

**GUIDE TO STAINLESS STEEL  
PASSIVATION**

**With Compliments From  
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## GUIDE TO STAINLESS STEEL PASSIVATION

### WHAT IS PASSIVATION ?

The term " passivity " is the property underlying the useful natural corrosion resistance of many metals and alloys including chromium, titanium and stainless steels.

**PASSIVITY** is conferred on the stainless steel by an invisible, tightly adherent conductive surface film only a few nanometres thick. The film is composed principally of water molecules and oxides of readily oxidising metals such as chromium, iron, silicon or aluminium. The analysis of the ' passive film ' depends on the metal substrate, on the prior surface treatments employed, and on the corrosive medium in which the material is immersed.

**Chromium** plays an essential role in the stabilisation of the passive film. At least 12% Cr is usually considered necessary for a steel to be " stainless ".

Naturally the stability of the protective layer also depends on the corrosive medium as pointed out above. In most environments, Chromium ( Cr ) contents of 18%, or even 20% and higher may prove to be indispensable.

In **nickel** containing austenitic stainless steels, nickel ( Ni ) does not take part directly in the composition of the passive film, but acts as a moderator during uniform corrosion.

As regards **molybdenum** ( Mo ), it is also present in the passive film, localised more in its outer layers. Molybdenum as  $Mo^{6+}$ , decreases the activity of surface - active sites through the formation on them of  $Mo^{6+}$  oxyhydroxide or Fe-Cr molybdate. Thus increasing the resistance of the passive film to localised attack caused by the chemisorption of chloride ( Cl<sup>-</sup> ) ions from the corrosive environment.

Chemisorbed chloride will replace oxygen or hydroxyl ions on the passive oxide film to form a metal - ion complex which promotes the breakdown of the passive films barrier effect leading to the onset of pitting and crevice corrosion.

In some stainless steels **copper** ( Cu ) is alloyed in concentrations of 0.7 - 3.0% to enhance the alloys corrosion resistance to sulphuric and phosphoric acid media. The copper while it is not present in the passive film, does form a metallic film of  $Cu^+$  and  $Cu^{++}$  ions on the metal surface which protects the steel from the corrosive medium by a barrier effect.

**Nitrogen** ( N ), is another important alloying element added to the newer grades of duplex / super duplex and super austenitic stainless steel. It is a nonmetallic interstitial alloying element. From the corrosion point of view, it improves corrosion resistance

pitting / crevice and general in acidic media by buffering the solution at the metal - solution interface, via ammonia formation resulting in an increase in the pH.

Nitrogen also retards the formation of intermetallic compounds, which allows higher quantities of Cr and Mo to be added to the stainless steel to enhance passivation.

The passive film forms spontaneously on contact with air, over a period of 8 - 24 hours; which is why stainless steels are self passivating under favourable conditions.

Once formed, the passive oxide layer can be disrupted or destroyed by corrosive chemicals, by contact with active metals such as adherent or embedded iron particles, or by oxygen starvation.

The surface free iron particles, dust and iron oxide contaminants arise from handling, fabrication / forming, welding, heat tints and arc strikes, grinding, machining, paint and crayon marks, polishing, tumbling and lapping, and workshop cross contamination.

These contaminants penetrate the passive film, adsorb and concentrate chlorides, ferric chloride or produce inorganic chlorides by the decomposition of organic compounds such as PVC in marking materials.

Passivation of stainless steels is actually a cleaning process in which surface free iron, iron oxides, and other contaminants are rapidly dissolved and the stainless steel remains virtually unattacked.

Nitric acid is normally used in passivation baths because it will selectively dissolve surface free iron and at the same time it " conditions " ( oxidises ) the surface for self passivation.

Conditioning involves the anodic oxidation of the surface.

## **WHY PASSIVATE ?**

The failure of stainless steel components due to corrosion can reach catastrophic proportions. The cost in time, materials and cost of lost production can be tremendous.

If passivation is not carried out stainless steel can rust due to surface free iron, and since the corrodent invariably contains chlorides, or absorbs it from the atmosphere, some ferric chloride will be produced.

Prolonged contact with ferric chloride will eventually initiate pitting and crevice corrosion on the stainless steel surface.

A properly cleaned and " passivated " stainless steel will be in optimum condition to afford maximum corrosion resistance to the intended application.

## PASSIVATION PROCEDURE

Passivation is carried out in a nitric acid bath. Stainless steels can tolerate a wide range of concentrations and temperature of nitric acid.

Complete immersion in a bath containing 15 - 20% by volume ( S. G. 1.42 ) in water at ambient 20°C to 70°C from 1 - 3 hrs. The clean surface should be washed acid free with clean water.

Full details of cleaning, passivation and pickling practices are presented in ASTM A380 - 78.

It should be noted that the nitric acid passivation treatment will not remove heat tints and heat affected zone ( HAZ ) burn marks caused by welding. To remove these high temperature oxides, the surface must be first pickled in Nitric + Hydrofluoric acid bath, and then clean rinsed in water, followed by the passivation treatment. Details are presented in ASTM A380-78.

## INSPECTION TEST METHODS

A number of passivation test methods have been used to detect iron contamination on stainless steel surfaces.

Water immersion and **high humidity** tests are used for visually detected rust spots due to surface free iron.

The **salt spray** test is an accelerated corrosion test in an atmosphere of chloride saturated fog under carefully controlled conditions. The quality of passivation is evaluated by the appearance of rust spots.

The acidified **copper sulphate** test is a galvanic type test in which the more noble copper plates out on the less noble iron particles, but not on the clean stainless steel surface. The appearance of the copper patches signals poorly passivated surface. This is useful for gross contamination.

A negative result does not necessarily mean that the tested surface is iron free.

The **Ferroxyl** test, requires some skill and practice depends upon the corrosion of small particles of iron in contact with the stainless steel under the influence of either dilute nitric acid or dilute sodium chloride. The presence of iron (  $Fe^{++}$  ) as blue spots is detected by the inclusion of potassium ferricyanide in the test solution.

This test is not popular because it has to be freshly made up and the presence of ' cyanide ' frightens most people.

