KARA Ferritic Stainless Steel

K44 18% Chromium with Molybdenum, Titanium and Niobium stabilized

KARA key for value

Chemical Composition

Elements (%)	C	Si	Mn	Cr	Mo	Ti+Nb
K44	0.015	0.50	0.30	17.70	1.85	0.45

Typical values

European designation	American designation
X2CrMoTi18-2/1. 4521 (1)	Type 444 (2)

(1) According to NF EN 10088-2

(2) According to ASTM A 240

This grade complies with:

- Stainless Europe Material Safety Data Sheet No. 1: stainless steels (European Directive 2001/58/EC)
- European Commission Directive 2000/53/EC for end-of-life vehicles, and to Annex II, dated 27 June 2002
- Standard NFA 36 711 "Stainless steel intended for use in contact with foodstuffs, products and beverages for human and animal consumption" (non packaging steel)
- NSF/ANSI 51–2009 edition International Standard for "Food Equipment Materials" and F.D.A. (United States Food and Drug Administration) requirements regarding materials used for food contact
- French Decree No. 92-631, dated 8 July 1992, and Regulation No. 1935/2004 of the European Parliament and of the Council, dated 27 October 2004, on materials and articles intended to come into contact with food (and repealing Directives 80/590/EEC and 89/109/EEC)
- French Order, dated 13 January 1976, relating to materials and articles made of stainless steel in contact with foodstuffs
- PED (Pressure Equipment Directive) according to EN 10028-7

Key Features

- Very good resistance to pitting corrosion in chloride media, outperforming 304L (18-9L) and 316L (18-11ML) grades
- Not sensitive to stress cracking and intergranular corrosion
- Low toughness at transition temperature, even in welded zones
- Good drawability and weldability
- Higher thermal conductivity and lower thermal expansion coefficient than austenitic grades

Applications

- Agrofood industry
- Hot water tanks
- Boilers
- Fume ducts
- Heat exchangers
- Sugar and sanitary tubes
- Photovoltaic frames
- Solar tanks
- Solar panels
- Cooking and catering equipment
- Water tanks

Product Range

	Coils	Sheets / Blanks	Discs	Precision Strip	Precision Sheet
Thickness (mm)	0.40 up to 4	0.40 up to 4	0.38 up to 2.50	0.06 up to 2.5	0.20 up to 2.5
Width (mm)	up to 1,500	up to 1,250	Ø 15 up to 1,000	3 up to 700	40 up to 670
Finish	2R / 2B / 2D	2R / 2B / 2D	2R / 2B / 2D	2R / 2B / 2D / 2H / 2F	2R / 2B / 2D / 2H / 2F

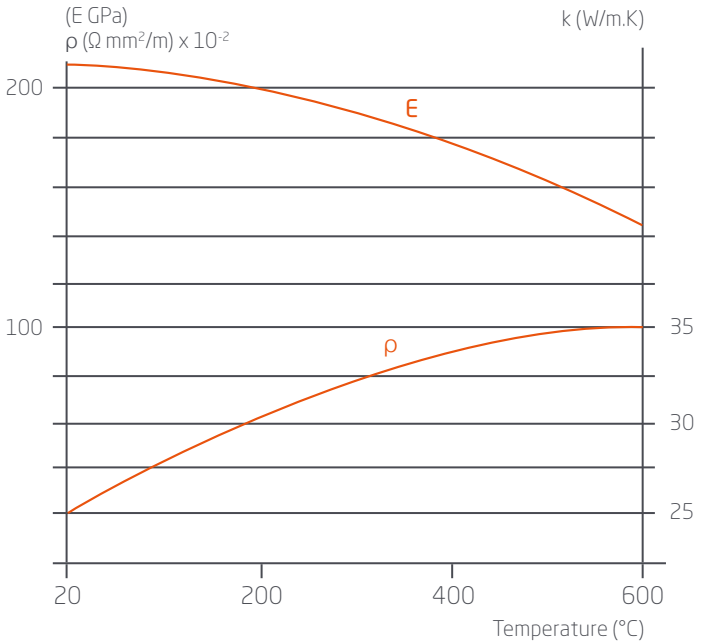
Please contact us regarding all other dimensions, forms and finishes.

Physical Properties

Cold rolled and annealed sheet

Density	d	kg/dm³	20°C	7.7
Melting temperature		°C		1,495
Specific heat	c	J/kg.K	20°C	430
Thermal conductivity	k	W/m.K	20°C	23
Mean thermal expansion coefficient	α	10^{-6}/K	20-200°C 20-400°C 20-600°C 20-800°C	10.8 11.6 12.0 12.5
Electric resistivity	ρ	Ω mm²/m	20°C	0.8
Magnetic resistivity	μ	at 0.8 kA/m DC or AC	20°C	800
Young's modulus	E	GPa	20°C	220

Curie point: 650°C
K44 thermal conductivity is superior to austenitic stainless steel 304L/316L (k = 15W/m.°C) and the mean coefficient of thermal expansion is lower (α=17x10^{-6} -20°C to 200°C for 304L or 316L.



Mechanical Properties

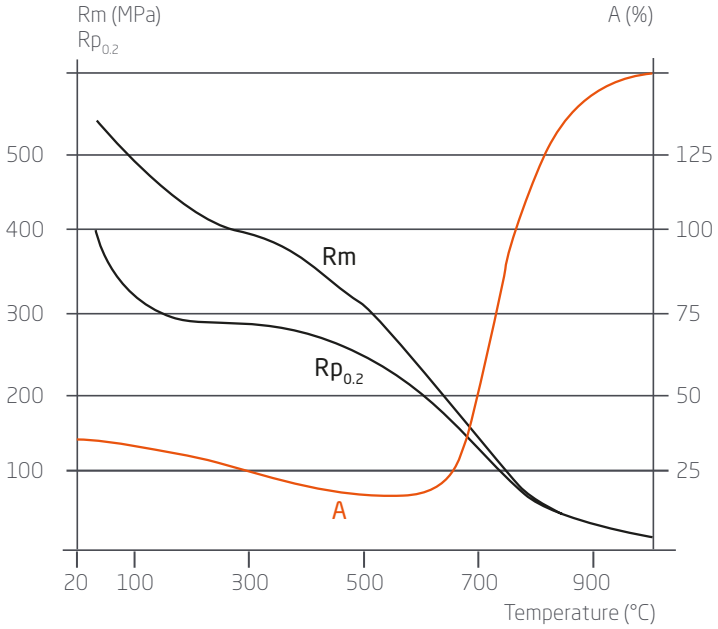
Test piece

Length = 80 mm (thickness < 3 mm)
Length = 5.65 √ S_o (thickness ≥ 3 mm)

In the annealed condition

In accordance with ISO 6892-1, part 1
Test piece perpendicular to rolling direction

At high temperatures (Typical values)



Grade	Condition	Rm(1) (MPa)	Rp0.2(2) (MPa)	A(3) %	HRB
K44	Cold- rolled	520	370	29	84

1 MPa = 1 N/mm² - Typical values
(1) Ultimate Tensile Strength (UTS) - (2) Yield Strength (YS) - (3) Elongation (A)

At 100°C the $Rp_{0.2}$ of K44 is > 300 MPa

Grade designation	$R_{p0,2}$ - 20°C (MPa)	$R_{p0,2}$ - 100°C (MPa)
K44/444	370	330
304L	320	260
316L	320	170

The yield stress of ferritic steels is higher than for austenitic grades.

Like all ferritic grades, K44 is prone to embrittlement after long exposure at a temperature around 475°C. When making certain structural calculations, such as for hot water tanks, it is important that this characteristic be taken into consideration.
In effect, the superior proof stress at room temperature, subjected to operating temperatures found in this type of product application, enables the same level of strain to be applied, thus preventing the risk of explosion and limiting thickness.

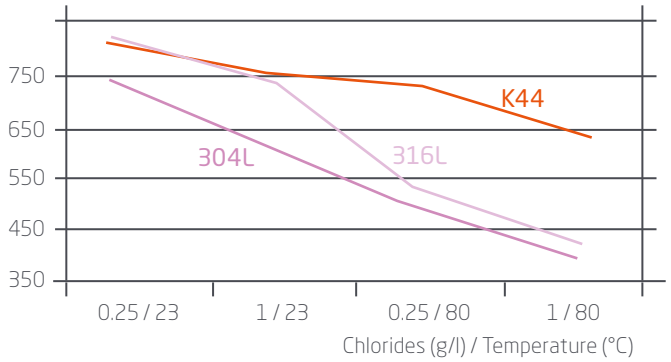
Complies with the following construction codes for pressure vessel applications: EN 13445, CODAP 2005, ASME VIII and DIN 44899.

Corrosion Resistance

Localised corrosion resistance

K44 presents a very good resistance to all types of corrosion, the result of its chromium and molybdenum levels and that it is stabilized with both niobium and titanium. Its PREN value is 24/25, which translated into a very good pitting corrosion resistance, outperforming that of such austenitic grade variants as 304L, 316L and 316Ti.

The effect of Cl concentration and temperature on pitting corrosion resistance



Salt spray

After 2000h of exposure in a salt-spray test, and in accordance with the norm NFX 41002, K44 in 2B or BA finish shows no sign of corrosion.

Intergranular corrosion

Our K44 grade has good resistance to intergranular corrosion (Strauss test), the result of its effective stabilization of carbon and nitrogen with titanium and niobium. Because of its high chromium content and the presence of molybdenum, precipitates of Laves phase can appear when heated in the range of 600 to 900°C.

These precipitates can alter the intergranular corrosion resistance in highly oxidizing media (e.g. Huey test), but do not modify the behaviour in the more usual Strauss test. For applications in such severe conditions, one should avoid heat treatment in the above noted range.

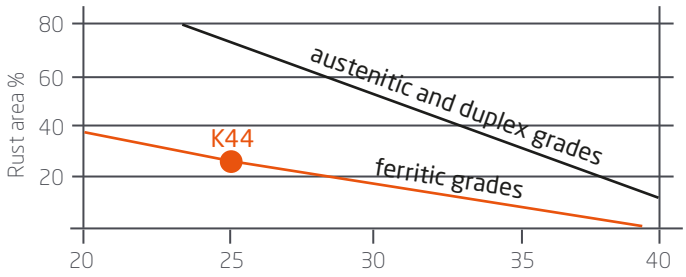
*PREN = %Cr+3.3%Mo+16%N.

Atmospheric corrosion

Recent studies in various countries have shown that ferritic stainless steels have greater resistance to atmospheric corrosion than austenitic or duplex grades of equivalent PREN, particularly with regard to rust area and glass retention criteria.

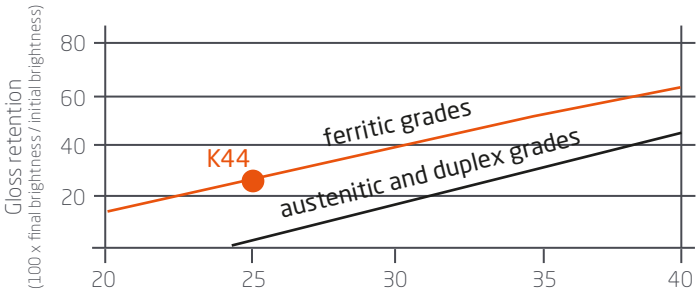
Relation between rust area and PREN after 3 years of exposure to a marine/industrial atmosphere

Relation between PREN and gloss retention after 3 years of exposure to a marine/industrial atmosphere



PREN = % Cr + 3.3% Mo + 16% N for austenitic steel.

PREN = % Cr + 3.3 % Mo for ferritic steel.

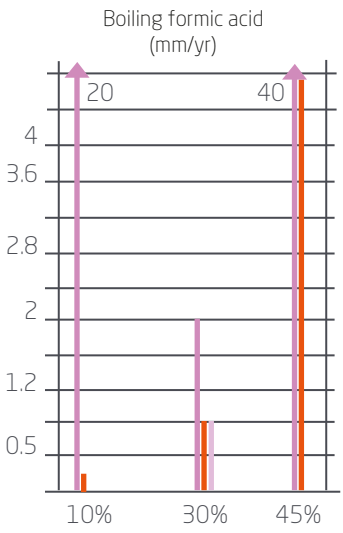


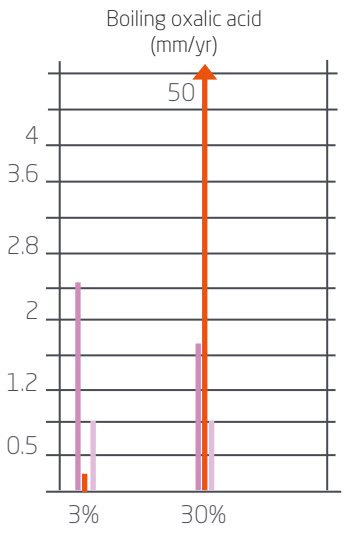
Atmospheric Corrosion Resistance of High Cr ferritic Stainless Steels for Architectural Exterior Applications Y. Yazawa, T. Ujiro, K. Yamato, H. Kalto «Stainless steeel 95», Düsseldorf 1996.

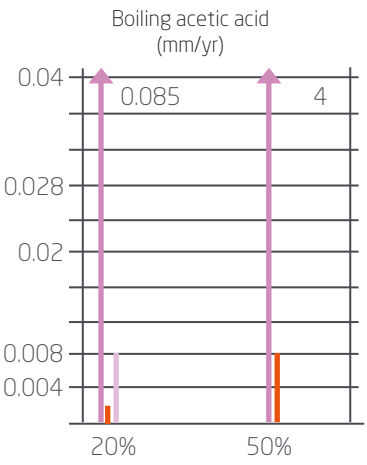
Acid corrosion

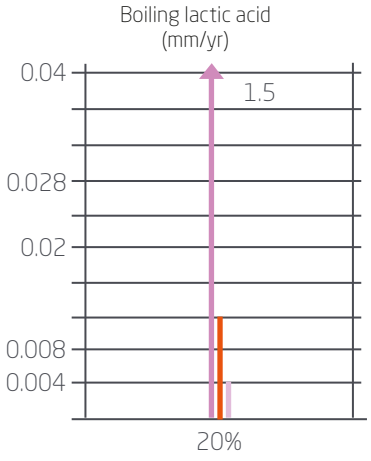
Although the corrosion rate is generally higher for ferritic steels than for austenitic grades with a similar molybdenum content, our K44 grade is perfectly suitable for use in numerous organic and mineral acids, as shown below. Furthermore, it is highly resistant to fume condensates and has been certified by the French building industry (CSTB - France) for use with high yield domestic heating oils.

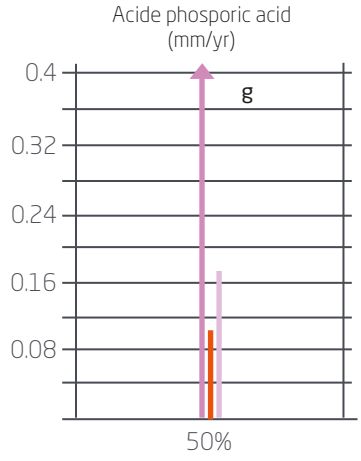
304L - K44 - 316

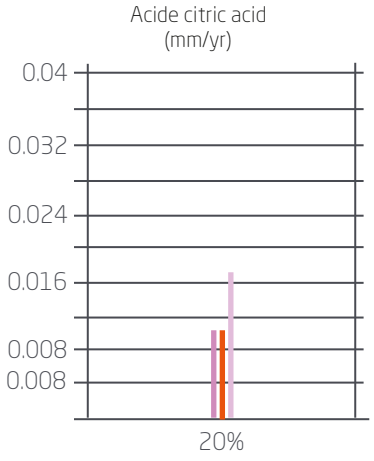


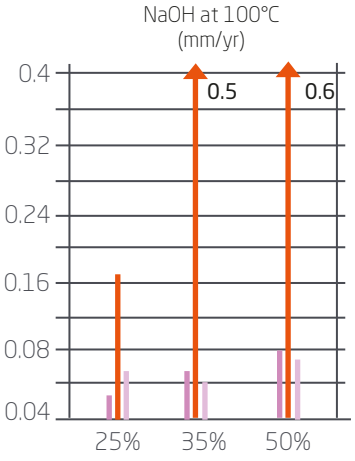


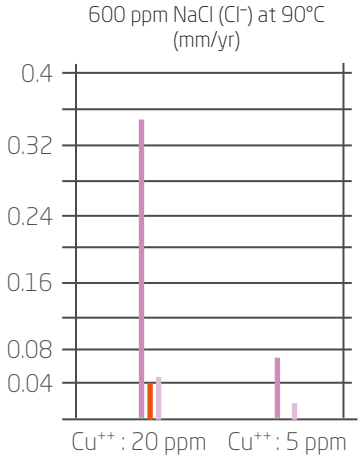


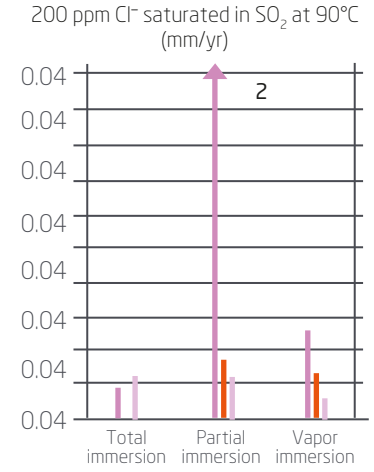






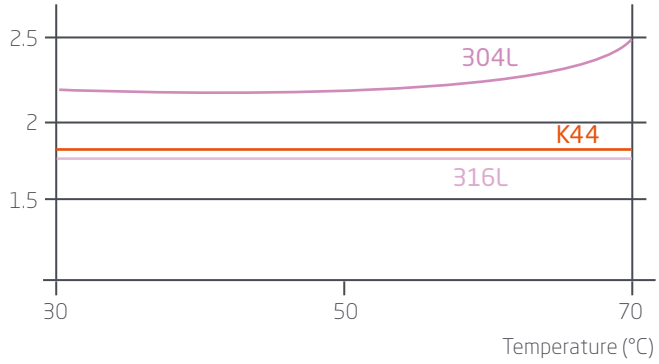






Crevice corrosion

Due to the presence of molybdenum, our K44 grade has good resistance to the initiation of crevice corrosion, similar to that of the 316L austenitic grade. This resistance is measured in terms of the depassivation pH, which for K44 is in the order of 1.8, with little sensitivity to temperature.



Stress corrosion cracking

Like all ferritic grades, our K44 grade is not susceptible to stress corrosion. For example, in hot seawater, and loaded to 95 % of the yield stress, no failure is observed after 3,000 hours.

Time to crack initiation (hours)

	304L	316L	K44
Boiling 42 % Mg Cl_2	< 2	< 16	> 1,700*
42 % $CaCl_2$ at 100°C	< 25	< 75	> 1,700*

* no crack initiation

Forming

K44 lends itself to all the current methods of cold forming (folding, profiling, bending, drawing, etc.). We suggest forming all ferritics, including K44, using deep drawing (reflected in the LDR ratio. This allows the metal to be absorbed into the punch, minimising the amount of blank holder pressure that needs to be applied in order to avoid creasing.

Stretching (Erichsen test) & Deep drawing (Swift test)

Grades	European designation	ASTM A 240	Bending (mm)	LDR (mm)
K44	1.4521	Type 444	8.6	2.10-2.15

0.8 mm thickness

Bending

180° bending can be performed up to 0.8 mm, but above 0.8 mm thickness, a radius of at least ½ the thickness should be allowed.

Welding

Our K44 grade is weldable using the following processes: resistance (spot, seam), electrical arc, high frequency, LASER and electron beam.

Welding process	No filler material	With filler metal			Shielding gas*
	Typical thicknesses	Thicknesses	Filler material		* Hydrogen and nitrogen forbidden in all cases
			Rod	Wire	
Resistance: spot, seam	≤ 2 mm				
TIG	< 1.5 mm	> 0.5 mm	G 19 12 3L [1] ER 316L [2] n°1.4430 [5]		Ar Ar + He
PLASMA	< 1.5 mm	> 0.5 mm		G 19 12 3L Si [1] ER 316L Si [2] n°1.4430 [5]	Ar Ar + He
MIG		> 0.8 mm		G 19 12 3L Si [1] ER 316L Si [2] n°1.4430 [5]	Ar + 2% CO_2 Ar + 2% O_2 Ar + 2% CO_2 + He
Electrode		Repairs	E 19 12 3L (3) E 316L (4)		
Laser	< 5 mm				He Ar in certain conditions

[1] In accordance with EN ISO 14343 - [2] In accordance with AWS A5.9 - [3] In accordance with EN 1600 - [4] In accordance with AWS A5.4 - [5] In accordance with VDEH.

The addition of hydrogen or nitrogen to the argon must be avoided since these gases decrease the ductility of the welds. For the same reason, nitrogen shielding must not be used and CO_2 additions must be limited to 3 %. In order to restrict grain growth in the HAZ, the use of high welding powers must be avoided. For example, in automatic TIG welding without filler metal, the power should not exceed 1.5 kJ/cm for a sheet thickness of 1.5 mm. Pulsed MIG/MAG welding has a lower power input than conventional MIG welding and enables better control of both bead geometry and grain size. Post-weld heat treatment is generally not necessary. The welds must be mechanically or chemically descaled, then passivated. Do not use Oxyacetylene torch welding.

Heat Treatment and Finishing

Polishing

Stabilised ferritic stainless steels in general, and K44 in particular, can be readily polished with abrasive belts from 3 to 6 finishes. However, because of the stabilizing elements (Ti, Nb), they do not give a good mirror finish. Do not polish with abrasives that contain iron salts. If the steel is contaminated with iron or iron salts, a final decontamination treatment must be performed. Before any heat treatment, the metal must be carefully degreased.

Annealing

After cold work, annealing is performed by treating for a few minutes at 925°C, followed by air cooling. For treatments longer than 5 minutes, never exceed 1,000°C.

Pickling

- Nitric-hydrofluoric acid mixture (20% HNO_3 + 1% HF)
- Use descaling pastes for weld zones

Passivation

- 20-25% cold nitric acid bath at 20°C
- Use passivating pastes for weld beads