

# SAF 2707 HD™ TUBE AND PIPE, SEAMLESS

## DATASHEET

SAF 2707 HD™ is a high-alloy duplex (austenitic-ferritic) stainless steel for service in highly corrosive conditions. The grade is particularly suited for use in aggressive acidic and chloride containing environments.

### Sandvik SAF 2707 HD™ characteristics:

- Excellent resistance to pitting and crevice corrosion
- Excellent resistance to stress corrosion cracking (SCC) in chloride containing environments
- High resistance to general corrosion in acidic environments
- Excellent resistance to erosion corrosion
- Excellent corrosion fatigue properties
- Extremely high mechanical strength
- Physical properties that offer design advantages
- Good weldability

### STANDARDS

- UNS: S32707
- EN Number: 1.4658

### Product standards

Seamless and welded tube and pipe: ASTM A789, A790

### Approvals

ASME Code Case 2586-1.

Particular Material Appraisal (PMA), austenitic-ferritic steel Sandvik SAF 2707HD™ (seamless tube): PED (Pressure Equipment Directive) 2014/68/EU and AD2000.

### CHEMICAL COMPOSITION (NOMINAL)

#### Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo
≤0.030	≤0.5	≤1.5	≤0.035	≤0.010	27	6.5	4.8

Others  
N=0.4  
Co=1.0

### APPLICATIONS

Typical applications for SAF 2707 HD™ are tubular heat exchangers operating in process industries, such as oil refineries, petrochemical and chemical plants.

### CORROSION RESISTANCE

### General corrosion

SAF 2707 HD™ is highly resistant to organic acid corrosion, e.g. formic acid and acetic acid, see Figures 2 to 5. It also remains resistant in contaminated acid. The alloy is, therefore, a competitive alternative to high alloyed austenitic stainless steels and Ni-base alloys in applications where standard austenitic stainless steels corrode at a high rate.

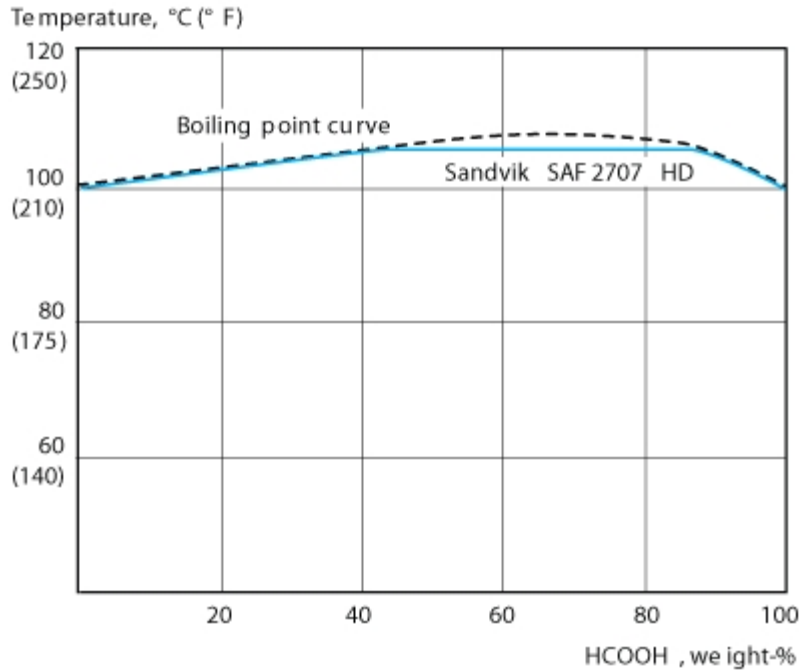


Figure 2. Isocorrosion diagram in naturally aerated formic acid. The curve represents a corrosion rate of 0.1mm/year (4mpy) in a stagnant test solution.

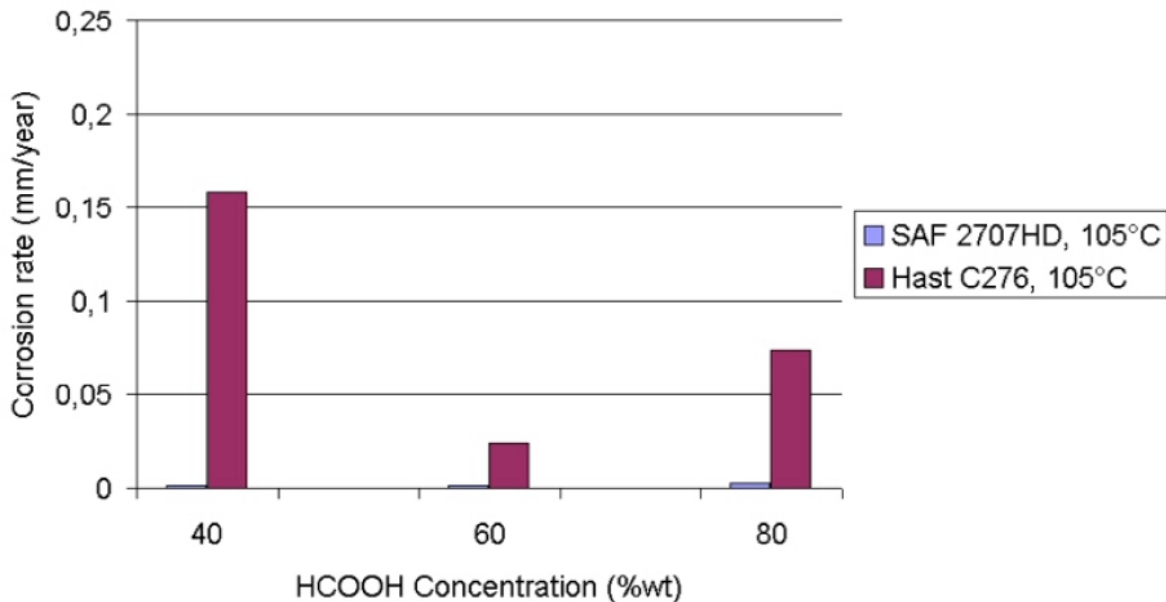


Figure 3. General corrosion resistance of SAF 2707 HD™ and Hastelloy C276 in various concentrations of formic acid at 105°C.

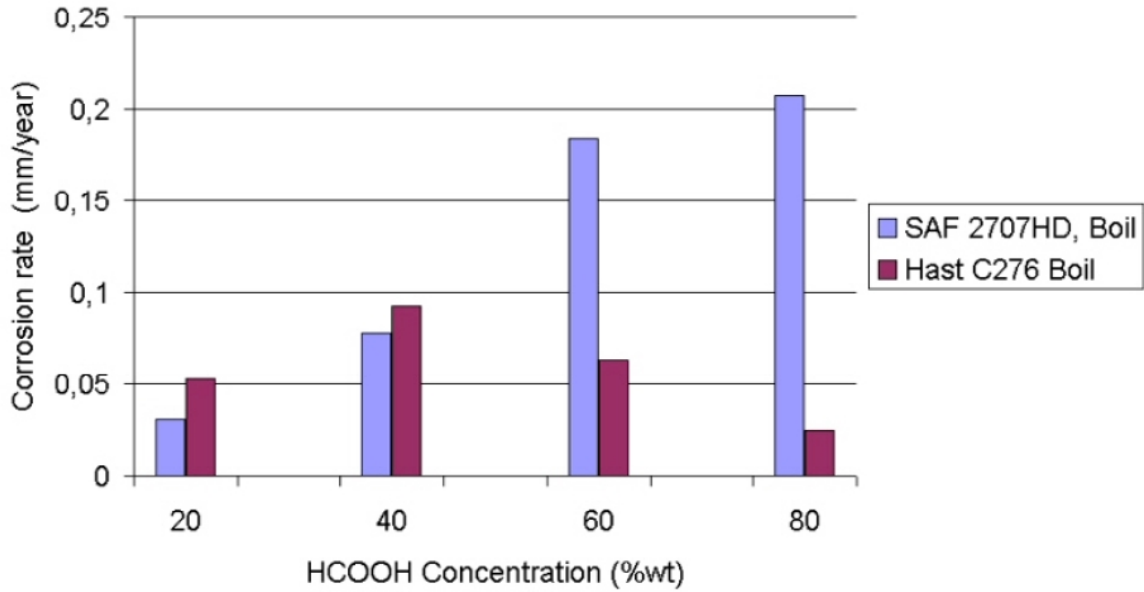


Figure 4. Corrosion rates of SAF 2707 HD™ and Hastelloy C276 in boiling formic acid at various concentrations.

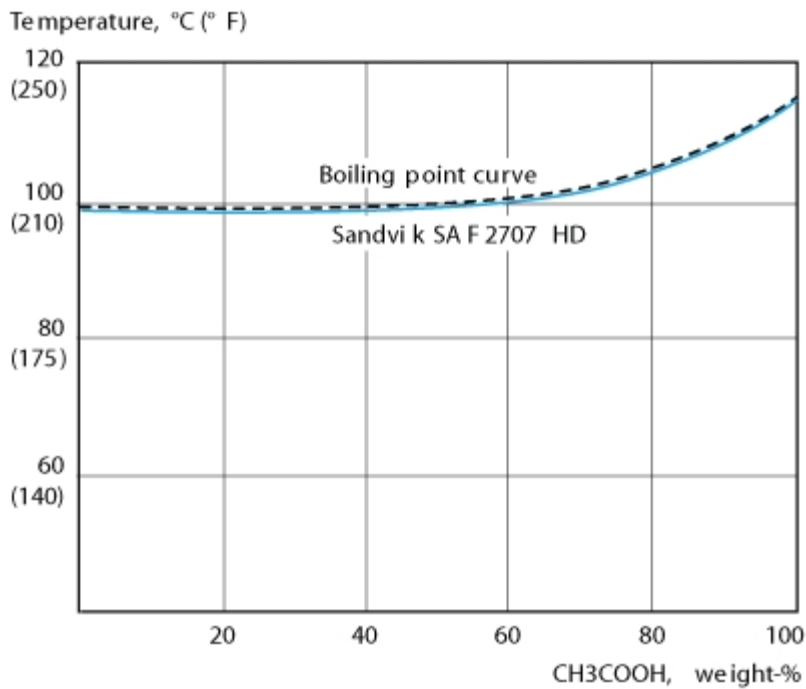


Figure 5. Isocorrosion diagram in naturally aerated acetic acid. The curve represents a corrosion rate of 0,1mm/year (4mpy) in a stagnant test solution.

Resistance to inorganic acids is comparable to, or even better than that of high alloy austenitic stainless steels in certain concentration ranges.

Figure 6 shows an isocorrosion diagram for sulphuric acid, where the resistance of SAF 2707 HD™ in up to 50% H<sub>2</sub>SO<sub>4</sub> exceeds the resistance of SAF 2507® and 316L.

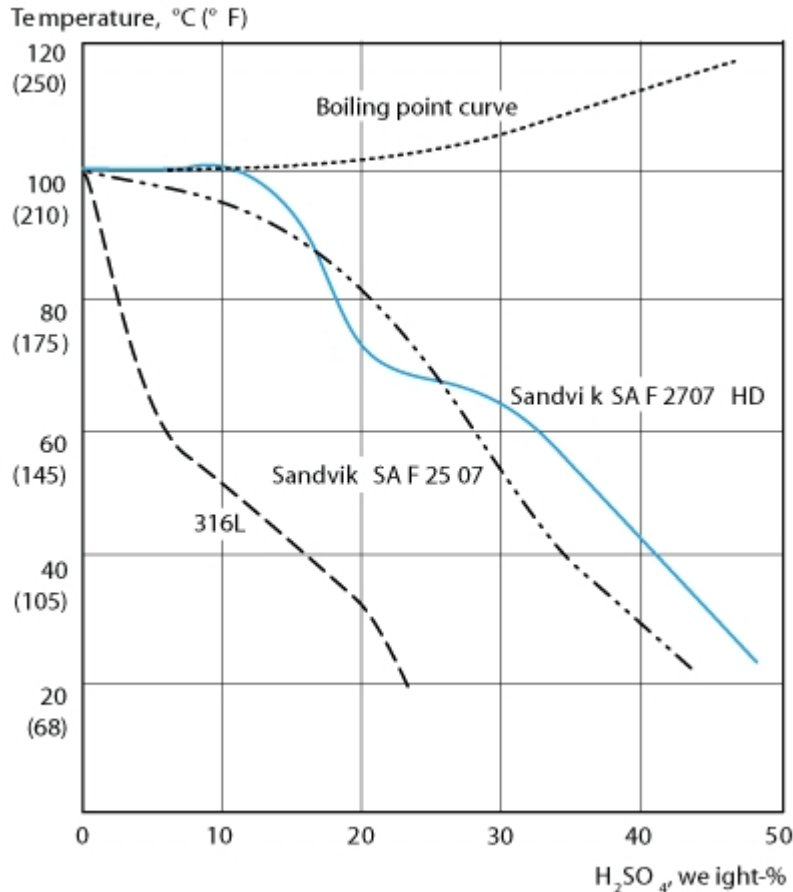


Figure 6. Isocorrosion diagram in naturally aerated sulphuric acid. The curves represent a corrosion rate of 0.1 mm/year (4 mpy) in a stagnant test solution.

#### Pitting and crevice corrosion

The pitting and crevice corrosion resistance of stainless steel is primarily determined by the content of chromium, molybdenum and nitrogen. An index for comparing the resistance to pitting and crevice corrosion in chloride environments is the PRE number (Pitting Resistance Equivalent). The PRE is defined as, in weight % :

$$PRE = \%Cr + 3.3x\%Mo + 16x\%N.$$

The minimum PRE value for SAF 2707 HD™ is 48.

One of the most severe pitting corrosion tests, applied to stainless steels, is ASTM G48 i.e. exposure to 6% FeCl<sub>3</sub>. In a modified version of the ASTM G48A test, the sample is exposed for periods of 24 hours. When pits are detected, together with a substantial weight loss (> 5 mg), the test is interrupted. Otherwise, the temperature is increased by 5°C (9°F) and the test continued with the same sample.

The corrosion resistance of SAF 2707 HD™ in oxidizing chloride solutions is illustrated by critical pitting temperature (CPT), determined in a "Green-Death" solution (1% FeCl<sub>3</sub> + 1% CuCl<sub>2</sub> + 11% H<sub>2</sub>SO<sub>4</sub> + 1.2% HCl).

The crevice corrosion test was performed in 6% FeCl<sub>3</sub> with a crevice specified in the MTI-2 procedure, where an artificial crevice is mounted on the sample with a torque of 0.28 Nm. The values obtained and a comparison with SAF 2507 are given in Figure 7. All test results show significantly higher values for SAF 2707 HD™ than for SAF 2507®.

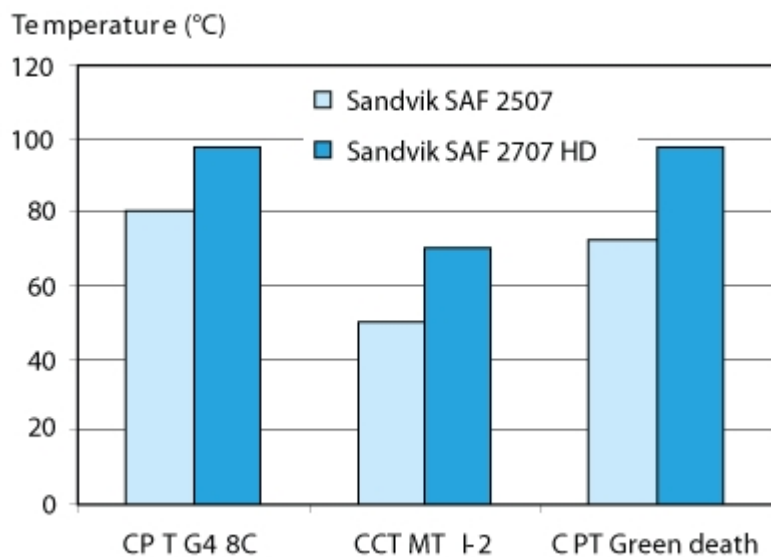


Figure 7. Critical pitting temperature measured in modified G48A and "Green death". Critical crevice corrosion temperature obtained in testing with a crevice specified in the MTI-2 procedure.

Potentiostatic tests in solutions with different chloride contents are reported in Figure 8. The CPT value for SAF 2707 HD™ is significantly better than for SAF 2507® in highly concentrated chloride solutions. Figure 9 shows the effect of increased acidity. SAF 2707 HD™ shows higher CPT values than austenitic stainless steels of the 6Mo+N type, especially at low pH values. In both cases the applied potential is 600mV vs SCE, a very high value compared with that which could be expected in natural, unchlorinated seawater, resulting in lower critical temperatures compared with most practical service conditions.

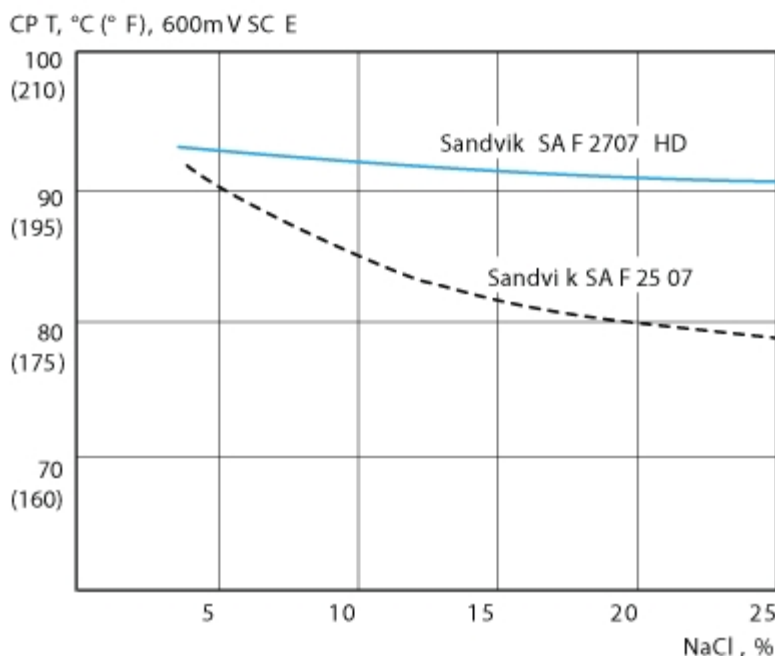


Figure 8. Critical pitting temperatures (CPT) at varying concentrations of sodium chloride, from 3 to 25% (potentiostatic determination at +600mV SCE with surface ground with 220 grit paper).

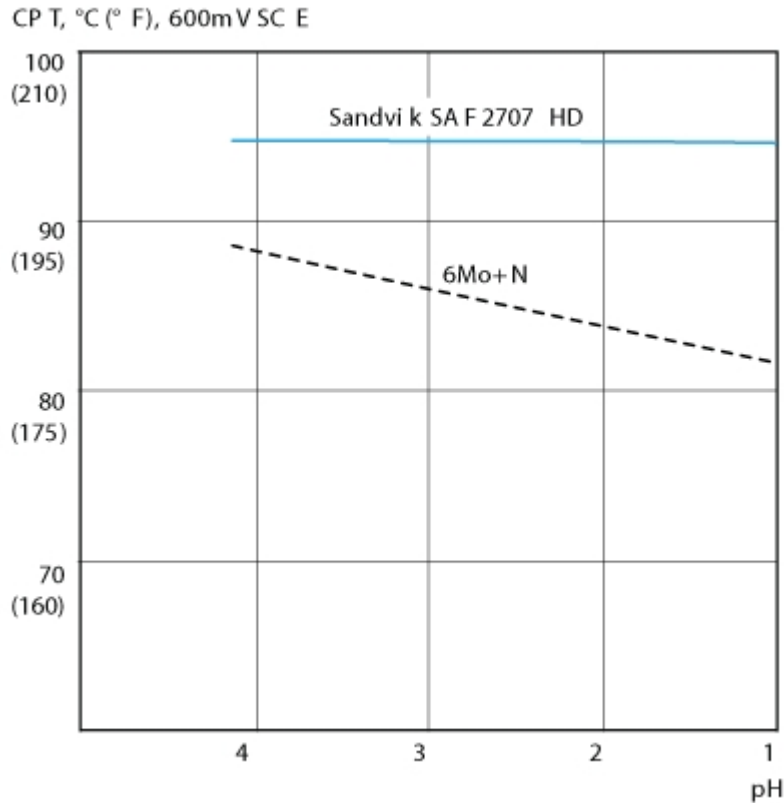


Figure 9. Critical pitting temperatures (CPT) in 3% NaCl with varying pH (potentiostatic determination at +600mV SCE with surface ground with 220 grit paper).

Full scale extended heat exchanger tests in chlorinated natural seawater heated to two different temperatures.

The very good pitting corrosion results in laboratory tests have also been verified in full scale extended heat exchanger tests in chlorinated natural seawater. The residual chlorine content was 0.5 ppm.

Model heat exchangers and heat exchanger tubing in SAF 2707 HD™ and SAF 2507®, welded into UNS S32750 tube sheets and SAF 2205 welded into a UNS S32205 tube sheet were tested for 6 months at each temperature. The inlet temperature of the seawater was 35°C with a seawater flow rate inside the tubes of 1 m/s. Heat was applied from the shell side with external heating elements and thus a heat flux through the tubes was achieved. As the results in the table show, no pitting was observed on SAF 2707 HD™ when the tube skin temperature on the seawater side was 70°C, after tubes were heated from the outside at a temperature of 105°C. At this temperature, SAF 2507® experienced pitting, but passed at 50°C. SAF 2205™ was attacked by pitting at both temperatures.

	PRE	T(skin-out)/T(skin-in), °C	
		65/50	105/70
SAF 2707 HD	≥48	NA*	NA*
SAF 2507	≥42.5	NA*	P*
SAF 2205	≥35	P*	P*

\* NA denotes no attack, P denotes pitting

#### Stress corrosion cracking

The stress corrosion cracking resistance of SAF 2707 HD™ in chloride environments is excellent.

SCC resistance of SAF 2707 HD™ in chloride solutions at high temperatures is illustrated in Figure 10. In these tests, there were no signs of SCC up to 1000 ppm Cl<sup>-</sup>/300°C (572°F) and 10000 ppm Cl<sup>-</sup>/250°C (482°F).

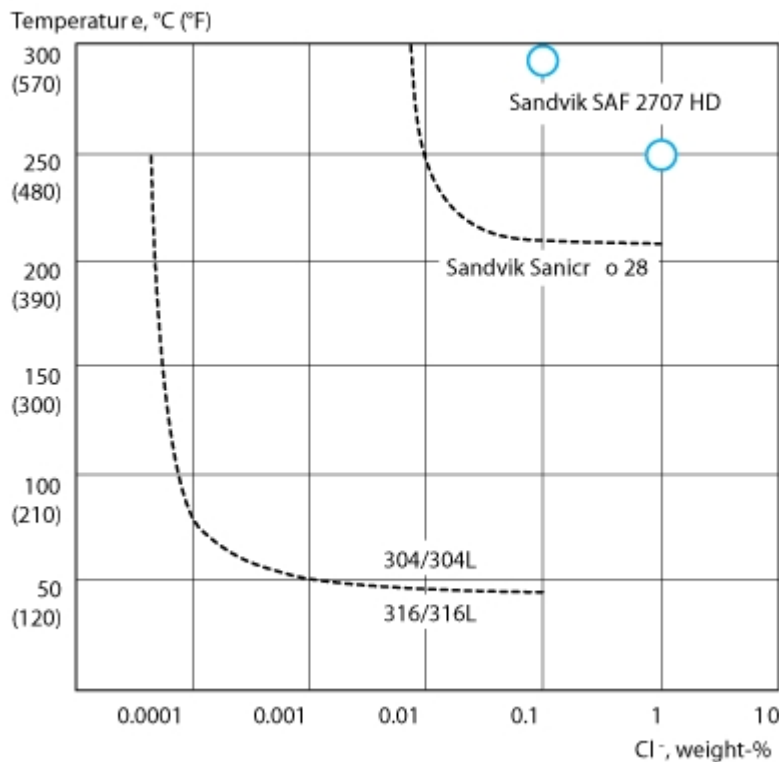


Figure 10. SCC resistance in oxygen-bearing (abt. 8 ppm) neutral chloride solutions. Testing time 1000 hours. Applied stress equal to proof strength at testing temperature.

## FABRICATION

### Bending

The force needed for bending SAF 2707 HD™ is higher than that for standard austenitic stainless steels, which is a natural consequence of higher proof strength. However, cold bending can be carried out with normal bending methods, and owing to its good ductility, SAF 2707 HD™ can be bent to very close bending radii. Normally, there is no need for subsequent heat treatment. Heat treatment, if any, should be carried out by solution or resistance annealing.

For pressure vessel applications using cold bent tubes, special conditions may apply regarding the minimum bending radii allowed without subsequent heat treatment.

### Expanding

Compared to austenitic stainless steels, SAF 2707 HD™ has higher proof and tensile strengths. This must be kept in mind when expanding tubes into tubesheets. Normal expanding methods can be used, but the expansion requires higher initial force and should be undertaken in a one-step operation. If the service conditions include a high chloride concentration, tube to tubesheet joints should generally be welded, in order to reduce the risk of crevice corrosion.

### Machining

Being a dual phase material (austenitic-ferritic), SAF 2707 HD™ will present a different tool wear profile from that of austenitic stainless steels. The cutting data (speed and feed) must, therefore, be lower than that recommended for austenitic grades. Further information is available on request.

## FORMS OF SUPPLY

## Seamless tube

Seamless tubes in SAF 2707 HD™ can be supplied in typical heat exchanger tube dimensions. Tubes are generally delivered solution annealed, with a pickled or light ground surface condition.

## HEAT TREATMENT

Tubes are normally delivered in the heat treated condition. If additional heat treatment is needed due to further processing, solution annealing is recommended. Please contact Sandvik for further information.

## MECHANICAL PROPERTIES

The following figures apply to solution annealed seamless tubes with wall thicknesses up to 4 mm.

At 20°C (68°F)

### Metric units

Proof strength, MPa		Tensile strength, MPa	Elongation, %		Hardness, HRC
R <sub>p0.2</sub> <sup>a)</sup>	R <sub>p1.0</sub> <sup>a)</sup>	R <sub>m</sub>	A <sub>b)</sub>	A <sub>2</sub> "	
≥700	≥800	920-1100	≥25	≥25	≤34

### Imperial units

Proof strength, ksi		Tensile strength, ksi	Elongation, %		Hardness, HRC
R <sub>p0.2</sub> <sup>a)</sup>	R <sub>p1.0</sub> <sup>a)</sup>	R <sub>m</sub>	A <sub>b)</sub>	A <sub>2</sub> "	HRC
≥101	≥116	133-160	≥25	≥25	≤34

1MPa = 1N/mm<sup>2</sup>

a) R<sub>p0.2</sub> and R<sub>p1.0</sub> correspond to 0.2% offset and 1.0% offset yield strength, respectively.

b) Based on  $L_0 = 5.65 \sqrt{S_0}$  where  $L_0$  is the original gauge length and  $S_0$  the original cross-section area.

## At high temperatures

If SAF 2707 HD™ is exposed to temperatures exceeding 250°C (480°F) for prolonged periods, the microstructure changes, resulting in a reduction in impact strength. This does not necessarily affect the behavior of the material at the operating temperature. For example, heat exchanger tubes can be used at higher temperatures with no detrimental effects. Contact Sandvik for more information.

### Metric units

Temperature, °C	Proof strength, MPa		Tensile strength, MPa
	R <sub>p0.2</sub> <sup>a)</sup>	R <sub>p1.0</sub> <sup>a)</sup>	R <sub>m</sub>
	min.	min.	min.
50	645	760	900
100	600	670	850
150	560	640	840
200	540	590	830
250	510	570	810
300	500	560	790

### Imperial units

Temperature, °F	Proof strength, ksi		Tensile strength, ksi
	R <sub>p0.2</sub> <sup>a)</sup>	R <sub>p1.0</sub> <sup>a)</sup>	R <sub>m</sub>
	min.	min.	min.



### Imperial units

Temperature, °F	Proof strength, ksi		Tensile strength, ksi
	R <sub>p0.2</sub> <sup>a</sup>	R <sub>p1.0</sub> <sup>a</sup>	R <sub>m</sub>
	min.	min.	min.
100	93	113	132
200	87	98	124
300	81	93	122
400	78	85	120
500	74	82	117
600	72	81	114

### Impact strength

SAF 2707 HD™ possesses very good impact strength. Figure 1 shows impact energy (KCV). The ductile-brittle transition temperature is below -50°C (-58°F).

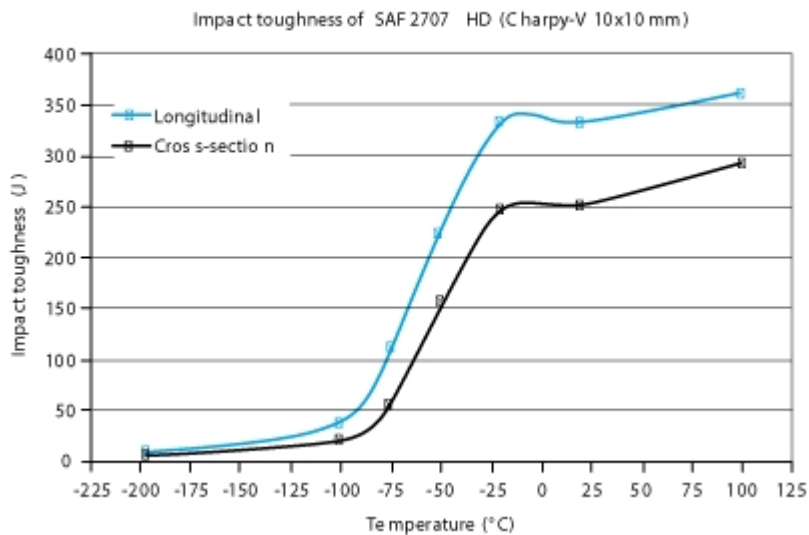


Figure 1. Impact energy curve for SAF 2707 HD™ using standard Charpy V specimens 10 x 10mm (average of 3 at each temperature). The samples are taken in the longitudinal and transversal direction from 200 x 13 mm hot extruded and solution annealed (1100°C / 2012°F) tube.

### PHYSICAL PROPERTIES

Density: 7.8 g/cm<sup>3</sup>, 0.28lb/in<sup>3</sup>

Specific heat capacity

#### Metric units, Imperial units

Temperature, °C	J/(Kg °C)	Temperature, °F	Btu/(lb °F)
20	470	68	0.11
100	495	200	0.12
200	530	400	0.13
300	560	600	0.13
400	590	800	0.14

## Thermal conductivity

### Metric units <sup>1)</sup>

Temperature, °C	20	100	200	300	400
SAF 2707 HD	12	14	16	18	19
AISI 316L	14	15	17	18	20

1) W/(m °C)

### Imperial units <sup>1)</sup>

Temperature, °F	68	200	400	600	800
SAF 2707 HD	7	8	9	10	11
AISI 316L	8	9	10	10	12

1) Btu/(ft h °F)

## Thermal expansion

SAF 2707 HD™ has a coefficient of thermal expansion at the same level as carbon steel. The values given are average values in the temperature ranges.

### Metric units <sup>1)</sup>

Temperature, °C	30-100	30-200	30-300	30-400
SAF 2707 HD	12.5	13	13.5	14
ASTM 316L	16.5	17	17.5	18

1) x10<sup>-6</sup>/°C

### Imperial units <sup>1)</sup>

Temperature, °F	86-200	86-400	86-600	86-800
SAF 2707 HD	7	7.5	7.5	7.5
ASTM 316L	9.5	9.5	10	10

1) x10<sup>-6</sup>/°F

## Resistivity

Temperature, °C	μΩm	Temperature, °F	μΩin.
22	0.75	72	29.5

## Modulus of elasticity <sup>1)</sup>

Temperature, °C	MPa	Temperature, °F	ksi
20	197	68	28.5
100	189	200	27.5
200	178	400	25.7
300	168	600	24.2

1) ( x10<sup>3</sup> )

## WELDING

The weldability of SAF 2707 HD™ is good. Welding must be carried out without preheating and subsequent heat treatment is normally not necessary. Suitable method of fusion welding is gas tungsten arc welding

GTAW/TIG with shielding gas of Ar+2% N<sub>2</sub>. For tube to tubesheet welding, it is recommended to use Ar+3% N<sub>2</sub> as shielding gas to have proper weld metal structure.

For SAF 2707 HD™, heat input of 0.2-1.5 kJ/mm and interpass temperature of <100°C (210°F) are recommended.

#### Recommended filler metals

GTAW/TIG welding

Exaton 27.7.5.L

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Disclaimer: Recommendations are for guidance only, and the suitability of a material for a specific application can be confirmed only when we know the actual service conditions. Continuous development may necessitate changes in technical data without notice. This datasheet is only valid for Sandvik materials.