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SALTON SEA UNIT 3

47.5 MWe Geothermal Power Plant

by
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Introduction

The 10,000 kilowatt Salton Sea Unit 1 power plant was designed to demonstrate that electrical power generation, using the highly saline brines from the Salton Sea geothermal reservoir, was technically and economically feasible. Unit 1, owned by Earth Energy, a Unocal subsidiary, began operating in 1982, initiating an intensive testing program which established the design criteria necessary to construct the larger 47,500 kilowatt Unit 3 power plant. Unit 3 contains many of the proprietary or patented technological innovations developed during this program.

Design, construction and startup of the Unit 3 power generating facility began in December, 1986, and was completed in 26 months. By the end of 1988, the brine handling system was in full operation, and the turbine had been tested at design speed. Desert Power Company, a Unocal subsidiary, owns the power generating facility. Unocal owns the brine resource production facility. Power is transmitted by the Imperial Irrigation District to Southern California Edison Company.

History of the Salton Sea Geothermal Area

In the mid 1850s, W.P. Blake set out to explore a route for a railroad line from the Mississippi River to the Pacific Ocean. When he reached the part of the desert that is now the Salton Sea, he found spectacular thermal springs and geysers, which he documented in an account of his travels. Fifty years later, the 1905 Colorado River flood formed in Salton Sea and quenched most of the geothermal sur-

face manifestations except for a few passive, gas-rich hot springs and several cool mud pots.

These thermal springs first attracted commercial interest in 1927. The Pioneer Development Company drilled three shallow wells to explore for steam. However, the heat provided from the wells was insufficient to support power generation. During the next ten years, more than fifty shallow wells were drilled to produce carbon dioxide for two dry ice plants. Concurrently, a well being drilled for potable water hit a very hot artesian source that gushed forth and created mud pots. Although the well was regarded as a failure and was abandoned, an entrepreneur named Theodore Pilger, who had experience with health spas, capitalized on the area by developing a popular hot mud bath resort for health-minded tourists. Pilger became the first of a series of commercial developers to tap the Salton Sea geothermal brines.

The first deep well to explore for oil was drilled into the Salton Sea anomaly by the Kent Imperial Corporation in 1958. Hot brine and steam were encountered instead. Although the well failed as a successful geothermal producer, it renewed interest in the exploration for geothermal steam.

Hot brine geothermal wells were drilled by P.H. O'Neil of Texas, Union Oil, Shell Oil, and Natomas. Other companies playing a major role in exploration and experimentation included Imperial Thermal Products, Geothermal Energy and Mineral, Magma Power, and Phillips Petroleum. Testing was aimed primarily at chemical extraction and mineral and salt recovery, with electrical power generation as a secondary product.

The need to develop geothermal energy became acute when our nation experienced the energy crises of the 1970s. The hot Salton Sea brines were recognized as potentially valuable for electrical power generation to help offset the need for imported fuel. Ten additional years of research and technological development were necessary to achieve commercial generation.

The Salton Sea Geothermal Reservoir

The Salton Sea geothermal reservoir is the largest of several hot brine geothermal resources within the Salton Trough in the Imperial Valley, California. The portion of the reservoir associated with the Unit 3 plant is located at the southern end of the Salton Sea geothermal anomaly (Figure 1).

The reservoir is composed of sand, silts and clays, deposited primarily by the Colorado River over the last 10 million years. The thickness of these sediments is about 20,000 feet. The reservoir is overlain by lake sediments which were deposited in the last few thousand years. These most recent deposits are in part the sealing caprock for the Salton Sea reservoir.

Recent faulting and volcanic activity near the Salton Sea created the geothermal resource. The reservoir sand, silts and clays show increasing consolidation and alteration with depth. This is due to the interaction with increasing temperatures and reservoir fluid salinity with depth. The typical reservoir fluid exceeds 450°F (230°C) and is seven times more salty than sea water. The challenge in developing the Salton Sea re-

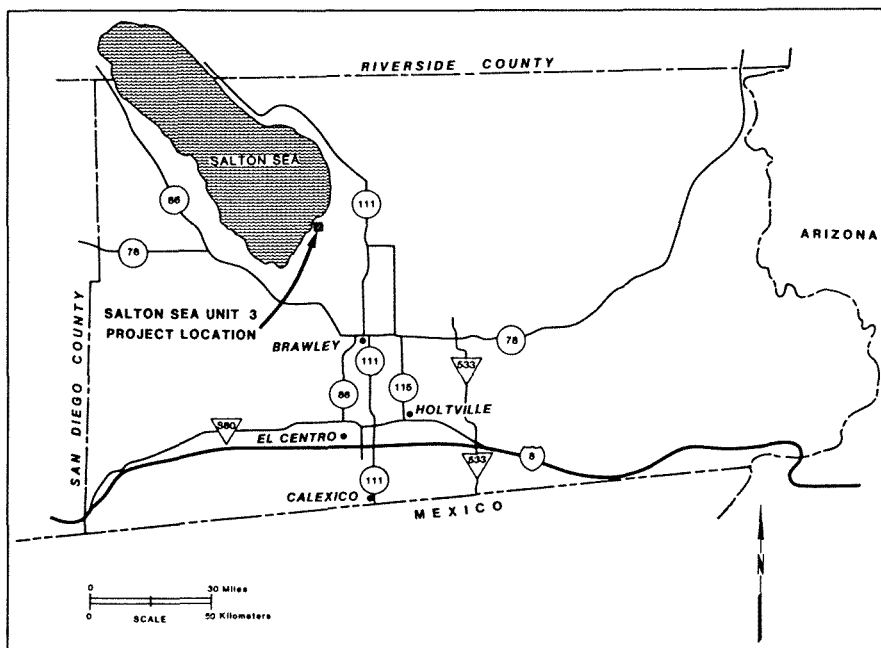


Figure 1. SALTON SEA UNIT 3 PLANT LOCATION
Imperial Valley, California

servoir has been learning how to handle these hot, highly saline brines.

The Resource Production Facility

Two producing wells are centrally located within the Salton Sea project area. These wells produce a total of 4,300,000 pounds per hour (lbs/hr) of hot fluid to the resource production facility. Flowing wellhead pressures range from 400 to 475 psig. Steam is processed here, then delivered to the dual inlet turbine at the

electrical generating plant. Figure 2 is a schematic of resource production and power generation. Figure 3 shows the well and facility layout.

The fluid from each producing well flows to large, high pressure wellhead separators where the two-phase mixture of steam and liquid brine is separated. The steam exits the top of each separator through a pressure controller and enters the main steam line to the power generation facility. The concentration of carbon dioxide and other noncondensable gases in the flashed steam is

low enough to permit the steam to go directly to the power generation facility without imposing an excessive load on the vacuum producing equipment of the condenser.

The liquid brine exits each wellhead separator and is combined into a single stream which is directed into the standard pressure crystallizer. The steam is flashed at slightly above delivery pressure of 100 psig. The steam, along with that flashed from the wellhead separator, is cleaned in two scrubber vessels. Most of the remaining particulates and moisture are removed in the scrubbers.

The brine flows from the bottom of the standard pressure crystallizer to a low pressure crystallizer where pressure is further reduced. The steam leaves the top of this separating vessel and is directed into the low pressure steam line leading to the turbine. This steam is also cleaned in two scrubbing vessels prior to entering the turbine. The remaining brine from the low pressure crystallizer flows to an atmospheric separator for final steam/ brine separation.

As steam is flashed in the above processes, the brine cools and the concentration of dissolved material increases. In this supersaturated condition, various compounds tend to come out of solution and form solid particles suspended in the brine. In the crystallizers, these particles tend to grow to a size which can be readily separated from the brine. This particle growth process also inhibits the very small particles from adhering to the vessel walls and downstream piping.

Maintaining balanced brine flow and stabilized vessel conditions was initially forecast as difficult. For this reason, there are two parallel trains of high and low pressure crystallizers and atmospheric separators. Each train is capable of handling up to 80 percent of the plant flow. One train can be serviced without interrupting plant operations.

The brine flows from the atmospheric separator into the clarifier. Here the suspended particles grow even larger and settle to the bottom of the vessel where they are removed. The clean brine rises to the top of the clarifier and flows to the secondary

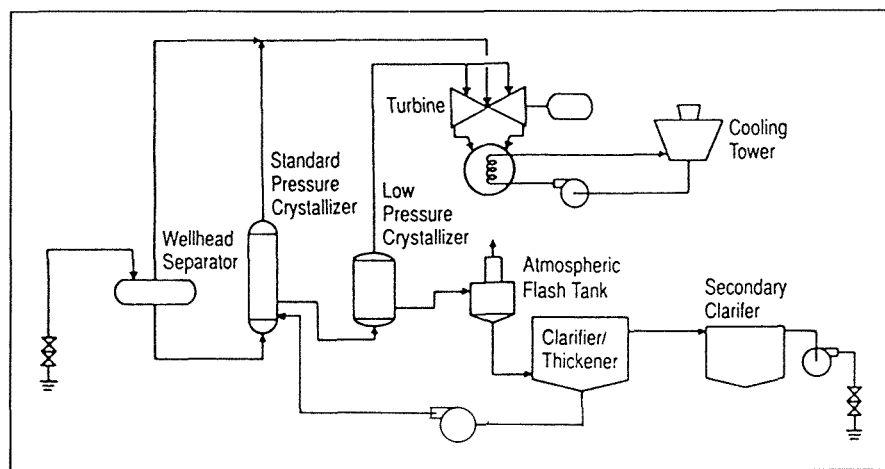


Figure 2. SALTON SEA UNIT 3. Simplified Process Schematic

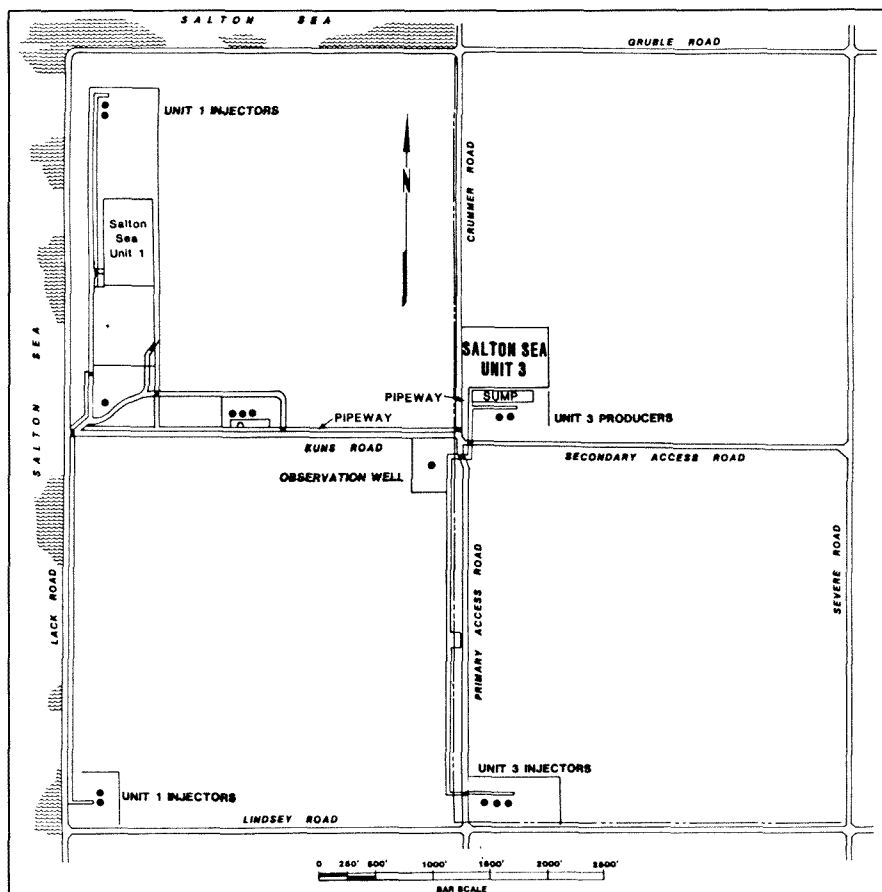


Figure 3. SALTON SEA UNIT 3; Well and Facility Layout

clarifier for final cleaning. The treated brine is then pumped through pipelines to the field injection wells.

The solids collected from the clarifiers are dewatered in a filter system. The solids are beneficially used in a construction grade soil cement which is placed in the local area. The crystallizers, clarifiers and dewatering filter are similar to equipment of the kind which might be found in a heavy chemical, ore processing or waste treatment plant, with special modifications for the unique geothermal environment.

The three brine injection wells are located at the south end of the field. Together, they dispose of a total of $3,200,000 \pm \text{lb/hr}$ of clarified brine.

If, for any reason, the power generation facility turbine must be shut down, the steam is automatically discharged to the atmosphere through a rock muffler until turbine operations are resumed, or the re-

source production facility is shut down. The brine can be directed to a brine storage pond in case of a malfunction in the production or injection equipment. The pond can maintain full load operation for three hours.

The Salton Sea Power Generation Facility

The Unit 3 power generation facility, owned by Desert Power Company, is located adjacent to the Unocal resource production facility.

The design steam flow rates to the power generation facility are $623,000 \text{ lbs/hr}$ of standard pressure steam at 100 psig, and $262,000 \text{ lbs/hr}$ of low pressure steam at 10 psig. These two steam trains flow to the turbine. The turbine is 54,000 kilowatt, 3,600 rpm, dual flow dual pressure unit with five stages. The first two stages are impulse type and the last three are reaction type blades.

The last stage blades are 25 inches long. Steam from the turbine is exhausted to the main condenser which is a dual pressure design.

Corrosion resistant stainless steels were used extensively in the construction of the surface condenser. All condensate from the plant is used for cooling tower makeup or returned for injection. Noncondensable gases are removed from the main condenser by three stages of steam-jet ejectors. The ejectors require a total of $40,000 \text{ lbs/hr}$ of steam at 90 psig to remove $6,500 \text{ lbs/hr}$ (design) of air and other noncondensibles from the main condenser. Noncondensable gases and motive steam from the ejectors flow to shell and tube type condensers, the last stage of which operates at a pressure of 0.9 psig. Steam condensate from the air ejector-condenser drains into the main condenser, from which it is returned to the resource production facility.

The noncondensable gases from the power generation facility are mixed with the air steam being discharged by the fans on the cooling tower. The seven cell, induced draft cooling tower is designed to cool $82,000 \text{ gpm}$ of water from 100° to 80° F , for a heat load of 820 MMBtu/hour . Makeup water to the tower is provided from stored condensate.

The Unit 3 power generation facility is designed for a net plant output of 49,800 kilowatts at the bushbar. Line losses through the 90 mile electrical transmission facility reduce the power delivered to the Southern California Edison Company in the Coachella Valley to 47,500 kilowatts. The amount of energy generated is sufficient to meet the needs of an estimated 50,000 residential customers, and can save about 500,000 barrels of oil per year.

Operations

Brine first flowed to the resource production facility on 14 December 1988. After successful testing of the brine-handling and power generation systems, the power generating plant achieved commercial operation on 14 February 1989. The plant has run continuously since that time at more than 95 percent capacity. □