

Material selection for storage tanks

Sandra Le Manchet
INDUSTEEL
56 rue Clémenceau
Le Creusot, 71200
France

John Grocki
INDUSTEEL
PO BOX 1117
Enfield CT 06083
Connecticut, USA

ABSTRACT

This paper is dedicated to material selection and Life Cycle Cost (LCC) of storage tanks. There are many materials options for the construction of storage tanks among which are coated carbon steels, austenitic stainless steels and duplex stainless steels. Material choice requires the designer to consider several features: material performance, material cost and availability, weight and strength aspects, fabrication and maintenance costs. All are important factors in determining the lowest project and life cycle cost. Duplex stainless steels are more often considered for storage tanks projects today due to their good corrosion resistance in many environments and their higher mechanical properties.

This paper will provide recent corrosion data for stored chemicals. Duplex stainless steel corrosion curves obtained in nitric, sulfuric, phosphoric acids as well as several kinds of waters will be provided. In addition, atmospheric corrosion data obtained after 15+ years of sample exposures in several geographic areas will be shown. These results will be compared to those obtained with other materials commonly used for the construction of storage tanks.

The second part of the paper will be focused on duplex fabrication considerations related to welding, forming and cutting. Fabrication guidelines will be outlined, including welding parameters, filler materials and dissimilar alloy welding.

Finally, several case studies of material selection for storage tank projects will be provided. Special attention will be paid to their LCC analyses. Simulations performed by means of a software program based upon API 650 calculation code will be shown considering several tank dimensions. Several cost components will be considered to compare the LCC of the different materials options: initial costs of metallic materials and coatings, fabrication costs and maintenance costs.

INTRODUCTION

There are many materials options for the construction of storage tanks. The most commonly used materials are coated carbon steels, austenitic stainless steels and duplex stainless steels.

Duplex stainless steels are more often considered for storage tanks projects today due to their high mechanical properties and good corrosion resistance in many environments. This paper provides recent data related to the use of duplex steels for storage tanks, focusing on corrosion resistance, fabrication and Life Cycle Cost (LCC).

The first part of this paper is dedicated to the corrosion resistance of duplex stainless steels in various chemical environments such as nitric, sulfuric, phosphoric acids as well as industrial water. In addition, atmospheric corrosion results obtained after long-term exposures in various locations are provided.

The second part of the paper focuses on duplex fabrication considerations related to welding, forming and cutting. Recent laboratory data on dissimilar welds is provided.

Finally, several case studies of material selection for storage tank projects are shown. Special attention is paid to their LCC analyses. Simulations are performed by means of a software program based upon API⁽¹⁾ 650 design/calculation code, considering several tank dimensions.

Chemical compositions

The typical chemical compositions of the steels mentioned in this paper are reported in Table 1. This table also shows their PREN (Pitting Resistance Equivalent Number) values. This empiric index is calculated using the following formula: $PREN = \%Cr + 3.3 \%Mo + 16 \%N$. The PREN is used to rank the pitting corrosion resistance of stainless steels in chloride-containing media.

The lean duplex grade UNS S32202 (2202) was developed to provide a cost-efficient alternative to the austenitic stainless steel S30403 (304L) ¹. Compared to 304L, this 2202 presents equal or better corrosion resistance performance, in terms of uniform, localized (pitting and crevice) and intergranular corrosion, and doubles the yield strength.

The lean duplex grade UNS S32304 (2304) was developed to match the corrosion resistance of the austenitic S31603 (316L) in most environments and enhanced mechanical properties. Today both lean duplex materials are widely used in the water and pulp & paper industries, i.e. for applications requiring a moderate corrosion resistance and good mechanical properties.

The medium-alloyed grade UNS S31803 (2205) is a 22%Cr steel which is commonly used in the oil & gas industry for piping and topside equipment. Finally, the 25%Cr super-duplex material UNS S32750 (2507) is dedicated to highly aggressive environments in the chemical industry or for seawater applications.

⁽¹⁾ API, 1220 L Street, NW, Washington, DC, 20005-4070, US

Table 1
Typical chemical compositions (weight %)

Family	Usual name	UNS	C	Cr	Ni	Mo	N	PREN
Austenitic	304L	S30403	<0.030	18	8.5	-	-	19
	316L	S31603	<0.030	17	10.5	2.1	-	24
Duplex	2202	S32202	<0.030	22	2	-	0.20	25
	2304	S32304	<0.030	23	4	-	0.14	25
	2205	S31803	<0.030	22.5	5.3	2.7	0.18	33-34
	2507	S32750	<0.030	25	7	3.5	0.27	41

Mechanical and physical properties

The typical mechanical properties of these materials are given in Table 2. The yield strength of the duplex materials is almost double that of standard austenitic stainless steels (which are not alloyed with nitrogen). This may allow the design engineer to decrease the wall thickness in some applications. Examples of thickness reductions will be provided.

The thermal expansion of duplex stainless steels is similar to carbon steels (and lower than austenitics) which helps when welding duplex to carbon steel structures. It should also be noted that duplex steels are magnetic.

Table 2
Typical mechanical properties (indicative values for 20 mm thick plates at room temperature)

Family	Usual name	UNS	YS _{0.2%}		UTS		E%
			MPa	Ksi	MPa	Ksi	
Austenitic	304L	S30403	270	39	570	83	45
	316L	S31603	295	43	580	84	45
Duplex	2202	S32202	520	75	710	103	30
	2304	S32304	480	70	670	97	25
	2205	S31803	530	77	750	109	25
	2507	S32750	620	90	820	119	25

INTERNAL CORROSION

Duplex stainless steels are often considered for storage of chemicals and industrial waters. Recent studies have demonstrated that they present equal or better corrosion resistance than austenitic stainless steels in a wide range of temperatures and concentrations. The following paragraphs report new data related to the corrosion resistance of duplex and austenitic grades in several corrosive media.

Nitric acid

Nitric acid is a highly corrosive mineral acid that is mainly used in the fertilizer industry to produce ammonium nitrate. The austenitic stainless steel 304L is commonly used in pure nitric acid. It is resistant over a wide range of temperatures and concentrations as shown on figure 1 ². Recent laboratory tests have demonstrated that the lean duplex stainless steel 2202 presents the same domain of use as 304L in pure nitric acid. It can therefore be considered as a cost effective alternative thanks to its better mechanical properties.

For applications at higher temperatures, 304L and 2202 will not be resistant enough. If the nitric acid concentration remains low, the best material is a modified version of 304L called 304L Nitric Acid Grade (NAG) with extra low carbon, sulfur, phosphorus and silicon, and higher nickel contents. At higher concentrations, the most resistant material will be 310L NAG containing even more chromium and nickel. For highly concentrated nitric acid (above 90%), S30600 with a silicon addition is an excellent material ³.

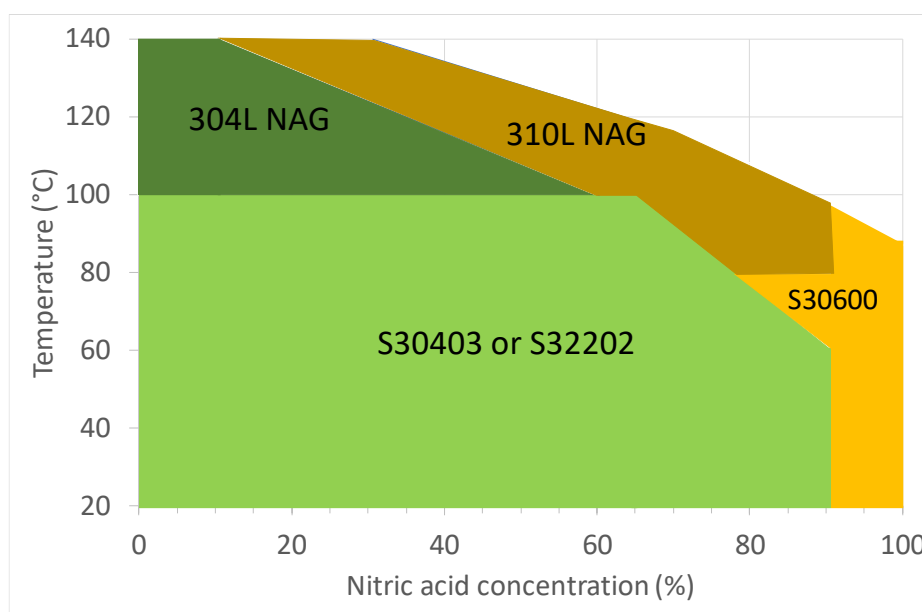


Figure 1: Iso-corrosion curves comparing 304L and 2202 in pure nitric acid – corrosion rate < 0.2 mm/yr below the curves

Sulfuric acid

Sulfuric acid is used in many industrial sectors, such as the fertilizer, chemical and hydrometallurgical industries. At low sulfuric acid concentrations, recent laboratory tests have shown that the lean duplex 2202 presents almost the same corrosion resistance as 2205 duplex stainless steel. It also offers a larger domain of use compared to the austenitic 316L. For instance, 316L can be recommended up to 30°C (86°F) in 10% pure sulfuric acid while 2202 is resistant up to 80°C (176°F) as illustrated on figure 2. However, 22%Cr duplex stainless steel cannot be recommended above 30% pure sulfuric acid. At higher concentrations, the super-duplex stainless steel 2507 can be used (figure 3). These results were obtained by means of 1-week immersion tests. The detailed experimental procedure can be found in a recent technical publication ⁴.