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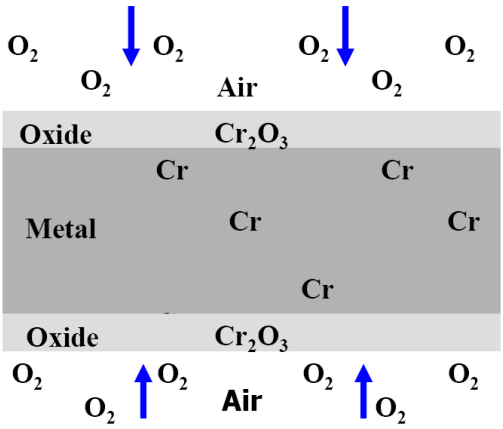
Passivation of Stainless Steel

Stainless steel is an alloy of steel – more iron than anything else – with chromium and sometimes another element such as nickel or molybdenum. Stainless steel is not resistant to chemical or physical attack. The corrosion resistance depends on the formation of a passive surface. Stainless steel is only "stainless" when the surface oxidizes with chromium and other elements to develop a protective film that resists further oxidation. This protected oxide film is considered a passive surface.

To passivate stainless steel, a minimum of 10.5-12% chromium is needed. Oxygen combines with chromium to create a film of chromium oxide (Cr_2O_3) on the surface. Oxygen must be present to replenish this film.



When stainless steel is newly made, it is cleaned of oils and greases used in the fabrication process. Acid, usually nitric, is used to remove free iron from the surface. Slowly and naturally, a passive layer develops on the surface as the chromium reacts with oxygen in the air. This layer is invisible and only a few molecules thick, but it provides a barrier to prevent oxygen and moisture from reaching the iron underneath.

Surface Damage

After stainless steel equipment has been installed and is in operation, the existing passive layer can be damaged or removed by physical abrasion (brushing, grinding, scraping) or by chemical reactions. It can also be weakened by physical damage due to expansion and contraction caused by heating and cooling. If this damage happens faster than the passive layer can heal itself naturally, rusting will result.

The natural reaction of oxygen from the air combining with chromium from the steel to produce chromium oxide may be interfered with by the processing going on or chemicals that are in contact with the surface. The regeneration of the passive oxide layer might not be adequate to provide constant protection. A more effective passive layer can be produced by chemical methods.

What is Chemical Passivation?

Chemical passivation is a two-step process. The first step is to remove any free iron or iron compound that is on the surface, otherwise this iron will create a localized site where corrosion can continue. Acid is used to dissolve away the iron and its compounds. The surface itself is not affected by this process. The second step is to use an oxidizer to force the conversion of chromium metal on the surface to the oxide form. This will create the uniform chromium oxide protective layer.

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Historically, nitric acid was the most commonly used chemical method to passivate a stainless steel surface. Nitric is a strong mineral acid so it can quickly dissolve all iron compounds and other trace metals that are on the surface. Nitric acid is also a strong oxidizer so it can generate the chromium oxide layer at the same time. On the negative side, nitric acid can be difficult to handle and dispose of after use.

Citric acid is becoming the choice for most processors for passivation. Citric acid is safer to use than nitric acid, is biodegradable, produces fewer effluent concerns and is commonly used as a food ingredient itself. Citric acid does an excellent job of cleaning iron from the surface, however it is not an oxidizer, so it cannot oxidize chromium – the traditional 2nd step. Build-up of the protective layer is typically done with air oxidation.

> *"Confusion exists regarding the meaning of the term passivation. It is not necessary to chemically treat a stainless steel to obtain the passive film; it forms spontaneously in the presence of oxygen. Most frequently, the function of passivation is to remove free iron, oxides and other surface contamination. For example, in the steel mill, the stainless steel may be pickled in an acid solution, often a mixture of nitric and hydrofluoric acids to remove oxides formed in heat treatment. Once the surface is cleaned and the bulk composition of the stainless steel is exposed to air, the passive film forms immediately"*

ASM Metals Handbook, Ninth edition, Vol. 13, page 550

When to Passivate

There is no simple rule that says when a piece of equipment must be passivated. The need will vary according to how the equipment is being used and whether the surface has been damaged. Some companies will choose to passivate processing equipment once per year as a scheduled maintenance procedure. Other companies will do it more frequently because they are processing foods that are aggressive on the stainless steel. Aggressive foods are those that contain high chloride levels and are acidic, for example salsa, tomato juice, etc. Plants that use water that has a naturally high chloride level may have to passivate more frequently since the chloride will disrupt the protective layer.

Pharmaceutical companies that use ultra-pure water for injection (WFI) are known to passivate 4 times per year because the high purity water itself is hard on the surface layer! Many times companies will passivate when they notice iron deposits forming on the stainless steel and it is not coming from the water. There are test kits available from chemical supply firms that will test for free surface iron. If a high level is found, it could be time to passivate.