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GEOTHERMAL STEAM CONDENSATE REINJECTION

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Geothermal electric generating plants which use condensing turbines generate an excess of condensed steam which must be disposed of. At the Geysers, California, the largest geothermal development in the world, this steam condensate has been reinjected into the steam reservoir since 1968. A total of 3,150,000,000 gallons of steam condensate has been reinjected since that time with no noticeable effect on the adjacent producing wells. Currently, 3,700,000 gallons/day from 412 MW of installed capacity are being injected into 5 wells. Reinjection has also proven to be a satisfactory method of disposing of geothermal condensate at Imperial Valley, California, and at the Valles Caldera, New Mexico.

The Geysers is a vapor-dominated reservoir with a reservoir pressure not exceeding 500 psig. Since the average depth of the injection wells is 5380 feet, no pumping of the injected water is required. The surface facilities consist of a settling basin to remove solids, transfer pumps, deaerating vessels, and fiberglass or plastic-coated steel pipelines.

I. INTRODUCTION

The native fluids produced from most geothermal systems recover only a fraction of the total energy within the system. The most apparent method of recovering additional heat from the system is to inject cold water back into the reservoir to extract heat from the reservoir rock. Also, geothermal electric generating plants which use condensing turbines generate an excess of condensed steam which must be disposed of. So even vapor-dominated or dry steam fields will have large volumes of excess steam condensate and liquid-dominated or hot water fields will have even larger volumes to dispose of.

The simplest and most economical method of disposing of this water and condensed steam is to reinject it into the geothermal reservoir. The alternatives to this course of action are either surface disposal or underground disposal in zones other than the geothermal reservoir. To purify the water adequately for surface disposal is often very expensive and disposal zones other than a geothermal reservoir are often not available in many areas of the country. The Union Oil Company has operated geothermal condensate reinjection projects at the Geysers and Imperial Valley, California, and at the Valles Caldera, New Mexico. The purpose of this paper is to provide a case history for each of these projects.

II. THE GEYSERS

At the Geysers, a vapor-dominated reservoir, steam condensate reinjection back into the reservoir began in 1969, and 3, 150, 000, 000 gallons of condensate have been reinjected since that time. Currently, 3, 700, 000 gallons per day from 412 MW of installed capacity are being injected into 5 wells.

The condensed steam is essentially fresh water, although there is a small volume (about 1%) of other gases in the steam, some of which is soluble in the steam condensate. These contaminants, principally ammonia and boron, are present in concentrations in excess of the limits set by the Regional Water Quality Control Board for discharge directly to the watershed.

The condensed steam is received from the cooling tower basins of the electric generating plants and piped to settling basins. These settling basins are approximately 50 X 50 ft and 8 ft deep, constructed of concrete with wooden baffles, and are designed to remove any settleable solids from the effluent. Level control valves are installed on the outlet of these basins to insure that no air is allowed to enter the discharge pipe that leads to the injection wells. From the settling basin, the water either flows by gravity or is pumped through plastic-coated welded steel pipelines to the injection wells. Deaerating vessels are installed on the lines as an additional precaution against air being injected into the wells and causing corrosion problems. A continuously recording orifice meter is also installed in the pipeline to record the volume of water injected into each well.

All of the five injection wells were originally drilled as steam production wells and then converted to injection service. The wells are drilled with water-based drilling fluid down to the top of the steam reservoir where a string of 9-5/8-in. casing is set. The producing interval is drilled using air as the circulating medium to the total depth of the well. Producing wells are left in this condition, but conversion to injection requires that a slotted liner be placed through the injection interval to prevent the formation from sloughing into the wellbore on contact with water (Fig. 1).

The Geysers steam reservoir is a fractured Graywacke with steam production occurring from a few hundred feet to over 9000 ft in depth. The initial reservoir pressure is about 500 psi. Since the injection wells have depths ranging from 2364 to 8045 ft, this low reservoir pressure causes a large pressure differential towards the formation, and the wells will inject large volumes of water without requiring pumping. The high permeability-thickness products (from 20, 000 to 150, 000 millidarcy feet) encountered in the wells are also a factor in the high injection rates (1200 gallons/minute) with no backpressure at the wellhead.

The locations of the injection wells are chosen such that they are as far as possible from existing producing wells and the injection interval is deeper than the producing interval in the adjacent producing wells. This precaution has so far been sufficient to prevent communication of the injection water to the producing wells. The importance of injection depth was illustrated early in the life of the injection project when communication from the first injection well to a nearby producing well was established. A spinner survey run in the injection well showed that due to a bridge in the wellbore, the water was being injected at a shallower depth than anticipated. The injection well was then cleaned out to total depth and a slotted liner run. The well was returned to injection and has been on injection for five years with no further evidence of communication.

There have been some problems with the injectivity of individual wells declining with time. The cause of this has been attributed to plugging of the fracture system with elemental sulphur in the steam condensate. This problem is easily overcome by shutting the well in and letting it heat up. Since the melting point of sulphur is 238°F and the reservoir temperature is 475°F, the sulphur is easily melted and can be pushed away from the wellbore and back into the formation.

The Division of Oil and Gas is the state agency responsible for regulation of geothermal reinjection projects. Before approving the project, they examine the geologic and engineering data, including reservoir conditions, injection fluid volumes and analyses, geologic maps, and cross-sections. They also must approve the drilling or conversion of each individual injection well. A report on the injection volumes is sent to the Division of Oil and Gas on a monthly basis. The water quality of the adjacent watershed is also monitored monthly.

The USGS is monitoring both seismically and by methods of triangulation any land movements that might occur as a result of our injection program. The data indicate that there is no noticeable change in the seismic activity within the area.

III. VALLES CALDERA, NEW MEXICO

Union Oil's reinjection experience at the Valles Caldera is a result of production testing two geothermal wells in that area during 1973 and 1974. The reservoir is a liquid-dominated reservoir, and the fluid flashes to a mixture of steam and water when the wells are produced. The wells were flowed through a steam-water separator and the water was flowed into holding ponds and then pumped to the injection well. The test has been underway for a little over a year, and during this time almost 100,000,000 gallons of water were reinjected. There have been no evidences of injectivity impairment during that time.

IV. IMPERIAL VALLEY

Union Oil's reinjection experience in the Niland area of the Imperial Valley is again the byproduct of a production test. This test was of one year's duration during 1964 and 1965. The reservoir is liquid-dominated and static wells have a wellhead pressure of 200 psig. After initially overcoming this pressure, the heavier column weight of the cold injection water allowed the injection well to take water at a vacuum. During the one-year test, approximately 126,000,000 gallons of water were reinjected. The injection rate into the well was approximately 600 gallons per minute. Again, there was no loss of injectivity during the test and there was no reservoir response.

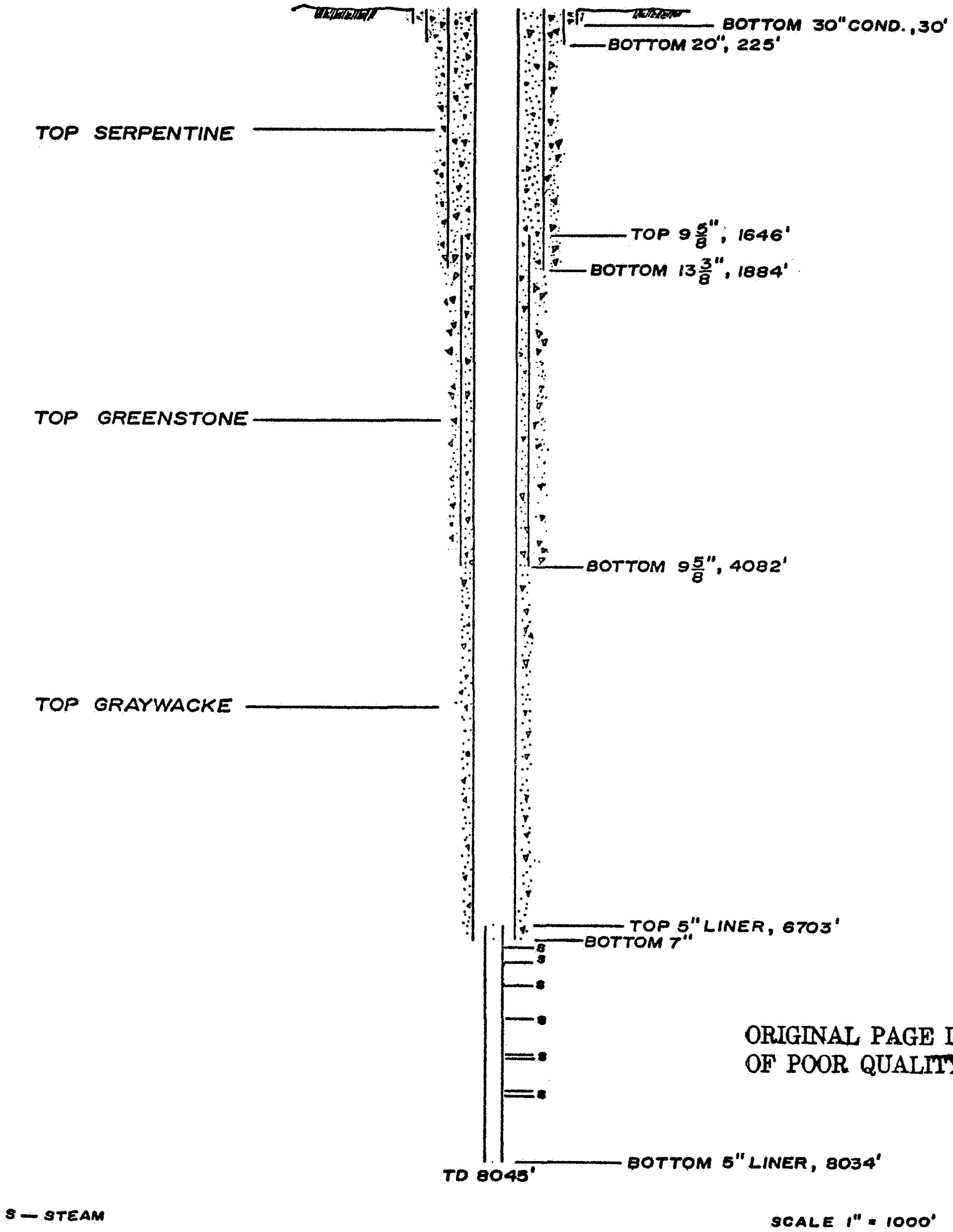

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Fig. 1. Typical Injection Well