aperam
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Duplex stainless steel offer

grade **DX2507**

Chemical composition

Elements	C	Cr	Ni	Mo	N	PREN*
% weight	<0.02	25.8	7.0	3.8	0.3	43

*Pitting Resistant Equivalent Number (% Cr+3.3x% Mo+16x% N)

Aperam produces high quality superduplex characterized by a high PREN of 43% minimum in order to fit to the most demanding applications. Additionally, superduplex with lower PREN are available.

Material standards

European designation [1]	American designation [2]
1.4410 – X2CrNiMoN25-7-4	UNS S32750 – 2507 type

[1] According to EN 10088 Standard
[2] According to ASTM A240 Standard

General characteristics

The principal features of the DX2507 are:

> **High mechanical properties:** DX2507 superduplex stainless steel has twice the tensile properties of austenitic grades and equals those of carbon steel for construction.

> **High corrosion resistance:** DX2507 is comparable to 6% Mo superaustenitic stainless and surpasses it in particular regarding stress corrosion cracking resistance. The superduplex grade has higher localized corrosion resistance than 825 nickel based alloy.

> **Cost efficient material selection:**
- Optimal material selection, regarding material cost and corrosion risk
- Optimized design (weight saving, easier erection)
- Attractive Life Cycle Cost (durability, limited maintenance)

Some market applications and examples of equipment

- Seawater desalination: sea water pipes
- Upstream oil and gas "Norsok qualified": flexibles and pipes for offshore wells, umbilicals
- Pollution control
- Chemical processing: pressure vessels and heat exchangers
- Wastewater treatment for all industries: storage tanks, concentrators


Photo by courtesy of SIDEM

Product size range

Forms: sheet, blank, coil, strip
Thicknesses: from 0.8 to 6.5 mm
Width: up to 1500 mm (depends on thickness)
Finishes: hot rolled, cold rolled

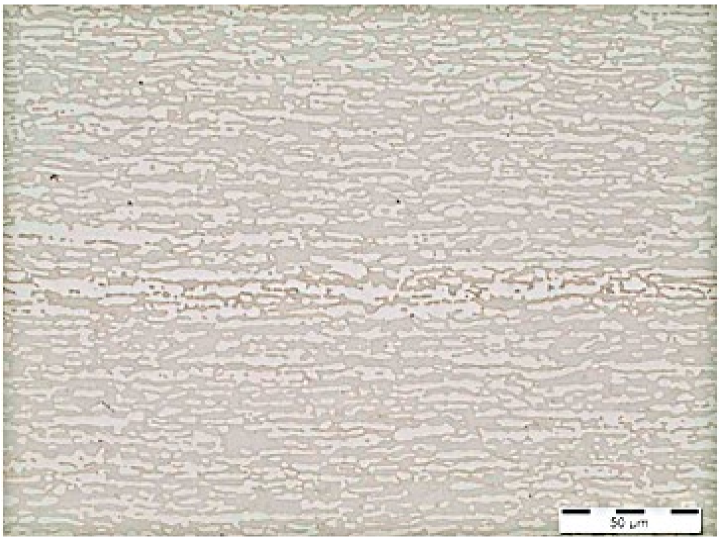
Metallurgical background

The DX2507 grade is a stainless steel of the austeno-ferritic group, whose microstructure is composed of ferrite (α) and austenite (γ) phases. The mix of two phases gives to the alloy elevated yield strength values while maintaining sufficient ductility. Hardening is provided by the ferritic phase, whereas the austenitic lattice enables to preserve both ductility and toughness.

The chemical composition of our DX2507 is designed to target 50% α -50% γ microstructure after annealing at 1025-1125 °C followed by water cooling, as per the ASTM A480 requirements.

The ferrite of superduplex is still susceptible to precipitation for exposure temperatures higher than 300 °C and limits the use of the grade for temperatures higher than -50 °C. Chemical composition and the microstructure is optimized to allow welding and heat treatment.

The different fabrication steps in Aperam's facilities enable the DX2507 to obtain optimal microstructure and a close control of the segregation at mid-thickness to prevent detrimental intermetallic phase precipitations.



Example of the microstructure observed at mid thickness of the DX2507 (ferrite in grey, austenite in white) – no intermetallic phases detected.

Mechanical properties

Tensile properties of the DX2507 have been evaluated at room temperature in transverse direction, according to the ISO 6892-1 standard test method.

Grade name	DX2507						S31254	Alloy 825
Properties	EN 10088-2			ASTM A240	Aperam typical values		ASTM A240	ASTM B424
	C	H	P		H	C		
Y.S. $_{0.2\%}$ (MPa)	550	530	530	600	670	690	280	241
U.T.S. (MPa)	750	730	730	40	900	920	600	586
E%	20	20	25	15	30	28	40	30

Toughness properties have been assessed according to ISO 10045-1 test method on subsized ISO-V specimens on a 5.2mm thick hot rolled coil.

Testing temperature (°C)	Typical energy to rupture (J/cm²)
20	380
-40	370

Physical Properties

On cold rolled and annealed sheet

Density	d	kg/dm³	20 °C	7.8
Melting temperature	-	°C	-	1445
Specific heat	c	J/kg.K	20 °C	460
Thermal conductivity	k	W/m.K	20 °C	13.5
Mean thermal expansion coefficient	α	10^{-6}/K	20-200 °C 20-400 °C	14.0 14.5
Electric resistivity	ρ	Ω mm²/m	20 °C	0.8
Magnetic	-	-	-	yes
Young's Modulus	E	10^3.MPa	20 °C	200

Fabrication

Welding

The DX2507 can be welded with the conventional welding processes. In order to achieve the optimal phase balance and properties for the welded joint, appropriate welding parameters have to be selected, such as the welding preparation, shielding and backing gas, filler metals, welding heat input.

General recommendations can be summarized as follows:

Too low heat input	Moderate welding parameters	Too high welding heat input
Limit austenite formation in Heat Affected Zone and Weld Metal => higher ferrite content	Balance between microstructure, weld properties and welding condition. Interpass temperature at 100 °C to limit deleterious precipitates	Allow austenite formation in Heat Affected Zone and Weld Metal => lower ferrite content. Risk of intermetallic phase precipitation
Risk of embrittlement in service condition while hydrogen presence and too high ferrite content		No risk of hot cracking due to the ferrite solidification

The use of a nitrogen-containing shielding gas is strongly recommended, in particular when no filler metal is used.

The following table illustrates different welding conditions based on the welding process that can be considered for thin plates.

Welding process	No filler material	With filler material			Shielding gas
	Typical thicknesses	Typical thicknesses	Filler material		
			Rod	Wire	
Resistance: spot, seam	≤ 2 mm				
TIG	≤ 1.5 mm	> 0.5 mm	W 25 9 4 N L [1] ER 25 9 4 L [2]	G 25 9 4 N L [1] ER 25 9 4 L [2]	Ar + 2-3% N_2 (+He)
PLASMA	≤ 1.5 mm	> 0.5 mm	W 25 9 4 N L [1] ER 25 9 4 L [2]	G 25 9 4 N L [1] ER 25 9 4 L [2]	Ar + 2-3% N_2 (+He)
MIG		> 0.8 mm		G 25 9 4 N L [1] ER 25 9 4 L [2]	Ar + 2-3 % N_2 + 2% CO_2 or O_2
S.A.W.		> 5 mm		25 9 4 N L [1] ER 25 9 4 L [2]	
F.C.A.W.		> 5 mm		25 9 4 N [4] E2553 [2]	Ar + CO_2, CO_2
S.M.A.W		Repairs	E 25 9 4 N L [3] E 2594 [2]		
Laser	≤ 5 mm				N_2 (Ar or He possible)

[1] EN ISO 14343 / [2] AWS 5.9 / 5.4 / [3] EN 1600 / [4] EN 12073

For the backing gas, pure nitrogen as well as 90% N_2 + 10% H_2 can be considered. More traditionally, pure argon or Ar + 2-3% N_2 can be used.

Pre or post-heating are not useful for duplex grades. Moreover, due to the high stress corrosion cracking resistance, Post Welding Heat Treatment is not necessary and improper conditions could lead to intermetallic phase precipitation.

When welding without filler metal and/or nitrogen addition in the shielding gas, additional heat treatment is often recommended. When required or needed after welding, only solution annealing with water cooling is advised.

Better corrosion resistance is achieved when the weld is pickled and passivated.

Forming

This grade can be used for forming applications. Since its yield strength is significantly higher than that of austenitic grades, the use of presses or section rolling equipment with suitable power is required.

The DX2507 tolerates severe cold forming conditions even with high mechanical properties and limited elongation to rupture compared to austenitic stainless steels.

A bending test is one of the most common tests to evaluate the forming ability of steel. The minimal bending radius equals the thickness for the base metal and 4 times the thickness for the weld.

When the plastic strain exceeds 10% after cold forming, construction code may impose heat treatment to restore both corrosion and ductility properties.

In the case of hot forming, heat treatment has to be performed.

Heat treatment

After forming, heat treatment can be required and the optimal heat treatment for duplex stainless steel is solution annealing (1025 - 1125 °C) followed by rapid cooling (water or air quenching), according to ASTM A790.

During heat treatment, attention must be paid to supporting pieces in order to limit creep deformation.

Fabrication (continued)

Pickling and Passivation

After welding or heat treatment, the stainless steel's surface exhibits oxides. Mechanical cleaning such as brushing, grinding, polishing or blasting contribute to restoring the properties of stainless steel but only partially. Maximal corrosion resistance is obtained after pickling and passivation.

Pickling is applied to remove surface oxides such as weld heat tint or heat treatment scale and is typically carried out with nitric/hydrofluoric acid solutions.

Pickling treatments restore corrosion resistance and result in a quality passive surface.

Due to the high chromium content, it is somewhat harder to remove the heat tint from a duplex grade than from an austenitic grade and may require longer exposure to the pickling products or higher temperature.

Chemical passivation treatments are used to clean the surface from surface contamination, such as free iron, and accelerate the formation of a protective passive film. Stainless steels are typically passivated with nitric acid solutions. Passivation treatments are recommended after fabrication processes such as rolling, bending, blasting, and machining.

Quality control

The quality control depends on the final application and on the fabrication process.

For the most stringent applications, such as for oil and gas industry, ASTM A923 and/or ISO 17781 can be applied.

The measurement of the ferrite content is required most of the time, as it influences the properties of the duplex material. The ferrite content can be evaluated with different methods either for the base metal or for the weld metal.

Prediction: based on the chemical composition of the investigated area, the ferrite content can be predicted by the Schaeffler diagram using Espy formula (Ferrite percent) or WRC93 (Ferrite Number). Other diagrams do not take into account the effect of nitrogen and are less relevant.

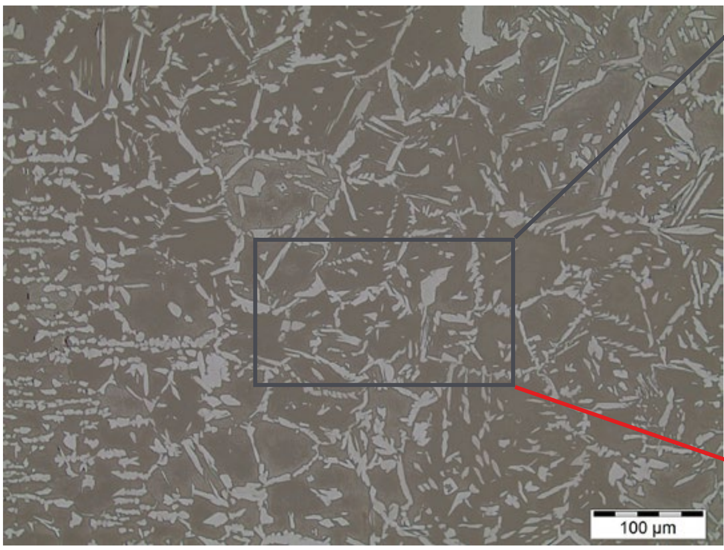
Measurement methods: The easiest measurement methods to determine ferrite content in weld metal are magnetic methods such as ferritscope (expressed in % or FN) or magnegage (expressed in FN). It is a useful in-shop method to rapidly check the quality of a heat treatment. But the tools are not suitable for very thin areas and the results can be scattered.

As soon as welds have to be analysed, particularly the HAZ, the metallographic grid method (ASTM E562) with sufficient magnification (x400, or higher depending on the size of the microstructure) is the only one which gives a significant result.

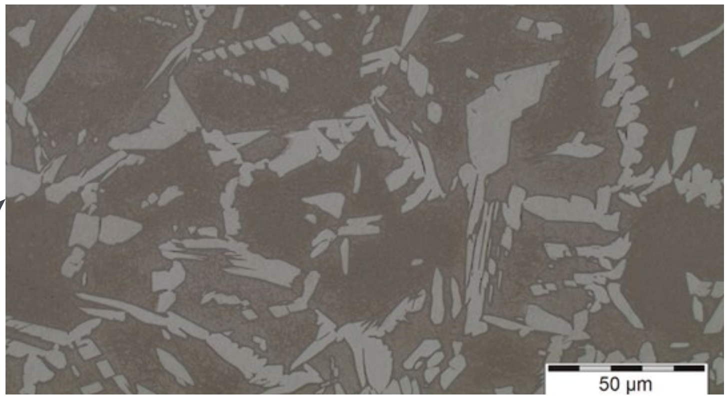
More recently, the use of image analysis has been developed, using the ASTM E1245 in addition to the ASTM E562.

Expression of results: The ferrite content results expressed in % or FN are not equivalent. In fact, there is a correlation between ferritscope or grid method results (ferrite percent F%), and those obtained by magnegage expressed in FN. For ferritic-austenitic steels and in accordance with IIW II 1196-92, the relation between F% and FN values of ferrite is as follows: F% = 0.54 FN + 9.7

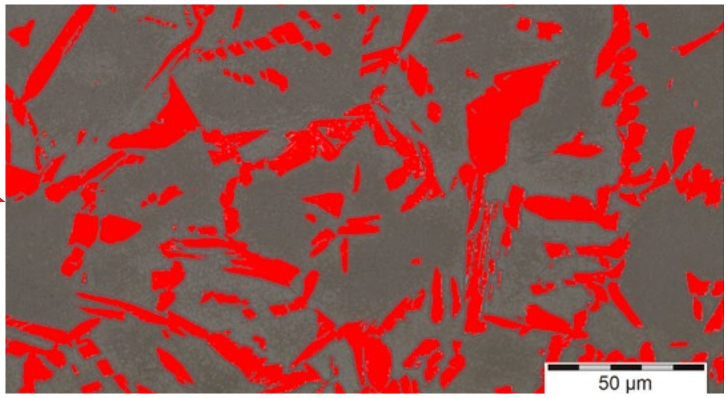
Duplex microstructure in a weld



Ferrite counting on metallograph:



Microscope counting



Counting with computer image analysis

Corrosion resistance

Uniform corrosion

Due to its high chromium content, our DX2507 shows a uniform corrosion resistance almost similar to the 6% Mo grades.

Intergranular corrosion

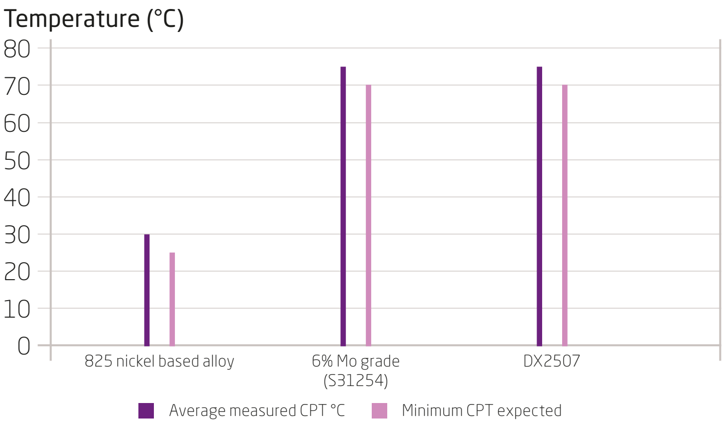
Generally speaking, duplex stainless steels exhibit high intergranular corrosion resistance, thanks to low carbon content, high chromium content and nitrogen addition.

As an example, the DX2507 is resistant to intergranular corrosion and can be tested in accordance with the Strauss test (ASTM A262E) without a sign of attack or according to the Huey test ASTM A262C.

Pitting corrosion resistance

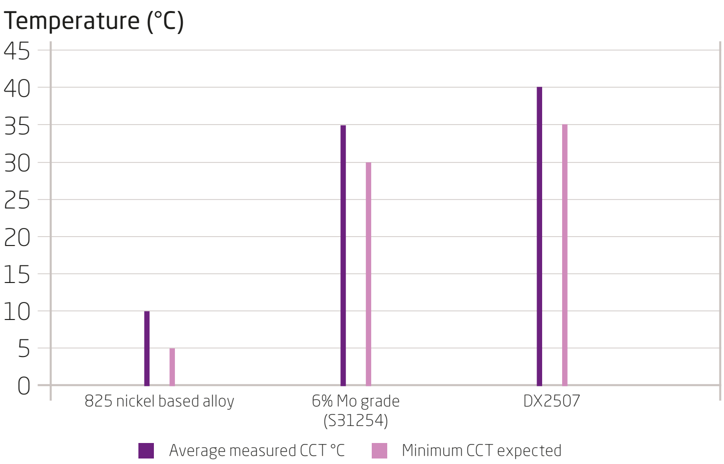
The 25.8% chromium and 0.29% nitrogen contents of the DX2507 allow the grade to have as high corrosion resistance as some 6% Mo stainless steels, and higher when compared to such nickel based alloy.

To compare relative corrosion resistance, ASTM G48E critical pitting temperatures are plotted on the following graph:



Crevice Corrosion

To compare relative corrosion resistance, ASTM G48F critical crevice temperatures are plotted on the following graph:

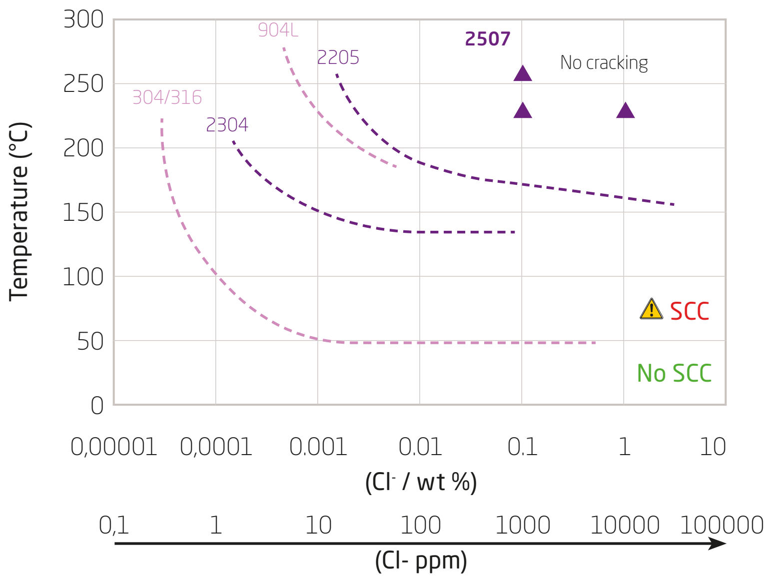


Stress corrosion cracking

Stress Corrosion Cracking (SCC) is a degradation mechanism induced by the combination of three main factors:

- the corrosive environment (aggressiveness of the media,...),
- the stress on the material (internal stresses from fabrication, in-service applied stresses, design selection...),
- the material susceptibility (corrosion resistance, microstructure, mechanical properties...).

Generally speaking, when the austenitic grades are more prone to SCC, duplex and in particular superduplex are more stress corrosion cracking resistant. DX2507 indeed exhibits excellent resistance to chloride-induced SCC, as illustrated by the following graph in chloride containing solutions at high temperatures. No signs of SCC up to 1000 ppm Cl /250 °C and 10000 ppm Cl /250 °C.



In accordance with ISO 15156/NACE MR 0175 solution annealed and liquid quenched wrought DX2507 is suitable for use at temperatures up to 450 °F (232 °C) in sour environments in oil and gas production, if the partial pressure of hydrogen sulphide does not exceed 3 psi (0.20 bar).

DX2507, with a maximum hardness of 32 HRC, solution annealed and rapidly cooled, according to NACE MR0103, is suitable for use in sour petroleum refining.

Hydrogen Induced Stress Cracking (HISC)

Hydrogen Induced Stress Cracking (HISC) is a failure phenomenon induced by the combination of:

- hydrogen presence (from cathodic protection),
- the stresses (loading, notch effect,...),
- the material (microstructure, mechanical properties,...).

Embrittlement due to HISC may occur when hydrogen diffuses into the metal. Hydrogen diffuses much faster in the ferrite phase than in the austenite phase. Therefore, ferritic steels and ferrite containing steels, e.g. superduplex stainless steels, are more susceptible to HISC than austenitic stainless steels. A high mechanical stress increases the risk of HISC by increasing the hydrogen diffusion rate, crack initiation and propagation in the material. In superduplex stainless steels, cracks tend to propagate in the embrittled ferrite phase and arrest at ferrite-austenite phase boundaries. Susceptibility to HISC significantly increases with increasing austenite spacing. Coarse-grained microstructures are therefore more susceptible, and DNV RP-F112 recommends a maximal austenite spacing of 30 µm.

Due to the metallurgical route to produce hot rolled and cold rolled coils, DX2507 exhibits a fine microstructure and a narrow austenite spacing. Less than 5 µm is a typical value.

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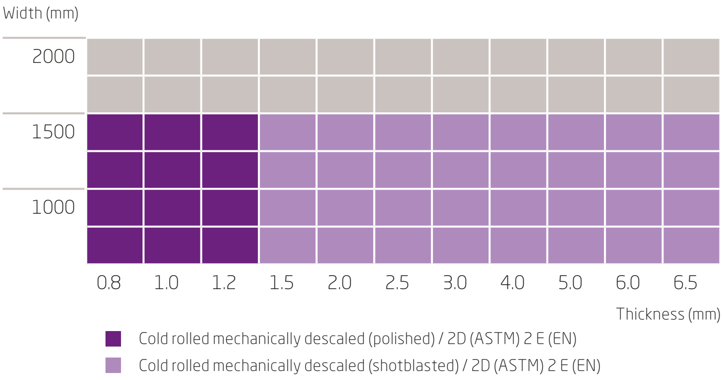
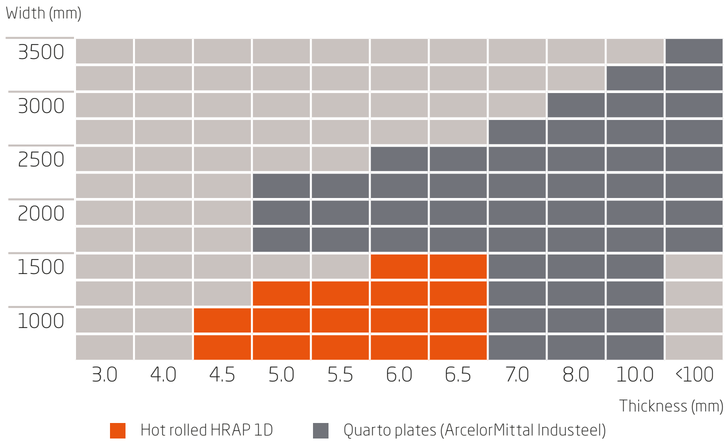
Size range





Please consult us for sizes outside this range.

Standards

ISO 15510 Stainless steels – Chemical composition

EN 10028-7 Flat products for pressure purposes – Stainless steels

EN 10088-2 Stainless steels – Corrosion resisting sheet/plate/strip for general and construction purposes

EN 10088-4 Stainless steel flat products, technical delivery conditions, steels for construction

ASTM A240 / ASME SA-240 Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purposes

ASTM A790 / ASME SA-790 Seamless and welded duplex stainless steel pipe

ASTM A928 Duplex stainless steel pipe welded with addition of filler metal

VdTÜV-Werkstoffblatt 508 Ferritisch-austenitischer Walz- und Schmiedestahl, 1.4410

NACE MR0175 / ISO 1515 Petroleum and natural gas industries - Materials for use in H_2S-containing environments in oil and gas production

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