

PHORGOTTEN PHENOMENON

Moderate Cathodic Protection: A Remedy Against Flowline Failure

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The offshore industry has experienced frustrating cracking problems with a number of stainless steel (SS) flowlines.

The SS used for flowlines include supermartensitic and duplex SS. With SS, no inhibition injection is required, so that operating costs are reduced, and there is a useful contribution to a cleaner environment. Their high strength is a valuable advantage—their reduced thickness means a lower weight of steel will be purchased, and this allows for a significant reduction in the cost of the pipeline.

Presently, the protection of the SS flowlines on the seawater side (external) is achieved through coating and normal cathodic protection (CP), as it is usually provided for carbon steel (CS) pipelines and the CS parts of subsea platforms and completions. Al-In sacrificial anodes are most widely used for these applications. They deliver a potential of $-1,050$ mV vs silver chloride (AgCl) in seawater (all of the potentials discussed in this article are vs AgCl).

At this potential, hydrogen is produced and it enters the steel at locations where there is any coating damage. In combination with high localized stresses, and particularly when the flowlines are out of service, cracking takes place through a hydrogen embrittlement (HE) corrosion mechanism.

It was demonstrated long ago that the protection of SS against corrosion can be achieved at potentials less negative than the hydrogen evolution potential.¹ At such potentials, there is no hydrogen production. The terms “protection potential” (against propagation of localized corrosion), or “repassivation potential,” are used to describe the potential that is required for what is now called “moderate CP (MCP).”

A very conservative value for this MCP potential is -550 mV. At potentials between -550 mV and the hydrogen evolution potential, supermartensitic and duplex SS are altogether protected against seawater corrosion and HE. The hydrogen evolution potential that is considered in practice takes into account an overpotential, and it is ~ -850 mV in seawater.

This means that any CP design that would maintain the potential between -550 and -850 mV would be perfectly safe for SS flowlines.

It has been argued that MCP differs from the established design basis offshore and that the flowlines cannot always be electrically isolated from the adjacent platforms, manifolds or subsea units. This argument is understandable, but it should not be an obstacle to the application of MCP.

Two points support this statement. First, the CP of the CS structures can be designed to impose a potential not much lower than -850 mV near the SS flowline ends. For this, the anodes used to protect the CS should not be installed too close to the flowlines. Second, the CP of CS does not require potentials as negative as $-1,050$ mV (AgCl). CP of CS is achieved at -800 mV, and—thanks to the alkalization of the steel-seawater interface layer—at potentials slightly more positive than -850 mV.

Sacrificial anodes with electrical resistors, diodes, or remote anodes can be used for the design of CP of mixed CS/SS assemblies. There is also a new system that uses normal Al-In anodes with a self-powered regulating device that can deliver any selected potential; for example, in the range -550 to -850 mV.²

Changes in the usual CP design approach are quite feasible, as long as sufficient attention is given to the design at an early enough stage of the project, and considering the complete subsea system as a whole. Thus, it is important to highlight the particular issue of SS flowline protection as soon as the material selection has been made.

From what is presented above, it seems unjustified and unacceptable to continue dealing with the external protection of SS flowlines in the manner of CS lines.

MCP is an efficient, reliable, and practical solution. It is worth the trouble of a slightly more complex design job, with the added benefit of suppressing the possibility of failures that have already caused major costs and risked environmental contamination.

References

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2. M. Stroe, V. Ligier, P. Toussaint, J.J. Dufrane, A. Pourbaix, "Moderate Cathodic Protection and Hydrogen Embrittlement of Supermartensitic Stainless Steel Flowlines," *Proc. Supermartensitic Stainless Steel 2002*, held Oct. 3-4, 2002 (Brussels, Belgium).

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