Designing Buried Seawater Intake Structures for Enhanced Corrosion Resistance and Prolonged Durability

Introduction

Recent advances in reverse osmosis membrane technology have dramatically reduced the cost of producing drinking water from seawater, and have accelerated the worldwide interest in desalination ("desal") as a viable option for water supply development. Whereas but a few years ago, desal plants were mostly thought of as solutions for regions like the Middle East where inexpensive energy was available, today numerous large- and small-scale desal plants are proposed along the California coast and other states (Florida, Texas and Hawaii). While state and local regulatory bodies struggle to come to grips with complex, highly scrutinized permitting matters, desal plant designers are racing to complete pre-design and design studies to ultimately bring on line numerous desal plants that offer realistic, long-term solutions for reliable water supplies.

Myriad professional papers and design guides are available that describe desal technologies, product water, operation scenarios, and waste discharges. The interested reader can find a plethora of information with little difficulty. This memorandum addresses an important facet of desal technology: buried seawater intake structures. Like most things technological, desal plants have a starting element that begins the process of producing potable water from seawater. That element is the seawater intake.

This memorandum presents a brief introduction on buried seawater intakes and explains how the choice of steel used to manufacture the intake can, if properly selected, provide enhanced corrosion resistance and prolonged durability.

Seawater Intakes

Submerged intakes are those that are situated on the seafloor and project from land to a designated point offshore. Construction costs for an offshore pipeline are always high, so designers prefer to lay pipelines to depths of 35 m and no more than 500 m offshore. A significant environmental consequence of a submerged intake is that it inevitably draws in marine life along with the seawater. This, unfortunately, brings about a level of mortality to fish and small marine life that become trapped on intake screens (referred to as "impingement"). Smaller organisms such as larvae and eggs that pass through intake screens are likewise killed (referred to as "entrainment") when they enter the membranes of the desal plant or the condensers in an electrical generating plant. Submerged intake screens do prevent debris from entering the pipeline; however, they collect raw seawater that has elevated levels of suspended solids and other constituents that must be removed.

Buried intakes include: 1) horizontal screens installed in the nearshore area; 2)vertical wells drilled on the beach; 3) slant wells drilled from the beach to a point offshore; and 4) radial collector wells that project several horizontal intakes from the beach to points beneath the nearshore. Compared to a submerged intake, a buried intake will minimize the environmental impacts associated with the mortality of fish and small marine life. That is, impingement and entrainment are eliminated because there is no direct contact between the intake(s) and aquatic life. Buried seawater intakes have other distinct advantages to offer that have serious implications to desal processes. They include: 1) they require little maintenance; 2) they serve as an intake and pretreatment component that pre-filters suspended solids, silt, oil and grease much like a sand filter in a treatment plant; and 3) the flow rate and operation are unaffected by wave action and tidal effects. In fact, there is actually some benefit from wave and tide turbulence which provide natural cleaning of the beach sand around the intake.

Intake Screens

The most common types of buried intakes are manufactured as continuous wire-wrapped screen or louvered screen. Information pertinent to the design of intakes using either screen type is presented in Technical Memorandum 005-5 (Roscoe Moss Company, 2005). Both types of screens are suitable for installation as horizontal intakes, vertical wells, and collector wells. Louvered screens are the favored material for slant well intakes and vertical wells because those applications require greater tensile strength and collapse strength. They can also be used for horizontal intakes with the appropriate filter pack to stabilize fine sands.

Seawater Quality

The major constituents of seawater are shown in the Table 1. Steel screens used for buried intakes must exhibit corrosion resistance to these (and other) constituents.

Table 1 – Major Constituents of Seawater

Ion	Parts per million	Equivalents per million	Parts per million per unit chlorinity[1]
Chloride	18,980.0	535.3	998.90
Sulfate	2.649.0	55.1	130.40
Bicarbonate	139.7	2.3	7.35
Bromine	64.6	0.8	3.40
Fluoride	1.3	0.1	0.07
Boric acid	26.0	[2]	1.37
Total		593.6	
Sodium	10,556.1	159.0	556.60
Magnesium	1,272.0	104.6	66.95
Calcium	400.1	20.0	21.06
Potassium	380.0	9.7	20.00
Strontium	13.3	0.3	0.70
Total		593.6	

Modified from H.U. Sverdrup, M.W., Johnson, and R.H. Fleming, *The Oceans,* Prentiss-Hall, Inc., New York, 1942.
[1] Chlorinity = 19.00 0/00 (0/00 is used to denote grams per kilogram or parts per thousand)
[2] Undissociated at usual pH

Materials

The majority of buried intakes are manufactured of corrosion-resistant steel. Non-ferrous materials (e.g. polyvinyl chloride) are sometimes used in shallow, small-diameter, vertical wells installed on the beach. However, polyvinyl chloride mill-slotted screens offer the least collapse strength and are highly prone to clogging. Table 2 presents the chemical properties of various casing and screen materials.

Table 2 – Material Properties

Material	UNS Designation	Yield Strength (Minimum psi)	Tensile Strength (Minimum psi)
316L Stainless Steel	S31603	35,000	75,000
SEA-CURE Super Ferritic Stainless Steel	S44660	65,000	85,000
AL=6XN Austenitic Stainless Steel	N08367	45,000	100,000

The Nickel Development Instituted presented the recommendations for selection of nickel stainless steels for marine environments, natural waters, and brines, as shown in Table 3.

Table 3 – Recommended Corrosion-Resistant Steels

Fresh water (<200 ppm Chloride)	304 Stainless Steel
Brackish water (<1,000 ppm Chloride)	304L/316L Stainless Steel
Seawater with galvanic protection	316/316L Stainless Steel
Seawater without galvanic protection	SEA-CURE or 6% Mo + N (i.e., AL-6XN)

Pilot Program – Doheny Beach, California

The Metropolitan Water District of Orange County (MWDOC) evaluated the feasibility of future installation of several slant wells at Doheny Beach that would serve as seawater intakes for a proposed desalination plant. The study was preceded by a comprehensive pre-design test well program, hydrogeologic investigation, water quality sampling, and computer modeling (Geoscience, 2007). The intake testing included evaluations of various types of steel from which corrosion-resistant seawater intakes could be manufactured. For the testing program the slant well was completed with louvered well screen that served as the seawater intake manufactured from 316L Stainless Steel. Louvered screen was selected for its collapse strength and tensile strength that were needed for installation of the casing and screen by the slant well drilling method, and for its durability to withstand aggressive development and redevelopment.

Future slant wells that will be installed as seawater intakes are to be completed with louvered screen manufactured from either SEA-CURE or AL-6XN.

Summary

Seawater intakes are vital components of desalination plants and must be designed to provide the appropriate corrosion resistance and durability to meet this application. Whether the intake screen is manufactured from continuous wire-wrapped screen or louvered screen, it is imperative for the steel such as SEA-CURE and AL-6XN to provide the requisite level of corrosion resistance for long-term durability.

References

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