DESIGN GUIDELINES OF SEAWATER INTAKE SYSTEMS

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Summary

Problems with seawater intakes and corrosion are the two primary causes for unscheduled downtime in desalination plants. On the surface, the design of seawater intake systems appears relatively easy. However, the dynamic, ever-changing characteristics of the sea, shoreline, and sea bottom present a variety of problems that must be considered when designing an intake system. Problems often develop in the operation of seawater intakes due to insufficient data for proper evaluation of the many parameters that can adversely affect the performance of a seawater intake. The seawater intake system for MSF or MED desalination plants must be designed taking into account a multitude of factors in order to provide a reliable source of seawater at the proper conditions for operation of the plant.

A proper assessment of site conditions is of fundamental importance for meeting the objectives of intake design. Factors that must be considered include physical site characteristics and meteorological and oceanographic data, as well as potential sources of contamination such as fouling by marine organisms, oil spills, or other pollution.

These factors also help in the ultimate decision in type of intake system. The lagoon-type intake is designed for protected areas, the pipe-type intake is an offshore design to protect from wave action and littoral transport, and the channel-type system should be restricted to areas of minimal wave activity and littoral transport.

The pump basin itself must also be designed to withstand and accommodate the conditions of the sea. One of the most important aspects of pump basin is the removal of "trash" from the water. Trash not only refers to solid materials such as driftwood and plastic containers, but also marine plants and animals which can find their way into the intake system. Another important design factor is the supply of an evenly distributed flow of water to the pump suction bells.

The effects of an improperly designed or located intake system can include corrosion of screens, pumps, and concrete structures, damage from waves, sand and silt in the pump basin, and trash and seaweed in the intake basin. These problems in turn result in reductions and/or interruptions in cooling water supply downstream.

1. Introduction

The primary purpose of the seawater intake system is to provide a reliable source of seawater in the proper quantity and at the proper quality and temperature to ensure satisfactory operation of the desalination plant. At first glance, supplying seawater from the ocean to a desalination plant along the coastline appears to be a relatively simple task. The ocean, however, is a dynamic entity which is constantly in motion and, therefore, constantly changing the shoreline and the near shore bottom profile. These changes are the result of the action of waves and currents which are capable of moving hundreds of cubic meters of sand and sediments. The ocean is extremely powerful and can create devastating forces in short periods of time. Seawater also acts slowly to cause the incipient corrosion of submerged structures. In addition, the ocean is alive with marine organisms which can rapidly attack or foul submerged objects. All of these factors combine to complicate the installation of equipment in the ocean and make the design of seawater intakes a task which requires careful attention and planning.

Because the design of seawater intake systems superficially appears simple, often the data used is insufficient to evaluate the many parameters that can adversely affect the performance of a seawater intake properly. For this reason, problems often develop in the operation of seawater intakes. Consequently, problems with seawater intakes and corrosion are the two primary causes for unscheduled downtime in desalination plants.

The following sections outline the design criteria and engineering guidelines for the design of reliable intake systems for multistage flash (MSF) or multieffect distillation (MED) desalination plants. The following items are addressed.

(a) Identification and evaluation of the effects of site conditions on seawater intake systems.
(b) Description of the various types of intake systems commonly employed, including the main design features and the applicability for different site conditions;
(c) Discussion of the primary design features of the seawater intake pump basin,

identification of the primary factors affecting the design of the pump basin and outline of engineering design criteria;

(d) Description of problems resulting from improper design of seawater intakes and the effects of these problems on the operation of the desalination plant;

(e) Analyses of specific case studies of the design and operation of actual seawater intake systems.

Reverse osmosis (RO) plants are more susceptible to suspended solids, organic matter, and bacteria in the seawater supply than are MSF or MED type plants. Additional design features may be considered to minimize these for seawater RO plants. Seawater wells, submerged intake filtration beds, and large onshore intake basins for silt settling may be investigated. Due to the more complex considerations, these special designs for RO plant intakes are not covered in this section. Usually if an open sea intake is used it is designed the same as those for MSF or MED plants.

2. Site Conditions

The objective of a seawater intake system is to provide a reliable source of fresh seawater within a proper temperature range which is free from contaminants. A proper assessment of site conditions for seawater intake is of fundamental importance for meeting this objective. To evaluate a site for seawater intake properly, the factors that must be considered include physical site characteristics and meteorological and oceanographic data. In addition, potential sources of contamination such as fouling by marine organisms, oil spills, or other pollution should be evaluated.

2.1. Water Depth

When considering the location of a desalination plant along the shoreline, it is important to remember that the ocean is in constant motion and is constantly changing. Water levels vary on a daily basis as tide levels change. A structure well above the waterline in the morning may be submerged 12 h later.

In addition, forces caused by waves and currents are constantly at work modifying the shoreline and the profile of the sea floor near shore. These forces can result in changes of several meters in elevation in just a few weeks time. For these reasons, it must be realized that water depth is not a set figure; instead it is a variable that changes with both the time of day and the time of year and is often expressed in relation to certain reference datum. The definitions of various reference datum for water levels are included in the discussion on tides (Section 2.5). In this section, consideration will be given to the effects of depth on intake performance characteristics.

The surf zone is the area in which waves approaching the shoreline break. Breaking waves create a great deal of turbulence. The churning motion of breaking waves lifts particles from the bottom into suspension and causes water in the surf zone to be more turbid and to have higher levels of suspended solids. For this reason, it is not advisable to take seawater directly from the surf zone.

Breaking waves also exert a tremendous amount of force. Objects installed near the surface in the surf zone could be subject to the direct impact of waves. As will be shown in a later section, the forces associated with wave movement decrease rapidly with depth. Therefore, by locating a structure at a sufficient depth below the water surface, the wave forces on the structure can be minimized.

Water temperature also varies with depth. The air-water interface is a heat transfer surface. The air heats up more rapidly during the day and cools off more quickly at night. Water, with its higher heat capacity, tends to change temperatures more slowly than air. Figure 1 illustrates the heat transfer which occurs at the air water interface.

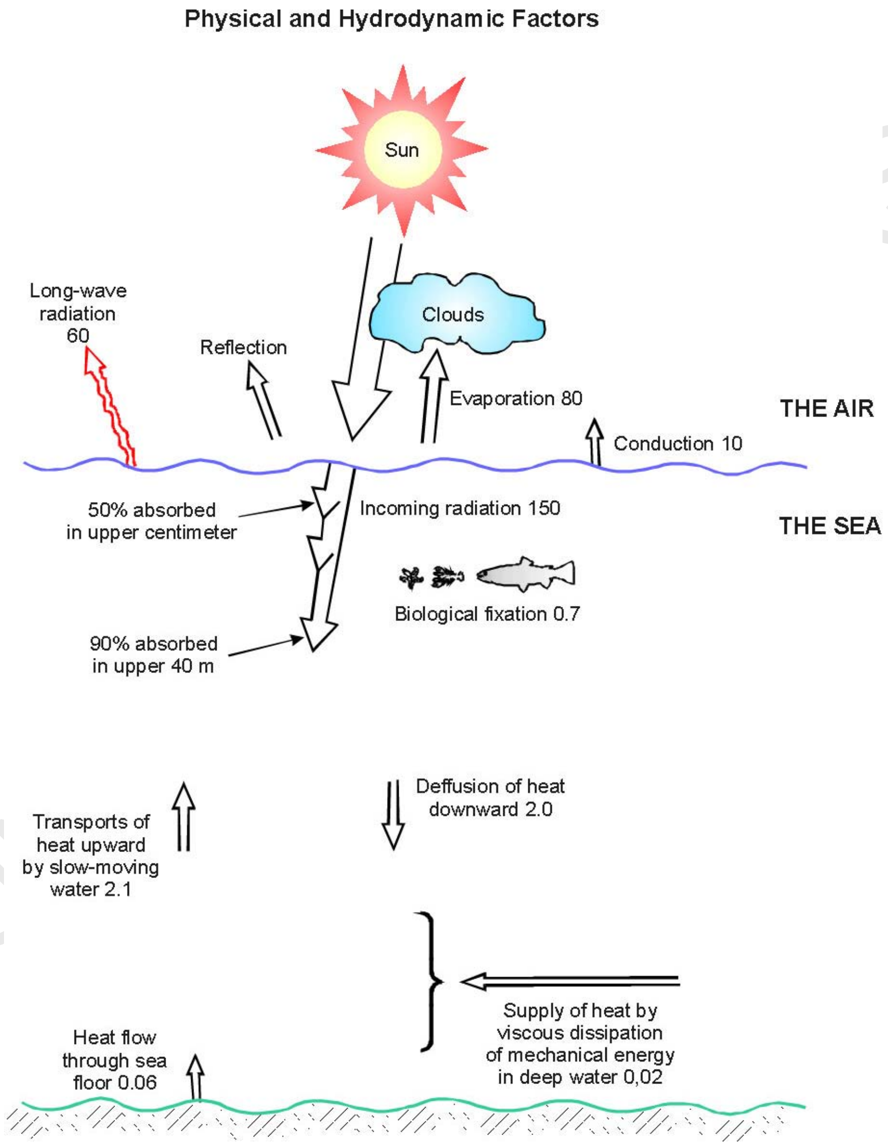

Figure 1. Heat transfer mechanism of the oceans.

The primary source of heat input is direct radiation from the sun. High percentages of this heat are returned to the atmosphere in the form of evaporation and long-wave radiation. The incoming radiation is attenuated rapidly by the water with 50 per cent being absorbed in the top centimeter and 90 per cent being absorbed in the top 40 m. In the deep oceans, this can result in thermoclines of 20 to 30°C between the surface and the bottom. Because of the rapid attenuation of radiant energy with depth, thermoclines of several degrees centigrade can exist between the surface and a depth of several meters. The magnitude of this surface thermocline is affected by the degree of mixing caused by waves. In shallow, protected bays, where there is limited heat transfer to cooler deeper waters and where wave-induced mixing is restricted, surface water temperatures may be several degrees centigrade higher than in open water.

It is important to keep water temperatures within a proper designed range for seawater intake. To reduce temperature fluctuations which can be experienced in stratified surface layers, it is preferred that seawater be obtained from a deeper layer.

One of the first considerations then, concerning the location of an intake for a desalination plant, is the proximity to the shore of a location deep enough to obtain cooler, less turbid water. Either a pipe- or channel-type intake can then be selected, depending on seabed conditions, to bring the water from this location to the plant.

2.2. Seabed Conditions

The seabed conditions will be one of the primary factors in determining the type of seawater intake structure for a particular location. If the intake is to draw water from the open coastline and not from a sheltered lagoon, the two most common types of intakes are the pipe and the channel intake.

In the pipe-type intake, a pipeline is run from the shoreline out past the surf zone. For sandy bottoms, a trench is usually dredged, the pipe laid, and the trench backfilled. For bottoms composed primarily of rock or coral, dredging and backfilling would be difficult and expensive. Pipelines are typically buried for anchorage and protection from wave forces and currents. Other methods of anchorage besides trenching and backfilling have been employed, including multihelix anchors, concrete saddles, engineered backfill, and grouted neoprene impregnated nylon bags or pillows filled with grout.

There are other problems associated with laying pipelines on a rocky bottom. Pipes laid in uneven terrain will only be supported at the high spots. This bridging between support points results in stresses that must be carried by the pipe. In addition, the danger of abrasion of the pipeline is increased with rock bottoms. For these reasons, rock bottoms are not conducive to the installation of a pipe-type intake.

A channel type intake can be constructed either by installing rocks to form walls along each side of the channel or by dredging. In sandy bottoms there is a tendency for the movement of sand due to littoral transport. This is discussed in more detail in a later section. This littoral transport can either act to erode sand from the channel walls or result in sand being deposited in the channel. This deposition of sand could result in blockage of the channel requiring redredging to keep the channel open. In addition, wave action in the channel would result in sand and silt being placed in suspension causing higher turbidity. The above problems can all seriously affect the operation of a channel-type intake for a sandy bottom. A detailed investigation of sediment gradation, settling rates, littoral transport patterns, currents, and wave activity is required for the design of a channel type intake in silty or sandy bottoms.

For rocky bottoms, the problems of littoral transport, erosion, and suspension of particles due to wave activity are not significant considerations in designing channel-type intakes. The bottom is generally more stable and problems of shifting sand and sediments should not occur. With properly selected materials for channel protection, erosion of channel walls should not be a problem. In addition, wave action will not result in the stirring up of sediments where rock bottoms are found. A channel-type intake installed on a rock bottom would not be encumbered by the sediment transport problems associated with a sandy bottom. The design of a channel-type intake on rock bottoms would primarily be concerned with resisting wave forces and eliminating debris.
It can be seen that a sandy bottom favors the installation of a pipe-type intake system while a rocky bottom tends to favor a channel-type intake.

2.3. Waves and Currents

The oceans are extremely dynamic systems constantly in motion as a result of external forces, such as wind and internal forces, such as temperature and salinity gradients. The rotation of the Earth results in oceanographic currents and wind forces cause waves and also affect the currents. Seismic forces in the Earth may also result in disruptive waves in the form of tsunamis and seiches.

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