aperam

KARA Ferritic Stainless Steel

K33X

18% Chromium with Molybdenum, Titanium stabilized

KARA key for value

"X" marks the spot for exhaust applications. K33X guarantees:

- Just in time deliveries
- Reliable quality
- The continuous improvement that the automotive market demands

Key Features

- Excellent corrosion results in exhaust gas environments
- High level of resistance to pitting corrosion, similar to that of austenitic 1.4301
- Not susceptible to stress and intergranular corrosion
- Ferritic structure means low thermal expansion coefficient
- High thermal conductivity guarantees a homogeneous aspect
- Good oxidation resistance (up to 850°C)
- Easy to form
- Good weldability

Chemical Composition

Elements (%)	C	N	Si	Mn	Cr	Ti	Mo
K33X	0.015	0.015	0.50	0.25	17.30	0.35	0.90

Typical values

European designation	IMDS
X2CrMoTi17-1/1.4513 (1)	5034227

(1) According to NF EN 10088-2

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

Applications

- Exhaust system mufflers (as a substitute to 1.4301 grade, K33X increases a muffler's life time)
- Various after-treatment systems (particulate filter system, Urea SCR)

Product Range

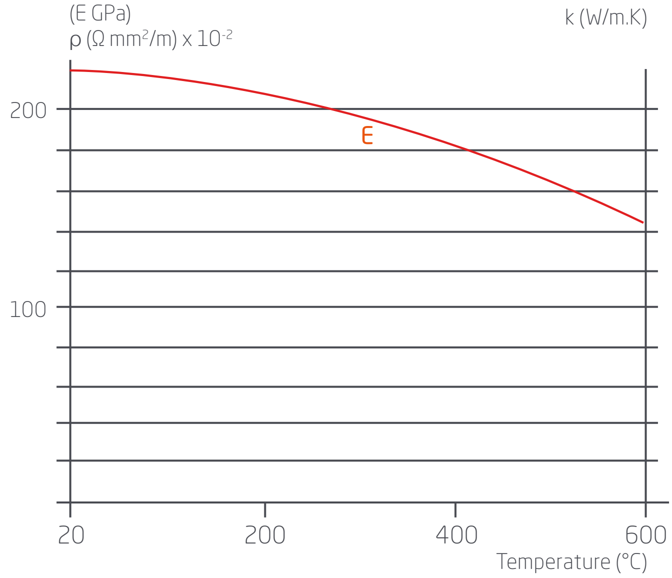
	Coils	Tubes
Thickness (mm)	0.40 up to 4	0.80 up to 2
Width (mm)	up to 1,524	Ø 8 up to 168
Finish	2B / 2D	2D

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	Liquidus	1,480
Specific heat	c	J/kg.K	20°C	440
Thermal conductivity	k	W/m.K	20°C 500°C	30 26.3
Mean thermal expansion coefficient	α	10^{-6}/K	20-200°C 20-400°C 20-600°C 20-800°C	11.7 12.1 12.7 14.2
Electric resistivity	ρ	Ω mm²/m	20°C	0.70
Magnetic resistivity	μ	at 0.8 kA/m DC or AC	20°C	550
Young's modulus	E	GPa	20°C	220



Mechanical Properties

Test piece

Length = 80 mm (thickness < 3 mm)
Length = 5.65 $\sqrt{S_o}$ (thickness ≥ 3 mm)

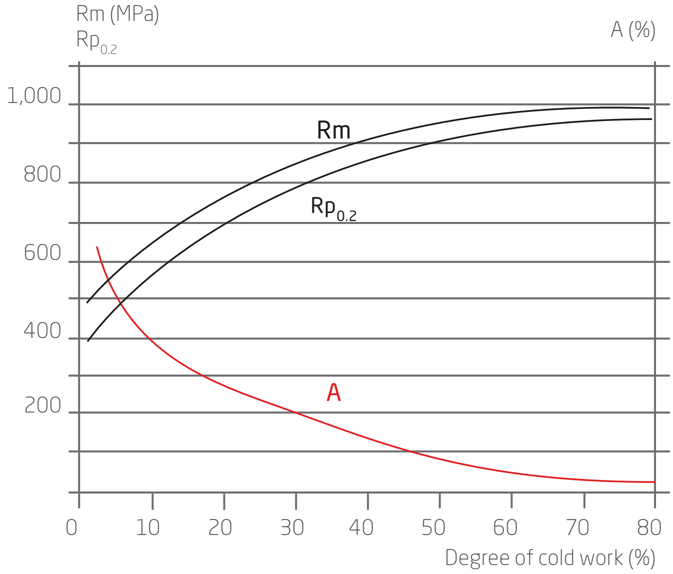
Grade	Condition	Rm[1] (MPa)	$Rp_{0.2}$[2] (MPa)	A[3] %	HRB
K33X	Cold- rolled	470	300	32	76

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

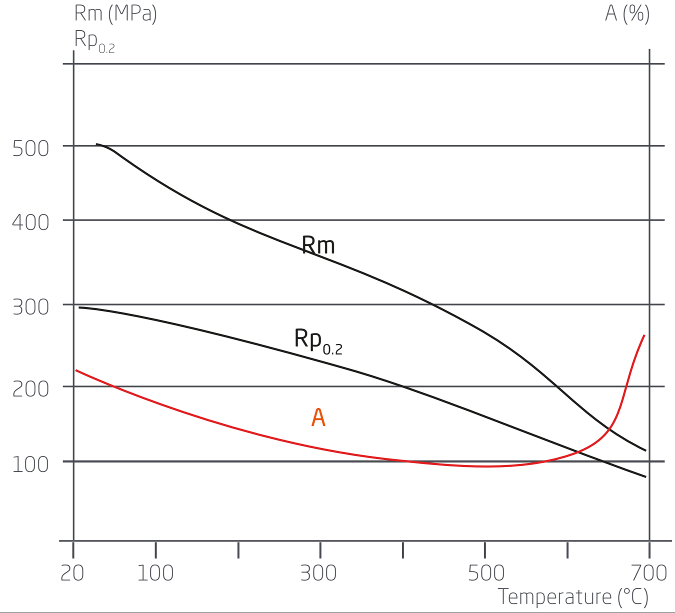
In the annealed condition

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

Effect of cold rolling (Typical values)



At high temperatures (Typical values)



Creep Properties

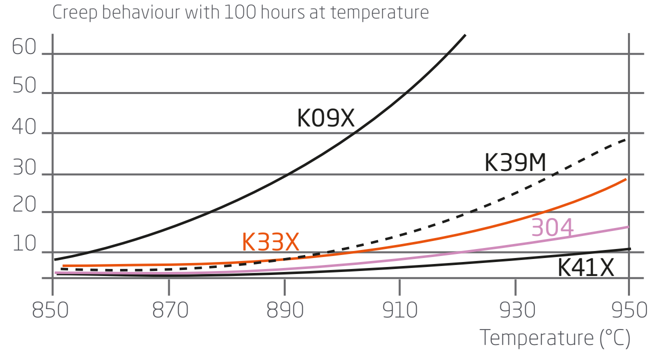
Our K33X grade has good creep resistance compared to our K09X grade (1.4512)

The additional molybdenum content provides K33X with a better hardness at high temperature. The result is a better creep resistance than K39M (1.4510).

Creep resistance

Deflection measurement in mm on a sample of: 200 x 25 x 1.5 mm positioned at the extremity between 2 sides and subjected to different temperatures during 100 hours.

Grade characteristics at high temperatures
Creep behaviour with 100 hours at temperature



Oxidation Resistance

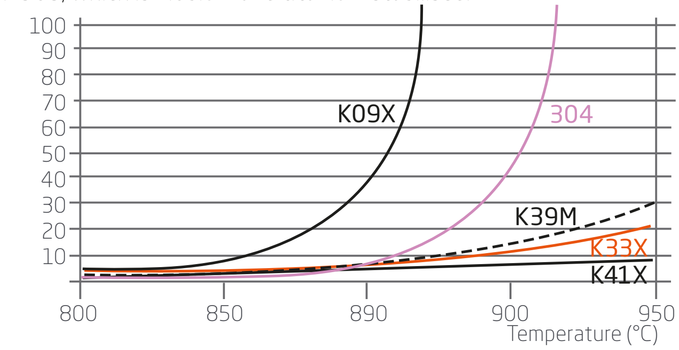
As with all our ferritic grades, K33X has a low coefficient of thermal expansion, which makes it less susceptible to the oxide layer scaling off as is common in austenitic 1.4301.

Our K33X is titanium stabilised, which allows it to retain its ferritic structure regardless of temperature to the phenomenon of carbide and chromium precipitations during thermal cycles.

Grades	Norms		
	ASTM	UNS	EN
K09X	409	S40900	1.4512
K39M	430Ti	S43036	1.4510
K33X			1.4513
K41X	441	S43932	1.4509
304D	304	S30400	1.4301

K33X's oxidation resistance is limited to 870°C. Its oxidation resistance is greater than that of 1.4301 austentic grade and that of, EN 1.4512. It is also slightly greater than that of K39M, EN 1.4510.

Its resistance to oxidation turns out to be limited compared to K41X, 1.4509, which is niobium and titanium stabilised.

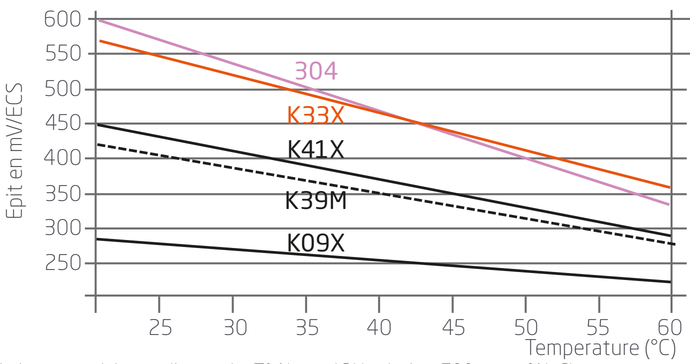


Cyclic oxidation: Temperature influence on oxidation (oxide metal loss)

Corrosion Resistance

Pitting Corrosion Resistance

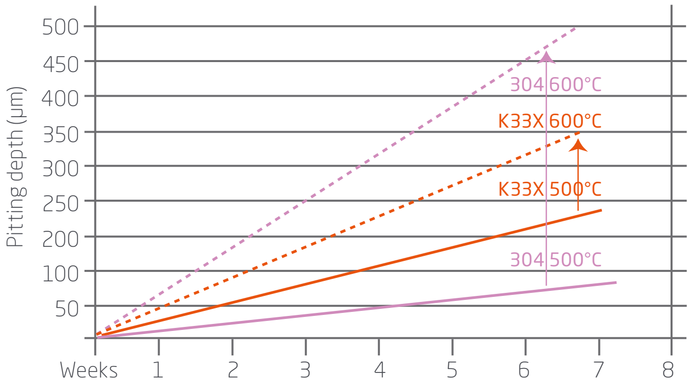
Our K33X grade is not susceptible to stress corrosion. Its molybdenum content offers an improved pitting corrosion resistance compared to K39M, 1.4510. The pitting corrosion resistance of stainless steel decreases according to temperature, with this change being more pronounced in austenitic grades than in ferritic grades.
K33X grade records good pitting corrosion resistance at high temperatures. As a result, it can be readily compared to austenitic 1.4301.



Pitting potential according to the T°. Neutral PH solution, 700 ppm of NaCl.

Temperature influence on condensates corrosion resistance

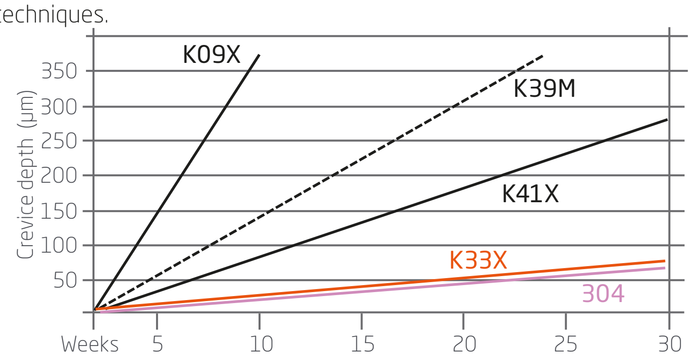
The arrival of new after-treatments, such as particulate filters and NO_x traps, increase the temperatures in the downstream exhaust. K33X is well-suited to this evolution, thanks to its low thermal expansion and stabilising elements. The stabilizers allow for the avoidance of intergranular corrosion, which becomes particularly present in 1.4301 as soon as the temperature exceeds 500°C.



Pitting depth depending on time. Dip and Dry trial with 100 ppm of Cl

Condensates corrosion resistance

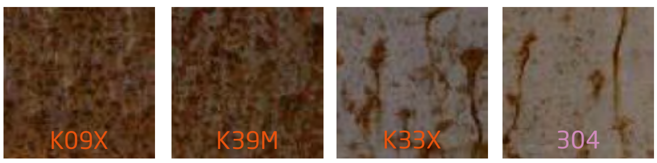
Good resistance to condensates corrosion is a key factor in the material qualification of an exhaust system. K33X grade has been optimized to satisfy these properties and to offer a ferritic substitute to the costly 1.4301 solution.
In the exhaust, the qualification of resistance to condensates corrosion is done by successive immersion/emersion phases, or 'Drip & Dry' testing, in chosen condensates with regular passing into the furnace to simulate an automotive cycle. K33X offers a good compromise between costs and techniques.



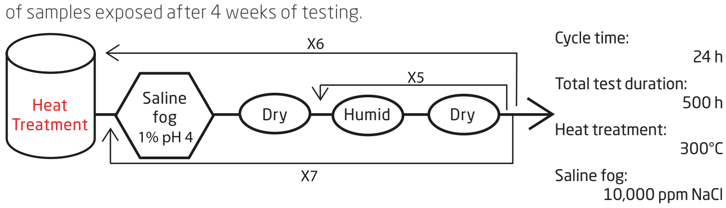
Pitting depth depending on time. Dip and Dry trial with 100 ppm of Cl

Resistance to external corrosion by salt

In addition to the durability criteria, car manufacturers are increasingly sensitive to the aspect of the exhaust system. In response to this demand, we built a test that simulates the external aggressions on the exhaust system by successive sequences of wetting and drying in a salty atmosphere with regular heating at 300°C. Samples are classified depending on oxidation and corrosion. K33X shows a corrosion resistance close to that of austenitic grade 1.4301.



Corrosion tests in climatic chambers to simulate external corrosion phenomena. Illustration of samples exposed after 4 weeks of testing.



Grade classifications in regards to cosmetic corrosion

Grade	K09X	K39M	304D	K41X	K33X	K09X AI [1]	K44X [2]
Cosmetic corrosion	--	0	+	+	+	++	++

[1] EN 1.4512 Alusi®, type 409Al - [2] EN 1.4521, Type 444

-- : Insufficient / - : Acceptable / 0 : Medium / + : Good / ++ : Excellent

Forming

K33X can be readily cold formed using standard processes (folding, bending, drawing, etc.).

Erichsen trial (stretching trial) & LDR (deep drawing trial)

Grades	European designation	Erichsen deflection*(mm)	LDR (mm)
K33X	1.4513	10.2	2.31

*Typical values – 1.0 mm thick sheet

Welded tube bending

Bending	Ra=R/Dmini
Tube Ø 50 mm x 1.5mm	1.2

Typical values - Ra = bending ratio, D = tube diameter, R = bending radius

Welding

K33X can be resistance welded using both spot and seam techniques. Good results are obtained without the need for post treatment so long as the forging of the weld is sufficient.

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

[1] According to EN ISO 14343 - [2] According to AWS A5.9 - [3] According to VDEH - [4] According to AWS A5.4 - [5] According to EN 1600

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 employed, while 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, the power should not exceed 2.5 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. K33X has excellent medium and high frequency induction weldability. Post-weld heat treatment is generally not necessary. The welds must be mechanically or chemically descaled, then passivated and decontaminated. Oxyacetylene torch welding must be avoided.

Heat Treatment and Finishing

Annealing

- At 950°C followed by air cooling. Do not exceed 1,000°C
- Parts must be thoroughly degreased prior to any heat treatment operation

Pickling

- Nitric-hydrofluoric acid mixture (10% HNO_3 + 2% HF)
- Use descaling pastes for weld zones

Passivation

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

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