52001861868,05000,751515,016,016,52001861861868,05000,75151515,016,0<	Designation	[kg/dm³]	ل-X•۲-۲	2. ² [W•mm²·m ⁻¹]	[W·m ^{·1} ·K ^{·1}]	from 20°C to 100°C	from 20°C to 200°C	to 20°C	to 200°C	correspondence
7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 15,0 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 200 8,0 500 0,75 15 16,0 16,5 200 186 200 186 200 186 200 186<	X10CrNi18-8 (1.4310)	6'2	500	0,73	15	16,0	17,0	200	186	AISI 301
7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 15,0 16,0 16,5 200 186 7,9 500 0,73 15 15,0 16,5 200 186 8,0 500 0,75 15 15,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 <td>X8CrNiS18-9 (1.4305)</td> <td>7,9</td> <td>500</td> <td>0,73</td> <td>15</td> <td>16,0</td> <td>16,5</td> <td>200</td> <td>186</td> <td>AISI 303</td>	X8CrNiS18-9 (1.4305)	7,9	500	0,73	15	16,0	16,5	200	186	AISI 303
7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 15,0 16,0 16,5 200 186 7,9 500 0,73 15 15,0 16,0 16,5 200 186 8,0 500 0,75 15 15,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 200 8,0 500 0,75 15 16,0 16,5 200 186 200 186 200 186 200 186 200 200 200 200 200 200 200 200	X5CrNi18-10 (1.4301)	2,9	500	0,73	15	16,0	16,5	200	186	AISI 304
7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,73 15 15 16,0 16,5 200 186 7,9 500 0,85 15 15 15,5 15,5 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 186 <td>X2CrNi18-9 (1.4307)</td> <td>7,9</td> <td>500</td> <td>0,73</td> <td>15</td> <td>16,0</td> <td>16,5</td> <td>200</td> <td>186</td> <td>AISI 304L</td>	X2CrNi18-9 (1.4307)	7,9	500	0,73	15	16,0	16,5	200	186	AISI 304L
7,9 500 0,73 15 16,0 16,5 200 186 7,9 500 0,85 15 15,5 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 450 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,5 17,5 200 186 186 8,0 500 0,75 15 16,5 17,5 200 186 186 8,0 500 0,85 15 15	X6CrNiTi18-10 (1.4541)	2,9	500	0,73	15	16,0	16,5	200	186	AISI 321
7,9 500 0,85 15 15,5 8,0 500 0,75 15 16,0 16,5 200 186 186 8,0 500 0,75 15 16,0 16,5 200 186 186 8,0 500 0,75 15 16,0 16,5 200 186 186 8,0 500 0,75 15 16,0 16,5 200 186 182 <td>X6CrNiNb18-10 (1.4550)</td> <td>6'2</td> <td>200</td> <td>0,73</td> <td>15</td> <td>16,0</td> <td>16,5</td> <td>200</td> <td>186</td> <td>AISI 347</td>	X6CrNiNb18-10 (1.4550)	6'2	200	0,73	15	16,0	16,5	200	186	AISI 347
8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 15,0 16,5 200 186 8,0 500 0,75 15 16,5 17,5 200 186 8,0 450 1,00 12 15,8 16,1 195 182 8,0 500 0,85 14 16,5 17,0 185 182	X8CrNi25-21 (1.4845)	7,9	500	0,85	15		15,5		-	AISI 310S
8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,5 17,5 200 186 8,0 450 1,00 12 15,8 16,1 195 186 8,0 500 0,85 14 16,5 17,0 185 182	X5CrNiMo17-12-2 (1.4401)	8,0	500	0,75	15	16,0	16,5	200	186	AISI 316
8,0 500 0,75 15 16,0 16,5 200 186 8,0 500 0,75 15 16,5 17,5 200 186 8,0 450 1,00 12 15,8 16,1 195 186 8,0 500 0,85 14 16,5 17,0 195 182	X2CrNiMo17-12-2 (1.4404)	8,0	500	0,75	15	16,0	16,5	200	186	AISI 316L
8,0 500 0,75 15 16,5 17,5 200 186 8,0 450 1,00 12 15,8 16,1 195 182 8,0 500 0,85 14 16,5 17,0 195 182	X2CrNiMoN17-13-3 (1.4429)	8,0	500	0,75	15	16,0	16,5	200	186	AISI 316LN
8,0 450 1,00 12 15,8 16,1 195 182 8,0 500 0,85 14 16,5 17,0 195 182	X6CrNiMoTi17-12-2 (1.4571)	8,0	500	0,75	15	16,5	17,5	200	186	316Ti*
8,0 500 0,85 14 16,5 17,0 195 182	X1NiCrMoCu25-20-5 (1.4539)	8,0	450	1,00	12	15,8	16,1	195	182	904 L*
	X1CrNiMoCuN20-18-7 (1.4547)	8,0	500	0,85	14	16,5	17,0	195	182	254 SMO*

*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 904 L).

Table 12 – Physical characteristics indicative of some of the main types of austenitic stainless steels [from EN 10088].

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EN Designation	Metallurgic condition	R _{p0,2} [MPa]	R _m [MPa]	A [%]	Hardness	AISI approximate correspondence
X10CrNi18-8 (1.4310)	Solubilised	250-300	600-750	40-50	170-220	AISI 301
X5CrNi18-10 (1.4301)	Solubilised	220-270	550-650	45-55	160-210	AISI 304
X8CrNiS18-9 (1.4305)	Solubilised	200-250	520-630	35-45	170-220	AISI 303
X2CrNi18-9 (1.4307)	Solubilised	200-250	520-630	45-55	160-210	AISI 304L
X6CrNiTi18-10 (1.4541) X6CrNiNb18-10 (1.4550)	Solubilised + Stabilized	230-280	550-650	40-50	170-220	AISI 321 AISI 347
X8CrNi25-21 (1.4845)	Solubilised	250-300	550-650	40-50	150-200	AISI 310S
X5CrNiMo17-12-2 (1.4401) X2CrNiMo17-12-2 (1.4404)	Solubilised	250-300	550-650	40-50	160-210	AISI 316 AISI 316L
X6CrNiMoTi17-12-2 (1.4571)	Solubilised + Stabilized	250-300	550-650	40-50	160-210	316Ті*
X2CrNiMoN17-13-3 (1.4429)	Solubilised	290-340	600-700	40-50	190-240	AISI 316LN
X1NiCrMoCu25-20-5 (1.4539)	Solubilised	230-280	550-650	35-45	170-220	904 L*
X1CrNiMoCuN20-18-7 (1.4547)	Solubilised	300-350	700-800	35-45	200-250	254 SMO*

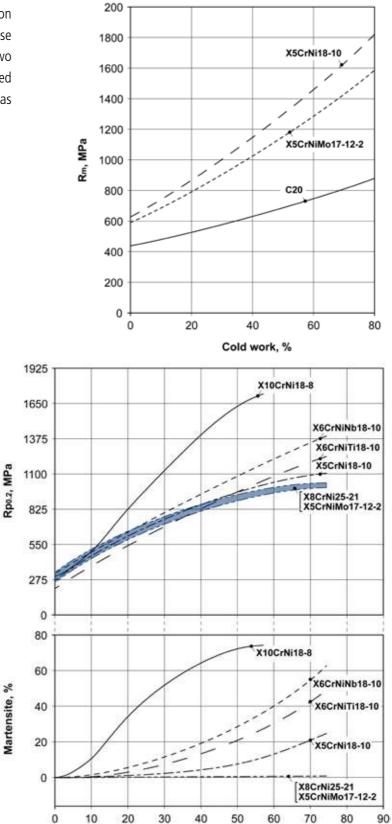
*The designation indicated does not refer to the AISI standard; it is often referred to as the "type" (for example type 904 L).

Table 13 – Mechanical characteristics indicative of some of the main types of austenitic stainless steel.

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Figure 38 – Effect of section reduction in drawing on the increase of the traction resistance of two austenitic stainless steels compared to a common carbon steel [from Atlas Speciality Metals 2003].

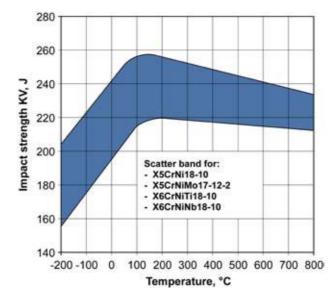


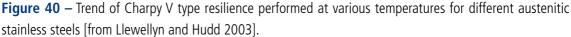
Cold work, %

Figure 39 – Effect of section reduction during cold rolling on the increase of the yield strength Rp_{0.2} and on the transformation of austenite into martensite for various austenitic stainless steels [from Llewellyn and Hudd 2003].

Rpo.2, MPa

One very interesting mechanical characteristic of this family of materials is the high resistance to brittle fracture. Due to the special crystalline matrix, the resilience curve of austenitic stainless steels never shows the transition towards the brittle component, but remain tough up to temperatures close to absolute zero (see Figure 40): for these reasons, austenitic stainless steels are widely used in cryogenic applications.





8.4 Types and applications

The steel X5CrNi18-10 (similar to AISI 304) was the first of the austenitic stainless steels with chromium and nickel: it is the single most produced and used material among all the stainless steels.

This type of steel is widely used in many contexts (industrial, civil, military, etc.) with mechanical characteristics which are not particularly high but with a resistance to corrosion significantly greater than martensitic and ferritic types containing only chromium. Type X5CrNi18-10 can be easily cold deformed and welded using suitable electrodes.

It is widely used in various applications: boilers, pressure tanks, vessels, heat exchangers, fluid transport pipes, plumbing, elevators and signs. It is also used in building and urban furnishings, in domestic utensils (cookware, cutlery, appliances), in sinks and cabinets, as well as in the chemical, petrochemical, nuclear and pharmaceutical industries as well as for the production of milk, beer, canned food, paper and pulp, colorants and explosives. Due to its high toughness at low temperatures, it is also widely used in the cryogenics sector for the storage and transport of liquefied gases.



In closest relationship to the steel X5CrNi18-10, the types X6CrNiTi18-10 (similar to AISI 321) and X6CrNiNb18-10 (similar to AISI 347) are the stabilised versions with titanium and niobium. As these materials have a high resistance to corrosion comparable with that of X5CrNi18-10, they are used in the same applications, especially for the production of large sized and/or very thick items that are subjected to welding operations. It should be underlined how the stabilised types are not suitable for decorative applications as the presence of titanium or niobium carbide appearing on the surface does not allow an optimum surface finish.

With regards to X6CrNiTi18-10 and X6CrNiNb18-10, they demonstrate a greater mechanical resistance to heat than traditional X5CrNi18-10: in addition to traditional applications, they are also used for making exhaust manifolds, boiler bodies, chemical reactors, pressure vessels and pipes for armoured resistors.

X2CrNi18-9 (similar to AISI 304L) is actually the low carbon version of X5CrNi18-10: this composition is also used to solve issues of the precipitation of chromium carbides during welding and is a good alternative to the previously indicated stabilised types. Mechanical resistance, both at ambient temperature and in heat, is however lower than that of stabilised stainless steels; however, the surface finish is excellent. X2CrNi18-9 is widely used to perform overlay welding, for the construction of large-scale tanks, for very thick reactors, as well as in all applications where the aesthetic aspect of the stainless steel is very important.

The steel X10CrNi18-8 (similar to AISI 301) is the most used austenitic stainless steel in its hardened condition: it is used with the specific aim of obtaining high mechanical resistance after cold plastic deformation. It is commonly used for making chains for conveyor belts, springs, load bearing structures for the automotive sector and, sometimes, also for manufacturing knives. It is not suitable for drawing operations or deep moulding operations.

The type X8CrNiS18-9 (similar to AISI 303) is the version of X5CrNi18-10 with improved machinability: the presence of sulphur promotes its machinability for the machining tools; it is known for its deterioration of resistance to corrosion, with particular regard to localised attack phenomena. X8CrNiS18-9 is widely used as metal for very small parts and for the production of screws, nuts, pins and bushings.

Finally, there is the type X8CrNi25-20 (similar to AISI 310S), an austenitic stainless steel resistant to high temperature oxidation. It is used for components or parts of a plant that must withstand oxidising non sulphurous atmospheres at temperatures up to 1100°C. In the case of sulphurous or carbon oxidising atmospheres, the maximum operating temperatures are usually 1000°C; in reducing atmospheres, the use temperature is limited to 750°C. This material is used to make forges for salt baths, carburizing boxes, conduit for thermoelectric couples, muffles for patenting furnaces, distillation retorts and piping for cracking and reforming plants.

In the chromium-nickel-molybdenum stainless steel family, the first steel is the type X5CrNiMo17-12-2 (similar to AISI 316) containing 2-2.5% of molybdenum. It is the reference material for manufacturing components or parts of a plant operating in marine atmospheres or subject to significant corrosion issues: it is usually used when chromium-nickel stainless steels (such as X5CrNi18-10) are not able to meet

the operating conditions. Produced in large quantities, it is an deformable and weldable steel and it has mechanical characteristics similar to those of the type X5CrNi18-10.

The stainless steel X5CrNiMo17-12-2 has high resistance to corrosion in seawater, in contact with process waters contaminated with halides (Cl⁻, l⁻, F⁻), with acid condensates and with waste water; it has excellent behaviour in the presence of organic acids or alkaline solutions, also showing a small resistance in dilute sulphuric, hydrochloric or phosphoric acid solutions.

This steel is widely used in chemical and petrochemical plants and in off-shore structures, as well as in the food and pharmaceutical industry and the dyeing industry. Due to its nonmagnetic behaviour, it is used in some military applications, such as for example, for constructing the hulls of submarines.

To this regard, for the stabilised type containing titanium, X6CrNiMoTi17-12-2 (similar to AISI 316Ti), and the low carbon type, X2CrNiMo17-12-2 (similar to AISI 316L), similar considerations should apply to those already made for the stabilised and low carbon types of X5CrNi18-10: both steels are ideal in welding operations, avoiding having to perform an additional solution treatment to eliminate any chromium carbides formed.

To further increase resistance to corrosion, the stainless steels X1NiCrMoCu25-20-5 (similar to 904L) and X1CrNiMoCuN20-18-7 (similar to 254 SMO) are used, the second belongs to the so-called "super austenitic" family: it is one of the two special stainless steels used in particular applications.

The type X1NiCrMoCu25-20-5, due to its high nickel content, is very resistance to solutions of sulphuric and phosphoric acids (both dilute and concentrate) and is used in storage and transport systems.

The type X1CrNiMoCuN20-18-7 has very high resistance to attack from chlorides due to its high chromium and molybdenum content. It is used in desalination plants, in the chemical sector and in pulp bleaching systems where the use of bleaching substances is extensive.

9. AUSTENITIC-FERRETIC STAINLESS STEELS

9.1 Metallurgy

Austenitic-ferritic stainless steels (also called duplex or biphasic) owe their name to the presence of a mixed structure of austenite and ferrite at ambient temperature. This is the result of the combination of chromium and nickel suitably balanced in the chemical composition of the alloy: typically, duplex stainless steels have a chromium content between 22% and 25%, nickel content between 4% and 7%, with added molybdenum (3-4%) and nitrogen (0.1-0.25%) in many cases.

Table 14 shows the chemical composition of some of the most used austenitic-ferritic stainless steels and the relative designation according to the standard EN 10088. Please note that the trade name originally developed by Sandvik is most commonly used: it includes two pairs of numbers of which the first indicates the chromium content and the second the nickel content (for example 2205 indicates a biphasic stainless steel containing 22% chromium and 5% nickel).

The status diagram of duplex stainless steels (already reported in Figure 9) shows an initial solidification during the ferritic phase and only after the structure becomes biphasic they remain almost unchanged up to ambient temperature. At temperatures between $1050^{\circ}C - 1150^{\circ}C$, an optimal ratio between the austenite and the ferrite is obtained (the two phases fluctuate between 40% and 60%), thus obtaining high mechanical characteristics and resistance to corrosion; in particular, biphasic stainless steels excel due to their significant resistance to stress corrosion cracking in solutions rich in chlorides.

Duplex stainless steels allow the combination of the specific properties of resistance to corrosion of the austenitic and ferritic stainless steels; however, they also share a number of specific problems, typical of both, such as the precipitation of chromium carbides and the presence of a harmful phase that forms at around 800°C as well as an embrittlement issue at 475°C.

The formation of carbides/nitrides and intermetal phases (σ , χ and Laves), even for short exposure periods between 550°C and 900°C, can cause slight reductions to the toughness of the material, as well as considerably worsen resistance to corrosion. Great attention must be placed on all those technological processes that involve thermal alteration with damage to the steel: this is the case of welding operations or during cooling after forging semi-finished products of medium-large dimensions.

Similar changes to toughness and resistance to corrosion occur at temperatures around 475°C due to the spinodal decomposition of the ferrite. The existence of this degradation phenomenon, together with the previous at around 800°C, limits the use of biphasic stainless steels in operation at temperatures no higher than 300 °C.

For an overall assessment of the two aforementioned problems, see Figure 41 which assesses the formation of deleterious phases with the variation of temperature and holding time for some types of biphasic stainless steels.

EN Designation	%С	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	Ν%	Sandvik Denomination
X2CrNiN23-4 (1.4362)	≤0,03	≤1,00	≤2,00	≤0,035	≤0,015	22,0-24,0	3,50-5,50	0,10-0,60	0,05-0,20	2304
X2CrNiMoN22-5-3 (1.4462)	≤0,03	≤1,00	≤2,00	≤0,035	≤0,015	21,0-23,0	4,50-6,50	2,50-3,50	0,10-0,22	2205
X2CrNiMoN25-7-4 (1.4410)	≤0,03		≤1,00 ≤2,00	≤0,035	≤0,015	24,0-26,0	6,00-8,00	3,00-4,50 0,24-0,35	0,24-0,35	2507

Table 14 – Chemical composition of some of the main types of austenitic-ferritic stainless steel (or duplex) [from EN 10088].

EN Designation	Solubilisation	Cooling	Sandvik Denomination
X2CrNiN23-4 (1.4362)	950°C-1050°C	water, air	2304
X2CrNiMoN22-5-3 (1.4462)	1020°C-1100°C	water	2205
X2CrNiMoN25-7-4 (1.4410)	1040°C-1120°C	water	2507

Table 15 - Characteristics indicative of annealing heat treatment of some of the main types of austenitic-ferritic stainless steel.

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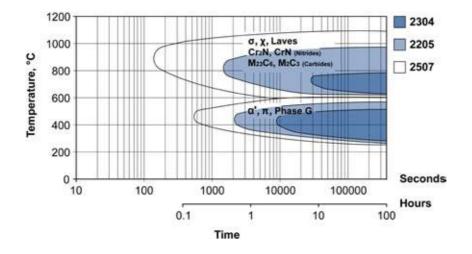


Figure 41 – Time-temperature diagram relative to the intervals of embrittlement at around 800°C and 475°C for three widely used duplex stainless steels.

9.2 Heat treatments

Semi-finished products made from biphasic stainless steels must always be subjected to an annealing treatment before being put into operation. This heat treatment is usually performed by holding the steel in the temperature interval of 1050-1150 °C; it is then rapidly cooled in water³⁴ to optimise the austenite-ferrite ratio (close to unity) and to encourage the resolution of unwanted phases possibly forming during manufacturing and transformation processes.

Table 15 indicates the heat treatment methods to be adopted for the most common types of biphasic stainless steel.

Also for these materials, both the annealing treatment and the subsequent cooling phase are often performed in a controlled atmosphere to avoid the surface oxidation of the semi-finished product.

9.3 Physical and mechanical properties

Table 16 shows the physical characteristics of some of the most common biphasic stainless steels. It should be observed how most of the physical properties are all comparable with those of austenitic stainless steels (specific heat, conductivity, resistance and elastic modulus); the only exception is thermal expansion between austenitic and ferritic stainless steels. When it is exposed to magnetic fields, the duplex component is ferromagnetic, similar to what happens for ferritic stainless steels.

³⁴ Cooling in air can only be considered in the case of small sized pieces.



	:	Concific hoat	Electrical	Thormal	Linear 1	Linear thermal	Modulus a	Modulus of elasticity	
EN Docimention	Mass		resistance		expansion	expansion [10 ⁻⁶ ·K ⁻¹]	פ	[GPa]	Sandvik
EN Vesignation	[kg/dm³]	aر در [J·kg ⁻¹ ·K ⁻¹]	at 20°C ^v [W·mm²·m ⁻¹]	[W·m ⁻¹ ·K ⁻¹]	from 20°C to 100°C	from 20°C from 20°C to 100°C	to 20°C	to 20°C to 200°C	Denomination
X2CrNiN23-4 (1.4362)	7,8	500	0,80	15	13,0	13,5	200	186	2304
X2CrNiMoN22-5-3 (1.4462)	7,8	500	0,80	15	13,0	13,5	200	186	2205
X2CrNiMoN25-7-4 (1.4410)	7,8	500	0,80	15	13,0	13,5	200	186	2507

Table 16 – Physical characteristics indicative of some of the main types of austenitic-ferritic stainless steel (or duplex) [from EN 10088].

X2CrNiN23-4 (1.4362) Solubilizatio 420-480 650-750 25-35 200-250 231 X2CrNiMoN22-5-3 (1.4462) Solubilizatio 460-520 700-800 25-35 200-250 221 X2CrNiMoN25-7-4 (1.4410) Solubilizatio 520-580 750-850 25-35 230-280 250	EN Designation	Metallurgic condition	R _{p0,2} [MPa]	R _m [MPa]	A [%]	Hardness	Sandvik Correspondence
Solubilizzato 460-520 700-800 25-35 200-250 Solubilizzato 520-580 750-850 25-35 230-280	X2CrNiN23-4 (1.4362)	Solubilizzato	420-480	650-750	25-35	200-250	2304
Solubilizzato 520-580 750-850 25-35 230-280	X2CrNiMoN22-5-3 (1.4462)	Solubilizzato	460-520	700-800	25-35	200-250	2205
	X2CrNiMoN25-7-4 (1.4410)	Solubilizzato	520-580	750-850	25-35	230-280	2507

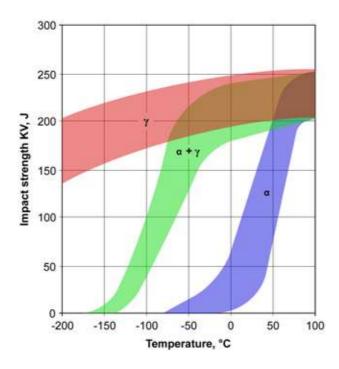
Table 17 – Mechanical characteristics indicative of some of the main types of austenitic-ferritic stainless steel (or duplex).

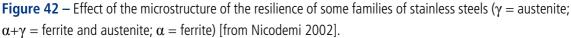
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The particular microstructure of biphasic stainless steels allows high values to be obtained of both the yield stress $Rp_{0.2}$ (which is around double that of austenitic stainless steels) and the tensile strength R_m . Table 17 reports some mechanical characteristics indicated of the main types of biphasic stainless steels.

The high resistance properties of duplex steels, greatly higher than those of traditional austenitic and ferritic stainless steels, are very important during the design phase because they allow the resistance sections of the component to be greatly decreased.

Furthermore, biphasic stainless steels have an excellent behaviour in terms of resilience: their transition temperature is around -80°C. A qualitative comparison of the resilience characteristics of these steels compared to austenitic or ferritic stainless steels is presented in Figure 42.





9.3 Types and applications

X2CrNiN23-4 (type 2304) was the first of the low alloy biphasic stainless steels: this steel was developed to economically compete with the traditional stainless steels X5CrNi18-10 and X5CrNiMo17-12-2 in the sectors where mechanical resistance and resistance to corrosion in chloride environments are essential. It is used in the production plants of nitric acid and for plants in contact with caustic substances (concentrations <30%), with organic acids or aqueous solutions rich in chlorides.

The steel X2CrNiMoN22-5-3 (type 2205) is definitely the most widespread of the biphasic stainless steels: it has a high mechanical resistance and excellent anti-corrosion characteristics, especially in marine environments where its behaviour is much superior than X5CrNiMo17-12-2. It is largely used in the petrochemical and chemical field, in environments contaminated by chlorides and in the presence of carbon dioxide CO₂ or hydrogen sulphide H₂S³⁵; it is widely used in desalinisation plants and plants in contact with dilute and concentrate solutions of sulphuric, phosphoric, acetic and formic acid.

Finally, the steel X2CrNiMoN25-7-4 (type 2507): is the evolution of type 2205 and was created to ensure a further increase of the tensile properties and resistance to corrosion. It has quite a niche use compared to the previous type, however it is a possible alternative to the "super austenitic" stainless steels and titanium alloys; it is used in oil wells and in subsea pipelines where high resistance to corrosion and fatigue phenomena as well as erosive wear is required, in addition to traditional degradation caused by the marine environment.



³⁵ Sulphuric acid is also know as hydrogen sulphide.

10. PRECIPITATION HARDENING STAINLESS STEELS

10.1 Metallurgy

Precipitation hardening (or PH) stainless steels were created with the aim of improving the mechanical behaviour of martensitic stainless steels (especially the fracture toughness), increasing the resistance to corrosion at the same time.

They are classified based on the microstructure that they have upon the initial annealing heat treatment: they are divided into martensitic, semi-austenitic and austenitic³⁶. The hardening phase (after annealing) involves cooling the material through the finely dispersed precipitation of intermetallic compounds and interstitials in the crystalline matrix of the steel. For this purpose, alloy elements are added such as aluminium, copper, titanium and niobium which give rise to compounds of the type Ni₃(Al, Ti), Ni₃Ti and NiAl or Fe₂(Mo, Nb) or even carbonitrides type M(C, N) with M = Nb, Ti, Cr; however the copper does not form compounds but precipitates under the form of very small metal particles that strengthen the matrix of the steel.

Nickel is always present in precipitation hardened stainless steels, both to improve resistance to corrosion and to make the metal mass tough; it usually has very low carbon content (C \leq 0.1%) and molybdenum is often added for anti-corrosion.

Table 18 reports the chemical composition of some of the main types of precipitation hardening stainless steels.

10.2 Heat treatments, physical and mechanical properties

At the state of supply, i.e. after the annealing treatment, semi-finished products in precipitation hardening stainless have a microstructure characterised by good cold plastic deformability and good machinability: the work piece is then subjected to the aging treatment to obtain mechanical properties aimed to withstand operating stresses.

Martensitic type precipitation hardening stainless steels, such as for example X5CrNiCuNb16-4 (also called 17-4 PH), are usually annealed at 1030°-1060°C and then cooled in air: a low carbon martensitic structure is obtained with low hardness and good deformability.

At the end of the operations of forming and chip removal, the semi-finished product is subjected to an aging treatment, performed at temperatures between 480°C and 630°C and for variable times from 1 to 4 hours³⁷.

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³⁶ As will be better seen in the paragraph dedicated to heat treatment, martensitic and austensitic PH stainless steels maintain their microstructure until the hardening heat process, whereas semi-austensitic PH undergo a further heat teatment that induces the transformation of the initial microstructure into martensite.

³⁷ Annealing treatment is indicated with the letter A (Annealing) where as hardening treatment is indicated by the letter H (Hardening) followed by the aging temperature in degrees Fahrenheit. For example A + H925 indicates that the steel was annealed and aged at 495° C (925° F).

EN Designation	Common name	УС	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	Other	AISI approximate denomination
VECTANISCIAN A 11 AEAD	17 / DL	20.02	02.0/	/1 EN	070 0/	/0 01E	15,0	3,50	090/	Ļ	
	L7 +- / I		01,0/	00,1/	_0,040		17,0	5,00	70,00	_	
VJC 7114:14-76	10 2 21			/		\0 01E	16,0	6,50		ç	
V/ CINIALI / - / (1.4300)		n'n7	01'07	00,1/1	_0,040		18,0	7,80		7	
VENIC FINALVOJE 1E 2/1 4606)	90C V		001/	1,00		\0 01E	13,0	24,00	1,00	c	
	007-H	on'no	00'I/I	2,00	(70')~		16,0	27,00	1,50	n	

1: %Cu = 3,00-5,00; %Nb = 5 x C - 0,45 2: %Al = 0,70 - 1,50 3: %B = 0,001 - 0,010; %Ti = 1,90 - 2,30; %V = 0,10 - 0,50; %Al \leq 0,35 Table 18 – Chemical composition of some of the main types of precipitation hardening stainless steel [from EN 10088].

In this way it is possible to obtain a tensile strength R_m between 850 MPa and 1400 MPa with an elongation A% variable from 25% to 12% (see Figure 43); resilience at ambient temperature fluctuates between 40J (se $R_m = 1400$ MPa) and 100J (if $R_m = 850$ MPa).

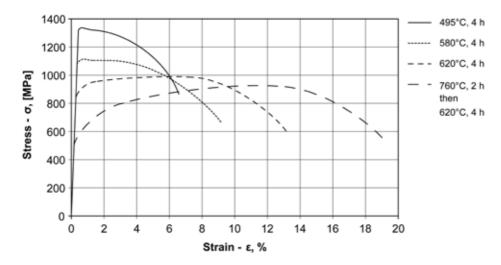


Figure 43 – Steel X5CrNiCuNb16-4 (also called 17-4 PH) annealed at 1050°C in air, then aged according to various methods: curves $\sigma - \varepsilon$ [Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano, Milan].

Semi-austenitic precipitation hardening stainless steels, such as for example X7CrNiAl17-7 (also called 17-7 PH), have a predominantly austenitic structure after annealing³⁸ at ambient temperature: this makes the execution of high pressure cold plastic deformation operations such as rolling very thin plates or strips easier. Due to the special chemical composition, after annealing the austenitic structure is unstable and, following the cold plastic deformation operations and the action of suitable heat treatments, it is transformed into martensite³⁹. The aging heat treatment will be performed on the martensitic structure obtained in this way, similarly to what happens in normal martensitic PH stainless steels.

A schematic of the possible technological processes which can be performed on a semi-austenitic precipitation hardening stainless steel type X7CrNiAl17-7 is shown in Figure 44. The mechanical characteristics fluctuate between 1300 MPa and 1700 MPa for the tensile strength R_m and between 1100 MPa and 1500 MPa for the yield stress $Rp_{0,2}$; the hardness is around 42-48 HRC.

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³⁸ In semi-austenetic precipitation hardening stainless steels the structure always contains a certain amount of ferrite after annealing.

³⁹ The name "semiaustenitic" stainless steels derives from the instability at ambient temperature of the austenite present in such steels.

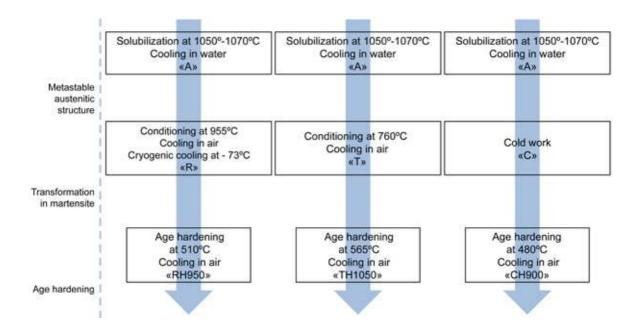


Figure 44 – Steel X7CrNiAl17-7 (also called 17-7PH): possible heat and thermo mechanical treatments necessary to cause precipitation hardening.

Finally, austenitic precipitation hardening stainless steels, such as X5NiCrTiMoVB25-15-2 (also called A-286⁴⁰).

Due to the high nickel content, the structure of this steel is completely austenitic and is very stable even after cold plastic deformation. The annealing treatment is performed between 970°C and 1050°C with cooling in water or in oil; aging occurs between 650°C and 750°C.

Figure 45 shows the hardness trend of the steel X5NiCrTiMoVB25-15-2 after annealing, cold hardening for rolling and subsequent aging at variable temperatures.

The physical properties of some of the main types of precipitation hardening stainless steels are shown in Table 19.

10.4 Types and applications

Precipitation hardening stainless steels are generally present on the market under the form of long products in round or hexagonal bars, plates and sheets are less widespread.

They are used in the aeronautical and aerospace industries, in the naval field, in the chemical and petrochemical industry and in the energy sector for the production of components characterised by

⁴⁰ It should be noted that this steel is also called Incoloy A-286: Incoloy is the trade name that the American Special Metal Corporation assigns to Fe-Ni-Cr superalloys produced by them.



high mechanical resistance and resistance to corrosion such as valves, shafts, bearings and turbine and compressor blades. They are also used in applications for load cells, sprockets, firearms, utensils, springs and surgical instruments.

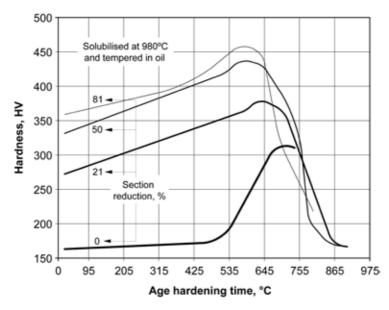


Figure 45 – Hardness trend according to the aging temperature for a steel X5NiCrTiMoVB25-15-2 (also called A-286) after annealing and quenching in oil and cold rolling at various levels of hardening [from McGuire 2008].

EN Designation	Common	Mass volume	Specific heat at	Electrical resistance	Thermal conductivity	Linear thermal expansion [10 ^{.6} .K ^{.1}]	:hermal nsion •K ⁻¹]	Modu elas [G	Modulus of elasticity [GPa]	AISI approximate
	name	[kg/dm³]	[J·kg ⁻¹ ·K ⁻¹]		[W·m ⁻¹ ·K ⁻¹]	from 20°C from 20°C to 100°C		to 20°C	to 200°C	denomination AISI
X5CrNiCuNb16-4 (1.4542)	17-4 PH	7,8	500	0,71	16	10,9		200	185	AISI 630
X7CrNiAI17-7 (1.4568)	17-7 PH	7,8	500	0,80	16	13,0	13,5	200	185	AISI 631
X5NiCrTiMoVB25-15-2 (1.4606)	A-286	6'2	460	0,91	14	16,5	16,8	211	200	AISI 600
X5NiCrTiMoVB25-15-2	17-7 PH A-286	8,7 7,9	500 460	0,80 0,91	16	13,0 16,5	13,5 16,8	200 211	185 200	

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11. THE CORROSION OF STAINLESS STEEL

11.1 Introduction⁴¹

Stainless steels are mainly used because of their excellent resistance to corrosion and it is perhaps for this reason that corrosion is the most typical form of operating degradation. This problem therefore needs to be investigated further, because only through understanding the mechanisms of damage will it be possible to identify the proper criteria of choice and use of this family of materials.

Corrosion is a form of degradation caused by chemical and electrochemical reactions that take place at the interface between the surface of a material and the environment with which it is in contact: the result is a gradual decay of the functional features of the stainless steels occurring when the main constituents of the alloy (Fe, C, Cr, Ni, etc.) combine with the aggressive agents present in the environment, thus forming corrosion products.

The corrosion of stainless steels can cause several problems. In the case of piping and tanks, the degradation can give rise to punctures that lead to leakage of the fluids contained within; in structural elements corrosion can cause the reduction of the resistant part with the consequent loss of the component's load capacity. Other problems are also linked to the formation of corrosion products, which can lead to the alteration of the aesthetic features of the surfaces or the contamination of the processed substances (for example, in the case of foods, possible alteration to their organoleptic characteristics)⁴².

The corrosion of stainless steels can be divided into two basic forms:

- electrochemical corrosion also called wet corrosion in which the metal alloy undergoes an oxidation
 reaction in the presence of an electrolyte (usually water); the oxidation reaction is coupled with a
 reduction reaction of the substances present in the environment (usually oxygen): the combination of
 the two reactions, anodic (oxidation) and cathodic (reduction), involve both chemical species (ions and
 molecules) and electrons;
- chemical corrosion (also called high temperature oxidation or dry corrosion) in which the metal alloy
 undergoes an oxidation reaction upon contact with a gaseous atmosphere (usually air); the phenomenon
 usually occurs at temperatures well above ambient temperature (>300°C) and the corrosion products
 are oxides and salts with low melting points.

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⁴¹ This paragraph and the two subsequent paragraphs were partially taken from the article by Boniardi M., Casaroli A., Tagliabue C., 'Fenomeni di danneggiamento dei materiali metallici dovuti all'esercizio (Failure Analysis)' (Phenomena of damage to metal materials caused by operation(Failure Analysis)), by Various Authors, Le Prove non Distruttive (Non-destructive testing), Vol. 1, Associazione Italiana di Metallurgia, Milan 2013.

⁴² The reader should consider that the phenomenon of "corrosion" is not limited to just iron based alloys (common steel, special steel, stainless steel, cast iron, etc.) but regards several types of metal materials (alluminium, magnesium, copper, titanium, nickel and their alloys). Failure to resolve problems of environmental degradation of metal materials has significant financial impact: it has been estimated that, in the most industrialised countries, the damage incurred due to corrosion is equal to 4-5% of the GDP, both in the form of direct damage from restoring the corroded structures and in terms of indirect damage from lack of production.

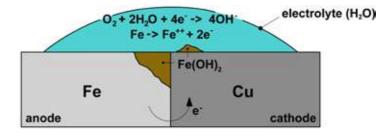
Most of the forms of degradation of stainless steels (~95%) are due to the action of electrochemical corrosion or wet corrosion, whereas only a very small percentage (~5%) of corrosion is relative to the problem of oxidation under heat.

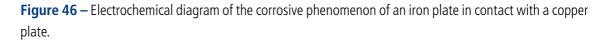
11.2 Wet corrosion and electrochemical corrosion

Wet corrosion of stainless steels can be described using the electrochemical model: the mechanism that governs the phenomenon depends on the presence of an anodic process, i.e. the oxidation of metal/ metal alloy subject to corrosion, and a cathodic process or reduction of a chemical species present in the aggressive environment (in many cases this is a reduction of oxygen and development of hydrogen). In order for corrosion to occur, the anodic reaction (oxidation) and the cathodic reaction (reduction) must occur at the same time and at the same speed on the surfaces of the metal mass.

In order for the redox reactions to take place, an ionic conductor in a liquid state must be present, the so-called electrolyte, which allows the passage of a current between the anodic zone and the cathodic zone: in most of the corrosive processes, the electrolyte is water (fresh water, sea water, condensation of aqueous steam and atmospheric moisture).

To understand the problem further, refer to the diagram shown in figure 46, in which an iron plate is placed in contact with a copper plate and the drop of water is the electrolyte.





As the copper is a nobler metal than iron (copper has a greater electrochemical potential than iron), a potential difference is established between copper and iron, i.e. an electromotive force that allows the circulation of current. The analogy using the galvanic cell is clear⁴³: the iron behaves as an anode and the copper as a cathode and the potential difference between the two metals allows the circulation of current. The anode (iron) and the reduction reaction of oxygen occurs to the cathode (copper) at the same time.

⁴³ For this reason the degradation phenomena caused by contact between dissimilar metals or metal alloys take the name of galvanic corrosion.



The two reactions are:

 $\begin{array}{ll} \mbox{Fe} \rightarrow \mbox{Fe}^{+2} + 2e^{-} & \mbox{(anodic reaction of oxidation)} \\ \mbox{$\frac{1}{2}$ O_2 + $H_2$$O + $2e^{-}$ $\rightarrow $2O$$H^{-}$ & \mbox{(cathodic reaction of reduction)} \\ \end{array}$

overall obtaining:

$$\frac{1}{2}$$
 O₂ + H₂O + Fe \rightarrow Fe (OH)₂

In summary: the iron gradually transforms into solution under the form of Fe^{+2} ions, corroding due to the effect of the presence of the copper cathode where the reduction of oxygen occurs.

In the example shown previously, the anodic and cathodic zones are clearly distinct: the corrosive phenomenon occurs due to a galvanic coupling⁴⁴ that creates a potential difference "E" because of the different nature of the two metals involved.

However, it should not be believed that corrosion only occurs in these conditions: the case of degradation phenomena on metal alloys not in contact with dissimilar metals is much more common.

To understand the problem better the experience of Evans⁴⁵ should be considered, as shown in figure 47: his experiment is especially significant as it explains the phenomenon of corrosion of homogenous metal materials.

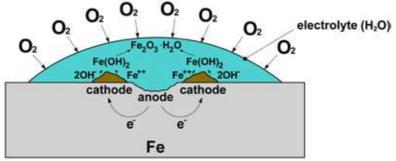


Figure 47 – Experience of Evans; phenomenon of electrochemical corrosion in a homogenous metal material [from Pedeferri 2010].

By taking an iron plate on which a deaerated drop of water is placed as the electrolyte, after a short time corrosion phenomena are only observed near the central area of the drop: this can be explained by considering the process of oxygen diffusion in the water drop, also called differential aeration corrosion. Initially, the chemical composition of the drop is constant and the oxygen is totally absent: over time however, due to contact with air, diffusive phenomena will occur near to the external surfaces of the drop (which is the surface of exchange with the surrounding air) and a variation of the oxygen concentration will take place

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⁴⁴ A particular form of corrosion is called galvanic corrosion and, as will be explained later, it occurs when stainless steel is placed in contact with a nobler metal (such as graphite) or with a less noble metal (such as aluminium).

⁴⁵ Ulick Richardson Evans (1889-1980) was one of the founding fathers of modern science who studied corrosion and the protection of metal materials.

in the drop. The different concentration of O_2 in the drop will create an anodic zone, i.e. the zone lacking in oxygen in the centre of the drop, and a cathodic zone, i.e. the zone rich in oxygen on the outside of the drop⁴⁶. Therefore, a local anode-cathode micro bond is created which is able to trigger the corrosion process. The "E" potential existing between the anode and cathode is a kind of electromotive force that allows the corrosive process to take place: it is called "free corrosion potential".

The anodic reaction and the cathodic reaction are all the same as those observed previously for galvanic contact:

$Fe \rightarrow Fe^{+2} + 2e^{-2}$	(anodi
$\frac{1}{2} O_2 + H_2 O + 2e^- \rightarrow 2OH^-$	(catho

(anodic reaction of oxidation) (cathodic reaction of reduction)

overall obtaining:

 $\frac{1}{2}$ O₂ + H₂O + Fe \rightarrow Fe(OH)₂

with the formation of corrosion products (iron oxides/hydroxides).

If the oxidation reaction of iron occurs in an acid environment (such as when an iron plate is immersed in chloride acid), the cathodic process will be the reduction of the hydrogen ion to hydrogen gas (hydrogen evolution), i.e.:

$Fe \longrightarrow Fe^{+2} + 2e^{-2}$	(anodic reaction of oxidation)
$2H^+ + 2e^- \rightarrow H_2$	(cathodic reaction of reduction)

overall obtaining:

 $2H^+ + Fe \rightarrow Fe^{+2} + H_2$

For corrosion to occur, the two reactions, anodic and cathodic, must happen at the same time: during the oxidation reaction of the iron, a certain number of electrons are generated on the anode which, following the reduction reaction, are consumed by the cathode.

The above reactions are very common in all metal materials subject to corrosion: the presence, for any reason, of an anodic-cathodic micro bond provides the electromotive force required to trigger and supply the degradation process.

However, the phenomenon of differential aeration corrosion is not the only type to give rise anodic-cathodic micro bonds able to trigger degradation: often in the corrosive 'material – environment' combination there are already particular local conditions suitable for generating zones with different electrical potential.

The problem arises for various reasons: heterogeneity of chemical composition of the metal mass, in homogenous phases of the microstructure of the matrix (inclusions, carbides, etc.), Tensile residual stress of high entity traction, local defects of the piece (micro cavities, blowholes, accentuated roughness etc.) All these areas act as the anode of the surrounding metal mass acting as a cathode, causing local micro bonds with preferential corrosion triggers.

Similar situations also arise due to the variability of the electrochemical characteristics of the corrosive

⁴⁶ The anode and the cathode – to clarify further – are areas located in the metal mass in contact with the liquid: where there has been an enrichment of oxygen developed in the cathode area, where there is a lack of oxygen in the anodic area.

environment, such as that which occurs, for example, in solutions with various concentrations of noxious species, in electrolytes with greater or smaller stagnation zones or with non-uniform temperatures.

11.3 Potentiodynamic curves

During a corrosive process there is always a certain number of ions in solution in the electrolyte and a concomitant movement of electrons in the metal, i.e. a circulation of electrical current, as what occurs in a cell.

The mechanism described is concatenated: the higher the quantity of iron ions, which will dissolve in the solution, the greater the number of electrons circulating per surface unit exposed to the corrosive environment. This causes the increase of the surrounding current density⁴⁷ "i_c" and the corrosion rate "V_{corr}" of this material will increase in that given environment, i.e.:

corrosion rate (V_{corr}) \propto i_{c} = i_{anodic} = i_{cathodic}^{48}

It should be repeated that the corrosive phenomenon is a degradation process that occurs when there is an anodic zone and a cathodic zone⁴⁹: among these two zones a potential difference "E" is established (called free corrosion potential in the case of short circuits between anodes and cathodes) which ensures the circulation of a current density "i" proportional to the corrosion rate of the system.

The correlation between potential "E" and current density "i" of the anode-cathode bond depends on both the electrochemical characteristics of the anodic process (i.e. "how quickly" the metal dissolves) and the electrochemical characteristics of the cathodic process (i.e. "how quickly" the oxygen or the hydrogen evolves).

If the two contributions are separated, i.e. if the correlation "E - i" is studied separately for the anodic reaction and the cathodic reaction, it is possible to estimate what the trend of the surrounding current density "i" will be, in order to change the applied electromotive force "E"⁵⁰.

This is exactly what Evans did experimentally and which is still possibly to recreate in the laboratory: to trace the curves that describe the anodic reaction and cathodic reaction with the variation of the tension

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⁴⁷ The parameter that best describes the electrochemical corrosive phenomena is the current density, that is to say the surrounding current per surface unit: this depends on the fact that the corrosion occurs on a given surface with respect to which a given current intensity develops.

⁴⁸ Simple calculations based on the Faraday alloy allow the numeric correlation of the surrounding current density with the corrosion rate: for every 1 μ A/cm² there is a degradation penetration equal to 10-12 μ m/year. The figure indicated is valid for most of iron alloys, copper alloys, aluminium and nickel.

⁴⁹ It is worth reiterating that the anodic zone and the cathodic zone can "reside" in two dissimilar materials (case of figure 46) or be present in different areas of the same material (case of figure 47).

⁵⁰ The potential correlation "E" – current density "i" that is measured experimentally is, mutatis mutandis, similar to what is looked for when you want to establish the electrical resistance of a conductor: the potential "V" continuously changes and the variations of current "I" are measured, obtaining the well noted Ohm relationship V = RI.

conditions "E" applied, or the reaction existing between the set tension "E" and the surrounding current density "i" both in the anodic area and in the cathodic area.

The curves obtained experimentally are shown in figure 48: they are called potentiodynamic curves, or Evans diagrams, due to the anodic process (anodic characteristics, metal/alloy that is corroded) and the cathodic process (cathodic characteristics, oxygen reduction and hydrogen evolution).

In the very simple case of common carbon steel in an aerated aqueous solution (the cathodic process is oxygen reduction), the two curves are as shown in figure 48a, whereas for a stainless steel, again in the same solution, the situation shown in figure 48b occurs⁵¹.

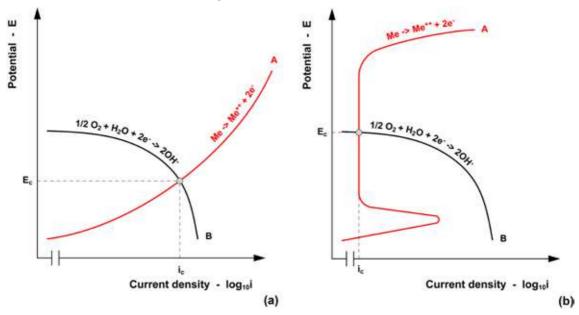


Figure 48 – Indicative potentiodynamic curves (anodic characteristic A: material – cathodic characteristic B: environment) in aqueous solution 0.05 M of H_2SO_4 : (a) for a material with active conduct and b) for a material with active-passive conduct.

The intersection point of curves A and B shown in figure 48 represents the condition of equivalence between the surrounding current densities (the rate of the two reactions, anodic and cathodic, is equal): it establishes the functioning point of the material-environment system and allows the determination of the free corrosion potential " E_c " and the surrounding current density " i_c ", as well as estimating the corrosion rate of the material in that particular environment ($V_{corr} \propto i_c$).

In the case of carbon steels, the anodic curve (curve A - figure 48a) increases monotonically: the current increases with the increasing tension applied and with it, the corrosion rate increases. With regards to

⁵¹ To be able to observe the typical active passive trend of stainless steel in practice, a small amount of an acid species must be added (in this case ~4.9 gllitre of sulphuric acid to obtain an aqueous solution 0.05 molar = 0.05M of H_2SO_a).



stainless steels (curve A – figure 48b) typical active-passive behaviour can be seen. It should be remembered that the two cathodic curves indicated by B in figure 48 have the same trend because they represent the same environment in which the two materials are inserted.

The comparison between these two conditions (figure 48a and figure 48b) is significant and accounts for the actual behaviour in operation of the two different materials: because the surrounding current " i_c " of case "a" is much greater than the surrounding current " i_c " of case "b", the corrosion rate of a carbon steel, in that determined environment, will be a lot greater than that of a generic stainless steel⁵².

11.3 The wet corrosion of stainless steels

We will now attempt to describe the curve characteristic of stainless steels in more depth (anodic curve), indicating the significant parameters that are better suited to classifying the behaviour of the material: see figure 49.

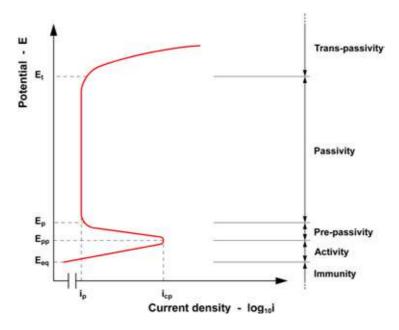


Figure 49 – Schematic of the anodic characteristic of a generic stainless steel.

Below the equilibrium potential " E_{eq} " the stainless steel is immune from any corrosive phenomenon: it is thermodynamically stable and the oxidation reaction cannot take place.

⁵² It should be noted that the x access shows the current density in a logarithmic scale with the base (not in a linear scale!): this means that a linear variation on the axis, leads to a variation of the size of the surrounding current, or rather the size of the corrosion rate of the material.



The anodic curve shows an active behaviour (from " E_{eq} ", equilibrium potential, up until point " $E_{pp} - i_{cp}$ ", primary passivation potential and critical current density of passivation): in this area the stainless steel acts like a common carbon steel with gradually increasing corrosion rate values with the increase of the set potential.

The passivation phenomenon occurs starting from point " E_{pp} - i_{cp} " with the consequent formation of the protective film of chromium oxide described in chapter 1: the electrochemical characteristic of the stainless steel is radically modified and, with the increase of the applied potential "E", there is a gradual decrease of the current density "i" which is stabilised around the value " i_p " (current density of passivation). In correspondence to " i_p " the corrosion rate is extremely low and can be considered as practically zero⁵³: this is the field in which the very thin chromium oxide/hydroxide film is formed and stabilised which protects the stainless steel.

The current density of passivation value " i_p " is constant for a wide potential interval (from " E_p ", passivation potential, up to " E_t ", transpassivation potential): beyond this value the stainless steel returns to behaving in an active manner due to the dissolution of the chromium oxide film. When the potential " E_t " is exceeded, localised forms of corrosion occur at the points where the passive film has been chemically attacked by the environment.

The high resistance to corrosion of stainless steels is linked to the low i_p values in the passivation field, i.e. in the " E_p - E_t " interval: the formation of the protective film (passivation) notably occurs when the environment has oxidising characteristics, such as for example in air or in aerated aqueous solutions.

However, how does a stainless steel behave in terms of resistance to corrosion when, in practice, it comes into contact with chemical environments having particular characteristics?

To be able to adequately answer this question, it is necessary to assess the interaction between the environment (cathodic curve) and the stainless steel (anodic curve): see figure 50 which shows the effect of four distinct cathodic processes (B1, B2, B3 and B4) alongside the anodic behaviour of a generic stainless steel (A).

The curves indicated by B1, B2, B3 and B4 represent four different cathodic processes (i.e. four different environments) characterised by increasing oxidising power.

Curve B1 is typical of an acid environment in which oxygen (or other oxidising species) is completely absent: the only process that can take place on the cathode is hydrogen evolution. The situation described here would occur for example in the case of a stainless steel immersed in a 50% sulphuric acid solution. In this case the stainless steel "works" at point X_1 and has an active behaviour, i.e. passivation cannot occur: consequently the degradation due to corrosion will be uniform and generalised across the entire surface.

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⁵³ the current density of passivation "i_p" of the stainless steels is generally very low (10⁻⁵-10⁻⁷ A/cm²): for this reason it can be reasonably assumed that, once the current density around the passivation value ("i_p") is stabilised, the corrosion rate is practically zero.

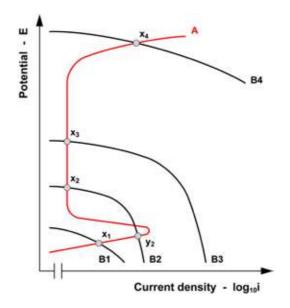


Figure 50 – Cathodic characteristics of four environments with increasing oxidising power (B1, B2, B3 and B4) and relative "functioning points" on the anodic characteristic of a generic stainless steel.

Curves B2 and B3 represent two cathodic processes where there is oxygen reduction; the difference is related to the oxygen concentration in the solution: lower in the case of B2 and greater in the case of B3. This is what would happen in a stagnant (B2 curve) or agitated (B3 curve) aqueous solution.

The two situations described by the cathodic processes B2 and B3 are very different from each other. In the case of the B2 curve, there are two functioning points of the anodic-cathodic system: X_2 and Y_2 . If stainless steel is immersed in the aqueous solution and is already in passive conditions⁵⁴, it will remain in this condition and preserve its typical resistance to corrosion (functioning point X_2). However, if the passive film becomes damaged for example due to mechanical action, the stainless steel will remain "functioning" in an active way (point Y_2), thus giving rise to localised corrosive phenomena.

If the agitation of the aqueous solution is increased or, in the same way, the concentration of oxygen in the liquid is increased, the cathodic curve will move towards high potentials equal to current density (B3 curve), giving rise to a single functioning point of the anode-cathode system (X_3): in this case the passive film on the stainless steel will be stable and will reform in a compact and adherent manner if mechanically damaged. Finally, the condition defined by the curve B4: this represents the cathodic behaviour of a strongly oxidising electrolyte, thus it could be an aqueous solution containing chromate. If the stainless steel is placed in this

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⁵⁴ During the production of components in stainless steel, it is common practice to put them in operation only after having performed a pickling treatment and chemical passivation (using nitric acid based solutions): this treatment has the aim of generating a stable and adherent passive film on the surface of the material.

environment, its passive film will be unstable: in some points there would be the chemical degradation of the protective layer of chromium oxide with consequent localised attacks in the metal mass.

11.4 The resistance to corrosion of stainless steels

The previous paragraphs should have clarified that the resistance to corrosion of any stainless steel is not an absolute characteristic of the material and its chemical composition, but rather depends on the environment in which the material is used⁵⁵.

Therefore, with the aim of separately assessing these two aspects (material and environment), we will now examine the changes to the anodic behaviour of the stainless steel with the variation of their chemical composition and the surrounding conditions, or rather the aggressive solutions within which they are put in contact.

First of all, it should be noted that in order to improve the characteristics of resistance to corrosion of a stainless steel (with equal environment) it is important to try to:

- extend the passive field, or widen the interval "E_p-E_t" (in particular, increase the potential value of transpassivation "E_t");
- decrease the value of "i_{cp}", the critical current density of passivation, which represents the level of current density to be exceeded in order to allow passivation of the steel;
- reduce the value of "i_p", the current density of passivation, which indicates the corrosion state of the stainless steel when it is under passive conditions.

In this regard, note figure 51: it clarifies the reason for which stainless steel, in the wide panorama of metal materials (Fe, Ni, Cr, and Mo) is the correct choice to hinder degradation caused by corrosion from very aggressive environments.

If the observation is limited to the iron-chromium-nickel alloys, it can be observed that the passivation phenomenon, in terms of electro chemicals, only becomes apparent when the chromium content increases, similar to that observed in chapter 1 regarding the formation of the protective film (figure 52).

When the chromium content is around 11.7%, the presence of a wide passivation range (" E_p - E_t ") is clear, with surrounding current density values of around 10 μ A/cm² (corrosion penetration: 100-120 μ m/year); on increase of the chromium content, the passive film becomes more stable, as can be observed from the decrease of the passivation current density, equal to approx. 0.1 μ A/cm² (1-1.2 μ m/year), and the further enlargement of the interval " E_p - E_t ".

⁵⁵ This statement is completely general and is valid for all metal materials that suffer corrosive phenomona. The resistance to degradation of any material always depends on the surrounding conditions: to understand corrosion fully it is never possible to separate the material from the environment in which the phenomena take place.



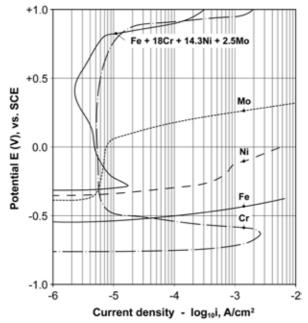


Figure 51 – Potentiodynamic curve for chromium, iron, nickel, molybdenum and stainless steel containing 18% chromium, 14.3% nickel and 2.5% molybdenum, in aqueous solution 0.1M of HCl + 0.4M of NaCl at 25°C [from Olefjord et al. 1985].

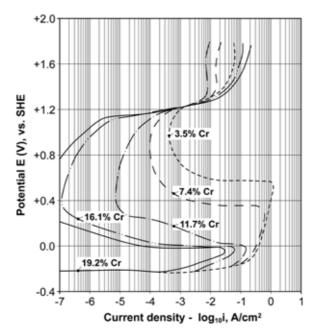


Figure 52 – Effect of chromium on the anodic characteristics (potentiodynamic curve) of iron-chromium alloys containing 8.3-9.6% nickel; 1M aqueous solution of H_2SO_4 at 90°C [from Osozawa and Engell 1966].



Again through the examination of the active-passive curve of stainless steel, it is possible to understand how the various elements of alloy influence the resistance to corrosion of stainless steels (see figure 53).

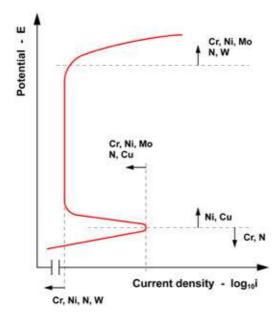


Figure 53 – Schematic trend of the active-passive characteristic of stainless steels according to the addition of various alloy elements [from Sedriks 1986].

The addition of nickel and molybdenum slightly improves the ability of the steel to passivate after the initial active phase (decrease of the current density of passivation " i_{cp} "), while extending the field of potentials in which the material is in passive conditions (increase of transpassivation potential " E_{r} ").

By contrast, the effect of alloy elements on the reduction of the current density of passivation " i_{p} " is much less evident: when the steel is in fact in these conditions (passive) its corrosion rate, i.e. the surrounding current density, is so low that in practice not very influenced by the chemical composition of the steel (see figure 54).

In a similar way, one can assess the effect of the same environment on the material: in this regard figure 55 should be noted, which shows the anodic behaviours of a type X5CrNi18-10 stainless steel in aqueous solution with varying concentrations of chlorides. Similar effects, with a consequent worsening of the corrosive behaviours of the acid, can be seen by increasing the temperature and/or decreasing the pH of the solution (figure 56).

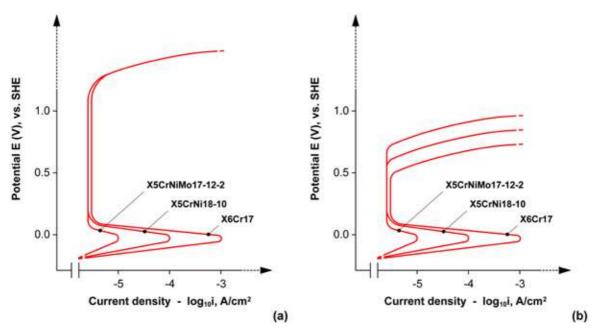


Figure 54 – Guide line potentiodynamic curve for three stainless steels in acid solutions with added chloride: (a) 0.05M solution of sulphuric acid, (b) 0.05M solution of sulphuric acid and 0.1M solution of sodium chloride. [from Talbot and Talbot 1998].

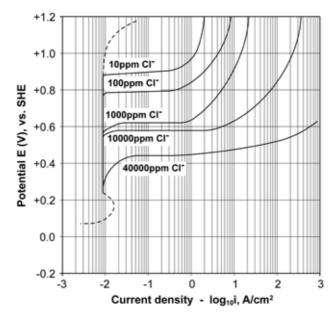


Figure 55 – Potentiodynamic curves for a type X5CrNi18-10 stainless steel in water at 25°C with increasing contents of chloride Cl⁻; the dashed curve approximately indicates the position of the peak of anodic current density and the transpassive zone [from Stansbury and Buchanan 2000].

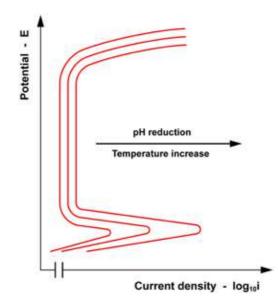


Figure 56 – Schematic trend of the active-passive curve of a generic stainless steel due to the increase of temperature or the acidification of the solution.

12. THE CORROSION MORPHOLOGY OF STAINLESS STEELS

12.1 Introduction⁵⁶

Corrosive phenomena can also be classified based on the morphology with which the degradation occurs in the components, or rather in relation to the aspect of chemical aggression as it appears upon simple visual observation or using magnification microscopy.

An initial distinction can be made between "generalised or uniform corrosion" and "localised corrosion":

- in the first case the whole surface of the material is subject to corrosive attack (generalised), with penetration of the degradation quite consistent along the whole section of the component (uniform);
- in the second case the aggressive action is only expressed in some areas of the surfaces (localised), with penetrating attacks, craters or cracks.

Many types of corrosion belong to this second morphology category: including those that appear most significant in the context of stainless steels, i.e. galvanic corrosion, pitting corrosion, crevice corrosion, intergranular corrosion and stress corrosion cracking.

12.2 Uniform or generalised corrosion

This form of corrosion affects the whole surface area of the metal material exposed to the aggressive environment, with limited local variations of the degree of penetration of the damage along the thickness of the component. A typical example of generalised and uniform corrosion is represented by stainless steels in contact with acid solutions (aqueous solutions of hydrochloric acid, sulphuric acid, phosphoric acid, oxalic acid, formic acid and citric acid etc.).

From an electrochemical point of view, the generalised corrosion of stainless steels takes place when the system "functions" in the active section of the anodic curve or in the interval between the equilibrium potential " E_{α} " and the primary passivation potential " E_{α} " (case B1 of figure 50).

In the cases of generalised corrosion, the corrosion rate " V_{corr} " can be suitably expressed in terms of mass loss (Δ m) per surface unit (A) over time (t), or rather:

$$V_{corr} = \Delta m / A \cdot t$$

usually measured in mg per day in dm² or 1mdd.

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⁵⁶ This paragraph and the two subsequent paragraphs were partially take from the article Boniardi M., Casaroli A., Tagliabue C., 'Fenomeni di danneggiamento dei materiali metallici dovuti all'esercizio (Failure Analysis)' (Damage phenomena of metal materials due to operation(Failure Analysis)), by various authors, Le Prove non Distruttive (Non-destructive tests), Vol. 1, Associazione Italiana di Metallurgia, Milan 2013.

In industrial applications it is often more interesting to talk about penetration or thinning rate " V_{thin} " of the corrosive phenomenon. To convert corrosion rate to the thinning rate simply add the material density (ρ), according to the formula:

$$V_{ass} = V_{corr} / \rho = \Delta m / \rho \cdot A \cdot t$$

The unit of measurement of thinning is μ m/year; for stainless steel and for other metals and common alloys used (steel for general construction use, special steels, copper, brass, zinc etc.) the equivalence between thinning and corrosion rate is around:

1 mdd \approx 5 $\mu\text{m}/\text{anno}$

The intervention methods that allow the preservation of the component from generalised corrosion are multiple. The formula is commonly used to predict the so-called "additional thickness for corrosion", i.e. a thickness "in excess" on the component which, during operation, will be gradually removed due to the corrosive action of the environment.

Usually, isocorrosion diagrams are used to ensure the correct choice of stainless steel. These are graphs that indicate, with the variation of various environments, the condition with constant corrosion rate (0.1 mm/ year) for the various stainless steels. Some typical examples are shown in figures 57 and 58.

12.3 Galvanic corrosion

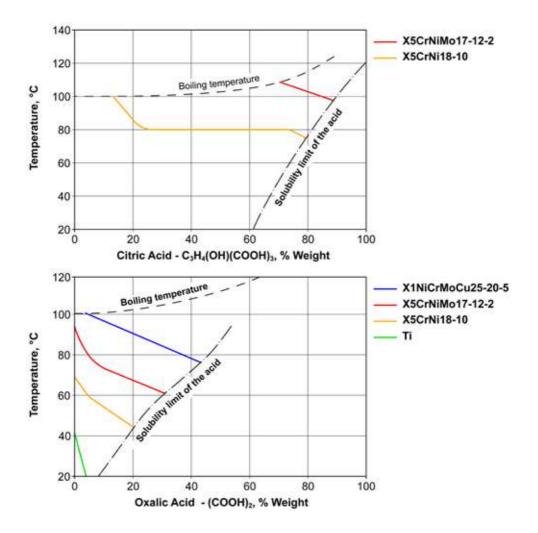
An early form of localised corrosion is galvanic corrosion or corrosion due to galvanic coupling⁵⁷. It occurs when a metal and a metal alloy is connected (i.e. is in electrical contact) with another metal/metal alloy with greater or lower thermodynamic nobility⁵⁸: if there is a significant potential difference, a redox reaction may develop with consequent corrosion phenomena, even in the presence of just a mildly aggressive environment. The mechanism is very similar to that shown in figure 46.

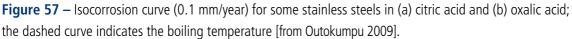
Every metal or metal alloy has its own potential that depends on its nature, its chemical composition and on the environment in which it is placed (temperature, pH, agitation, presence of oxidants or other harmful species, etc.).

If the difference between the various potentials exceeds a certain threshold, a significant passage of electrons is created between the donator (anode – less noble metal) and the receiver (cathode – nobler metal). The intensity of this movement of electrons (actually an electric current) will be greater as the potential difference increases: as a consequence, the corrosion rate will be higher the further distance between the two materials on the nobility scale.

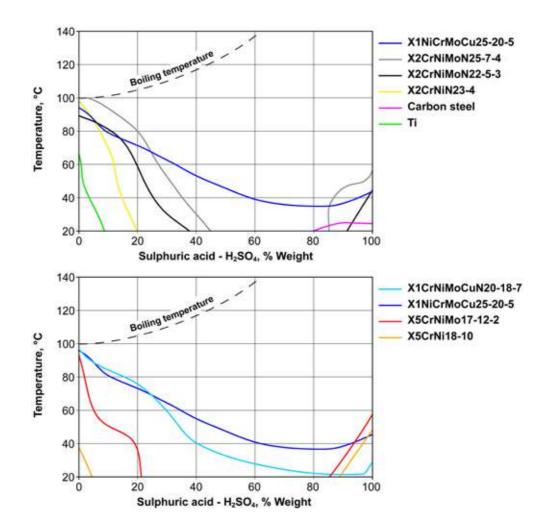
⁵⁷ This form of corrosion is also called bimetalic corrosion.

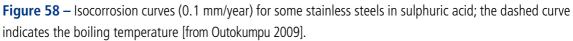
⁵⁸ The thermodynamic nobility scale (or standard potential scale) is the scale of electrode potential measured with regards to the electrode of reference of hydrogen ($E_0 = 0,00 \text{ V}$) at 298K and 100kPa of pressure, when all the species involved in the electrochemical process have unitary activities.





Another relevant aspect that governs the phenomenon of galvanic corrosion is the relationship between the areas of the two materials in contact: the rate of degradation increases with the increase of the ratio between the area of the cathodic zone (nobler) to that of the anodic zone (less noble) exposed to the environment. In order to assess whether the conditions of galvanic contact between the two metals/metal alloys can cause problems practically, it is better NOT to refer to the standard electrical potential scales: this is because there is a great variability in the behaviour of the same material between one corrosive environment and another (and at times also within the same environment) and also because there are never conditions of equilibrium in the actual environments and electrochemical system. Therefore the saltwater scale of nobility is used (figure 59), which is a scale of the potentials measured under conditions close to actual operation.





A typical example of galvanic corrosion is when it occurs on carbon steel sheet metal (also galvanised) or on aluminium alloy sheet metal in contact with stainless steel fasteners, placed in marine environments, in aerate aqueous solutions or in mildly aggressive environments (see figure 60).

The opposite situation would be much more serious, i.e. that of stainless steel sheets fastened with carbon steel or galvanised steel rivets: in this second case, in addition to the nobility difference between the two materials, the relationship between the areas would be very negative, in favour of stainless steel.

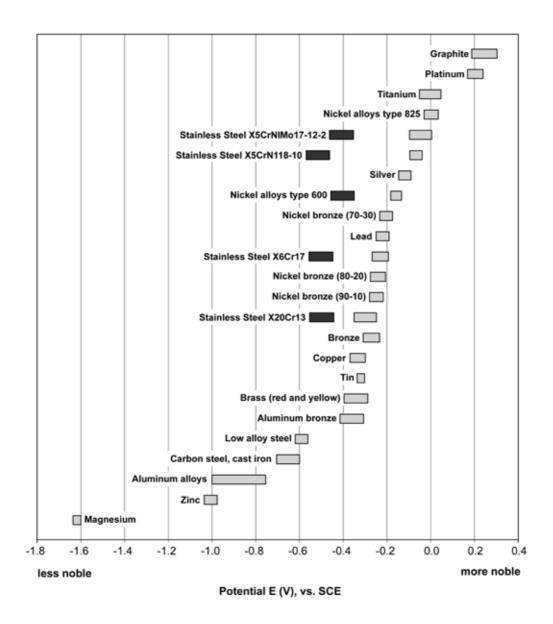


Figure 59 – Saltwater scale of nobility [from ASM-H.13 1992].

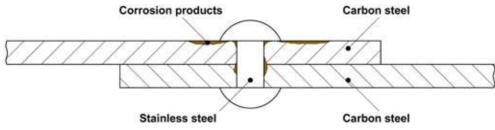
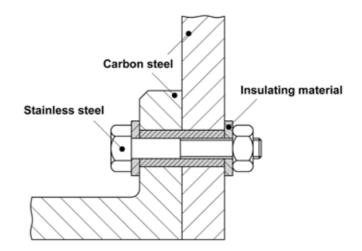
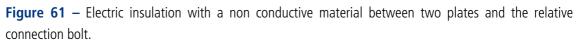


Figure 60 – Galvanic corrosion of a carbon steel plate with stainless steel fasteners.

The most correct solution to eliminate the corrosion phenomenon from galvanic contact is to avoid putting it into "electrical contact" (or direct contract with electronic continuity) with metal materials of different nobility or, if impossible, providing for electrical insulation of the parts (see figure 61).





A particular type of galvanic corrosion is corrosion by superficial contamination.

The degradation occurs when the surface of the stainless steel is "sullied" by foreign particles, such as dust from ferrous material that is often generated during grinding operations and from common steel.

The particles deposited on the surface can create conditions for localised corrosive attacks, even in not very aggressive environments. Marks appear on the surface (rust-coloured in case of ferrous contamination, whitish in the case of contamination from aluminium or zinc) as a consequence of the rapid oxidation of the contaminant (steel, aluminium or zinc) and not, as wrongly believed, of the stainless steel. In the most extreme situation, the contaminant substance can also cause damage to stainless steel, as it can hinder the passivation phenomenon, as well as constitute a preferential trigger zone for other forms of corrosion.

To work around the problem, greater attention has to be made during all the machining/cutting/handling operations of stainless steel semi-finished or finished products. The working tools and packaging methods (winders, unwinders, cutting systems, shears, brakes, chains, ropes and straps, etc.) must be appropriate for contact with only stainless steel; the use of tools that may have been used in the machining of other materials must be strictly avoided.

If surface contamination is suspected, the foreign particles must be removed through a chemical passivation operation, using nitric acid based dilute solutions.

12.4 Pitting corrosion

Pitting is the phenomenon of localised corrosion of stainless steel: it produces serious penetrating damage and dangerous holes in the components during operation.

Characteristic elements of pitting are the presence on the surface of the work piece of multiple small pits (hence the name of this corrosion); pitting usually leads to even deeper pits, i.e. grooves, ulcers, craters etc. The surface size of the holes is small, between 0.1 and 2 mm, as in the pitting phenomena the extent of the corrosion products is very limited.

The greatest problem related to this form of corrosion is not the loss of mass affected by the degradation phenomenon, but rather the damage caused by penetrating through the resistant section of the component. For example, consider the case of a stainless steel tank affected by the pitting phenomenon: the pitting could lead to the creation of a hole in the recipient, the subsequent spilling of the process fluid and the overall disruption of the system.

Degradation due to pitting has various aspects; figure 62 shows some morphologies typical in sections, as classified by the American standard ASTM G46.

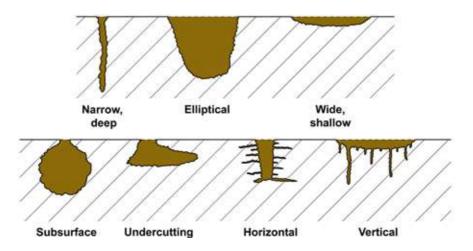


Figure 62 – Typical morphologies of degradation due to pitting [from ASTM G46].

Pitting occurs both on the materials in active behaviour, such as carbon steels, and especially on materials that passivate such as stainless steels⁵⁹. Corrosion is caused by neutral or oxidising environments able to chemically attack the protective film present on the surface of the material.

The typical degradation due to pitting of stainless steels occurs in aqueous solutions containing chlorides, such as in marine environments (wet-dry areas or areas exposed to sea spray).

In addition to the concentration of chlorides⁶⁰, the parameters that influence the occurrence of pitting are linked to the increase of temperature, the acidification of the electrolyte and any presence of other aggressive substances in the environment (such as in industrial atmospheres or in the contaminated process fluids).

Corrosion due to pitting is a phenomenon that, once triggered, tends to be self-sustaining: the cavity of the pit gradually recalls chloride ions due to the electrophoresis effect⁶¹ and an increase of the pH occurs due to the acid hydrolysis of the water⁶² (figure 63).

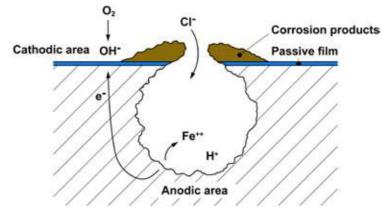


Figure 63 – Schematic of the damage mechanism caused by pitting.

In terms of electrochemistry, pitting occurs when the passivation conditions in the active-passive curve of the stainless steel are exceeded, i.e. when the potential of the cathodic reaction is greater than the transpassivation potential " E_t " of the anodic reaction (case B4 of figure 50). Consequently, the transpassivation potential E_t ", also known as pitting potential, is an excellent parameter for classifying, in an equal environment, the

⁶² In the presence of metal ions and water, acid hydrolysis can occur with variation of the pH of the solution, according to the reaction: $Fe^{+2} + 2H_2O \rightarrow Fe(OH)_2 + 2H^+$.



⁵⁹ Pitting corrosion is also common in other materials that passivate, such as aluminium or its alloys or titanium or its alloys.

⁶⁰ In the case of stainless steels, pitting occurs not only upon contact with aqueous solutions contaminated by chlorides, but also due to the effect of the presence of other halides, such as fluorides (F·) and iodides (I·).

⁶¹ The electrophoresis effect is a phenomenon of the movement of electrically charged particles (ions), immersed in a fluid, as the result of the effect of an electric field induced by the anode-cathode micro bond. The ions move towards the cathode if they have positive charge and towards the anode if they have negative charge. In the case of degradation due to pitting, this attracts Cl⁻ ions to the anodic zone of the corrosion crater.

resistance to corrosion due to pitting of the stainless steels. It also can be used to assess the various effects of the environmental conditions of stainless steels: the higher the pitting potential, the higher the resistance of the material to the phenomenon.

For example figures 64-66 show the potential pitting trend, for two stainless steels commonly used, upon the variation of the temperature, the concentration of chloride and the pH.

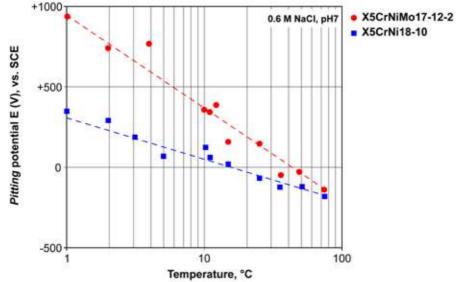


Figure 64 – Pitting potential trend according to the temperature of the solution for the austenitic stainless steels X5CrNi18-10 and X5CrNi17-12-2; aqueous solution 0.6M of NaCl at pH 7 [from Shirer 1994].

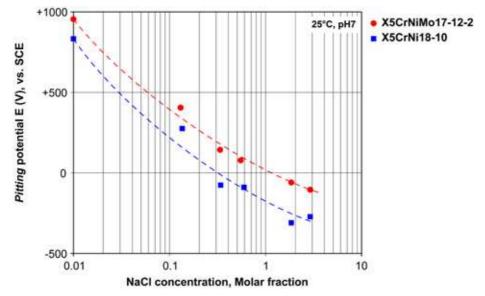


Figure 65 – Pitting potential trend according to chloride solution concentration for austenitic stainless steels X5CrNi18-10 and X5CrNi17-12-2; aqueous solution with pH 7 at 25°C [from Shirer 1994].

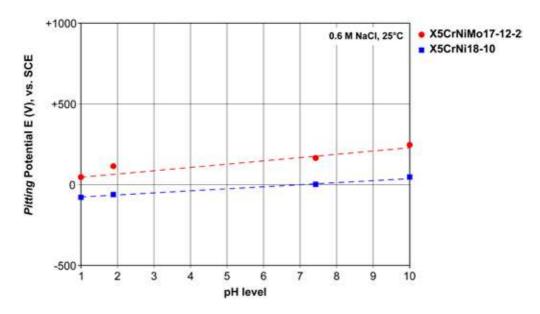


Figure 66 – Pitting potential trend according to the pH of the solution for austenitic stainless steels X5CrNi18-10 and X5CrNi17-12-2; aqueous solution 0.6M of NaCl at 25°C [from Shirer 1994].

In order to determine the pitting resistance without having to resort to experimental tests, it is possible to make assessments based on the chemical composition of these steels: it is well known in fact that elements such as chromium, molybdenum and nitrogen promote the expansion of the passive field (they raise the transpassivation potential " E_t "). To this end, a parameter has been experimentally developed that is well suited to describing the corrosive phenomenon: it is called PREN (Pitting Resistance Equivalent Number) and is directly correlated to the chemical analysis of the material with the formula⁶³:

 $\mathsf{PREN} = \%\mathsf{Cr} + 3.3 \cdot \%\mathsf{Mo} + 16 \cdot \%\mathsf{N}$

This index gives the possibility of classifying the various types of stainless steel with regards to the resistance to corrosion caused by pitting (figure 67): the higher the PREN, the higher the resistance of the steel to pitting.

In addition to the diagram included in figure 67, it also worth observing the graph in figure 68: this demonstrates the great variability existing in the correlation between PREN and the pitting potential, especially for PREN values >30. Therefore, it takes into account that the PREN index, albeit easy to determine, only allows a qualitative classification of the stainless steels; furthermore, it is worth repeating that the PREN can only be used for pitting corrosion.

⁶³ The PREN formula is not unambiguous: various multiplication coefficient are available, in particular for molybdenum and nitrogen. In the case of molybdenum both 3 and 3.3 can be used; in the case of nitrogen a coefficient equal to 13, 16, 27 or 30 can be used. The equation proposed here is the most common.



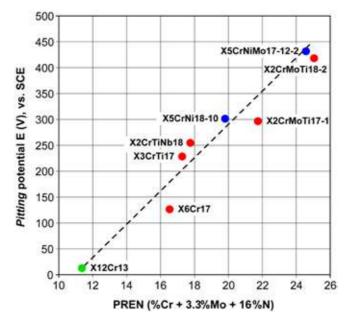


Figure 67 – Potential pitting trend according to the PREN for some stainless steels, aqueous solution 0.5M of NaCl at 50°C with pH 6.6 [from ArcelorMittal 2010].

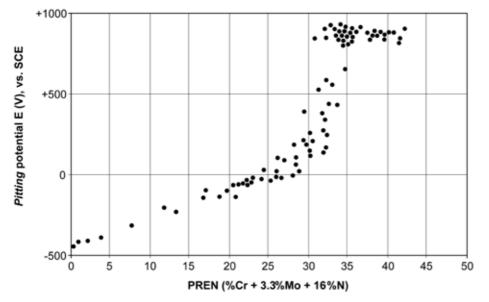


Figure 68 – Pitting potential trend according to the PREN in aqueous solution 0.5M of NaCl at 50°C with pH 6.6; iron based alloys with $%Cr=0.021\div28$ $\%Ni=0.22\div20.39$ $\%Mo=0.01\div4.23$ $\%N=0.01\div0.455$ $\%Mn=0.22\div4.53$ $\%Si=0.13\div0.71$ [from Shirer 1994].

The tendency of a stainless steel to undergo pitting phenomena can also be evaluated through standard laboratory tests. A typical example is given by the American standard ASTM G48 – 2003 (Standard Test Methods for Pitting

and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution) which allows the classification of the materials according to the temperature at which pitting corrosion occurs. The test includes the immersion of the sample in aqueous solution of ferric chloride⁶⁴. By gradually raising the temperature, the threshold at which pitting occurs can be derived experimentally: this threshold, called the Critical Pitting Temperature (CPT), can be used as an index of the resistance to the corrosion of the material (see figure 69).

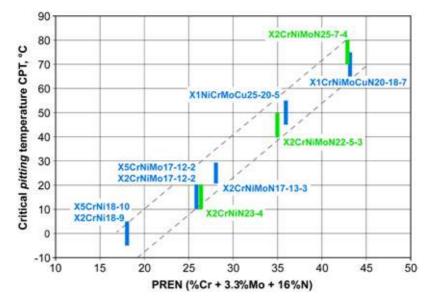


Figure 69 – Critical pitting temperature trend according to ASTM G48 as a function of the PREN for some austenitic and austenitic-ferritic stainless steels.

As is typical for all the morphologies of localised attack, pitting is also a phenomenon that must be prevented rather than hindered: in this regard it is appropriate to choose the material to be used in relation to the environment and its surrounding conditions (temperature, pH, harmful agents, chloride concentration, agitation-stagnation, etc.).

12.5 Crevice corrosion

Crevice corrosion is another form of localised aggression very common in stainless steels: it occurs in the presence of cracks, crevice, incrustations, deposits and geometrical discontinuities in which the electrolyte (generally water) is in stagnation with regards to the surrounding environment.

⁶⁴ Iron chloride, FeCl₃, is the iron salt (III) of hydrochloric acid: it is a compound soluble in water (with solubility equal to 920 g/ litre at 20°C) and is very corrosive to common and special steels.



A typical case of degradation due to crevice corrosion regards the seals of flanged piping or in the contact zones between bolted or riveted plates (figure 70). Similar situations can occur in welded plates for points on cars, in arc welded seals where penetration is incomplete, between the strands of metal cables, underneath lubricating films such as graphite or molybdenum graphite and on surfaces coated with Teflon or polyethylene.

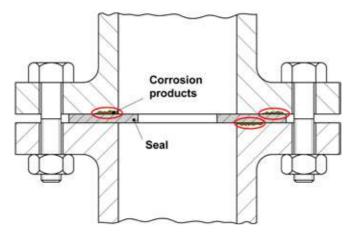


Figure 70 – Schematic of a constructive solution which could cause crevice corrosion.

The presence of the geometric discontinuities create a macro bond due to differential aeration between the interstitial area, i.e. the anodic zone where the diffusion of oxygen is limited, and the surrounding metal mass which represents the cathodic zone in which the oxygen saturation is ensured (figure 71). It should be noted that in the interstices, the same critical factors occur that are in a pit formed by corrosion, i.e. gradual consumption of oxygen, accumulation of positive metal ions, chloride ions attracted due to the electrophoresis effect and acid hydrolysis with pH decrease (compare figure 71 with figure 63).

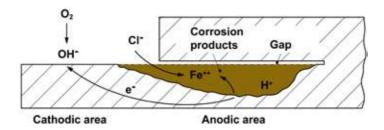


Figure 71 – Schematic of crevice corrosion

The analogy between the two degradation mechanisms leads to a classification identification of the stainless steels in the comparison of pitting and crevice corrosion. The better the behaviour of the material when subject to to pitting corrosion, the better its response against crevice corrosion: therefore the PREN

can be a valuable aid to make the correct choice of stainless steel also in the case of crevice corrosion. However, it should be indicated how, if the material used and environmental conditions set are equal, it is much easier to trigger crevice corrosion than pitting corrosion. However, for pitting to occur the cavity must be formed as a result of the chemical aggression of the environment but in the case of crevice corrosion the "cavity" is already physically present in the component due to the geometric discontinuity: and crevice corrosion is much more critical then pitting!

Another important parameter that governs degradation is the dimension of the interstitial area in which the liquid can stagnate: above a certain threshold the electrolyte can flow freely without creating problems, whilst below this threshold stagnation will be promoted and crevice corrosion will be triggered (see figure 72).

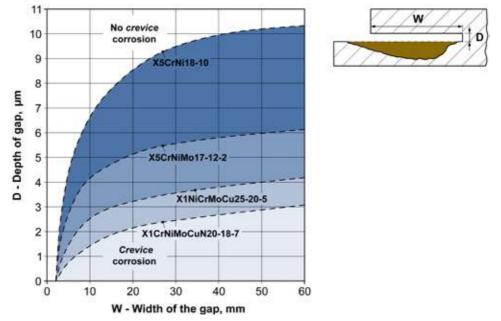
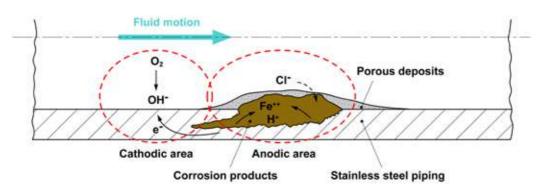
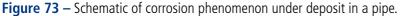


Figure 72 – Geometric characteristics of the interstices that can cause crevice corrosion in relation to the type of stainless steel used [from Sedriks 1996].

As is indicated from the previous observations, focus must be placed on the design of the system, in order to avoid interstices, cracks, incrustations or, in general, the presence of possible points of preferential aggression of the stainless steel.

A particular form of crevice corrosion is corrosion under a deposit. The degradation occurs in the presence of lime scale accumulations and/or deposits (such as in household pipes penetrated by water rich in limestone): in the vicinity of the deposit and below it "clogged cells" are established with the formation of anodic-cathodic macro bonds and degradation phenomena characterised by mechanisms similar to those of the interstitial corrosion (see figure 73).





12.6 Intergranular corrosion

Intergranular corrosion or intercrystalline corrosion is a form of environmental degradation associated with a chemical composition discontinuity of the material's microstructure: it is a symptom of the formation of a continuous network of carbides or intermetal phases, mainly rich in chromium or chromium/molybdenum, near to the grain boundary of the stainless steel (see figure 10).

It is a mechanism of localised corrosion, also called "sensitisation", that occurs on many families of stainless steels even in mildly aggressive environments; some authors prefer to classify it as selective corrosion because the aggression is preferential and occurs along the boundaries of the crystalline grain.

The cause of the degradation is the local depletion of chromium or chromium/molybdenum in correspondence with the grain boundaries: in the work piece, the corrosion is developed in the form of individual or branched cracks that "follow" the grain boundaries where the precipitation of carbides has occurred.

This issue was discussed at length in chapter 3 (paragraph 3.4) and in the various chapters regarding the individual families of stainless steels: please refer to these chapters for further information. Certain considerations previously mentioned will be repeated below; the list was made starting from the stainless steel families most used industrially.

In the case of austenitic stainless steels, the sensitisation, i.e. the precipitation of the carbides, occurs due to prolonged exposure of the material in the critical interval between 450°C and 900°C. Three factors explain the reason why the depletion of the chromium occurs in this deleterious way at the grain boundary:

- the carbon can "bind" a quantity of chromium, in the form of carbides, equal to about 16 times its own quantity in weight (carbides type $Cr_{23}C_6$);
- the carbon diffuses into the austenite much more quickly than the chromium and then "captures" a very large quantity of chromium; however, the chromium has a much lower diffusivity than carbon and therefore the depletion of chromium only occurs near to the grain boundary;
- the carbides preferentially precipitate at the grain boundary, an area with less atomic density where the nucleation of the precipitates is facilitated.

The austenitic stainless steels with carbon content greater than 0.03% are at risk of intercrystalline corrosion if exposed in the critical temperature interval. This can occur, for example, during the heat treatment of the semi-finished product, due to the effect of inappropriate operating temperatures, or due to welding operations. In the latter case the phenomenon typically occurs in the areas adjacent to the welding bead (heat affected zone), where the time spent in the critical precipitation interval is longer (see Figure 74).

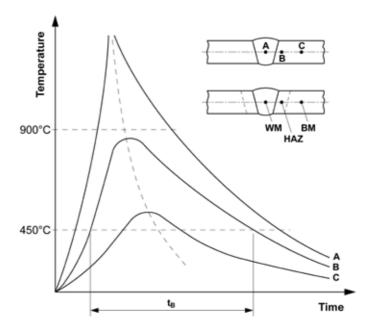


Figure 74 – Temperature trend as a function of time in a welded joint: WM: welded metal (A); HAZ: heat affected zone (B); BM: base metal(C). The zone where intergranular corrosion can occur is zone B because it is more exposed to the critical interval compared to A and C.

In electrochemical terms, the effect of the carbide precipitation occurs as an increase of the surrounding current density equal to the applied potential (Figure 75): consequently, in relation to the environment and the degree of sensitisation of the steel, they may have different criticalities.

To work around this problem, as already mentioned in chapter 8, the carbon content can be reduced to values lower than 0.03% (low carbon austenitic stainless steels) or elements can be added that stabilise the chromium such as titanium or niobium (stabilised austenitic stainless steels). Alternatively, an annealing treatment can be performed at 1050°C, if possible, followed by rapid cooling in water after welding.

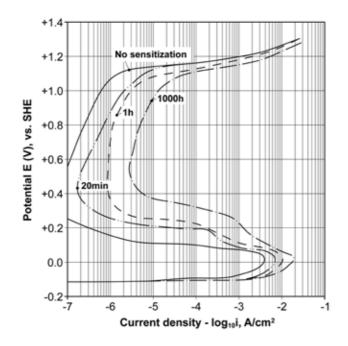


Figure 75 – Trend of the potentiodynamic curves of stainless steel type X5CrNi18-10 in its annealed status and after sensitisation at 650°C for various times; aqueous solution 1M of H_2SO_4 at 90°C [from Osozawa et al. 1966].

In the case of ferritic stainless steels, sensitisation problems can also occur due to the formation of carbides: the critical temperatures are lower than those of austenitic stainless steels and precipitation occurs in very short times (see Figure 76). To alleviate this phenomenon, the semi-finished product must be annealed at temperatures of 800°C during which the chromium notably diffuses towards the depleted zones; alternatively, as in the case of austenitic stainless steels, the material can be stabilised using titanium or niobium during the casting phase. The solution of reducing the carbon content to very low levels is not practicable, as it greatly limits the solubility of the carbon in the body centred cubic matrix of the ferrite.

Finally, duplex stainless steels: these materials have greater resistance to intergranular corrosion compared to both the families of austenitic and ferritic stainless steels.

The lower sensitivity to this problem depends on the fact that, in duplex steels, chromium carbides form at the interface between the austenite grains and the ferrite grains. As the speed of diffusion of chromium in ferrite is 100-150 times greater than what occurs in austenite, the carbides preferentially enrich at the expense of the chromium present in the ferrite: although this causes a depletion of chromium, the γ/α (similar case to what is shown in Figure 10a).

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The problem of duplex stainless steels is mainly linked to the formation of the phases rich in chromium or chromium/molybdenum (phases σ , χ and Laves) or to the presence of embrittlement at 475°C, as shown previously in Figure 41.

For this family of stainless steels, stabilisation is not provided for, therefore, in the event of the formation of unwanted phases (such as during welding large sections), performing a solution heat treatment is recommended followed by cooling in water.

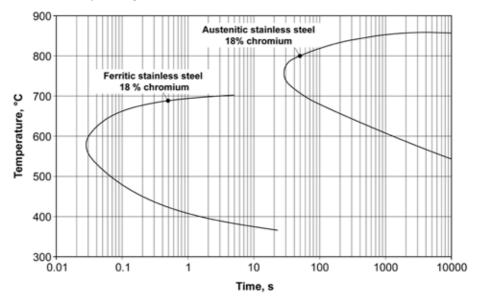


Figure 76 – Schematic trend of the sensitisation curves for ferritic stainless steels and austenitic stainless steels with the same chromium content [from Cowan and Tedmon 1973].

12.7 Stress Corrosion Cracking (SCC)

Stress Corrosion Cracking is another form of localised damage, and is very hazardous because it occurs in environments not particularly aggressive for stainless steel: it generally has very short incubation and propagation times (from 3 to 12 months) and often leads to the malfunction of the component or the plant as the problem is only recognised when the phenomenon is overt⁶⁵.

Stress corrosion cracking only occurs if three conditions are simultaneously met:

- a stainless steel with specific chemical composition,
- a specific corrosive environment,
- a mechanical stress traction greater than a specific threshold⁶⁶.

⁶⁶ The traction forces may derive from the action of external agent force on the component, and the presence of residual stress induced by previous machining of the material (cold moulding, drawing, stamping, folding, welding etc.).



⁶⁵ This problem is common to many families of materials: for example, copper alloys undergo SCC in ammonia rich environments, aluminium alloys in the presence of aqueous solutions with chlorides and high resistant steels in distilled water.

The combined action of all three conditions is critical: usually mechanical stress and a corrosive environment, if considered individually, do not cause problems of a mechanical nature nor corrosion.

Furthermore, in order for the degradation to develop, the temperature must be greater than ambient temperature: the most common forms of stress corrosion cracking of stainless steels occur in temperatures of 45-50°C.

Stress corrosion causes the formation of simple or branched cracks; propagation of cracks can be both intergranular (i.e. it follows the grain boundary) and transgranular (crosses the grains indistinctly): sometimes the propagation can be mixed.

Usually, products of corrosion are not often observed, so much so that in some cases the cracks are wrongly attributed to problems of an exclusively mechanical nature.

A possible schematic of that described is shown in Figure 77.

In all circumstances of degradation that will be described below, the prevention of stress corrosion cracking is implemented by changing the material in contact with the critical environment. A further solution, only valid in certain conditions, is that of reducing the mechanical stresses applied to the component, both increasing the resistant sections (with a consequent reduction of the nominal forces), and eliminating the auto stresses through suitable heat treatments (stress relieving)⁶⁷.

Stress Corrosion Cracking does not occur in all stainless steels in any corrosive environment: in practice there are only two "material – environment" couples that are critical for this form of degradation.

The most common case of SCC is that of austenitic stainless steels in seawater or in chloride solution (even with very low concentrations of Cl⁻⁶⁸). Typical components that are susceptible to this form of degradation are seawater heat exchangers.

In environments rich in chlorides, the stress corrosion cracks of austenitic stainless steels are generally transgranular and their trigger is very often associated with the presence of surface pits. The phenomenon is aided by the temperature, the chloride concentration and the dissolved oxygen in the solution increase. The critical stress threshold is between 70-90 MPa, i.e. a third of the yield stress in its solubilised state; beyond this value, the situation worsens and the fracture time gradually reduces with the increase of the load applied.

Stress corrosion cracking of austenitic stainless steels in chloride environments depends on the presence of nickel in the alloy: it is observed how the most critical conditions occur when the nickel content is around 8-10%, i.e. the typical percentages of the most common stainless steels (see figure 78).

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⁶⁷ To further act on the mechanical stress applied to the component, it is also possible to perform mechanical treatments such as shot peening that, by inducing the residual compressive stresses in the material, has a beneficial effect against stress corrosion cracking.

⁶⁸ Some authors indicate the critical concentration to not exceed to avoid stress corrosion cracking problems in 10ppm of Cl.

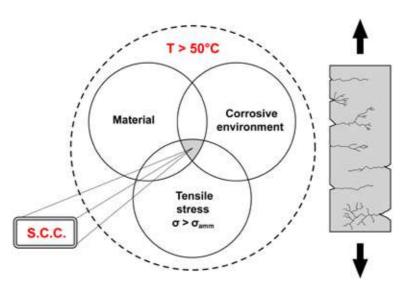


Figure 77 – Schematic of the Stress Corrosion Cracking phenomenon.

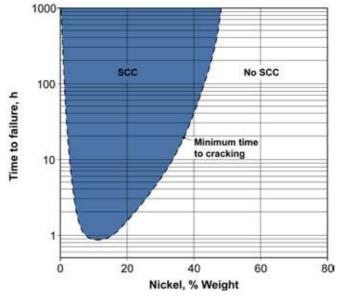


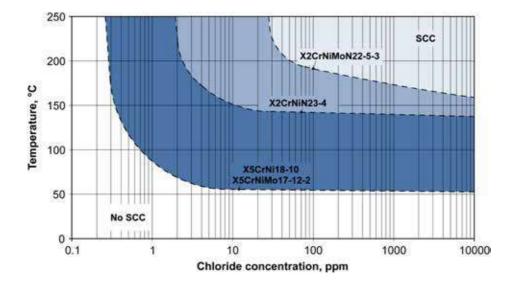
Figure 78 – Stress corrosion cracking of stainless steel wires with 18-20% of chromium, variable nickel content, in aqueous solution with 42% magnesium chloride at 154°C [from Copson 1956].

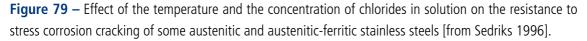
If the nickel is greater than 40 or completely absent, the steel will be much less sensitive to stress corrosion: this is the reason why nickel based super-alloys or common ferritic stainless steels, in which nickel is absent, are practically insensitive to the problem⁶⁹.

⁶⁹ SCC in chloride environments can also occur on ferritic stainless steels if precipitation of carbides and/or embrittlement has occurred in the material, for example on welded joints.



Duplex stainless steels are another good alternative in seawater to austenitic stainless steels, due to the high resistance to stress corrosion of the ferritic phase, present in about 50% of their microstructure (figure 79). Finally, a particular case in which SCC occurs is at temperatures much lower than the threshold. The problem, which has flagrantly occurred since the mid-eighties in indoor swimming pools, takes place at around 30°C on tie rods for false ceilings or on support elements: in this environment the high humidity and high chloride concentrations and other harmful species aggravate degradation and encourage the occurrence of the phenomena.





Caustic solutions (solutions rich in sodium or potassium hydroxide) are also critical for stainless steels: Stress corrosion cracking can occur in these environments, but also pitting or generalised corrosion can also take place.

The phenomenon is typical of austenitic stainless steels and occurs at temperatures between 80°-100°C, both in aerate and deaerate solutions with various concentrations of NaOH (see figure 80). In caustic stress corrosion cracking, the fracture can be transgranular, intergranular or mixed.

The behaviour in operation slightly improves with an increase of the nickel content or using austenitic-ferritic stainless steels, even though, in both cases, it is not possible to guarantee complete immunity from the phenomenon.

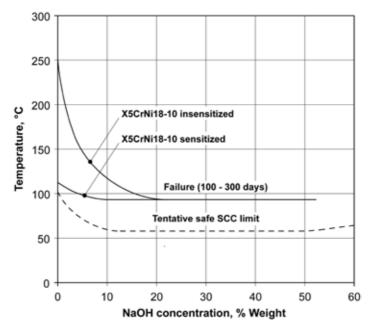


Figure 80 – Effect of the temperature and concentration of sodium hydroxide (NaOH) in solution on the resistance to stress corrosion cracking of austenitic stainless steel X5CrNi18-10 [from Lacombe 1993].

A final combination that can cause stress corrosion cracking is relative to austenitic, duplex or martensitic stainless steels in contact with hydrogen sulphide (H₂S).

This form of corrosion is known as SSCC (Sulphide Stress Corrosion Cracking) but it is, for all effects and purposes, a phenomenon of hydrogen embrittlement⁷⁰: awareness of it is very important in the sector of the extraction and refining of petroleum products and natural gas.

Hydrogen embrittlement is produced due to the reaction between hydrogen sulphide and iron: sulphurs and atomic hydrogen (H^+) form that then easily penetrate the matrix of the steel, inducing intergranular fragility. The chemical species that encourage the occurrence of SSCC are, in addition to hydrogen sulphide, chloride ions and the presence of H^+ ions in solution (as what occurs in acid environments); the most critical temperatures are located in the interval 60°-100°C.

⁷⁰ Hydrogen in its ionic state (such as H⁺ ions) is a very small atom which, under appropriate conditions of temperature and pressure, diffuses into the crystalline matrix, making the steel particularly fragile.



In the case of austenitic, martensitic or PH-martensitic stainless steels, the degradation also depends on the mechanical resistance of the material: according to the standard NACE MR0175 / ISO 15156⁷¹, so that the steel is adequate for these uses, it is necessary to prescribe a maximum hardness threshold of 22 HRC. To avoid the problem, it is often preferable to use duplex stainless steels, super-austenitic stainless steels or nickel based alloys.

⁷¹ The international standard NACE MR0175/ISO15156 called Petroleum and Natural Gas Industries – Materials for use in H₂S containing Environments in Oil and Gas Production.

13. HIGH TEMPERATURE CORROSION OF STAINLESS STEELS

High temperature corrosion is a phenomenon of degradation that occurs when stainless steels are subject to chemical attack by hot gases, such as in the case of components operating at high temperatures in contact with air, oxygen, carbon dioxide and superheated steam. Forms of degradation with similar morphologies occur in the presence of reducing, fuel, nitrate or sulphurous atmospheres, with salt baths or molten metals (NaCI, KCI, Na₂SO₄, KCN, zinc, aluminium, low-melting metals etc.). Because the temperatures at which all the aforementioned phenomena occur are much higher than ambient temperature (T>300°C), the corrosion manifests in the form of dry corrosion or high temperature corrosion.

Typical components that are susceptible to these forms of damage are turbine or compressor blades, combustion chambers, chemical and nuclear reactors, boilers, vehicle exhaust pipes, distillation columns of petroleum products and equipment for industrial furnaces or steel plants.

The degradation that occurs at high temperature derives from the interaction between gas and the metal alloy and can be explained as the sum of an oxidation reaction combined with a reduction reaction, in perfect analogy with what happens for wet corrosion.

For simplicity, we will now consider the high temperature oxidation phenomenon of a stainless steel, i.e. that which occurs when a generic iron-chromium alloy is placed into contact with an oxygen rich environment: for example, a chamber of an industrial furnace of heat treatment operating in air at high temperature.

The chemical species that oxidise are iron and chromium whilst oxygen is the species that reduces. In this specific case the formulae are:

$2\text{Fe} \rightarrow 2\text{Fe}^{+2} + 4\text{e}^{-1}$	$4Cr \rightarrow 4Cr^{+3} + 12e^{-1}$
$0_2 + 4e \rightarrow 20^{-2}$	$30_2 + 12e \rightarrow 60^{-2}$

from which:

 $2Fe + O_2 \rightarrow 2FeO \qquad \qquad 4Cr + 3O_2 \rightarrow 2Cr_2O_3$

The reactions indicated represent an oxide-reduction process in which degradation occurs mainly at the interface between metal and oxygen, as the iron oxides and the chromium oxides are permeable to the penetration of oxygen (although in different ways). A possible schematic of the high temperature oxidation phenomenon is described in figure 81.

In order to understand the behaviour of a generic metal material in contact with an oxidising atmosphere, it is necessary to know whether the oxide that will form on the surface of the component will be fragile, porous and not very protective or adherent and compact.

In the first case, the degradation will happen quickly as the metal mass is continually exposed to attack. However, in the second case, a barrier will be created which will impede the oxygen, or other harmful species, from entering into contact with the substrate; consequently the damage of the component in operation will be drastically reduced.

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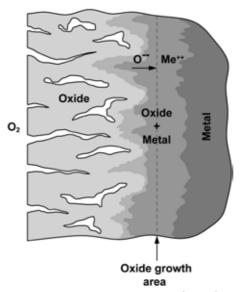


Figure 81 – Schematic of the oxidation phenomenon on the surface of a stainless steel in contact with an oxidising hot gas.

This is precisely what occurs in industrial alloys.

In common steels – i.e. those without alloying elements – only iron oxide will form. Iron oxide (FeO), at temperatures exceeding 570°C, is porous and tends to fragment, breaking away from the surface of the component: in such conditions high temperature oxidation and the degradation phenomenon will continually occur.

In stainless steels, however, the presence of high percentages of chromium ensures the formation of a stable oxide, well adherent to the surface, at least up to 900°C: with the increase of the chromium content in the alloy, the stability of the oxide will also increase along with the resistance to high temperature corrosion of the component. There are also other chemical elements that could be added to the composition of the stainless steel to improve its behaviour at high temperatures: i.e. silicon, which generates protective and stable oxides up to $1200^{\circ}C$ (SiO₂), or aluminium, which forms compact oxides up to $1300^{\circ}C$ (Al₂O₃).

Again in relation to stainless steels, it is also worth highlighting what happens when molybdenum and nickel are present.

Molybdenum, like chromium, improves the resistance of stainless steel to high temperature oxidation because it forms a stable and adherent oxide on the surface (MoO₃): however, it should be kept in mind that, at the temperature of 795°C, this oxide becomes liquid and phenomena of catastrophic corrosion will occur. Instead, nickel is a chemical element always beneficial with regards to high temperature corrosion in that it does not depend on the possibility of forming stable and protective oxides, but rather on the fact that nickel is not very similar to oxygen, i.e. it has a very poor aptitude for the formation of oxides. Furthermore, the presence of nickel encourages the adhesion of the chromium oxides to the surface of the steel.

The fact that the resistance to high temperature corrosion of the stainless steels does not only depend on their chemical composition should be considered. Other factors influence degradation significantly: the temperature of the hot gases, the chemical composition of the atmosphere, the presence of aqueous vapour, as well as the "operating regime" of the same component, i.e. whether it "works" in conditions with stable temperatures (stationary regime) or fluctuating heat (cyclic regime)⁷². An indication of the maximum operating temperatures of common stainless steels, both in stationary and cyclic regime, is reported in table 20.

		Maximum service temperature °C	
EN Designation	Stainless Steels	Intermittent service	Continuous service
X5CrNi18-10 (1.4301)	austenitic	870	925
X6CrNiTi18-10 (1.4541)	austenitic	870	925
X6CrNiNb18-10 (1.4550)	austenitic	870	925
X5CrNiMo17-12-2 (1.4401)	austenitic	870	925
X8CrNi25-21 (1.4845)	austenitic	1035	1150
X12Cr13 (1.4006)	ferritic	815	705
X2CrTi12 (1.4512)	ferritic	815	705
X6Cr17 (1.4016)	ferritic	870	815
X10CrAlSi25 (1.4762)	ferritic	1175	1095
X12Cr13 (1.4006)	martensitic	815	705
X12CrS13 (1.4005)	martensitic	760	675
X30Cr13 (1.4028)	martensitic	735	620
X105CrMo17 (1.4125)	martensitic	815	760

Table 20 – Maximum temperature in cyclic and stationary regime of some of the most common stainless steels [from Schweitzer 2007].

⁷² Cyclic regimes are more critical than stationary because, due to the repeated heat expansions and contractions of the surface oxide and the metal substrate, fragmentation and detachment from the protective surface layer occur more easily.

Martensitic stainless steels, ferritic stainless steels and austenitic stainless steels are the three most used to compare degradation in oxidising environments.

In general terms, the rule is that with the increase of chromium content, the resistance to high temperature oxidation increases, at least in a stationary regime: alloys with 13% chromium content are suitable up to 660°-680°C, 17% chromium content up to 800°-820°C and 18-20% up to 960°-980°C. In order to be able to reach the upper use limit of stainless steel in oxidising environments, it is necessary to resort to alloy contents of 25% chromium: in this case the maximum temperatures are between 1050°-1100°C.

However, when the heat regime becomes cyclic, alloying with nickel must be employed. Therefore, at equal temperature of use and chromium alloy content, an austenitic stainless steel will usually have superior behaviour in terms of duration in operation, compared to a martensitic or ferritic stainless steel⁷³.

Although stainless steels types X6Cr17, X5CrNi18-10 and X5CrNiMo17-12-2 are widely used at high temperatures, it should not be forgotten that there are specific chemical compositions developed for extreme applications. In this regard, some examples are ferritic stainless steel X10CrAlSi25 (similar to AISI 446), with high chromium content with added aluminium and silicon, or austenitic stainless steel X8CrNi25-21, with high chromium and nickel content: in both cases the materials are very resistant up to 1000°-1100°C.

If, at the same time as high temperature corrosion, resistance to creep corrosion is required, ferritic stainless steels are certainly more suitable: beyond 400°C embrittlement occurs of the structure that drastically reduces its mechanical properties at high temperatures.

In these contexts, austenitic stainless steels should be used, which are very resistant to creep corrosion due to the face-centred cubic lattice: they can be used up to temperatures of around 850-870°C. Alternatively, martensitic stainless steels can be used, but only up to a maximum temperature between 500°-550°C.

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⁷³ Carefully consult the temperatures indicated in table 20. In the case of ferric and martensitic stainless steels, the higher operating temperatures are those in cyclic regime, whilst for austenitic stainless steels the highest are those in stationary regime. This seemingly strange result is linked to greater linear heat expansion of the austenitic structure compared to the ferritic or martensitic structure: a characteristic that induces greater mechanical tension between the substrate and the oxide film, negatively influencing the compactness of the protective barrier.

BIBLIOGRAPHICAL RECOMMENDATIONS

With regards to stainless steels the bibliography available is extensive; if in addition to books, scientific journals and the conference papers on the subject are considered, the number of contributions – at least just in the English language – becomes endless.

In our opinion, there are three basic reference texts.

Firstly, the now unobtainable Peckner D., Bernstein I. M., <u>Handbook of Stainless Steels</u>, McGraw Hill, New York, USA, 1977. This is a collective works with contributions from various authors. Despite being a little dated, it gives an overall framework of the most important issues relative to stainless steels; it also contains very interesting information which is still very relevant.

The second text we recommend is another collective work: Lacombe P., Baroux B., Beranger G., Stainless Steels, Les Edition de Physique, Les Ulis, France, 1993. Initially published in French, it was then translated into English for greater use by an international audience. Both scientific and the more typically technological and application subjects are addressed in depth.

Last but certainly not least is a reference volume on stainless steel corrosion. It is Sedriks A. J., <u>Corrosion of</u> <u>Stainless Steels</u>, 2nd, John Wiley & Sons, New Jersey, USA, 1996: the text was specifically written to address the issues of stainless and non stainless steel corrosion, as is usual, it is a text about corrosion in which the stainless steels are just one of the many topics described.

In Italian, the choice is much more meagre: there are only two reference texts on stainless steels.

On one hand there is Di Caprio G., <u>Gli Acciai inossidabili</u> (Stainless Steels), 4^a ed., Hoepli, Milan, Italy, 2003. The text by Prof. Di Caprio is very good, especially for non-experts: it is a very interesting introduction (the term "introduction" should not be misleading) to stainless steels and their problems; the volume has been translated into various languages. It contains a myriad of information on the application principles of stainless steels that the author has collected starting from the sixties until his death in 2010.

The other Italian book is Nicodemi W., <u>Introduzione agli acciai inossidabili</u> (Introduction to stainless steels), 2^a Ed., Associazione Italiana di Metallurgia, Milan, Italy, 2002. First published in the late eighties and nineties of the last century in a single volume; it suffers a little as it has never been re-published in a composite way. It is a very interesting book that also includes some practical cases of failure due to corrosion of stainless steels; it is the metallurgic counterpart to the text by Prof. Di Caprio.

Unfortunately, there is nothing specific in Italian on the subject of corrosion of stainless steels. We refer the reader who wishes to deepen their knowledge to the volume Pedeferri P., <u>Corrosione e protezione dei materiali metallici</u> (Corrosion and protection of metallic materials), Polipress, Milan, Italy 2010 which contains many references to stainless steels.

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[Vander Voort 1991] Vander Voort G. F., <u>Atlas of Time-Temperature Diagrams for Irons and Steels</u>, ASM International, Metals Park, Ohio, USA, 1991.

[Verhoeven 2007] Verhoeven J. D., <u>Steel Metallurgy for the Non-Metallurgist</u>, ASM International, Metals Park, Ohio, USA, 2007.

[Wever et al. 1954/56/58] Wever F. et al, <u>Atlas zur Warmebehandlung der Stahle</u>, Verlag Stahleisen mbH, Dusseldorf, West Germany, 1954/56/58, Wever F., Rose A., Vol. 1; Rose A., Peter W., Strassburg W., Rademacher L., Vol. 2.





APPENDIX 1

MICROSTRUCTURES AND FORMS OF STAINLESS STEEL CORROSION



For the micrographs that follow, hearfelt thanks to the following laboratories:

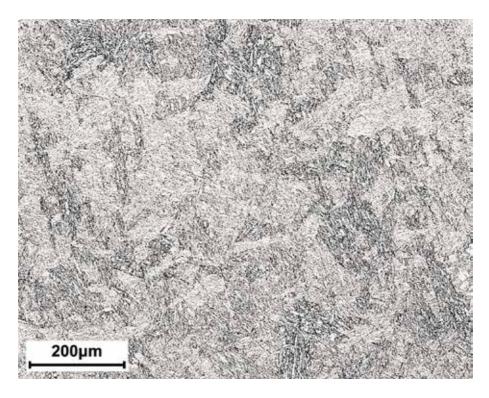
Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano, I-20156 Milan, Via La Masa, 1 (Sig. Piero Pellin, Sig. Maurizio Pardi, Ing. Silvia Barella, Ing. Silvia Cincera, Ing. Mattia Bellogini, Ing. Fabrizio D'Errico, Ing. Andrea Casaroli, Prof. Marco Boniardi)

Hammer Laboratory S.r.l., I-20017 Rho (MI), Via Risorgimento, 69/22 (Sig.ra Patrizia Maio, Ing. Marco Feraboli, Ing. Luca Bonvini)

Omeco Laboratory S.r.l., I-20900 Monza (MB), Via Monviso, 56 (Ing. Alessandra Marelli, Ing. Marco Casaril, Ing. HC Clemente Marelli)

Due to constraints of space, it has not been possible to include in this appendix all of the micrographs in our possession. The complete gallery with over fifty images is available free of charge on the following website **www.fa-fe.com** in the micrographs section **http://www.fa-fe.com/files/educational_metallografie.html**





Round bar quenched and tempered at 650°C

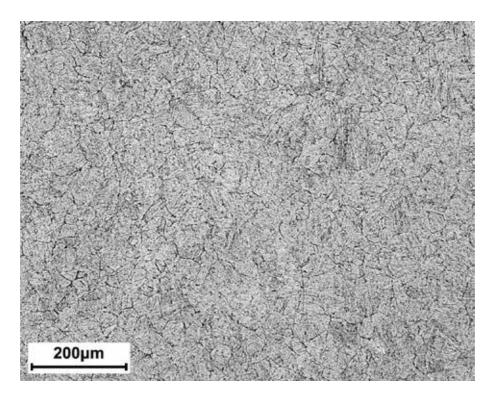
Martensitic stainless steel type X20C13 (similar to AISI 420)

Reactant: Vilella

Homogeneous martensitic structure

Source: Hammer Laboratories S.r.l., Rho (MI)

Further images can be found on www.fa-fe.com,



Semi-finished part, forged, tempered and aged at 620°C

Martensitic PH Stainless Steel type X5CrNiCuNb16-4 (similar to type 17-4PH)

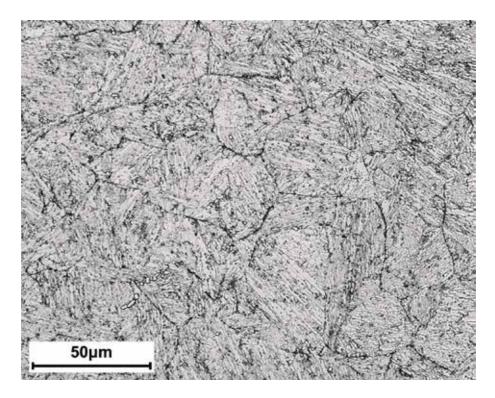
Reactant: Vilella

Homogenous martensitic structure with carbides along the edge of the austenitic grain

Source: Hammer Laboratories S.r.l., Rho (MI)

Further images can be found on **www.fa-fe.com**,

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Details of the previous image with greater enlargements

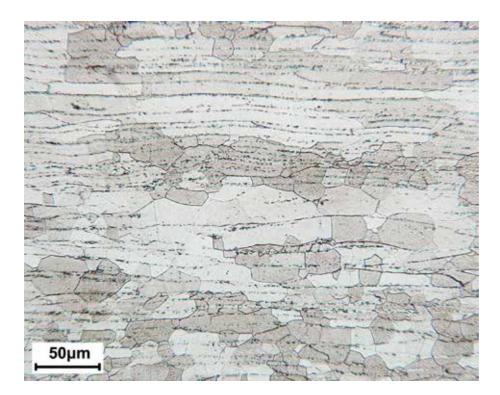
Martensitic PH Stainless Steel type X5CrNiCuNb16-4 (similar to type 17-4PH)

Reactant: Vilella

Homogenous martenistic structure with carbides along the edge of the original austenitic grain

Source: Hammer Laboratories S.r.l., Rho (MI)

Further images can be found on **www.fa-fe.com**,



Annealed and cold drawn strip

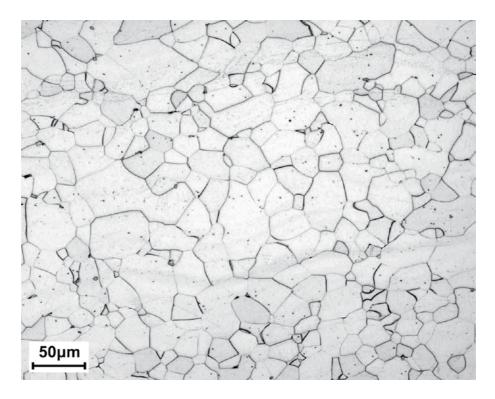
Ferritic stainless steel type X6Cr17 (similar to AISI 430)

Reactant: Vilella

Homogeneous ferritic types with carbides arranged in the direction of drawing

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Annealed and cold drawn strip

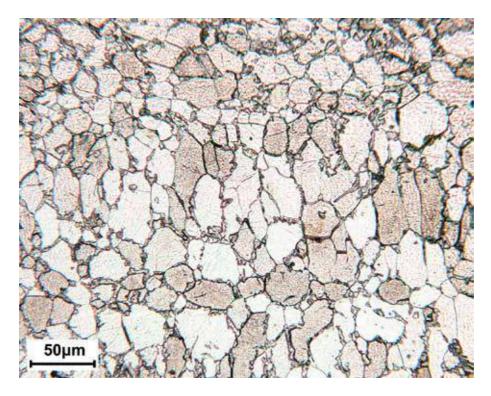
Ferritic stainless steel type X2CrTiNb18 (similar to AISI 441)

Reactant: Vilella

Homogenous ferritic grains

Source: OMECO Laboratories S.r.l., Monza (MB)

Further images can be found on **www.fa-fe.com**,



Cold drawn and annealed strip; heat affected zone after resistance welding

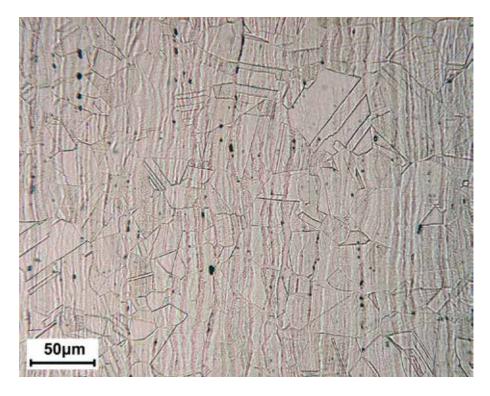
Ferritic stainless steel type X6Cr17 (similar to AISI 430)

Reactant: Vilella

Homogenous ferritic grains surrounded by martensite blisters

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on www.fa-fe.com,



Round bar solution annealed and drawn in line

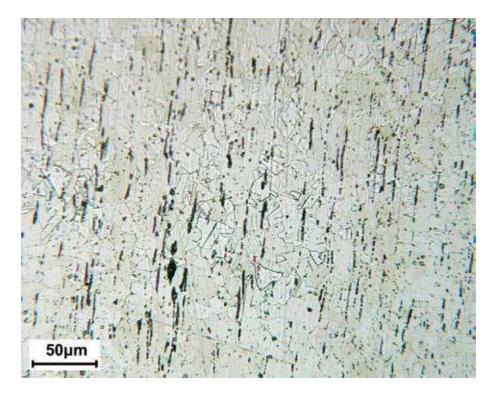
Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

Reactant: Oxalic acid (electrolyte)

Austenitic grains with homogeneous deformation bands arranged in the direction of drawing

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Round bar drawn and solution annealed

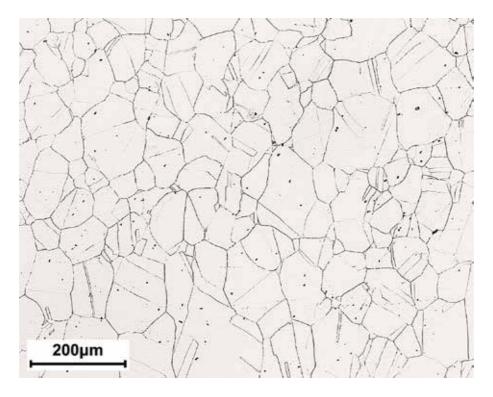
Austenitic stainless steel type X8CrNiS18-9 (similar to AISI 303)

Reactant: Oxalic acid (electrolyte)

Notes: Homogeneous austenitic grains with manganese sulphide in the direction of drawing

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Semi-finished part, forged and solution annealed

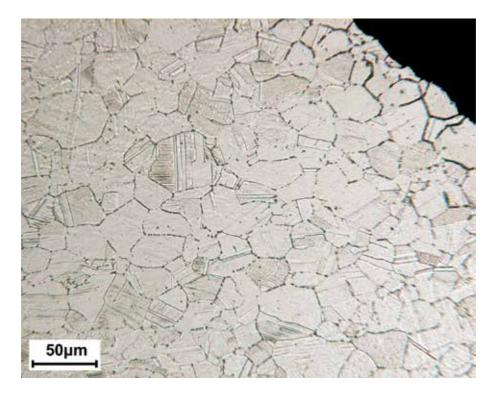
Austenitic stainless steel type X2CrNiMoN17-13-3 (similar to AISI 316LN)

Reactant: Oxalic acid (electrolyte)

Note: Homogeneous austenitic grains

Source: Hammer Laboratories S.r.l., Rho (MI)

Further images can be found on www.fa-fe.com,



Cold drawn solution annealed strip

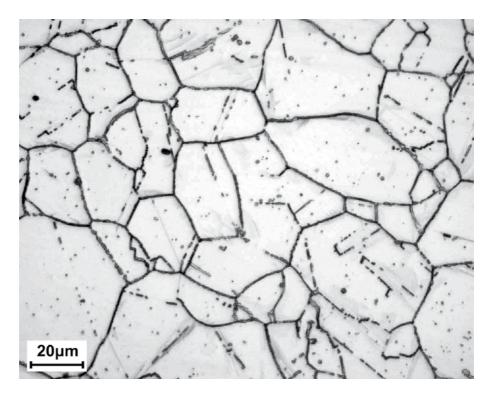
Austenitic stainless steel type X5CrNiMo17-12-2 (similar to AISI 316)

Reactant: Oxalic acid (electrolyte)

Homogeneous austenitic grains with abundant precipitation of carbides at the grain boundary

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on www.fa-fe.com,



Hot rolled sheet, solution annealed and sensitized

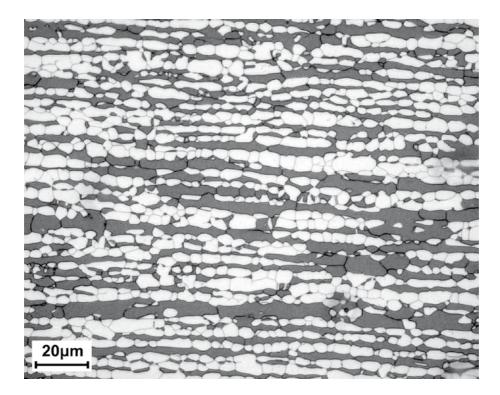
Austenitic stainless steel type X2CrNiMo17-12-2 (similar to AISI 316L)

Reactant: Oxalic acid (electrolyte)

Homogeneous austenitic grains with abundant precipitation of carbides at the grain boundary

Source: OMECO S.r.l. Laboratories, Monza (MB)

Further images can be found on **www.fa-fe.com**,



Hot rolled solution annealed strip

Duplex stainless steel type X2CrNiMoN22-5-3 (similar to 2205)

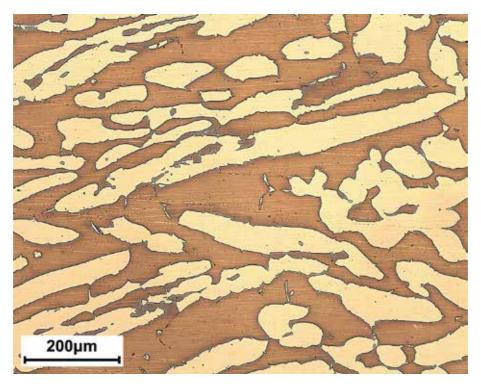
Reactant: Sodium hydroxide solution (electrolyte)

Homogenous austenitic grains and homogeneous ferritic grains extended along the rolling axis

Source: OMECO S.r.I Laboratories, Monza (MB)

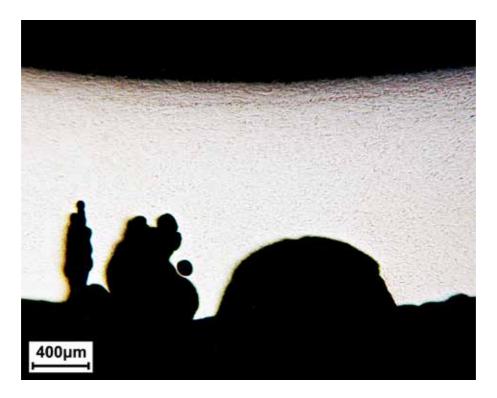
Further images can be found on **www.fa-fe.com**,

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Semi-finished part, forged and solution annealed Duplex stainless steel type X2CrNiMoN22-5-3 (similar to 2205) Reactant: Caustic soda (electrolyte) Note: Clear austenitic grains in a dark ferritic matrix Source: Hammer S.r.l. Laboratories Rho (MI)

Further images can be found on www.fa-fe.com,



Piping

Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

Reactant: Oxalic acid(electrolyte)

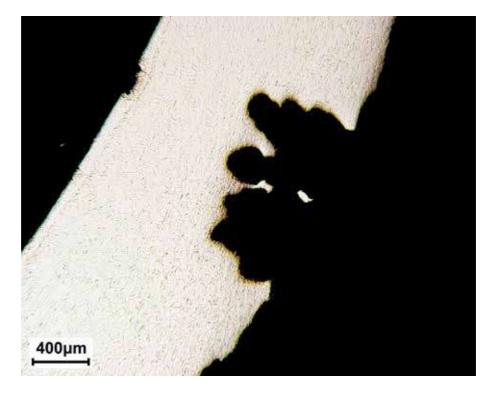
Localized corrosion pitting in fresh stagnant water ; temperature $\sim 60^{\circ}C$

Multiple pitting with uniform penetration

Homogenous austenitic grains

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Piping

Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

Reactant: Oxalic acid (electrolyte)

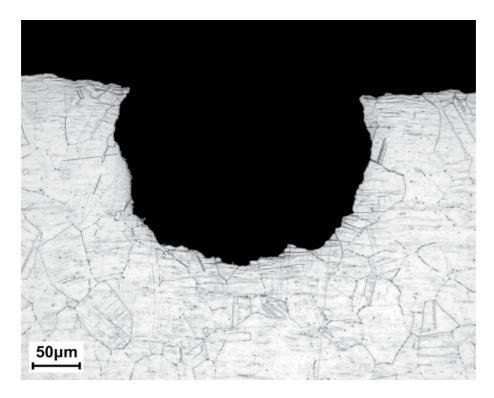
Localized corrosion pitting in fresh stagnant water; temperature ~ 60°C

Single pitting with multiple cavities

Homogeneous austenitic grains

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Piping for heat exchanger

Austenitic stainless steel type X5CrNiMo17-12-2 (similar to AISI 316)

Reactant: Oxalic acid (electrolyte)

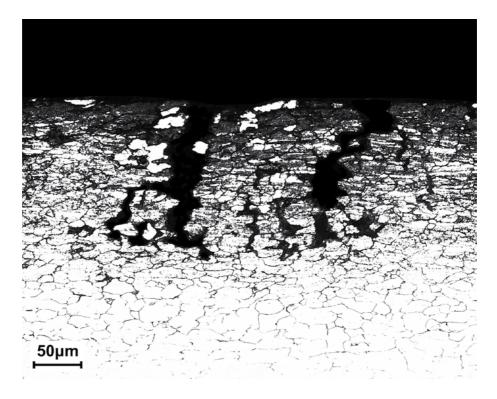
Localized corrosion pitting in sea water; temperature ~ 50°C

Detail of rounded cavity

Homogeneous austenitic grains

Source: OMECO S.r.l. Laboratories Monza (MB)

Further images can be found on **www.fa-fe.com**,



Welded join on piping

Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

Reactant: Oxalic Acid (electrolyte)

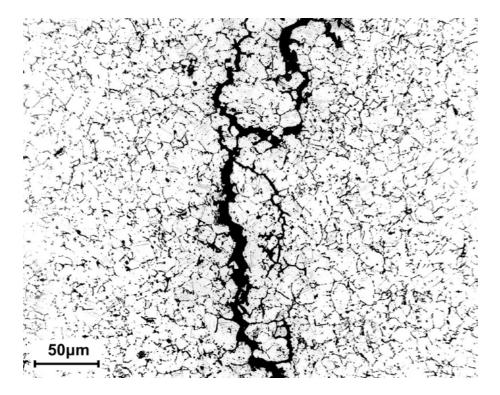
Intergranular corrosion in water solutions pH 5.5; temperature ~ 20°C

Ramified multiple intergranular cracks

Homogenous austenitic grains with carbides along the grain boundary

Source: OMECO S.r.l. Laboratories, Monza (MB)

Further images can be found on www.fa-fe.com,



Gas check valve

Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

Reactant: Oxalic acid (electrolyte)

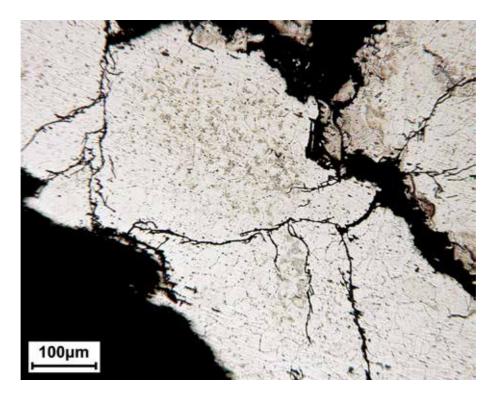
Intergranular corrosion in humid atmospheres; temperature ~ 20°C

Ramified intergranular cracks

Homogenous austenitic grains with carbides along the grain boundary

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Piping

Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

Reactant: Oxalic Acid (electrolyte)

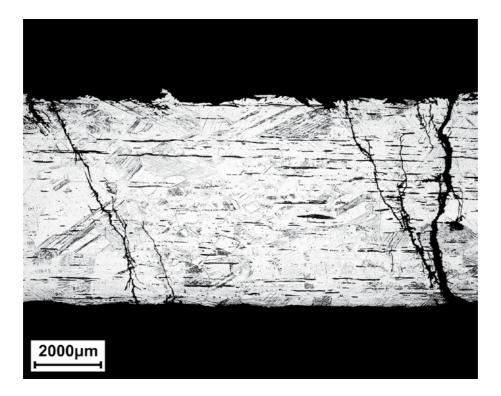
Stress corrosion in water-based solutions containing chloride ; temperature ~ 80°C

Presence of ramified multiple cross-granular cracks

Homogenous austenitic grains with carbides along the boundary

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on www.fa-fe.com,



Piping

Austenitic stainless steel type X8CrNiS18-9 (similar to AISI 303)

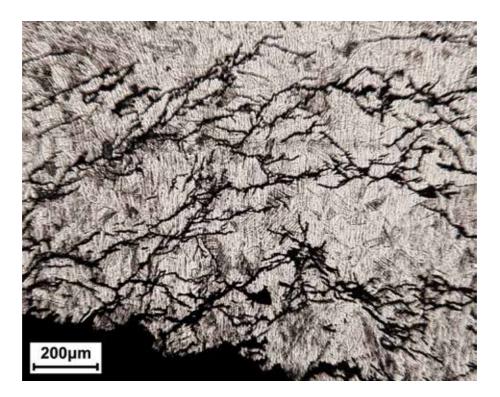
Reactant: Oxalic acid (electrolyte)

Stressed corrosion in water-based solutions containing chloride; temperature 80°-100°C

Presence of ramified cross-granular cracks; Homogeneous austenitic grains

Source: Omeco S.r.l. Laboratories, Monza (MB)

Further images can be found on www.fa-fe.com,



Fixing screws

Austenitic stainless steel type X5CrNi18-10 (similar to AISI 304)

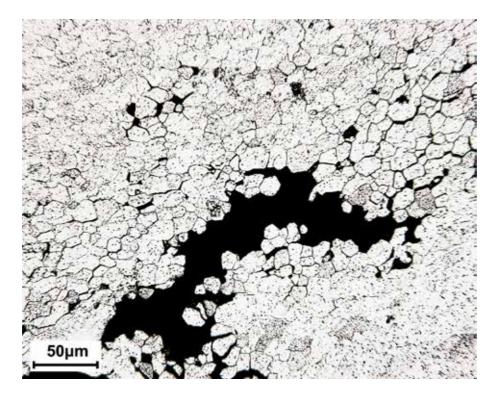
Reactant: Oxalic acid (electrolyte)

Stressed corrosion in water-based solutions containing chloride; temperature 50°-90°C

Presence of ramified multiple cross-granular cracks; austenitic strain-hardened grains

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on www.fa-fe.com,



Basket for washing machine

Ferritic stainless steel type X6Cr17 (similar to AISI 430)

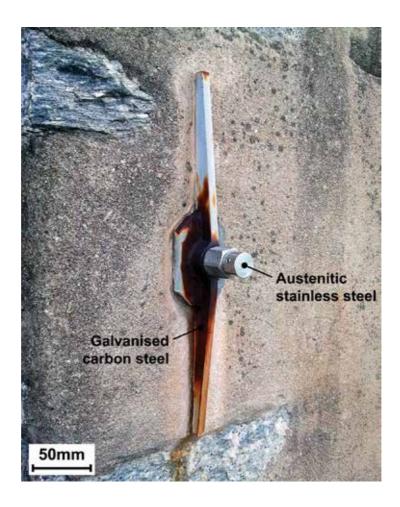
Reactant: Vilella

Stressed corrosion in watery solutions containing chloride; temperature 90°C

Presence of multiple intergranular cracks; homogenous ferritic grains

Source: Metallurgical Laboratory, Department of Mechanical Engineering, Politecnico di Milano (MI)

Further images can be found on **www.fa-fe.com**,



Santa Caterina del Sasso Hermitage , Leggiuno (VA), repair work Tie rod in austenitic stainless steel and frame in galvanized carbon steel Corrosion by galvanic contact in air; temperature range 0°-30°C Source: photo Marco Boniardi

Further images can be found on www.fa-fe.com,



APPENDIX 2

LUCEFIN S.P.A.

STAINLESS STEEL TECHNICAL DATA SHEETS



Quality	y)	(12CrS13				<i>l</i> artensitic			Technic	al card 2014
Number		•	.4005				Stainless St	eel		Lucefii	n Group
Chemi	cal com	position									
C%	Si	-	Mn%	P%	S%		Cr%	Mo%			
	m		max	max				max			
0,06-0,1			1,50	0,040	0,15	-0,35	12,0-14,0	0,60		EN 1008	38-1: 2005
± 0.01		0.05	<u>+</u> 0.04	+ 0.005	± 0.0)2	± 0.15	± 0.03			
Product	deviations	are allowed									
Tempe	erature °	С									
Melting	range	Hot-formin		stallization	Soft annea	aling Ful	l annealing			- AWS ele	
1500 11	00	1190-925	+RA		+A 780-750	070	040	pre-hea	ting		welding
1530-14	80	1190-925	not suitab	ام	780-750 air		-840 cooling °C/h to 590,			stres 600	s-relieving
Isotherr	nal	Quenching			Stress-reli		n air	joint wit	h steel	000	
anneali		+Q	+T	enng	+SR	eving and		carbon		lo alloyed	stainless
885-830	•	1010-980	680- 6	60	250-210			E309	E30		E309-E308
	d cooling	oil/polymer	fast co		air			cosmeti			2000 2000
to 720, t		air	in air					E410 - E		.9	
				Ac 1 ~ 820, Ac			g Ms ~ 330,	Mf ~ 180			
Chemic	al treatme	nt • Pickling	(10 - 15% H	NO3) + (0.5 –	1.5 HF) cold						
Mecha	nical pr	operties									
			2005 in cor	ditions 1C, 1E	E, 1D, 1X, 10	6, 2D					
size		Testing at ro				,					
mm		R	Rp 0.2	A %	Kv +20) °С	HB a)	^{a)} for infe	ormatior	n only	
from	to	N/mm ²	N/mm ²	min min	J min		max				
		730 max					220	+A anne			
	160	650-850	450	12				+QT650	quench	ned and te	empered
Bright b	ars of he	at-treated ma	aterial EN 10	088-3: 2005 i	n conditions	2H, 2B, 2G,	2P				
size		Testing at re	oom tempera	ature							
mm		R	HB a)				R	Rp 0.2		A %	Kv +20 °C
from	to	N/mm ² ma					N/mm ²	N/mm ²	min	min	J min
	10 ^{b)}	880	280				700-1000			8	
10	16	880	280				700-1000			8	
16	40	800	250				650-930	450		10	
40 63	63 160	760 730	230 220				650-880 650-850	450 450		10 12	
03	100	+A anneale						quenched ar	nd tomn		rial
a) for info	ormation o						+010000	quenoneu ai	iu temp		ilai
			nm. values a	re valid only f	or rounds – t	he mechanio	cal properties	s of non rou	nd bars	of < 5 m	n of
				equest and or							
Forged	(ASTM A	173-99 steel A	ASTM 416)								
			com tempera	ature							
		R	Rp 0.2	A %	C%	Kv +20 °C	HB	HRC			
size					min	J min	max	min			
	to	N/mm ² min			45		223		+A ar	nealed m	aterial
size mm	to	485	275	20	40				<u> </u>	obing of (55 °C in air
size mm	to		275	20	-10			35	Quen	ching at s	
size mm from		485				n after quen	ching at 980		Quen	ching at s	
size mm from		485 g values at ro	oom tempera	20 ature on round 20 1410	ls of Ø 10 mi	n after quen 1450	ching at 980 1420	0°C in oil		740	690
size mm from Table of	f temperir	485 g values at ro 1490 1	oom tempera 450 14	ature on round	ls of Ø 10 mi 1430			0°C in oil 1150	Quen 860 650	0	
size mm from Table of R	f temperir N/mm²	485 g values at ro 1490 1 1210 1	oom tempera 450 14	ature on round 20 1410 50 1150	ls of Ø 10 mi 1430	1450	1420	0°C in oil 1150 870 16.5	860	740	690
size mm from Table of R Rp 0.2 A Kv	f temperir N/mm ² N/mm ² % J	485 g values at ro 1490 1 1210 1 10.8 1 25 3	00000000000000000000000000000000000000	ature on round 20 1410 50 1150 .9 12.0 19	ls of Ø 10 mi 1430 1160 12.5 18	1450 1180	1420 1140 16.0 18	0°C in oil 1150 870 16.5 20	860 650	740 550 20.0 49	690 500
size mm from Table of R Rp 0.2 A	f temperir N/mm ² N/mm ² % J	485 g values at ro 1490 1 1210 1 10.8 1 25 3	00m tempera 450 14 170 11 0.8 10	ature on round 20 1410 50 1150 .9 12.0 19	ls of Ø 10 m 1430 1160 12.5	1450 1180 13.0	1420 1140 16.0	0°C in oil 1150 870 16.5 20	860 650 18.0	740 550 20.0	690 500 21.5
size mm from Table of R Rp 0.2 A Kv Temperi	f temperir N/mm ² N/mm ² % J ng °C	485 g values at ro 1490 1 1210 1 10.8 1 25 3 200 2	00000 tempera 450 14 170 11 0.8 10 00 26 50 30	ature on round 20 1410 50 1150 .9 12.0 19 0 350	ls of Ø 10 mi 1430 1160 12.5 18 400	1450 1180 13.0 17	1420 1140 16.0 18	0°C in oil 1150 870 16.5 20	860 650 18.0 31	740 550 20.0 49	690 500 21.5 90
size mm from Table of R Rp 0.2 A Kv Temperi	f temperir N/mm ² N/mm ² % J ng °C	485 g values at ro 1490 1 1210 1 10.8 1 25 3 200 2 king (hot-rolle	00000 tempera 450 14 170 11 0.8 10 00 26 50 30	ature on round 20 1410 50 1150 .9 12.0 19 0 350 Approximate	ls of Ø 10 mi 1430 1160 12.5 18 400	1450 1180 13.0 17	1420 1140 16.0 18	0°C in oil 1150 870 16.5 20 550	860 650 18.0 31	740 550 20.0 49	690 500 21.5 90
size mm from Table of R Rp 0.2 A Kv Temperi Effect of	f temperir N/mm ² N/mm ² % J ng °C	485 g values at ro 1490 1 1210 1 10.8 1 25 3 200 2 king (hot-rolle 720 7	200m tempera 450 14 170 11 0.8 10 20 26 250 30 ed +QT+C).	ature on round 20 1410 50 1150 .9 12.0 19 0 350 Approximate v 0 770	is of Ø 10 m 1430 1160 12.5 18 400 values	1450 1180 13.0 17 450	1420 1140 16.0 18 500	0°C in oil 1150 870 16.5 20 550 820	860 650 18.0 31 600	740 550 20.0 49 650	690 500 21.5 90 700
size mm from Table of R Rp 0.2 A Kv Temperi Effect of R	f temperir N/mm ² N/mm ² % J ng °C Cold-wor N/mm ²	485 g values at ro 1490 1 1210 1 10.8 1 25 3 200 2 king (hot-rolle 720 7 480 6	Doom tempera 450 14 170 11 0.8 10 00 26 250 30 ed +QT+C). 76	ature on round 20 1410 50 1150 .9 12.0 19 0 350 Approximate v 0 770 0 650	ls of Ø 10 mi 1430 1160 12.5 18 400 values 780	1450 1180 13.0 17 450 785	1420 1140 16.0 18 500 800	0°C in oil 1150 870 16.5 20 550 820 730	860 650 18.0 31 600 830	740 550 20.0 49 650 835	690 500 21.5 90 700 840

X12CrS13 n° 1.4005 r	nartensitic stainless ste	el					Luc	efin Group
Thermal expansion	10 ⁻⁶ ∙ K ⁻¹	•	10.5	11.0	11.5	12.0	12.2	12.7
Modulus of elasticity	longitudinal GPa	215	212	205	200	190		
Poisson number	V	0.235	0.210					
Electrical resistivity	$\Omega \bullet mm^2/m$	0.60						
Electrical conductivity	Siemens.m/mm ²	1.67						
Specific heat	J/(Kg•K)	460						
Density	Kg/dm ³	7.70						
Thermal conductivity	W/(m•K)	30						
Relative magnetic perm	neability µr	900 1)						
°C		20	100	200	300	400	600	800

	x steam, gasoline, fue		
	x steam, gasoline, fue		
	x steam, gasoline, fue oil, alcohol, ammonia		
reducing			
°C 00°			
India	Republic of Korea		
IS	KS		
	STS 416		
	60 °C India		





Quality	X12Cr13	Martensitic	Technical card 2014
Number	1.4006	Stainless Steel	Lucefin Group
Chemical composi	ition		

onenneur	composition	1					
C%	Si%	Mn%	P%	S% ^{a)}	Cr%	Ni%	
	max	max	max	max		max	
0,08-0,15	1,00	1,50	0,040	0,015	11,5-13,5	0,75	EN 10088-1: 2005
± 0.01	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.15	± 0.03	

Product deviations are allowed

a) for improving machinability, it is allowed a sulphur content of 0,015 % - 0,030; for polishability, it is suggested a controlled sulphur content of max 0,015 %

ai	25-745 ir tress-relieving	870-840 cooling 15 °C/h to 590, then air		750-7	00
mpering St	tress-relieving	to 590 then air	in int with sta	,	
+{	SR		joint with stee carbon C	<i>el</i> rMo alloyed	stainless
st cooling ai			cosmetic well		E309 – E308
st ai	650 2 cooling a r	650 200 cooling air r	650 200 cooling air r	650 200 E60 xx E cooling air cosmetic we r E410	650 200 E60 xx E8018-B 2 cooling air cosmetic welding

Chemical treatment - Pickling (20 - 50% HNO₃) hot or cold

Mechanical properties

Heat-treated material EN 10088-3: 2005 in conditions 1C, 1E, 1D, 1X, 1G, 2D

size		Testing at ro	om temperature				
mm		R	Rp 0.2	A %	Kv +20 °C	HB ^{a)}	^{a)} for information only
from	to	N/mm ²	N/mm ² min	min	J min	max	
		730 max				220	+A annealed material
	160	650-850	450	15	25		+QT650 quenched and tempered

Bright bars of heat-treated material EN 10088-3: 2005 in conditions 2H, 2B, 2G, 2P

size		Testing at roor	m temperature				
mm		R	HB ^{a)}	R	Rp 0.2	A %	Kv +20 °C
from	to	N/mm ² max	max	N/mm ²	N/mm ² min	min	J min
	10 ^{b)}	880	280	700-1000	550	9	
10	16	880	280	700-1000	500	9	
16	40	800	250	650-930	450	10	25
40	63	760	230	650-880	450	10	25
63	160	730	220	650-850	450	15	25
		+A annealed r	naterial	+QT650 qu	enched and ten	npered	material

a) for information only

b) in the range of 1 mm < d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order

Forged	EN 10250-4	: 2001											
size		Testing	g at roon	n temper	ature								
mm		R		Rp 0.2		A %	H	(v +20 °C	HB				
from	to	N/mm ²	2	N/mm ²	min	min		J min	ma	х			
		730 m	ax						220)	+A anr	nealed	
	160	650-85	50	450		15	2	25			+QT65	0 quenched and t	empered
Table o	of tempering	values at	room ter	nperatur	e on roui	nds of Ø	10 mm a	after quen	ching at	980°C	in oil		
R	N/mm ²	1490	1450	1420	1410	1430	1450	1420	1150	860	740	690	
Rp 0.2	N/mm ²	1210	1170	1150	1150	1160	1180	1140	870	650	550	500	
A	%	10.8	10.8	10.9	12.0	12.5	13.0	16.0	16.5	18.0	20.0	21.5	
Kv	J	35	40	36	29	28	27	28	30	41	49	100	
Temper	ring ° C	200	250	300	350	400	450	500	550	600	650	700	
Transit	ion-curve de	termined	with Kv.	Material	quenche	ed at 970	°C in oli						
Average	e J	6	16	26	50	80	120	140	150	170	temper	ring at 790 °C	690
Average	e J	5	12	18	26	50	84	110	114	140	temper	ring at 665 °C	820
Averag	e J	4	6	8	14	26	36	76	78	120	temper	ring at 595 °C	950
Tests a	t °C	-160	-120	-80	-40	0	+40	+80	+100	+200	tensile	strenght	N/mm

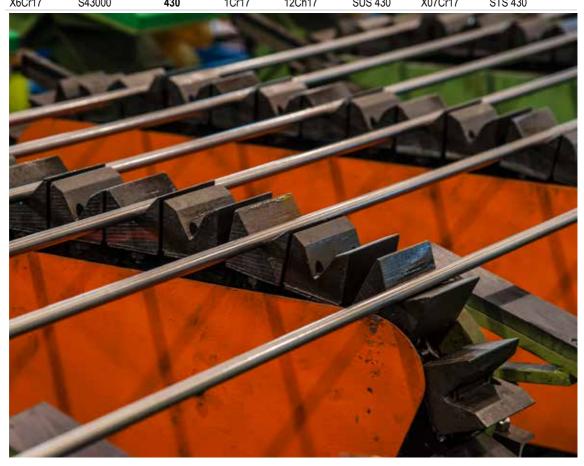
X12Cr13	3 n° 1.4006 m	artensitic s	stainless stee						Luc	efin Group
Effect of	f cold-working	(hot-rolled	+A+C). Appro	oximate value	es					
R	N/mm ²	580	650	700	750	790	800	850	920	1050
Rp 0.2	N/mm ²	380	500	580	600	690	720	780	810	900
A	%	20	10	8	8	8	8	8	8	7
Reduction	on %	0	10	20	30	40	50	60	70	80
Minimu	m values at hig	h tempera	atures on que	enched and t	empered	d material EN	10088-3: 20)5		
Rp 0.2	N/mm ²	420	410	400	385	365	355	305		+QT 650
Test at	°C	100	150	200	250	300	350	400		
Therma	I expansion	10 ⁻⁶ • K	1	•	10.5	11.0	11.5	12.0		
Modulu	s of elasticity	longitudi	nal GPa	215	212	205	200	190		
Poissor	n number	V		0.235	0.210					
Electric	al resistivity	$\Omega \bullet mm^2$	²/m	0.60						
Electric	al conductivity	Siemens	s∙m/mm²	1.67						
Specific	c heat		460							
Density	1	Kg/dm ³		7.70						
Therma	I conductivity		W/(m∙K)	30						
Relative	e magnetic peri	neability	μr	900 ¹⁾						
°C				20	100	200	300	400		
	nbol ► indicates 00 for material i						°C			
Corrosi	on resistance		Atmospheri	с		Chemical			x petroleum	, gasoline,
Fresh w	vater		industrial	marine		medium	oxidizing	reducing	alcohol, am	monia,
x						X			mercury, for	bc
Magnet	ic		yes							
Machin	ability		good on an	nealed and g	uenche	d and temper	ed			
Harden	ing		by quenchir	ng		·				
Service	temperature in	air	continuous	service up to	705 °C	; intermittent	service up to	815 °C		
Europe			USA	China		ussia	Japan	India		olic of Korea
EN X12Cr1:	UNS 3 S41000	1	ASTM 410	GB 1Cr12		OST 2Ch13	JIS SUS 410	IS X12Cr12	KS STS 4	10
A12011	5 541000	1	410	10112	14	0113	303 410	A120112	3134	10



Qualit Numbe			Cr17 016			Ferritic Stainless St	teel		al card 2014 n Group
Chem	ical con			,					
C%		Si%	Mn%	P%	S%	(o a)	Cr%		
max		max	max	max	ma	ах			
0,08		1,00	1,00	0,040	0,0)30	16,0-18,0	EN 100	88-1: 2005
± 0.01		+ 0.05	+ 0.03	+ 0.00)5 ± (0.005	± 0.2		
		is are allowed olishability, it is su	uggested a con	trolled sulphu	r content of max	0,015 %			
Temp	erature	°C							
	g range	Hot-forming	Recrystal +RA		+4	-	MMA welding		ectrodes ealing after v
1510-1	425	1120-850	810-700 c	ooling to 300,	then air 85 air	0-750	200	800	-750
Isothe		Quenching	Temperin	g			joint with stee		
anneal	-	+Q	+T					rMo alloyed	
not suit	able	not suitable	not suitab	е			E60 xx E cosmetic well E430	8018-B 2 ding	E309 – E30
Heat-tr size		roperties terial EN 10088- Testing at roor	n temperature						
mm		R	Rp 0.2	A %	Kv +20 °C	HB ^{a)}	a) for informat	ion only	
from	to	N/mm ²	N/mm ² min	min	J min	max			
	100	400-630	240	20		200	+A annealed	material	
Bright	bars of he	eat-treated mate	rial EN 10088-	3: 2005 in cor	ditions 2H, 2B,	2G, 2P			
size		Testing at roor							
mm		R	HB			R	Rp 0.2	A %	Kv +20 °C
from	to	N/mm ² max	max			N/mm ²	N/mm ² min	min	J min
40	10 ^{b)}					500-750	320	8	
10	16					480-750	300	8	
16 40	40 63					400-700	240	15 15	
40 63	100					400-700	240	20	
00	100					+A anneale		20	
^{b)} in the thickne	range of ss have to	1 mm <u><</u> d < 5 mm be agreed at the	n, values are va e time of reques	lid only for rou at and order	unds – the mech		es of non round ba	rs of < 5 m	im of
	I EN 1025		•						
			n tomporatura						
size		Testing at roor	in temperature						
size mm		R	Rp 0.2	A %	Kv +20 °C	HB			
	to			A% min	Kv +20 ℃ J min	HB max			

					Jmin	max				
	100	400-630	240			200	+A ann	ealed mat	terial	
Effect of	cold-wor	king (hot-rolle	d +RA+C). Appr	oximate values						
R	N/mm ²	550	620	680	700	720	770	790	820	860
Rp 0.2	N/mm ²	320	500	590	620	650	680	700	750	800
A	%	22	11	10	9	9	9	9	9	9
Reductio	n %	0	10	20	30	40	50	60	70	75
Minimun	n values	at high tempe	ratures EN 100	88-3: 2005						
Rp 0.2	N/mm ²	220	215	210	205	200	195	190	+A ann	ealed
Test at	°C	100	150	200	250	300	350	400		

X6Cr17 nº 1.40	16 ferritic steel							Lu	cefin Group
Thermal expans	ion 10 ⁻⁶ • k	(-1	•	10.0	10.5	10.5	10.5	11.0	12.0
Modulus of elast	ticity longitud	dinal GPa	220	215	210	205	195		
Poisson number	r v		0.144	0.138					
Electrical resisti	vity Ω.mm	n²/m	0.60		0.77		0.93	1.05	1.25
Electrical condu	ctivity Siemer	ls∙m/mm²	1.67						
Specific heat	J/(Kg∙k	()	460		495		570	660	760
Density	Kg/dm ³		7.75						
Thermal conduc	tivity	W/(m∙K)	25						
Relative magnet	ic permeability	μr	600-1000 ·	~					
°C			20	100	200	300	400	600	800
The symbol ► inc	dicates between	20 °C and 10	00 °C, 20 °C	and 200 °	С				
Corrosion resist	ance	Atmospheri	C		Chemical				ol, food,
Fresh water		industrial	mar	rine	medium	oxidizing	reducing	0	ents, weak
X		X			X	X		organi	c acids
Magnetic		yes							
Machinability		good							
Hardening		cold-drawin	g and other o	cold plastic	deformatio	ns			
Service tempera	ture in air	up to 800 °	C continuous	s service a	nd up to 87	5 °C intermi	ttent service		
	ISA NS	USA ASTM	China GB	Russi GOST	a Ja Jis	apan S	India IS	Repu KS	blic of Korea
X6Cr17 S	43000	430	1Cr17	12Ch1	7 S	US 430	X07Cr17	STS 4	30





Quality	X20Cr13	Martensitic	Technical card 2014
Number	1.4021	Stainless Steel	Lucefin Group

Chemical composition

C% Si% Mn%		Mn%	P%	S% a)	Cr%	
	max	max	max	max		
0,16-0,25	1,00	1,50	0,040	0,015	12,0-14,0	EN 10088-1: 2005
± 0.01	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.15	

Product deviations are allowed

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Temperature °	С				
Melting range	Hot-forming	Recrystallization +RA	Soft annealing +A	Full annealing	MMA welding – AWS electrodes pre-heating annealing after w.
1510-1460	1200-930	not suitable	825-745 air	900-870 cooling 15 °C/h to 590,	250-200 750
Isothermal annealing +I	Quenching +Q	Tempering +T	Stress-relieving +SR	then air	<i>joint with steel</i> carbon CrMo alloyed stainless
885-830	1050-950	700-650	250-150		E60 xx E8018-B 2 E309
controlled cooling	oil/polymer/air	fast cooling	air		cosmetic welding
to 705, then air	(HRC 46 ~)	in air			E420 – E410
Transformation ter	nperature during	heating Ac1 ~ 790, Ac3	a ~ 850 and during co	oling Ms ~ 240, Mf	~ 90

Chemical treatment - Pickling (20 - 50% HNO₃) hot or cold

Mechanical properties

Heat-treated material EN 10088-3: 2005 in conditions 1C, 1E, 1D, 1X, 1G, 2D

°C HB a) a) for information only max
max
230 +A annealed
+QT700 quenched and tempered
+QT800 quenched and tempered
_

Bright bars of heat-treated material EN 10088-3: 2005 in conditions 2H, 2B, 2G, 2P

size		Testing at roo	m temperature				
mm		R	HB ^{a)}	R	Rp 0.2	A %	Kv +20 °C
from	to	N/mm ² max	max	N/mm ²	N/mm ² N/mm ² mir	n min	J min
	10 ^{b)}	910	290	750-10	000 600	8	
10	16	910	290	750-10	00 550	8	
16	40	850	260	700-95	50 500	10	25
40	63	800	230	700-90	0 500	12	25
63	160	760	220	700-85	50 500	13	25
		+A annealed r	naterial	+QT70	0 quenched and ter	npered ma	aterial

^{a)} for information only

^{b)} in the range of 1 mm \leq d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order

Forged	EN 10250-	4: 2001									
size		Testing at	room temp	erature							
mm		R	Rp	0.2	A %	Kv +20 °0	C HB				
from	to	N/mm ²	N/mr	n² min	min	J min	max				
		760 max					230		+A annealed	[
	160	700-850	500		13	25			+QT700 que	nched and	tempered-
	160	800-950	600		12	20			+QT800 que	nched and	tempered
Table o	f temperin	g values at	room temp	erature on	rounds of Ø	10 mm after	quenching	at 970°C	C in oil		
R	N/mm ²	1650	1550	1540	1530	1530	1500	1200	900	790	600
Rp 0.2	N/mm ²	1320	1280	1260	1250	1230	1180	980	680	600	560
A	%	12	11	10.5	10.5	11	12	15	17	18	20
Kv	J	25	22	18	12	10	12	18	32	36	60
Temper	ing °C	200	300	350	400	450	500	550	600	650	700
Effect o	f cold-worl	king (hot-ro	lled +A+C)	. Approxim	ate values						
R	N/mm ²	580	650	670	680	685	690	720	745	760	
п	1 1/11111										

X20Cr13 nº 1.4021 martensitic stainless steel

R	N/mm ²	760	810	830	840	855	870	880	895
Rp 0.2	N/mm ²	570	740	770	780	795	800	820	830
A	%	18	16	15	15	14	13	12	11
Reductio	on %	0	8	10	12	14	16	18	20
Minimu	m values at hig	gh tempera	tures EN 1	0088-3: 20	05				
Rp 0.2	N/mm ²	460	445	430	415	395	365	330	material +QT700
Rp 0.2	N/mm ²	515	495	475	460	440	405	355	material +QT800
Test at	°C	100	150	200	250	300	350	400	
Therma	l expansion	10 ⁻⁶ •	K-1	•	10.5	11.0	11.5	12.0	
Modulu	s of elasticity	longitu	idinal GPa	215	212	205	200	190	
Poissor	n number	v		0.235	0.210				
Electric	al resistivity	Ω•m	m²/m	0.60					
Electric	al conductivity	Sieme	ns•m/mm²	1.67					
Specific	c heat	J/(Kg∙	K)	460					
Density		Kg/dm	3	7.70					
Therma	I conductivity		W/(m∙K)	30		31			
Relative	e magnetic peri	meability	μr	950 ¹⁾					
°C				20	100	200	300	400	

¹⁾ max 950 for full annealed material

Corrosion I	resistance	Atmospher	iC	Chemi	cal		x aggressive		
Fresh water		industrial	marine	mediui	m oxidizing	reducing	atmosphere lacking		
X						chlorine-derived substances			
Magnetic		yes							
Machinabil	ity	good	good						
Hardening		by quenching							
Service ten	nperature in air	continuous	service up to	650 °C; intermi	ttent service up to	o 750 °C			
Europe	USA	USA	China	Russia	Japan	India	Republic of Korea		
EN	UNS	ASTM	GB	GOST	JIS	IS	KS		
X20Cr13	S42000	(420)	2Cr13	20Ch13	SUS 420J1		STS 420J1		



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Quality		K30Cr13		Martens		Technical card 2014		
Number		1.4028		Stainles	s Steel	Lucefin Group		
Chemical of	composition							
C%	Si%	Mn%	P%	S% a)	Cr%			
	max	max	max	max				
0,26-0,35	1,00	1,50	0,040	0,015	12,0-14,0	EN 10088-1: 2005		
± 0.02	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.15			

Product deviations are allowed

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Melting range	Hot-forming	Recrystallization +RA	Soft annealing +A	Full annealing	MMA weldi pre-heating	ng – AWS elec anne	trodes aling after w.
1490-1480	1200-930	not suitable	825-745 air	not suitable	300	750	
Isothermal annealing +I	Quenching +Q	Tempering +T	Tempering +T	Stress- relieving +SR	<i>joint with ste</i> carbon	ee <i>l</i> CrMo alloyed	stainless
not suitable	1080-980 oil/air	200-150 fast cooling in air (HRC 50 ~)	675-625 air (HRC 24-31)	300-200 air	E70 xx cosmetic we E309 – E420	U	E309 – E308

Chemical treatment - Pickling (20 - 50% HNO₃) hot or cold

Mechanical properties

size		Testing at ro					
mm		R	Rp 0.2	A %	Kv +20 °C	HB a)	^{a)} for information only
from	to	N/mm ²	N/mm ² min	min	J min	max	
		800 max				245	+A annealed material
	160	850-1000	650	10	15		+QT850 guenched and tempered

Bright bars of heat-treated material EN 10088-3: 2005 in conditions 2H, 2B, 2G, 2P

size		Testing at roor	m temperature				
mm		R	HB ^{a)}	R	Rp 0.2	A %	Kv +20 °C
from	to	N/mm ² max	max	N/mm ²	N/mm ² min	min	J min
	10 ^{b)}	950	305	900-1050	700	7	
10	16	950	305	900-1150	650	7	
16	40	900	280	850-1100	650	9	15
40	63	840	260	850-1050	650	9	15
63	160	800	245	850-1000	650	10	15
		+A annealed n	naterial	+QT850 (quenched and ten	npered	

^{a)} for information only

^{b)} in the range of 1 mm \leq d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order

Forged	I EN 10250	-4: 2001									
size		Testing at	room tempe	rature							
mm		R	Rp 0.2	. 1	۹%	Kv +20 °C	HB				
from	to	N/mm ²	N/mm ²	min r	nin	J min	max				
		800 max					245	+A	annealed m	aterial	
	160	850-1000	650	1	0			+Q	T850 quencl	hed and ter	npered
Table o	of temperir	ng values at	room tempe	erature or	n rounds of Q	ð 10 mm after	quenching	at 1000°C	in oil		
R	N/mm ²	1700	1650	1630	1630	1620	1600	1350	1000	850	800
Rp 0.2	N/mm ²	1400	1380	1360	1350	1340	1300	1100	790	650	600
A	%	9	10	10	9	9	10	11	12	15	18
Kv	J	18	20	18	14	12	12	16	22	32	40
Temper	ring ° C	200	300	350	400	450	500	550	600	650	700
Effect o	of cold-wor	king (hot-ro	lled +A+C).	Approxin	nate values						
R	N/mm ²	700	780	850	900	950	1000				
Rp 0.2	N/mm ²	500	620	680	720	750	780	800	880	960	
A	%	20	13	12	11	11	11	10	10	10	
Reduct	ion %	0	10	20	30	40	50	60	70	80	

X30Cr13 n°	1.4028 ma	irtensitic s	stainless steel							Lucefin Group
Thermal exp	pansion	10 ⁻⁶ • K ⁻	1	•	10.5		11.0	11.5	12.0	12.6
Modulus of	elasticity	longitudi	nal GPa	215	212		205	200	190	
Poisson nu	mber	V		0.235	0.210)				
Electrical re	sistivity	$\Omega \cdot mm^2$	²/m	0.65						
Electrical co	onductivity	Siemens	s∙m/mm²	1.54						
Specific hea	at	J/(Kg∙K)		460						
Density		Kg/dm ³		7.70						
Thermal con	nductivity		W/(m∙K)	30						
Relative ma	gnetic perm	eability	μr	700-1000 ~						
°C				20	100		200	300	400	600
The symbol I	 indicates t 	petween 2	20 °C and 10	0 °C, 20 °C an	d 200 '	°C				
Corrosion r	esistance		Atmospheri	;		Chemica	I			x rust, diluted nitric
Fresh water			industrial	marine		medium	oxidiz	ing rea	lucing	acid, weak organic
x								•		acids
Magnetic			yes							
Machinabili	ty		excellent							
Hardening	•		by quenchin	g						
Service tem	perature in	air	continuous	service up to 65	50 °C; i	ntermitten	t service up	to 750 °C		
Europe	USA UNS		USA ASTM	China _{GB}	Rus	ssia	Japane	Ind IS	ia	Republic of Kore
X30Cr13	S42020		(420)	3Cr13		2h13	SUS 420		0Cr13)	STS 420J2
			. /					· · ·	/	



Quality	X39Cr13	Martensitic	Technical card 2014
Number	1.4031	Stainless Steel	Lucefin Group

Chemical composition

Chemical c	omposition					
C%	Si%	Mn%	P%	S% ^{a)}	Cr%	
	max	max	max	max		
0,36-0,42	1,00	1,00	0,040	0,015	12,5-14,5	EN 10088-1: 2005
± 0.02	+ 0.05	+ 0.03	+ 0.005	+ 0.003	± 0.15	

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %.

	erature	°C							
•	g range	Hot-forming	Recrystalliz +RA	ation	Soft annealing +A		MMA weldin	g – AWS electr annea	odes aling after w.
1480-14	470	1200-930	not		780 slow cooling		, Difficult; addr	ess qualified el	ectrodes
			suitable		to a 630 after air		producers		
Quencl +Q	hing		Tempering +T		Stress-relieving +SR	Stress-relieving +SR	<i>joint with ste</i> carbon	el CrMo alloyed	stainless
pre-hea	ating at 850	0, then 1025	700-650		180	550-200	E70 xx	E8015-B 2	E309-E308
cooling	oil/air		fast cooling		air	air	cosmetic wel	ding	
-			in air		(HRC 52)		E420		
Transfo	ormation te	mperature during	heating Ac1 ~ 8	325, Ac :	a ~ 930 and during c	ooling Ms ~ 255, N	lf ~ 105		
		ent - Pickling (20							
			,						
		roperties							
	eated mat			tions 1C	, 1E, 1D, 1X, 1G, 2I)			
size		Testing at roor							
mm		R	Rp 0.2	A %	Kv +20 °C	HB ^{a)}	a) for information	tion only	
	to	N/mm ²	Rp 0.2 N/mm ² min	A% min	Kv +20 °C J min	max		,	
			N/mm² min	min	J min		^{a)} for informative the second secon	,	
mm from	to 160	N/mm ²	•			max	+A annealed	,	pered
from	160	N/mm ² 800 max 800-1000 eat-treated mater	N/mm ² min 650 rial EN 10088-3	min 10	J min	max 245	+A annealed	material	pered
from Bright	160	N/mm ² 800 max 800-1000 eat-treated mater Testing at roor	N/mm² min 650 rial EN 10088-3 n temperature	min 10	J min	max 245 , 2G, 2P	+A annealed	material nched and temp	
from Bright size	160	N/mm ² 800 max 800-1000 eat-treated mater Testing at roor R	N/mm ² min 650 rial EN 10088-3	min 10	J min	max 245 , 2G, 2P R	+A annealed +QT800 quer Rp 0.2	material	bered Kv +20 °C
from	160	N/mm ² 800 max 800-1000 eat-treated mater Testing at roor	N/mm² min 650 rial EN 10088-3 n temperature	min 10	J min	max 245 , 2G, 2P	+A annealed +QT800 quer	material nched and temp	
from Bright size mm	160 bars of he	N/mm ² 800 max 800-1000 eat-treated mater Testing at roor R	N/mm ² min 650 rial EN 10088-3 n temperature HB ^{a)}	min 10	J min	max 245 , 2G, 2P R	+A annealed +QT800 quer Rp 0.2	material nched and temp A % min 7	Kv +20 °C
from Bright size mm from	160 bars of he	N/mm ² 800 max 800-1000 eat-treated mater Testing at roor R N/mm ² max	N/mm ² min 650 rial EN 10088-3 n temperature HB ^{a)} max	min 10	J min	max 245 , 2G, 2P R N/mm ²	+A annealed +QT800 quer Rp 0.2 N/mm ² min	material nched and temp A % min	Kv +20 °C
from Bright size mm from	160 bars of he to 10 ^{b)}	N/mm ² 800 max 800-1000 eat-treated mater Testing at roor R N/mm ² max 950	N/mm ² min 650 rial EN 10088-3 n temperature HB ^{a)} max 305	min 10	J min	max 245 , 2G, 2P R <u>N/mm²</u> 850-1100	+A annealed +QT800 ques Rp 0.2 N/mm ² min 700	material nched and temp A % min 7	Kv +20 °C
from Bright size mm from 10	160 bars of he to 10 ^{b)} 16	N/mm ² 800 max 800-1000 Eat-treated mater Testing at roor R N/mm ² max 950 950	N/mm ² min 650 rial EN 10088-3 n temperature HB ^{a)} max 305 305	min 10	J min	max 245 , 2G, 2P R <u>N/mm²</u> 850-1100 850-1100	+A annealed +QT800 quer Rp 0.2 N/mm ² min 700 700	material nched and temp A% min 7 7	Kv +20 °C J min
from Bright size mm from 10 16	160 bars of he to 10 ^{b)} 16 40	N/mm ² 800 max 800-1000 Eat-treated mater Testing at roor R N/mm ² max 950 950 900	N/mm ² min 650 rial EN 10088-3 n temperature HB ^{a)} max 305 305 280	min 10	J min	max 245 , 2G, 2P R <u>N/mm²</u> 850-1100 850-1100 800-1050	+A annealed +QT800 quer Rp 0.2 N/mm ² min 700 700 650	material nched and temp A% min 7 7 8	Kv +20 °C J min 12

^{a)} for information only

^{b)} in the range of 1 mm \leq d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order

size		Testing at	room temperature	;				Testing at room temperature												
mm		R	Rp 0.2	A %	Kv +20 °C	HB ^{a)}														
from	to	N/mm ²	N/mm ² min	min	J min	max														
						245	+A	annealed m	aterial											
a) for infe	ormation	only																		
		,	room temperature	on rounds of	Ø 10 mm after ou	enching at ?	1020 °C i	n oil												
Table o		,	room temperature		Ø 10 mm after qu 512	enching at 7 442	1020 °C i 381	n oil 336	327	286										
		ing values at		504		0			327 35	286 30										

X39Cr13 nº 1	1031 m	rtoncitio ot	ainlaga staal	1					Lucefin Group
V280112 II	.4031 1118	intensitic st	ainiess steel						Eucenn Group
Thermal expa	Insion	10 ⁻⁶ • K ⁻¹		►	10.5	11.0	11.5	i 1	2.0
Modulus of e	lasticity	longitudir	nal GPa	215	212	205	200	1	90
Poisson num	ber	V		0,27-0,30 ~					
Electrical res	istivity	$\Omega \cdot mm^2/$	′m	0.55					
Electrical cor	nductivity	Siemens	•m/mm ²	1.82					
Specific heat		J/(Kg•K)		460					
Density		Kg/dm ³		7.70					
Thermal cond	ductivity		W/(m∙K)	30					
Relative mag	netic perm	eability	μr	700-1000 ~					
°C				20	100	200	300	4	00
The symbol ►	indicates b	between 20	0°C and 10	00 °C, 20 °C an	d 200 °C	;			
Corrosion res	sistance		Atmospheric	0		Chemical			x corrosive plastic,
Fresh water			industrial	marine		medium	oxidizing	reducing	dilute nitric acid, weak
X							Ū	0	organic acids
Magnetic			yes						
Machinability	,		mean						
Hardening			by quenchin	Ig					
Service temp	erature in	air	continuous	service up to 62	20 °C; in	termittent se	rvice up to 735	5 °C	
Europe EN	USA UNS		USA ASTM	China GB	Russ GOST	ia J	apan S	India IS	Republic of Korea
X39Cr13	-		(420)	4Cr13	(40Ch	n13)		(X40Cr13)	
			· · ·			,		. ,	



Quality Number		X46Cr13 1.4034			ensitic Iless Steel	Technical card 2014 Lucefin Group
Chemical of	composition					
C%	Si%	Mn%	P%	S% a)	Cr%	
	max	max	max	max		
0,43-0,50	1,00	1,00	0,040	0,015	12,5-14,5	EN 10088-1: 2005
± 0.02	+ 0.05	+ 0.03	+ 0.005	+ 0.003	± 0.15	

Product deviations are allowed

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Melting range	Hot-forming	Recrystallization +RA	Soft annealing +A	MMA welding – AWS electrodes pre-heating annealing after w
1480-1470	1180-930	not suitable	850-750 slow cooling to 600, then air	250-200 750
Quenching +Q	Tempering +T	Stress-relieving +SR	Stress-relieving +SR after +C	joint with steel carbon CrMo alloyed stainless
1050-950 oil / air (HRC 50 ~)	700-650 air	200 fast cooling in air	650-600 furnace cooling	E70 xx E8016-B 2 E309-E308 cosmetic welding E420

Chemical treatment - Pickling (20 - 50% HNO₃) hot or cold

Mechanical properties

size		Testing at ro	om temperature				
mm		R	Rp 0.2	A %	Kv +20 °C	HB a)	^{a)} for information only
from	to	N/mm ²	N/mm ² min	min	J min	max	
		800 max				245	+A annealed material
	160	850-1000	650	10	12		+QT850 guenched and tempered

Bright bars of heat-treated material EN 10088-3: 2005 in conditions 2H, 2B, 2G, 2P

size		Testing at roor	m temperature				
mm		R	HB ^{a)}	R	Rp 0.2	A %	Kv +20 °C
from	to	N/mm ² max	max	N/mm ²	N/mm ² min	min	J min
	10 ^{b)}	950	305	900-1150	700	7	
10	16	950	305	900-1150	700	7	
16	40	900	280	850-1100	650	8	12
40	63	840	260	850-1000	650	8	12
63	160	800	245	850-1000	650	10	12
		+A annealed r	naterial	+QT850 c	uenched and temp	ered mate	erial

^{a)} for information only

^{b)} in the range of 1 mm \leq d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order

Forged	ł											
size		Testing a	at room ter	nperature								
mm		R	Rp	0.2	A %	Kv +	20 °C	HB ^{a)}				
from	to	N/mm ²	N/	mm² min	min	Jmi	'n	max				
								245	+A an	nealed ma	aterial	
^{a)} for in	formation o	nly										
Table (of temperin	g values a	at room tei	nperature	on rounds	of Ø 10 mr	n after qu	enching at	1000°C in	oil		
R	N/mm ²	1800	1700	1700	1690	1680	1640	1300	1000	840	750	
Rp 0.2	N/mm ²	1400	1320	1300	1300	1290	1250	1000	700	600	550	
A	%	6	8	8	9	9	10	11	13	16	16	
Κv	J	14	20	18	14	12	12	14	20	28	40	
Tempe	ring ° C	200	300	350	400	450	500	550	600	650	700	
Effect of	of cold-wor	king (hot-	rolled +A+	C). Approx	kimate valu	es						
R	N/mm ²		750	755	760	770	795	805	835	900	930	960
Reduct	ion %	0	5	6	8	10	15	18	20	25	30	36

A400113 II 1.4034	martensitic s	tainless steel						Lucefin Group
Thermal expansion	10 ⁻⁶ • K-	1	•	10.5	11.0)	11.5	12.0
Modulus of elasticity	longitudi	nal GPa	215	212	205		200	190
Poisson number	V		0.235					
Electrical resistivity	$\Omega \bullet mm^2$	/m	0.55					
Electrical conductivi	y Siemens	•m/mm ²	1.82					
Specific heat	J/(Kg•K)		460					
Density	Kg/dm ³		7.70					
Thermal conductivity	-	W/(m•K)	30					
Relative magnetic pe	rmeability	μr	700 ~					
°C			20	100	200		300	400
The symbols indicate		a hatuaan 20	°C and 100 %	0 00 00	and 200 °C			
The symbol Indicate	s temperatur	e between 20	C and TOU	C, 20 °C				
		Atmospheric		C, 20 °C	Chemical			,
Corrosion resistance				U, 20 °C		oxidizing	reducing	x rust, diluted nitric acid weak organic acids in
Corrosion resistance Fresh water		Atmospheric		U, 20 °C	Chemical		reducing	,
Corrosion resistance Fresh water x		Atmospheric		U, 20 °C	Chemical		reducing	weak organic acids in
Corrosion resistance Fresh water x Magnetic		Atmospheric industrial	marine		Chemical		reducing	weak organic acids in
Fresh water x Magnetic Machinability		Atmospheric <i>industrial</i> yes	marine		Chemical		reducing	weak organic acids in
Corrosion resistance Fresh water x Magnetic Machinability Hardening		Atmospheric industrial yes good after a by quenchin	marine		Chemical medium	oxidizing		weak organic acids in
Corrosion resistance Fresh water x Magnetic Machinability Hardening Service temperature Europe USA		Atmospheric industrial yes good after at by quenchin continuous s USA	marine nnealing g ervice up to 63 China	50 °C; ir Russia	Chemical medium	oxidizing	750 °C India	weak organic acids in the passive state
Corrosion resistance Fresh water x Magnetic Machinability Hardening Service temperature		Atmospheric industrial yes good after a by quenchin continuous s	<i>marine</i> nnealing g ervice up to 63	50 °C; ir	Chemical medium atermittent se a Jap JIS	oxidizing	750 °C	weak organic acids in the passive state



Quali	tv		1.4034	DE				Martensiti	C	Technic	al card 2014
Numbe			(1.4034)					Stainless	Steel	Lucefi	n Group
Chem	nical com	nosition									
C%		Si%	Mn	%	P%		S%		Cr%		
0 /0		nax	ma		max		070				
0,43-0,	46 ⁻	,00	1,0	0	0,040)	0,018	-0.026	12,5-14,5	EN 100	88-1: 2005
± 0.02	-	- 0.05	+ 0	.03	+ 0.0	05	<u>+</u> 0.00)5	± 0.15		
Non-me	t deviations etallic inclus e structure r	ions K3 m	ax 50, only		les; DIN 5060 ard	02 standard					
Temp	erature °	С									
Melting	g range	Hot-f	orming	Recry +RA	stallization	+A	nealing	-	MMA welc pre-heatin	ding – AWS g ar	electrodes nnealing after v
1480-1	470	1050	-930	not su	itable		0 750 s then ai	low cooling r	250-200	75	50-700
	ar annealir		ching	Temp	ering		-relieviı	ng	joint with s		
`	oidized) +A		000	+T	0	+SR				CrMo alloyed	stainless
	oling furnac , then air	e 1030 oil/a		650-60 fast co		200 air			E70 xx cosmetic v	E8016-B 2 velding	E309-E308
	, men an ax 210)	011/8		in air	Joiling	(HRC 5	52)		E420	aciuny	
		nt • Picklir	ng (20 - 50) hot or cold		-,				
			• •		steel X46Cr	13 No. 1 403	84)				
					ditions 1C, 1						
size	satsa male		t room terr			L, ID, IA,	. 0, 20				
mm		R	Rp		A%	Kv +20)°C	HB a)	a) for inforr	mation only	
from	to	N/mm ²		m² min	min	J min		max		- 1	
		800 max						245		ed material	
	160	850-1000	650		10	12			+QT850 q	uenching an	d tempering
Bright	bars of hea	t-treated	material E	EN 1008	8-3: 2005 in	conditions 2	H, 2B, 2	2G, 2P			
size		Testing a	t room terr	perature							
mm		R	HB					R	Rp 0.2	A %	Kv +20 °C
from	to		nax max					N/mm ²	N/mm ² m		J min
10	10 ^{b)}	950	305					900-1150	700	7	
10	16	950	305					900-1150	700	7	10
16 40	40 63	900 840	280 260					850-1100 850-1000	650 650	8	12 12
40 63	160	800	260					850-1000	650	10	12
00	100		led materi						enched and te		12
^{a)} for in	formation or			u 1						mporou	
^{b)} in the	range of 1	 mm <u><</u> d < :			alid only for est and order		e mecha	anical proper	ies of non rou	und bars of <	5 mm of
Forged	d										
i oigee		Testing a	t room terr								
		R	Rp		A %	Kv +20	0°C	HB ^{a)}			
size mm		N/mm ²	N/mi	m² min	min	J min		max		ا - ارتبا میں او	
size mm	to							245	+A anneale	u material	
size mm from		nlv				60.40	-0	an alalis is at t	00000 1		
size mm from ª) for in	formation o	,				TT 1/1 111 mm	atter qu	ienching at 7			
size mm from ^{a)} for in Table (formation of of temperin	g values a			e on rounds o		1640		1000	Q/O 70	50
size mm from ^{a)} for in Table o R	formation or of temperin N/mm ²	g values a 1800	1700	1700	1690	1680	1640	1300		840 75 600 55	
size mm from ^{a)} for in Table (R Rp 0.2	formation or of temperin N/mm ² N/mm ²	g values a 1800 1400	1700 1320	1700 1300	1690 1300	1680 1290	1250	1300 1000	700	600 55	50
size mm from ^{a)} for in Table o R Rp 0.2 A	formation or of temperin N/mm ² N/mm ² %	g values a 1800 1400 6	1700 1320 8	1700 1300 8	1690 1300 9	1680 1290 9	1250 10	1300 1000 11	700 13	600 55 16 16	50 S
size mm from ^{a)} for in Table o R Rp 0.2 A Kv	formation or of temperin N/mm ² N/mm ² % J	g values a 1800 1400	1700 1320 8 20	1700 1300 8 18	1690 1300 9 14	1680 1290	1250	1300 1000	700 13 20	600 55 16 16 28 40	50 5)
size mm from ^{a)} for in Table o R Rp 0.2 A Kv Tempe	formation or of temperin N/mm ² N/mm ² % J ring ° C	g values a 1800 1400 6 14 200	1700 1320 8 20 300	1700 1300 8 18 350	1690 1300 9 14 400	1680 1290 9 12 450	1250 10 12	1300 1000 11 14	700 13 20	600 55 16 16 28 40	50 5)
size mm from ^{a)} for in Table o R Rp 0.2 A Kv Tempe	formation or of temperin N/mm ² N/mm ² % J ring ° C	g values a 1800 1400 6 14 200 king (hot-r	1700 1320 8 20 300	1700 1300 8 18 350	1690 1300 9 14	1680 1290 9 12 450	1250 10 12	1300 1000 11 14	700 13 20 600	600 55 16 16 28 40	50 5 0 00

nº 1.4034 DE martensi	tic stainless steel						Lucefin Group
Thermal expansion	10 ⁻⁶ • K ⁻¹	►		11.0		11.7	12.3
Modulus of elasticity	longitudinal GPa	206					
Poisson number	V	0.235					
Electrical resistivity	$\Omega \bullet mm^2/m$	0.60					
Electrical conductivity	Siemens.m/mm2	1.82					
Specific heat	J/(Kg•K)	460					
Density	Kg/dm ³	7.70					
Thermal conductivity	W/(m•K)	30					
Relative magnetic perm	eability µr	700 ~					
°C		20	100	200	300	400	600
The symbol ► indicates to	emperatures between 2	20 °C and 200) °C, 20 °C a	nd 400 °C			
Corrosion resistance	Atmosphe	ric		Chemical		ĺ	x plastics, weak
Fresh water	industrial	mari	ne	medium	oxidizing	reducing	organic acids,
x						-	petroleum, gasoline
Magnetic	yes						
Machinability	good						
Hardening	by guench	ning					
Service temperature in	air continuou	s service up t	o 650 °C; inte	ermittent ser	vice up to 75	0°C	
Europe USA	USA ASTM	China GB	Russia GOST	Jap JIS	an li	ndia	Republic of Korea



Qualit	y	х	46CrS13				Marter			Technical	card 2014
Number	r	1	.4035				Stainle	ess Stee		Lucefin	Group
Chem	ical con	nposition									
C%		Si%	Mn%	Р	%	S%	þ	Cr%			
		max	max	r	nax					_	
0,43-0,5	50	1,00	2,00	0	,040	0,1	5-0,35	12,5	-14,0	EN 10088	-1: 2005
± 0.02		+ 0.05	+ 0.04	+	0.005	± ().02	± 0.1	15		
Product	deviation	is are allowed									
Tempe	erature	°C									
Melting		Hot-forming	g Recrystal +RA	lization	Sof +A	t annealing			1MA welding re-heating	g – AWS ele annea	ctrodes ling after w.
1480-14	160	1100-930	not suitabl	е		-750 slow coo 00, then air	ling	'n	ot recomme		0
Quench	ning		Temperin	g		ess-relieving		-	oint with stee		
+Q	_		+T		+SF			C	arbon	CrMo alloyed	stainless
1050-95	50		675-625	~	200				ocmotio wel	dina	
oil / air			fast coolin in air	y	air				osmetic weld	ung	
Transfo	rmation te	emperature duri	ng heating Ac1	~ 805, Ac	:3 ~ 87	70 and during	cooling Ms	~ 280. M	f ~ 130		
			20 - 50% HNO3			J					
Mecha	anical n	roperties									
			8-3: 2005 in con	ditions 1	C, 1E.	1D, 1X. 1G. 2	D				
size			om temperature		_ , · _ ,	-,,, .					
mm		R	Rp 0.2	A %		Kv +20 °C	HB a)	a)	for informat	ion only	
from	to	N/mm ²	N/mm ² min	min		J min	max				
	63	800 max					245	+	A annealed	material	
Bright I	bars of h		terial EN 1008		in co	nditions 2H, 2I	3, 2G, 2P				
size			om temperature)							
mm	4.0	R N/mm2 mm	HB ^{a)}				R N/mm2		Rp 0.2	A %	Kv +20 °C
from	10 ^{b)}	N/mm ² ma: 880	x max 280				N/mm ²	ſ	N/mm² min	min	J min
10	10 %	880	280								
16	40	800	250								
40	63	760	230								
		+A annealed	d material								
^{b)} in the	be agree	nm <u>´<</u> d < 5 mm	, values are valio request and orc		round	ls – the mecha	anical prope	rties of n	on round ba	rs of < 5 mm	of thickness
rorgea size		Testing at ro	om temperature	,							
mm		R	Rp 0.2	, A%		Kv +20 °C	HB a)				
from	to	N/mm ²	N/mm ² min	min		J min	max				
							245	•	A annealed	material	
^{a)} for inf	ormation	only									
			om temperature ues are quoted	on roun	ds of (ð 10 mm after	quenching	at 1000	°C in oil		
R	N/mm ²		1700 170		690	1680	1640	1300	1000	840	750
Rp 0.2	N/mm ²		1320 130		300	1290	1250	1000	700	600	550
Α	%		8 8	9		9	10	11	13	16	16
Kv	J		20 18		4	12	12	14	20	28	40
Temper	0		300 350		00	450	500	550	600	650	700
		• (d +A+C). Appro								
R	N/mm	² 640	710 740	7	60	830	840	860	880	895	920
Reducti			8 10		5	18	20	22	24	26	30

Α	%	6	8	8	9	9	10	11	13	16	16	
Κv	J	14	20	18	14	12	12	14	20	28	40	
Tempe	ering °C	200	300	350	400	450	500	550	600	650	700	
Effect	of cold-w	orking (ho	t-rolled +A+C	C). Approxim	ate values							
R	N/mr	n² 640	710	740	760	830	840	860	880	895	920	
Reduc	tion %	0	8	10	15	18	20	22	24	26	30	

X46CrS13 nº 1.4035 m	artensitic stainless ste	el					Lucefin Group
Thermal expansion	10 ⁻⁶ ∙ K ⁻¹	•	10.5	11.0	11.5	12.0	
Modulus of elasticity	longitudinal GPa	215	212	205	200	190	
Poisson number	V	0.235					
Electrical resistivity	$\Omega \bullet mm^2/m$	0.55					
Electrical conductivity	Siemens•m/mm ²	1.82					
Specific heat	J/(Kg∙K)	460					
Density	Kg/dm ³	7.70					
Thermal conductivity	W/(m∙K)	30					
Relative magnetic perm	eability µr	700-1000 ~					
°C		20	100	200	300	400	
The symbol ► indicates te	emperature between 2	0 °C and 100	°C, 20 °C an	d 200 °C			
Corrosion resistance	Atmospher	ic	Ch	iemical			x weak acid, steam,
Fresh water	industrial	marine	me	edium ox	ridizing redu		ammonia, petroleum
X							organic material
Magnetic	yes						
Machinability	high						
Hardening	by quenchi	ng					
Service temperature in	air continuous	service up to 6	00 °C; interm	ittent service	up to 700 °C		
Europe USA	USA	China	Russia	Japan	India		Republic of Korea
EN UNS X46CrS13	ASTM	GB	GOST	JIS	IS		KS





Qualit			X17CrNi1	5-2				lartensitic	44.41			al card 2014
Numbe	r		1.4057				5	tainless S	leel		Lucefin	Group
Chem	ical com	nposition										
C%	S	i% lax	Mn% max	P% max	S% ma		Cr	%	Ni%			
0,12-0,	22 1	,00	1,50	0,040	0,0	15	15	,0-17,0	1,50-2	2,50	EN 10088	8-1: 2005
± 0.01		0.05	+ 0.04	+ 0.005	,	.003		0.20	+ 0.07			
^{a)} for im	nproving m	s are allowed achinability, it f max 0,015 %		a controlled	sulphur cont	ent of 0,	015 %	- 0,030 %;			it is suggest	ed a controll
Temp	erature	°C										
	g range	Hot-formin		ecrystallizatio RA	on Softa +A	nnealin	9			weldin eating	i g – AWS ele anne	ectrodes aling after w.
1510-1	430	1200-930	nc รเ	ot iitable		0 furna h to 600			350	U	750	0
lsotheı anneal		Quenchin +Q	g To +1	empering F	Stress +SR	-relievi	ng		<i>joint</i> carbo	<i>with ste</i> n	e <i>l</i> CrMo alloyed	stainless
not suit	table	1030-980 oil / polyme (HRC 45 ~	er/air fa	70-600 st cooling air	250-21 air	0				E309 le <i>tic we</i> l special	E8016-B 2 Iding	E309-E308
		mperature du	, iring heatin	g Ac 1 ~ 725, A HNO ₃) hot or		d during	cooling	g Ms ~ 145		opoolai		
		roperties										
			88-3: 2005	in conditions	IC, 1E, 1D.	1X, 1G.	2D					
size		Testing at			-, , ,	, -,						
mm		R	Rp 0		K	v +20 °	СН	B a)	^{a)} for	informa	tion only	
from	to	N/mm ²	N/mm			min		nax				
-		950 max			-			95	+A ar	nnealed	material	
	60	800-950	600	14	2	5	_				nched and te	mpered
60	160	800-950	600	12	2						780-800 °C)	P - 24
	60	900-1050	700	12	2						nched and te	mpered
60	160	900-1050	700	10	1						600-670)	
					F in conditio	-		20		- (
-	bars of ne			10088-3: 200	5 In conditio	ns ZH, Z	2B, 2G,	28				
size		Testing at		erature					D.,		A 0/	K 00.00
mm	4-	R N/mm2 m	HB a)				R		Rp		A %	Kv +20 °C
from	to	N/mm ² m						/mm ²		n² min	min	J min
10	10 b)	1050	330					50-1100	750		7	
10	16	1050	330					50-1100	700		7	05
16	40	1000	310					00-1050	650		9	25
40	63	850	295					00-1000	650		12	25
63	160	850	295					00-950 OT 000 mm	650	L	12	20
^{b)} in the			mm, value:	s are valid only	for rounds	- the me					pered materia pars of < 5 m	
Foraed	EN 10250)-4: 2001										
size		Testing at I	room temp	erature								
mm		R	Rp 0.2	A%	A%	Kv ⊦	-20 °C	Kv +20 °C	: НВ			
from	to	N/mm ²	N/mm ² r		min (T)		in (L)	J min (T)				
	250	1000 max					. /		295	+A ar	nnealed	
	250	800-950	600	10	8	20		15			00 quenched	and temper
	250	900-1050	700	10	8	15		10			00 quenched	
					-		0 mm -		hing of 4			
Table				erature on hot 1460								000
					1440	1400	136	o∪ 12	250	1080	910	800
R	N/mm ²	1580	1490				400		0	000	700	600
R Rp 0.2	N/mm ² N/mm ²	1290	1240	1220	1190	1130	106	60 98		860	780	690 10
R	N/mm ²						100 15 18		6	860 17 30	780 18 34	690 19 38

X17CrNi1	6-2 n° 1.40	57 marten	sitic stainless	steel					Luce	fin Group
Effect of c	old-working	(hot-rolled	d +QT+C). App	roximate values	6					
R	N/mm ²	836	900	910	930	945	965	990	1000	1020
Rp 0.2	N/mm ²	720	754	792	820	804	880	910	920	950
Α	%	23	18	16	14	14	14	14	13	13
Reductior	1 %	0	7	8	10	12	14	17	18	20
Minimum	values at hi	gh tempe	ratures, quenc	hed and tempe	red ma	terial EN 100	88-3: 2005			
Rp 0.2	N/mm ²	515	495	475	460	440	405	355	+QT800	
Rp 0.2	N/mm ²	565	525	505	490	470	430	375	+QT900	
Test at	°C	100	150	200	250	300	350	400		
Thermal	expansion	10 ⁻⁶ • I	K -1	•	10.0	10.5	10.5	10.5		
Modulus	of elasticity	longitu	dinal GPa	215	212	205	200	190		
Poisson	number	V		0.144	0.13	8				
Electrical	resistivity	Ω•mr	m²/m	0.70						
Electrical	conductivity	y Siemei	ns∙m/mm²	1.43						
Specific I	neat	J/(Kg∙l	K)	460		500		590	720	860
Density		Kg/dm	3	7.70						
	conductivity		W/(m∙K)	25						
	magnetic per	meability	μr	700-1100 ~						
°C				20	100	200	300	400	600	800
The symb	ol ► indicates	temperat	ure between 20) °C and 100 °C	C, 20 °(C and 200 °C)			
Corrosio	n resistance		Atmospheric			Chemical				cid, alkaline
Fresh wat	er		industrial	marine		medium	oxidizing	reducing	water an	d well wate
x			X	x		X				
Magnetic			yes							
Machinat	oility		good in annea	aled condition, r	nean fo	or quenched a	and tempered	I material		
Hardenin	g		by quenching							
Service to	emperature i	n air	continuous se	ervice up to 750	°C; int	ermittent serv	vice up to 800	O° (

Service temp	erature in an								
Europe	USA	USA	China	Russia	Japan	India	Republic of Korea		
EN	UNS	ASTM	GB	GOST	JIS	IS	KS		
X17CrNi16-2	S43100	431	1Cr17Ni2	14Ch17N2	SUS 431	15Cr16Ni2	STS 431		





	ity		X14CrMoS	17			artensitic		Technie	cal card 2014
Numbe	er		1.4104			Sta	ainless S	teel	Lucefi	in Group
Chen	nical co	mpositio	n							
С%		Si% max	Mn% max	P% max	S%	C	r%	Мо%		
0,10-0		1,00	1,50	0,040	0,15-0,	35 15	5,5-17,5	0,20-0,60	EN 100	88-1: 2005
± 0.01		+ 0.05	+ 0.04	+ 0.005	± 0.02		0.2	+ 0.03		
Produc	ct deviatio	ons are allov	ved							
Temp	perature	e °C								
	g range		-forming	Recrystalli +RA	zation	Soft ann +A	ealing	MMA welding - pre-heating		trodes a <i>ling after w.</i>
1510-			0-930	790-710 co 300, then a	ir	850-750 air		difficult; addres producers	s qualified o	electrodes
	ling +l	+Q	enching	Tempering +T					rMo alloyed	
not sui		air/c	0-980 bil/ /polymer	650-550 fast cooling in air HNO ₃) + (2 - 6%		(0) bot or co	ald	E309 E cosmetic weldin E309	309 ng	E309 – E30
		properties		TINO3) + (2 - 0 /8	INd201207.2112		Jiu			
				in conditions 1C,	1E. 1D. 1X. 1	G. 2D				
size			at room temp		,,, .	0,20				
mm		R	Rp 0		Kv +20	D°C HE	a)	^{a)} for informatio	on only	
from	to	N/mm ²	N/mm	² min min	J min	ma	ах			
		730 ma				22	0	+A annealed m		
	60	650-850		12				+QT650 quenc		
60	160	650-850) 500	10				+QT650 quenc	hed and te	mpered
Bright	t bars of I	heat-treated	d material EN	10088-3: 2005 ir	n conditions 2	H, 2B, 2G, 2	2P			
size			at room temp							
mm		R	HB a)			R		Rp 0.2	A %	Kv +20 °C
	to		HB a)				/mm ²	Rp 0.2 N/mm ² min	A% min	Kv +20 ℃ J min
	to 10 ^{b)}	R	HB a)			N				
from		R N/mm ²	HB ^{a)} max max			N 70	/mm ²	N/mm² min	min	
from 10	10 ^{b)} 16 40	R N/mm ² 880 880 800	HB a) max max 280 280 280 250			N 70 70	/mm ²)0-980	N/mm ² min 580 530 500	min 7 7 9	
from 10 16 40	10 ^{b)} 16 40 63	R N/mm ² 880 880 800 760	HB a) max max 280 280 250 230			N. 7(65 65	/mm ² 00-980 00-980 50-930 50-880	N/mm ² min 580 530 500 500	min 7 7 9 10	
from 10 16 40	10 ^{b)} 16 40	R N/mm ² 880 880 800 760 730	HB a) max max 280 280 280 250 230 230 220 220			N 70 65 65	/mm ² 00-980 00-980 50-930 50-880 50-850	N/mm ² min 580 530 500 500 500	min 7 7 9 10 10	
from 10 16 40 63	10 ^{b)} 16 40 63 100	R N/mm ² 880 880 800 760 730 +A anne	HB a) max max 280 280 250 230			N 70 65 65	/mm ² 00-980 00-980 50-930 50-880 50-850	N/mm ² min 580 530 500 500	min 7 7 9 10 10	
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne	10 ^{b)} 16 40 63 100 nformation e range of ess have t	R N/mm ² 880 880 760 730 +A anne n only f 1 mm ≤ d < to be agreed	HB a) max max 280 280 250 230 220 ealed material 4 < 5 mm, value of at the time or	s are valid only for		N 7(65 65 +(/mm ² 00-980 00-980 50-930 50-880 50-850 QT650 qu	N/mm ² min 580 530 500 500 500	min 7 7 9 10 10 ered	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne	10 ^{b)} 16 40 63 100 nformation e range of ess have t	R N/mm ² 880 880 760 730 +A anne n only f 1 mm <u><</u> d < to be agreed A 473-99 st	HB a) max max 280 280 250 230 220 2aeled material < 5 mm, value	s are valid only for f request and orde 0F)		N 7(65 65 +(/mm ² 00-980 00-980 50-930 50-880 50-850 QT650 qu	N/mm ² min 580 530 500 500 500 enched and tempe	min 7 7 9 10 10 ered	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size	10 ^{b)} 16 40 63 100 nformation e range of ess have t	R N/mm ² 880 880 760 730 +A anne n only f 1 mm ≤ d < to be agreed A 473-99 st Testing	HB a) max max 280 280 250 230 220 220 280 ealed material 4 4 < 5 mm, value	s are valid only for f request and orde OF) erature	er	N, 7(65 65 +(/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe es of non round ba	min 7 7 9 10 10 ered	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm	10 ^{b)} 16 40 63 100 nformatior e range of ess have f d (ASTM	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R	HB a) max max 280 280 250 230 220 ealed material < 5 mm, value	s are valid only for f request and orde OF) erature 2 A %	er C%	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe es of non round ba HB a)	min 7 7 9 10 10 ered	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm	10 ^{b)} 16 40 63 100 nformation e range of ess have t	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm²	HB a) max max 280 280 250 230 220 ealed material < 5 mm, value	s are valid only for f request and orde OF) erature 2 A % ² min min	er C% min	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 enched and tempe ess of non round ba HB ^{a)} max	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm from	10 ^{b)} 16 40 63 100 nformatior e range of ess have f d (ASTM	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485	HB a) max max 280 280 250 230 220 ealed material < 5 mm, value	s are valid only for f request and orde OF) erature 2 A %	er C%	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe es of non round ba HB a)	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm from ^{a)} for ir	10 b) 16 40 63 100 nformation e range of erange of eass have f d (ASTM to nformation	R N/mm² 880 880 800 760 730 +A anne n only f1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only	HB a) max max 280 280 250 230 220 2aled material < 5 mm, value	s are valid only for f request and orde OF) erature 2 A % ² min min 20	er C% min 45	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe ess of non round ba HB ^{a)} max	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm from ^{a)} for ir	10 b) 16 40 63 100 nformation e range of erange of eass have f d (ASTM to nformation	R N/mm² 880 880 800 760 730 +A anne n only f1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only	HB a) max max 280 280 250 230 220 2aled material < 5 mm, value	s are valid only for f request and orde OF) erature 2 A % ² min min 20 in conditions 2H (er C% min 45	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe ess of non round ba HB ^{a)} max	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm from ^{a)} for ir	10 b) 16 40 63 100 nformation e range of eass have the d (ASTM to nformation work hard size	R N/mm² 880 880 800 760 730 +A anne n only f1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only	HB a) max max 280 280 280 220 230 220 2aled material 4 <	s are valid only for f request and orde OF) erature 2 A % 2 min min 20 in conditions 2H (erature	er C% min 45	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe ess of non round ba HB ^{a)} max	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thickne Forge size mm from ^{a)} for ir	10 b) 16 40 63 100 nformatior e range of ess have to d (ASTM to nformatior work hard size mm	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R	HB a) max max 280 280 280 220 230 220 240	s are valid only for f request and orde OF) erature 2 A % 2 min min 20 in conditions 2H (rerature 1.2 A %	er C% min 45	N. 7(65 65 +(• mechanica	/mm ²)0-980)0-980 50-930 50-850 QT650 qu Il propertie	N/mm ² min 580 530 500 500 500 enched and tempe ess of non round ba HB ^{a)} max	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ^{b)} in the thicknet Forge size mm from ^{a)} for ir Cold-v	10 b) 16 40 63 100 nformatior e range of ess have f d (ASTM to nformatior work harc size mm to	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R N/mm²	HB a) max max 280 280 280 220 230 220 240	s are valid only for f request and orde 0F) erature 2 A % 2 min min 20 in conditions 2H (erature 1.2 A % 1 ² min min	er C% min 45	N, 7(6; 6; 6; 6; • (• mechanica • mechanica	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu al propertion r +20 °C min	N/mm ² min 580 530 500 500 enched and tempe es of non round ba HB ^{a)} max 223	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir for ^{b)} in the thickne Forge mm from ^{a)} for ir Cold-v	10 b) 16 40 63 100 nformatior e range of ess have to d (ASTM to nformatior work hard size mm	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R	HB a) max max 280 280 280 220 230 220 240	s are valid only for f request and orde OF) erature 2 A % 2 min min 20 in conditions 2H (rerature 1.2 A %	er C% min 45	N, 7(6; 6; 6; 6; • (• mechanica • mechanica	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu al propertion r +20 °C min	N/mm ² min 580 530 500 500 500 enched and tempe ess of non round ba HB ^{a)} max	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 a) for ir b) in the thickne Forge size mm from a) for ir Cold-v from	10 b) 16 40 63 100 hformatior e range of erange	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R N/mm² 485 n only	HB a) max max 280 280 250 230 220 220 ealed material at the time o < 5 mm, value	s are valid only for f request and orde OF) erature 2 A % ² min min 20 in conditions 2H (erature -2 A % p ² min min 15	er C% min 45 ex. +A+C)	N, 7(6; 6; 6; +(e mechanica Kv J 1 +C	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu Il propertio +20 °C min 5550 cold-	N/mm ² min 580 530 500 500 enched and tempe es of non round ba HB ^{a)} max 223 drawn material	min 7 7 9 10 10 ered ars of < 5 m	J min
from 10 16 40 63 ^{a)} for ir ir ^{b)} in the thickne Forge size mm from ^{a)} for ir Cold-v from Table	10 b) 16 40 63 100 hformatior e range of erange	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R N/mm² 550-750 ring values	HB a) max max 280 280 250 230 220 220 ealed material 3 < 5 mm, value	s are valid only for f request and orde OF) erature 2 A % 2 min min 20 in conditions 2H (erature 1.2 A % 1 ² min min	er C% min 45 ex. +A+C)	N, 7(6; 6; 6; +(e mechanica Kv J 1 +C	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu Il propertio +20 °C min 5550 cold-	N/mm ² min 580 530 500 500 enched and tempe es of non round ba HB ^{a)} max 223 drawn material	min 7 7 9 10 10 ered ars of < 5 m	J min
^{b)} in the thickne Forge size mm from a) for ir Cold-v	10 b) 16 40 63 100 nformatior e range of eass have to a (ASTM to nformation work hard size mm to 25 of tempe N/mm ²	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R N/mm² 550-750 ring values 880	HB a) max max 280 280 250 230 220 220 ealed material 4 < 5 mm, value	s are valid only for f request and orde OF) erature 2 A % ² min min 20 in conditions 2H (erature ¹² A % ¹² min min 15 erature on rounds	er C% min 45 ex. +A+C)	N, 7(6; 6; 6; +(e mechanica kv J 1 +C after quencl	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu Il propertio +20 °C min 550 cold- hing at 10	N/mm ² min 580 530 500 500 enched and tempe es of non round ba HB ^{a)} max 223 drawn material 100°C in oil	min 7 7 9 10 10 ered ars of < 5 m +A anne	J min
from 10 16 40 63 a) for ir b) in the thickne Forge size mm from a) for ir Cold-v from Table R	10 b) 16 40 63 100 hformatior e range of eases have to d (ASTM to hformation work hard size mm to 25 of tempe N/mm ²	R N/mm² 880 880 800 760 730 +A anne n only f 1 mm ≤ d to be agreed A 473-99 st Testing R N/mm² 485 n only dened EN 1 Testing R N/mm² 550-750 ring values 880	HB a) max max 280 280 250 230 220 230 ealed material 25 5 mm, value d at the time o eel ASTM 43 at room temp Rp 0 N/mm 275 0088-3: 2005 at room temp Rp 0 N/mm 275 0088-3: 2005 at room temp Rp 0 N/mm 275 0088-3: 2005 at room temp Rp 0 N/mm 275	s are valid only for f request and orde OF) erature 2 A % ² min min 20 in conditions 2H (erature .2 A % ¹² min min 15 erature on rounds 860 900	er C% min 45 ex. +A+C) : of Ø 20 mm a 920	N, 7(7(65 65 +(• mechanica • mechanica • (• mechanica • +(J + - +C after quencl 910	/mm ²)0-980)0-980 50-930 50-880 50-850 QT650 qu I propertion +20 °C min 5550 cold- hing at 10 880	N/mm ² min 580 530 500 500 enched and tempe es of non round ba HB ^{a)} max 223 drawn material 000°C in oil 820 660	min 7 7 9 10 10 ered ars of < 5 m +A anne 600	J min m of aled materia

X14CrMoS17 nº 1.4104 martensitic stainless steel

R N/mm	² 550	570	proximate value 600	620	650	710	755	765	775
		440	480	490	540	620	635	640	650
A %	22	18	16	14	13	12	10	10	9
Reduction %	0	5	8	10	15	20	25	26	29
Thermal expar	sion 10 ⁻⁶ •	K -1	•	10.0	10.5	10.5	10.5		
Modulus of ela	sticity longitu	udinal GPa	215	212	205	200	190		
Poisson numb	er v		0,27-0,30						
Electrical resis	tivity Ω∙m	ım²/m	0.70						
Electrical cond	luctivity Sieme	ens∙m/mm²	1.43						
Specific heat	J/(Kg	•K)	460						
Density	Kg/dn	1 ³	7.70						
Thermal condu	ictivity	W/(m∙K)	25						
Relative magn	etic permeability	y μr	600-1100						
°C			20	100	200	300	400		
The symbol ► in	idicates tempera	ture between 2	20 °C and 100 °	C, 20 °C ar	nd 200 °C				

Contosion resistance		Autosphe	Almospheric						
Fresh water x		industrial	marine	e mea	lium oxidizii	ng reducing	household cleaners,		
		X	food						
Magnetic		yes							
Machinability Hardening		high by quenching, cold-drawn and and other cold plastic deformations							
Europe	USA	USA	China	Russia	Japan	India	Republic of Korea		
EN	UNS	ASTM	GB	GOST	JIS	IS	KS		
X14CrMoS	17	Y10Cr17			SUS 430F	STS 430F			



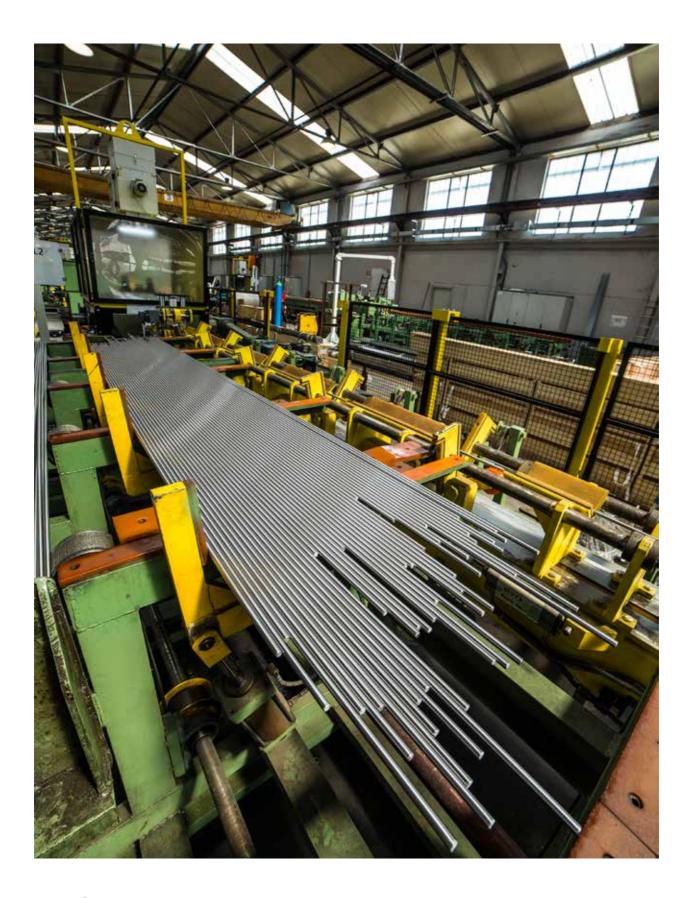


Lucefin Group

Qualit							Ferritic	Ferritic Stainless Steel			Technical card 2014	
			1.4105	1.4105					eel		Lucefin Group	
Chem	ical cor	nposition										
C%		Si%	Mn%	I	⊃%	S%		Cr%	Mo%			
max		nax	max		max							
0,08		1,50	1,50	(0,040	0,15-0,	35	16,0-18,0	0,20-0,6	0	EN 1008	38-1: 2005
± 0.01	-	<u>+</u> 0.10	<u>+</u> 0.04	-	+ 0.005	± 0.02		± 0.2	<u>+</u> 0.03			
Product	deviation	ns are allowe	ed									
Tempe	erature	°C										
Melting range		Hot-f	orming	+RA			Soft annealing +A			MMA welding – AWS electrodes pre-heating annealing after w		
1500-1490			1150-815		790-710 cooling to 300, then air		850-750 air		difficult; ad producers		ualified e	lectrodes
Isothermal annealing +I		+Q			Tempering +T		Annealing for magnetic properties		<i>joint with st</i> carbon	CrMo	o alloyed	stainless
not suitable		not si	not suitable not suitable			825-805 protectet atmosphere cooling 50-100 °C/h to 400. then air			E309 E309 E309 E309 – E308 cosmetic welding E309			
Chemic	al treatn	nent - Pickli	ng (20 - 50	% HNO3)	+ (2 - 6% Na			r cold	_000			
		roperties		,	•							
				05 in cond	itions 1C, 1E	E, 1D, 1X. 1	G, 2D					
size			t room ten			,,,	,, 					
mm		R		0.2	A %	Kv +	20 °C	HB ^{a)}	^{a)} for infor	mation o	only	
from	to	N/mm ²		nm² min	min	J min		max			-	
	100	430-630	250		20			200	+A anneal	led mate	erial	
Bright I	bars of h	eat-treated	material	EN 10088-	-3: 2005 in c	onditions 2	H, 2B, 20	G, 2P				
size			it room ten									
mm		R	HB					R	Rp 0.2	A	%	Kv +20 °C
from	to	N/mm ²	max ma	х				N/mm ²	N/mm ² m		in	J min
	10 ^{b)}							530-780	330	7		
10	16							500-780	310	7		
16	40							430-730	250	12		
40	63							430-730	250	12		
63	100							430-630	250	20	J	
h) in the		1	Empressel		lid only for	undo 4	mashr	+A material		ad b = =::	of 2 5	m of
		1 mm <u><</u> d < be agreed				ounas — the	mechar	nical propertie	s of non rour	na bars	01 < 5 mi	TI OT
Forged		J	-									
size		Testing a	it room ten	nperature								
mm		R		0.2	A %	Kv +2	20 °C	HB a)				
fra	to	N/mm ²		nm² min	min	J mii	ı	max				
from	ormation	only						200	+A anneal	ed mate	erial	
	unnation	•	ollod · D ^		vinata val:	00						
^{a)} for inf		лкіпа (ПОТ-І		+C). Appro 690	710 710	es 740	780	800	840 8	380	920	
^{a)} for inf Effect o	f cold-we		620		/ 10			730		300	920 850	
^{a)} for inf Effect o R	f cold-w o N/mm²	570	620 510			650						
^{a)} for inf Effect o R Rp 0.2	f cold-w o N/mm ² N/mm ²	570 280	510	590	620	650 8	690 8					
^{a)} for inf Effect o R Rp 0.2 A	f cold-we N/mm ² N/mm ² %	570 280 20	510 10	590 9	620 9	8	8	8	8 8	3	8	
^{a)} for inf Effect o R Rp 0.2 A Reducti	f cold-w a N/mm ² N/mm ² % on %	570 280 20 0	510 10 10	590 9 20	620 9 30				8 8			
^{a)} for inf Effect o R Rp 0.2 A Reducti Minimu	f cold-wo N/mm ² N/mm ² % on % m value	570 280 20 0 s at high ter	510 10 10 nperature	590 9 20 s EN 1008	620 9 30 38-3: 2005	8 40	8 50	8 60	8 8 70 7	3 7 5	8 80	
^{a)} for inf Effect o R Rp 0.2 A Reducti	f cold-w a N/mm ² N/mm ² % on %	570 280 20 0	510 10 10	590 9 20	620 9 30	8	8	8	8 8	3 7 5	8 80	

X6CrMoS17 r	n° 1.410 5 i	ferritic ste	el						Luce	efin Group	
Thermal expansion 10 ⁻⁶ • K ⁻¹			K -1	•	10.0	10.5	10.5	10.5	12.0	12.6	
Modulus of el	asticity	longitu	dinal GPa	220	215	210	205	195			
Poisson number V				0.27-0,30 ~							
Electrical resistivity Ω • mn			m²/m	0.70							
			ns•m/mm²	1.43							
Specific heat J/(Kg-			K)	460							
Density		Kg/dm	3	7.75							
Thermal cond	luctivity		W/(m•K)	25							
Relative mag	netic perme	eability	μr	640 ~							
°C				20	100	200	300	400	600	800	
The symbol ►	indicates te	mperatur	e between 20) °C and 100 °	C, 20 °C a	and 200 °C					
Corrosion resistance Atm			Atmospheri	ic Chemical					x steam, food and dair		
Fresh water			industrial	marine						ganic products,	
X		X		x	x nitric acid						
Magnetic			yes								
Machinability high											
· · · · ·			-	old-drawn and other cold plastic deformations							
Service temp	erature in a	ir	continuous	service up to 8	10 °C; inte	ermittent sei	rvice up to 8	60 °C			
Europe	USA		USA	China	Russia	Jap	an	India	Republic	of Korea	
EN	UNS		ASTM	GB	GOST	JIS		IS	KS		
X6CrMoS17	43020		430F								





Quality	у	X2CrM	oSiS18-2-1				hining Ferritic	Technical card 2014	
Number		1.410	6 MOD			Stainless	Steel	Lucefin Group	
Chemi	cal compos	ition							
C%	Si%	Mn%	P%	S%	Cr%	Mo%	N%		
max			max				max	AFNOR FD A 35-570: 199	
0,03	1,25-1,50	0,30-0,60	0,040	0,25-0,30	17,5-18,5	1,50-2,00	0,04		
Гетре	erature °C								
Melting	range	Pre-heating	Hot-for	ming	Recrystalliza +RA	ation	MMA welc pre-heating	ling – AWS electrodes g annealing after w.	
1490-14	480	870-815 pause, then ▲	▲ 1150-	1050	810-700 coo 300, then air	ling to	not recom	mended	
Soft anr +A	nealing	Quenching +Q	Tempei +T	U	Annealing for magnetic		<i>joint with s</i> carbon	teel CrMo alloyed stainless	
820-750 air		not suitable	not suita		860-850 prote cooling 55 °C then air	ected atmosph C/h to 420,	ere cosmetic v	velding	
					has a dew po		ırie temperature - 25% HNO₃ hc		
Macha	inical prope	rties							
Hot-roll	ed (ASTM A 58	2 582M-05 ste	,						
size		sting at room te		• • /					
nm	R		0.2	A %	Kv +20 °C		a) for infor	mation only	
from	to N/n	nm ² N/	mm² min	min	J min	max 262	+A annea	led material	
Therma	l expansion	10 ⁻⁶ • K ⁻¹		•	12.0				
	s of elasticity		al GPa	225					
	number	V		0,27-0,30~					
	al resistivity	Ω • mm ² /	m	0.76					
		32 • 11111 /							
	al conductivity	Siemens	m/mm ²	1.31					
Electric	al conductivity heat	•	m/mm²	1.31 500 ~					
Electric Specific	cheat .	J/(Kg∙K)	m/mm²	500 ~					
Electric Specific Density	c heat	J/(Kg•K) Kg/dm³		500 ~ 7.75					
Electric Specific Density Therma	c heat I conductivity	J/(Kg•K) Kg/dm³ W	//(m•K)	500 ~ 7.75 15					
Electric Specific Density Therma Relative	c heat	J/(Kg•K) Kg/dm³ W	//(m•K)	500 ~ 7.75 15 1200 ~	100				
Electric Specific Density Therma Relative °C The sym	c heat I conductivity e magnetic per nbol ► indicates	J/(Kg•K) Kg/dm ³ W meability µ temperatures	//(m∙K) r between 20	500 ~ 7.75 15 1200 ~ 20 °C and 100 °	100 °C ay be increase	ed by stress re	lief heat treatme	ent	
Electric Specific Density Therma Relative °C The sym	c heat I conductivity e magnetic per nbol ► indicates	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n	//(m∙K) r between 20	500 ~ 7.75 15 1200 ~ 20 °C and 100 °	°C ay be increase	ed by stress re	lief heat treatme	ent x environment with	
Electric Specific Density Therma Relative °C The sym ") cold de Corrosid	t heat I conductivity a magnetic per hool ► indicates eformations res on resistance	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n	//(m∙K) r between 20 nodulus of e	500 ~ 7.75 15 1200 ~ 20 °C and 100 °	°C ay be increase C	hemical	lief heat treatme	x environment with	
Electric Specific Density Thermal Relative °C The sym b) cold de Corrosie Fresh wa	t heat I conductivity a magnetic per hool ► indicates eformations res on resistance	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n	//(m•K) r between 20 nodulus of e tmospheric	500 ~ 7.75 15 1200 ~ 20 °C and 100 ° astucity; it ma	°C ay be increase C	hemical		x environment with	
Electric Specific Density Therma Relative °C The sym °C Corrosie Fresh wax	t heat I conductivity magnetic per abol ► indicates eformations res on resistance ater	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n A in x	//(m•K) r between 20 nodulus of e tmospheric	500 ~ 7.75 15 1200 ~ 20 °C and 100 ° astucity; it ma	°C ay be increase C	hemical		x environment with	
Electric: Specific Density Thermal Relative °C The sym b) cold de Corrosic Fresh wa x Magneti	t heat I conductivity magnetic per abol ► indicates eformations res on resistance ater ic	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n A in x	//(m•K) r between 20 nodulus of e tmospheric <i>dustrial</i>	500 ~ 7.75 15 1200 ~ 20 °C and 100 ° astucity; it ma	°C ay be increase C	hemical		x environment with	
Electric Specific Density Therma Relative °C The sym o cold de Corrosie Fresh wa x Magneti Machina	c heat I conductivity a magnetic per abol ► indicates eformations res on resistance ater ic ability	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n A in x ye hi	//(m•K) r between 20 nodulus of e tmospheric <i>dustrial</i> es gh	500 ~ 7.75 15 1200 ~ 20 °C and 100 ° astucity; it m <i>marine</i>	°C ay be increase C m	hemical hild oxid		x environment with	
Electric: Specific Density Therma Relative °C The sym b) cold de Corrosie Fresh wa x Magneti Machina Hardeni	c heat I conductivity a magnetic per abol ► indicates eformations res on resistance ater ic ability	J/(Kg•K) Kg/dm ³ W meability µ temperatures sult in a lower n A in x ye hi co	//(m•K) r between 20 nodulus of e tmospheric <i>dustrial</i> es gh	500 ~ 7.75 15 1200 ~ 20 °C and 100 ° astucity; it m <i>marine</i> d other cold	C ay be increase C m plastic deform	hemical hild oxid	dizing reduc	x environment with	

Quality Number					artensitic ainless Steel	Technical card 2014 Lucefin Group		
Chemica	l composit	ion						
C%	Si%	Mn%	P%	S% a)	Cr%	Mo%	V%	
	max	max	max	max				
0,85-0,95	1,00	1,00	0,040	0,015	17,0-19,0	0,90-1,30	0,07-0,12	EN 10088-1: 2005
± 0.03	+ 0.05	+ 0.03	+ 0.005	+ 0.003	± 0.2	+ 0.05	+ 0.03	

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Melting range	Hot-forming	Full annealing	Soft annealing +A	MMA weldin	i g – AWS elec annea	trodes aling after w.
1440-1420	1175-930	910-890 cooling 15 °C/h to 590, then air	840-780 slow cooling	200-150	750-7	00
Isothermal	Quenching	Tempering	Stress-relieving	joint with ste	el	
annealing +l	+Q	+T	+SR	carbon	CrMo alloyed	stainless
900-840 controlled	1050-1000	550-450	350-100	E70 xx	E8018-B 2	E309 – E308
cooling to	oil / polymer	air	air	cosmetic we	ldina	
690, then air	(HRC 58)			E309 special	5	

Chemical treatment • *Pickling* (20 - 50% HNO₃) hot. *Passivation* (20 - 25% HNO₃) + (2.5% Na₂Cr₂O₇.2H₂O) hot

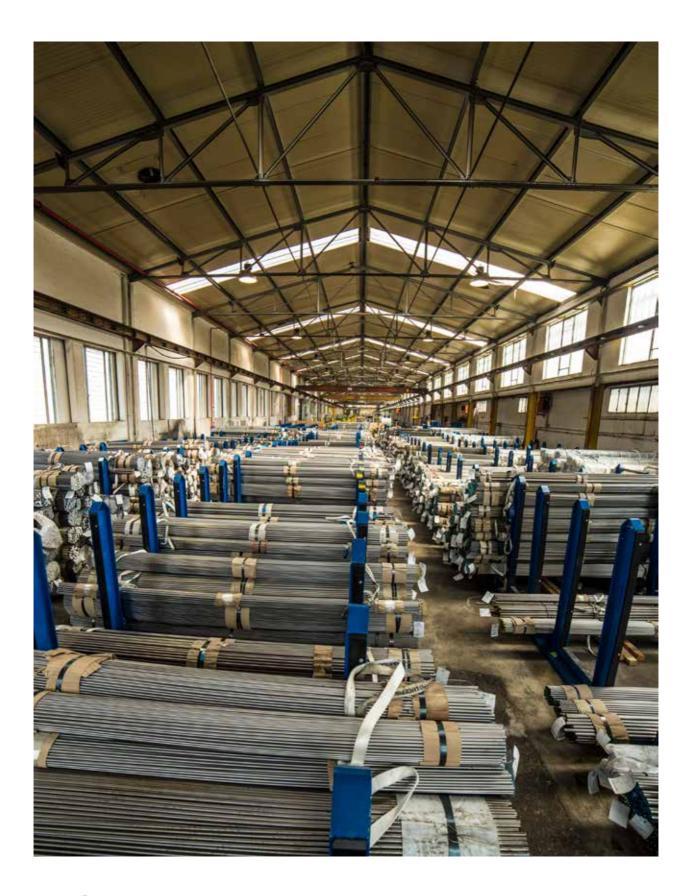
Mechanical properties

Heat-treated material EN 10088-3: 2005 in conditions 1C, 1E, 1D, 1X, 1G, 2D

size		Testing at	room temperatu	re								
mm		R	Rp 0.2	A %	Kv +20 °C	HB a)	a)	for info	ormation of	only		
from	to	N/mm ²	N/mm ² min	min	J min	max						
	100					265	+/	A anne	ealed mat	erial		
Bars, ty	ypical valu	es according	to UNS S44003	steel 440E	}							
size		Testing at	room temperatu	re								
mm		R	Rp 0.2	A%	C%	HB	R		Rp 0.2	A%	C%	HB
from	to	N/mm ²	N/mm ²				N	/mm ²	N/mm ²			
		min	min	min	min	max	m	in	min	min	min	max
		738	427	18	35	269	82	27	655	9	20	285
		+A hot-ro	lled annealed				+/	4+C c	old-drawı	1 I		
Forged	d (ASTM A	473-99 steel	ASTM 440B)									
size		Testing at	room temperatu	re								
mm		R	Rp 0.2	A %	Kv +20 °C	HB a)						
from	to	N/mm ²	N/mm ² min	min	J min	max						
						269	+/	A anne	ealed mat	erial		
^{a)} Only	for guida	nce										
Table (of temper	ing values at	room temperatur	e after qu	enching at 1020 °	°C in oil						
HB		595	560	543	525	525	371	31	1	279		
HRC		57	55	54	53	53	40	33	3	29		
T	ring °C	100	200	300	400	500	600	65	:0	700		

X90CrMoV18 n° 1	.4112 martensiti	c stainless ste	el						Lucefin Group
Thermal expansion	n 10 ⁻⁶ • K ⁻¹		•	10.4	10.8		11.2	11.6	11.9
Modulus of elasti	city longitudin	al GPa	215	212	205		200	190	
Poisson number	V		0,27-0,30 ~						
Electrical resistiv	ity Ω • mm²/	m	0.80						
Electrical conduc	tivity Siemens.	m/mm ²	1.25						
Specific heat	J/(Kg•K)		430						
Density	Kg/dm ³		7.70						
Thermal conducti	vity	W/(m•K)	15.0						
Relative magnetic	permeability	μr	700-1000 ~						
°C			20	100	200		300	400	600
The symbol ► indic	ates temperature	between 20 °0	C and 100 °C, 2	20 °C and	d 200 °C				
Corrosion resista	nce	Atmospheric		С	hemical				am, petroleum,
Fresh water		industrial	marine	n	nedium	oxidizing	reducing	0	line, alcohol, food
x								fruit j	uices
Magnetic		ves							
Machinability		difficult							
Hardening		by quenching	3						
				doformo	tions and 76	60 °C for h	ot-formed pro	ducts	
Service temperate	ure in air	max 300 °C	for cold plastic	ueioima		00 01011	lot lolling pro	Juucio	
Service temperatu Europe US		max 300 °C	China	Russia		pan	India		epublic of Korea
Europe US EN UN	SA				Ja JIS	pan	•	R K	epublic of Korea S TS 440B





Quality Number	X50CrMoV15 1.4116				artensitic ainless Steel	Technical card 2014 Lucefin Group		
Chemical	composit	ion						
C%	Si%	Mn%	P%	S% a)	Cr%	Mo%	V%	
	max	max	max	max				
0,45-0,55	1,00	1,00	0,040	0,015	14,0-15,0	0,50-0,80	0,10-0,20	EN 10088-1: 2005
± 0.02	+ 0.05	+ 0.03	+ 0.005	+ 0.003	± 0.15	+ 0.05	+ 0.03	

a) for improing machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Temperature °C

Melting range	Hot-forming	Full annealing	Soft annealing +A	MMA welding – AWS electrodes pre-heating annealing after w
1480-1460	1100-930	930-870 furnace	850-750 slow cooling	260 760-740
Isothermal annealing +I	Quenching +Q	Tempering +T	Stress-relieving +SR	joint with steel carbon CrMo alloyed stainless
910-890 controlled cooling to 750, then air	1030-980 oil / polymer (HRC 55)	500-400 air	250-150 air	E70 xx E8018-B 2 E309 – E30 cosmetic welding E309
	()	Ac1 ~ 880, Ac3 ~ 920 and	durina coolina Ms ~ 280	

Chemical treatment - Pickling (20 - 50% HNO₃) hot. Passivation (20 - 25% HNO₃) + (2.5% Na₂Cr₂O₇.2H₂O) hot

Mechanical properties

Heat-treate	d material EN	10088-3: 200)5 in condi	tions 1C, 1E, 1	D, 1X, 1G, 2D					
size		Testing at r	oom temp	erature						
mm		R	Rp 0.2	Α%	Kv +20 °C	HB a)	^{a)} for in	formation	only	
from	to	N/mm ²	N/mm ²	min	J min	max				
		900 max				280	+A ann	ealed ma	aterial	
Table of ter	npering value	s at room ten	perature a	after quenching	at 990 °C in oil					
HB		543	518	512	518	512	525	496	381	301
HRC		54	52,5	52	52.5	52	53	51	41	32
Tempering ^c	C	200	250	300	350	400	450	500	550	600
Thermal ex	pansion	10 ⁻⁶ • K ⁻¹		►	10.5	11.0	11.0	11.5		
Modulus of	elasticity	longitudina	GPa	215	212	205	200	190		
Poisson nu	mber	V		0,27-0,30	0					
Electrical re	esistivity	$\Omega \bullet mm^2/m$		0.65						
Electrical c	onductivity	Siemens.n	n/mm²	1.54						
Specific he	at	J/(Kg∙K)		460						
Density		Kg/dm ³		7.70						
Thermal co	nductivity	W/(m∙K)	30						
	gnetic perme	eability µr		700 ~						
°C				20	100	200	300	400		
The symbol	 indicates ter 	mperature be	tween 20 °	°C and 100 °C	, 20 °C and 200	°C				
Corrosion r	esistance	Atn	nospheric		Chemical				x steam, p	
Eroch water		ind	istrial	marino	modium	ovidizina	roduo	ina	gasoline, a	alcohol,

Corrosion re	esistance	Atmospheri	С	Chemical			x steam, petroleum,
Fresh water		industrial	marine	medium	oxidizing	reducing	gasoline, alcohol,
x				x			ammonia, organic material
Magnetic		yes					
Machinabilit	ty .	mean					
Hardening		by quenchir	וg				
Service tem	perature in air	up to 760 °	C				
Europe	USA	USA	China	Russia	Japan	India	Republic of Korea
EN	UNS	ASTM	GB	GOST	JIS	IS	KS
X50CrMoV1	5		(7Cr17)	50Ch14MF	(SUS 440A)		

Quality	X39CrMo17-1	Martensitic	Technical card 2014
Number	1.4122	Stainless Steel	Lucefin Group

l composition

onennea												
C%	Si%	Mn%	P%	S% ^{a)}	Cr%	Mo%	Ni%					
	max	max	max	max			max					
0,33-0,45	1,00	1,50	0,040	0,015	15,5-17,5	0,80-1,30	1,00	EN 10088-1: 2005				
± 0.02	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.2	<u>+</u> 0.05	± 0.03					

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Melting range	Hot-forming	Recrystallization +RA				MMA welding – AWS electrodes pre-heating annealing after w.				
1480-1465	1100-930	not suitable	850-750 air	Difficult; a producers	ddress qualified	electrodes				
Isothermal annealing +I	Quenching +Q	Tempering +T		<i>joint with s</i> carbon	teel CrMo alloyed	stainless				
not suitable	1060-980 air / oil / polymer (HRC 48)	750-650 air		E309 cosmetic v E309	E309 velding	E309 – E308				

Transformation temperature during heating Ac1 ~ 810, Ac3 ~ 900 and during cooling Ms ~ 280, Mf ~ 130 Chemical treatment - Pickling (20 - 50% HNO₃) hot or cold

Mechanical properties

Heat-treated material EN 10088-3: 2005 in conditions 1C, 1E, 1D, 1X, 1G, 2D

	Testing at re	Testing at room temperature									
	R	Rp 0.2	A %	Kv +20 °C	HB ^{a)}	^{a)} for information only					
to	N/mm ²	N/mm ² min	min	J min	max						
	900 max				280	+A annealed material					
60	750-950	550	12	20		+QT750 quenched and tempered					
160	750-950	550	12	14		+QT750 quenched and tempered					
	60	R to N/mm² 900 max 60 750-950	R Rp 0.2 to N/mm² N/mm² min 900 max 60 750-950 550	R Rp 0.2 A% to N/mm² N/mm² min min 900 max 900 max 12	R Rp 0.2 A% Kv +20 °C to N/mm² N/mm² min min J min 900 max	R Rp 0.2 A% Kv +20 °C HB a) to N/mm² N/mm² min J min max 900 max 280 60 750-950 550 12 20					

Bright bars of heat-treated material EN 10088-3: 2005 in conditions 2H, 2B, 2G, 2P

size		Testing at roor	Testing at room temperature											
mm		R	HB ^{a)}	R	Rp 0.2	A %	Kv +20 °C							
from	to	N/mm ² max	max	N/mm	n ² N/mm ² m	n min	J min							
	10 ^{b)}	1000	340	800-1	050 650	8								
10	16	1000	340	800-1	050 600	8								
16	40	980	310	800-1	000 550	10	20							
40	63	930	290	750-9	50 550	12	20							
63	100	900	280	750-9	50 550	12	14							
		+A annealed n	naterial	+QT7	50 quenched and te	mpered								

^{a)} for information only

^{b)} in the range of 1 mm \leq d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order

Forgeo	1									
size		Testing at I	room temperature							
mm		R	Rp 0.2	A %	Kv +20 °C	HB a)				
from	to	N/mm ²	N/mm ² min	min	J min	max				
						280	+A	annealed m	aterial	
a) for in	formation	only								
Table (of temner	ing values at	room temperature	on rounds	of Ø 20 mm after o	uonchina a	at 1050°C	in oil		
	ortemper	455	432	432	432	442	442	421	400	319
HB	ortemper	•							400 43	319 34
HB HRC	ring °C	455	432	432	432	442	442	421		
HB HRC Tempe	ring °C	455 48 200	432 46 250	432 46 300	432 46	442 47 400	442 47	421 45	43	34
HB HRC Tempe	ring °C	455 48 200	432 46 250	432 46 300	432 46 350	442 47 400	442 47	421 45	43	34

X39CrMo17-1	n° 1.4122	2 marten	sitic stainless	steel						Lucefin Group
Thermal expa	ansion	10 ⁻⁶ •	K-1	•	10.4	1	0.8	11.2	11.	6
Modulus of e	lasticity	longitu	udinal GPa	215	212	2	05	200	190)
Poisson num	ber	V		0,27-0,30 ~						
Electrical res	istivity	Ω•m	m²/m	0.80						
Electrical con	nductivity	Sieme	ens∙m/mm²	1.25						
Specific heat		J/(Kg∙	•K)	430						
Density		Kg/dm	1 ³	7.70						
Thermal con			W/(m∙K)	15						
Relative mag	netic perme	ability	μr	700-1000 ~						
°C				20	100		00	300	400	
The symbol ►	indicates ter	mperatu	re between 20) °C and 100 °	C, 20 °	C and 200	°C			
Corrosion re	sistance		Atmospheric	0		Chemical				x organic and nitric
Fresh water			industrial	marine		medium	oxidizir	ng reducing	g	acids
X										
Magnetic			yes							
Machinability	/		low							
Hardening			by quenchin	g						
Service temp	erature in a	ir	good resista	ince to oxidatio	n and h	neat up to 5	00 °C			
	USA		USA	China	Rus		Japan	India		Republic of Korea
Europe										
Europe EN X39CrMo17-1	UNS		ASTM	GB	GOST	r 16M	JIS	IS		KS





Quality	,		X105CrMo17						Martensitic		Te	Technical card 2014		
Number			1.41	25					Stainless St	eel	Lu	ıcefin	Group	
Chemio	cal comp	osition												
C%	Si%		Mn	%	Р%		S% a)		Cr%	Mo%				
	max		ma	X	ma	x	max							
0,95-1,20) 1,00)	1,0	0	0,0	40	0,015		16,0-18,0	0,40-0,80	EN	1008	8-1: 2005	
± 0.03	+ 0.	05	+ 0	.03	+ 0	.005	+ 0.003		± 0.2	+ 0.05				
Product of	deviations a	re allowed	1											
	roving macl content of m			wed a co	ontrolled	sulphur c	ontent of 0	,015 9	% - 0,030 %; f	or polishability,	it is sug	gested	l a control	
Tempe	rature °C	;												
Melting I	range		Hot-for	ming	Fu	ll anneali	ıg	Soft +A	annealing	MMA weldin	•		rodes ling after v	
1440-14	10	1100-930			0-845 furn		840-		Difficult; add	ress qual	ified e	lectrodes		
Isothermal						oling to 59	0 after air		HB max 285)	producers				
			Quench	ning		mpering			ss-relieving	joint with ste				
annealin	i g +i controlled c	aaliaa	+Q 1050-10	000	+T	5-180		+SR 300-		carbon E309	CrMo al E309	loyed	stainless E309 – E3	
900-840 to 690, th				polymer				300- air	100				E909 - E9	
(HB 243-					all			all		cosmetic we	laing			
Transforr Chemica	mation temp	berature d t - <i>Picklin</i> g		ating Ac1					ng Ms ~ 180, N ₃) + (2.5% Na₂(ot			
Transforr Chemica Mechai	nation temp Il treatmen nical prop	perature d t - <i>Picklin</i> ę perties	uring he g (20 - 5	ating Ac1 0% HNO	3) hot. <i>F</i>	Passivatior	(20 - 25%	HNO		/f ~ 30	ot			
Transforr Chemica Mechai Heat-trea	nation temp Il treatmen nical prop ated materi	perature d t - <i>Picklin</i> ę perties	uring he g (20 - 5)88-3: 2(ating Ac1 0% HNO	₃) hot. <i>F</i> nditions	Passivatior	(20 - 25%	HNO		/f ~ 30	ot			
Transforr Chemica Mechai Heat-trea size	nation temp Il treatmen nical prop ated materi	perature d t • <i>Picklin</i> e perties ial EN 100	uring he g (20 - 5)88-3: 2(room te	ating Ac1 0% HNO	₃) hot. <i>F</i> nditions	Passivatior 1C, 1E, 1	(20 - 25%	HNO		/f ~ 30		/		
Transforr Chemica Mechai Heat-trea size mm	nation temp al treatmen nical prop ated materi ated materi to	berature d t • <i>Pickling</i> perties ial EN 100 Testing at	uring he g (20 - 5)88-3: 2(room te F	ating Ac 1 0% HNO 005 in com	3) hot. F nditions e A	Passivatior 1C, 1E, 1 % Kv	(20 - 25% D, 1X, 1G, +20 °C	HNO	₃) + (2.5% Na ₂ (/f ∼ 30 Cr ₂ O ₇ .2H ₂ O) ho		1		
Transforr Chemica Mechai Heat-trea size mm	nation temp Il treatmen nical prop ated materi	berature d t • <i>Pickling</i> perties ial EN 100 Testing at R	uring he g (20 - 5)88-3: 2(room te F	ating Ac1 i0% HNO 005 in col mperatur Rp 0.2	3) hot. F nditions e A	Passivatior 1C, 1E, 1 % Kv	(20 - 25% D, 1X, 1G, +20 °C	HNO	3) + (2.5% Na ₂ 0 H B ^{a)}	/f ∼ 30 Cr ₂ O ₇ .2H ₂ O) ho	ation only			
Transforr Chemica Mechai Heat-trea size mm from	nation temp al treatmen nical prop ated materi ated materi to	perature d t - <i>Pickling</i> perties ial EN 100 Testing at R N/mm ²	uring he g (20 - 5)88-3: 20 room te F	ating Ac1 0% HNO 005 in col mperatur Rp 0.2 N/mm ² m	3) hot. <i>F</i> nditions e <u>A</u> in m	Passivatior 1C, 1E, 1 % Kv in J m	(20 - 25% D, 1X, 1G, +20 °C	HNO	3) + (2.5% Na ₂ (H B ^{a)} max	Af ~ 30 Cr ₂ O7.2H ₂ O) ho ^{a)} for informa	ation only			
Transforr Chemica Mechai Heat-trea size mm from Bars, typ	nation temp il treatmen nical prop ated materi I to 1 100 ical values a	perature d t - <i>Pickling</i> perties ial EN 100 Testing at R N/mm ²	uring he g (20 - 5)88-3: 2(room te F N to UNS	ating Ac1 0% HNO 005 in col mperatur Rp 0.2 N/mm ² m S44004 s	3) hot. <i>F</i> nditions e <u>A</u> in m	Passivatior 1C, 1E, 1 % Kv in J m	(20 - 25% D, 1X, 1G, +20 °C	HNO	3) + (2.5% Na ₂ (H B ^{a)} max	Af ~ 30 Cr ₂ O7.2H ₂ O) ho ^{a)} for informa	ation only			
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size	nation temp I treatmen nical prop ated materi I to 100 ical values a	perature d t - <i>Pickling</i> perties ial EN 100 Testing at R N/mm ² according	uring he g (20 - 5)88-3: 2(room te F N to UNS room te	ating Ac1 0% HNO 005 in col mperatur Rp 0.2 N/mm ² m S44004 s	3) hot. <i>F</i> nditions e <u>A</u> in m	Passivatior 1C, 1E, 1 % Kv in J m 0C	(20 - 25% D, 1X, 1G, +20 °C	HNO	3) + (2.5% Na ₂ (H B ^{a)} max	Af ~ 30 Cr ₂ O7.2H ₂ O) ho ^{a)} for informa	ation only		НВ	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm	nation temp al treatmen nical prop ated materi to 1 100 ical values a f to 1	perature d t - Pickling perties ial EN 100 Testing at R N/mm ² according Testing at R	to UNS room te F norm te F N to UNS	ating Act 0% HNO 005 in comperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 V/mm ² m	a) hot. <i>F</i> nditions e A in m steel 44 e A? in mi	Passivation 1C, 1E, 1 % Kv in J m 0C % C% n min	D, 1X, 1G, +20 °C in HB max	HNO	 a) + (2.5% Na₂4 HB a) max 285 R N/mm² min 	If ~ 30 Cr ₂ O ₇ .2H ₂ O) ho a) for information +A annealed Rp 0.2 N/mm ² min	ation only d materia A % min	l C% min	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm	nation temp al treatmen nical prop ated materi to n 100 ical values a to n	perature d t - Pickling perties ial EN 100 Testing at R N/mm ² according Testing at R N/mm ² mi 758	to UNS room te Fin N	ating Act 10% HNO 1005 in comperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 J/mm ² m 148	a) hot. F nditions e A in m steel 44 e A9	Passivation 1C, 1E, 1 % Kv in J m 0C % C% n min	D, 1X, 1G, +20 ℃ in HB	HNO	 HB a) max 285 R N/mm² min 862 	 a) for information a) for information +A annealed Rp 0.2 N/mm² min 689 	ation only d materia A %	l C%		
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm	nation temp al treatmen nical prop ated materi to n 100 ical values a to n	perature d t - Pickling perties ial EN 100 Testing at R N/mm ² according Testing at R	to UNS room te Fin N	ating Act 10% HNO 1005 in comperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 J/mm ² m 148	a) hot. <i>F</i> nditions e A in m steel 44 e A? in mi	Passivation 1C, 1E, 1 % Kv in J m 0C % C% n min	D, 1X, 1G, +20 °C in HB max	HNO	 a) + (2.5% Na₂4 HB a) max 285 R N/mm² min 	 a) for information a) for information +A annealed Rp 0.2 N/mm² min 689 	ation only d materia A % min	l C% min	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (nation temp I treatment nical prop ated materi T to 1 100 ical values a T to 1 ASTM A 47	perature d t - Pickling perties ial EN 100 Testing at R W/mm ² according Testing at R N/mm ² mi 758 +A hot-rol '3-99 stee	to UNS room te F to UNS room te F in N 4 Iled ann	ating Act 10% HNO 005 in comperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 V/mm ² m 48 ealed 440C)	a) hot. <i>F</i> nditions e A' in m steel 44 e A? in mi 14	Passivation 1C, 1E, 1 % Kv in J m 0C % C% n min	D, 1X, 1G, +20 °C in HB max	HNO	 HB a) max 285 R N/mm² min 862 	 a) for information a) for information +A annealed Rp 0.2 N/mm² min 689 	ation only d materia A % min	l C% min	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size	nation temp I treatment nical prop ated materi I to I 100 ical values a I to I ASTM A 47	perature d t • Pickling perties ial EN 100 Testing at R W/mm ² according testing at R N/mm ² mi 758 +A hot-rol '3-99 stee Testing at	to UNS room te Fin N Illed ann I ASTM room te	ating Act 10% HNO 1005 in comperatur 1005 i	a) hot. <i>F</i> nditions e A in m steel 44 e A? in mi 14 e	Passivation 1C, 1E, 1 % Kv in J m 0C 6 C% n min 25	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269	2D	HB a) max 285 R N/mm ² min 862 +A+C cold-d	 a) for information a) for information +A annealed Rp 0.2 N/mm² min 689 	ation only d materia A % min	l C% min	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size mm	nation temp al treatmen nical prop ated materi to r 100 ical values a to r ASTM A 47	perature d t • Pickling perties ial EN 100 Testing at R N/mm ² according testing at R N/mm ² mi 758 +A hot-rol '3-99 stee Testing at R	to UNS room te Fin N Iled ann I ASTM For te Fin N Fin S Fin	ating Act i0% HNO 005 in col mperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 V/mm ² m 48 ealed 440C) mperatur Rp 0.2	a) hot. <i>F</i> nditions e A in m steel 44 e A in mi 14 e A	Passivation 1C, 1E, 1 % Kv in J m 0C 6 C% n min 25 % C%	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269 Kv +20	HNO: 2D	HB a) max 285 R N/mm ² min 862 +A+C cold-cd HB a)	 a) for information a) for information +A annealed Rp 0.2 N/mm² min 689 	ation only d materia A % min	l C% min	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size mm	nation temp al treatmen nical prop ated materi to 1 100 ical values a to 1 ASTM A 47	perature d t • Pickling perties ial EN 100 Testing at R W/mm ² according testing at R N/mm ² mi 758 +A hot-rol '3-99 stee Testing at	to UNS room te Fin N Iled ann I ASTM For te Fin N Fin S Fin	ating Act 10% HNO 1005 in comperatur 1005 i	a) hot. <i>F</i> nditions e A in m steel 44 e A 9 in mi 14 e A 9 A	Passivation 1C, 1E, 1 % Kv in J m 0C 6 C% n min 25 % C%	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269 Kv +20	HNO: 2D	HB a) max 285 R N/mm ² min 862 +A+C cold-d HB a) max	 Af ~ 30 Cr₂O₇.2H₂O) ho a) for informative the annealed A annealed Rp 0.2 N/mm² min 689 rawn 	ation only d materia A % min 7	l C% min 20	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size mm from	nation temp al treatmen nical prop ated materi to r 100 ical values a to r ASTM A 47	perature d t • Pickling perties ial EN 100 Testing at R N/mm ² according Testing at R N/mm ² mi 758 +A hot-roi '3-99 stee Testing at R N/mm ²	to UNS room te Fin N Iled ann I ASTM For te Fin N Fin S Fin	ating Act i0% HNO 005 in col mperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 V/mm ² m 48 ealed 440C) mperatur Rp 0.2	a) hot. <i>F</i> nditions e A in m steel 44 e A in mi 14 e A	Passivation 1C, 1E, 1 % Kv in J m 0C 6 C% n min 25 % C%	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269 Kv +20	HNO: 2D	HB a) max 285 R N/mm ² min 862 +A+C cold-cd HB a)	 a) for information a) for information +A annealed Rp 0.2 N/mm² min 689 	ation only d materia A % min 7	l C% min 20	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size mm from	nation temp al treatmen nical prop ated materi to 100 ical values a to 1 ASTM A 47 to 1 to 1	perature d t • Pickling perties ial EN 100 Testing at R N/mm ² according testing at R N/mm ² mi 758 +A hot-rol '3-99 stee Testing at R N/mm ²	to UNS room te Fin N I led ann I ASTM N	ating Act i0% HNO 005 in col mperatur Rp 0.2 V/mm ² m S44004 :: mperatur Rp 0.2 V/mm ² m 48 ealed 440C) mperatur Rp 0.2 V/mm ² m	a) hot. <i>F</i> nditions e A' in m steel 44 e A9 in mi 14 e A9 in mi	Passivation 1C, 1E, 1 % Kv in J m 0C % C% n min 25 % C% n mir	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269 Kv +20 J min	2D	HB a) max 285 R N/mm ² min 862 +A+C cold-d HB a) max	 Af ~ 30 Cr₂O₇.2H₂O) ho a) for informative of the second seco	ation only d materia A % min 7	l C% min 20	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size mm from	nation temp al treatmen nical prop ated materi to 100 ical values a to 1 ASTM A 47 to 1 to 1 to 1 to 1 to 1 to 1 to 1	perature d t • Pickling perties ial EN 100 Testing at R N/mm ² according testing at R N/mm ² mi 758 +A hot-rol '3-99 stee Testing at R N/mm ²	to UNS room te Fin N I led ann I ASTM N	ating Act i0% HNO 005 in col mperatur Rp 0.2 V/mm ² m S44004 s mperatur Rp 0.2 V/mm ² m 48 ealed 440C) mperatur Rp 0.2 V/mm ² m 48 ealed 440C) mperatur Rp 0.2 V/mm ² m	a) hot. <i>F</i> nditions e A' in m steel 44 e A9 in mi 14 e A9 in mi	Passivation 1C, 1E, 1 % Kv in J m 0C % C% n min 25 % C% n mir	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269 Kv +20 J min 16 mm afte	2D	HB a) max 285 R N/mm ² min 862 +A+C cold-d HB a) max 269	 Af ~ 30 Cr₂O₇.2H₂O) ho a) for informative of the second seco	ation only d materia A % min 7	l C% min 20	max	
Transforr Chemica Mechai Heat-trea size mm from Bars, typ size mm from Forged (size mm from	nation temp al treatmen nical prop ated materi to 100 ical values a to 1 ASTM A 47 to 1 to 1 to 1 to 1 to 1 to 1 to 1 to 1	perature d t • Pickling perties ial EN 100 Testing at R N/mm ² according Testing at R N/mm ² mi 758 +A hot-rol '3-99 stee Testing at R N/mm ² y values at	to UNS room te in N I ASTM room te Fin N I ASTM room te R N N	ating Act 50% HNO 50% HNO 50	a) hot. <i>F</i> nditions e A' in m steel 44 e A9 in mi 14 e A9 in mi steel 44 re	Passivation 1C, 1E, 1 % Kv in J rr 0C % C% n min 25 % C% n mir unds of Ø	(20 - 25%) D, 1X, 1G, +20 °C in HB max 269 Kv +20 J min 16 mm afte	HNO: 2D 	HB a) max 285 R N/mm ² min 862 +A+C cold-d HB a) max 269 mching at 1020	 Af ~ 30 Cr₂O₇.2H₂O) ho a) for informative the annealed Rp 0.2 N/mm² min 689 rawn +A annealed *C in oil 	ation only d materia A % min 7 d materia	l C% min 20	max 285	

X105CrMo17 r	n° 1.4125 mar	tensitic st	ainless s	teel						Lucefin Group
Thermal expan	nsion 10) ⁻⁶ • K ⁻¹		•	10.4	ļ	10.8	11.2	11.6	12.0
Modulus of ela	asticity lor	ngitudinal	GPa	215	212		205	200	190	
Poisson numb	oer v	0		0,283						
Electrical resis	stivity Ω	• mm²/m		0.80						
Electrical cond	ductivity Sid	emens•m	/mm ²	1.25						
Specific heat	J/((Kg•K)		430						
Density	Kç	g/dm ³		7.70						
Thermal cond	uctivity	W/(r	n∙K)	15						
Relative magn	etic permeabil	ity µr		700-1000 ~						
°C				20	100		200	300	400	500
	ndicates temper	rature bet	ween 20					300	400	500
The symbol ► i	· · ·		ween 20 ospheric	°C and 100 °	C, 20 °		0 °C	300		500 x steam, petroleum,
The symbol ► in Corrosion resi	· · ·	Atm		°C and 100 °	C, 20 °	°C and 20	0 °C	300 reducing		x steam, petroleum, ammonia, gasoline,
°C The symbol ► in Corrosion resi Fresh water x	· · ·	Atm	ospheric	°C and 100 °	C, 20 °	°C and 20 Chemical	0 °C			x steam, petroleum,
The symbol ► in Corrosion resi Fresh water x	· · ·	Atm	ospheric	°C and 100 °	C, 20 °	°C and 20 Chemical	0 °C			x steam, petroleum, ammonia, gasoline,
The symbol ► in Corrosion resi Fresh water	· · ·	Atm indu	ospheric <i>strial</i>	°C and 100 °	C, 20 °	°C and 20 Chemical	0 °C			x steam, petroleum, ammonia, gasoline,
The symbol ► in Corrosion resi Fresh water x Magnetic	· · ·	Atm indu yes diffic	ospheric <i>strial</i>	°C and 100 ° <i>marine</i>	C, 20 °	°C and 20 Chemical	0 °C			x steam, petroleum, ammonia, gasoline,
The symbol ► in Corrosion resi Fresh water X Magnetic Machinability Hardening	istance	Atm indu yes diffic by q	ospheric strial cult uenching	°C and 100 ° <i>marine</i>	C, 20 °	°C and 20 Chemical <i>medium</i>	0 °C			x steam, petroleum, ammonia, gasoline,
The symbol ► in Corrosion resi Fresh water x Magnetic Machinability	istance	Atm indu yes diffic by q	ospheric strial cult uenching istance to	°C and 100 ° <i>marine</i>	C, 20 °	°C and 20 Chemical <i>medium</i> 0 °C sia	0 °C			x steam, petroleum, ammonia, gasoline,



Quality	X5CrNi18-10	Austenitic	Technical card 2014
Number	1.4301	Stainless Steel	Lucefin Group
Chamical com	nosition		

onenne												
C%	Si%	Mn%	P%	S% ^{a)}	Cr%	Ni%	N%					
max	max	max	max	max			max					
0,07	1,00	2,00	0,045	0,015	17,5-19,5	8,0-10,5	0,11	EN 10088-1: 2005				
± 0.01	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.2	± 0.1	± 0.01					

a) for machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

		C Hot-formi	•	n annealing zation) +AT	Stabilizing	Soft annealing	+A	MMA pre-he	Welding - e eating	electrodes post we	
1460-14	00	1800-950	1120-10 water	/	not necessary				ecessary	slow co	0
Sensitiz	ation	Quenchin +Q	ng Temper +T	ing	Stress-reliev +SR	ing		<i>joint</i> w carbor	<i>vith steel</i> n CrMo	o alloyed	stainless
not recor	mmended	not suitabl	le not suita	ible	430-350 air				E308 E309 etic welding - E308L	9-E308	E308
Chemica	al treatme	nt • Pickling	(6 - 25% HNO ₃)	+ (0.5 - 8% H	IF) hot • Passiva	ation 20 - 50°	% HNO	₃ hot			
		operties				_					
	ated mate				E, 1D, 1X, 1G, 2	20					
size			pom temperatur		A 0/	K	V	0 00			
mm	4-	R	Rp 0.2	A %	A%	Kv +20 °C	Kv +2		HB a)		
rom	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J mir	1(1)	max		
	160	500-700	190	45	05	100	00		215		solubilizatio
60	250	500-700	190		35		60		215	+AI :	solubilizatio
) for info	ormation o	nly		(L) = longitu	dinal (T) = transve	ersal					
	ars of hea				conditions 2H, 2	B, 2G, 2P					
ize			oom temperatur								
nm		R	Rp 0.2	A%	A%	Kv +20 °C		20 °C			
rom	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J mii	ו (T)			
	10 ^{b)}	600-950	400	25							
0	16	600-950	400	25						+AT :	solubilizatio
6	40	600-850	190	30		100					
10	63	580-850	190	30		100					
53	160	500-700	190	45		100					
160	250	500-700	190		35		60				
nave to b	be agreed		nm, values are frequest and or		ounds – the me	chanical prop	erties o	f non r	ound bars o	of < 5 mm	of thickness
- · · ·	+AT solub	ilization EN 1	0250-4: 2001								
-orgea ·											
•		Testing at ro	oom temperatur	е							
size		Testing at ro R	com temperatur Rp 0.2	e A%		Kv +20 °C	Kv +2	0°C	Kv -196 °	°C	
size mm	to	v	•			Kv +20 °C J min (L)	Kv +2 J min		Κν -196 ° J min (T)		
size mm	to 250	R	Rp 0.2	A %	min (T))	0250-4
size mm		R N/mm ²	Rp 0.2 N/mm ² min	A %	min (T) 35	J min (L)	J min) EN 1	0250-4 0222-5
size mm over	250 250	R N/mm ² 500-700 500-700	Rp 0.2 N/mm² min 190 200	A % min (L) 45	min (T) 35 35	J min (L) 100 100	J min 60		J min (T)) EN 1	
size mm over	250 250	R N/mm ² 500-700 500-700 y cold-drawi	Rp 0.2 N/mm² min 190 200	A% min (L) 45 : 2005 in cond	min (T) 35	J min (L) 100 100	J min 60		J min (T)) EN 1	
size mm over Nork-ha	250 250	R N/mm ² 500-700 500-700 y cold-drawi	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 10088-3	A% min (L) 45 : 2005 in cond	min (T) 35 35	J min (L) 100 100	J min 60		J min (T)) EN 1	
size nm over Vork-ha size nm	250 250	R N/mm ² 500-700 500-700 y cold-drawi Testing at ro	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 10088-3	A% min (L) 45 : 2005 in conc e	min (T) 35 35	J min (L) 100 100	J min 60		J min (T)) EN 1	
ize nm over Vork-ha ize nm	250 250 ardened b	R N/mm ² 500-700 500-700 y cold-drawi Testing at ro R N/mm ²	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 0.0 pom temperatur Rp 0.2 N/mm²	A% min (L) 45 : 2005 in conc e A% min	min (T) 35 35 Jition 2H (ex. +A	J min (L) 100 100 T+C)	J min 60 60		J min (T)) EN 1	
ize nm over Vork-ha ize nm	250 250 ardened b	R N/mm ² 500-700 500-700 y cold-drawi Testing at ro R	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 pom temperatur Rp 0.2 0.2	A% min (L) 45 : 2005 in conc e A%	min (T) 35 35	J min (L) 100 100 .T+C) Id-drawn mat	J min 60 60 erial		J min (T)) EN 1	
size nm over Work-ha size nm from	250 250 ardened b to 35 25	R N/mm² 500-700 500-700 y cold-drawi Testing at ro R N/mm² 700-850 800-1000	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 000 poom temperatur Rp 0.2 N/mm² N/mm² min 350 500	A% min (L) 45 : 2005 in conce e A% min 20 12	min (T) 35 35 dition 2H (ex. +A +AT+C700 co +AT+C800 co	J min (L) 100 100 .T+C) Id-drawn mat	J min 60 60 erial erial	(T)	J min (T) 60) EN 1 EN 1	0222-5
size Nork-ha size nm rom	250 250 ardened b to 35 25 on curve	R N/mm² 500-700 500-700 y cold-drawi Testing at ro R N/mm² 700-850 800-1000 determined by	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 0.00000000000000000000000000000000000	A% min (L) 45 : 2005 in conce A% min 20 12 laterial solubili	min (T) 35 35 Jition 2H (ex. +A +AT+C700 co +AT+C800 co ized at 1050 °C	J min (L) 100 100 T+C) Id-drawn mai	J min 60 60 erial erial + <i>A</i>	(T) T mate	J min (T) 60 erial – appro	EN 1 EN 1 EN 1	0222-5
size Nover Work-ha size nm rom Fransitio	250 250 ardened b to 35 25 on curve of J	R N/mm² 500-700 500-700 y cold-drawi Testing at ro R N/mm² 700-850 800-1000 determined b 210 2	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 000000000000000000000000000000000000	A% min (L) 45 : 2005 in conce e A% min 20 12 iaterial solubili 212	min (T) 35 35 Jition 2H (ex. +A +AT+C700 co +AT+C800 co ized at 1050 °C 218 228	J min (L) 100 100 .T+C) Id-drawn mat Id-drawn mat	J min 60 60 erial erial	(T) T mate	J min (T) 60 erial – appro R	EN 1 EN 1 EN 1	lues A%
size Nover Work-ha size nm rom Fransitio	250 250 ardened b to 35 25 on curve	R N/mm² 500-700 500-700 y cold-drawi Testing at ro R N/mm² 700-850 800-1000 determined b 210 2	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 0.00000000000000000000000000000000000	A% min (L) 45 : 2005 in conce A% min 20 12 laterial solubili	min (T) 35 35 Jition 2H (ex. +A +AT+C700 co +AT+C800 co ized at 1050 °C	J min (L) 100 100 .T+C) Id-drawn mat Id-drawn mat	J min 60 60 erial erial +A °C	(T) T mate	J min (T) 60 erial – appro R N/mm²) EN 1 EN 1 ximate va Rp 0.2 N/mm ²	0222-5 lues A% %
size Nover Work-ha size nm rom Fransitio	250 250 ardened b to 35 25 on curve of J	R N/mm² 500-700 500-700 y cold-drawi Testing at ro R N/mm² 700-850 800-1000 determined b 210 2	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 000000000000000000000000000000000000	A% min (L) 45 : 2005 in conce e A% min 20 12 iaterial solubili 212	min (T) 35 35 Jition 2H (ex. +A +AT+C700 co +AT+C800 co ized at 1050 °C 218 228	J min (L) 100 100 .T+C) Id-drawn mat Id-drawn mat	J min 60 60 erial erial + <i>A</i> °C +2	(T) T mate	J min (T) 60 erial – appro R N/mm ² 520) EN 1 EN 1 ximate va Rp 0.2 N/mm ² 210	lues A% % 45
size Mork-ha size mm irom	250 250 ardened b to 35 25 on curve of J	R N/mm² 500-700 500-700 y cold-drawi Testing at ro R N/mm² 700-850 800-1000 determined b 210 2	Rp 0.2 N/mm² min 190 200 ing EN 10088-3 000000000000000000000000000000000000	A% min (L) 45 : 2005 in conce e A% min 20 12 iaterial solubili 212	min (T) 35 35 Jition 2H (ex. +A +AT+C700 co +AT+C800 co ized at 1050 °C 218 228	J min (L) 100 100 .T+C) Id-drawn mat Id-drawn mat	J min 60 60 erial erial +A °C	(T) T mate 4	J min (T) 60 erial – appro R N/mm²) EN 1 EN 1 ximate va Rp 0.2 N/mm ²	0222-5 lues A% %

X5CrNi1	8-10 nº 1.4	301 auster	nitic stainless	s steel								Lı	icefin G	roup
Effect of	cold-worki	ng (hot-rolle	d +AT+C). A	pproxima	ate value	s								
R	N/mm ²	560	715	830	1000	1110	1240	1400	1500	1600				
Rp 0.2	N/mm ²	300	490	600	860	1000	1100	1210	1350	1400				
Α	%	38	20	12	10	10	10	10	8	8				
Reductio	n %	0	10	20	30	40	50	60	70	75				
Minimur	n yield stre	ss and tens	ile strength	values	at high t	empera	tures on	+AT ma	iterial, El	V 10088	-3: 2005	/ EN 102	269: 200	1
Rp 0.2	N/mm ²	155	140	127	118	110	104	98	95	92	90			
R	N/mm ²	450	420	400	390	380	380	375	360	335	300			
Test at	°C	100	150	200	250	300	350	400	450	500	550			
Thermal	expansion	10 ⁻⁶ •	K -1		13.4	13.8	14.8	►	16.0	16.5	17.0	17.5	18.8	20.2
Modulus	s of elastici	ty longitu	dinal GPa	180				200	194	186	179	172		127
Poisson	number	v						0.24	0.256					
Electrica	al resistivity	γ Ω•mr	n²/m	0.55			0.64	0.73		0.86		1.00	1.11	1.21
Electrica	al conductiv	vity Sieme	ns•m/mm²					1.37						
Specific	heat	J/(Kg∙	K)					500		510		550	585	630
Density		Kg/dm	3					7.93						
Thermal	conductivi	ty	W/(m∙K)					15.0	16.3	17.5	19.9	21.5		25.1
	magnetic p	permeability	/µr					1.021						
°C				-196	-184	-128	-74	20	100	200	300	400	600	800
The sym	bol► indica	ites betweer	120°C and	l 100 °C,	20 °C a	nd 200 °	°C							
Corrosio	on resistanc	ce	Atmosph	eric		C	Chemical						acid, we	
Fresh wa	ater		industria	l n	narine	n	nedium	oxi	dizing	redu	cing		,	ural and
x			x			x		X				urban	atmosph	eres
Magneti	c		not											
Machina	bility		high											
Hardeni	ng		cold-drav	vn and of	ther cold	plastic o	deformati	ons						
Service	temperatur	e in air	continuo	us servic	e up to 8	50 °C; ir	ntermitte	nt servic	e up to 8	00 °C				
Europe	US		USA		nina	Rus		Japa	an	India	1		ublic of	Korea
EN	UN		ASTM	GB		GOS		JIS		IS		KS		
X5CrNi1	8-10 S3	0400	(304)	00	r18Ni9	07C	h18N10			X040	Cr19Ni9			





Quality	/		BCrNiS18-9				tenitic		Technical card 2014		
lumber		1	.4305			Stai	nless Steel		Luce	efin Group	
Chemi	cal com	position									
:%	Si%	Mn%	P%	S%	Cr%	Ni%	N%	Cu%			
nax	max	max	max	0.45.0.05	47.0.40.0	0.0.40.0	max	max		0000 4. 0005	
,10	1,00	2,00	0,045	0,15-0,35	17,0-19,0		0,11	1,00		0088-1: 2005	
: 0.01 Iroduct (+ 0.0; doviations	5 <u>+</u> 0.04 are allowed	+ 0.005	<u>+</u> 0.02	± 0.2	± 0.1	± 0.01	± 0.0	/		
	rature °										
lelting		Hot-formir	(Solubili	annealing zation) +AT	Stabilizin	g	MMA weldin pre-heating	•	S electrodes post we	lding	
420-140	00	1200-900	1150-10 water / a		not necess	sary	not recomme joint with stee				
Sensitiza	ation	Quenching +Q	g Temper +T	ing	Soft anne +A	aling	carbon butter E309 - E	312,	CrMo alloyed the same as	stainless E308 - E312	
ensitiza	tion	not suitable	e not suita	ble	not suitabl	е	finish with E30	8	carbon steels		
est at							cosmetic wel	ding			
800-450	-1 4		00 500/ 1110) . (0 . 00/ 11	- 0- 0 01	()	E308 – E312				
		• (20 - 50% HNO:	s) + (2 - 6% N	a2Ur2U7.2H2) not or col	a				
		operties									
	ated mate		3-3: 2005 in cor		E, 1D, 1X, 1	G, 2D					
ize nm		l esting at ro	om temperature Rp 0.2	e A%	A%	Kv +20 °C	Kv +20 °	°C	HB ^{a)}		
om	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J min (T	-	max		
•	160	500-750	190	35		• (2)	•	/		T solubilization	
for info	rmation o	nly		(L) = longitu	dinal (T) = tra	nsversal					
Briaht b	ars of he	at-treated ma	terial EN 1008	8-3: 2005 in a	conditions 2H	H, 2B. 2G. 2F	D				
size			om temperatur			.,,_,_,_					
nm		R	Rp 0.2	A%	A%	Kv +20 °C	Kv +20	°C			
om	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J min (1)			
0	10 ^{b)} 16	600-950 600-950	400 400	15 15						AT solubilization	
6	40	600-950	190	20		100					
.0	63	500-850	190	20		100					
3	160	500-750	190	35		100					
hickness	s have to		m, values are v ne time of reque		ounds – the	mechanical	properties of n	on roun	d bars of < 5	mm of	
orged ((ASTM A	473-99 steel A	STM 303)								
size		.	om temperatur								
nm	4.	R N/mm2 min	Rp 0.2	A %	C%	Kv +20 °C	Kv +20				
rom	to	N/mm ² min 515	N/mm ² min 205	min (L) 40	min (L) 50	J min (L)	J min	(1)		T colubilization	
									+/	AT solubilization	
	irdned by		g EN 10088-3: :		tion 2H (ex.	+AI+C)					
ize nm		R I esting at ro	om temperature Rp 0.2	e A%							
rom	to	N/mm ²	N/mm ² min	min							
	35	700-850	350	20	+AT+C700	cold-drawn r	naterial				
	25	800-1000	500	12		cold-drawn r					
ransitio	on curve	determined by	Kv impacts. M	aterial solubili	zed at 1050	°C					
verage		212		230	238	244	250		258		
est at	°C	-160		-80	-40	0	+40		+80		
Effect of	cold-wor	king (hot-rolle	d +AT+C). App	roximate valu	es						
	N/mm ²	610	800	1000	1200	1320	1480		1600	1750	
κ	N/mm ²	240		740	880	1020	1200		1320	1450	
							-		^	•	
Rp 0.2 A	%	40		16	10	8	8		8	6	
R Rp 0.2 A permeat Reductio	% pility µr	40 1.005 0	1.06	16 1.64 20	10 3.44 30	8 40	8 50		8 60	6 70	

X8CrNiS18-9 n	° 1.4305 a	ustenitic stainless s	steel					Luc	efin Group
Thermal expan	sion	10 ⁻⁶ • K ⁻¹	•	16.0	16.5	17.0	17.5		
Modulus of ela	sticity	longitudinal GPa	200	194	186	179	172		127
Poisson numb	er	V	0.24	0.256					
Electrical resis	tivity	$\Omega \cdot mm^2/m$	0.73		0.86		0.97		1.15
Electrical cond	uctivity	Siemens•m/mm ²	1.37						
Specific heat		J/(Kg•K)	500		510		550	585	630
Density		Kg/dm ³	7.84						
Thermal condu	ictivity	W/(m∙K)	15.3	16.3	17.5	19.9	21.5		25.1
Relative magne	etic permeal	bility µr	1.021						
°C			20	100	200	300	400	600	800
The symbol ► ir	idicates temp	peratures between	20 °C and 100	°C, 20	°C and 200	°C			
Corrosion resis	stance	Atmospher	ic	(Chemical				and organic
Fresh water		industrial	marine	1	nedium	oxidizing	reducing		ces, 5% nitric
x		x	X	3	(acid	
Magnetic		not							
Machinability		high							
Hardening		cold-drawn	and other cold	l plastic	deformatior	ı			
Service temper	rature in air	continuous	service up to 8	370 °C; i	intermittent	service up to 7	760 °C		
Europe	USA UNS	USA ASTM	China GB	Rus GOST		Japan JIS	India IS	Republ KS	ic of Korea
	UNO	ASTIV	GD	605	1	010	10	кo	



Quality	X2CrNi19-11	Austenitic	Technical card 2014
Number	1.4306	Stainless Steel	Lucefin Group
Chamical com	naaltion		

Chemical	l composition	۱
••		•

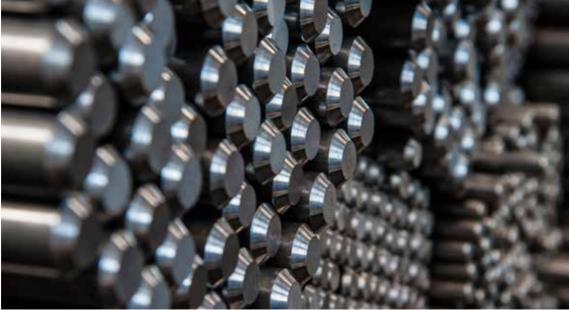
Cnemica	ai compos	tion						
C%	Si%	Mn%	P%	S% a)	Cr%	Ni%	N%	
max	max	max	max	max			max	
0,03	1,00	2,00	0,045	0,030	18,0-20,0	10,0-12,0	0,11	EN 10088-1: 2005
+ 0.005	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.005	± 0.2	± 0.15	± 0.01	

Product deviations are allowed ^{a)} for machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015%

	erature °				04-1-11	0.4					te e el e
Melting		Hot-forming	(Solubiliza	annealing ation) +AT	Stabilizing	Soft annea +A	aling	MMA w pre-hea	velding – A ating	WS elec post w	
1450-14	00	1200-930	1100-105	0	885	not suitable	9	not nec	essary	slow c	ooling
			water		calm air						
Sensitiz	ation	Quenching +Q	Temperir +T	Ig	Stress-relievi +SR	ng		<i>joint wi</i> carbon		alloyed	stainless
not suita	able	not suitable	not suitab	le	450-230			E309-E3 cosmet E308 L	308 E309 tic welding	-E308	E308
Chemic	al treatme	ent • Pickling (6	5 - 25% HNO3)	+ (0.5 - 8% H	F) hot • Passivati	on 20 - 50% HN	O₃ hot				
Mecha	inical pr	operties									
Heat-tre	eated mat	erial EN 10088-	-3: 2005 in con	ditions 1C, 1E	E, 1D, 1X, 1G, 2D						
size		Testing at roo	m temperature								
mm		R	Rp 0.2	A %	A%	Kv +20 °C	Kv +	20 °C	HB a)		
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	Jmi	n (T)	max		
	160	460-680	180	45		100			215	+AT so	olubilizatio
160	250	460-680	180		35		60		215	+AT so	olubilizatio
^{a)} for info	ormation o	nly		(L) = longitu	dinal (T) = transvers	al					
Bright b	are of he	at-treated mat	arial EN 10088	-3· 2005 in c	onditions 2H, 2B,	2G 2P					
size			m temperature	-5. 2005 1110	011010013 211, 20,	20, 21					
mm		R	Rp 0.2	A%	A%	Kv +20 °C	Ky .	20 °C			
from	to	N/mm ²	N/mm ² min	min (L)							
ITOITI	10 ^{b)}	600-930	400	25	min (T)	J min (L)	J mir	1(1)			
10	10 %			25							olubilizatio
		600-930	380			100				+AT SC	Judilizatio
16	40	460-830	180	30		100					
40	63	460-830	180	30		100					
63	160	460-680	180	45	05	100	00				
160	250	460-680	180		35		60		6.5	6.0.1	
to be ag	reed at the	mm <u><</u> d < 5 mr e time of reques) = transversal	,	alid only for ro	ounds – the mech	anical properties	of non	rouna b	ars of < 5 n		ckness nav
Forged	EN 1025	0-4: 2001									
size		Testing at roo	m temperature								
mm		R	Rp 0.2	A %	A%	Kv +20 °C	Kv -	+20 °C			
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	Jm	in (T)			
	250	460-680	180		35	100	60			+AT so	olubilizatio
Work-ha	ardned by	/ cold-drawing	EN 10088-3: 2	005 in conditi	ion 2H (es. +AT+)	C)					
size			m temperature		``	,					
mm		R	Rp 0.2	A %							
from	to	N/mm ²	N/mm ² min	min							
	35	700-850	350	20	+AT+C700	cold-drawn mater	rial				
	25	800-1000	500	12		cold-drawn mater					
Annrovi					Material solubilize						
Approxi R	N/mm ²	1450	1300	1000	600						
	N/mm ²	350	320	320	290						
Rp 0.2											
A	%	40	45	50	55						
Test at	°C	-254	-196	-100	0						

X2CrNi19-1	1 nº 1.43	06 austeni	tic stainless	steel						Lucef	in Group
Effect of co	d-working	(hot-rolled	+AT+C). Ap	proximat	e values						
R	N/mm ²	600	780	880	1000	1080	1150	1220	1350		
Rp 0.2	N/mm ²	300	440	600	720	820	960	1040	1180		
A	%	60	40	20	14	12	12	12	12		
Reduction	%	0	10	20	30	40	50	60	70		
Minimum	alues at hi	gh temper	atures on m	naterial +/	AT, EN 10	088-3: 2005 so	olubilized				
Rp 0.2	N/mm ²	145	130	118	108	100	94	89	85	81	80
Test at	°C	100	150	200	250	300	350	400	450	500	550
Thermal ex	cpansion	10 ⁻⁶ •	K-1		►	16.0	16.5	17.0	17.5	18.0	
Modulus o	f elasticity	long.	GPa		200	194	186	179	172	165	
Poisson n	umber	v		0.30	0.30	0.30	0.31	0.31	0.32	0.32	
Electrical I	esistivity	Ω.m	1m²/m		0.73						
Electrical of	conductivit	y Sieme	ens•m/mm ²		1.37						
Specific he	eat	J/(Kg	•K)		500						
Density		Kg/dn	n ³		7.90						
Thermal co	onductivity		W/(m∙K)		15.0						
Relative m	agnetic per	rmeability	µr max	~ 2	1.02						
°C				-196	20	100	200	300	400	500	
The symbo	I lindicates	s temperatu	ire between	20 °C an	d 100 °C,	20 °C and 20	0 °C				
Corrosion	resistance		Atmosphe	eric		Chemical				x intercrys	
Fresh wate	r		industrial	ma	arine	medium	oxidizi	ng r	educing	corrosion,	
X			X			x	x)	(colouring a substance	and organic s
Magnetic			no								
Machinabi	lity		high								
Hardening						astic deformati					
Service ter	nperature i	n air	continuou	s service	up to 850	°C; intermitte	nt service u	p to 800 °	°C		
Europe	USA		USA	China	a	Russia	Japan		India		ic of Korea
EN VOC-NE10 1	UNS		ASTM	GB	-101:10	GOST (02Ch19NI11	JIS		IS V020-NI:10	KS	





Quality	/		X2CrN	i18-9					enitic			Technical	
Number			1.430	7				Stair	iless Steel			Lucefin	Group
Chemi	cal com	position											
C%	Si%	-	Mn%	P%	5	5% ^{a)}	Cr%		Ni%	N%			
max	max	c r	nax	max	r	nax				max			
0,03	1,00) 2	2,00	0,04	5 (),015	17,5-1	9,5	8,0-10,5	0,11		EN 10088	-1: 2005
+ 0.005	+ 0.		<u>+</u> 0.04	+ 0.0)05 +	- 0.003	± 0.2		± 0.1	± 0.0	1		
^{a)} for imp	roving ma	s are allowe achinability max 0,015	, it is allo	owed a co	ntrolled su	lphur cont	ent of 0,0	15 % - 0	,030 %; fo	polishal	oility, it is	suggeste	d a control
Tempe	rature °	°C											
Melting		Hot-for	ming		n annealin zation) +A		lizing	Soft anneal	ing +A	MMA w pre-hea	•	AWS elect	
1460-140	00	1200-9	30	1120-10 water	00	not n	ecessary	not suit	able	not nece	essary	slow co	oling
Sensitiz	ation	Quenc +Q	hing	Temper +T	ing					<i>joint witi</i> carbon		lo alloyed	stainless
sensitiza test at 70		not suit	able	not suita	ible					E309-E3 cosmeti E308 L	08 E30 c welding	19-E308 7	E308
Chemica	al treatme	ent • Pickli	ng (10%	HNO3) +	(2% HF) at	60° or col	d • Passi	vation 20)-50% HN	O₃ cold			
Heat-tre size mm	ated mat	erial EN 10 Testing a R	it room te	emperatur 0.2		, 1E, 1D, 1		, +20 °C	Kv +	20 °C	HB a)		
from	to	N/mm ²	N/r	nm² min	min (L)	min	(T) J	min (L)	Jm	n (T)	max		
	160	500-700	17		45		10	0			215		lubilization
160	250	500-700	17			35			60		215	+AT so	lubilization
	rmation o		-	al (T) = tra									
-	ars of he	at-treated				in conditio	ns 2H, 2E	8, 2G, 2F					
size		Testing a		emperatur		A 0/	μ.		V	20.00			
mm from	to	N/mm ²	•	0.2 nm² min	A% min (L)	A% min		/ +20 °C min (L)	Jmi	20 °C			
nom	10 ^{b)}	600-930	400		25		1) 01	IIIII (L)	5 111	1(1)			
10	16	600-930	380		25							+AT so	lubilization
16	40	500-830	175	5	30		10	0					
40	63	500-830	175		30		10						
63	160	500-700	175		45		10	0					
160	250	500-700	175		المراجعة المراجع	35	41	h a start a	60	f		- 6 - 7	- f th: - 1
have to t (L) = long	e agreed itudinal (T)	at the time = transvers	e of requ			or rounds -	- ine met		properties o				
	+AT solub		t room to	morativ	0								
size mm		R		emperatur 0.2	e A%	A %	K,	/ +20 °C	Kv +20	°C K	✔ -196 °C		
from	to	N/mm ²		nm² min	min (L)	min		min (L)	J min		min (T)		
	250	460-680	180		(-)	35	10	()	60	., .	1.1	EN 102	250-4: 200
	250	500-700	200		45	35	10	0	60	60)	EN 102	222-5: 200 ⁻
Work-ha	rdned by	/ cold-drav	ving EN	10088-3:	2005 cond	ition 2H (e	s. +AT+C)					
size				emperatur		(-		,					
mm		R		0.2	A %								
from	to	N/mm ²		nm² min	min								
	35	700-850	350		20		C700 colo						
	25	800-1000) 500)	12	+AT+	C800 colo	1-drawn i	material				
Transitio	on curve	determined					1050 °C					mate value	
Average	J	230	230	232	236	245	268	290	°C	R		Rp 0.2	A%
T	°C	-160	-120	-80	-40	0	+40	+80			mm ²	N/mm ²	%
Test at									1 1 2 4	C	v11	200	45
l est at									+24	55			
l est at									+24 -80 -196	83		200 220 300	35 30

R	N/mm ²	650	850	. 1000	1100	1190	1280	1380	1500	1570	
Rp 0.2	N/mm ²	300	400	650	790	950	1120	1270	1370	1420	
A	%	45	38	32	25	20	18	12	10	8	
Reduction	%	0	10	20	30	40	50	60	70	75	
Minimum	yield stress	and tens	ile strength	values at	high temp	eratures on	material +/	AT, EN 100	88-3: 2005	5 / EN 10269	: 2001
Rp 0.2	N/mm ²	145	130	118	108	100	94	89	85	81	80
R	N/mm ²	410	380	360	350	340	340	330			
Test at	°C	100	150	200	250	300	350	400	450	500	550
Thermal e	xpansion	10 ⁻⁶	• K ⁻¹	•	16.0	16.5	17.0	18.0	18.0		
Modulus c	of elasticity	long.	GPa	200	194	186	179	172		127	
Poisson n	umber	v		0.28							
Electrical	resistivity	Ω • I	nm²/m	0.72		0.86		1.00	1.11	1.21	
Electrical	conductivity	/ Siem	ens•m/mm2	1.37							
Specific h	eat	J/(Kg	J∙K)	500		503		520	541	559	
Density		Kg/d	m ³	7.90							
	onductivity		W/(m∙K)	15.0	16.3	17.2	18.7	20.2		25.8	
Relative m	nagnetic per	meability	µr max	1.021							
°C				20	100	200	300	400	600	800	
The symbo	ol ► indicates	temperat	ure between	20 °C and	100 °C, 2	0 °C and 20	0 °C				
Corrosion	resistance		Atmosphe	ric		Chemic	al			x intercrys	
Fresh wate	er		industrial	т	arine	mild	oxidi	zing re	educing	corrosion,	
x			X	x		X	X	x		urban atm	ospheres
Magnetic			no								
Machinabi	ility		high								
Hardening	1					tic deformat					
Service te	mperature i	n air	continuou	s service	up to 850 °	C; intermitte	nt service u	p to 800 °0	2		

Europe	USA	USA	China	Russia	Japan	India	Republic of Korea
EN	UNS	ASTM	GB	GOST	JIS	IS	KS
X2CrNi18-9	S30403	(304L)	00Cr19Ni10	03Ch18N11		X02Cr18Ni11	



Ċ, 197

Lucefin Group

Quality			10CrNi18-8				enitic			Technical card 2014		
Number		1	.4310			Stair	less Stee			Lucefin	Group	
Chemic	al com	position										
C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	N%				
	max	max	max	max		max		max				
0,05-0,15	2,00	2,00	0,045	0,015	16,0-19,0	0,80	6,0-9,5	0,11		EN 10088	8-1: 2005	
+ 0.01	<u>+</u> 0.10	<u>+</u> 0.10	+ 0.005	+ 0.003	± 0.2	± 0.05	± 0.1	± 0.	01			
Product de	eviations	are allowed										
Tempera	atur °C											
Melting ra		Hot-formi		annealing ation) +AT	Stabilizing	Soft anneal	ina +A	MMA we	•	AWSelectr	odes velding	
1435-1400)	1250-1150	· ·	,	not necessary			not nece	0	slow c		
Sensitizat	tion	Quenchin +Q	g Temperi +T	ng	Stress-reliev +SR	ing		<i>joint with</i> carbon		Mo alloyed	stainless	
avoid slow	/ heating	not suitable	e not suita	ble	400-250			E309-E30		09-E308	E308	
in the rang 420 and 8	ge of							cosmetic E308	welding	g		
Chemical	treatme	nt • Pickling 2	20 - 50% HNO ₃	hot or cold								
Mechan	ical pro	operties										
		•	8-3: 2005 in cor	nditions 1C. 1	E. 1D. 1X. 1G.	2D						
size			om temperature		_,,,,							
mm		R	Rp 0.2	A %	A%	Kv +20	°C Kv	+20 °C	HB a)			
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L) Jr	nin (T)	max			
	40	500-750	195	40					230	+AT so	olubilization	
^{a)} for inform	mation or	ıly		(L) = longitu	dinal (T) = transv	ersal						
Hot-forme	ed (hot-ro	olled) ASTM A	A 276-04									
size			om temperature	9								
mm		R	Rp 0.2	A%	C%	Kv +20	°C Kv	+20 °C				
	to	N/mm ² min	N/mm ² min	min (L)	min (L)	J min (L	.) Jn	nin (T)				
				40	50					+AT se	olubilizatio	
from all		515	205	10	00							
all		515 lization AST		-10								
all Forged +/		lization AST										
all Forged +/ size		lization AST	M A 473-99		C%	Kv +20	°C Kv	+20 °C	Kv -19	96 °C		
all Forged +/ size mm		ilization AST Testing at ro R N/mm ² min	M A 473-99 om temperature Rp 0.2 N/mm ² min	e A% min (L)	C % min (L)	Kv +20 J min (+20 °C nin (T)	Kv -19 J min			
all Forged +/ size mm	AT solubi	ilization AST Testing at ro R	M A 473-99 oom temperature Rp 0.2	e A%	C %							
all Forged +/ size mm from	AT solubi	lization AST Testing at ro R N/mm ² min 517	M A 473-99 om temperature Rp 0.2 N/mm ² min	e A% min (L) 40	C% min (L) 50							
all Forged +/ size mm from Work-har	AT solubi	lization AST Testing at ro R N/mm ² min 517 10088-3: 20	M A 473-99 om temperature Rp 0.2 N/mm ² min 207	A % min (L) 40 2H (ex. +AT+	C% min (L) 50							
all Forged +/ size mm from Work-har size	AT solubi	lization AST Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R	M A 473-99 iom temperature Rp 0.2 N/mm ² min 207 05 in condition 2	A % min (L) 40 2H (ex. +AT+	C% min (L) 50							
all Forged +/ size mm from Size mm from	AT solubi to dned EN	lization ASTI Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R N/mm ²	M A 473-99 som temperature Rp 0.2 N/mm ² min 207 05 in condition 2 som temperature Rp 0.2 N/mm ² min	 A% min (L) 40 2H (ex. +AT+ A% min 	C % min (L) 50 C)	J min (L) Jr					
all Forged +/ size mm from Size mm from	AT solubi to dned EN	lization AST Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R	M A 473-99 som temperature Rp 0.2 N/mm ² min 207 05 in condition 2 som temperature Rp 0.2	e ▲% min (L) 40 2H (ex. +AT+ e ▲%	C% min (L) 50	J min (L) Jr					
all Forged +/ size mm from Size mm from	AT solubi to dned EN to 20	lization ASTI Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R N/mm ² 800-1000	M A 473-99 som temperature Rp 0.2 N/mm ² min 207 05 in condition 2 som temperature Rp 0.2 N/mm ² min 500	 A% min (L) 40 2H (ex. +AT+ A% min 12 	C% min (L) 50 C) +AT+C800 c	J min (L) Jr					
all Forged +/ size mm Work-hard size mm from from Transition	AT solubi to dned EN to 20	lization ASTI Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R N/mm ² 800-1000	M A 473-99 som temperature Rp 0.2 N/mm ² min 207 05 in condition 2 som temperature Rp 0.2 N/mm ² min	A% min (L) 40 2H (ex. +AT+ A% min 12 aterial solubil 230	C% min (L) 50 C) +AT+C800 c	J min (L) Jr	nin (T)				
all Forged +/ size mm from size mm from from from Transition Average	AT solubi to dned EN to 20	lization ASTI Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R N/mm ² 800-1000 determined by	M A 473-99 from temperature Rp 0.2 N/mm ² min 207 05 in condition 2 from temperature Rp 0.2 N/mm ² min 500 y Kv impacts. M	A% min (L) 40 2H (ex. +AT+ A% min 12 aterial solubil	C% min (L) 50 C) +AT+C800 c ized at 1050 °C	J min (old-drawn	L) J r	nin (T)	J min	n (T)		
all Forged +/ size mm from Work-har size mm from Transition Average Test at	AT solubi to dned EN to 20 n curve o J °C	lization ASTI Testing at ro R N/mm ² min 517 10088-3: 200 Testing at ro R N/mm ² 800-1000 determined by 210 -200	M A 473-99 from temperature Rp 0.2 N/mm ² min 207 005 in condition 2 from temperature Rp 0.2 N/mm ² min 500 V v impacts. M 220 -150	 A% min (L) 40 2H (ex. +AT+ A% min 12 aterial solubil 230 -100 	C% min (L) 50 C) +AT+C800 c ized at 1050 °C 240 -50	J min (old-drawn 245 0	L) J r material 250 +50	nin (T)	J min 255	n (T)		
all Forged +/ size mm from Work-har size mm from Transition Average Test at Approxim	AT solubi to dned EN to 20 n curve o J °C nate mec	lization AST Testing at ro R N/mm ² min 517 10088-3: 200 Testing at ro R N/mm ² 800-1000 determined by 210 -200 hanical prop	M A 473-99 from temperature Rp 0.2 N/mm ² min 207 05 in condition 2 from temperature Rp 0.2 N/mm ² min 500 (Kv impacts. M 220 -150 perties at low te	A% min (L) 40 2H (ex. +AT+ A% min 12 aterial solubil 230 -100 emperatures	C% min (L) 50 C) +AT+C800 c ized at 1050 °C 240 -50 Material solubi	J min (old-drawn 245 0	L) J r material 250 +50	nin (T)	J min 255	n (T)		
all Forged +/ size mm from work-har size mm from Transition Average Test at Approxim R	AT solubi to dned EN to 20 n curve o J °C nate mec N/mm ²	Ilization ASTI Testing at ro R N/mm ² min 517 10088-3: 20 Testing at ro R N/mm ² 800-1000 determined by 210 -200 hanical prop 660	M A 473-99 from temperature Rp 0.2 N/mm ² min 207 05 in condition 2 from temperature Rp 0.2 N/mm ² min 500 V v impacts. M 220 -150 Perties at low te 1100	A% min (L) 40 2H (ex. +AT+ A% min 12 aterial solubil 230 -100 emperatures 1570	C% min (L) 50 C) +AT+C800 c ized at 1050 °C 240 -50 Material solubi 1900	J min (old-drawn 245 0	L) J r material 250 +50	nin (T)	J min 255	n (T)		
all Forged +/ size mm from from size mm from from Average Test at Approxim R Rp 0.2	AT solubi to dned EN to 20 n curve o J °C nate mec	lization AST Testing at ro R N/mm ² min 517 10088-3: 200 Testing at ro R N/mm ² 800-1000 determined by 210 -200 hanical prop	M A 473-99 from temperature Rp 0.2 N/mm ² min 207 05 in condition 2 from temperature Rp 0.2 N/mm ² min 500 (Kv impacts. M 220 -150 perties at low te	A% min (L) 40 2H (ex. +AT+ A% min 12 aterial solubil 230 -100 emperatures	C% min (L) 50 C) +AT+C800 c ized at 1050 °C 240 -50 Material solubi	J min (old-drawn 245 0	L) J r material 250 +50	nin (T)	J min 255	n (T)		

After cold forming, a stress relieving treatment at 280-420 °C, can increase the value of tensile strength of about 250 N/mm². This heat treatment also increases the fatigue limit

X10CrNi18	-8 nº 1.431	0 austenit	ic stainless	steel						Lucef	ïn Group
Effect of co	old-working	(hot-rolled	+AT+C). Ap	proxima	te values						
R	N/mm ²	620	820	1000	1200	1320	1440	1620	1780		
Rp 0.2	N/mm ²	300	580	730	880	1020	1180	1300	1460		
Α	%	46	22	14	10	9	9	9	9		
Reduction	%	0	10	20	30	40	50	60	70		
Minimum	yield stress	values at l	high tempe	ratures	on hot-rolled	material +A	T EN 1008	8-3: 2005	,		
Rp 0.2 N	l/mm ²	210	200	190	185	180					
Test at °	С	100	150	200	250	300					
Thermal e	xpansion	10 ⁻⁶ • K	-1		►	16.0	17.0	17.0	18.0	18.0	
Mod. of el	asticity b)	long. G	BPa	186	200	194	186	179	172	165	
Poisson n	umber	V			0.28						
Electrical	resistivity	$\Omega \bullet mm^2$	²/m		0.72	0.78	0.86		1.00		1.11
Electrical	conductivity	Siemens	s∙m/mm²		1.39	1.28	1.16		1.00		0.90
Specific h	eat	J/(Kg∙K))		500						
Density		Kg/dm ³			8.027						
Thermal c	onductivity		W/(m∙K)		15.0	16.3				21.5	
Relative m	agnetic peri	meability	µr _{max}		1.02 ^{a)}						
°C				-196	20	100	200	300	400	500	600
					nd 100 °C, 20				ized material		
b) cold defe	ormations res	ult in a low	er modulus	; it may b	e increased l	by stress-re	elief heat tre	eatment			
Corrosion	resistance		Atmosphe	ric		Chemic	al			x foods, o	rganic acids
Fresh wate	er		industrial	п	narine	mild	oxidi	izing	reducing	urban atm	osphere,

Fresh water		muusinai	manne	mila	oxiaizirig	reducing	uiban aunosphere,
x		X	x	x	X		petroleum
Magnetic		no					
Machinability		difficult					
Hardening		cold-drawn a	and other cold pla	astic deformations			
Service tempe	erature in air	max 400 °C	for cold plastic of	leformations and 7	780 °C for hot-f	ormed products	
Europe	USA	USA	China	Russia	Japan	India	Republic of
EN	UNS	ASTM	GB	GOST	JIS	IS	Korea KS
X10CrNi18-8	S30100	301	1Cr17Ni7	07Ch16N6	SUS 302	X07Cr18N	i9 STS 302



Quality	X2CrNiN18-10	Austenitic	Technical card rev. 2014
Number	1.4311	Stainless Steel	Lucefin Group

Chemical composition

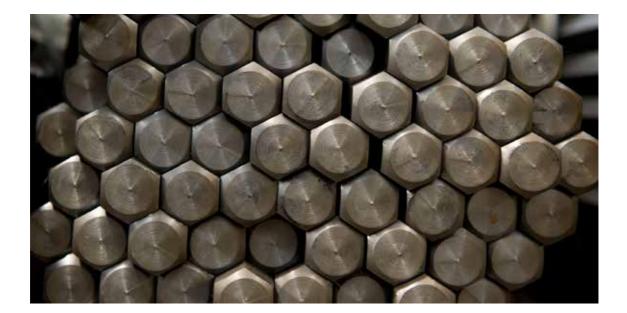
onennee	in composi							
C%	Si%	Mn%	P%	S% a)	Cr%	Ni%	N%	
max	max	max	max	max				
0,03	1,00	2,00	0,045	0,015	17,5-19,5	8,5-11,5	0,12-0,22	EN 10088-1: 2005
+ 0.005	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.2	± 0.1	± 0.02	

Product deviations are allowed

a) for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

	erature °														
Melting	range	Hot-fo	rming			nealing	So						elding – A		
1460-14	00	1200-9	050	1120-1		n) +AT		nealing t suitabl				<i>pre-hea</i> not nece		post we	0
		1200-3	50	water	000		10	Suitable	5			ioint wit	h steel		5
SR	elieving	Queno +Q	ching	Tempe +T	ering		Sta	abilizza	zione			carbon E309-E3		,	ainless 308
450-230		not		not			no						c welding		
urnace		suitab		suitabl				cessary				E308 L			
Chemic	al treatme	ent • Pick	ling (15 - 1	25% HN	O3) + ((1 - 8% ł	HF) hot	or cold							
Necha	nical pr	operties	5												
leat-tre	ated mat	erial EN 1	0088-3: 2	005 in c	onditic	ons 1C. ²	1E. 1D.	1X. 1G.	2D						
size			at room te			,	, ,	, -,							
mm		R		0.2	A %	6	Α%		Kv +2	20 °C	Kv -	-20 °C	HB a)		
rom	to	N/mm ²	N/r	nm² mir	i mii	n (L)	min	(T)	J mir	ו (L)	Jm	in (T)	max		
	160	550-760	270)	40				100				230	+AT	•
160	250	550-760	270)			30				60		230	solu	Ibilizatio
) for info	ormation o	nly (L) =	longitudir	al (T) = t	ansver	rsal									
-lat pro	ducts EN	10028-7:	2007 +A	T solubi	ized m	naterial									
hicknes			at room te												
mm		R		0.2		(tr)	A ₅(t	r)	Kv +2	20 °C	Kv -	-20 °C	Kv -196	5°C	
rom	to	N/mm ²		nm ²	%	min	% m		J		J		J		
			mir	n	t <	3	t > 3	}	min (l	I)	min	(tr)	min (tr)		
	8	550-750	290)	40		40								
	13,5	550-750	270)	40		40		100		60		60		
	75	550-750	270)	40		40		100		60		60		
	rolled stri nsversal;			ip; P = h	ot rolle	ed plate									
orged	+AT solu	ibilized m	aterial												
size		•	at room te	•											
nm		R		0.2	Α%		A%		Kv +2			-20 °C	Kv -196		
from	to	N/mm ²		nm² mir	i mii	n (L)	min	(T)	J mir	ו (L)		in (T)	J min (
	250	550-760					30		100		60				10250-4
	250	550-750	270)	45		35		100		60		60	EN 1	10222-5
lot rolle	ed ASTM	A 479 +A	T conditio	n											
size		Testing	at room te	mperatu	ire										
mm		R	Rp	0.2	A %	6	C%								
from	to	N/mm ²	min N/r	nm² mir	i mii	n	min								
	all	515	20	5	30		40								
Fransiti	on curve	determine	ed by Ky i	npacts.	Materi	al solubi	ilized at	1050 °C	;		EN	10028-	7:2007 +	AT conditi	on
Average					00	232	236	245	270	290	°C		R	Rp 0.2	Α
	°C	-253			120	-80	-40	0	+40	+80			N/mm ²	N/mm ²	%
Test at											+ 2	0	550	270	40
Test at											~ ~ ~		050	050	40
Test at											-80		850	350	40
Test at											-80 -15		1050	350 450	40 35

X2CrNiN	18-10 nº 1.4	311 aust	enitic							Lucef	in Group
Effect of	cold-working	(hot-rolled -	+AT+C). Ap	proximate	values						
R	N/mm ²	620	800	950	1080	1180	1280	1390	1520	1580	
Rp 0.2	N/mm ²	250	440	630	810	970	1120	1230	1380	1480	
A	%	46	38	30	24	18	16	14	9	6	
Reductio	n %	0	10	20	30	40	50	60	70	80	
Mnimum	yield stress	and tensile	strength v	alues at l	high tempe	ratures on	material +A	T.EN 100)88-3: 2005 /	EN 10222-5	5: 2001
Rp 0.2	N/mm ²	205	175	157	145	136	130	125	121	119	118
R [.]	N/mm ²	490	460	430	420	410	410				
Test at	°C	100	150	200	250	300	350	400	450	500	550
Thermal	expansion	10 ⁻⁶ • K ⁻¹		•	16.0	16.5	17.0	17.5	18.0		
Modulus	of elasticity	longitudina	al GPa	200	194	186	179	172	165		
	of elasticity	tangential		77	75	71	68	65	62		
	number	V		0.30	-				-		
Electrica	al resistivity	$\Omega \bullet mm^2/r$	n	0.73	0.78	0.86	0.91	1.00	1.02	1.11	
Electrica	al conduc.	Siemens.	m/mm ²	1.37							
Specific	heat	J/(Kg∙K)		500	500	520	530	540	540		
Density		Kg/dm ³		7.90							
Thermal	conductivity		W/(m•K)	15.0	16.0	17.5	19.0	20.5	22.0		
Relative	magnetic per	rmeability	µr max	1.02							
°C				20	100	200	300	400	500	600	
The sym	bol ► indicates	s temperatur	e between	20 °C and	100 °C, 20) °C and 20	0 °C				
Corrosio	on resistance		Atmosphe	ric		Chemic	al			x intergra	nular,
Fresh wa	iter		industrial	та	arine	mild	oxidi	zing	reducing	petrochem	ical, foods,
x			X	X		X	X			textile, dye	eing
Magneti	C		no								
Machina	bility		good								
Hardeniı	ng		cold-draw	n and othe	r cold plast	ic deformati	ons				
Service	temperature i	n air	continuous	s service u	ip to 850 °C	C; intermitter	nt service u	p to 800 °	°C		
Europe EN	USA UNS		USA ASTM	Chi GB	na	Russia GOST	Jap JIS	an	India IS	Republ i KS	ic of Korea
X2CrNiN		53	304LN		r18Ni10N	6031		S 304LN	10	STS 304	11 N
	10-10 33040	55	JUHLIN	000			30	5 304LIN		515 30	



Qualit	у	X	2CrNiN23-4				Austenitio				Technica	l card 2014
Number	•	1	.4362				Stainless	Stee	l (Dupl	ex)	Lucefin	Group
Chem	ical con	nposition										
C%	Si%	Mn%	P%	S%	Cr%	Ni%	N%	Cu	%	Mo%		
max	max	max	max	max							_	
0,03	1,00	2,00	0,035	0,015	22,0-24,0	3,5-5,5	0,05-0,20	0,1	0-0,60	0,10-0,60	EN 100	88-1: 2005
+ 0.005	+ 0.05	5 <u>+</u> 0.04	+ 0.005	+ 0.003	± 0.25	± 0.07	± 0.02	± 0	.07	± 0.03	-	
Product	deviation	is are allowed										
Tempe	erature	°C										
Melting	range	Hot-forming	Solution a (Solubiliza		Stabilizi	ng	Soft annealing +	A	MMA prehe	welding – . ating		trodes velding
1480-14	160	1150-1000	1100-1020 water		not requi	red	not suitable			ecessary vith steel	, solubi	lization
Sensitiz	zation	Quenching +Q	Tempering +T	g	Stress-re +SR sho		Recrystalliz n +RA	atio	carbor E2209		o alloyed 9L	stainless E309LMo
not suita	able	not suitable	not suitable	e	600-550		1050-950			etic welding		
<u>.</u>			500(1010)	(050/115)	air		quick cooling		AWS	A 5.9		
Chemic	cal treatm	ent • Pickling (52% HNO ₃) +	(65% HF)	hot • Passi	ation 20	- 45% HNO ₃ c	old				
		roperties terial EN 1008	8-3: 2005 in co	onditions 1	C, 1E, 1D, ²	1X, 1G, 2	D					
size		Testing at ro	om temperatu	re								
mm		R	Rp 0.2	A %	A%		Kv +20 °C	Kv	-40 °C	HB a)		
from	to	N/mm ²	N/mm ² min	min (L)	min	(T)	J min (L)	J	min ^{b)} (1 .		
	160	600-830	400	25			100	40		260	+AT s	olubilizatio
a) for inf	ormation	only		(L) = lo	ngitudinal (T)	= transve	rsal ^{b)} EN 102	272 :	2003			
Foraed	+AT solu	ubilization EN 1	0250-4: 2001									
size			om temperatu	re								
mm		R	Rp 0.2	A %	A %		Kv +20 °C	Kv	+20 °C	Kv -19	6 °C	
from	to	N/mm ²	N/mm ² min	min (L)	min	(T)	J min (L)	J	min (T)	J min	(T)	
	160	600-830	400	25	20		100	60				
Effect o	f cold-wo	rking (hot-rolle	ed +AT+C). Ap	proximate	values							
R	N/mm ²	740	780	830	880		910	95	0			
Rp 0.2	N/mm ²	520	690	720	800		840	87	0			
A	%	40	38	34	28		25	16				
Reducti	on %	0	5	10	15		20	30				
		tress and tens	sile strength v	alues at l	nigh tempe	ratures o	on material +A	T EN	10028	-7: 2007		
Rp 0.2	N/mm ²	374 ^{a)}	330	300	280		265					
R	N/mm ²	577 ^{a)}	540	520	500		490					
	°C	50	100	150	200		250					
Test at	-	linear interpolat		100	200		200					

		stainless steel				
Thermal expansion	10 ⁻⁶ ∙ K ⁻¹	►	13.0	13.5	14.0	
Modulus of elasticity	longitudinal GPa	200	194	186	180	
Poisson number	V	0.33				
Electrical resistivity	$\Omega \bullet mm^2/m$	0.80				
Electrical conductivity	Siemens•m/mm ²	1.25				
Specific heat	J/(Kg∙K)	482				
Density	Kg/dm ³	7.75				
Thermal conductivity	W/(m∙K)	15.0				
Relative magnetic perm	neability µr	magnetizal	ole			
°C		20	100	200	300	
The symbol ► indicates t	emperature between	20 °C and 100	°C, 20 °C and	d 200 °C		
Corrosion resistance	Atmosph	eric	Chemical			x intercrystalline, stress
Fresh water	industrial	marine	medium	oxidizing	reducing	corrosion, pitting
x	X	X	X	x		
Magnetic	yes					
Machinability	difficult					
Hardening	cold-drav	vn and other co	old plastic defo	rmations		
Service temperature	do not pr	otractedly expo	ose to tempera	tures over 300 °	°C; results in a r	educing in impact strength
Europe USA	USA	China	Russ	ia Jap	an In	dia R. Corea
		GB	GOST	JIS	IS	KS



C%		1.4	401							
C%			1.01			Staini	ess Stee	1		Lucefin Group
	ai com	position								
	Si%	Mn%	P%	S% a)	Cr%	Ni%	N%	Mo%		
max	max	max	max	max			max			
),07	1,00	2,00	0,045	0,015	16,5-18,5	10,0-13,0	0,11	2,0-2	,5	EN 10088-1: 2005
± 0.01	+ 0.05	<u>+</u> 0.04	+ 0.005	+ 0.003	± 0.2	± 0.15	± 0.01	± 0.1		
) for impr	oving ma	are allowed ichinability, it is max 0,015 %	allowed a co	ontrolled sulph	nur content of 0	,015 % - 0,0	030 %; fo	r polishabi	lity, it is	s suggested a control
Temper	ature °	С								
Melting ra		Hot-forming		n annealing ization) +AT	Stabilizing	Soft ann +A	nealing	MMA wel pre-heatin	•	AWS electrodes post welding
1400-138	0	1200-900	1100-10 water		unnecessary	not suita	ble	not neces	sary	slow cooling
Sensitiza	tion	Quenching +Q	Tempe +T	ring	Stress reliev +SR	ving		<i>joint with</i> carbon		lo alloyed stainless
sensitizati test at 800		not suitable	not suit	able	400 furnace			E309-E308 cosmetic E 316 or E	welding	
Chemica	l treatme	nt - Pickling (6	- 25% HNO3) + (0.5 - 8%	HF) hot • <i>Passi</i>	vation 20 - 5	50% HNC	D₃ hot		
		operties								
		rial EN 10088-			E, 1D, 1X, 1G,	2D				
size		Testing at room		re						
mm			Rp 0.2	A %	A%	Kv +20 °C	Kv +2	20 °C	HB a)	
rom	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J mii	n (T)	max	
	160	500-700	200	40		100			215	+AT
160	250	500-700	200		30		60		215	solubilization
^{a)} for infor	mation or	nly		(L) = longitu	udinal (T) = trans	versal				
Bright ba	rs of hea	at-treated mate	erial EN 100	88-3: 2005 in	conditions 2H,	2B, 2G, 2P				
size		Testing at room				, -,				
mm		R	Rp 0.2	A%	A%	Kv +20 °C	Kv.	+20 °C		
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J mi	in (T)		
	10 ^{b)}	600-950	400	25						
10	16	580-950	380	25						+AT
16	40	500-850	200	30		100				solubilization
40	63	500-850	200	30		100				
63	160	500-700	200	40		100				
160	250	500-700	200		30		60			
have to be	e agreed	mm <u><</u> d < 5 mn at the time of re = transversal			rounds – the m	echanical pr	operties	of non roun	d bars	of < 5 mm of thicknes
Forged +	AT solub									
size		Testing at room			A 0/	17			17 .	
mm	1	R	Rp 0.2	A%	A%	Kv +20 °C		+20 °C	Kv -19	
	to		N/mm ² min	min (L)	min (T)	J min (L)		iin (T)	J min	()
	250	500-700	200	45	30	100	60		60	EN 10250-4
	250 dned by		205 EN 10088-3-	45 2005 in cond	35 ition 2H (es. +A	100 T+C)	60		60	EN 10222-5
size	aneu by	Testing at room			1.1011 ZTI (03. +A					
mm			Rp 0.2	A%						
	to		N/mm ² min	min						
	35		350	20	+AT+C700 (cold-drawn r	naterial			
	25	800-1000	500	12	+AT+C800 (cold-drawn r	naterial			
Transitio	n curve (determined by I	Kv impacts. N	Aterial solubi	lized at 1050 °C	 C				
Average	J	198	206	218	225	238	2	45	250	
Test at	°C	-160	-120	-80	-40	0	+	40	+80	
	nate mec	hanical prope	rties at low	temperatures	. Material solub	pilized at 108	30 °C			
Approxin	N/mm ²	580	820	1270	1440					
R		045	330	520	580					
R Rp 0.2	N/mm ²	245	000							
R Rp 0.2 A		55	50	45 - 196	40 -254					

X5CrNiMo	17-12-2 n	° 1.4401 aust	enitic stainle	ss steel							L	ucefin G	iroup
Effect of c	old-workir	ng (hot-rolled +	AT+C). Appr	oximate v	alues								
R	N/mm ²	550	660	800	1000	1110	1220	1320	1430				
Rp 0.2	N/mm ²	260	510	640	790	840	920	1020	1120				
A	%	50	22	14	13	10	8	8	8				
Reduction	%	0	10	20	30	40	50	60	70				
Minimum	vield stres	ss and tensile	strength va	lues at h	igh tempe	rature	es on materia	al +AT, E	N 1008	8-3: 2005/	EN 10269	: 2001	
Rp 0.2	N/mm ²	175	158	145	135	127	120	115	112	110	108		
R	N/mm ²	460	440	420	415	410	410	410	405	390	375		
Test at	°C	100	150	200	250	300	350	400	450	500	550		
Thermal e	xpansion	10 ⁻⁶ • K ⁻¹		12.8	13.3	14.1	►	16.0	16.5	17.0	17.5	18.8	20.2
Modulus o	of elasticit	v longitudii	nal GPa				200	194	186	179	172		127
Poisson n		v					0.256	0.280					
Electrical	resistivity	$\Omega \bullet mm^2$	/m	0.58		0.66	0.75		0.86		0.97	1.07	1.15
Electrical	conductiv	vity Siemens	•m/mm ²				1.33						
Specific h	eat	J/(Kg∙K)					500		510		550	585	630
Density		Kg/dm ³					7.98						
Thermal c	onductivi	ty	W/(m∙K)				15.0		17.5	19.9			25.1
	nagnetic p	ermeability	μr				1.02						
°C				-184	-128	-74	20	100	200	300	400	600	800
The symbol	ol► indica	tes between 20	°C and 10	0 °C, 20	°C and 200)°C.							
Corrosion	resistanc	e	Atmosphe	ric		(Chemical					des, sulfu	
Fresh wate	er		industrial	т	arine	r	nedium	oxidizin	g r	educing		horic, org	anic and
x			X	X)	(x	x	(formic	acids	
Magnetic			no										
Machinab	ility		low										
Hardening	3		cold-draw	n and oth	er cold pla	stic de	formations						
Service te	mperature	e in air	continuou	s service	up to 850 °	°C; int	ermittent se	rvice up t	o 800 °	C			
Europe		JSA	USA	Chi	ina		ussia	Japar		ndia		Rep. of	Korea
EN		JNS	ASTM	GB		GC		JIS		S		KS	_
X5CrNiMo	17-12-2	531600	316	1O0	17Ni12Mo	2 08	Ch17N13M2	2 SUS 3	316)	X04Cr17N	i12Mo2	STS 31	6



Quality			CrNiMo17-12	-2		Auste				Technical	
Number		1.4	4404			Stainl	ess Stee	I		Lucefin (Group
Chemi	cal com	position									
C% max	Si% max	Mn% max	P% max	S% ^{a)} max	Cr%	Ni%	N% max	Mo%			
0.03	1,00	2,00	0,045	0,015	16,5-18,5	10,0-13,0	0,11	2,0-2	5	EN 10088-	1.2005
± 0.005	+ 0.05		+ 0.005	+ 0.003	± 0.2	± 0.15	± 0.01	± 0.1	,		
		are allowed	0.000	0.000	_ 0.2	_ 0.10	_ 0.0 .				
		chinability, it is	allowed a co	ntrolled sulph	ur content of C).015 % - 0.0)30 %: fo	r polishabi	itv. it is	suaaested	a controll
		max 0,015 %				,,-		P	. , ,		
Tempe	rature °	C									
Melting		Hot-formin		n annealing	Stabilizing	Soft ann	ealing	MMA we	ding –	AWS elect	rodes
			`	zation) +AT		+A		pre-heati	ng	post we	
1400-138	30	1200-925	1110-10)40	885	not		not neces	sary	slow co	oling
			water		calm air	suitable					
Sensitiza	ation	Quenching		ing				joint with			
		+Q	+T					carbon	CrN	No alloyed	stainless
sensitiza	tion	not suitable	not suita	able				E309-E30	8 E30	09-E308	E308
test at								cosmetic	welding	g	
700-450								E 316L			
Chemica	al treatme	nt • Pickling (6	- 25% HNO ₃)	+ (0.5 - 8% H	IF) hot • Passi	ivation 20 - 5	0% HNO)₃ hot			
	nical pro										
	ated mate	rial EN 10088			E, 1D, 1X, 1G,	2D					
size			om temperatur				<u> </u>				
mm		R	Rp 0.2	A %	A%	Kv +20 °		+20 °C	HB a)		
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)) Jn	nin (T)	max		
100	160	500-700	200	40	20	100			215		ubilization
160 3) for info	250	500-700	200	(1) - 1	30		60		215	+AI SO	ubilization
	rmation or	liy		(L) = longitu	dinal (T) = trans	versai					
-	ars of hea	t-treated mate			conditions 2H,	2B, 2G, 2P					
size		•	om temperatur		A.0/	1/ 00 0	• K				
mm	1	R	Rp 0.2	A%	A%	Kv +20 °		+20 °C			
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	Jm	nin (T)			
10	10 b)	600-930	400 380	25 25						olubilizatior	
10 16	16 40	580-930 500-830	200	30		100			TAIS	οιαριίζατιοι	I
40	63	500-830	200	30		100					
40 63	160	500-830	200	40		100					
160	250	500-700	200	40	30	100	60				
				valid only for r	ounds – the m	ochanical pr		of non roun	d hare	of < 5 mm	of thicknes
						containiour pr		n non roun			
^{b)} in the r have to b (L) = longi	e agreed itudinal (T)	at the time of r = transversal	equest and or	der							
^{o)} in the ra have to b (L) = longi F orged -	e agreed	at the time of r = transversal lization	•								
^{b)} in the ra have to b (L) = longi Forged - size	e agreed itudinal (T)	at the time of r = transversal lization Testing at roc	om temperatur	e	۸۹/	K w . 00 9	o v	.20 °C	Ky 10)6 °C	
^{b)} in the ra have to b (L) = longi Forged - size mm	e agreed itudinal (T) AT solubi	at the time of r = transversal lization Testing at roc R	m temperatur Rp 0.2	e A %	A%	Kv +20 °		+20 °C	Kv -19		
^{b)} in the ra have to b (L) = longi Forged - size mm	be agreed itudinal (T) ⊢AT solubi to	at the time of r = transversal lization Testing at roo R N/mm ²	m temperatur Rp 0.2 N/mm² min	e	min (T)	J min (L)) Jn	+20 °C nin (T)	Kv -19 J min	(T)	10250 4
^{b)} in the ra have to b (L) = longi Forged - size mm	to to 250 be agreed to to	at the time of r = transversal lization Testing at roc R N/mm ² 500-700	m temperatur Rp 0.2 N/mm ² min 200	e A% min (L)	min (T) 30	J min (L) 100) Jn 60		J min	(T) EN	10250-4
^{b)} in the r have to b (L) = longi Forged - size mm from	to 250 250	at the time of r = transversal lization Testing at roo R N/mm ² 500-700 490-690	om temperatur Rp 0.2 N/mm ² min 200 190	e A % min (L) 45	min (T) 30 35	J min (L) 100 100) Jn			(T) EN	10250-4 10222-5
^{b)} in the r have to b (L) = longi Forged - size mm from Work-ha	to 250 250	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3:	e A % min (L) 45 2005 in condi	min (T) 30 35	J min (L) 100 100) Jn 60		J min	(T) EN	
^{b)} in the r. have to b (L) = longi Forged - size mm from Work-ha size	to 250 250	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: om temperatur	e A% min (L) 45 2005 in condi e	min (T) 30 35	J min (L) 100 100) Jn 60		J min	(T) EN	
^{b)} in the r. have to b (L) = longi Forged - size mm from Work-ha size mm	to 250 rdned by	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: om temperatur Rp 0.2	e A % min (L) 45 2005 in condi e A %	min (T) 30 35	J min (L) 100 100) Jn 60		J min	(T) EN	
^{b)} in the r. have to b (L) = longi Forged - size mm from Work-ha size mm	tudinal (T) AT solubit to 250 250 rdned by to	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ²	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: m temperatur Rp 0.2 N/mm ² min	e A % min (L) 45 2005 in condi e A % min	min (T) 30 35 tion 2H (es. +A	J min (L) 100 100 \T+C)) J n 60 60		J min	(T) EN	
^{b)} in the r. have to b (L) = longi Forged - size mm from Work-ha size mm	tudinal (T) AT solubities to 250 250 rdned by to 35	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ² 700-850	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: m temperatur Rp 0.2 N/mm ² min 350	e A% min (L) 45 2005 in condi e A% min 20	min (T) 30 35 tion 2H (es. +A +AT+C700	J min (L) 100 100 \(T+C) cold-drawn	J n 60 60		J min	(T) EN	
^{b)} in the r. have to b (L) = longi Forged - size mm from Work-ha size mm from	e agreed tudinal (T) AT solubi to 250 250 rdned by to 35 25	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ² 700-850 800-1000	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: om temperatur Rp 0.2 N/mm ² min 350 500	e A % min (L) 45 2005 in condi e A % min 20 12	min (T) 30 35 tion 2H (es. +A +AT+C700 +AT+C800	J min (L) 100 100 \T+C)	J n 60 60 material material	nin (T)	J min 60	(T) EN EN	10222-5
^{b)} in the r have to b (L) = longi Forged - size mm from Work-ha size mm from Effect of	e agreed tudinal (T) AT solubi to 250 250 rdned by to 35 25 cold-worl	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ² 700-850 800-1000 cing (hot-rollec	m temperatur Rp 0.2 N/mm² min 200 190 EN 10088-3: 500 m temperatur Rp 0.2 N/mm² min 350 500 +AT+C). App	e A % min (L) 45 2005 in condi e A % min 20 12 roximate valu	min (T) 30 35 tion 2H (es. +A +AT+C700 +AT+C800 es	J min (L) 100 100 T+C) cold-drawn i cold-drawn i) J n 60 60 material material	nin (T)	J min 60 – Appi	(T) EN EN	10222-5
^{b)} in the r have to b (L) = longi Forged - size mm from Work-ha size mm from Effect of R	to 250 250 rdned by to 35 25 cold-worl N/mm ²	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ² 700-850 800-1000 cing (hot-rollec 500 650	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: om temperatur Rp 0.2 N/mm ² min 350 500 +AT+C). App 790	e A % min (L) 45 2005 in condi e A % min 20 12 vroximate valu 850 940	min (T) 30 35 tion 2H (es. +A +AT+C700 +AT+C800 es 1030	J min (L) 100 100 XT+C) cold-drawn i cold-drawn i 1100 12) J n 60 60 material material + <i>P</i> 00 ° C	nin (T) \T material	J min 60 – Appr	(T) EN EN roximate va Rp 0.2	10222-5 lues A
^{b)} in the r have to b (L) = longi Forged - size mm from Work-ha size mm from Effect of R Rp 0.2	to 250 250 content by to 250 cold-work N/mm ² N/mm ²	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ² 700-850 800-1000 cing (hot-rollec 500 650 200 520	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: m temperatur Rp 0.2 N/mm ² min 350 500 I +AT+C). App 790 700	e A% min (L) 45 2005 in condi e A% min 20 12 roximate valu 850 940 760 830	min (T) 30 35 tion 2H (es. +A +AT+C700 +AT+C800 es 1030 920	J min (L) 100 100 XT+C) cold-drawn i cold-drawn i 1100 12 1000 10) J n 60 60 material material +/ 00 °C	nin (T) AT material C F N	J min 60 – Appr //mm ²	(T) EN EN roximate va Rp 0.2 N/mm ²	10222-5 lues A %
^{b)} in the r have to b (L) = longi Forged - size mm from Work-ha size mm from Effect of R	to 250 250 rdned by to 35 25 cold-work N/mm ² %	at the time of r = transversal lization Testing at roc R N/mm ² 500-700 490-690 cold-drawing Testing at roc R N/mm ² 700-850 800-1000 cing (hot-rollec 500 650	m temperatur Rp 0.2 N/mm ² min 200 190 EN 10088-3: om temperatur Rp 0.2 N/mm ² min 350 500 +AT+C). App 790	e A % min (L) 45 2005 in condi e A % min 20 12 vroximate valu 850 940	min (T) 30 35 tion 2H (es. +A +AT+C700 +AT+C800 es 1030	J min (L) 100 100 XT+C) cold-drawn i cold-drawn i 1100 12) J n 60 60 material material + <i>P</i> 00 °C 80 +2	NT material T material F N 24 5	J min 60 – Appr	(T) EN EN roximate va Rp 0.2	10222-5 lues A

X2CrNiM	o17-12-2	n° 1.4404 á	austenitic stain	less steel						Lucei	fin Group
Minimum	n yield str	ess and tens	sile strength v	/alues at h	igh tempe	ratures on ma	terial +AT	, EN 100	088-3: 2005	/EN 10269:	2001
Rp 0.2 1	V/mm ²	165	150	137	127	119	113	108	103	100	99
R	N/mm ²	430	410	390	385	380	380	380	375	360	335
Test at	°C	100	150	200	250	300	350	400	450	500	550
Thermal	expansio	n	10 ⁻⁶ ∙ K	-1 🕨	16.0	16.5	17.0	17.5			
Modulus	of elastic	ity loi	ngitudinal GF	°a 200	194	186	179	172		127	
Poisson	number	-	-	v 0.256	0.280						
Electrica	l resistivi	ty	$\Omega \bullet mm^{2/2}$	m 0.75							
Electrica	I conduct	ivity S	iemens•m/mn	1 ² 1.33							
Specific	heat		J/(Kg∙ł	<) 500							
Density			Kg/dn	n ³ 8.00							
Thermal	conductiv	/ity	W/(m∙ł	<) 15.0							
Relative	magnetic	permeability	y i	ur 1.02							
Tempera	ture		0	C 20	100	200	300	400	600	800	
The symb	ool ► indic	ates tempera	ture between	20 °C and 1	100 °C, 20	°C and 200 °C	C				
Corrosio	n resistar	nce	Atmosphe	ric		Chemical	l			x intercrys	
Fresh wa	ter		industrial	та	rine	medium	oxidiz	zing	reducing		m chlorides
x			X	X		X	X		X	salts, orga	anic acids
Magnetic	;		no								
Machinal	bility		high								
Hardenin	g		cold-drawr	n and other	cold plastic	c deformations	5				
Service t	emperatu	re in air				; intermittent s		to 800 °(2		
Europe EN		USA UNS	USA ASTM	China _{GB}		Russia GOST	Japa JIS	n	India IS		R. Core KS
								316L			



Quality		X20	CrNiMo18-14	Ctainlana Ctaal						Technical card 2014
Number		1.4	435			Stainl	ess Stee	1		Lucefin Group
Chemi	cal com	position								
C%	Si%	Mn%	P%	S% ^{a)}	Cr%	Ni%	N%	Mo%		
max	max	max	max	max			max			
0,03	1,00	2,00	0,045	0,015	17,0-19,0	12,5-15,0	0,11	2,5-3,	0	EN 10088-1: 2005
± 0.005	+ 0.05	5 <u>+</u> 0.04	+ 0.005	<u>+</u> 0.005	± 0.2	± 0.15	± 0.01	± 0.1		
		are allowed chinability, it is	allowed a co	ntrolled sulphi	ur content of 0,	015 % - 0,0	30 %			
Tempe	rature °	С								
Melting	range	Hot-forming		n annealing zation) +AT	Stabilizing	Soft anneali	ng +A	MMA wel	•	AWS electrodes post welding
1450-14	00	1150-980	1180-11 water	20	not required	not suita	able	not neces	sary	slow cooling
Sensitiz	ation	Quenching +Q	Temper +T	ing				<i>joint with</i> carbon		o alloyed stainless
not requi		not suitable nt • <i>Pickling</i> (6	not suita		JE) hot - Doooi	inction 20	50% LINI	E309-E308 cosmetic E 316L		9-E308 E308
		01	- 23 /0 TINO3)	+ (0.3 - 0 % 1	11) 1101 - 1 4331	valion 20 - C		J3 1101		
		operties erial EN 10088-	3. 2005 in con	aditions 10 1		20				
Heat-tre size	ateu mate	Testing at roo	o. 2000 III COl m temperatur		L, ID, IA, IG,	20				
mm		R	Rp 0.2	A%	A%	Kv +20 °	°C K v	′ +20 °C	HB a)	
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L	-	min (T)	max	
	160	500-700	200	40	(1)	100	, 0		215	+AT solubilization
160	250	500-700	200		30		60		215	+AT solubilization
			320	55		210			200	Tunical values
a) for info	rmation or		520		dinal (T) = trans				200	Typical values
				•	()					
-	ars of hea	at-treated mate			onditions 2H, 2	2B, 2G, 2P				
size		Testing at roo	•		A 0/	V ₁₀ 00 0				
mm from	to	R N/mm ²	Rp 0.2	A%	A%	Kv +20 °		r +20 °C		
from	to 10 ^{b)}	N/mm ² 600-950	N/mm ² min	min (L) 25	min (T)	J min (L)	Jn	nin (T)		
10	10 5	600-950	400 400	25					+ΔT cc	olubilization
10	40	500-850	235	25 30		100			771 50	παριπεατιστι
40	63	500-850	235	30		100				
40 63	160	500-850	235	40		100				
160	250	500-700	235	ν	30	100	60			
^{b)} in the r	ange of 1	mm <u><</u> d < 5 mn	n, values are			echanical p			d bars o	of < 5 mm of thicknes
(L) = long	itudinal (T)	at the time of re = transversal	equest and or	uer						
	EN 10250									
size		Testing at roo			A 0/	V	o 17	00.00		
mm from	to	R N/mm ²	Rp 0.2	A %	A %	Kv +20 °		r +20 °C		
from	to 250	N/mm ² 500-700	N/mm ² min 200	min (L)	min ((T) 30	J min (L 100	.) J 60	min (T)	+ AT 66	olubilization
							00		74150	παρμιζαίψη
		determined by I								
Average		190	210	215	220	230		240	250	
Test at	°C	-160	-120	-80	-40	0	-	-40	+80	
	cold-wor	king (hot-rolled	+AT+C). App	proximate valu	ies					
Effect of		640	780	900	1050	1180	1	280	1350) 1400
	N/mm ²									
Effect of R Rp 0.2	N/mm ² N/mm ²	320	640	800	910	1000	1	080	1120) 1190
R		320 50	640 30	800 18	910 12	1000 8	1		1120 8) 1190 7

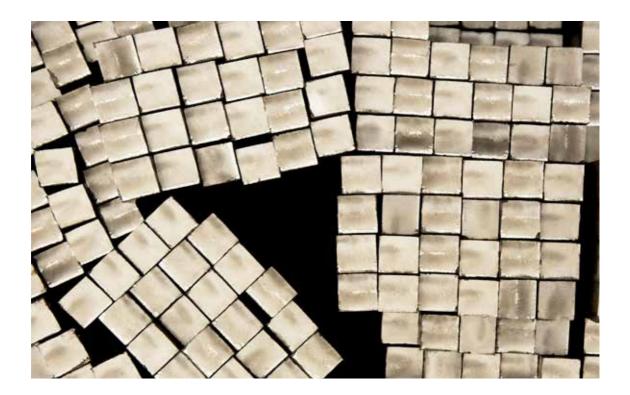
X2CrNiMo18	-14-3 n°	1.4435 a	austenitic stai	nless stee							Lu	cefin Group
Minimum va	lues at hi	gh temp	eratures on n	naterial +A	T							
Rp 0.2 N	/mm ²	165	150	137	127	11	9	113	108	103	100	98
R N	/mm ²	420	400	380	375	37	C	370				
Test at °	C	100	150	200	250	30	D	350	400	450	500	550
Thermal exp	ansion	10 ⁻⁶	• K-1	►	16.0	16	5	17.0	17.5	18.0		
Modulus of	elasticity	G	Pa	200	194	18	6	179	172	165		
Poisson nur	nber	V		0.28								
Electrical re	sistivity	Ω.	mm²/m	0.75								
Electrical co	onductivit	y Sier	mens•m/mm ²	1.33								
Specific hea	ıt	J/(K	lg∙K)	500								
Density		Kg/o	dm ³	8.00								
Thermal cor	nductivity		W/(m∙K)	15.0								
Relative mag	gnetic pe	rmeabilit	y μr	1.1~								
°C				20	100	20	0	300	400	500		
The symbol •	indicates	s tempera	ture between	20 °C an	d 100 °C	, 20 °C a	nd 200	°C				
Corrosion re	esistance		Atmosphe	eric			Chemic	al			x interg	granular, food
Fresh water			industrial		marine		mediun	n ox	idizing	reducing	acids (organic,
x			X		X		x	X			sulfurio	c and
Magnetic			no								phospł	noric acids), o
Machinabilit	v		mean									
Hardening	.,		cold-draw	n and oth	er cold pl	astic defe	ormatio	ns				
Service tem	perature i	n air	continuou						up to 800	°C		
Europe	US	SA	USA	China		Russia		Japa	in	India		R. Corea
EN .	UN		ASTM	GB		GOST		JIS		IS		KS
X2CrNiMo18	-14-2 (S	31603)	(316L)	00Cr18Ni	15Mo3	03Ch17	N14M3	(SUS	S 316L)	(X02Cr17	Ni12Mo2)	(STS 316L)



	y	7201	rNiMoN22-5-	3			ustenitic-F			T	echnical c	aru 2014
Number	r	1.44	162 a)			S	tainless St	eel (Dup	lex)	L	ucefin G	roup
Chem	ical com	position										
C%	Si%	Mn%	P%	S%	Cr%	Ni%	N۶	6	Mo	%		
max	max	max	max	max								
0,03	1,00	2,00	0,035	0,015	21,0-23,0	4,5-	6,5 0,1	10-0,22	2,5-	-3,5 E	N 10088-1	: 2005
± 0.005	+ 0.05	5 <u>+</u> 0.04	+ 0.005	+ 0.003	± 0.25	± 0.	10 ± (0.02	± 0	.10		
		are allowed ment, this steel g	rade can be	delivered wit	h a Pitting Res	sistanc	e Equivale	nt n° (PF	RE = Cr +3	3,3Mo + 16	N) higher	than 34
Tempe	erature °											
Melting	range	Hot-forming		annealing ation) +AT	Stabilizing		Soft annealing	g +A	MMA w pre-hea	elding – A ting	WS electro post wel	
1440-13	390	1150-950	1100-102 water		not suitable		not suitab	le	100		solubiliza	ation
Embritt	lement	Carbides precipitation	Sigma p formatio		Stress-relie +SR short s	•	Recrysta +RA	llization	<i>joint wit</i> carbon	h steel CrMo a	alloyed s	tainless
475		800-450	950-700		600-550		1100-102	0	E309L-1	6 E309N	1oL-15 E	317L
					air		quick cool		cosmeti E 2209-1	c welding		
Chemic	al treatme	ent - Pickling (52	% HNO3) + (6	65% HF) hot	 Passivation 	20 - 4	5% HNO₃ c	old	L 2209-	17		
Mecha	anical pr	operties										
Heat-tre	eated mate	erial EN 10088-3			E, 1D, 1X, 1G	G, 2D						
size		Testing at room	•									
mm			Rp 0.2	A %	A%		Kv +20 °C		-40 °C	HB a)		
from	to		N/mm ² min	min (L)	min (T)		J min ^{b)} (I	,	nin (L)	max		
	160	650-880 nly (L) = longitud	450	25			40	40		270	+AT solu	bilizatio
-	bars of he	at-treated mater			conditions 2H,	2B, 20	G, 2P					
size	bars of he	Testing at room	n temperature Rp 0.2		conditions 2H, A%	2B, 20	G, 2P Kv +20 °C	Kv	+20 °C			
size mm	to	Testing at room R N/mm ²	n temperature Rp 0.2 N/mm ² min	• A% min (L)		2B, 20			+20 °C in (T)			
size mm from	to 10 ^{b)}	Testing at room R N/mm ² 850-1150	n temperature Rp 0.2 N/mm ² min 650	A% min (L) 12	A%	2B, 20	Kv +20 °C					
size mm from 10	to 10 ^{b)} 16	Testing at room R N/mm ² 850-1150 850-1100	n temperature Rp 0.2 N/mm ² min 650 650	e A% min (L) 12 12	A%	2B, 20	Kv +20 °C J min (L)				+AT	
size mm from 10 16	to 10 ^{b)} 16 40	Testing at room R N/mm ² 850-1150 850-1100 650-1000	n temperature Rp 0.2 N/mm ² min 650 650 450	e Min (L) 12 12 12 15	A%	2B, 20	Kv +20 °C J min (L) 100				+AT solubil	ization
size mm from 10 16 40	to 10 ^{b)} 16 40 63	Testing at room R N/mm ² 850-1150 850-1100 650-1000 650-1000	n temperature Rp 0.2 N/mm ² min 650 650 450 450	A% min (L) 12 12 15 15	A%	2B, 20	Kv +20 °C J min (L) 100 100					zation
size mm from 10 16 40 63	to 10 ^{b)} 16 40 63 160	Testing at room R N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880	n temperature Rp 0.2 N/mm ² min 650 650 450 450 450 450	A% min (L) 12 12 15 15 25	A% min (T)		Kv +20 °C J min (L) 100 100	Jm	in (T)	pars of $z \in$	solubil	
size mm from 10 16 40 63 ^{b)} in the have to	to 10 ^{b)} 16 40 63 160 range of 1 be agreed	Testing at room R N/mm ² 850-1150 850-1100 650-1000 650-1000	temperature Rp 0.2 N/mm ² min 650 650 450 450 450 values are v	A% min (L) 12 12 15 15 15 25 alid only for	A% min (T)		Kv +20 °C J min (L) 100 100 100	Jm	in (T)	pars of < 5	solubil	
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (Testing at room R N/mm² $850-1150$ $850-1100$ $650-1000$ $650-1000$ $650-880$ mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025	n temperature Rp 0.2 N/mm ² min 650 650 450 450 450 values are v quest and orce 50-4: 2001	A% min (L) 12 12 15 15 25 alid only for ler	A% min (T)		Kv +20 °C J min (L) 100 100 100	Jm	in (T)	pars of < 5	solubil	
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged size	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (Testing at room R N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room	n temperature Rp 0.2 N/mm ² min 650 650 450 450 values are v quest and orce 50-4: 2001 n temperature	A% min (L) 12 12 15 15 25 alid only for ler	A% min (T) rounds – the n		Kv +20 °C J min (L) 100 100 100 100	J m	in (T) on round l		solubili	
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged size mm	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub	Testing at room R N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room R	temperature Rp 0.2 N/mm ² min 650 650 450 450 values are v quest and orce 50-4: 2001 temperature Rp 0.2	A% min (L) 12 12 15 15 25 alid only for ler A%	A% min (T) rounds – the n		Kv +20 °C	J m rties of no Kv	in (T) on round l +20 °C	Kv -196	solubili mm of thic	
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged size mm	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub	Testing at room \mathbf{R} N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of ree T) = transversal ilization EN 1025 Testing at room \mathbf{R} N/mm ²	temperature Rp 0.2 N/mm ² min 650 650 450 450 450 450 values are v values and orce 60-4: 2001 temperature Rp 0.2 N/mm ² min	A% min (L) 12 12 15 15 25 alid only for ler A% min (L)	A% min (T) rounds – the n A% min ((T)		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n	in (T) on round l		solubili mm of thic	
size mm from 10 16 40 63 $^{(b)}$ in the have to (L) = lor Forged size mm from	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350	Testing at room R N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room R N/mm ² 650-880	temperature Rp 0.2 N/mm ² min 650 650 450 450 values are v quest and orce 60-4: 2001 temperature Rp 0.2 N/mm ² min 450	A% min (L) 12 12 15 15 25 alid only for ler A%	A% min (T) rounds – the n		Kv +20 °C	J m rties of no Kv	in (T) on round l +20 °C	Kv -196	solubili mm of thic	
size mm from 10 16 40 63 $b^{b)}$ in the have to (L) = lor Forged size mm from Cold-ha	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350	Testing at room R N/mm² 850-1150 850-1100 650-1000 650-1000 650-800 mm ≤ d < 5 mm, at the time of rec T) = transversal ilization EN 1025 Testing at room R N/mm² 650-880 N 10263-5: 2003	temperature Rp 0.2 N/mm ² min 650 650 450 450 values are v quest and orce 650 650 650 650 650 650 650 650	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25	A% min (T) rounds – the n A% min ((T)		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n	in (T) on round l +20 °C	Kv -196	solubili mm of thic	
size mm from 10 16 40 63 have to(L) = lorForgedsizemmfromCold-hasize	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350	Testing at room \mathbf{R} N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room \mathbf{R} N/mm ² 650-880 N 10263-5: 2003 Testing at room	temperature Rp 0.2 N/mm ² min 650 650 450 450 450 450 values are v valuest and orce 60-4: 2001 temperature Rp 0.2 N/mm ² min 450 temperature	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25	A% min (T) rounds – the n A% min ((T)		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n 60	in (T) on round l +20 °C	Κν -196 J min (1	solubili mm of thic	
size mm from 10 16 63 ^{b)} in the have to (L) = lor Forged size mm from Cold-ha size mm	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350	Testing at room \mathbf{R} N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room \mathbf{R} N/mm ² 650-880 N 10263-5: 2003 Testing at room \mathbf{R} Z	temperature Rp 0.2 N/mm ² min 650 650 450 450 values are v quest and orce 650 650 650 650 650 650 650 650	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25	A% min (T) rounds – the n A% min ((T)		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n	in (T) on round l +20 °C nin (T)	Kv -196 J min (1 Z%	solubili mm of thic	
size mm from 10 16 63 63 69 in the have to (L) = lor Forged size mm from Cold-ha size	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350 ardened E	Testing at room \mathbf{R} N/mm ² 850-1150 850-1100 650-1000 650-1000 650-880 mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room \mathbf{R} N/mm ² 650-880 N 10263-5: 2003 Testing at room \mathbf{R} Z	temperature Rp 0.2 N/mm ² min 650 650 450 450 450 values are v valuest and orce 60-4: 2001 temperature Rp 0.2 N/mm ² min 450 temperature %	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25	A% min (T) rounds – the n A% min ((T)		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n 60 R N/m	in (T) on round l +20 °C nin (T)	Κν -196 J min (1	solubili mm of thic	kness
size mm from 10 16 40 63 b^{b} in the have to (L) = lorForgedsizemmfromCold-hasizemmfrom5	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350 ardened E	Testing at room R N/mm² 850-1150 850-1100 650-1000 650-1000 650-1000 650-880 mm ≤ d < 5 mm, at the time of rect Testing at room R N/mm² 650-880 N 10263-5: 2003 Testing at room R N10263-5: 2003 Testing at room R Z N/mm² nor	temperature Rp 0.2 N/mm ² min 650 650 450 450 450 values are v valuest and orce 60-4: 2001 temperature Rp 0.2 N/mm ² min 450 temperature %	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25	A% min (T) rounds – the n A% min ((T)		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n 60 R N/m 900	in (T) on round B +20 °C nin (T) nm ²	Kv -196 J min (1 Z% min	solubil mm of thic °C	Ckness
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged size mm from Cold-ha size mm from 5 10	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350 ardened E to 10 25	Testing at room N/mm² 850-1150 850-1100 650-1000 650-1000 650-880 mm ≤ d < 5 mm, at the time of rect T) = transversal ilization EN 1025 Testing at room R N/mm² 650-880 N 10263-5: 2003 Testing at room R N/mm² 020-880	n temperature Rp 0.2 N/mm ² min 650 650 450 450 450 values are v values and orce 60-4: 2001 n temperature Rp 0.2 N/mm ² min 450 n temperature % nin	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25 * * * * * * * * * * * * *	A% min (T) rounds – the n A% min ((T) 20		Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n 60 R N/m 900	in (T) on round t +20 °C nin (T) mm ² max	Kv -196 J min (1 Z% min 55	solubili mm of thic °C T) +AT+C	Ckness
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged size mm from Cold-ha size mm from 5 10 Effect of Effect of	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350 ardened E to 10 25	Testing at room R N/mm² $850-1150$ $850-1150$ $850-1100$ $650-1000$ $650-1000$ $650-1000$ $650-1000$ $650-880$ mm $\leq d < 5$ mm, at the time of rec T) = transversal ilization EN 1025 Testing at room R N/mm² $650-880$ N 10263-5: 2003 Testing at room R Z N/mm² n 1020 max 1000 max 1000 max 1000 max	temperature Rp 0.2 N/mm ² min 650 650 450 450 450 values are v values and orce 60-4: 2001 temperature Rp 0.2 N/mm ² min 450 temperature % nin AT+C). Approx	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25 * * * * * * * * * * * * *	A% min (T) rounds – the n A% min ((T) 20	mechai	Kv +20 °C J min (L) 100 100 100 100 100 100 100 Kv +20 °C J min (L)	J m rties of no Kv J n 60 <u>R</u> N/m 900 880	in (T) on round t +20 °C nin (T) mm ² max	Kv -196 J min (1 Z% min 55	solubili mm of thic °C T) +AT+C +AT+C	C+AT C+AT
size mm from 10 16 40 63 ^{b)} in the have to (L) = lor Forged size mm from Cold-ha size mm from 5 10	to 10 ^{b)} 16 40 63 160 range of 1 be agreed ngitudinal (+AT solub to 350 ardened E to 10 25 f coldwork	Testing at room N/mm² 850-1150 850-1150 850-1000 650-1000 650-1000 650-1000 650-1000 650-1000 650-1000 650-1000 650-880 mm ≤ d < 5 mm, at the time of rect Testing at room R N/mm² 650-880 N 10263-5: 2003 Testing at room R Z N/mm² 1020 max 1000 max 1000 max 1000 max 1000 max	n temperature Rp 0.2 N/mm ² min 650 650 450 450 values are v values and orce 60-4: 2001 n temperature Rp 0.2 N/mm ² min 450 h temperature % nin AT+C). Appre- 50 1	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25 +AT+C +AT+C +AT+C poximate valu	A% min (T) rounds – the n A% min ((T) 20 es 1120		Kv +20 °C J min (L) 100 100 100 nical proper Kv +20 °C J min (L) 100	J m rties of no J n 60 <u>R</u> <u>N/m</u> 900 880	in (T) on round b +20 °C nin (T) im ² max max	Kv -196 J min (1 Z% min 55 55	solubili mm of thic °C () +AT+C +AT+C	Ckness
size mm from 10 16 40 63 ^(b) in the have to (L) = lor Forged size mm from Cold-ha size mm from 5 10 Effect of R	to 10 ^{b)} 16 40 63 160 range of agitudinal (+AT solub to 350 ardened E to 10 25 f coldwork N/mm ² %	Testing at room N/mm² 850-1150 850-1150 850-1000 650-1000 650-1000 650-1000 650-1000 650-1000 650-1000 650-1000 650-880 mm ≤ d < 5 mm, at the time of rect Testing at room R N/mm² 650-880 N 10263-5: 2003 Testing at room R Z N/mm² 1020 max 1000 max 1000 max 1000 max 1000 max	temperature Rp 0.2 N/mm² min 650 650 450 450 450 450 values are v quest and orce 60-4: 2001 temperature Rp 0.2 N/mm² min 450 450 Attemperature 7% nin Attemperature 50 1 00 5	A% min (L) 12 12 15 15 25 alid only for ler A% min (L) 25 +AT+C +AT+C +AT+C +AT+C cximate valu	A% min (T) rounds – the n A% min ((T) 20 es 1120 1080	nechai	Kv +20 °C J min (L) 100 100 100 nical proper Kv +20 °C J min (L) 100	J m rties of no J n 60 <u>R</u> <u>N/m</u> 900 880	in (T) on round B +20 °C nin (T) max max 1340	Kv -196 J min (1 Z% min 55 55 1370	solubili mm of thic °C () +AT+C +AT+C	C+AT C+AT C+AT C+AT C+AT C+AT C+AT C+AT

X2CrNi	2CrNiMoN22-5-3 n° 1.4462 austenitic-ferritic stainless steel (Duplex)										
Minimu	m yield stress	and tensi	le strength va	alues at high ter	mperatur	es on material +	AT EN 10028-7: 2007				
Rp 0.2	N/mm ²	422 ^{a)}	360	335	315	300					
R	N/mm ²	621 ^{a)}	590	570	550	540					
Test at	°C	50	100	150	200	250					
^{a)} detern	nined by linear i	nterpolatio	n								
Therma	l expansion	10 ⁻⁶ •	K-1	•	13.0	13.5	14.0				
Modulu	s of elasticity	longit	udinal GPa	200	194	186	180				
Poissor	number	V		0.25							
Electric	al resistivity	Ω•m	1m²/m	0.80	0.85	0.90	1.00				
Electric	al conductivity	/ Sieme	ens•m/mm ²	1.25							
Specific	c heat	J/(Kg	•K)	500	530	560	590				
Density	,	Kg/dr	n ³	7.8							
Therma	I conductivity		W/(m•K)	15.0	16.0	17.0	18.0				
Relative	e magnetic per	meability	μr	magnetizable							
°C				20	100	200	300				
The sym	nbol ► indicates	temperatu	ure between 2	0 °C and 100 °C	;, 20 °C a	nd 200 °C					
Corrosi	on resistance		Atmospheri	<u>`</u>		Chemical		x intercrystalline			

Corrosion resistan	се	Atmosphe	ric	Chemical		x intercrystalline,	
Brackish water		industrial	marine	medium	oxidizing	reducing	pitting, crevice, stress
X		X	X	X	X		corrosion cracking
Magnetic		yes					
Machinability		difficult					
Hardening		cold-draw	n and other cold plast	ic deformations			
Service temperatur	e	in pressur	e vessels, up to -200	°C; do not use ove	er +340 °C.	Ossidazione i	n aria 1000 °C
Europe	USA	USA	China	Russia	Japan	India	R. Corea
EN	UNS	ASTM	GB	GOST	JIS	IS	KS
X2CrNiMoN22-5-3	S31803	Type 2205	022Cr22Ni5Mo3N	02Ch22N5AM2	(SUS 329J	3L)	(STS 329J3L)



À. 211

Quality Number	/		X2CrNiMoCuWN25-7-4 1.4501				enitic-Ferri Iless Steel		olex)		hnical ca efin Gi	ard 2014 'oup
Chemi	cal con	nposition										
C%	Si%	Mn%	P%	S%	Cr%	Ni%	N%	Mo%	Cu%	W%		
max	max	max		max	0.70	11170	11/0	1110 / 0	eu //		FN [·]	10088-1:
0,03	1,00	1,00		0,015	24,0-26,0	6,0-8,0	0,20-0,30	3,0-4,0	0,5-1,0	0,5-1,0	200	
± 0.005	+ 0.05				± 0.25	± 0.10	± 0.02	± 0.10	± 0.07	± 0.05		
		s are allowed. 16N) > 40 (Pitt										
Tempe	rature	°C										
Melting	range	Hot-forming		n anneali ization) +/	•	oilizing	Soft annea	ling +A	MMA we	elding – A ing		trodes velding
1480-144	40	1250-1100	1120-10 water)50		suitable	not su	itable		not reco	mmend	ed
Embrittle	ement	Carbides precipitation	Sigma formati		Stre +SR	ss-relievi	ng Recry +RA	stallizat.	<i>oint with</i> carbon		alloyed	stainless
-50 +300		950-600	1000-60	00	nots	suitable	not su	itable	cosmetic	c welding		
Chemica	al treatm	ent • Pickling (52% HNO3) + (65% ł	HF) hot • P	assivation	20 - 45% 	INO₃ cold				
Mecha	nical p	roperties		,	,							
		terial EN 1008	8-3: 2005 in	conditior	ns 1C, 1E,	1D, 1X, 10	G, 2D					
size		Testing at ro										
mm		R	Rp 0.2	A %	A%	Kv -	-20 °C K	v +20 °C	Kv -40	°C	HB ^{a)}	
from	to	N/mm ²	N/mm ² mir	ו min (L) min (1	⁻) Jm	in (L) J	min (T)	J min	^{b)} (L)	max	
	160	730-930	530	25		100			40		290	+AT
	75 ^{c)}	730-930	530	25	25	100	60)			:	solubiliza
^{a)} for info	ormation	only. ^{b)} EN 10	272 : 2003.	^{c)} EN 10	088-2 : 20	05. (L)	= longitudina	al (T) = trasv	versal			
cold wor these lim	teel can k in exce nits can re	be adequately ess of 10% - 20 esult in hardnes	0% is remo ss levels ab	ved by so ove those	olution ann	ealing and	d water que	nching. It	should be i	noted that		
	+AT solu	bilization EN 1										
size mm		Testing at ro	•		A 0/	V··	00 °C 1/					
THEFT	ta	R N/mm ²	Rp 0.2	A%	A%			v +20 °C				
	to 160	N/mm ² 730-930	N/mm ² m 530		(L) min (([*] 20	l) Jm 100	in (L) J 60	min (T)				
	100	120-930	530	25								
from						Ind Allove	US data sh	leet)				
from Typical	values a	t high tempera		ormed flat	S +AT (RO			70				
from Typical y Test		thickness up	to 30 mm.	ormed flat	S +AT (RO	thick	ness 31 to					
from Typical Test temperat	ture	thickness up R	to 30 mm. Rp 0.2	ormed flat	S +A1 (KO	thick R	ness 31 to R	p 0.2				
from Typical Test temperat °C	ture °F	thickness up R N/mm ²	to 30 mm. Rp 0.2 N/mm ²	ormed flat	S +AT (RO	thick R N/m	ness 31 to R m ² N	p 0.2 /mm ²				
from Typical Test temperat °C 20	ture °F 68	thickness up R N/mm ² 780	to 30 mm. Rp 0.2 N/mm ² 580	ormed flat	s +AT (Ro	thick R N/m 750	ness 31 to R m ² N 55	p 0.2 /mm ² 50				
from Typical Test temperat °C 20 50	ture °F 68 122	thickness up R N/mm ² 780 725	to 30 mm. Rp 0.2 N/mm ² 580 500	ormed flat	s +AT (Ro	thick R N/m 750 700	ness 31 to R m ² N 55 47	p 0.2 /mm ² 50 70				
from Typical v Test temperat °C 20 50 100	ture °F 68 122 212	thickness up R N/mm ² 780 725 700	to 30 mm. Rp 0.2 N/mm ² 580 500 470	prmed flat	s +AT (Ro	thick R N/m 750 700 670	ness 31 to R m ² N 55 47 43	p 0.2 /mm ² 50 70 80				
from Typical Test temperat °C 20 50 100 150	ture °F 68 122 212 302	thickness up R N/mm ² 780 725 700 680	to 30 mm. Rp 0.2 N/mm ² 580 500 470 450	ormed flat	S +AT (KO	thick R N/m 750 700 670 620	ness 31 to R m ² N 55 47 47 43	p 0.2 /mm ² 50 70 80 00				
from Typical Test temperat °C 20 50 100 150 200	ture °F 68 122 212 302 392	thickness up R N/mm ² 780 725 700 680 670	to 30 mm. Rp 0.2 N/mm ² 580 500 470 450 430	prmed flat	s +AT (Kol	thick R N/m 750 700 670 620 610	rness 31 to R m ² N 55 47 47 43 40 38	p 0.2 /mm ² 50 70 80 90 80				
from	ture °F 68 122 212 302	thickness up R N/mm ² 780 725 700 680	to 30 mm. Rp 0.2 N/mm ² 580 500 470 450	prmed flat	s +AT (Kol	thick R N/m 750 700 670 620	rness 31 to R m ² N 55 47 47 43 40 38	p 0.2 /mm ² 50 70 80 00				

X2CrNiM	oCuWN25-7-4	n° 1.4501	Superduplex	(
Minimum	n yield stress	and tensile	strength va	lues at high	temp	eratures on I	material +AT	EN 10028-7:	2007
Rp 0.2	N/mm ²	500 ^{a)}	450	420	400	380			
R	N/mm ²	711 ^{a)}	680	660	640	630			
Prova a	°C	50	100	150	200	250			
^{a)} determi	ned by linear i	nterpolation							
Thermal	expansion	10 ⁻⁶ • K ⁻¹		•	13.0	13.5	14.0		
Modulus	of elasticity	longitudina	l GPa	200	194	186	180		
Poisson	number	V		0.32					
Electrica	l resistivity	$\Omega \cdot mm^2/m$	I	0.80	0.89	0.95	1.01		
Electrica	l conductiv.	Siemens.n	n/mm ²	1.25					
Specific	heat	J/(Kg∙K)		500		523	547		
Density		Kg/dm ³		7.8					
Thermal	conductivity		W/(m•K)	15.0		16.3	18.2		
Relative	magnetic per	meability	μr	29					
°C			·	20	100	200	300		
The symb	ool ► indicates	temperature	e between 20	°C and 100	°C, 2	0 °C and 200	°C		
Corrosio	n resistance		Atmospheric			Chemical			x erosion, pitting, crevice,
Brackish	water		industrial	marine		medium	oxidizing	reducing	organic and inorganic a.
x			x	X		X			stress corrosion cracking
Magnetic	;	yes							
Machina	bility					t of austenitio	steels		
Hardenin	Ig	cold-dra	awn and othe	r cold plastic	defo	rmations			
Service t	emperature	not reco	ommended fo	or uses to ten	npera	tures greater	than +300 °0	and lower -5	0 °C

Service temperature	notrecomi		to temperatures greater the			0	
Europe	USA	USA	China	Russia	Japan	India	R. Corea
EN	UNS	ASTM	GB	GOST	JIS	IS	KS
X2CrNiMoCuWN25-7-4	S32760	Type F 55	022Cr25Ni7Mo3WCuN		SM25Cr		





			6CrNiTi18-	10			Austenit				l card 2014
Number		1	1.4541				Stainless	Steel		Lucefin	Group
Chemi	cal com	position									
C% nax	Si% max	Mn% max		% Iax	S% ^{a)} max	Cr%	Ni%	Ti% max			
0.08	1,00	2,00		.045	0,015	17,0-19	9,0 9,0-12,0		0.70	FN 1008	8-1: 2005
± 0.01	+ 0.0	,		0.005	+ 0.003	± 0.2	± 0.1	+ 0.05	0,10		
		s are allowed		0.000	0.000	_ U.L	2 0.1	<u>·</u> 0.00			
				ed a controll	ed sulph	ur content of	0,015 % - 0,0	30 %			
Tempe	rature '	°C									
Velting		Hot-form	(Sol	u tion annea ubilization)		Stabilizing	Soft annealing +/	MMA w pre-hea		AWS elec post v	ctrodes velding
1430-140	00	1200-100	0 112 wate	0-1010 er		900-840 alm air	not suitable	not nec	essary	slow o	cooling
Sensitiz	ation	Quenchir +Q	ng Ten +T	npering				<i>joint wit</i> carbon		lo alloyed	stainless
not suital		not suitab		suitable				E347	ic welding	9-E308 7	E308-E347
			/ (6 - 25% H	HNO3) + (0.5	5 - 8% HF) hot or cold	. Passivation 2	0 - 45% HNO ₃	cold		
		roperties rerial EN 100	88-3: 2005	in condition:	s 1C, 1E,	1D, 1X, 1G.	2D				
size		Testing at r			, _,	,					
mm		R	Rp 0.2	A %		A%	Kv +20 °C	Kv +20 °C	HB a)		
rom	to	N/mm ²	N/mm ²	min min (_)	min (T)	J min (L)	J min (T)	max		
	160	500-700	190	40			100		215	+	AT
60	250	500-700	190			30		60	215	s	olubilization
) for info	rmation o	only	(L) = long	jitudinal (T) =	transvers	al					
Bright h	are of he	at-treated m	natorial FN	10088-3.2	105 in co	nditions 2H	2B 2G 2P				
size			oom temper				-0, 20, 21				
nm		R	Rp 0.2	A%		A%	Kv +20 °C	Kv +20 °C			
rom	to	N/mm ²	N/mm ²)	min (T)	J min (L)	J min (T)			
	10 ^{b)}	600-950	400	25	-/		Unin (L)	0 mm (1)			
10	16	580-950	380	25						+	AT
	40										
16		500-850					100			S	olubilization
		500-850 500-850	190	30			100			S	olubilization
40	63 160	500-850 500-850 500-700					100 100 100			S	oludilization
have to b (L) = longi	63 160 ange of 1 be agreed itudinal (T	500-850 500-700 mm <u><</u> d < 5 d at the time o) = transversal	190 190 190 mm, values of request a	30 30 40 are valid or	nly for rou	unds – the m	100 100	erties of non ro	ound bars		
40 53 e) in the ranave to b L) = longi Forged -	63 160 ange of 1 be agreed	500-850 500-700 mm <u><</u> d < 5 d at the time o) = transversal pilization	190 190 190 mm, values of request a	30 30 40 are valid or nd order	nly for rou	unds – the m	100 100	erties of non ro	ound bars		
40 53 ^{a)} in the ranave to b L) = longi F orged - size	63 160 ange of 1 be agreed itudinal (T	500-850 500-700 mm <u><</u> d < 5 d at the time o) = transversal bilization Testing at r	190 190 mm, values of request a	30 30 40 are valid or nd order	nly for rou		100 100 echanical prop			of < 5 m	
40 53 o) in the random to b L) = longi Forged - size mm	63 160 ange of 1 be agreed itudinal (T +AT solul	$500-850$ $500-700$ $mm \le d < 5$ $d at the time of th$	190 190 mm, values of request a oom temper Rp 0.2	30 30 40 are valid or nd order rature A%		A%	100 100 echanical prop Kv +20 °C	Κν +20 °C	Kv -19	of < 5 m 06 °C	
40 53 o) in the random to b L) = longi Forged - size mm	63 160 ange of 1 be agreed itudinal (T +AT solut	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ d at the time of a state of the time of a state of the time of a state of the time of time of$	190 190 mm, values of request a com temper Rp 0.2 N/mm ²	30 30 40 are valid or nd order rature A %		A% min (T)	100 100 echanical prop Kv +20 °C J min (L)	Κν +20 °C J min (T)		of < 5 m 6 °C (T)	m of thicknes
40 53 o) in the random to b L) = longi Forged - size mm	63 160 ange of 1 be agreed itudinal (T +AT solut to 450	$500-850$ $500-700$ mm $\leq d < 5$ at the time of time of time of the time of t	190 190 mm, values of request a oom temper Rp 0.2 N/mm ² 190	30 30 40 e are valid or nd order rature A% min min (A% min (T) 30	100 100 echanical prop Kv +20 °C J min (L) 100	Κν +20 °C J min (T) 60	Kv -19 J min	of < 5 mi 06 °C (T) E	m of thicknes
40 53 have to b L) = longi F orged - size mm from	63 160 ange of 1 be agreec itudinal (T +AT solut to 450 450	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ d at the time of time of time of the time of $	190 190 mm, values of request a com temper Rp 0.2 N/mm ² 190 200	30 30 40 a are valid or nd order rature A% min min 0 40	Ľ)	A% min (T) 30 30	100 100 echanical prop Kv +20 °C J min (L) 100 100	Κν +20 °C J min (T)	Kv -19	of < 5 mi 06 °C (T) E	m of thicknes
40 53 ^{a)} in the ranave to b (L) = longi Forged - size mm from Work-ha	63 160 ange of 1 be agreec itudinal (T +AT solut to 450 450	$500-850$ $500-700$ mm $\leq d < 5$ d at the time of time of the time of tim	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper	30 30 40 a are valid on nd order rature A % min min 40 38-3: 2005 ir rature	Ľ)	A% min (T) 30 30	100 100 echanical prop Kv +20 °C J min (L) 100 100	Κν +20 °C J min (T) 60	Kv -19 J min	of < 5 mi 06 °C (T) E	m of thicknes
40 53 ^{a)} in the r. have to b L) = longi Forged - size nm rom Work-ha size nm	63 160 ange of 1 be agreec itudinal (T +AT solut to 450 450 rdned b	$500-850$ $500-700$ mm $\leq d < 5$ d at the time of time of the time of tim	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2	30 30 40 a are valid on nd order rature A% min min 40 38-3: 2005 in rature A%	Ľ)	A% min (T) 30 30	100 100 echanical prop Kv +20 °C J min (L) 100 100	Κν +20 °C J min (T) 60	Kv -19 J min	of < 5 mi 06 °C (T) E	m of thicknes
40 53 ^{a)} in the r. have to b L) = longi Forged - size nm rom Work-ha size nm	63 160 ange of 1 be agreed itudinal (T +AT solut to 450 450 rrdned by to	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ d at the time of time$	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2 N/mm ²	30 30 40 a are valid on nd order rature A% min min 40 38-3: 2005 in rature A% min min	Ľ)	A% min (T) 30 30 n 2H (es. + <i>A</i>	100 100 echanical prop Kv +20 °C J min (L) 100 100 \\T+C)	Kv +20 °C J min (T) 60 60	Kv -19 J min	of < 5 mi 06 °C (T) E	m of thicknes
40 53 ^{a)} in the r. have to b (L) = longi Forged - size mm from Work-ha size mm	63 160 ange of 1 be agreective itudinal (T +AT solution to 450 450 rdned by to 35	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ d at the time of $	190 190 190 mm, values of request a 000m temper Rp 0.2 N/mm ² 190 200 ng EN 1008 000m temper Rp 0.2 N/mm ² 350	30 30 40 a are valid or nd order rature A% min min 40 38-3: 2005 in rature A% min min 20	Ľ)	A% min (T) 30 30 n 2H (es. +A +AT+C700	100 100 echanical prop Kv +20 °C J min (L) 100 100 XT+C)	Kv +20 °C J min (T) 60 60 terial	Kv -19 J min	of < 5 mi 06 °C (T) E	m of thicknes
40 53 ²⁾ in the ra- have to b (L) = longi Forged - size mm from Work-ha size mm from	63 160 ange of 1 be agreed tudinal (T +AT solut to 450 450 rdned by to 35 25	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ d at the time of $	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2 N/mm ² 350 500	30 30 40 are valid or nd order rature A% min min 40 38-3: 2005 ir rature A% min min 20 12	L) 1 conditic	A% min (T) 30 30 m 2H (es. +A +AT+C700 (+AT+C800 (100 100 echanical prop Kv +20 °C J min (L) 100 100 T+C)	Kv +20 °C J min (T) 60 60 terial terial	Kv -19 J min 60	o of < 5 mi)6 °C (T) E E	m of thicknes N 10250-4 N 10222-5
40 53 Pin the ranave to b L) = longi Forged - size nm rom Work-ha size nm rom	63 160 ange of 1 be agreed tudinal (T +AT solut to 450 450 wrdned by to 35 25 on curve	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ d at the time of $	190 190 190 mm, values of request a 000m temper Rp 0.2 N/mm ² 190 200 ng EN 1008 00m temper Rp 0.2 N/mm ² 350 500 by Kv impace	30 30 40 a are valid or nd order rature A% min min 40 38-3: 2005 in rature A% min min 20 12 xts. Material	L) n conditic	A% min (T) 30 30 n 2H (es. +A +AT+C700 (+AT+C800 (ed at 1050 °C	100 100 echanical prop Kv +20 °C J min (L) 100 100 NT+C) cold-drawn ma cold-drawn ma	Kv +20 °C J min (T) 60 60 terial terial terial ↓AT material	Kv -19 J min 60 – Approv	i of < 5 mi)6 °C (T) E E kimate va	m of thicknes N 10250-4 N 10222-5
40 53 ^{a)} in the ra- have to b L) = longi Forged - size nm rom Nork-ha size nm rom Fransitic Average	63 160 ange of 1 be agreed itudinal (T +AT solut to 450 450 rdned by to 35 25 on curve J	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ at the time of ti$	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2 N/mm ² 350 500 by Kv impace 40 24	30 30 40 are valid or nd order rature A% min min 40 38-3: 2005 ir rature A% min min 20 12 cts. Material 40 250	L) n conditic solubilize 25	A% min (T) 30 30 m 2H (es. +A +AT+C700 (+AT+C800 (ed at 1050 °C 50 260	100 100 echanical prop Kv +20 °C J min (L) 100 100 100 VT+C) cold-drawn ma cold-drawn ma c 260	Kv +20 °C J min (T) 60 60 terial terial terial erial erial	Kv -19 J min 60 – Approx	i of < 5 m 16 °C (T) E E kimate va Rp 0.2	m of thicknes
40 53 ^{a)} in the ra- have to b L) = longi Forged - size nm rom Nork-ha size nm rom Fransitic Average	63 160 ange of 1 be agreed tudinal (T +AT solut to 450 450 wrdned by to 35 25 on curve	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ at the time of ti$	190 190 190 mm, values of request a 000m temper Rp 0.2 N/mm ² 190 200 ng EN 1008 00m temper Rp 0.2 N/mm ² 350 500 by Kv impace	30 30 40 are valid or nd order rature A% min min 40 38-3: 2005 ir rature A% min min 20 12 cts. Material 40 250	L) n conditic solubilize 25	A% min (T) 30 30 n 2H (es. +A +AT+C700 (+AT+C800 (ed at 1050 °C	100 100 echanical prop Kv +20 °C J min (L) 100 100 100 VT+C) cold-drawn ma cold-drawn ma c 260	Kv +20 °C J min (T) 60 60 terial terial terial *AT material °C I	Kv -19 J min 60 – Approx R	i of < 5 mi 16 °C (T) E E kimate va Rp 0.2 N/mm ²	m of thicknes
40 53 ²⁾ in the ra- have to b (L) = longi Forged - size mm from Work-ha size mm from Transitic Average	63 160 ange of 1 be agreed itudinal (T +AT solut to 450 450 rdned by to 35 25 on curve J	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ at the time of ti$	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2 N/mm ² 350 500 by Kv impace 40 24	30 30 40 are valid or nd order rature A% min min 40 38-3: 2005 ir rature A% min min 20 12 cts. Material 40 250	L) n conditic solubilize 25	A% min (T) 30 30 m 2H (es. +A +AT+C700 (+AT+C800 (ed at 1050 °C 50 260	100 100 echanical prop Kv +20 °C J min (L) 100 100 100 VT+C) cold-drawn ma cold-drawn ma c 260	Kv +20 °C J min (T) 60 60 terial terial +AT material °C I +24	Kv -19 J min 60 – Approx R V/mm ²	i of < 5 mi 16 °C (T) E E kimate va Rp 0.2 N/mm ² 200	m of thicknes EN 10250-4 EN 10222-5
40 63 ^{o)} in the ro- have to b (L) = longi Forged - size mm from Work-ha size mm from	63 160 ange of 1 be agreed itudinal (T +AT solut to 450 450 rdned by to 35 25 on curve J	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ at the time of ti$	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2 N/mm ² 350 500 by Kv impace 40 24	30 30 40 are valid or nd order rature A% min min 40 38-3: 2005 ir rature A% min min 20 12 cts. Material 40 250	L) n conditic solubilize 25	A% min (T) 30 30 m 2H (es. +A +AT+C700 (+AT+C800 (ed at 1050 °C 50 260	100 100 echanical prop Kv +20 °C J min (L) 100 100 100 VT+C) cold-drawn ma cold-drawn ma c 260	Kv +20 °C J min (T) 60 60 terial +AT material *C I +24 -80	Kv -19 J min 60 – Approx R V/mm ² 500 355	r of < 5 mi 16 °C (T) E E Kimate va Rp 0.2 N/mm ² 200 300	m of thicknes EN 10250-4 EN 10222-5
40 53 ²⁾ in the ra- have to b (L) = longi Forged - size mm from Work-ha size mm from Transitic Average	63 160 ange of 1 be agreed itudinal (T +AT solut to 450 450 rdned by to 35 25 on curve J	$\begin{array}{c} 500-850\\ 500-700\\ mm \leq d < 5\\ at the time of ti$	190 190 190 mm, values of request a Rp 0.2 N/mm ² 190 200 ng EN 1008 oom temper Rp 0.2 N/mm ² 350 500 by Kv impace 40 24	30 30 40 are valid or nd order rature A% min min 40 38-3: 2005 ir rature A% min min 20 12 cts. Material 40 250	L) n conditic solubilize 25	A% min (T) 30 30 m 2H (es. +A +AT+C700 (+AT+C800 (ed at 1050 °C 50 260	100 100 echanical prop Kv +20 °C J min (L) 100 100 100 VT+C) cold-drawn ma cold-drawn ma c 260	Kv +20 °C J min (T) 60 60 terial terial +AT material °C I +24 -80	Kv -19 J min 60 – Approx R V/mm ² 500	i of < 5 mi 16 °C (T) E E kimate va Rp 0.2 N/mm ² 200	m of thicknes EN 10250-4 EN 10222-5

X6CrNiTi18	-10 n° 1.4	541 auster	nitic stainles	s steel							Lucefi	n Group
Effect of co	ld-workina	(hot-rolled	+AT+C). Ac	proximate	e values	s						
R	N/mm ²	600	710	850	1000		20	1240	1360	1500	1600	
Rp 0.2	N/mm ²	280	600	760	880	99	0	1100	1200	1330	1390	
A	%	38	20	9	8	8		8	8	8	8	
Reduction	%	0	10	20	30	40		50	60	70	75	
Minimum v	alues at hi	gh tempera	tures on m	aterial +A	T, EN ²	10088-3	: 2005					
	N/mm ²	175	165	155	145	13		130	125	121	119	118
Test at 6	°C	100	150	200	250	30	0	350	400	450	500	550
Thermal ex	pansion	10 ⁻⁶ • K ⁻	1	•	16.0	16	.5	17.0	17.5	18.0		
Modulus of	f elasticity	longitudi	nal GPa	200	194	18	6	179	172	165		
Poisson nu		v		0.30	0.30	0.3	31		0.32			
Electrical r	esistivity	$\Omega \bullet mm^2$	²/m	0.73								
Electrical c	conductivity	Siemens	s∙m/mm²	1.37								
Specific he	eat	J/(Kg∙K)		500								
Density		Kg/dm ³		7,90								
Thermal co	onductivity		W/(m∙K)	15.0								
	agnetic per	meability	μr	1.02								
°C				20	100	20		300	400	500		
The symbol	Indicates	temperatu	re between	20 °C and	d 100 °	C, 20 °(C and 2	00 °C	••			
Corrosion	resistance		Atmosphe	ric			Chemi	cal			x interg	
Fresh water	r		industrial	т	arine		mediu	m ox	idizing	reducing	corrosio	. ,
x			x	X			X	X		Ū	industri	al furnace
Magnetic			no									
Machinabil	lity		low on col	d-work ha	ardened	materia	al					
Hardening	•		cold-draw	n and oth	er cold	plastic o	leforma	tions				
Service ten	nperature i	n air	continuou						ce up to	750 °C		
Europe EN	USA UNS		USA ASTM	China _{GB}		Russi GOST	a	Japan JIS	1	India IS	R. (KS	Corea
X6CrNiTi18		00	321	0Cr18N	li11Ti		8N10T	SUS 3	21	X04Cr18Ni1		5 321
	10 0021		V2 I	001101		00011	011101	0000	~_ I		011 010	





Quality Number	,	X5CrNiCuNb16-4 Precipitation hardening 1.4542 (17-4 PH) Stainless Steel					Ū	Technical card 2014 Lucefin Group	
Chemic	cal compo	sition							
C%	Si%	Mn%	P%	S% a)	Cr%	Ni%	Cu%	Nb%	
max	max	max	max	max					
0,07	0,70	1,50	0,040	0,015	15,0-17,0	3,0-5,0	3,0-5,0	5 x C < 0,70	EN 10088-1: 2005
± 0.01	+ 0.05	+ 0.04	+ 0.005	+ 0.003	± 0.2	± 0.07	+ 0.10	± 0.05	

^{a)} for improving machinability, it is allowed a controlled sulphur content of 0,015 % - 0,030 %; for polishability, it is suggested a controlled sulphur content of max 0,015 %

Melting range	Hot-forming	Solution annealing				- AWS electrodes
		(Solubilization) +AT	hardening ·	+P	pre-heating	annealing after w
1440-1400	1175-1095	1060-1030	+P800		100-200	aging
		oil, air (HB max 360)	760 air + 62	0 air		
Stress-relieving	Mill				oint with steel	
+SR	annealing		+P930	+P960	carbon Cr	Moalloyed stainless
	Ū		620 air	590 air	E308L EF	R630 E630-16
660-600	1050-1020		-			
furnace	air, oil under Mf		+P1070	+P1300	cosmetic weldir	ıg
	(HB max 229)		550 air	480 oil	E630-16	Ŭ

Transformation temperature during heating Ac1 ~627, Ac3 ~ 704 and during cooling Ms ~ 130, Mf ~ 30 Chemical treatment • Pickling (6 - 25% HNO₃) + (0.5 - 8% HF) hot or cold. Passivation 20 - 25% HNO₃ hot

Mechanical properties

Heat-treated material EN 10088-3: 2005 in conditions 1C, 1E, 1D, 1X, 1G, 2D

size		Testing at room temperature								
mm		R	Rp 0.2	A %	A%	Kv +20 °C	Kv +20 °C	HB a)	heat treatment	
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J min (T)	max	condition	
	100	1200 max						360	+AT	
	100	800-950	520	18		75			+P800	
	100	930-1100	720	16		40			+P930	
	100	960-1160	790	12					+P960	
	100	1070-1270	1000	10					+P1070	
a) for in	formation	only (L) =	longitudinal (T) =	transversal						

Bright bars of heat-treated material EN 10088-3: 2005 in conditions 2H, 2B, 2G, 2P

size		Testing at room temperature								
mm		R	Rp 0.2	A%	A%	Kv +20 °C	Kv +20 °C	heat treatment		
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)	J min (T)	condition		
	10 ^{b)}	900-1100	600	10						
10	16	900-1100	600	10						
16	40	800-1050	520	12		75		+P800		
40	63	800-1000	520	18		75				
63	160	800-950	520	18		75				
	100	930-1100	720	12		40		+P930		
	100	960-1160	790	10				+P960		
	100	1070-1270	1000	10				+P1070		

b) in the range of 1 mm \leq d < 5 mm, values are valid only for rounds – the mechanical properties of non round bars of < 5 mm of thickness have to be agreed at the time of request and order (L) = longitudinal (T) = transversal

size		Testing at roo	Testing at room temperature								
mm		R	Rp 0.2	A %	A%	Kv +20 °C	Kv +20 °C	heat treatment			
from	to	N/mm ² min	N/mm ² min	min (L)	min (T)	J min (L)	J min (T)	condition			
	250	930	720	15	12	40	30	+P930			
	250	1070	1000	12	10	20	15	+P1070			
	250	1300	1150	8	6			+P1300			

HRC	34	34	38	43	47	42	36	33	
HV 10	336	336	372	423	458	412	354	327	
N/mm ²	1050	1050	1180	1390	1700	1340	1110	1030	
°C	100	200	300	400	450	500	600	650	

X5CrNiC	uNb16-4 i	n° 1.4542 p	precipitation h	ardening I	ЭΗ					Lucef	in Group
Effect of	cold-work	ing (hot-rolle	d, solution an	nealing ar	nd cold-drav	wn). Approx	imate value	S			
R	N/mm ²	880	960	1000	1020	1060	1100	1120	1160	1200	1260
Rp 0.2	N/mm ²	700	820	860	900	980	1000	1000	1020	1050	1080
A	%	20	12	11	10	8	8	8	8	8	8
Reductio	on %	0	10	15	20	30	40	50	60	70	75
		ess and tens				eratures.				heat trea	
		cipitation hare								conditio	า
Rp 0.2	N/mm ²	500	490	480	470	460				+P800	
Rp 0.2	N/mm ²	680	660	640	620	600				+P930	
Rp 0.2	N/mm ²	730	710	690	670	650				+P960	
Rp 0.2	N/mm ²	880	830	800	770	750				+P1070	
Prova a	°C	100	150	200	250	300					
Therma	l expansio	n 10 ⁻⁶ ∙	K-1	•	10.8	11.0	11.3	11.6	12.0		
Modulu	s of elastic	ity longitu	idinal GPa	200	193	186	180	175	170		
Poissor	number	V		0.291							
Electric	al resistivi	ty Ω∙m	m²/m	0.71							
Electric	al conduct	ivity Sieme	ns∙m/mm²	1.41							
Specific	heat	J/(Kg∙	K)	500							
Density		Kg/dm	3	7,80							
Therma	l conducti	vity	W/(m•K)	14.0	16	18.5	20.0	22.0	23.0		
Relative	magnetic	permeability	/μr	max 135	5						
°C	-			20	100	200	300	400	500		
The sym	ibol 🕨 indic	ates betweer	n 20 °C and	100 °C, 2	0 °C and 20	O° 00					
Corrosi	on resista	nce	Atmosphe	ric		Chemic	al			x petrolche	emical,
Fresh wa	ater		industrial	ma	arine	medium	n oxidi	izing	reducing	stress corr	
x			X	X		X	X			food proce	ssing
Magneti			yes								
Machina			related to								
Hardeni	ng		precipitati								
Service	temperatu	re in air	do not use	e at tempe							
Europe		USA UNS	USA ASTM	China GB		Russia GOST	Jap JIS	oan	India IS		R. Core
	uNb16-4	S17400	Type 630	05Cr17		5001		S 630	10		STS 630





	у	X30	CrNiCu18-9-4			Auste			Technical card 2014		
Number		1.4	567			Stain	less Stee		Lucefin (Group	
Chemi	ical com	position									
C%	Si%	Mn%	P%	S% a)	Cr%	Ni%	N%	Cu% ^{b)}			
max	max	max	max	max	0170	11170	max	Cu / C			
0,04	1,00	2,00	0.045	0,015	17,0-19,0	8,5-10,5	0,11	3.0-4.0	EN 10088-	1: 2005	
± 0.01	+ 0.05		+ 0.005	+ 0.003	± 0.2	± 0.1	± 0.01	± 0.1			
^{a)} for imp	proving ma	are allowed chinability, it is I to cold-work h)			
Tempe	erature °										
Melting	•	Hot-forming	, (Solubiliz	annealing ation) +AT	Stabilizing	+A	nnealing	pre-heating	post we	elding	
1450-1400		1200-900	1100-10 water		not necessary	not suita	able	not necessary	slow co	oling	
Sensitization		on Quenching Tempering +Q +T		ng					rMo alloyed	stainless	
sensitization test at 700-450		not suitable	not suita					cosmetic weld E 316L	316L ing	E 316L	
Chemic	al treatme	nt • Pickling (6	5 - 25% HNO3)	+ (0.5 - 8% l	HF) hot or cold	1. Passivatio	n 20 - 45%	6 HNO₃ cold			
Heat-tre size mm	eated mate	erial EN 10088- Testing at roo R			E, 1D, 1X, 1G A%	, 2D Kv + 20	°C Kv	+20 °C HB :	a)		
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L	.) Jr	nin (T) max	[
	160	450-650	175	45				215	+AT so	lubilizatior	
	ormation of	nlv		(L) = longitu	dinal (T) = trans						
^{a)} for info	ormation of	iny		() 0	uinai (1) – tians	sversal					
		,	rial EN 1008	., .	. /						
Bright b		at-treated mate		8-3: 2005 in o	. /						
Bright b size		,		8-3: 2005 in o	. /		°C Kv	+20 °C			
Bright b size mm		at-treated mate Testing at roo	m temperature	8-3: 2005 in o	conditions 2H,	2B, 2G, 2P		+20 °C iin (T)			
Bright b size mm	oars of hea	at-treated mate Testing at roo R	m temperature Rp 0.2	8-3: 2005 in o	conditions 2H,	2B, 2G, 2P Kv +20 °					
Bright b size mm from	to	at-treated mate Testing at roo R N/mm ² 600-850 600-850	m temperature Rp 0.2 N/mm ² min 400 340	8-3: 2005 in (A% min (L) 25 25	conditions 2H,	2B, 2G, 2P Kv +20 °			+AT so	lubilizatior	
Bright b size mm from 10	to 10 ^{b)} 16 40	at-treated mate Testing at roo R N/mm ² 600-850 600-850 450-800	m temperature Rp 0.2 N/mm ² min 400 340 175	8-3: 2005 in o A% min (L) 25	conditions 2H,	2B, 2G, 2P Kv +20 °			+AT so	lubilizatior	
Bright b size mm from 10 16 40	to 10 ^{b)} 16 40 63	at-treated mate Testing at roo R N/mm ² 600-850 600-850	m temperature Rp 0.2 N/mm ² min 400 340 175 175	8-3: 2005 in (A% min (L) 25 25 30 30	conditions 2H,	2B, 2G, 2P Kv +20 ^c J min (L 100 100			+AT so	lubilizatior	
Bright b size mm from 10 16 40 63	to 10 ^{b)} 16 40 63 160	at-treated mate Testing at roo R N/mm ² 600-850 600-850 450-800 450-800 450-650	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 175	8-3: 2005 in (A% min (L) 25 25 30 30 40	A% min (T)	2B, 2G, 2P Kv +20 ^c J min (L 100 100 100) Jm	iin (T)			
Bright b size mm from 10 16 40 63 63 63 (L) = long	to 10 ^{b)} 16 40 63 160 range of 1 be agreed	at-treated mate Testing at roo R N/mm ² 600-850 600-850 450-800 450-800 450-650	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 175 n, values are v	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r	A% min (T)	2B, 2G, 2P Kv +20 ^c J min (L 100 100 100) Jm				
Bright b size mm from 10 16 40 63 63 63 63 63 (L) = long Forged	to 10 ^{b)} 16 40 63 160 range of 1 be agreed	At-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re = transversal	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 n, values are ward or of the second s	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der	A% min (T)	2B, 2G, 2P Kv +20 ^c J min (L 100 100 100) Jm	iin (T)			
Bright b size mm from 10 16 40 63 63 (L) = long Forged size	to 10 ^{b)} 16 40 63 160 range of 1 be agreed	at-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re = transversal Testing at roo	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 n, values are v equest and ord	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der	A% min (T) rounds – the n	2B, 2G, 2P Kv +20 ^o J min (L 100 100 100 nechanical p) J m	hin (T)			
Bright b size mm from 10 16 40 63 63 (L) = long Forged size mm	to 10 ^{b)} 16 40 63 160 range of 1 be agreed gitudinal (T)	at-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re = transversal Testing at roo \mathbf{R}	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 n, values are v squest and ord m temperature Rp 0.2	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der A%	A% min (T) ounds – the n	2B, 2G, 2P Kv +20 ° J min (L 100 100 100 nechanical p Kv +20 °) J m roperties (°C HB	a)			
Bright b size mm from 10 16 40 63 b) in the inhave to l (L) = long Forged size mm from	to 10 ^{b)} 16 40 63 160 range of 1 be agreed jitudinal (T) to	at-treated mate Testing at roo R N/mm² 600-850 600-850 450-800 450-650 mm ≤ d < 5 mn	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 n, values are v equest and ord	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der A%	A% min (T) rounds – the n	2B, 2G, 2P Kv +20 ^o J min (L 100 100 100 nechanical p) J m roperties (°C HB	a) x	rs of < 5 mm	of thicknes	
Bright b size mm from 10 16 40 63 b) in the nave to (L) = long Forged size mm from a) for info	to 10 ^{b)} 16 40 63 160 range of 1 be agreed gitudinal (T) to	at-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re = transversal Testing at roo \mathbf{R} N/mm ²	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 n, values are way aquest and ord m temperature Rp 0.2 N/mm ² min	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der A% min (L)	A% min (T) counds – the n A% min (T)	2B, 2G, 2P Kv +20 ° J min (L 100 100 100 nechanical p Kv +20 °) J m roperties o 2C HB .) ma	a) x	rs of < 5 mm	of thicknes	
Bright b size mm from 10 16 40 63 ^{e)} in the r have to (L) = long Forged size mm from a) for info Effect of	to 10 ^{b)} 16 40 63 160 range of 1 be agreed gitudinal (T) to cormation of f cold-worl	at-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re = transversal Testing at roo \mathbf{R} N/mm ² nly king (hot-rolled	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 1, values are v population of the second m temperature Rp 0.2 N/mm ² min +AT+C). App	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der A% min (L)	A% min (T) ounds – the n A% min (T)	2B, 2G, 2P Kv +20 ° J min (L 100 100 100 100 nechanical p Kv +20 ° J min (L) J m roperties o ² C HB .) ma 215	a) a) x	rs of < 5 mm +AT so	of thicknes	
Bright b size mm from 10 16 40 63 b) in the n have to (L) = long Forged size mm from a) for info Effect of R	to 10 ^{b)} 16 40 63 160 range of 1 be agreed jitudinal (T) to ormation of f cold-wor N/mm ²	at-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re- transversal Testing at roo \mathbf{R} N/mm ² hly king (hot-rolled 560	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 n, values are v aquest and ord m temperature Rp 0.2 N/mm ² min +AT+C). App 720	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der A% min (L) roximate valu 820	A% min (T) ounds – the n A% min (T) les 940	2B, 2G, 2P Kv +20 ° J min (L 100 100 100 100 nechanical p Kv +20 ° J min (L 1010) J m roperties of roc HB .) ma 211	a) a) x 5 20 118	rs of < 5 mm +AT so 0 1300	of thickness	
size mm from 10 16 40 63 63 63 (L) = long Forged size mm from	to 10 ^{b)} 16 40 63 160 range of 1 be agreed gitudinal (T) to cormation of f cold-worl	at-treated mate Testing at roo \mathbf{R} N/mm ² 600-850 600-850 450-800 450-800 450-650 mm $\leq d < 5$ mn at the time of re = transversal Testing at roo \mathbf{R} N/mm ² nly king (hot-rolled	m temperature Rp 0.2 N/mm ² min 400 340 175 175 175 1, values are v population of the second m temperature Rp 0.2 N/mm ² min +AT+C). App	8-3: 2005 in (A% min (L) 25 25 30 30 40 valid only for r der A% min (L)	A% min (T) ounds – the n A% min (T)	2B, 2G, 2P Kv +20 ° J min (L 100 100 100 100 nechanical p Kv +20 ° J min (L) J m roperties o ² C HB .) ma 215	a) a) x 5 20 118	rs of < 5 mm +AT so 0 1300	lubilization	

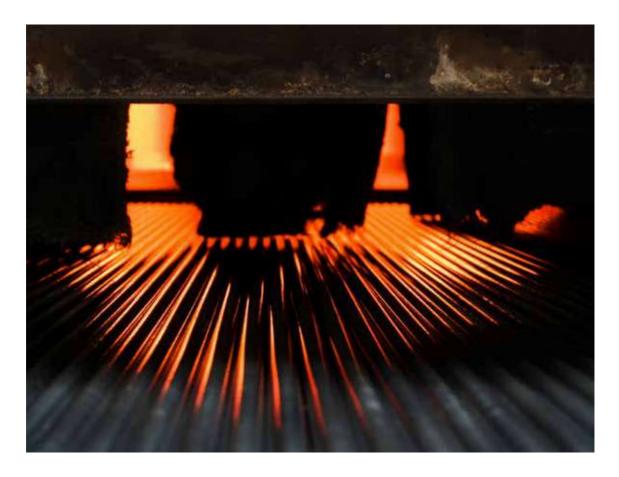
X3CrNiCu18-9-4 n	° 1.4567 aus	tenitic stainles	s steel					Luc	efin Group		
Thermal expansio	n 10 ⁻⁶ .	K-1	►	16.7	17.2	17.7	18.1				
Modulus of elastic	ity longit	udinal GPa	200	194	186	179	172		127		
Poisson number	V		0.28								
Electrical resistivity	t y Ω ∙m	1m²/m	0.73								
Electrical conduct	ivity Siem	ens•m/mm ²	1.33								
Specific heat	J/(Kg	•K)	500								
Density	Kg/dr	n ³	8.027								
Thermal conductiv	/ity	W/(m∙K)	15.0	16.6							
Relative magnetic	permeability	µr _{max}	1.02								
°C			20	100	200	300	400	600	800		
The symbol ► indica	ates temperatu	ire between 2) °C and 10	00 °C, 20 °C	and 200 °C						
Corrosion resistar	ice	Atmospher	ic		Chemical			x intercry	stalline c.		
Fresh water		industrial	ma	rine	medium	oxidizing	reducing	pitting, ur	ban water,		
x		X	X		X	X		stress cor	rosion		
Magnetic		no									
Machinability		high									
Hardening		cold-drawn	d-drawn and other cold plastic deformations								
Service temperatu	re in air	continuous	service up								
Europe EN	USA UNS	USA ASTM	China GB	-		Japan JIS	India IS	Repub KS	ic of Korea		
X3CrNiCu18-9-4	· · · · · · · · · · · · · · · · · · ·			vi9Cu3		SUS XM7		STS XM	Л7		





Qualit	ty	Х	(6CrNiCuS18-	9-2			Austenit					Technical card 2014
Numbe	r	1	1.4570				Stainles	s Steel				Lucefin Group
Chem	ical com	position										
C%	Si%	Mn%	P%	S%	Cr%	Ni%	N%	Cu%	b)	Mo%	, 0	
max	max	max	max				max			max		
0,08	1,00	2,00	0,045	0,15-0,35	17,0-19,0	8,0-10,0	0,11	1,40-	1,80	0,60		EN 10088-1: 2005
± 0.01	+ 0.05	<u>+</u> 0.04	+ 0.005	± 0.02	± 0.2	± 0.1	± 0.01	± 0.1		± 0.0)3	
Product	t deviation	s are allowed										
^{o)} for ste	eels intend	ed to cold-wor	rk hardening a	nd extrusio	on, it is allow	/ed a Cu c	ontent of ma	ix 1,0 %	6			
Temp	erature '	°C										
Melting	g range	Hot-form		on anneal ilization) +		ilizing	Soft annealing +A		MMA welding – AV			AWS electrodes post welding
Sensitization Que +Q		1150-900 1100-1050 water Quenching Tempering		water		suitable		not welded				
				ering					<i>joint</i> carbo	<i>with s</i> on		lo alloyed stainless
		not suitab	not suitable not suitable						cosmetic welding			
Chemio	cal treatm	ent • Pickling	(6 - 25% HNC	0 ₃) + (0.5 -	8% HF) hot	or cold. Pa	assivation 20) - 45%	HNC)₃ colo	4	
Maabo	onical n	onortion										
		operties	0.0.0005 :				`					
	eated mat		8-3: 2005 in c		C, 1E, 1D,	1X, 1G, 2L)					
size			oom temperatu		A 0/		K 00.00		00.0	~		
nm	1	R	Rp 0.2	A %	A%		Kv +20 °C		+20 °		HB ^{a)}	
rom	to 160	N/mm ²	N/mm ² mir	()	min	(1)	J min (L)	Jn	nin (T)		max	AT ash hillestic
		500-710	185	35							215	+AT solubilization
" tor int	formation o	oniy.	(L) = longitud	linal (1) = tr	ansversal							
Bright	bars of he	at-treated ma	aterial EN 100	088-3: 200	5 in conditio	ns 2H, 2B	, 2G, 2P					
size		Testing at re	oom temperatu	ure								
nm		R	Rp 0.2	A%	A%		Kv +20 °C	Kv +	-20 °C)		
rom	to	N/mm ²	N/mm ² mir	n min (L)	min	(T)	J min (L)	J mi	n (T)			
	10 ^{b)}	600-950	400	15								
10	16	600-950	400	15								+AT solubilization
16	40	500-910	185	20								
40	63	500-910	185	20								
53	160	500-710	185	35								
nave to	be agreed		nm, values are f request and c		for rounds	- the mech	nanical prop	erties o	f non	round	d bars o	of < 5 mm of thickne
Forged	1											
size		Testing at r	oom temperatu	ure								
mm		R	Rp 0.2	A %	A%		Kv +20 °C	HB	a)			
from	to	N/mm ²	N/mm ² mir	n min (L)	min	(T)	J min (L)	max				
								215				+AT solubilization
	formation o	,										
		•	ed +AT+C). Ap	•			1400	4400			1000	
	N/mm ²	600	680	800	960		1100	1180			1220	
	0/	-0	~~									
R A Reducti	%	50 0	30 10	20 20	10 30		3 40	8 50			8 60	

9.2							
127							
00 800							
chemical and							
organic products							
gh Id-drawn and other cold plastic deformations							
Republic of Korea							
S							



Quality			CrNiMoTi17-1	2-2		Auste				Technical c	
Number		1.4	571			Stainl	ess Steel			Lucefin G	roup
Chemi	cal com	position									
C%	Si%	Mn%	P%	S% a)	Cr%	Ni%	Mo%	Ti%			
max	max	max	max	max				max			
0,08	1,00	2,00	0,045	0,015	16,5-18,5	10,5-13,5	2,0-2,5	0,70		EN 10088-	1: 2005
± 0.01	+ 0.05	<u>+</u> 0.04	+ 0.005	<u>+</u> 0.005	± 0.2	± 0.15	± 0.1	± 0.0	5		
^{a)} for imp	proving ma	are allowed chinability, it is max 0,015 %	allowed a cont	rolled sulphu	Ir content of 0,	015 % - 0,03	0 %; for p	olishability	, it is su	iggested a o	controlled
Temne	erature °	c.									
Melting		Hot-forming		annealing ation) +AT	Stabilizing	Soft	Soft annealing +A		•	– AWS electrodes after welding	
1470-14	50	1180-950 1120		,	900-845 calm air	not	•	pre-hea not nec	•	slow co	•
		water Quenching Tempering		Stress-relie		joint wit					
		+Q +T			+SR		Mo alloyed	stainless			
not suita	ible	not suitable	air cosmetic weldi		809-E308 Ing	E316L					
Chemic	al treatme	nt - Pickling (6	- 25% HNO3)	+ (0.5 - 8%	HF) hot or cold	. Passivatior	20 - 25%	E 318 hNO₃ hot	t		
Mecha	nical pro	operties									
		erial EN 10088-	3: 2005 in con	ditions 1C. 1	E, 1D, 1X, 1G.	2D					
size		Testing at room			, , , -,						
mm		R	Rp 0.2	A %	A%	Kv +20	°C K	v +20 °C	HB a)	
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	Jmin (L) J	min (T)	max		
	160	500-700	200	40		100			215	+AT solu	ibilization
160	250	500-700	200		30		60)	215		
^{a)} for info	ormation or	nly		(L) = longitu	idinal (T) = trans	versal					
Bright b	ars of hea	at-treated mate	rial EN 1008	8-3: 2005 in (conditions 2H,	2B, 2G, 2P					
size		Testing at room	m temperature								
mm		R	Rp 0.2	A%	A%	Kv +20 °		+20 °C			
from	to	N/mm ²	N/mm ² min	min (L)	min (T)	J min (L)) Jr	nin (T)			
10	10 ^{b)}	600-950	400	25							
10	16	580-950	380	25		400				+AT solu	ubilization
16	40	500-850	200	30		100					
40 63	63 160	500-850 500-700	200	30 40		100 100					
^{b)} in the have to (L) = long	range of 1 be agreed	mm <u><</u> d < 5 mm at the time of re = transversal	n, values are v	alid only for r	rounds – the m		operties c	f non roun	d bars o	of < 5 mm o	f thicknes
size	·AT SUIUD	Testing at rooi	m temperature	2							
mm		R	Rp 0.2	, A%	Kv +20 °C	Kv +20 °	°C K v	-196 °C			
from	to	N/mm ²	N/mm ² min	min (T)	J min (L)	J min (min (T)			
	450	500-700	200	30	100	60	, -	1.1		EN 1025	50-4: 2001
	450	510-710	210	35	100	60	60				22-5: 2001
(L) = long	gitudinal (T)	= transversal									
Work-h	ardned by	cold-drawing	EN 10088-3: 2	2005 in condi	tion 2H (es. +A	T+C)					
		Testing at rooi				,					
		v	Rp 0.2	A %							
size	to	N/mm ²	N/mm² min	min							
size mm			350	20	+AT+C700	cold-drawn r	naterial				
size mm	35				AT. 0000	ي من يعم ام الم	natorial				
size mm		800-1000	500	12	+AT+C800	cold-drawn r	laterial				
size mm from	35 25						Indlendi				
size mm from	35 25	800-1000 at high temper 185			N 10088-3: 200)5		135	131	129	127

1	6:	A	
Luce	rın	Gro	up

Effect of	f cold-working	(hot-rolled	+AT+C). Ap	proximate valu	les					
R	N/mm ²	600	730	880	1040	1140	1280	1360	1600	
Rp 0.2	N/mm ²	230	590	780	920	1100	1220	1230	1420	
Reducti	ion %	0	10	20	30	40	50	60	70	
Typical	l values at hig	h temperat	ure properti	es. For inform	ation only					
R	N/mm ²	518	455	443	433	423	375	261	155	78
Rp 0.2	N/mm ²	208	179	159	146	145	146	146	112	55
Test ter	mperature °C	93	204	316	427	538	649	760	871	982
Therma	al expansion	10 ⁻⁶ •	K -1	►	16.5	17.5	18.0	18.5	19.0	
Modulu	us of elasticity	longitu	idinal GPa	200	194	186	179	172	165	
Poisso	n number	v		0,30						
Electric	cal resistivity	Ω•m	m²/m	0.75	0.79	0.87	0.94	0.98	0.102	
Electric	cal conductivi	ty Sieme	ns•m/mm ²	1.33						
Specifi	c heat	J/(Kg•	K)	500	500	520	530	540	540	
Density	/	Kg/dm	3	8.0						
Therma	al conductivity	/	W/(m•K)) 15	16	17.5	19	20.5	22	
Relativ	e magnetic pe	rmeability	μr	1.02						
°C				20	100	200	300	400	500	
The syn	mbol indicate	s temperatu	ure between 2	20 °C and 100	°C, 20 °C	and 200 °C .				
Corrosi	ion resistance	;	Atmosph	neric		Chemical			x salts,	organic acids
Fresh w	vater		industria	nl mari	ne	medium	oxidizing	reducing	food	
x			X	X		X				
Magnet	tic		no							
Machin	ability						m suggests to	use carbide c	utting insert	S
Harden	ing		cold-dra	wn and other	cold plastic	deformations	;			
Service	e temperature	in air	continuo	ous service up	to 850 °C; i	ntermittent s	ervice up to 80	0°C		
Europe		USA UNS	USA ASTM	China GB		issia IST	Japan JIS	India IS		Korea
		S31635	Type 316Ti	06Cr17Ni12		Ch17N13M2			li12Mo2Ti	STS 316Ti
VOCUMI	10101117-12-2	331033	Type STOTT	00017/1012			1 303 3101			313 310



Qualit	ty	X15	CrNiSi25-21			stenitic					Technica	I card 2014
Numbe	r	1.4	841		Sta	ainless St	eel (refra	ctory st	eel)	1	Lucefin	Group
Chem	ical comp	osition										
C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%		N%			
max	01/0	max	max	max	01/0	110 /0			max			
0,20	1,50-2,		0.045	0,015	24,0-26,0		19.0	-22,0	0,11		EN 100	88-1: 2005
+ 0.01	+ 0.10	+ 0.10	+ 0.005	+ 0.003	± 0.25		± 0.		± 0.0	1		
_	t deviations a		0.000		1 0.20		± 0.		2 0.0	•		
Temp	erature °C	;										
	g range	Hot-forming	Solution annealing	+AT	Soft annealing +A	Stabi	ilizing		MMA weldin		AWS elect post v	
1430-14	400	1190-1000 1150-1050 water			not suitable	not necessary		no	t neces	sary	solutio	on annealin
Sensitization		Quenching Tempering +Q +T		g	Stress relieving +SR			joint with steel carbon CrM			D	stainless
avoid s	low heating	ig not not			650 E309-E308					B E309	9-E308	E310
in the range of 600 and 900		suitable				air cosmetic we						
Chemi	cal treatmer	t • Pickling (6	- 25% HNO3) +	• (0.5 - 8%	HF) hot or col	d. Passiva	tion 20 - 1	25%HN	O₃ hot			
	anical pro											
			eformation EN	10095: 2	2001							
bar size		Testing at roor										
mm		R ¹⁾	Rp 0.2	Jam et 1)	A% min fo	r products flat		H	B ¹⁾			
from	to	N/mm ² min	N/mm ² min	long ¹⁾ (I)	da 0.5 a <		> 3 (I) (tr) m	ах			
^{I)} The value b	160 max HB valu e lowered to		N/mm ² min 230 ed by 100 units n and bars of <u><</u>	(I) 30 s or the m		3 (I) (tr) gth value		22 aised by			lution an nd the mi	<u> </u>
¹⁾ The value b (I) = lon Hot-fin	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r	550-750 es may be rais 20% for sectio = transversal olled) ASTM A	230 ed by 100 units n and bars of <u><</u> 276-04	(I) 30 s or the m	28 ax tensile stren	3 (I) (tr) gth value	30 may be ra	22 aised by	23			<u> </u>
¹⁾ The value b (I) = lon Hot-fin size	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature	(I) 30 s or the m 35 mm th	28 ax tensile stren nickness having	3 (I) (tr) gth value g a final co	30 may be ra ld deform	22 iised by ation.	23 7 200 N			<u> </u>
¹⁾ The value b (I) = lon Hot-fin size mm	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature Rp 0.2	(I) 30 s or the m 35 mm th A%	28 ax tensile stren nickness having C%	3 (I) (tr) gth value g a final co Kv +20 °C	30 may be ra Id deform	22 atised by ation.	23 7 200 N °C			<u> </u>
¹⁾ The value b (I) = lon Hot-fin size mm from	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature	(I) 30 s or the m 35 mm th	28 ax tensile stren nickness having	3 (I) (tr) gth value g a final co	30 may be ra Id deform	22 iised by ation.	23 7 200 N °C	I/mm² ar		in elongatio
¹⁾ The value b (I) = Ion Hot-fin size mm from all Forged	160 max HB valu e lowered to igitudinal (tr) ished (Hot-r to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99	(I) 30 5 or the m 35 mm th A% min (L)	28 ax tensile stren iickness having C% min (L)	3 (I) (tr) gth value g a final co Kv +20 °C	30 may be ra Id deform	22 atised by ation.	23 7 200 N °C	I/mm² ar	nd the mi	in elongatio
¹⁾ The value b (I) = lon Hot-fin size mm from all Forged ssize	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature	(I) 30 s or the m 35 mm th A% min (L) 40	28 ax tensile stren nickness having C% min (L) 50	3 (l) (tr) gth value g a final co Kv +20 °C J min (L)	30 may be ra Id deform	22 alised by ation. (v +20 ° min (T	23 7 200 N PC)	I/mm² ar +AT so	nd the mi	in elongatio
value b (I) = lon Hot-fin size mm from all Forged ssize mm	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2	(I) 30 s or the m 35 mm th A% min (L) 40	28 ax tensile stren nickness having C% min (L) 50 C%	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b (I) = Ion Hot-fin size mm from all Forged ssize mm	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min	(I) 30 s or the m 35 mm th A% min (L) 40 A % min (L)	28 ax tensile stren nickness having C% min (L) 50 C% min (L)	3 (l) (tr) gth value g a final co Kv +20 °C J min (L)	30 may be ra Id deform	22 alised by ation. (v +20 ° min (T	23 7 200 N 2C 7)	I/mm² ar +AT so	nd the mi lution an	in elongatio
¹⁾ The value b (I) = lon Hot-fin size mm from all Forged ssize mm from	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205	(I) 30 s or the m 35 mm th A% min (L) 40	28 ax tensile stren nickness having C% min (L) 50 C%	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b (I) = lon Hot-fin size mm from all Forged ssize mm from Hard-d	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to to rawn ASTM	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A ²	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C)	(I) 30 s or the m 35 mm th A% min (L) 40 A % min (L)	28 ax tensile stren nickness having C% min (L) 50 C% min (L)	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b (I) = lon Hot-fin size mm from all Forged ssize mm from Hard-d	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to to rawn ASTM	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A [*] Testing at roor	230 ed by 100 units n and bars of <u><</u> 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C)	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b (I) = Ion Hot-fin size mm from all Forged ssize mm from Hard-d size mm	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to to	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A Testing at roor R	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A%	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b (I) = lon Hot-fin size mm from all Forged ssize mm from	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r- to to to to rawn ASTM	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A Testing at roor R N/mm ² min	230 ed by 100 units n and bars of \leq 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min (L)	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b value b (I) = lon Hot-fin size mm from all Forged ssize mm from Hard-d size mm from Hard-d size mm	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to rawn ASTM to 12.7	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A ² Testing at roor R N/mm ² min 620	230 ed by 100 units n and bars of \leq 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min (L) 30	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatic
¹⁾ The value b value b (l) = lon Hot-fin size mm from all Forged ssize mm from Hard-d size mm from Hard-d size mm from the size mm from from the size mm from the size	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to rawn ASTM to 12.7	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A Testing at roor R N/mm ² min	230 ed by 100 units n and bars of \leq 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min (L)	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C	30 may be ra Id deform	22 ation. (v +20 ° min (T	23 7 200 N 2C 7)	+AT so Kv -196	nd the mi lution an	in elongatio
¹⁾ The value b value b (I) = lon Hot-fin size mm from all Forged ssize mm from size mm from 12.7	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to rawn ASTM to 12.7 properties E	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A Testing at roor R N/mm ² min 620 515 N 10095 : 200	230 ed by 100 units n and bars of \leq 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 205	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min (L) 40 Verage value	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) gth for 1%	30 may be ra Id deform	22 ised by ation. (v +20 ° min (1 (v +20 °	23 7 200 N C) C) C ()	I/mm² ar +AT so Kv -196 J min (Iution an S°C (T)	nealing
¹⁾ The value b value b (l) = lon Hot-fin size mm from all Forged ssize mm from Hard-d size mm from 12.7 Creep I the stree	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to to to ta ta ta ta ta ta ta ta ta ta ta ta ta	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A Testing at roor R N/mm ² min 620 515 N 10095 : 200 ure (<i>R</i> m) at ele	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperat	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage va ture for 1	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40	3 (l) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) gth for 1% n and 100	30 may be ra ld deform C I C I C I C I C I C I C I C I C I C I	222 ised by ation. (v +20 ° min (1 (v +20 °	23 7 200 N C C T) P C C T)	I/mm² ar +AT so Kv -196 J min (Iution an S°C (T)	nealing
¹⁾ The value b value b (l) = lon Hot-fin size mm from all Forged size mm from 12.7 Creep 1, the stree Test ter	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to I +AT solubili to rawn ASTM 12.7 properties E ength for rupt mperature	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 Zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A Testing at roor R N/mm ² min 620 515 N 10095 : 200 ure (<i>R</i> m) at ele Strength elong	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperat ation Rp 1.0 N/n	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage vature for 1 mm ²	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40 40 lue of the stren 000 h, 10 000 h	3 (I) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) gth for 1% n and 100 Strer	30 may be ra ld deform C F C C C F C F C C C F C C C C C F C C C CCCCCCCCCCCCC	222 ised by ation. (v +20 ° min (1 (v +20 ° min (1 (v +20 ° min (1) (v +20 ° (v +20 °) (v +20 ° (v +20 °) (v +20	23 7 200 N C C T) C C T) D D n and mm ²	I/mm ² ar +AT so Kv -196 J min (estimate	Iution an B°C (T) ed avera	nealing ge value o
¹⁾ The value b value b (l) = lon Hot-fin size mm from all Forged size mm from 12.7 Creep the stree Trest ter soc	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to I +AT solubili to rawn ASTM 12.7 properties E ength for rupt mperature	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 Zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A ² Testing at roor R N/mm ² min 620 515 N 10095 : 200 ure (<i>R</i> m) at ele Strength elong 1000 hours	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 F+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperal ation Rp 1.0 N/n 10.000 ho	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage vature for 1 mm ²	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40	3 (I) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) kv +20 °C J min (L) Strer s 1000	30 may be ra ld deform C I C I C I C I C I C I C I C I C I C I	222 iised by ation. (v +20 ° min (1 (v +20 ° min (1) longatid	23 7 200 N C C T) P C C T) D D n and mm ² 0.000	I/mm ² ar +AT so Kv -196 J min (estimate	Iution an S°C (T) ed avera	nealing ge value of
¹⁾ The value b value b (l) = lon Hot-fin size mm from all Forged size mm from Hard-d size mm from 12.7 Creep I the stree Test ter °C 600	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to I +AT solubili to rawn ASTM to 12.7 properties E ength for rupt mperature	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 Zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A [*] Testing at roor R N/mm ² min 620 515 N 10095 : 200 ure (<i>R</i> m) at ele Strength elong 1000 hours 105	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperat ation Rp 1.0 N/n 10.000 ho 95	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage vature for 1 mm ²	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40 40 lue of the stren 000 h, 10 000 h	3 (I) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20	30 may be ra ld deform C F C C C F C F C C C F C C C C C F C C C CCCCCCCCCCCCC	222 iised by ation. (v +20 ° min (1 (v +20 ° min (1 longatid longatid longatid 1 1	23 7 200 N C C T) P C C T) D D n and 2000 0.000 30	I/mm ² ar +AT so Kv -196 J min (estimate	Iution an S °C (T) ed avera 100. 80	nealing
¹⁾ The value b (l) = lon Hot-fin size mm from all Forged ssize mm from 12.7 Creep the stre Test ter °C 600 700	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to I +AT solubili to rawn ASTM to 12.7 properties E ength for rupt mperature	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 Zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A ^T Testing at roor R N/mm ² min 620 515 N 10095 : 200 urre (<i>R</i> m) at ele Strength elong 1000 hours 105 50	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperat ation Rp 1.0 N/t 10.000 ho 95 35	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage vature for 1 mm ²	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40 40 lue of the stren 000 h, 10 000 h	3 (I) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) Kv +20 °C J min (L) Streft and 100 Streft s 1000 170 90	30 may be ra ld deform C F C C C F C F C C C F C C C C C F C C C CCCCCCCCCCCCC	222 iised by ation. (v +20 ° min (T (v +20 ° min (T longatic longatic longatic 1 1 4	23 7 200 N C C 7) P C C T) D D n and 2000 30 0	I/mm ² ar +AT so Kv -196 J min (estimate	Iution an S °C (T) ed avera 100. 80 18	nealing ge value of
¹⁾ The value b (l) = lon Hot-fin size mm from all Forged smm from Hard-d size mm from 12.7 Creep the stre Test ten °C 600 700 8800	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to I +AT solubili to rawn ASTM to 12.7 properties E ength for rupt mperature	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 Zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A ^T Testing at roor R N/mm ² min 620 515 N 10095 : 200 ure (<i>R</i> m) at ele Strength elong 1000 hours 105 50 23	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperat ation Rp 1.0 N/t 10.000 ho 95 35 10	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage vature for 1 mm ²	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40 40 lue of the stren 000 h, 10 000 h	3 (I) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) Kv +20 °C J min (L) Stref s 1000 170 90 45	30 may be ra ld deform C F C C C F C F C C C F C C C C C F C C C CCCCCCCCCCCCC	222 iised by ation. (v +20 ° min (T (v +20 ° min (T longatid longatid re R N/ 1 1 4 2	23 7 200 N C C T) P C C T) D D n and 30 0 0	I/mm ² ar +AT so Kv -196 J min (estimate	Iution an S °C (T) ed avera 100. 80 18 7	nealing ge value of
¹⁾ The value b value b (l) = lon Hot-fin size mm from all Forged ssize mm from Hard-d size mm from 12.7 Creep I the stree	160 max HB valu e lowered to ngitudinal (tr) ished (Hot-r to to I +AT solubili to rawn ASTM to 12.7 properties E ength for rupt mperature	550-750 es may be rais 20% for sectio = transversal olled) ASTM A Testing at roor R N/mm ² min 515 Zed material A Testing at roor R N/mm ² min 515 A 276-04 (+A ^T Testing at roor R N/mm ² min 620 515 N 10095 : 200 urre (<i>R</i> m) at ele Strength elong 1000 hours 105 50	230 ed by 100 units n and bars of ≤ 276-04 n temperature Rp 0.2 N/mm ² min 205 STM A 473-99 n temperature Rp 0.2 N/mm ² min 205 T+C) n temperature Rp 0.2 N/mm ² min 310 205 1. Estimated a vated temperat ation Rp 1.0 N/t 10.000 ho 95 35	(I) 30 s or the m 35 mm th A% min (L) 40 A% min (L) 40 A% min 30 30 verage vature for 1 mm ²	28 ax tensile stren nickness having C% min (L) 50 C% min (L) 50 C% min 40 40 40 40 lue of the stren 000 h, 10 000 h	3 (I) (tr) gth value g a final co Kv +20 °C J min (L) Kv +20 °C J min (L) Kv +20 °C J min (L) Streft and 100 Streft s 1000 170 90	30 may be ra ld deform C F C C C F C F C C C F C C C C C F C C C CCCCCCCCCCCCC	222 iised by ation. (v +20 ° min (T (v +20 ° min (T longatid longatid re R N/ 1 1 4 2	23 7 200 N C C 7) P C C T) D D n and 2000 30 0	I/mm ² ar +AT so Kv -196 J min (estimate	Iution an S °C (T) ed avera 100. 80 18	nealing ge value of

X15CrNi	Si25-21 n° 1. 4	4841 auster	iitic								Lucefin	Group
Transitio	on-curve dete	rmined with	Kv. Solubilize	ed materia	al at 1050	°C						
Average	J	60	70	85	100	120	150	170				
Test at	°C	-160	-120	-80	-40	0	40	80				
Approxi	mate values a	t high tem	peratures. M	aterial +A	T solubiliz	ed at 1050	°C					
R	N/mm ²	630	610	580	560	520	460	400	300			
Rp 0.2	N/mm ²	290	240	200	190	180	170	150	140			
A	%	46	42	40	40	38	34	25	22			
С	%	72	70	68	62	58	40	28	38			
Test at	°C	100	200	300	400	500	600	700	800			
Thermal	expansion	10 ⁻⁶ • K ⁻¹		•		15.5		17.0	1	7.5	18.0	19.0
Modulus	of elasticity	longitudina	al GPa	200		184		167	1	50	135	
Modulus	of elasticity	tangential	GPa	86								
Poisson	number	V		0.30 ~								
Electrica	al resistivity	$\Omega \bullet mm^2/r$	n	0.90								
Electrica	al conductiv.	Siemens.	m/mm ²	1.11								
Specific	heat	J/(Kg•K)		500								
Density		Kg/dm ³		7.90								
Thermal	conductivity		W/(m∙K)	15								
Relative	magnetic per	rmeability	µr max	1.02								
°C				20	100	200	300	400	500 6	00	800	1000
The sym	bol indicates	s temperatu	re between 2	0 °C and	200 °C, 20) °C and 4	00 °C .					
Corrosic	on resistance		Atmospheric	;		Chemi	cal			x ra	idiant tub	es, boiler
Fresh wa	iter		industrial	mar	ine	mediur	n	oxidizing	reducing	heat	treating	boxes
x			X	X		X		X				
Magneti	C		no									
Machina	bility		mean									
Hardeniı	ng		by cold-drav	vn and an	d other co	ld plastic d	eforma	tions				
Service	temperature		max 1125 °	C								
Europe	US		USA	China	a	Russia		Japan	India			Korea
EN	UN		ASTM	GB		GOST		JIS	IS		KS	
X15CrNi	Si25-21 S3	1400	314	1Cr2	5Ni20Si2	20Ch25N	120S2	SUH 310 ~	X20Cr	25Ni20	STS (310 TB ~



Quality			CrNi25-21			Technical card 201					
Number		1.4	1845			Stainle	ss Steel	retrac	ctory steel)	Lucefin	Group
Chemi	ical comp	osition									
C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%		N%		
max	max	max	max	max					max		
0,10	1,50	2,00	0,045	0,015	24,0-26,0		19,0-2	2,0	0,11	EN 100	88-1: 2005
<u>+</u> 0.01	<u>+</u> 0.10	<u>+</u> 0.10	+ 0.005	+ 0.003	3 ± 0.25		± 0.15		± 0.01		
Product	deviations	are allowed									
Tempe	erature °C)									
Melting	range	Hot-forming	g Solution annealin		Soft annealing +A	Stabiliz	ing		A welding heating	– AWS elec post v	
1450-14	.00	1175-990 water	1150-104 water	10	not suitable	not necessa	ary	not	necessary	solutio	on annealir
Sensitiz	zation	Quenching +Q	Temperi +T	ng	Stress relieving +SR	l		<i>joint</i> carb	t with steel on C	CrMo alloyed	stainless
avoid slo	ow heating	not	not		after hard-drawn			ENiC	CrFe-3 E	ENiCrFe-3	E310Nb
in the ra 600 and	nge of	suitable	suitable		1080-1050 water 400-200 air	r		cosi E310	metic weld	ling	
Chemic	al treatmer	n t - Pickling (*	10% HNO3) + (0.5 – 1.5%	6 HF) hot or cold.	Passivation	20 - 45%	6 HNC	D₃ cold		
Mecha	inical pro	perties									
Product		with plastic	deformation E		2001						
flat size	_	=	m temperature								
mm		R	Rp 0.2	A %	C%	Kv +20		-			
from	to	N/mm ² min	N/mm ² min	min	min	J min	ma				· · · P · · ·
	75 35	500-700 500-900	210 210	35 20			19 29		+A1 +A1	solution an	nealing
				20			20	2	.7(1		
		olled) ASTM A	A 276-04 m temperature								
size mm	-	R	Rp 0.2	, A%	C%	Kv +20 °	°C K	/ +20 °	۲ <u>۲</u>		
from	to	N/mm ² min	N/mm ² min	min (L)	min (L)	J min (L		nin (T)			
all		515	205	40	50	0 mm (L	, 01			solubilized	I material
Forged	+AT solubil	ized material <i>I</i>	ASTM A 473-9	9							
size			m temperature								
mm	-	R	Rp 0.2	A%	C %	Kv +20 °	°C K v	/ +20 °	C Kv	-196 °C	
from	to	N/mm ² min	N/mm ² min	min (L)	min (L)	J min (L	_) J	min (T) Jm	nin (T)	
		515	205	40	50		,		,		
Hard-dr	awn ASTM	A 276-04 (+A	AT+C)								
size			m temperature)							
mm	-	R	Rp 0.2	A %	C%						
from	to	N/mm ² min	N/mm² min	min	min						
	12.7	620	310	30	40						
12.7		515	205	30	40						
Creep p	roperties E	EN 10095 : 200	01. Estimated	average v	alue of the streng	th for 1% (<i>I</i>	Rp1,0) elor	ngatio	n and estir	mated avera	ge value o
	ngth for rupt	ure (<i>R</i> m) at el	evated temper	ature for 1	000 h, 10 000 h	and 100 0Ò	0 h.	•			
			gation Rp 1.0 N					ruptur	e R N/mm		
°C		1000 hours	10.000 h.	100	.000 h.		1000 h.		10.000		00.000 h.
600		100	90				170		130	80	
700		45	30				80		40	18	
800		18	10				35		18	7	
900		10	4				15		8.5	3	
			n Kv. Solubilize								-
Average		50	62	84	106		130		150	1	70
Test at	°C	-160	-120	-80	-40		0		40	8	

X8CrNi25-21 nº 1.4845 austenitic

	21 n° 1.48 4										Lucefin	Group
Effect of c	old-working		•АТ+С). Ар	proximate	values							
R	N/mm ²		600	760	880	990	1080	1150	1220	126		
Rp 0.2	N/mm ²		310	460	690	880	990	1040	1080	110	0	
Α	%		42	30	18	8	6	6	5	5		
Reduct.	%		0	10	20	30	40	50	60	70		
Relative r	nagnetic per	meability	Jr as a func	tion of ma	ignetic field	d intensity	and red	uction. App	roximate v	/alues		
Reduction	%			0	14,7	26,8	64,2					
Magnetic	field intensity	4000 A/m		1.0018	1.0016	1.0018	1.0019	9				
Magnetic	field intensity	16000 A/m		1.0035	1.0041	1.0043	1.004	1				
Mechanic	al properties	on variou	s temperat	ures. Mat	erial +AT s	olubilized	at 1050	°C. Approx	imate valu	Jes		
R	N/mm ²	1223	1085	658	620	600	580	550	520	440	380	240
Rp 0.2	N/mm ²	796	585	310	280	230	200	190	180	170	160	150
A	%	52	54	60	44	42	40	40	40	38	28	20
С	%	50	54	65	70	68	66	62	58	40	28	38
Test at	°C	-254	-195	24	100	200	300	400	500	600	700	800
Thermal e	expansion	10 ⁻⁶ • K ⁻¹		•		15.5		17.0		17.5	5 18.5	19.0
Modulus	of elasticity	longitudina	I GPa	200	190	185	180	170	158	150	130	120
Modulus	of elasticity	tangential	GPa	86								
Poisson r	number	V		0.29~								
Electrical	resistivity	$\Omega \cdot mm^2/n$	ı	0.85								
Electrical	conductiv.	Siemens•r	n/mm²	1.18								
Specific h	neat	J/(Kg∙K)		500								
Density		Kg/dm ³		7.90								
Thermal of	conductivity		W/(m•K)	15					19			
Relative r	nagnetic per	meability	µr max	1.008								
°C			- max	20	100	200	300	400	500	600	800	1000
The symb	ol ► indicates	temperatur	e between 2	20 °C and	200 °C, 2	0 °C and	400 °C .					
Corrosion resistance Atmos		Atmospher	Atmospheric Chemical							xoil pumping station,		
		industrial	ma	marine		um	oxidizing	reducing		hig-heat salt bath, h		
x			x	X		X		X			gases> 550	°C
Magnetic			no									
Machinab	oility		high									
Hardenin	g _		by cold-dra	wn and a	nd other co	old plastic	deforma	itions				
Service te	emperature i	n air						rvice up to 1	000 °C			

Oct vice temp		continuous		o, intermitterit o		0 0	
Europe	USA	USA	China	Russia	Japan	India	R. of Korea
EN	UNS	ASTM	GB	GOST	JIS	IS	KS
X8CrNi25-21	S31008	310S	0Cr25Ni20	10Ch23N18	SUH 310	10Cr25Ni18 ~	STS 310S



À. 227

Quality	1			FMo						erritic ainless Ste	ما	Technical card 201
Number			(1.4	105)					ગ	anness 316		Lucefin Group
Chemi	cal cor	npositi	on									
C% max	Si	%	Mn%		P% max		S%	Cr	6	Mo%	Ni% max	
0,08	0,3	80-0,80	0,40-1	,25	0,040		0,20-0,3	0 16,	0-18,0	0,80-1,10		
+ 0.01).05	+ 0.03		+ 0.00	5	+ 0.02	+ 0		+ 0.05	+ 0.03	
		ns are allo	owed									
Tempe	rature	°C										
Melting		Pre-hea	ating		Hot-for	ming	So +A	ft annea	ling		MMA welding – pre-heating	AWS electrodes
1500-14	80	870-820)		1140-90	00	80	0-780 air B max 19	0)			qualified electrodes
Natural s	state	pause Recrys	tallizati	on	Quencl	hina		inealing		etic	joint with steel	
+U	Juio	+RA	amzuti		+Q			operties a				Mo alloyed stainless
-		820-760) slow		930			5-800 co				130 E309
(HB min	195)	cooling (HB ma			calm or	forced		°C/h to 4		air	cosmetic weldin E309	g
`	,	e 671 °C	,									
				6 - 25%	6 HNO₃)	+ (0.5	- 8% HF)	hot or col	d. Passi	vation 20 - 2	25% HNO₃ hot	
		roperti			-7	, -	,					
Hot-form		operin										
size		Testina	at room	n temp	erature							
mm		R		Rp 0		A %		Kv +20 °	C H	B a)	a) for information	n only
from	to	N/mm ²		N/mm		min		J min	m	ax		·
	100	430		245		16			20	00	+RA recrystalliz	ation annealing
Cold-dra	wing											
size			at room									
mm		R		Rp 0		A %		Kv +20 °	C H	В		
from	to	N/mm ²	min	N/mm	² min	min		J min	m	ax		
10	10	520		320		7						- 10 C
10	16	480		300		7						allization annealing an
16	40	420		240		12					cold-drawing	
40	63	420		240		12						
Thermal	-		10 ⁻⁶ •			•		10.6	1	1.4	12.0	
Modulus				udinal	GPa	206						
Poisson			V O m	1m²/m		0.29	~					
Electrica Electrica				im²/m ens∙m/	lmm ²	1.42						
Specific		ionvity	J/(Kg		······*	460						
Density	ireat		Kg/dn			7.61						
Thermal	conduc	tivity	ng/un		m∙K)	25						
		tic perme	eabilitv	μr		600-8	300 ~					
°C	J •			•		20		200	4	00	600	
The sym	bol 🕨 ind	licates te	mperatu	ure bet	ween 20) °C ar	d 200 °C,	20 °C ar	nd 400 °(C		
Corrosic	on resis	tance		Atm	ospheric	>			Chemic	al		x food, nitric acid,
Fresh wa				_	istrial		marine		medium		ing reducing	dairy products
X				X					X		- 5	
Magneti	C			yes								
Machina				high	1							
Hardenii				cold	-drawn		ner cold pla					
		ature in a	ir	cont	tinuous s	service	up to 780	°C; inter	mittent s	ervice up to	830 °C	
Service												
Service Europe		USA UNS		U SA ASTM		China GB	a	Russia GOST		Japan JIS	India IS	Republic of Kore

(X6CrMoS17)

Quality Number			CrMoTi18-2	-		Ferr Stai	I	Technical card 2014 Lucefin Group			
Number		1.4	521			otu		•	L	.ucerin G	sroup
Chemic	al comp	position									
C%	Si%	Mn%	P%	S%	Cr%	Ti% ^{a)}	N%	Mo%			
max	max	max	max	max	(= 0.00.0	max	max	4.00		EN 4000	
0,025	1,00	1,00	0,040	0,015	17,0-20,0	0,80	0,030			EN 1008	8-1:200
+ 0.005	+ 0.05		+ 0.00		3 ± 0.2	± 0.05	± 0.01	± 0.1			
		are allowed	9 11. (4 X(C	+ N) + 0.15)							
Temper											
Melting r	ange	Hot-forming		ion aling +AT	Stabilizing	Curie tempe	rature	MMA wel	•	AWS ele post	ectrodes weldin
1510-148	0	1100-950	not suitat	-	not necessary	650		not neces	•	•	necessa
Sensitiza	tion	Quenching	Temp +T	ering	Soft annealing			joint with			ata:ala
		+Q			(controlled atm	iosphere)		carbon		rMo	stainle
avoid slov		not suitable	not suitat	lo	880-820 air. awatar			E309-E30		309-E308	E308L
in the ran 900 and 6		Suitable	suitat	ie	air, awater			cosmetic 1.4430	welall	ıg	
		nt • Picklina (?	0 - 40% HN	$(0_3) + (2 - 6)$	6 Na2Cr2O7 . 4%	2H2O) hot •	Passivatio		HNO	3 hot	
			- 1070 H		ц. 01207. т /0					,	
Mechan			ndition A								
EN 10088 size		in annealing co Testing at roo									
size mm	-		m tempera Rp 0.2	ure Rp	0.2	A % t<3	A % 1	< 3	HB		produc
	to		Kp 0.2 N/mm² mir		0.2 m ² min (T)	A % (< 3 min (L)	A% min			f. only	form
nom			300	320	III- IIIIII (I)	20	20	(1)	125-1		C
			280	300		20	20		119-1		H
			280	300		20	20		125-1		P
(L) = long					= hot rolled strip				120-	150	
· · · ·		, 1-11b plate, sh					•				
size mm			Rp 0.2	A%		НВ					
	to		N/mm ² mir			max					
5			275	20		217					
					1	<u>- 11</u>					
		ting (hot-rolled				040	050	000			
R Reductior	N/mn 1 %	m ² 480 0	660 10		780 800 80 40	810 50	850 60	900 70			
Reduction	/0	0	10	20 3	50 40	30	00	10			
Minimum	values f	or the 0.2 % p	roof stren	th at elevat	ed temperature	s. annealed	material +/	A EN 1008	8-2: 20	005 / EN 1	10028-7
Rp 0.2	N/mm ²	294	250		230 220	210	205	200			
Test at	°C	50	100		200 250	300	350	400			
		50		130 2							
Thormal	avnanala			150 2	•	10 /	10.9	11 0	11 6	11 0) 1
	•	n 10 ⁻⁶ • K ⁻¹		150 2	► 220	10.4	10.8	11.2	11.6	11.9	
Modulus	of elastic	n 10 ⁻⁶ • K-	nal GPa	130 2	220	10.4 215	10.8 210	11.2 205	11.6 195	11.9	
Modulus Modulus	of elastic of elastic	n 10 ⁻⁶ • K- ity longitudin ity tangentia	nal GPa	130 2	220 65	215				11.9	
Poisson	of elastic of elastic number	n 10 ⁻⁶ • K- ity longitudin ity tangentia V	nal GPa I GPa		220 65 0.28 ~	215				11.9	
Modulus Modulus Poisson Electrica	of elastic of elastic number I resistivit	n $10^{-6} \cdot K^{-1}$ bity longitudin bity tangentia <i>V</i> ty $\Omega \cdot mm^2$	nal GPa I GPa		220 65 0.28 ~ 0.80	215				11.9	
Modulus Modulus Poisson Electrica Electrica	of elastic of elastic number I resistivit I conduct	n 10 ⁻⁶ • K- sity longitudii sity tangentia v ty Ω • mm ² siemens	nal GPa I GPa		220 65 0.28 ~ 0.80 1.25	215				11.9	
Modulus Modulus Poisson Electrica Electrica Specific	of elastic of elastic number I resistivit I conduct	n $10^{-6} \cdot \text{K}^{-6}$ city longitudii city tangentia V ty $\Omega \cdot \text{mm}^2$ city. Siemens $J/(\text{Kg}\cdot\text{K})$	nal GPa I GPa		220 65 0.28 ~ 0.80 1.25 430	215				11.9	
Modulus Modulus Poisson Electrica Electrica Specific Density	of elastic of elastic number I resistivit I conduct heat	n 10 ⁻⁶ • K ⁻¹ city longitudin city tangentia ν ty Ω • mm ² city. Siemens J/(Kg•K) Kg/dm ³	nal GPa I GPa /m •m/mm²		220 65 0.28 ~ 0.80 1.25 430 7.70	215	210		195		1
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal	of elastic of elastic number I resistivit I conduct heat conductiv	n 10 ⁻⁶ • K ⁻ City longitudii vity tangentia v Ω • mm ² tiv Siemens J/(Kg•K) Kg/dm ³	nal GPa I GPa •m/mm² W/(m•K)		220 65 0.28 ~ 0.80 1.25 430 7.70 23.0	215					1
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal Relative	of elastic of elastic number I resistivit I conduct heat conductiv	n 10 ⁻⁶ • K ⁻¹ city longitudin city tangentia ν ty Ω • mm ² city. Siemens J/(Kg•K) Kg/dm ³	nal GPa I GPa •m/mm² W/(m•K)	kA/m DC / A	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 .C 800	215	210	205	195 34.0		3
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal Relative °C	of elastic of elastic number I resistivit I conduct heat conductiv magnetic	n 10 ⁻⁶ • K- ity longitudii ity tangentia V ty Ω • mm ² Siemens J/(Kg•K) Kg/dm ³ vity permeability	hal GPa I GPa •m/mm² W/(m•K) μr at 0.8	kA/m DC / A	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 .C 800 20	215 26.8 100	210 29.0 200		195		3
Modulus Modulus Poisson Electrical Specific I Density Thermal Relative °C The symb	of elastic of elastic number I resistivit I conduct heat conductiv magnetic	n $10^{-6} \cdot K^{-1}$ city longitudii v ty $\Omega \cdot mm^2$ iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa il GPa /m .m/mm ² W/(m.K) μr at 0.8 re betweer	kA/m DC / A 20 °C and 1	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 .C 800 20 100 °C, 20 °C ar	215 26.8 100 nd 200 °C	210 29.0 200	205	195 34.0	500	3
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal Relative °C The symb Corrosio	of elastic of elastic number I resistivit I conduct heat conductiv magnetic nol ► indica n resistar	n $10^{-6} \cdot K^{-1}$ city longitudii v ty $\Omega \cdot mm^2$ iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa i GPa /m -m/mm ² W/(m-K) μr at 0.8 re betweer Atmosph	kA/m DC / A I 20 °C and 1 Pric	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 100 °C, 20 °C ar Chemi	215 26.8 100 nd 200 °C	210 29.0 200	205 300	195 34.0 400	500 x pitting,	1 3 6 crevice
Modulus Modulus Poisson Electrica Specific Density Thermal Relative °C The symb Corrosio Fresh wat	of elastic of elastic number I resistivit I conduct heat conductiv magnetic nol ► indica n resistar	n $10^{-6} \cdot K^{-1}$ city longitudii v ty $\Omega \cdot mm^2$ iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa i GPa 'm -m/mm ² W/(m-K) μr at 0.8 re betweer Atmosph industrial	kA/m DC / A I 20 °C and 1 Pric ma	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 C 800 20 100 °C, 20 °C ar chemi <i>rine mediu</i>	215 26.8 100 nd 200 °C	210 29.0 200 oxidizing	205	195 34.0 400	500 x pitting, intercryst	1 3 crevice talline, s
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal Relative °C The symb Corrosio	of elastic of elastic number I resistivit I conduct heat conductiv magnetic nol ► indica n resistar	n $10^{-6} \cdot K^{-1}$ city longitudii v ty $\Omega \cdot mm^2$ iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa i GPa /m -m/mm ² W/(m-K) μr at 0.8 re betweer Atmosph	kA/m DC / A I 20 °C and 1 Pric	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 100 °C, 20 °C ar Chemi	215 26.8 100 nd 200 °C	210 29.0 200	205 300	195 34.0 400	500 x pitting,	1 3 crevice talline, s
Modulus Modulus Poisson Electrica Specific Density Thermal Relative °C The symb Corrosio Fresh wat	of elastic of elastic number I resistivil I conduct heat conductin magnetic nol ► indica n resistar	n $10^{-6} \cdot K^{-1}$ city longitudii v ty $\Omega \cdot mm^2$ iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa i GPa 'm -m/mm ² W/(m-K) μr at 0.8 re betweer Atmosph industrial	kA/m DC / A I 20 °C and 1 Pric ma	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 C 800 20 100 °C, 20 °C ar Chemi <i>rine mediu</i>	215 26.8 100 nd 200 °C	210 29.0 200 oxidizing	205 300	195 34.0 400	500 x pitting, intercryst	1 3 crevice talline, s
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal Relative °C The symb Corrosio Fresh wat x	of elastic of elastic number I resistivil I conduct heat conductiv magnetic iol ► indica n resistar ter	n $10^{-6} \cdot K^{-1}$ city longitudii v ty $\Omega \cdot mm^2$ iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	hal GPa I GPa m.m/mm ² W/(m•K) μr at 0.8 re betweer Atmosph <i>industrial</i> x	kA/m DC / A I 20 °C and 1 Pric ma	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 C 800 20 100 °C, 20 °C ar Chemi <i>rine mediu</i>	215 26.8 100 nd 200 °C	210 29.0 200 oxidizing	205 300	195 34.0 400	500 x pitting, intercryst	1 3 crevice talline, s
Modulus Modulus Poisson Electrica Specific Density Thermal Relative °C The symb Corrosio Fresh wat x Magnetic Machinal Hardenin	of elastic of elastic number I resistivil I conduct heat conductiv magnetic tol ► indica n resistar ter bility g	n 10 ⁻⁶ • K ⁻ ity longitudii vity α • mm ² iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa il GPa im	kA/m DC / A 20 °C and 1 eric ma x	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 100 °C, 20 °C ar 7 100 °C, 20 °C ar 8 100 °C, 20 °C ar 100	215 26.8 100 nd 200 °C cal m	210 29.0 200 x	205 300 reducir	195 34.0 400	500 x pitting, intercryst	1 3 crevice talline, s
Modulus Modulus Poisson Electrica Electrica Specific Density Thermal Relative °C The symb Corrosio Fresh wat x Magnetic Machinal	of elastic of elastic number I resistivil I conduct heat conductiv magnetic tol ► indica n resistar ter bility g	n 10 ⁻⁶ • K ⁻ ity longitudii vity α • mm ² iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa il GPa im	kA/m DC / A 20 °C and 1 eric ma x	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 100 °C, 20 °C ar rine mediui x	215 26.8 100 nd 200 °C cal m	210 29.0 200 x	205 300 reducir	195 34.0 400	500 x pitting, intercryst	1 3 crevice talline, s
Modulus Modulus Poisson Electrica Specific Density Thermal Relative °C The symb Corrosio Fresh wat x Magnetic Machinal Hardenin	of elastic of elastic number I resistivil I conduct heat conductiv magnetic tol ► indica n resistar ter bility g	n 10 ⁻⁶ • K ⁻ ity longitudii vity α • mm ² iv. Siemens J/(Kg-K) Kg/dm ³ vity permeability ates temperatu	nal GPa il GPa im	kA/m DC / A 20 °C and 1 eric ma x	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 100 °C, 20 °C ar 7 100 °C, 20 °C ar 8 100 °C, 20 °C ar 100	215 26.8 100 °C cal m d plastic de mittent serv	210 29.0 200 x	205 300 reducir	195 34.0 400	500 x pitting, intercryst corrosion	1 3 6 crevice talline, s 1, food
Modulus Modulus Poisson Electrica Electrica Specific I Density Thermal Relative °C The symb Corrosio Fresh wat x Magnetic Machinal Hardenin Service t	of elastic of elastic number I resistivil I conduct heat conductiv magnetic tol ► indica n resistanter bility g emperatu	n 10 ⁻⁶ • K- ity longitudii vity Ω • mm ² iv. Siemenss J/(Kg•K) Kg/dm ³ vity permeability ates temperatu nce	nal GPa I GPa m/mm ² W/(m•K) μr at 0.8 re betweer Atmosph <i>industrial</i> x yes good moderate continuo	kA/m DC / A 20 °C and ° eric ma x • by cold-drav us service up	220 65 0.28 ~ 0.80 1.25 430 7.70 23.0 C 800 20 100 °C, 20 °C ar Chemi <i>rine mediu</i> x wn and other col to 850 °C; inter Rus: GOS	215 26.8 100 nd 200 °C cal m d plastic de mittent serv sia	210 29.0 200 x formations ice up to 95	205 300 reducir	195 34.0 400	500 x pitting, intercryst corrosion	1 3 crevice, talline, s n, food





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Along with Andrea Casaroli he is the founder of the www.fa-fe.com website.



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Along with Marco Boniardi he is the founder of the **www.fa-fe.com** website.



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