



# Learn the Anti-Corrosion Code

White Paper



ENGINEERING YOUR SUCCESS.

*Clara Moyano has been an innovation engineer and metallurgist at Parker Hannifin, Instrumentation Products Division, Europe for over a decade, involved in all metallurgical issues and new product development.*

Probably the most significant trend in the instrumentation products world today is the design of increasingly corrosion-resistant systems. Led by oil and gas companies, instrumentation and piping engineers are now focusing far more attention on the materials used to fabricate valves, manifolds and tubing systems. In the offshore project world, for example, Parker Hannifin is currently seeing exponential growth in the use of 6Mo in preference to traditional 316 stainless steel. So, why are so many choosing that particular material?

## Alloy selection

How do you select the best and most cost-effective alloy for the job - something that's going to resist corrosion for a design life of say 20 or more years? In the past, for harsh applications such as offshore oil and gas fields, the answer always seemed to be '316' - because it was a "stainless" steel and appeared to provide the most cost-efficient answer. But corrosion remains unchecked and continues to wreak havoc on infrastructure, posing both an economic threat and a human safety risk. The problem is becoming even more pressing, because most operators now want to extend the life expectancy of offshore infrastructure

and are operating in ever more remote and harsh environments.

Evaluating material performance does not come easily to most instrumentation and piping engineers: it's a complex branch of science, and even if they were lucky enough to have a materials science component as one of their courses, it was probably very generalised covering a broad range of materials, such as ceramics and polymers, as well as metals. In addition, the metallurgical portion addressed a wide range of metals that would not have application in oil and gas. What would be beneficial would be a solid

basis of metallurgical principles that target both upstream and downstream use.

Not so long ago, corrosion resistance would be tested and scored using qualitative terms, such as 'resistant', 'somewhat resistant', and 'not resistant'. 'Somewhat resistant' may sound like a reasonable choice for an application, but this loose descriptive category can encompass a range of damage that many engineers would probably not be comfortable with when specifying a material for continued exposure on a platform with, say, a 30 year lifecycle.

## Measurement of relative corrosion resistance

Pitting and crevice corrosion are a major cause of corrosion failure of series 300 stainless steels in aqueous chloride environments such as offshore oil and gas platforms. Once a pit or crevice corrosion site is initiated it will continue to propagate rapidly, leading to failure of the component.



PREN, CPT and CCT stand for Pitting Resistance Equivalent Number, Critical Pitting Temperature, and Critical Crevice Corrosion Temperature. Understanding these acronyms takes you a long way towards choosing the best material for the job.

CPT is the temperature at which the onset of pitting occurs, and CCT is the temperature of the onset of crevice corrosion. The quantitative measurement of pitting and crevice corrosion resistance is performed by the ASTM G150 test (in lieu of the ASTM G48). These standard tests are useful for determining the relative corrosion resistance of corrosion resistant alloys (CRA) in environments similar to the test environment.

PREN is an empirically developed guideline that indicates the relative corrosion resistance of CRA (corrosion resistant alloys) materials, based upon the percentages of the key elemental components of chromium, molybdenum, tungsten and nitrogen. The PREN formula is:

$$\text{PREN} = \% \text{chromium} + 3.3(\% \text{molybdenum} + 0.5\% \text{W}) + 16(\% \text{N})$$

CPT and CCT numbers provide us with a quantitative measurement of the likelihood of pitting and crevice corrosion resistance. When combined with the PREN, (which is qualitative in nature) as in the Table, they can provide a simple approach to predicting a material's suitability for a specific application. When CPT and CCT measurements for a specific lot of material are not available, the PREN can act as indicative of the performance in the corrosive environment when compared to other materials composed of these elements. Though not a component of the PREN number, nickel is important for determining the phase balance of the material which can have a significant effect on the corrosion resistance of the material.

These measured values, coupled with knowledge of the mechanisms of corrosion (which is beyond the scope of this short article), can help predict a material's useful service

life in harsh applications and environments, in order to guide the selection of the most cost-effective alloys. The table shows us why 316 is not always the best choice: it can be subject to pitting and crevice corrosion at ambient temperatures. Crevice corrosion is the most difficult to prevent, both because of the lower temperature for the onset of this corrosion mechanism and the difficulty in minimizing crevices in the design and installation of equipment.

If you factor relative material costs into this table, it becomes obvious why we're seeing the growth in the use of 6Mo. It should also be noted that there is no "silver bullet" wherein there is one material that can economically perform well in every application. 6Mo, though the material of choice for many offshore applications, isn't a 'blanket solution' for all offshore applications. In some cases, the temperature is too high or the H2S content (which causes another type of corrosion failure) is too great to resist the environment.

Table 1. Comparing alloys using PREN, CPT and CCT.

Alloy	UNS Number	MINIMUM Composition – Weight % (min)						PREN* (min)	CPT** (°C)	CCT*** (°C)
		Cr	Ni	Mo	N	W	Nb			
316	S31600	16	10	2	0	0	0	23	20	<0 <b>Least Resistant</b>
316L	S31603	16	10	2	0	0	0	23	20	<0
825	N08825	19.5	38	2.5	0	0	0	28	30	5
Duplex	S31803	21	4.5	2.5	0.08	0	0	31	30	20
904L	N08904	19	23	4	0	0	0	32	40	24
Super Duplex	S32750	24	6	3	0.24	0	0	38	65	35
6Mo	S31254	19.5	17.5	6	0.18	0	0	42	75	38
625	N06625	20	bal	8	0	0	3.15	52	90	40
C-276	N10276	14.5	bal	15	0	3	0.35	69	>100	50 <b>Most Resistant</b>

\*PREN = %Cr + 3.3(%Mo + 0.5%W) + 16(%N) - As per NACE MR0175/ISO 15156

\*\* CPT – Critical Pitting Temperature in 6% FeCl3 as per ASTM G48.

\*\*\* CCT – Critical Crevice Corrosion Temperature in 6% FeCl3 as per ASTM G48.

CPT & CCT values provided by Outokumpu (316/L, Duplex, 904L, Super duplex, Alloy 625, and Alloy C276), Avesta Polarit (6Mo), and Special Metals (Alloy 825).



Of course, the numbers don't tell us everything we need to know about a material, but they do provide a helpful initial guide before other properties such as allowable yield and tensile strength are factored into the selection process.

The Parker Hannifin Corporation is involved in many large project applications, and it's common for a material to be pre-selected in the specification document. We've learned in recent years that it's worth exploring that decision in depth before generating the quote - to ensure it's been thoroughly analysed for all the environmental and process environments across the project, such as methanol and chemical injection, H<sub>2</sub>S and chloride compositions, and so on. Although metallurgical know-how is becoming quite common on the project teams run by operators and their EPC (Engineering, Procurement and Construction) contractors, it's just as important that this expertise is integral on the supplier side as well.

Once the alloy selection is finalised, the next step is to ensure optimal processing of the material to maximise the chemical resistance and minimise undesirable inclusions and post processing variations, such as improper heat treating and/or annealing.

An in-depth understanding of materials throughout the production, purchasing and subsequent processing/machining phases involved in creating instrumentation products is absolutely critical. For instance, not all T-316 is equal to other heats of T-316 stainless steel. The more expensive alloying elements are minimised or "leaned out" to yield maximum profit by the mill. The allowable range of molybdenum, for example, is 2-3%, yet the difference in corrosion

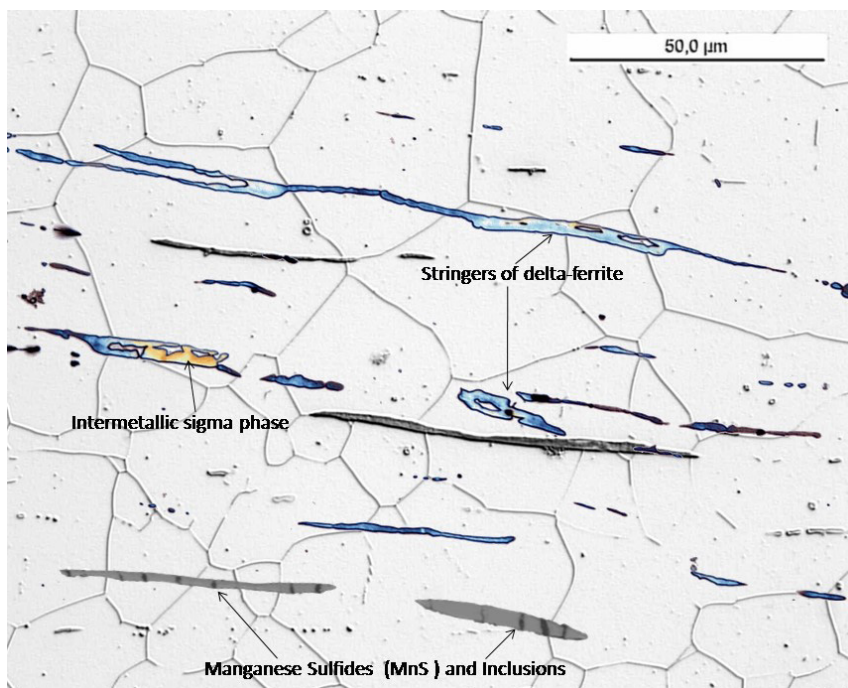


Figure 1. Low quality 316 Austenitic stainless steel with lots of inclusions and detrimental phases: manganese sulphides (grey), delta-ferrite stringers (blue) and intermetallic sigma phase (orange). Source: Parker Hannifin

resistance of 2.5% molybdenum content versus 2% is dramatic. Also, poorly processed T-316 stainless steel when viewed under a microscope (Figure 1), can contain an undesirable number of inclusions and impurities in the material, which can become initiation sites for corrosion.

A major element of the background of Parker Hannifin is materials expertise, derived in great part from its heavy involvement in the aerospace and semiconductor industries. That experience also incorporates all aspects of the supply chain. Virtually all Parker's materials are purchased from mills and foundries in Western Europe, which operate to the highest possible quality standards. These, in turn, are monitored by Parker's technical team, who also subject those materials to a range of tests, ensuring that the material meets or exceeds the desired specification. A great

example of this would be Parker's NORSOK approved 6Mo material to meet the M-650 standard.

Combine this attention to detail with design features on instrumentation products which are also important to avoid corrosion - for example the way that fittings grip the tube without opening up an avenue for corrosion - and good installation practice, you have a solid foundation for building instrumentation systems with genuine longevity.

In summary and in a more lighthearted vein, Parker Hannifin is exercising the very concept of 'exotic materials' as much as possible from its vocabulary. In industry, the word, exotic means rare and hard to get. At Parker Hannifin, these corrosion resistant alloy solutions are readily available and already installed to a huge array of mega projects around the world.

