11. General Desalination Definitions and Terminology

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Desalination is a process that removes dissolved minerals (including but not limited to salt) from seawater, brackish water, or treated wastewater. A number of technologies have been developed for desalination, including reverse osmosis (RO), distillation, electrodialysis, and vacuum freezing. Two of these technologies, RO and distillation, are being considered by municipalities, water districts, and private companies for development of seawater desalination in California. The following are broad descriptions of the various technologies which are used for desalination plants but are not necessarily applicable to the Cambria facility.

Reverse Osmosis (RO)

In RO, feedwater is pumped at high pressure through permeable membranes, separating salts from the water. The feedwater is pretreated to remove particles that would clog the membranes. The quality of the water produced depends on the pressure, the concentration of salts in the feedwater, and the salt permeation constant of the membranes.

Distillation

In the distillation process, feedwater is heated and then evaporated to separate out dissolved minerals. The most common methods of distillation include multistage flash (MSF), multiple effect distillation (MED), and vapor compression (VC).

In MSF, the feedwater is heated and the pressure is lowered, so the water "flashes" into steam. This process constitutes one stage of a number of stages in series, each of which is at a lower pressure. In MED, the feedwater passes through a number of evaporators in series. Vapor from one series is subsequently used to evaporate water in the next series. The VC process involves evaporating the feedwater, compressing the vapor, then using the heated compressed vapor as a heat source to evaporate additional feedwater. Some distillation plants are a hybrid of more than one desalination technologies. The waste product from these processes is a solution with high salt concentration.

Input Water (Feedwater)

Desalination plants may use seawater (directly from the ocean through offshore intakes and pipelines, or from wells located on the beach or sea floor), brackish groundwater, or reclaimed water as feedwater. Since brackish water has a lower salt concentration, the cost of desalting brackish water is generally less than the cost of desalting seawater. Intake pipes for desalination plants should be located away from sewage treatment plant outfalls to prevent intake of discharged effluent.

Product Water

Distillation plants produce a high-quality product water that ranges from 1.0 to 50 ppm tds, while RO plants produce a product water that ranges from 10 to 500 ppm tds. (The recommended California drinking water standard for maximum tds is 500 mg/L, which is equivalent to 500 ppm.) Salt concentrations of feed water and the salt concentration requirements of product water account for most of the variation. In desalination plants that produce water for domestic use, post-treatment processes are often employed to ensure that product water meets the health standards for drinking water as well as recommended aesthetic and anti-corrosive standards.

Desalination product water may be used in its pure form (e.g., for make-up water in power plant boilers) or it may be mixed with less pure water and used for drinking water, irrigation, or other uses. The desalination product water is usually more pure than drinking water standards, so when product water is intended for municipal use, it may be mixed with water that contains higher levels of total dissolved solids. Pure water is acidic and is thus corrosive to pipes, so it has to be mixed with other sources of water that are piped on-site or else adjusted for pH, hardness, and alkalinity before being piped off-site.

Product Water Recovery

The product water recovery relative to input water flow is 15 to 60 percent for most seawater desalination plants. For every 100 gallons of seawater, 15 to 60 gallons of pure water would be produced along with concentrated brine containing all of the remaining water and dissolved solids. A desalination plant's recovery varies, in part because the particulars of plant operations depend on site-specific conditions. In several locations in California, pilot projects are being proposed to test plant operations before full-scale projects are built.

Pretreatment Processes

Pretreatment processes are needed to remove substances that would interfere with the desalination process. Algae and bacteria can grow in both RO and distillation plants, so a biocide (usually less than 1 mg/L chlorine) is required to clean the system. Some RO membranes cannot tolerate chlorine, so dechlorination is required. Ultraviolet light may also be used to remove marine organisms. If ozone is used, it must be removed with chemicals before reaching the membranes.

In RO plants, suspended solids and other particles in the feedwater must be removed to reduce fouling of the membranes. Suspended solids are removed with coagulation and filtration. Metals in the feedwater are rejected along with the salts by the membranes and are discharged in the brine. With normal concentrations for metals in seawater, the metals present in the brine discharge, though concentrated by the RO process, would not exceed discharge limits established by State regulatory agencies for water quality protection. Some distillation plants may also need to remove metals due to potential corrosion problems.

Filter Backwashing, Membrane Cleaning and Storage, Scaling Prevention and Removal, and Pipeline Cleaning

The filters for pretreatment of feedwater at RO plants must be cleaned every few days (backwashed) to clear accumulated sand and solids (depending upon the intake technology, structures, etc). The RO membranes must, at the most, be cleaned approximately four times a year and must be replaced every three to seven years. Proper care could further extend the life of the membrane. Alkaline cleaners are used to remove organic fouling, and acid cleaners are used to remove scale and other inorganic precipitates. All or a portion of RO plants must be shut down when the membranes are replaced. When RO plants are not used continuously, the RO membranes must be stored in a chemical disinfection/preservation solution that must be disposed of after use. Distillation plants can also be shut down for tube bundle replacement, which is analogous to membrane replacement.

Desalination plant components must be cleaned to reduce scaling-- a condition where salts crystallize 2onto hard surfaces, such as pipes, tubing or membranes. Scaling is caused by the high salt concentration of seawater and can result in reduced plant efficiency and corrosion of the pipes. In general, scaling increases as temperature increases; thus scaling is of greater concern for distillation plants, since RO plants require lower temperatures to operate. Scaling can be reduced by introducing additives such as polyacrylates to inhibit crystal growth, reducing temperature and/or salt concentrations, removing scale-forming constituents, or seeding to form particles. Once scales have formed, they can be removed with chemical or mechanical means.

In addition to scaling, both RO and distillation plant intake and outfall structures and pipelines can become fouled with naturally occurring organisms or corroded. Structures and pipelines may be cleaned by mechanical means or by applying chemicals or heat. Feedwater may also be deaerated to reduce corrosion.

Waste Discharges

Desalination plants produce liquid wastes that may contain all or some of the following constituents: high salt concentrations, chemicals used during defouling of plant equipment and pretreatment, and toxic metals absorbed on particulate matter filtered from seawater. Some facilities (not including Cambria) may discharge liquid wastes directly into the ocean, combine the wastes with other discharges (e.g., power plant cooling water or sewage treatment plant effluent) before ocean discharge, discharge into a sewer for treatment in a sewage treatment plant, or dry the liquid and disposed of the residue in a landfill. Desalination plants also produce a small amount of solid waste (e.g., spent pretreatment filters and solid particles that are filtered out in the pretreatment process).

Energy Use

The energy used in the desalination process is primarily electricity and heat. Energy requirements for desalination plants depend on the salinity and temperature of the feedwater, the quality of the water produced, and the desalting technology used. Estimates for electricity use requirements for various technologies for seawater desalination are:

Multistage Flash (MSF)	3,500 - 7,000 kWh/AF
Multiple Effect Distillation (MED)	2,500 - 5,000 kWh/AF
Vapor Compression (VC)	10,000 - 15,000 kWh/AF
Reverse Osmosis (RO) - single pass	5,800 - 11,000 kWh/AF
Reverse Osmosis (RO) - double pass	6,500 - 12,000 kWh/AF

(Source: Wilf, 1991.)

In addition to electricity requirements, MSF, MED, and some VC plants also use thermal energy to heat feedwater. (Because of the inefficiency of converting thermal energy to electricity, there is a high energy "penalty" if electricity is used to heat feedwater.) For example, in addition to the 3,500 to 7,000 kWh/AF of energy required for electricity, the thermal energy needs for a MSF distillation plant is estimated at 270 million Btu/AF (about 26,000 kWh/AF); for MED plants, the estimated additional thermal energy requirements are 230 million Btu/AF (about 22,000 kWh/AF). Consequently, the total energy needs for distillation technologies are higher than for RO technologies.

Energy use requirements for desalination plants are high. For example, an estimated 50 million kWh/yr would be required for full-time operation of the City of Santa Barbara's desalination plant to produce 7,500 AF/yr of water. In contrast, the energy needed to pump 7,500 AF/yr of water from the Colorado River Aqueduct or the State Water Project to the Metropolitan Water District (MWD) of Southern California is 15 to 26 million kWh/yr. For comparison, these energy requirements are much larger than to the energy use of a small- to medium-sized industrial facility (such as a large refinery, small steel mill, or large computer center) which uses 75,000 to 100,000 kWh/yr.

Both RO and distillation plants can benefit from cogeneration plants to reduce energy use. Since increased energy use may cause adverse environmental impacts, the individual and cumulative impacts of energy use and production at a proposed desalination plant will require case-by-case analysis.