Notes of a technical nature – Stainless Steel

The name 'Stainless Steel' is used very widely for types of steel that are much more resistant to staining and corrosion than ordinary steel. However, just because stainless steel is much more resistant to staining and corrosion, this does not mean that it is completely resistant.

There are many different types of stainless steel for different uses and any of these will stain or corrode in particular types of adverse situations. The purpose of these notes is to provide some extra information to help understand stainless steel and avoid these adverse situations, so that people can benefit from the safety, durability and attractiveness for which stainless steel is so well known.

Different types of stainless steel

Stainless steel is an alloy of iron plus smaller amounts of other elements, containing less than 0.25% carbon plus a minimum of 11% chromium by weight. It is this relatively high content of chromium that distinguishes stainless steels from others.

There are many variations on this basic composition, with different alloys having different levels of chromium and other metals such as nickel, manganese, molybdenum, titanium and aluminium combined with different levels of carbon.

Stainless steel alloys can also differ in terms of their structure at a microscopic level of detail. For example, in '300 series' stainless steels which make up the bulk of stainless steel production, the alloy's basic state has a microscopic structure that is in some ways disorganised and this makes it non-magnetic. Other types of stainless steel alloys have highly organised crystalline structures and this makes them strongly magnetic. An example of this would be Type 420 'Cutlery Grade' stainless steel.

The combination of alloy composition and microscopic structure gives each different alloy its own particular properties in terms of resistance to staining and corrosion, as well as hardness, toughness and the extent to which it can be formed, machined and welded to make products without losing its valuable properties.

The most common grade is Type 304, the classic '18/8' or '18/10' stainless, which contains 18-20% chromium and 8-10.5% nickel and is used widely in flatware and a vast range of fittings because of its excellent workability, durability and resistance to staining and corrosion in a very broad range of situations.

The second most common grade is Type 316, which is similar to Type 304 but with the addition of 2-3% molybdenum in the alloy which provides some increase in resistance to corrosion by chlorides such as those in sea salt, giving rise to its common name of 'marine grade stainless'.

There are over 150 other grades of stainless steel. Most of these are produced in relatively small quantities for use in situations where their special characteristics have a particular value.

How does stainless steel resist staining and corrosion

It might seem strange when you first consider it, but the reason why stainless steel seems so

un-reactive is actually because the chromium it contains is very reactive. When it comes into contact with the oxygen in the atmosphere, it reacts almost instantly to form a very thin, even, transparent layer of chromium oxide that covers the surface. This layer of chromium oxide is very un-reactive and it seals the surface to prevent any further reaction by the chromium or rusting by the iron in the alloy.

This is important to understand for two reasons. On the positive side, it means that an open scratch or cut on stainless steel that is exposed to the atmosphere will very quickly replace its protective coating of chromium oxide and, in the absence of any other contamination, the surface itself will become just as resistant to corrosion as it was before the scratch. This 'self-healing' provides stainless steel with its renowned durability.

On the negative side, anything that disrupts the formation of this layer of chromium oxide will largely destroy the resistance of the stainless steel to staining and corrosion.

Adverse situations

Having understood this, it becomes clear that an adverse situation for stainless steel is any situation that disrupts the protective surface coating of chromium oxide. This includes:

- Contact with strongly corrosive acids. This is generally not an issue for domestic items except where noted below, but it is important for many industrial applications and requires specialist assessment

- Contact with chlorides. Chlorides corrode all stainless steels, although some types are more resistant than others. Chlorides are found in high concentrations in:
  - sea salt and many other salts
  - brick-cleaning acid (hydrochloric or muriatic acid) used for cleaning cement off bricks and tiles during building construction
  - household cleaning products that contain chlorine bleach

- Contact with 'ordinary ' or carbon steel in a moist situation. This sets up an electro-chemical reaction that can very quickly corrode the stainless as it rusts away the carbon steel. Carbon steel can commonly be found in:
  - non-stainless kitchen utensils, eg carbon steel butcher's knives, meat cleavers, etc
  - household hardware items, eg nails, screws, hammers, chisels, etc
  - steel wool (the common non-stainless type)

- Fine, deep grooves, gaps or cracks. These have two effects. Firstly, they act to trap moisture and contaminants. Even household dust can become quite corrosive if it is allowed to accumulate and collect moisture. Secondly, if a very narrow space becomes blocked by moisture or other material, this can prevent oxygen from reaching the surface of the stainless steel. This in turn will prevent the protective coating of chromium oxide from forming, resulting in damage to the stainless steel by any corrosive materials in contact with it. Situations where this could occur include:
  - under gaskets that do not seal completely
  - sharp inside corners
  - gaps in welds or other joins
  - any surface that is allowed to build up a fixed layer of contamination. It is especially difficult to prevent this completely on a surface that is coarsely grained or linished.

These factors often work in combination. For example, a surface left uncleaned for some time could develop tiny corrosion pits which trap salt and moisture regardless of subsequent cleaning, which causes more corrosion which traps more contamination, and so on. This can mostly be dealt with very effectively by **preventing the adverse situations from occurring**. Stainless steel is such a popular material because in general it is quite simple to do this.

Things to avoid

- Never expose stainless steel items to brick cleaning acid or its fumes
- Never clean stainless steel with products containing chlorine bleach
- Never clean stainless steel with ordinary (non-stainless) steel wool, or leave carbon steel items in contact with it, or clean stainless steel with scouring pads that have already been used on carbon steel items
- Never leave salt deposits on stainless steel for prolonged periods
- Never allow stainless steel surfaces to accumulate dust or other contaminants without regular cleaning.

Things to do

- Clean stainless steel items regularly. Please see "Care and Maintenance " on our website for details. In general, washing with warm soapy water followed by a rinse with clean water and drying off will give the best results for surfaces in good condition.
- Ensure that products are designed without gaps or crevices, particularly if they are going to be exposed to contamination of any sort.
- Choose products with a finish that is as fine-grained as possible if the products are going to be routinely exposed to contamination, particularly if it involves sea salt or other chlorides:
  - either a fine mill finish, fine linished finish (240 or 320 grit) or a mirror polished finish can be suitable
  - consider additional surface treatment by electro-polishing for any of these finishes if maximum resistance to corrosion is required. Electro-polishing works like electro-plating in reverse. It leaves the smoothest possible finish, but it requires additional expense and it may not be possible with fabricated items that include materials other than the stainless steel.
- Consider stainless steel alloys with higher resistance to corrosion in situations where they are more exposed, while understanding that:
  - the desired products may not be available in the more specialised, highly resistant grades of stainless. In severely adverse situations such as exposed fittings adjacent to a surf beach or in many industrial processing applications, it is probable that items would have to be specially fabricated and surface-treated at considerable expense
  - more resistant grades of stainless steel will still corrode in sufficiently adverse situations. For example, Type 316 'marine grade' stainless steel can be a

good choice in many situations exposed to the elements, including some salt spray, and frequently will be considered to give better resistance to corrosion than Type 304 stainless, but it will still stain and corrode if it is not kept clean. Other alloys are designed to give much greater resistance to salt corrosion than '316 marine grade', but with limited availability of off-the shelf products and still with the possibility of corrosion, just at a higher level of resistance.

Things to do - conclusions

In situations with particular critical requirements there will certainly be a need to investigate stainless steel alloys with special characteristics and surface treatments.

However, in many routine situations keeping the item clean may be the best solution, rather than trying to source the product in an alloy and surface treatment that is more expensive and less readily available.

Tests – how can you tell if you have stainless steel

As mentioned previously, '300 series' stainless steels such as the very widely used Type 304 and Type 316 have a fairly disorganised microscopic structure in their basic state and in this situation they are non-magnetic. A magnet can be used as a simple test of many products that are made of these stainless steels: if the magnet is attracted to the product, then there is doubt that it is made of one of these alloys.

This works well for products that are made from '300 series' stainless steel plates, bars, rods or other sections that are produced from the near-molten alloy in pretty much their final form. However, if the manufacture of the product involves a lot of squeezing or bending of the material when cold, this causes the material to develop a microscopic crystalline structure which makes it magnetic. This applies especially to products made from cold-formed sheet and tubing. The material in these products has often been squeezed and bent to a very great degree and as a result they can be quite noticeably magnetic, even though they are completely genuine Type 304 or Type 316 or other '300 series' stainless steels.

Of course, the 'non-magnetic' test also does not apply to the many other types of stainless steel that should be magnetic because of their very organised microscopic structure. If there is doubt over whether a particular item is genuinely of the type of stainless steel that has been specified and there is a critical need to be certain, then specialist metallurgical testing is needed. In Australia, contact with the Australian Stainless Steel Development Association ('ASSDA') via their web site would be a good starting point.

Sources of information

These notes have been compiled by Kethy from a variety of internet-based sources including the ASSDA, a number of specialist stainless steel processing companies and general reference sources such as Wikipedia. The information is consistent across a broad range of sources and reflects discussions directly with a number of people who make a living from processing stainless steel, so it is considered to be reliable and reflecting current best practices.

There is a great deal more detailed information available from these sources and we recommend a search on the internet to anyone who wants to explore the subject.