

Invar® M93 : Perfect Corrosion Management.

It is a common and recommended practice to keep the tanks of LNG carriers away from a marine atmosphere during their construction or when they are empty, this in order to protect them from possible corrosion due to water and the detrimental elements (Cl, S, etc.) that are present in the air close to the sea.

A major fact to be pointed out is that there is not only one kind of corrosion, but many different types which may develop depending on the atmosphere itself but also on the internal stresses and the metallurgical state of the steel (ie : annealed or cold worked) , its surface condition as well as the outer temperature.

Let us focus on the three main types of corrosion that can appear in a marine atmosphere :

- the surface corrosion
- the bulk corrosion
- the stress corrosion.

The first is visible to the naked eye, the second is generally associated with surface corrosion and so it can be easily detected. However, stress corrosion is unnoticeable without metallurgical inspection until its ultimate stage (breaking) is reached.

The table below summarizes the types of corrosion that can affect various steels submitted to marine atmosphere conditions.

	Type of corrosion		
	Surface	Bulk	Stress
Carbon steel	yes	yes	no
Low Ni stainless	no	no	yes
Invar® M93	yes	no	no

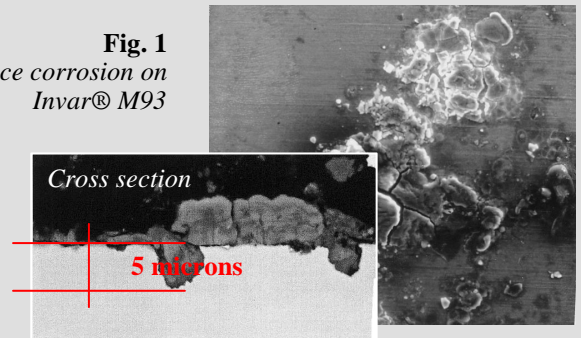
The reasons explaining this quite different behaviour for alloys which all belong to the « steel family » can be found in literature.

For example, it is clearly shown that for iron-nickel alloys containing more than 30%Ni, no stress corrosion nor bulk corrosion can occur. Only surface corrosion is observed, characterised by a very low thickness, in the micronic range (**fig. 1**). This type of corrosion for Ni > 30% develops slowly in the course of time at operating temperatures and can be easily repaired when the ship is docked for maintenance.

In short :

If simple precautions are taken during construction and lay up of LNG carriers no corrosion should be observed on Invar® M93 surface. If some occurred, it would be visible immediately, its depth would be only a few microns and it would evolve very slowly in the course of time. This type of corrosion can be repaired easily with a well known procedure whose efficiency has been proven for decades and, even if not repaired at once, there is absolutely no risk for the membrane integrity.

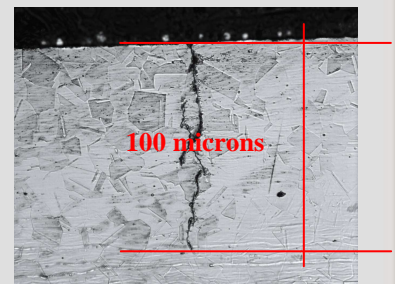
Fig. 1
Surface corrosion on
Invar® M93



On the contrary, alloys having less than 30% Ni can undergo stress corrosion cracking (**fig. 2**), enhanced by fatigue cycling in usage, the maximum effect being observed around 10% Ni even if the alloy contains chromium.

As shown in the table, stainless steels do not exhibit any surface nor bulk corrosion in marine atmosphere.

Fig. 2
Stress corrosion cracking
in low Ni stainless steel
(cross section)



In conclusion, whatever the material used for the membranes, it must be protected against marine atmospheres, albeit for different reasons. On one hand, Invar® M93 can be subject to surface corrosion if the state of the art procedures are not followed during construction and storage of the LNG carriers. On the other hand, stainless steel, although looking visually safe, can develop severe stress corrosion without any visible evidence before cracking.