

# Strong sustainable storage tanks

Duplex stainless steel storage tanks are increasingly being used due to their long, low-maintenance service life. Surprisingly, they can also reduce initial costs for tank owners. The higher strength of duplex grades permits thinner walls requiring less steel. Because costly protective coatings or cathodic protection are not necessary, they can compete on installed cost with carbon steel tanks.

Storage tanks range in size from home water heaters to industrial tanks containing millions of liters of petrochemicals. They can be stationary or mobile, and hold solids (powder, grain), liquids (water, milk, food products, petrochemicals, inorganic chemicals, liquefied gases), or gases (biogas, inert gas, reactive gases). Some even transport live fish! Usually made from carbon steel, concrete, plastics, or corrosion-resistant alloys, they are widely used around the world.

Carbon steel tanks dominate the chemical and petrochemical storage business because generally such products are not very corrosive. Even so, moisture and environmental corrosion are still of concern. Therefore, coatings, impressed currents,

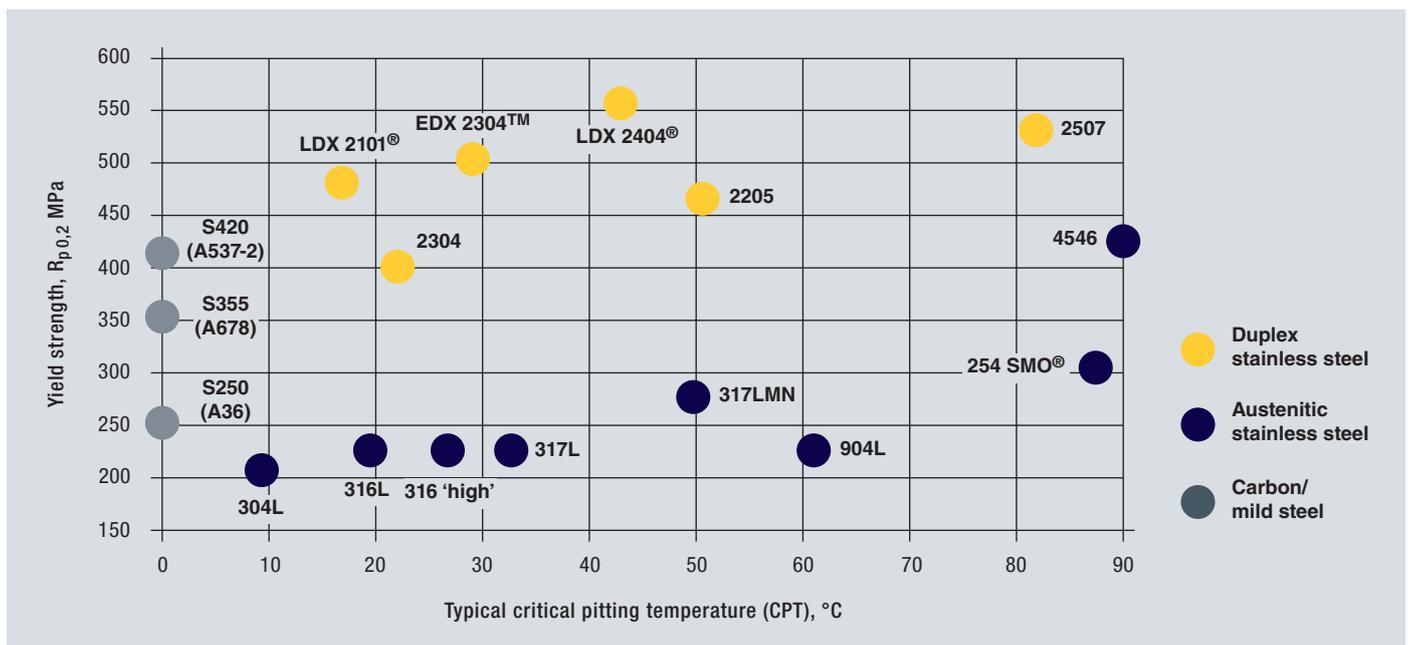
or sacrificial electrodes must be used for protection. Austenitic stainless steel tanks, made from Type 304 or Type 316 stainless steel, are corrosion resistant, so can be used as an alternative. However, they require thicker walls because of their lower strength, which means higher weight and higher material cost, making them somewhat more expensive.

Thanks to their high strength, duplex stainless steel tanks can be less expensive to build than either austenitic stainless steel or carbon steel tanks. The cost advantage is even more pronounced when the whole life-cycle costs are considered. Tank designers most often specify lean duplex steels with 0.3 to 0.5% molybdenum, but select higher-

molybdenum grades for more corrosive environments.

## The strength advantage

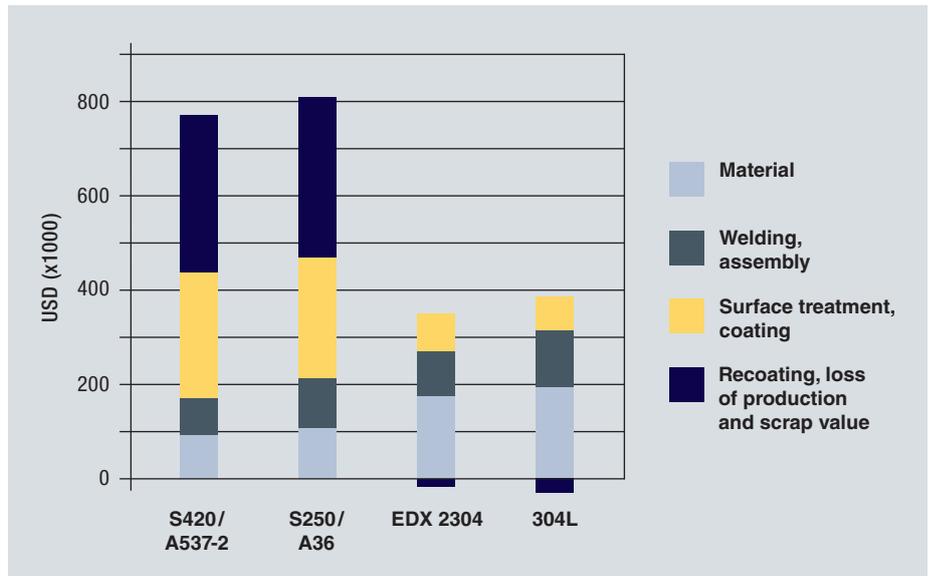
Structural design codes such as EN 14015 (Europe) and API 650 (United States) now incorporate duplex stainless steels. This permits designers to build thinner-walled tanks. The figure below shows the yield strength and pitting corrosion resistance of several carbon and stainless steels. Duplex stainless steels have a great strength advantage over both austenitic stainless steels and carbon steels. As designers and end users learn of these advantages, they increasingly specify, build, and commission duplex stainless steel tanks. ➤



Yield strength and corrosion resistance of a wide range of stainless steels. Carbon steels are added for comparison of their strength only on the 0°C line. Source: Outokumpu

## Benefits beyond strength

**Construction cost** – Corrosion-control measures add substantial cost to carbon steel tank construction. Designs must incorporate a ‘corrosion allowance’, an extra wall thickness beyond what is needed for structural strength, to accommodate any metal loss due to corrosion. Carbon steel tanks also require internal and external coatings to prevent corrosion and often additional anodic or cathodic protection. These elements make a coated carbon steel tank more expensive to build than a duplex stainless steel tank, especially if the tank is built for corrosive contents. The figure summarizing a 30-year life-cycle cost analysis clearly shows that the duplex stainless steel tank is less expensive to build than the alternatives.



30-year life-cycle cost (LCC) for a 20 meter diameter, 20 meter tall tank containing liquid with the density of water operating at 20 °C and designed to API 650. The duplex stainless steel EDX 2304 is compared to two carbon steels on the left and Type 304L stainless steel. It has the lowest installed cost and much lower LCC than the carbon steels. Source: Outokumpu



Palm oil storage tanks in Holland made of LDX 2101® stainless steel. © Lodders Crokiaan



A biogas tank made of LDX 2404 in Germany. © Börger GmbH

**Operating cost and life-cycle cost –**

The same image illustrates the long-term cost advantage of duplex stainless steel. A carbon steel tank must be recoated every five to ten years to keep it protected. Cathodic and anodic protection adds further operating costs for electricity and equipment maintenance for the former as well as electrode replacement for the latter. Duplex stainless steel will require little attention beyond cleaning, increasing tank availability and productivity. A properly specified duplex stainless steel tank will operate practically forever. Even if it is retired for reasons other than deterioration, its higher scrap value further reduces the life-cycle cost.

**Environmental benefits –** Duplex stainless steels are produced with a significant portion of recycled material, partially eliminating the need for energy-intensive mining and refining steps. This conserves resources and reduces overall energy consumption.

Stainless steel tanks also eliminate volatile organic compounds associated with coating processes. Their corrosion resistance greatly reduces the risk of tank failure and the potential for associated spills and damage to life and environment. When decommissioned, duplex stainless steel tanks will be recycled.

**Versatility –** Unlike carbon steel, stainless steel resists many corrosive chemicals. It is compatible with foods and beverages, and is easily cleaned and sanitized. This versatility is particularly important for owners and operators of tank shipping containers and chemical tank ships whose cargo is frequently changing. The greater corrosion resistance ➤

Name	UNS No.	EN No.	C	N	Cr	Ni	Mo
304L	S30403	1.4307	0.03	0.06	18.5	9	–
316L	S31603	1.4404	0.03	0.06	17	11	2.2
LDX 2101	S32101	1.4162	0.03	0.22	21.5	1.5	0.3
2304	S32304	1.4362	0.02	0.10	23	4.8	0.3
EDX 2304	S32304	1.4362	0.02	0.18	23.8	4.3	0.5
LDX 2404	S82441	1.4662	0.02	0.27	24	3.6	1.6
2205	S31803	1.4462	0.02	0.17	22	5.7	3.1

Typical chemical composition in weight percent of stainless steels considered for storage tank applications.



A 2205 stainless steel tank at a brewery in Spain. © Outokumpu

(and flexibility) of a Type 316L austenitic stainless steel with 2% or 2205 duplex stainless steel with 3% molybdenum can therefore almost always justify its higher cost in mobile applications. Versatility can be important for land tanks as well. Building one tank is certainly cheaper than building two tanks, and the ability to handle multiple products is a clear advantage to owners and operators of third-party storage terminals.

Multiple duplex stainless grades with a range of corrosion resistance and costs provide users with a variety of options. The chart of critical pitting temperature (CPT) vs. strength in chloride environments emphasizes this fact. Similar data are available for many corrosive solutions, which allows the tank owner to select the optimal material for a given environment.

### Real-life installations

Although duplex stainless steels are relatively new to tank construction, some duplex tanks have been in use for

many years. An early example is a 2205 duplex stainless steel phosphoric acid storage tank built in 1989 in Sweden. The tank was used continuously until it was shut down just a few years ago due to problems, not with the tank, but with its retaining embankment.

The same 2205 grade was used when one of Spain's largest brewers replaced an old, severely corroded carbon steel storage tank in 2015. The duplex alloy's 460-MPa yield strength allowed a 25% weight saving compared to carbon steel. The duplex grade is highly resistant to both general corrosion and stress-corrosion cracking and has a very high PREN (Pitting Resistance Equivalent Number) value of 35. Its availability as wide plate and sheet lowered construction costs by minimizing welding time and filler metal consumption. Based on this initial experience with duplex stainless steel, the company intends to use it for future needs.

In Germany, a tank builder selected LDX 2404 duplex stainless steel with 1.6% molybdenum for a biogas tank instead of a standard grade because of its higher



2304 duplex stainless steel tanks at the tank terminal in Bilbao, Spain. © Outokumpu/Acedika

strength and good corrosion resistance. This choice reduced material weight up to 25%, and associated costs. The bolted tank can be dismantled and moved, so less weight also means lower moving costs.

EDX 2304 is a version of the traditional duplex stainless steel 2304 with higher chromium, molybdenum (0.5% vs. 0.3%) and nitrogen content. The steelmaker developed this grade for the offshore oil and gas industry but it is now used in storage tanks as well. The modified alloy has higher strength and greater corrosion resistance than 2304, and a guaranteed PREN above 28 – an improvement over the original grade's PREN of 26. The first tank using this material was built for a Swedish company, and the second project was built in the Netherlands.

### Tanks of the future

Duplex stainless steel offers multiple advantages to owners and operators of storage tanks. Construction costs are often lower than for carbon steel tanks. Operating costs are significantly lower due to nearly zero maintenance. Duplex stainless steel tanks have a practically unlimited life because of their high corrosion resistance. They are easily cleaned and can handle a variety of substances, making them more versatile than carbon steel tanks. If and when end of life arrives they have higher scrap value than traditional tanks. Moreover, their resistance to degradation and material loss during operation, and their higher material value, provide substantial sustainability benefits. They are profitably recycled, require lower energy consumption and reduce the risk of failure-related environmental contamination. These advantages not surprisingly come in large part thanks to molybdenum. Together with the competitive as-installed cost of duplex tanks, they should translate to increasing demand in the future. (Erik Stark)