Alleima

SAF™ 2205

Billets

Datasheet

SAF™ 2205 is a duplex (austenitic-ferritic) stainless steel characterized by:

- High resistance to stress corrosion cracking (SCC) in chloride-bearing environments and environments containing hydrogen sulphide
- High resistance to general corrosion, pitting and crevice corrosion
- High resistance to erosion corrosion and corrosion fatigue
- High mechanical strength - roughly twice the proof strength of austenitic stainless steels
- Physical properties that offer design advantages
- Good weldability

Standards

- UNS: S31803
- EN Number: 1.4462
- EN Name: X2CrNiMoN22-5-3
- W.Nr.: 1.4462

Product standards

EN 10088-3
Suitable for production of flanges etc. according to ASTM A-182 Grade F51
Analysis according to ASTM A-479, UNS S31803.

Certificates

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Status according to EN 10 204/3.1

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo	N
≤0.025	≤1.0	≤2.0	≤0.030	≤0.015	22	5	3.2	0.18

Applications

Due to its excellent corrosion properties, SAF™ 2205 is a highly suitable material for service in environments containing chlorides and hydrogen sulfide. The material is suitable for use in refineries and in-process solutions contaminated with chlorides. SAF™ 2205 is particularly suitable for heat exchangers, where chloride-bearing water or brackish water is used as a cooling medium. The steel is also suitable for use in dilute sulphuric acid solutions and for handling organic acids, e.g. acetic acid and mixtures.

The high strength of SAF™ 2205 makes the material an attractive alternative to the austenitic steels in structures subjected to heavy loads.

The good mechanical and corrosion properties make SAF™ 2205 an economical choice in many applications, by reducing the life cycle cost of equipment.

Industrial categories	Typical applications
Chemical industry	Flanges
Refineries	Valves
Petrochemical industry	Fittings
Oil & Gas industry	Couplings
	Rings
	Shafts
	Forgings
	Discs

Corrosion resistance

General corrosion

In most media, SAF™ 2205 possesses better resistance to general corrosion than steel types ASTM 316L and 317L. This improved resistance of SAF™ 2205 is illustrated by the isocorrosion diagram for corrosion in sulphuric acid, figure 3, and the diagram showing the corrosion rates in mixtures of acetic and formic acid, figure 4. Figure 5 shows the isocorrosion diagram for SAF™ 2205 in hydrochloric acid.

Impurities that increase corrosivity are often present in acid process solutions. If there is a risk of active corrosion, higher alloyed stainless steels should be chosen, e.g. the austenitic grades Alleima™ 2RK65 and Sanicro® 28, or the super duplex grade SAF™ 2507.

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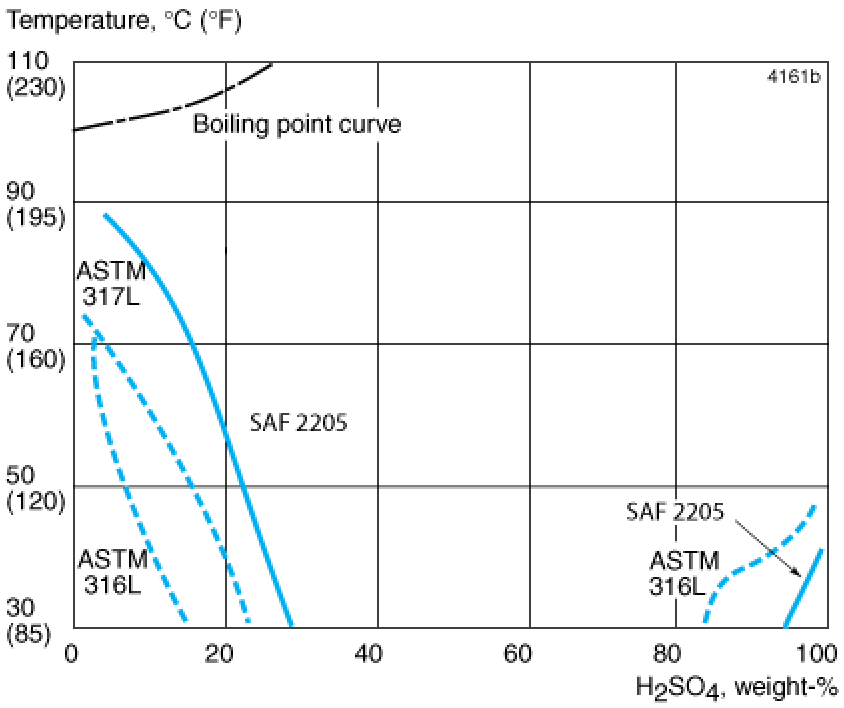
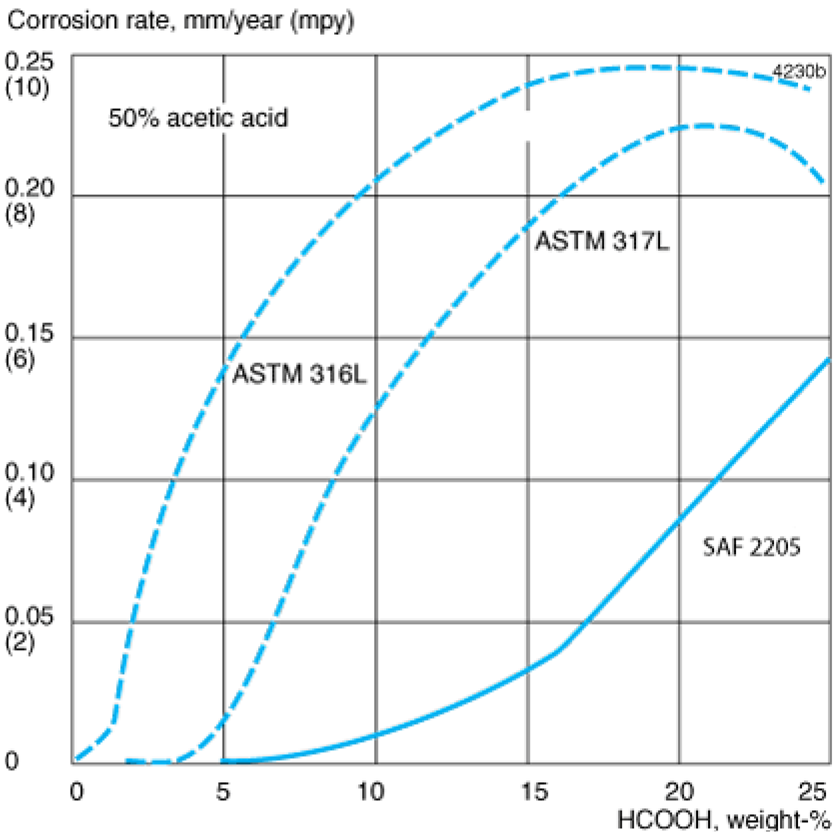


Figure 3. Isocorrosion diagram for SAF 2205, AISI 316L and AISI 317L in sulphuric acid. The curves represent a corrosion rate of 0.1 mm/year (4mpy) in a stagnant test solution.



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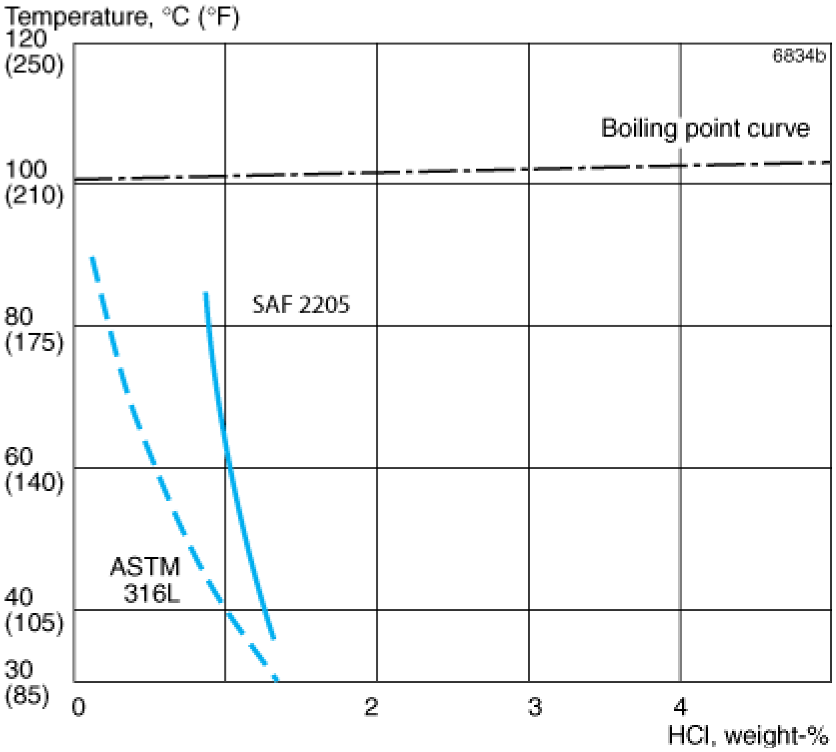

Pitting corrosion

The pitting resistance of a steel is determined primarily by its chromium and molybdenum contents, but also by its nitrogen content, slag composition and slag content. A parameter for comparing the resistance of different steels to pitting is the PRE number (*P*itting *R*esistance *E*quivalent). The PRE is defined as, in weight-%: PRE = % Cr + 3.3 x % Mo + 16 x % N

The PRE numbers for SAF™ 2205 and other materials are given in the following table

Alloy	% Cr	% Mo	%N	PRE
SAF 2205	22	3.2	0.18	>35
Alloy 825	21.5	3.0	-	31
ASTM 317L	18	3.5	-	30
ASTM 316L	17	2.2	-	24

The ranking given by the PRE number has been confirmed in laboratory tests. This ranking can generally be used to predict the performance of an alloy in chloride-containing environments.

Laboratory determinations of critical temperatures for initiation of pitting (CPT) at different chloride contents are shown in figure 6. The chosen testing conditions have yielded results that agree well with practical experience. Thus, SAF™ 2205 can be used at considerably higher temperatures and chloride contents than ASTM 304 and ASTM 316 without pitting occurring. SAF™ 2205 is, therefore, far more serviceable in chloride-bearing environments than standard austenitic steels.

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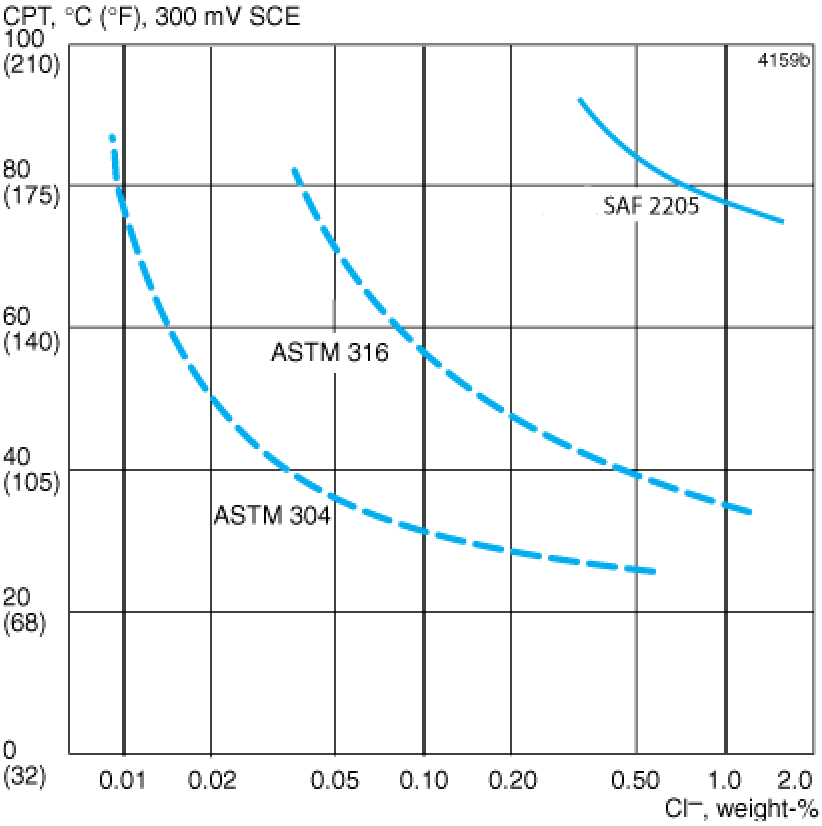
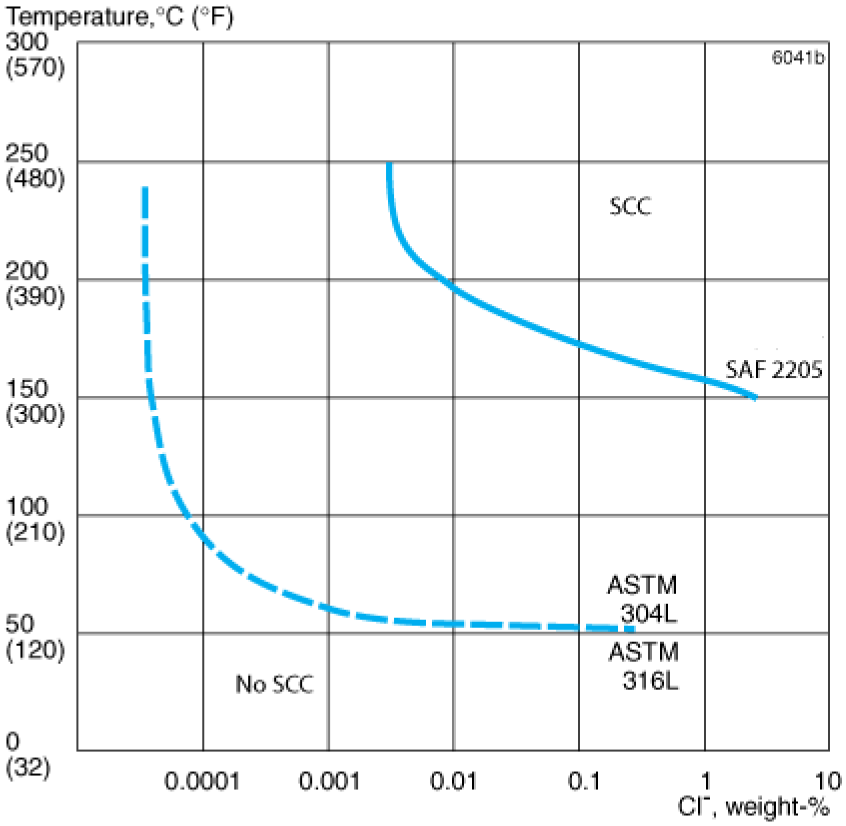
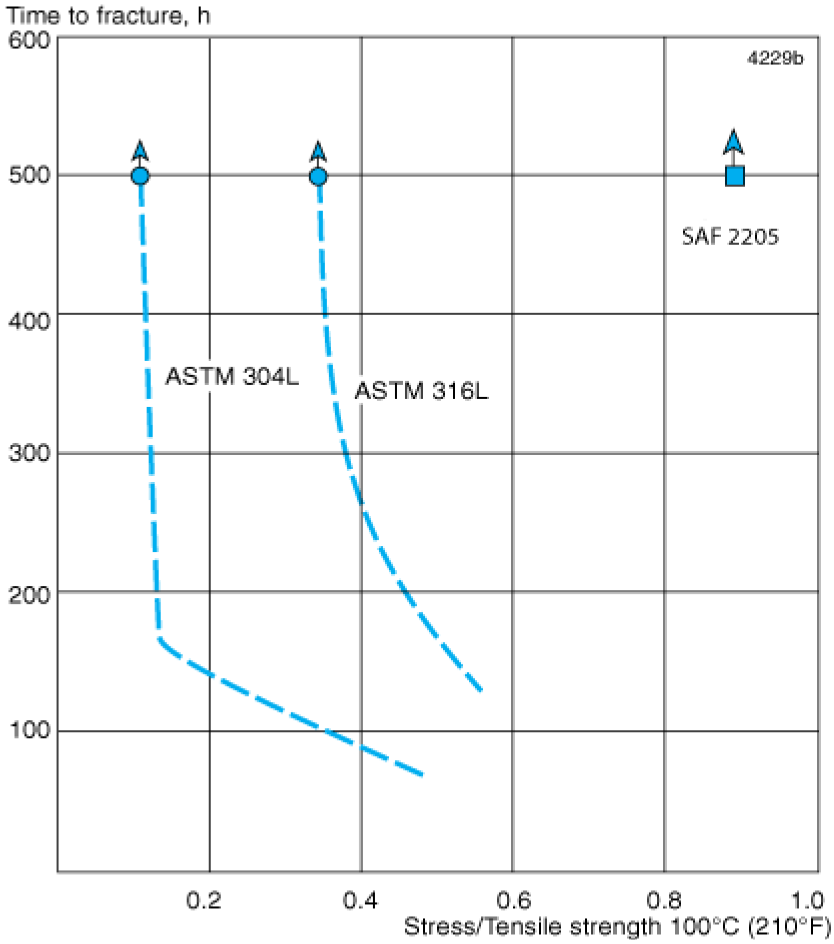

CPT, °C (°F), 300 mV SCE
4159b
100 (210)
80 (175)
60 (140)
40 (105)
20 (68)
0 (32)
SAF 2205
ASTM 316
ASTM 304
0.01
0.02
0.05
0.10
0.20
0.50
1.0
2.0
Cl⁻, weight-%


Temperature,°C (°F)
6041b
300 (570)
250 (480)
200 (390)
150 (300)
100 (210)
50 (120)
0 (32)
SCC
SAF 2205
ASTM 304L
ASTM 316L
No SCC
0.0001
0.001
0.01
0.1
1
10
Cl⁻, weight-%



Stress corrosion cracking

The standard austenitic steels of the ASTM 304L and ASTM 316L types are prone to stress corrosion cracking (SCC) in chloride- bearing solutions at temperatures above 60 °C (140 °F).

Duplex stainless steels are far less prone to this type of corrosion. Laboratory tests have shown good resistance to stress corrosion cracking of SAF™ 2205. Results from these tests are presented in figure 7. The diagram indicates the temperature-chloride range within which SAF™ 2205 and the standard steels ASTM 304L and ASTM 316L can be used without risk of stress corrosion cracking.

Results of laboratory tests carried out in calcium chloride are shown in figure 8. The tests have been continued to failure or a max. test time of 500h.

The diagram shows that SAF™ 2205 has a much higher resistance to SCC than the standard austenitic steels ASTM 304L and ASTM 316L.

In aqueous solutions containing hydrogen sulphide and chlorides, stress corrosion cracking can also occur in stainless steels at temperatures below 60 °C (140 °F). The corrosivity of such solutions is affected by acidity and chloride content. In direct contrast to ordinary chloride-induced stress corrosion cracking, ferritic stainless steels are more sensitive to this type of stress corrosion cracking, than austenitic steels.

Laboratory tests have shown that SAF™ 2205 possesses good resistance to stress corrosion cracking in environments containing hydrogen sulphide. This has also been confirmed by available operating experience.

In accordance with NACE MR 0175, solution annealed and cold-worked UNS S31803 (SAF™ 2205) is acceptable for use at any temperature up to 450 °F (232 °C) in sour environments, if the partial pressure of hydrogen sulphide does not exceed 0.3 psi (0.02 bar), the proof strength of the material is not greater than 160 ksi ($R_{p0.2}$ <1100 MPa), and its hardness is not greater than HRC 36.

Figure 9 shows the results of stress corrosion cracking tests at room temperature in a NACE solution with hydrogen sulphide. The high resistance of SAF™ 2205 is shown in the figure by the fact that very high stresses, about 1.1 times the 0.2% proof strength, are required to induce stress corrosion cracking. The resistance of welded joints is slightly lower. The ferritic chromium steel ASTM 410 fails at considerably lower stress.

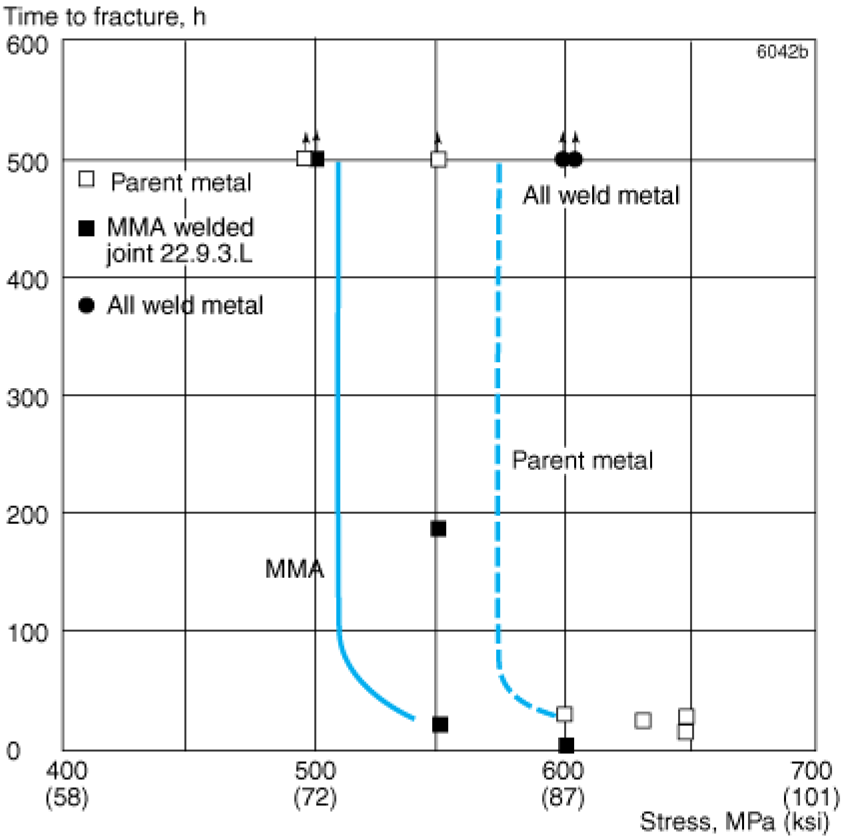


Figure 9. Results of tests according to NACE TM 0177 of SAF 2205 in welded and unwelded condition.

Intergranular corrosion

SAF™ 2205 is a member of the family of modern duplex stainless steels whose chemical composition is balanced in such a way that the reformation of austenite in the heat-affected zone adjacent to the weld takes place quickly. This results in a microstructure that gives corrosion properties and toughness roughly equal to that of the parent metal. Testing according to ASTM A262 PRE (Strauss test) constitutes no problem for welded joints in SAF™ 2205, which pass without reservation.

Crevice corrosion

In the same way as the resistance to pitting can be related to the chromium, molybdenum and nitrogen contents of the steel, so can the resistance to crevice corrosion. SAF™ 2205 possesses better resistance to crevice corrosion than steels of the ASTM 316L type.

Erosion corrosion

Steels of the ASTM 316 type are attacked by erosion-corrosion if exposed to flowing media containing highly abrasive, solid particles, e.g. sand, or to media with very high flow velocities. Its combination of high hardness and good corrosion resistance enables SAF™ 2205 to displays very good resistance under such conditions.

Corrosion fatigue

SAF™ 2205 possesses higher strength and better corrosion resistance than ordinary austenitic stainless steels. It, therefore, also possesses better fatigue strength under corrosive conditions than such steels.

In rotary bending fatigue tests in a 3% NaCl solution (pH = 7; 40 °C (104 °F); 6000 rpm), the following results were obtained. The tabulated values indicate the stress required to bring about rupture after 2 * 10^7 cycles.

Steel	Stress level			
	Specimen without notch		Specimen with notch	
	MPa	ksi	MPa	ksi
SAF™ 2205	430	62	230	33
ASTM 316L (17Cr12Ni2.5MoN)	260	38	140	20

For further information regarding corrosion resistance of SAF™ 2205 please refer to datasheet, Seamless tube and pipe - SAF™ 2205. The data should be considered in the knowledge that it may not be applicable for thick sections such as forgings.

Forms of supply

Sizes and tolerances

Round-cornered square, as well as round billets, are produced in a wide range of sizes according to the following tables. Larger sizes offered on request.

Surface conditions

Square billets

Unground, spot ground or fully ground condition.

Round billets

Peel turned or black condition.

Square billets

Size	Tolerance	Length
mm	mm	m
80	+/-2	4 - 6.3
100, 114, 126, 140, 150	+/-3	4 - 6.3
160, 180, 195, 200	+/-4	4 - 6.3
>200 - 350	+/-5	3 - 5.3

Sizes and tolerances apply to the rolled/forged condition.

Peel turned round billets

Size	Tolerance	Length
mm	mm	m
75 - 200 (5 mm interval)	+/-1	max 10
>200 - 450	+/-3	3 - 8

Size	Tolerance	Length
mm	mm	m
77 - 112 (5 mm interval)	+/-2	max 10
124, 134	+/-2	max 10
127, 147, 157	+/-2	max 10
142, 152, 163	+/-2	max 10
168, 178, 188	+/-2	max 10
183, 193	+/-2	max 10

Other products

- Seamless tube and pipe
- Welded tube and pipe
- Fittings and flanges
- Strip electrodes and flux for surfacing
- Strip, annealed or cold-rolled to different degrees of hardness
- Plate, sheet and wide strip
- Forged products
- Cast products

Heat treatment

Billets are supplied in the hot worked condition. The following heat treatment is recommended.

Solution annealing

1020 - 1100 °C (1870-2010 °F), rapid cooling in water.

Mechanical properties

Testing is performed on separately solution annealed and quenched test piece.

At 20°C (68°F)

Metric units

Proof strength		Tensile strength	Elong.	Hardness Brinell
$R_{p0.2}$[a)]	$R_{p1.0}$[a)]	R_m	A[b)]	
MPa	MPa	MPa	%	
≥450	≥500	660-860	≥25	≤270

Imperial units

Proof strength		Tensile strength	Elong.	Hardness Brinell
$R_{p0.2}$[a)]	$R_{p1.0}$[a)]	R_m	A[b)]	

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ksi	ksi	ksi	%	
≥65	≥73	96-125	≥25	≤270

1 MPa = 1 N/mm ^{2}
a) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% offset yield strengths respectively.
b) Based on L_O = 5.65ÖS$_O$, where L_O is the original gauge length and S_O the original cross-sectional area.

Impact strength

SAF™ 2205 possesses good impact strength both at room temperature and at low temperatures, as is evident from figure 1. The values apply for standard Charpy-V specimens (10 x 10 mm, 0.39 x 0.39 in.).

The impact strength of welded SAF™ 2205 is also good, although the impact strength values in the as-welded condition are slightly lower than for weld-free material. Tests have shown that the impact strength of material, welded by means of gas-shielded arc welding, is good in both the weld metal and the heat-affected zone down to -50°C (-58°F). At this temperature, the impact strength is a minimum of 27J (20 ft lb). If very high impact strength demands are made on the weld metal at low temperatures, solution annealing is recommended. This restores the impact strength of the weld metal to the same level as that of the parent metal.

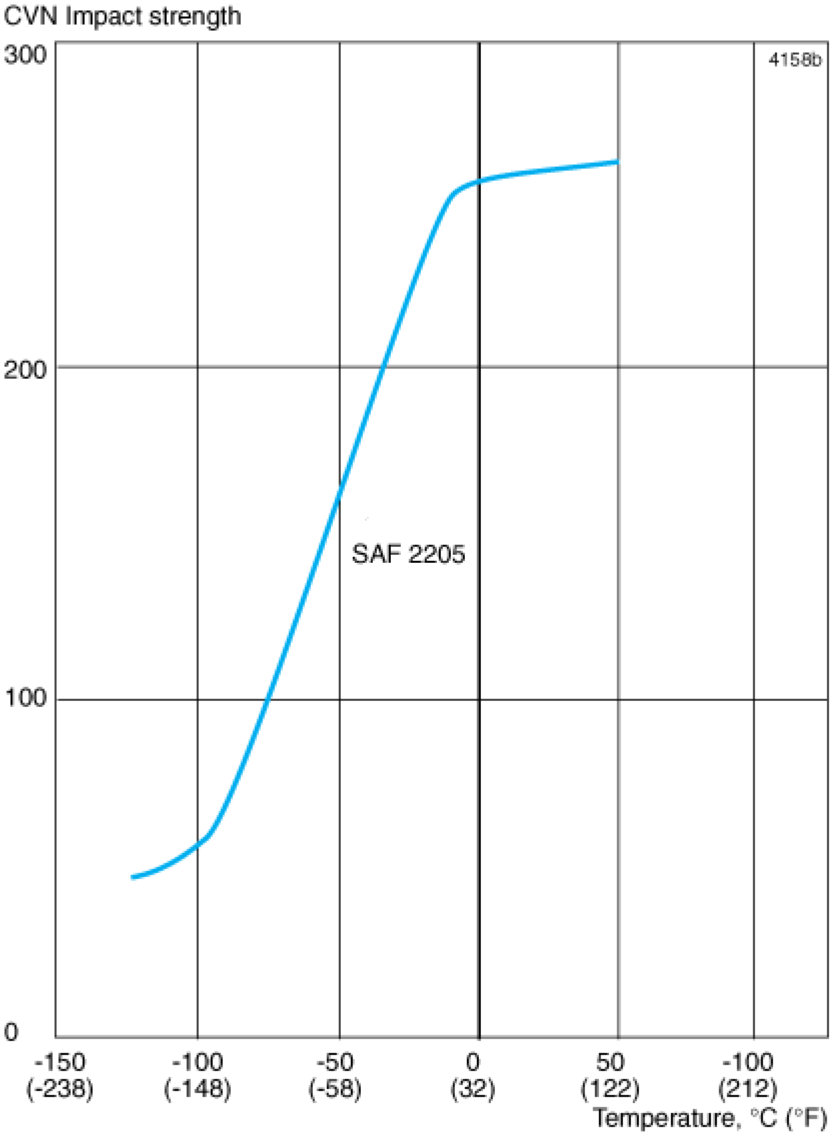

Figure 1. Curve showing typical impact strength values (Charpy-V) for SAF 2205. Specimen size 10x10 mm (0.39

x 0.39 in.).

At high temperatures

If SAF™ 2205 is exposed to temperatures exceeding 280 °C (540 °F) for prolonged periods, the microstructure changes which results in a reduction in impact strength. This effect may alter the behavior of the material at the operating temperature. Contact Alleima for advice. Testing is performed on separately solution annealed and quenched test piece.

Physical properties

Density: 7.8 g/cm^3, 0.28 lb /in^3

Specific heat capacity

Temperature, °C	J/(kg °C)	Temperature, °F	Btu/(lb °F)
20	480	68	0.11
100	500	200	0.12
200	530	400	0.13
300	550	600	0.13
400	590	800	0.14

Thermal conductivity

Metric units

Temperature,°C	20	100	200	300	400
	W/(m °C)				
SAF 2205	14	16	17	19	20
ASTM 316L	14	15	17	18	20

Imperial units

Temperature, °F	68	200	400	600	800
	Btu/(ft h °F)				
SAF 2205	8	9	10	11	12
ASTM 316L	8	9	10	10	12

Thermal expansion, mean values in temperature ranges (X10^{-6})

Metric units

Temperature, °C	30-100	30-200	30-300	30-400
	Per °C			
SAF 2205	13.0	13.5	14.0	14.5
Carbon steel	12.5	13.0	13.5	14.0
ASTM 316L	16.5	17.0	17.5	18.0

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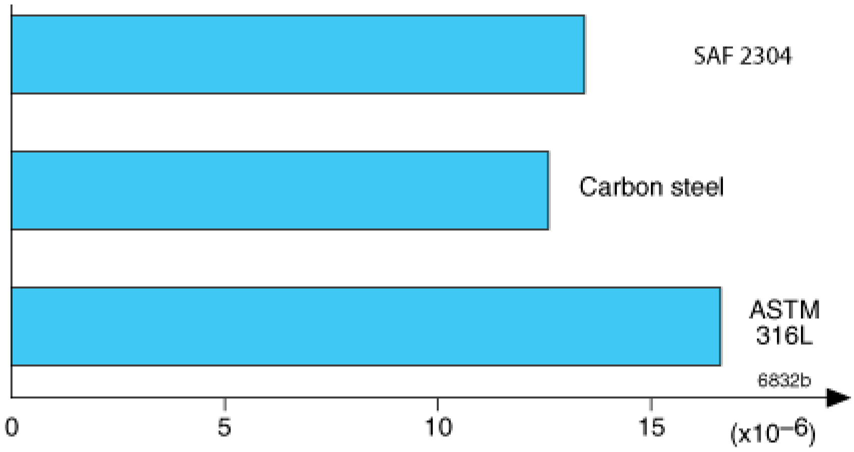
Imperial units

Temperature, °F	86-200	86-400	86-600	86-800
	Per °F			
SAF 2205	7.0	7.5	8.0	8.0
Carbon steel	6.8	7.0	7.5	7.8
ASTM 316L	9.0	9.5	9.8	10.0

SAF™ 2205 has a far lower coefficient of thermal expansion than austenitic stainless steels and can therefore offer certain design advantages.



Modulus of elasticity [1)]

Temperature, °C	MPa	Temperature, °F	ksi
20	200	68	29.0
100	194	200	28.2
200	186	400	27.0
300	180	600	26.2

1) (x10^3)

Hot working

The hot forming range for SAF™ 2205 is 950-1200°C (1740-2190°F), followed by quenching in air or water. Subsequent heat treatment should be carried out in accordance with the recommendations given for heat treatment.

Welding

The weldability of SAF™ 2205 is good. Suitable methods of fusion welding are manual metal-arc welding (MMA/SMAW) and gas-shielded arc welding, with the TIG/GTAW method as first choice. Preheating and subsequent heat treatment are normally not necessary

For SAF™ 2205, heat input of 0.5-2.5 kJ/mm and interpass temperature of <150°C (300°F) are recommended.

Recommended filler metals

TIG/GTAW or MIG/GMAW welding

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ISO 14343 S 22 9 3 N L / AWS A5.9 ER2209 (e.g. Exaton 22.8.3.L)

MMA/SMAW welding

ISO 3581 E 22 9 3 N L R / AWS A5.4 E2209-17 (e.g. Exaton 22.9.3.LR)

ISO 3581 E 22 9 3 N L B / AWS A5.4 E2209-15 (e.g. Exaton 22.9.3.LB)

Machining

The machining of SAF™ 2205, as with other stainless steels, requires an adjustment of tooling data and machining method in order to achieve satisfactory results. Compared to Sanmac® 2205, the cutting speed must be reduced by approximately 20-30% when turning SAF™ 2205 with coated cemented carbide tools. Much the same applies to other operations. Feeds should only be reduced slightly and with care.

Detailed recommendations for the choice of tools and cutting data are provided in the datasheet for Sanmac® 2205.

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