Material Selection in Topsides Seawater Injection Systems

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Carbon Steel	Duplex Stainless Steels
Low Cost	High Cost
Most Suitable for Deaerated Systems	Require PRE_N > 40 for Oxygenated Seawater Service
Susceptible to Oxygen Corrosion	Failures due to High Temperatures & Chlorine Levels
Susceptible to Bacterial Attack	May Pit Due to Bacterial Attack

Copper-Based Alloys	Plastics & Fiber Glass
Moderate Cost	Moderate Cost
Naturally Resists Biofouling	Suitable for Low Pressure Systems (<250 psi)
Corrosion in Stagnant Conditions (<2 ft/s)	Resistant to Corrosion and Errosion
Erosion at High Flow (>11 ft/s)	Need Effective Quality Control and Fabrication Oversight

The difficulty in selecting the materials of construction for the topsides portion of seawater injection systems is associated with uncertainty around the reliability and performance of their associated oxygen removal systems.

Common material selection options for seawater injection systems include carbon steel, stainless steels, copper-based alloys, and composites. Other materials, such as titanium and high nickel alloys, may be used in niche applications, but their increased cost ensures that these are not the first line materials of choice.

Impact of Deoxygenation System Design & Performance

In general, deoxygenation systems are designed to deliver a dissolved oxygen specification of less than 10 parts per billion (ppb), where mechanical deoxygenation generally removes oxygen down to 50 to 100 ppb levels and liquid oxygen scavenger is used as a supplemental treatment to meet the 10 ppb level. This approach is used for many carbon steel and corrosion resistant alloy (CRA) systems.

Mechanical deoxygenation systems designed to perform to 10 ppb or less often do not achieve this performance consistently. During excursions, they will also require supplemental scavenger application to meet injection specifications.

Oxygen removal from the injected seawater is a critical part of many waterflood facilities, where only a small number have considered injection of oxygenated seawater. Historically, the use of CO_2 gas-stripping towers, or vacuum towers, have predominated for oxygen removal. These are considered to be reliable and mature technologies, but can be large and have a high center of gravity. In recent years, this has driven the adoption of the compact stripping systems, particularly for deepwater installations where weight and space constraints are paramount. However, many of these compact systems have been plagued by poor mechanical reliability and control system issues.

Even piping and equipment downstream of reliable deoxygenation units may be at risk of increased oxygen-induced corrosion. If an oxygen scavenger is used for polishing downstream of a deoxygenation unit, it is important to note that this will not be effective during routine batch biocide treatments as it will react with the biocide in preference to the dissolved oxygen. Depending on the nature of the system, this may mean that for up to 4 to 12 hours per week the deoxygenation of the injected seawater is solely dependent on mechanical removal. Even in good systems this may relate to 100 ppb oxygen in water levels.

Carbon Steel

Carbon steel can experience rapid corrosion resulting from biological attack or exposure to oxygenated or chlorinated seawater. As such, it is typically only employed downstream of the deaeration system. Even here, it can be susceptible to corrosion due to excursions in design oxygen levels or as a result of microbiologically influenced corrosion (MIC). However, this is often an attractive option due to low material cost and ease of fabrication.

Where used upstream of deaeration, such as for seawater lift caissons, carbon steel will typically be protected by cathodic protection, CRA cladding, or robust liners such as glass flake epoxy.

Stainless Steels

For passive materials, such as stainless steels and the nickel-base alloys, localized corrosion is the primary corrosion form in seawater. Resistance to localized corrosion for CRAs of this type is frequently ranked using the pitting resistance equivalent number (PRE_N). This is an empirical measure of the ability of the material to withstand localized corrosion.

There is considerable discussion in the industry as to whether a PRE_N of greater than 40 is required for long-term service in seawater. Operating experience broadly supports the use of this limit as a materials selection criterion. This is primarily based upon observation of topsides and injection system seawater handling and the known impact of service temperature and free chlorine contents on the applicability of this limit.

Lower grade stainless steels with a PRE_N significantly below 40, such as the 304 and 316 austenitics, are susceptible to external chloride stress corrosion cracking and internal crevice attack from oxygenated seawater and MIC. This typically excludes their use in seawater handling systems, both upstream and downstream of oxygen removal systems. However, an exception is the internals of deoxygenation towers, which commonly contain 316 trays and fittings.

Duplex materials such as 2205 are generally not used to handle oxygenated seawater due to the fact that their PRE_N is less than 40 and as they have proven to be susceptible to crevice attack. However, they can successfully be used for valves and vessel housings downstream of oxygen removal systems, if oxygen excursions are well controlled.

Material grades with a PRE_N greater than 40 must still be used with caution. Experiences of failures of 6% Molybdenum (6Mo) super austenitic stainless steels (e.g. SMO254) and superduplex grades (e.g. 2507 and Zeron 100) have been reported following exposure to elevated temperatures or excessive free chlorine levels.

Copper Based Alloys

Copper and copper-nickel alloys have been used for many years to handle aerated seawater based on their intrinsic corrosion resistance and the ability of copper-based materials to resist biofouling. However, their use has not been without problems. These are largely associated with MIC and under-deposit corrosion at flow rates below 2ft/s, exposure to sulfides in polluted water or following biological activity, and erosion at fluid velocities in excess of 11ft/s.

A more recent limitation of these materials is associated with the fact that copper alloys cannot be used upstream of sulfate removal membranes. The copper that dissolves into the injection water subsequently deposits on the membranes and can greatly reduce their performance and service life.

Plastic Composites

Glass-reinforced plastics (GRP) are becoming the material of choice for low pressure water handling systems. They are resistant to oxygenated and chlorinated waters and are lightweight, which is a factor that can be particularly important for floating production facilities.

Although GRP systems generally provide acceptable performance, certain operators have experienced recent failures of offshore GRP systems during hydrotesting. This has been traced to incorrect wrapping and curing of pipe joints. Hence, it is important that a detailed quality control plan and joining procedure is developed prior to starting installation activities.

Conclusion

Components handling fully-oxygenated seawater and hypochlorite are generally selected to be intrinsically resistant to corrosion and are commonly selected from copper-base alloys, superduplex stainless steels with a PRE_N greater than 40, and plastic composites. Where carbon steel is used, it requires internal cladding or lining, and is often supported by supplemental cathodic protection.

For components downstream of deoxygenation systems, carbon steel is the lowest cost option and becomes suitable for a 20-year design life only in cases where rigorous oxygen control can be achieved. Where significant oxygen excursions are expected, then a move to CRA materials often becomes necessary. This provides high corrosion resistance, but at a significant price differential above carbon steel. However, this is an approach that is often taken for topsides pipework, where the incremental cost over carbon steel is minimal in terms of overall project expenditure.

PRE_N

The PRE_N is typically calculated as a function of the alloy chemistry as related to chromium, molybdenum, tungsten and nitrogen contents in a stainless steel by the equation below, although specialized forms of this equation can be used for certain materials.

$$PRE_N = \%Cr + 3.3 \times \%Mo + 3.3 \times \%W + 16\%N$$

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