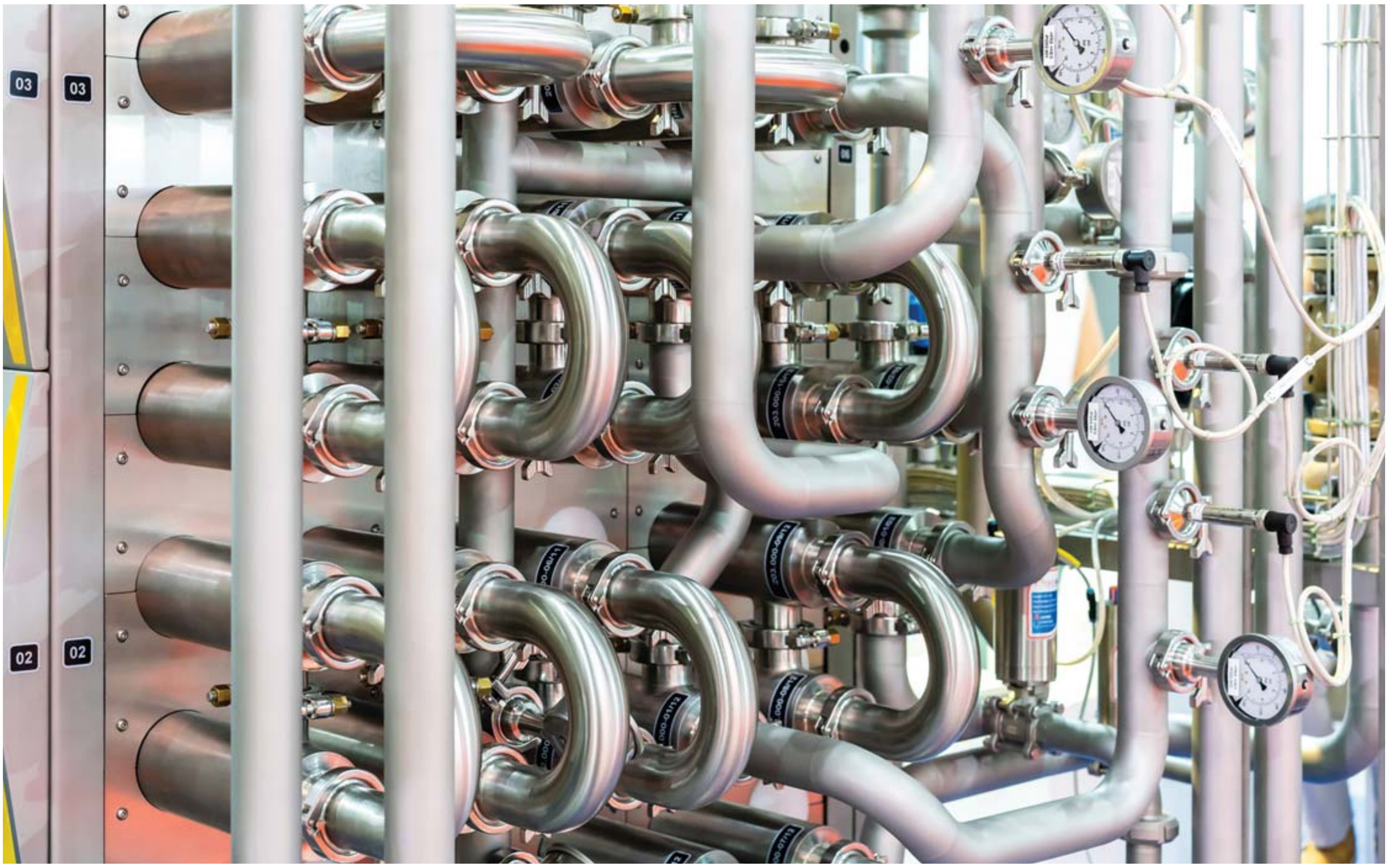

Austenitic stainless steel grades for high-temperature applications

Stainless steel grade 310 is the most popular heat and creep resistant steel used in super-heater tubing. The grade is popular for heat exchanger applications due to its corrosion and heat resistance, design flexibility for fabrication, and suitability for a wide range of pressures and temperatures.

By Srikumar Chakraborty, ex Sr. Executive, ASP/SAIl, Member of Freelance Consulting Team; and Abhijit Niyogy, ex DGM I/C, RCL, ASP, Former Consultant, MN Dastor CO, India

Heat exchangers are key elements in many gas furnace applications. High-efficiency gas furnaces typically include a primary heat exchanger where hot combustion products are cooled by extracting high heat, with a secondary condensing heat exchanger mounted in tandem. Partially cooled combustion products are conveyed to the secondary heat exchanger in the form of condensing heat to effect further heat extraction and cooling. In practice, heat extraction and cooling commonly result in the condensation of water vapour from combustion products and a release of about 10-20 per cent of the heat which would be otherwise unavailable. Consequently, furnaces equipped with such condensing heat exchangers can desirably operate at efficiencies above 88 per cent. In fact, typical modem condensing furnaces can achieve fuel utilisation efficiency above 96 per cent. Stainless 310 grade stainless is the most popular heat and creep resistant steel used in super-heater tubing. Its popularity in heat exchanger applications is due to its quality, corrosion and heat resistance properties, and ease and flexibility of design for fabrication while allowing for a wide range of pressures and temperatures. Shell and tube exchangers produced in this grade consist of tubes mounted inside a cylindrical shell. Such heat exchangers are most commonly used in the petrochemical and power industries, for instance in power plant condensers and feed-water heaters.

Grade characteristics

Within the stainless steel family, chromium is the defining alloying element giving steel its ‘stainless’ property. It creates a passive layer of chromium oxide on the surface which blocks oxygen diffusion into the metal, protecting the metal’s internal structure from corrosion. Oxide ions are also similar in size to steel molecules, resulting in a strong bond between the two and enabling oxide ions to remain

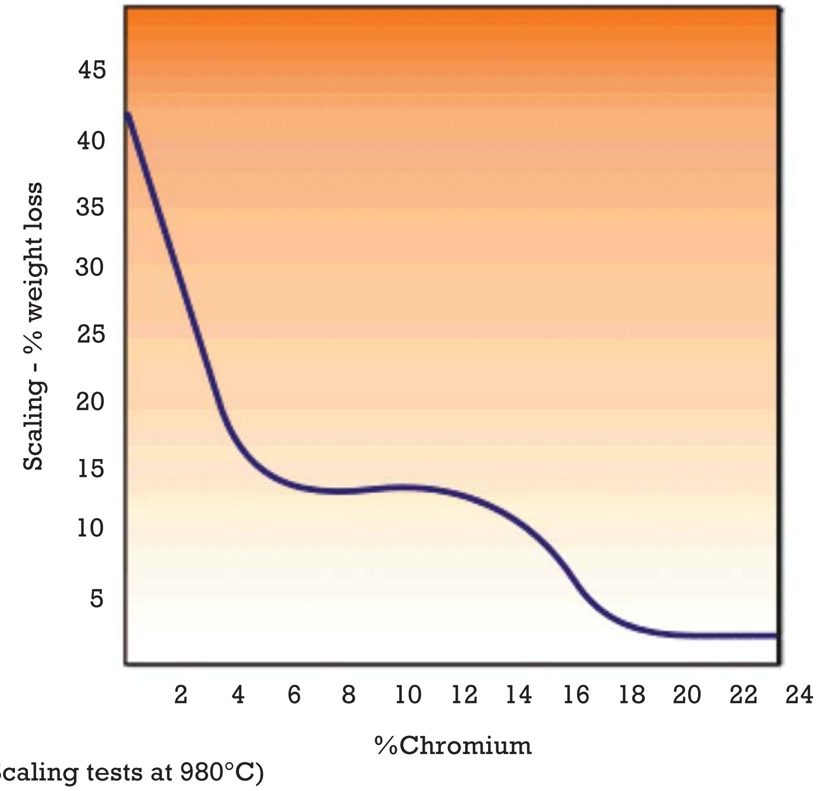

Figure 1. Effect of chromium content on scaling resistance of chromium-iron alloys.

Oxidation rate of grade 310 (MPY*)	
871 °C	1093 °C
< 5	64

**MPY = 0.001 inch (0.0254mm), penetration in 2 inch (50mm), square 1/6 inch (3.175mm) thick coupon (in air) data[1].*

strongly attached to the surface under normal working conditions. Members of the stainless steel family also have heat resistant properties.

A minimum of 10.5 per cent chromium is necessary for a steel to be 'stainless'. The addition of more chromium when balanced with increased nickel results in highly corrosion and heat resistant stainless steel with improved mechanical properties, e.g. grades 310 and 309. Chromium acts as a ferrite stabiliser, causing the formation of the ferrite microstructure in stainless steel. Higher nickel addition in this grade further improves corrosion resistance and acts as an austenite stabiliser, prompting austenite structure formation. High nickel in this grade provides excellent welding properties during fabrication and also ease of workability.

Resistance to oxidation, or scaling, is dependent on the chromium content in the same way as the corrosion resistance is, as shown in Figure 1. However, most austenitic steels, with chromium contents of at least 18%, can be used at temperatures up to 870°C and Grades 309, 310 and 308 even higher. Most martensitic and ferritic steels have lower resistance to oxidation and hence are useful at lower operating temperatures. An exception to this is the ferritic grade 446 which contains approximately 24% chromium, and can be used to resist scaling at temperatures up to 1100°C.

Table 1 shows the approximate maximum service temperatures (°C) at which the various grades of stainless steels (AISI) can be used while still resisting oxidation in dry air.

The values of Table 1 indicate the safe working of stainless steel in heated parts of a furnace or heat exchanger. Both the grade 309 and grade 310 are suitable for use. These temperatures depend very much on the actual environmental conditions, and in some instances, substantially lower temperatures result in destructive scaling.

Grade 310 is a low carbon (0.25% max) austenitic stainless steel. It is suitable for high-temperature applications such as furnace parts, heat treatment equipment and heat exchangers where parts can safely be used at operating temperatures up to 1150°C in continuous service, and 1035°C in intermittent service. It has excellent resistance to oxidation under mildly cyclic conditions through 1093°C, and resistance to hot corrosion and moderate strength at high temperature. Its high Cr and high Ni contents provide comparable corrosion resistance, superior resistance to oxidation and the retention of a larger fraction of room temperature strength than the common austenitic alloys such as grade 304. Stainless 310 is often used at cryogenic temperatures, with excellent toughness to - 232°C, and low magnetic permeability.

Application areas of grade 310

Various industries utilise products fabricated in grade 310. These include

Table 1. Maximum service temps (°C) in dry air

Grade	202	302	304	309	**310**	316	321	333	410	442	446
Intermittent	815	870	870	980	**1035**	870	870	1035	815	1035	1175
Continuous	845	925	925	1095	**1150**	925	925	1150	705	980	1095

Table 2. Process metallurgy & chemical composition of austenitic stainless steel (%)

Grade	Cmax	Simax	Mn max	P max	S max	Cr	Ni	Mo
304	0.08	1.00	2.00	0.035	0.030	18-20	8-10.5	–
316	0.08	1.00	2.00	0.035	0.030	16-18	10-14	2-3
309	0.20	1.00	2.00	0.035	0.030	22-24	12-15	–
310	**0.25**	**1.50**	**2.00**	**0.035**	**0.030**	**24-26**	**19-22**	**–**
333*	0.08	0.75	2.0	0.035	0.030	24-27	44-47	2.5-4 &
W 2.5- 4.0, Co 2.5- 4.0, Alloying elements> 80%								

Products manufactured from stainless steel grade AISI 310


Tubes in heat exchanger


Radiant tube heat exchanger


Gas cooling heat exchanger


U-tube heat exchanger


Heat resistant seamless coil tubing


Heat resistant flange

Grade AISI 310 high-temperature parts of heating furnace

Common quality problems with carbon steel heat exchanger tubing


Corroded Tube


Erosion in Tube


Erosion at Bending


Fatigue Crack in Tube

tube fittings, kilns, heat exchangers, radiant tubes, mufflers, retorts, annealing covers, tube hangers for petroleum refining and steam boilers, coal gasified internal components, furnace parts, conveyor belts, rollers, oven linings, fans, food processing equipment and cryogenic structures. Stainless steel 333 may be termed as a super-alloy. It is a costly, high Cr-Ni based alloy with excellent resistance to carburisation and high-temperature oxidation, and an exceptional ability to withstand the repeated thermal shock of water or oil quenching. It is one of the few stainless steel alloys that can resist polythionic acid stress corrosion cracking and dew point corrosion by sulfuric acid. Stainless steel grades, scrap and ferro-alloys are melted at 1510°C in electric arc or induction furnaces. Bottom Poured Ingots are either rolled or forged at hot working temperatures of 1150-1200°C, with finishing temperatures maintained preferably at 900-950°C. For annealing, products should be slowly heated to between 1050-1150°C, depending on product size, and quenched in water when all the carbides present will go in solution. Carbon steel was previously used for heating parts and components in low-temperature applications in. However, as defects led to shorter end life products gradually shifted at stainless steel grades.

Conclusion

Grade 310 is a fully austenitic stainless steel containing 25% Cr, 20% Ni and 1.5% Si and 2% Mn, and is well known for its multi-purpose high-temperature corrosion resistance behaviour. A carbon level of 0.25% is optimised to provide improved creep resistance properties. Products of this grade can be easily welded during fabrication and safely designed for high-temperature applications up to 1100°C in oxidising atmospheres, nitriding, cementing, sulphurising conditions as well as with thermal cycling when the maximum temperature of use may be reduced.

References

1. Dr. Jack Titus, Journal on Thermal Processing
Ref: AISI, Journal of Thermal Processing, Observation in Mini Steel Plant