So the product is finished and ready to take to market. But where do you put it? And when the order finally comes through, how do you transport it? This article examines some of the countless types of storage and transportation tanks used across a wide variety of industries. Whether because of corrosion, weight considerations, hygienic, environmental or maintenance issues, stainless steel is increasingly preferred to carbon steel when it comes to storing and transporting certain products. Within the various types of stainless steel, duplex has been replacing austenitics because of its favourable strength-to-weight ratio and anti-corrosion properties.

Keywords: Austenitics, Duplex, Fabrication, Fuel efficiency, Storage, Tanks, Transport

By James Chater

Introductory
As the economy becomes increasingly global, so the importance of storage and transportation increases. In certain circumstances strong, durable materials are required. This is why stainless steel has been replacing carbon steel, and why the choice of stainless steel grade continues to evolve. Tanks can be broadly divided into pressure vessels (where high pressures are often combined with high temperatures), and those used for the storage and transport of finished products, usually at ambient or near-ambient pressures. This article is primarily concerned with the second group.

Transportation
Tanks can serve for storage or for transportation. In the case of transportation, weight saving is often
especially important, since a lighter load will result in fuel savings or higher payload. Austenitics such as 304L and 316L are standard for the tankers used to transport foods, dairy products and mineral water. Type 304 has also been used to transport the bitumen (asphalt) used to tar roads. But three Italian fabricators have started to use LDX 2101®, an attractive alternative that allows thinner gauges and therefore reduces weight. For more corrosive substances still, something tougher than 304 or 316 is required, and here too, lean duplex can possibly provide a solution. Tests are under way to allow use of Outokumpu’s lean grade LDX 2101® to transport sulphuric acid.

Fabrication of storage tanks

Storage tanks come in various shapes and sizes. Most are cylindrical; some, especially the larger kind, are vertical, others are horizontal. The tops and bottoms can be flat or coned. Those with cones at the bottom include food tanks fitted with agitators (revolving screws that blend the substances) and fermentation tanks used in brewing and wine making.

The material and design of tanks depend on many factors, including the substance being stored, its volume, the size and dimensions of the tank, its configuration and drainage. Regulation also plays a role, varying according to country, purpose of use (domestic or industrial) and the potential risks (for instance, whether the tank is near a water course; whether it is underground, in-ground or at ground level). For some applications a choice of materials is available: for instance septic tanks can be made of carbon steel, stainless steel, polyester or fibre; and for LNG storage, there are several grades of nickel alloy steels or stainless steels to choose from. The advantages of using stainless generally include corrosion resistance, hygiene, favourable strength-to-weight ratio, little or no maintenance, no need for coatings, no waste products and recyclability. This is one of the reasons why lean duplex stainless steel, with good corrosion resistance and high mechanical strength, is tending to replace coated carbon steel. Lean duplex grades have been chosen for several projects because of the life cycle cost, but they have also been more economical when the initial investment costs are considered. Tank fabrication is a highly specialized art. Fabricators and their clients can choose whether to erect the tank in the shop or on-site, and whether the tank will be welded or bolted. On-site erection is the more common option for large tanks, because of space restrictions at the site. Often the fabricator will send a staff member along with the tank components to supervise on-site erection. Tanks can be constructed from sheets (vertical or horizontal) or coil that is rolled out to obtain each lap. Decoilers are used to erect tanks made of coil, which are constructed from top-to-bottom in order to avoid the hazards of scaffolding. Welding (usually by the FCAW method) is more common than bolting. After welding, tanks are mechanically cleaned and pickled to restore the surface. In the case of pharmaceutical or food products, a high degree of hardness and smoothness is required to enhance cleanability and guarantee the purity of the substance being stored.

Welding is more secure in the case of highly corrosive substances, but bolting has certain advantages: there is a much shorter on-site construction time, and bolted tanks can be dismantled and moved more quickly. Mobility can be important, for instance when a farmer wants to transfer a biogas tank from one location to another.
applied in palm oil storage tanks and corn silos. In a sugar refinery, syrup at 80°C caused stress corrosion cracking (SCC) of 316L. The problem was solved by erecting tanks made of duplex 2205. The dairy industry is another field in which types 304L and 316L dominate. However, in a few applications, these do not offer sufficient corrosion protection. In the brine used in cheese salting, the sodium chloride content can reach 30%. In ice-cream preparation, refrigerant (calcium chloride) in combination with steam led to pitting and SCC formation in the moulds. In both cases, 6Mo or 254 SMO® proved an effective replacement for 316L. Brewing is likewise dominated by 304L and 316L, with some use of 301LN. Type 201 is used in beer kegs to avoid buckling. In wine making, type 316L is standard. However, in both wine and brewery applications, lean duplex (LDX 2101®) can provide weight saving benefits (for instance in a wine tank park in Spain), and its superior strength makes it attractive for the pressurized tanks required to store sparkling wines such as Prosecco. Storage tanks in the chemical, pharmaceutical and bio-energy industries use a wide range of materials, right the way from austenitics through to 6Mo, 904L, duplex, Ni-based alloys, titanium and zirconium. Both temperature and corrosion are important determinants, and duplex use is limited to the range of around -40 to +250°C. As elsewhere, for moderately corrosive chemicals, lean duplex is replacing austenitic, allowing down-gauging and material and weight savings. A recent example is Acidea’s decision to use lean duplex 2304 for its new storage tanks, resulting in a 20% material saving compared with 316L. An even greater saving, 25%, was achieved when Börger applied LDX 2404® to build biogas production tanks in Germany.

Liquefied gas

Liquefied gas storage and transport involve a wide range of products, including ammonia, argon, carbon dioxide, ethylene, LPG, LNG, oxygen and nitrogen. In mildly cold conditions, duplex can be used. For example, duplex 2205 and LDX 2101® were applied by the Italian company OMSP Macola in the inner hull of road tankers that transport liquefied carbon dioxide.

Relisa S.A.’s tank farm in the Port of Barcelona is the largest to date built entirely out of lean duplex stainless steel grade LDX 2101®. The tanks are meant for storing honey, oils and other mild liquids.
For colder applications such as LNG, steel or stainless steel nickel alloys are required. LNG is methane gas that has been liquefied and reduced to one-six-hundredth of its size for ease of transport. Its boiling point is around -162°C. This extremely low temperature requires materials that do not become brittle at low temperatures. LNG storage tanks resemble giant thermoses, and generally consist of an inner and an outer tank located at or below ground level. Various configurations are possible, but in all cases the inner wall consists of a material, usually 9% nickel, that can withstand the cryogenic conditions.

At sea, LNG gas is transported on special double-hulled carriers. The carriers are of two types: carriers with spherical tanks and membrane-type carriers. The spherical (Kvaerner-Moss) system normally has aluminium tanks, though 9%Ni steel was used in the early days. The membrane system, which is now the most common, can be subdivided into two subsystems called No. 96 and Mark III. The No. 96 System consists of two membranes both made of Invar (36%Ni). Perlite acts as insulation between the two membranes and between the outer membrane and the inner hull. The Mark III system consists of a primary membrane made of corrugated stainless steel type 304L and a secondary one made of a composite laminated material. On land, LNG road tankers transport the fuel at -196°C and have an inner hull often made of type 304 and an outer one of painted carbon steel.

**Nuclear storage**

Nuclear waste is classified into three categories, depending on the degree and duration of its radioactivity: low-level, intermediate and high-level. Storage of high-level waste (HLW, the type originating from the fission process itself), is a thorny problem. Long-term storage remains an elusive goal, particularly after the project to create a storage site at Yucca Mountain was abandoned. For HLW, the most favored storage method is vitrification, i.e. combining the radioactive liquid waste with glass to form a solid compound. This mixture is placed in a canister made of two walls of borated stainless steel 304L. Boron is added to improve absorption of radiation. This alloy is difficult to produce, though recent advances in pre-alloyed powder metallurgy techniques have lowered production costs.

**Conclusion**

In tank fabrication, stainless steel has replaced carbon steel in many cases; within the field of stainless steel tanks, duplex grades are beginning to replace austenitics. Depending on the price of nickel, duplex can bring raw material cost savings. An additional advantage of duplex is that it saves weight, making transportation, on-site erection and dismantling easier. In smaller structures, there can often be no advantage in using duplex, but in larger structures, weight is an issue and the advantages of duplex are more obvious.

**Acknowledgement and sources**


This stainless steel canister, fabricated by Columbiana Hi Tech, is used to transport enriched uranium hexafluoride UF6.