Alleima® 3RE60
Tube and pipe, seamless
Datasheet

Alleima® 3RE60 is a duplex (austenitic-ferritic) stainless steel characterized by the following properties:

- High resistance to stress corrosion cracking (SCC) in chloride-bearing environments
- Good resistance to general corrosion and pitting
- High mechanical strength – roughly twice the proof strength of austenitic grades
- Good resistance to erosion corrosion and corrosion fatigue
- Physical properties that present design advantages
- Good weldability

Standards

- UNS: S31500
- EN Number: 1.4424
- EN Name: X2CrNiMoSi18-5-3
- W.Nr.: 1.4417
- DIN: X 2 CrNiMoSi 19 5
- SS: 2376
- AFNOR: Z2 CND 18.05.03

Product standards
Seamless and welded tube: ASTM A789
Seamless and welded pipe: ASTM A790
Seamless tube: EN 10216-5, NFA 49-217

Approvals
Approved for use in ASME Boiler and Pressure Vessel Code section VIII div. 1 and 2 construction NGS 1604 (Nordic rules for application of SS 2376)
VdTÜV-Werkstoffblatt 385 (Nichtrostender ferritisch-austenitischer Stahl).

Chemical composition (nominal)

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo	N
≤0.030	1.6	1.5	≤0.030	≤0.015	18.5	4.5	2.6	0.07

Applications

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3RE60 is an excellent material for use in chloride-bearing environments where pitting and stress corrosion cracking are potential problems. In such environments, 3RE60 is far superior to the standard austenitic steels. The material is therefore particularly well suited for use in heat exchangers that work with cooling water with moderate chloride contents.

Typical application examples are found in oil refineries, chemical and petrochemical plants and within the pulp industry.

The high strength and hardness of 3RE60 make the material an attractive alternative to the austenitic steels in structures that are subjected to heavy loads or wear.

Corrosion resistance

General corrosion

In terms of resistance to general corrosion, 3RE60 is comparable or superior to AISI 316L in most media. The table below contains examples of corrosion data obtained from laboratory tests in formic and hydrochloric acid.

Per cent by weight	**Temperature[1)]**		**Corrosion rate 3RE60**		**AISI 316L**	
	°C	**°F**	**mm/year**	**mpy**	**mm/year**	**mpy**
Formic acid, HCOOH	B	B	0.04	1.6	0.17	6.8
5	B	B	0.15	5.9	0.37	14
10	B	B	0.5	20	0.6	24
25	50	122	0.00	0.0	0.00	0.0
50	B	B	1.1	43	1.5	59
80	B	B	0.35	14	1.0	40
100	70	158	0.01	0.4	0.00	0.0
Hydrochloric acid, HCL	70	158	0.02	0.8	0.36	14
0.3	80	176	0.10	4.0	0.93	37
0.5						
0.5						

1) B=Boiling solution

Resistance to sulphuric acid is shown by the isocorrosion diagram in figure 3. The diagram shows that 3RE60 compares well with AISI 316L in this respect.

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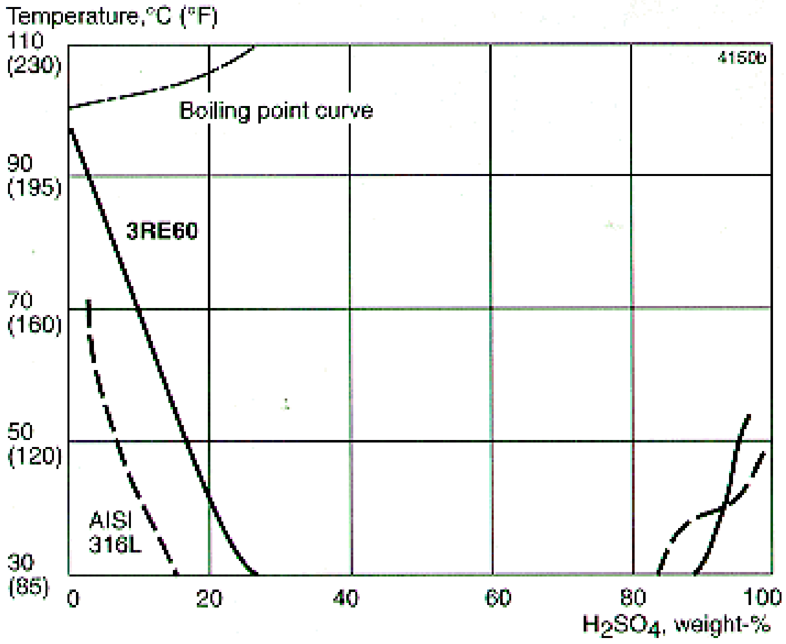

Figure 3. Isocorrosion diagram in sulphuric acid for 3RE60 and AISI 316L. The curves represent a corrosion rate of 0.1 mm/year (4 mpy) in stagnant test solution

For use under strongly oxidizing conditions, e.g. in nitric acid, 3RE60 is not recommended. In such environments, an austenitic steel should be chosen, e.g. Alleima® 3R12 (AISI 304L) or the special steel Alleima® 2RE10 (AISI 310L).

Pitting

The pitting resistance of a steel is improved by increasing the contents of chromium and molybdenum, for example. Compared to steel of the AISI 316 type, 3RE60 has a higher chromium content and therefore better resistance to pitting. Compared to steel of the AISI 304 type, which does not contain molybdenum, 3RE60 is clearly far superior. This is confirmed by potentiostatic measurements of the critical temperature for the initiation of pitting corrosion (CPT) performed in chloride-bearing aqueous solutions, figure 4.

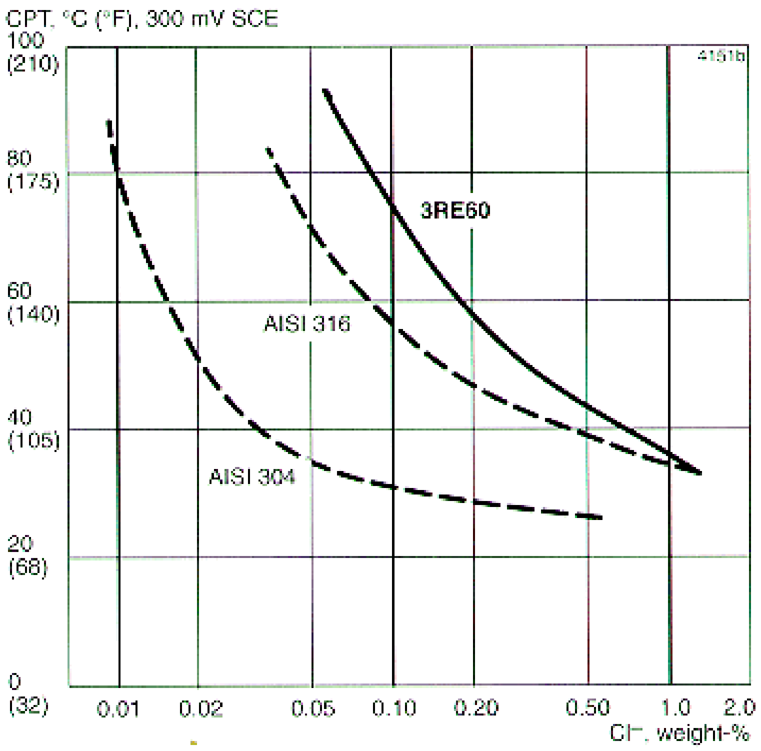

Figure 4. Critical pitting temperature (CPT) for 3RE60, AISI 304 and AISI 316 in neutral chloride solutions (potentiostatic determination at +300 mV SCE.

Stress corrosion cracking

The standard austenitic steels AISI 304L and AISI 316L are prone to stress corrosion cracking (SCC) in chloride-bearing solutions at temperatures exceeding about 60°C (140°F).

Duplex stainless steels are much less sensitive to this type of corrosion. The good resistance of 3RE60 to SCC has been proved by laboratory tests, but more significantly by extensive operating experience during the past 20 years. Operating experience and laboratory results have been compiled in figure 5.

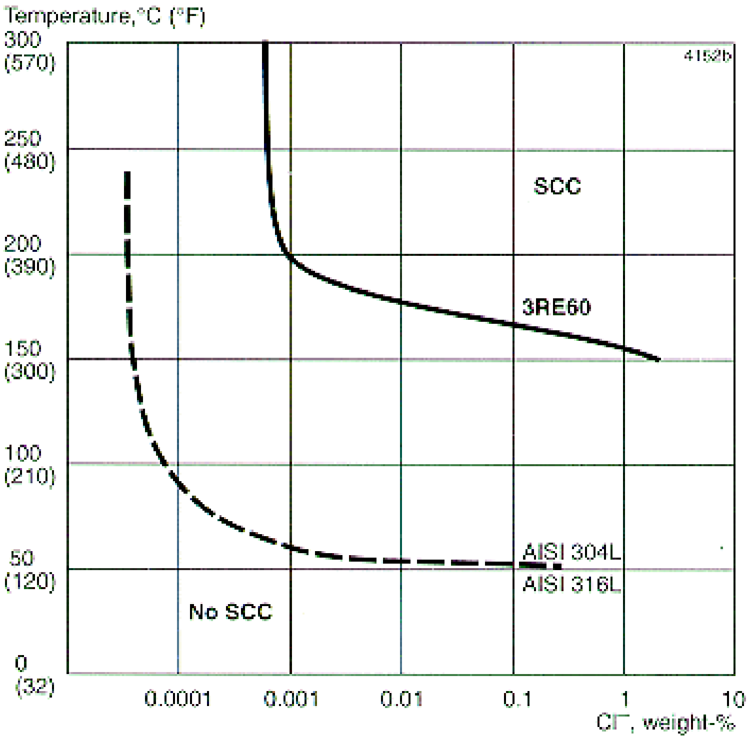

Figure 5. Resistance to stress corrosion cracking, compilation of laboratory results and practical experience.

The diagram indicates the temperature-chloride range within which 3RE60 and the standard steels AISI 304L and AISI 316L can be used without any risk of stress corrosion cracking. At high chloride contents, resistance to pitting is often a limiting factor. In such cases, we recommend using the duplex stainless steel SAF™ 2205, a steel with 22% Cr, 5.5% Ni and 3% Mo.

Results of laboratory tests carried out in calcium chloride are shown in figure 6. The tests have been continued to failure or a maximum of 500 h. The diagram shows the much greater SCC resistance of 3RE60 compared to the austenitic standard steels AISI 304L and AISI 316L.

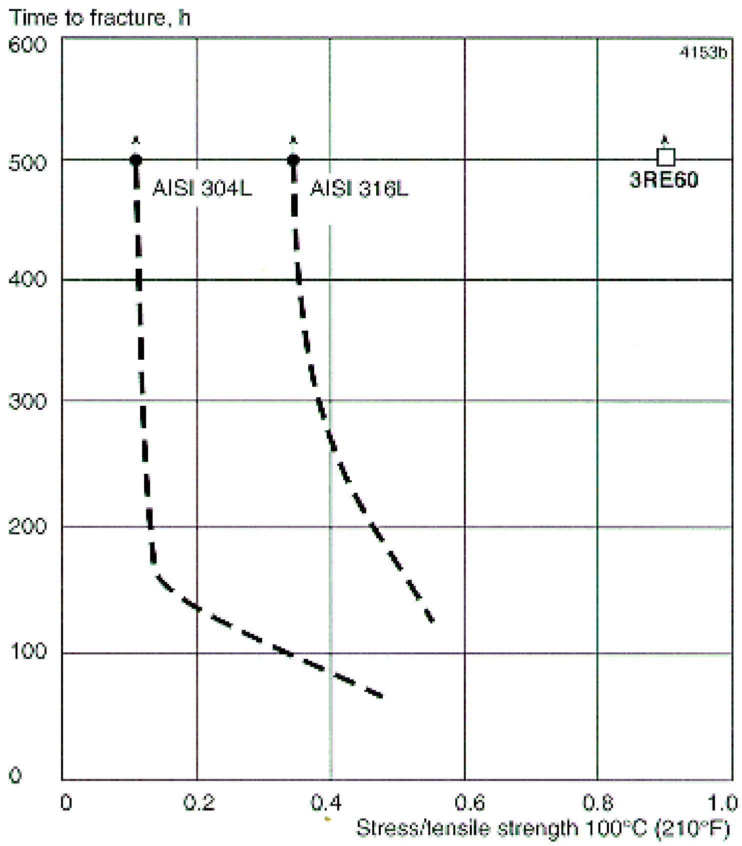

Figure 6. Results of SCC tests on 3R60, AISI 316L and AISI 304L in 40% $CaCl_2$ at 100°C (210°F) with aerated test solution.

Intergranular corrosion

3RE60 is a member of the family of modern duplex stainless steels whose composition has been balanced in such a manner that, when welded, the reformation of austenite in the heat-affected zone adjacent to the weld takes place quickly. This results in a micro-structure that gives corrosion properties and toughness roughly equal to that of the parent metal. The long experience with 3RE60 in welded structures has confirmed the steels high resistance to intergranular corrosion.

Crevice corrosion

In the same way as the resistance to pitting can be related to the chromium and molybdenum contents of the steel, so can the resistance to crevice corrosion. 3RE60 therefore possesses better resistance to crevice corrosion than steels of the AISI 316L type.

Erosion corrosion

Steels of the AISI 316L type are attacked by erosion corrosion if exposed to flowing media containing highly abrasive solid particles. Due to its high hardness, 3RE60 displays very good resistance under such conditions.

Corrosion fatigue

In certain applications, e.g. suction rolls in paper mills, the resistance of the material to corrosion fatigue has a crucial bearing on its service life.
Laboratory tests have shown that 3RE60 has far better fatigue strength under corrosive conditions than the AISI 316L type of steels. This applies to both quench-annealed and welded material. The difference between the two steel grades is explained by the superior mechanical strength of 3RE60.

Rotary bending fatigue tests have been carried out on 3RE60 and AISI 316L at room temperature in a solution containing 400 ppm Cl^- and 250 ppm SO_4^{2-}, pH = 3.5. The test results are shown in figure 7.

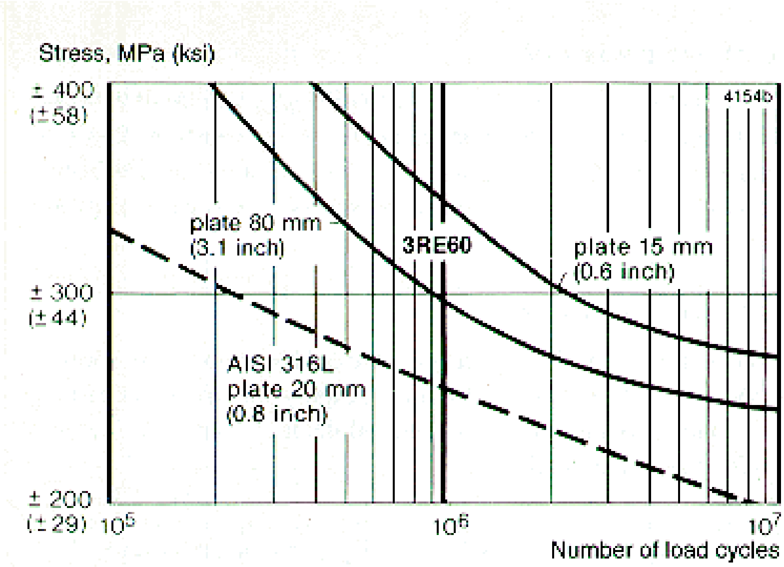

Figure 7. Results of corrosion fatigue tests on 3RE60 and AISI 316L.

Fabrication

Bending

The force requirement for bending is about twice as high for 3RE60 as for AISI 304L/316L, but when the proof strength is exceeded, the plastic deformation takes place just as easily in 3RE60 as in austenitic stainless steels. 3RE60 can be cold-bent to 25% deformation without requiring subsequent heat treatment.

However, under service conditions where the risk of stress corrosion cracking starts to increase for example where the material temperature is nearly 150°C (300°F) in an oxygen-bearing environment with around 100 ppm Cl^-, heat treatment is recommended even after moderate cold bending.

Heat treatment is carried out in the form of solution-annealing (see under this heading) or resistance annealing. Hot bending is carried out at 1100-950°C (2010-1740°F) and should be followed by solution-annealing.

Expanding

In comparison with austenitic stainless steels, 3RE60 has a higher 0.2% proof strength and a higher tensile strength. This must be borne in mind when expanding tubes into tube-sheets. Normal expanding methods can be used, but the expansion requires higher initial force and should be undertaken in one operation.

Machining

The mechanical machining of stainless steels always requires an adjustment of cutting data and machining method to give satisfactory results. When turning is undertaken with carbide-tipped tools, the cutting speed should be reduced by 20% for finish machining and 60% for rough machining compared to the cutting speeds applied for AISI 316. Much the same applies to other operations. If high-speed steel tools are used, approximately the same cutting speed can be used as for AISI 316.

Detailed recommendations for the choice of tools and cutting data are provided in brochure S-1,462-ENG. Select data as for grade 5R60 (AISI 316), taking into account the above comments.

Forms of supply

Seamless tube and pipe

Seamless tube and pipe are supplied in the solution-annealed and white-pickled condition. Smaller sizes may be bright-annealed. The principal size range is shown in figure 1. Tubes can be bent according to customer drawings, and on request annealed after bending.

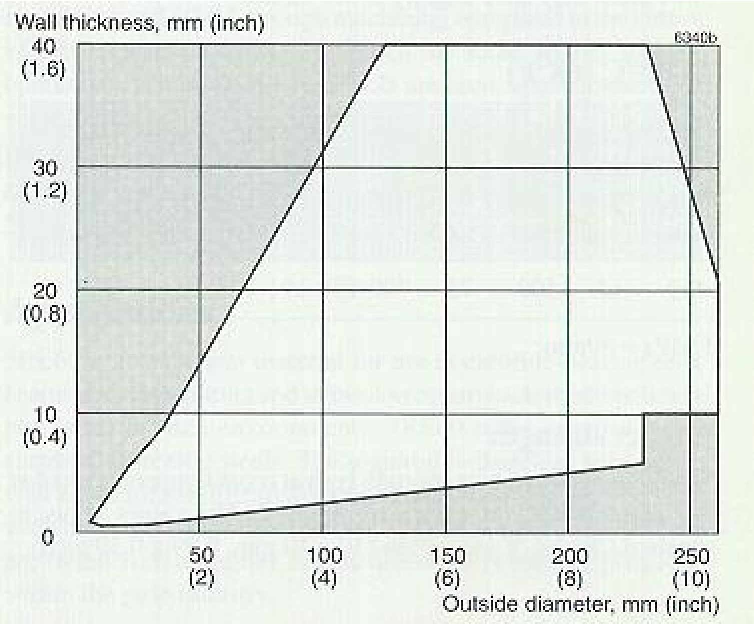

Figure 1. Principal size range for seamless tube and pipe.

Other forms of supply

Alleima 3RE60 can also be supplied in forms of

- Welded tube and pipe
- Fittings
- Strip, annealed or cold-rolled to different degrees of hardness
- Bar steel
- Plate, sheet and wide strip
- Forged tube-sheets

Stock availability

Seamless tube and pipe

Seamless tube for heat exchangers according to ASTM A789 is stocked in the solution-annealed and white-pickled condition in size (average wall): 32 x 1.5 mm.

Filler metal for welding

Filler metal for welding is stocked in the following diameters:
welding wire Alleima 22.8.3.L
0.80, 1.60, 2.0 and 2.4 mm (2/64, 1/16, 5/64 and 3/32 in.)
covered electrodes Alleima 22.9.3.LR
2.5, 3.25 and 4.0 mm (3/32, 1/8 and 5/32 in.)

Heat treatment

The tubes are normally delivered in heat treated condition. If additional heat treatment is needed after further processing the following is recommended.

Solution annealing

990-1130°C (1815-2065°F), rapid cooling in air or water.

Mechanical properties

The following values apply to material in the solution-annealed condition. Tube and pipe with wall thicknesses above 20 mm (0.79 in.) may have slightly lower values.

At 20°C (68°F)

Metric units

Proof strength		Tensile strength	Elong.		Hardness
$R_{p0.2}$[a]	$R_{p1.0}$[a]	R_m	A[b]	$A_{2"}$	HRC
MPa	MPa	MPa	%	%	
≥480	≥500	700-880	≥30	≥30	≤28

Imperial units

Proof strength		Tensile strength	Elong.		Hardness
$R_{p0.2}$[a]	$R_{p1.0}$[a]	R_m	A[b]	$A_{2"}$	HRC
ksi	ksi	ksi	%	%	
≥65	≥73	101-128	≥30	≥30	≤28

1 MPa = 1 N/mm^2
a) $R_{p0.2}$ and $R_{p1.0}$ 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.

Impact strength

3RE60 has good impact strength both at room temperature and at low temperatures, as shown by figure 2. The values apply to standard Charpy-V specimens (10 x 10 mm, 0.39 x 0.39 in.).

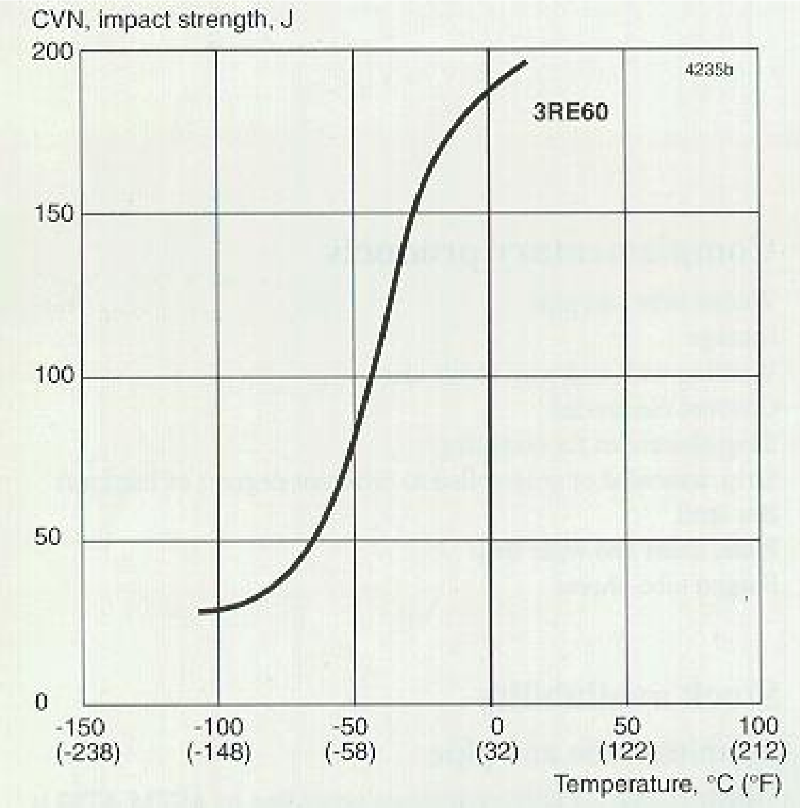

Figure 2. Curve showing typical impact strength values (Charpy-V) for 3RE60. Specimen size 10 x 10 mm (0.39 x 0.39 in.).

At high temperatures

If 3RE60 is exposed for prolonged periods to temperatures exceeding 300 °C (570 °F), the microstructure changes which results in a reduction in impact strength. This effect does not necessarily affect the behavior of the material at the operating temperature. For example, heat exchanger tubes may be used at higher temperatures without any problems. Contact Alleima for advice.

For pressure vessel applications, 300 °C (570 °F) is required as maximum according to VdTÜV-Wb 385 and NGS 1604.

Metric units

Temperature	Proof strength
	$R_{p0.2}$
°C	MPa
	min
50	430
100	370
150	350
200	330
250	325

300	320

Imperial units

Temperature	Proof strength
	$R_{p0.2}$
°C	ksi
	min
120	62.5
200	55.0
300	51.0
400	48.0
500	47.0
600	46.0

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	475	68	0.11
100	505	200	0.12
200	530	400	0.13
300	555	600	0.14
400	580	800	0.15

Thermal conductivity

Metric units

Temperature, °C	20	100	200	300	400
W/m °C	13	15	16	17	19

Imperial units

Temperature, °F	68	100	200	300	400
Btu/(ft h °F)	7.5	8.5	9.0	10.0	11.5

Thermal expansion, mean values (x10^{-6})
3RE60 has a far lower coefficient of thermal expansion than austenitic stainless steels and can therefore possess certain design advantages.

Metric units

Temperature, °C	30-100	30-200	30-300	30-400
	Per C			
3RE60	13.0	13.5	14.0	14.5
Carbon steel	12.5	13.0	13.5	14.0
AISI 316L	16.5	17.0	17.5	18.0

Imperial units

Temperature, °F	86-200	86-400	86-600	86-800
	Per F			
3RE60	7.0	7.5	7.8	8.0
Carbon steel	7.0	7.0	7.5	7.8
AISI 316L	9.0	9.5	10.0	10.0

Modulus of elasticity

Temperature, °C	MPa	Temperature, °F	ksi
20	200	68	29.0
100	194	200	28.2
200	186	400	28.1
300	180	600	26.0

1) (x10^{3})

Welding

The weldability of Alleima® 3RE60 is good. Welding must be carried out without preheating and subsequent heat treatment is normally not necessary. 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.

For Alleima® 3RE60, 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

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)

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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 Alleima materials.