SDGEE PIONEERING GEOTHERMAL TEST WORK IN THE IMPERIAL VALLEY OF SOUTHERN CALIFORNIA

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The San Diego Gas E Electric Company (SDGEE) is actively engaged in testing to develop methods to utilize geothermal resources at Niland and Heber in California's imperial Valley.

This paper describes San Diego's test program at the Niland area which is characterized by high temperature brines of high salinity.

San Diego's first testing began in April 1972. One production well was flowed at the Niland site for about ten days. The well flowed without pumping. Brine temperature and pressure at the production wellhead averaged 375°F and 150 psig. The geothermal brines which were produced were injected back into the reservoir through a 2,400 ft. deep well located about ¼ mile away.

The production of the well was, on the average, 400,000 lbs/hr. total mass flow. This was 324,000 lbs/hr of liquid (81%), 64,000 lbs/hr of steam (16%), and 12,000 lbs/hr of noncondensable gases (3%). The wellhead temperature and pressure remained stable at 375°F and 150 psig. The total dissolved solids averaged 225,000 parts per million and the indicated bottomhole temperature was 510°F at a depth of 2,250 feet.

Based on these tests, San Diego proceeded with a preliminary design of a Geothermal Test Facility. A direct steam turbine cycle was rejected because of the relatively high volume of noncondensable gases.

Field tests were carefully designed to simulate the phase separation and heat transfer conditions which would exist in the full-scale Geothermal Test Facility. The separator and heat exchangers used in these field tests were 1/20th scale versions of the proposed test facility equipment.

In the 1973 field test program, production of geothermal fluids from the well was held to a test flow of 20,000 lbs/hr. Brine, steam and noncondensable gases exited at the top of the separator and passed through the shell side of the steam heat exchanger. Brine, leaving the bottom of the separator, flowed through the tube side of the brine heat exchanger. The temperature of both the steam and the brine was 375°F. Distilled water was used for the heat exchange fluid. The dissolved solids in the geothermal brine flowing through the brine heat exchanger ranged from 200,000 to 245,000 parts per million. Dissolved solids in the steam at the exit of the test separator were 40,000 to 80,000 parts per million. Both the steam heat exchanger and brine heat exchanger heat transfer performance declined to unacceptable limits in about 100 hours of operation.

inspection of the brine heat exchanger tubes and header showed a scale buildup which averaged 0.060 inch thick. Amorphous deposits near the tube end were considerably thicker. The major constituents were silica (SiO_2 38%), iron sulfide (FeS_3 23%), and lead sulfide (PbS 11%). A layer of scale approximately .045 inch thick in the steam heat exchangers was attributed to the high carryover which was due to an undersized separator design and a lack of a scrubber downstream of the separator.

Scaling within pipelines which handled brine was another trouble area. A scale buildup one inch thick was observed in a pipe spool removed after six months of continuous brine handling service. The brine was exposed to air in the injection pump sump prior to pumping back into the reservoir. The brine process pipe was above ground and was not insulated to reduce heat loss.

Neither the mild carbon steel process piping nor the titanium heat exchanger tubing showed signs of corrosion during or after these tests. These findings were determined by metalographic inspection of the containment materials and chemical analysis of the scale.

We tested two methods of cleaning scale from heat exchanger tubes. Caustic solution cleaning proved to be more effective and faster than the hydrojetting method.

in March 1974, San Diego resumed field test work at the Niland geothermal field using scale models of a new design. The flow diagram for the test hardware is shown in Fig. 1. The flow of geothermal fluid from the producing well was controlled at a rate ranging from 50,000 to 100,000 lbs/hr at various times during the test program to map the separator performance. The geothermal fluids from the producing well entered the first stage separator at 150 psig and 370°F for this flow range. Approximately 5,000 to 12,000 lbs/hr of steam flowed out of the first stage separator to a scrubber where it was cleaned and then directed through the shell of the steam heat exchanger. The remaining brine flowed from the bottom of the first stage separator to the second stage separator which was operated at 50 psig. An average of 2,300 to 6,000 lbs/hr of steam flowed from the top of the second stage separator to the second scrubber where it was cleaned and then flowed through the tubes of the second stage heat exchanger.

Fig. 2 is a cutaway view of one of the separators showing the simple interior of the vessel. Both the first stage and second stage separators used in this test had the same configuration. Well fluid enters the separator at the port located in the bottom and impinges on the vessel end dome where a wearplate provides for protection of the vessel wall. Steam leaves the vessel through the upper port. Brine collects at the bottom of the vessel and flows to the second stage separator.

The test determined that a maximum liquid level of one quarter to one third of the separator diameter produced the most effective separation. The parameters found to be associated with this liquid level range are an inlet mass velocity not exceeding 50 feet per second, a steam velocity of no more than 5 feet per second and a separator length equal to approximately four vessel diameters. Test results indicated approximately 100 to 200 parts per million of dissolved solids remained in the steam leaving both the first stage and second stage separators.

Fig. 3 shows the internals of the steam scrubbers used for the 1974 test program. Steam from the separator enters the scrubber through the lower port. It flows up through five trays which hold pure water obtained from the steam condensate at a point downstream from the heat exchangers. The water contacting the steam scrubs the solids entrained in the steam. Clean steam exits at the top, and the washwater, which is continuously added to the scrubber at a rate of 0.2 gallons per hour, enters at the top of the vessel. It cascades from tray to tray to the drain at the bottom and after leaving the scrubber is recombined with the brine stream and reinjected into the reservoir.

During the 1974 tests, the solids in the steam leaving the scrubbers were reduced to the level of 10 to 20 ppm, which is acceptable for steam heat exchanger operation.

The graphs in Fig. 4 show the results of the 1974 heat exchanger tests. The lines plot overall heat transfer coefficient for the first stage and second stage heat exchangers as a function of time of operation. The 1974 tests accumulated total operating time for the first stage heat exchangers of 398 hours. While the first stage heat exchanger was under test, an upset of operation in the scrubber occurred which resulted in a high carryover of dissolved solids from the scrubber into the first stage heat exchanger. This carryover was in excess of 3,000 ppm for a period of approximately 37 hours during the initial test operation. An extrapolation of the data indicates that, including the upset, the first stage heat exchangers would operate for about 3,200 hours before reaching design conditions requiring cleanup. Without the upset it is estimated this heat exchanger could operate up to a year before requiring cleaning.

A comparable analysis of the second stage steam heat exchangers indicates that they will operate for 10,000 hours before reaching design heat exchange conditions. Total actual operating time for the second stage heat exchangers was 587 hours.

The 1974 field tests at the Niland geothermal field demonstrated that the technology could be developed to handle the Niland brines for purposes of effective heat exchange. It also gave a good indication that a successful reinjection program can be accomplished at the Niland geothermal reservoir. At the start of the 1974 tests, the injected geothermal brine flow averaged 90,000 lbs/hr. at an average temperature of 165°F. Initially the injection pump discharge pressure required was nearly 400 psig, but after 16 hours of continuous pumping, the injection pressure dropped and brine flowed into the injection well by gravity. During the 6-month test program, injection by gravity flow could be maintained an average of six days before injection pressure gradually rose requiring another short period of pumping. The flow was varied between 60,000 and 120,000 lbs/hr. Temperature was maintained in a range between 150°F and 180°F by adding 10% irrigation water to cool the hot spent brine to prevent cavitation in the injection pump.

SDG&E directed the Ben Holt Company of Pasadena to proceed with engineering for a Geothermal Test Facility utilizing the multi-stage steam flash process with steam scrubbing and steam heat exchanger. This facility is the thermal loop portion of a 10 MW binary electric generation plant. The isobutane turbine and associated generator set are simulated by an expansion valve in the isobutane loop. Fig. 5 is a flow diagram of the facility. This process does not make use of the brine in heat exchangers, but instead flashes the brine to steam in four stages to extract maximum heat. The condensate from the steam heat exchangers will be recombined with the remaining brine and the fluids reinjected to the reservoir through two wells.

In 1975 the U.S. Energy Research and Development Administration (ERDA) entered into a joint project agreement with San Diego Gas & Electric Co. for construction and operation of the 10 MWe sized geothermal loop experimental facility at Niland in the Imperial Valley. Under the agreement, costs will be shared 50-50 by SDG&E and ERDA. Estimated cost for the facility and experimental programs is approximately $8 million.

SDG&E and ERDA plan for the completion of this facility in April 1976. Using two production and two injection wells, the operation of the Geothermal Test Facility should obtain essential data to confirm the design of the binary power cycle and to provide a first step in the determination of the Niland geothermal reservoir characteristics. SDG&E, ERDA, and others will continue to develop and test equipment as well as to establish required reservoir operating parameters and procedures. The goal of this program is to achieve the conversion of geothermal energy in the Imperial Valley to commercial electric energy.

1974 GEOTHERMAL FIELD TEST
TWO·STAGE FLASH SYSTEM

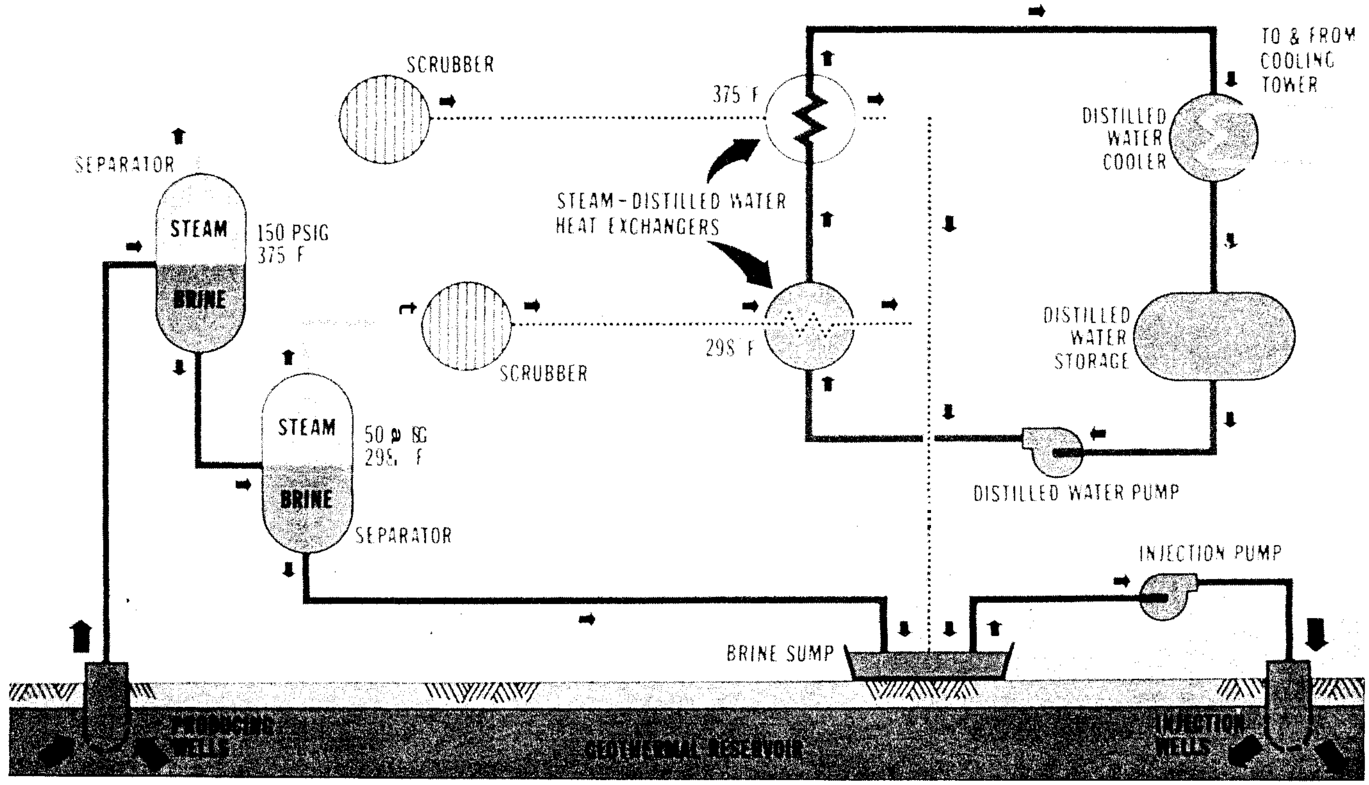


FIGURE I.

C.F. BRAUN SCALE-MODEL SEPARATOR
1974 FIELD TEST

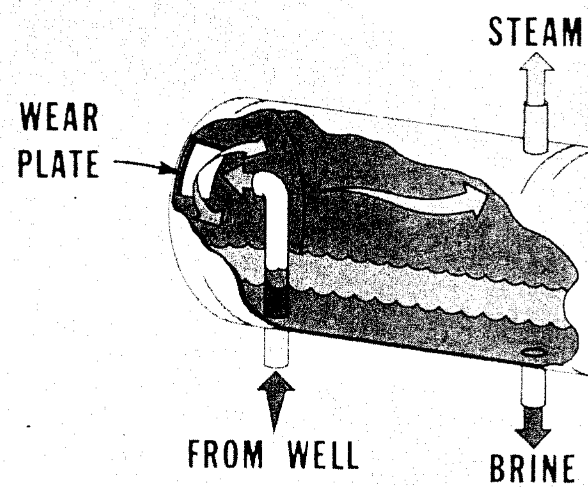


FIGURE 2.

BEN HOLT
STEAM SCRUBBER
1974 FIELD TEST

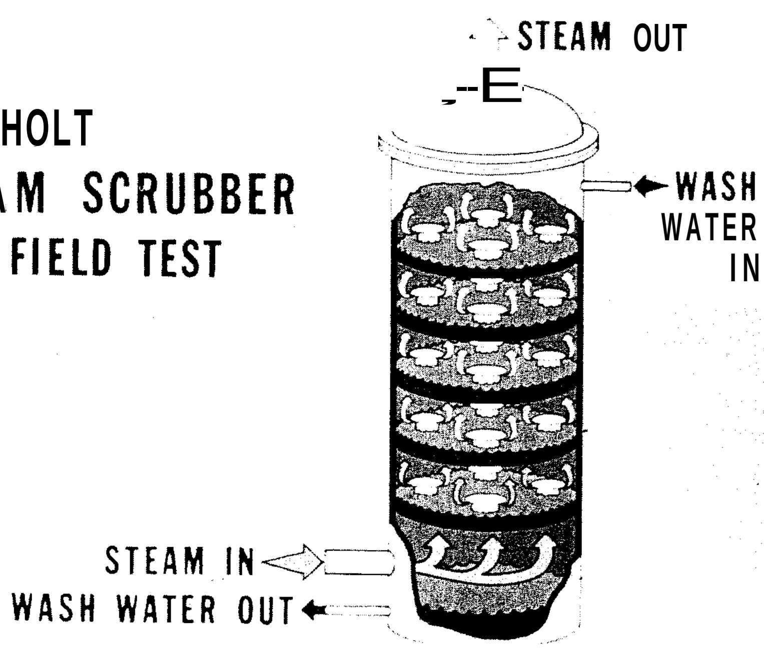
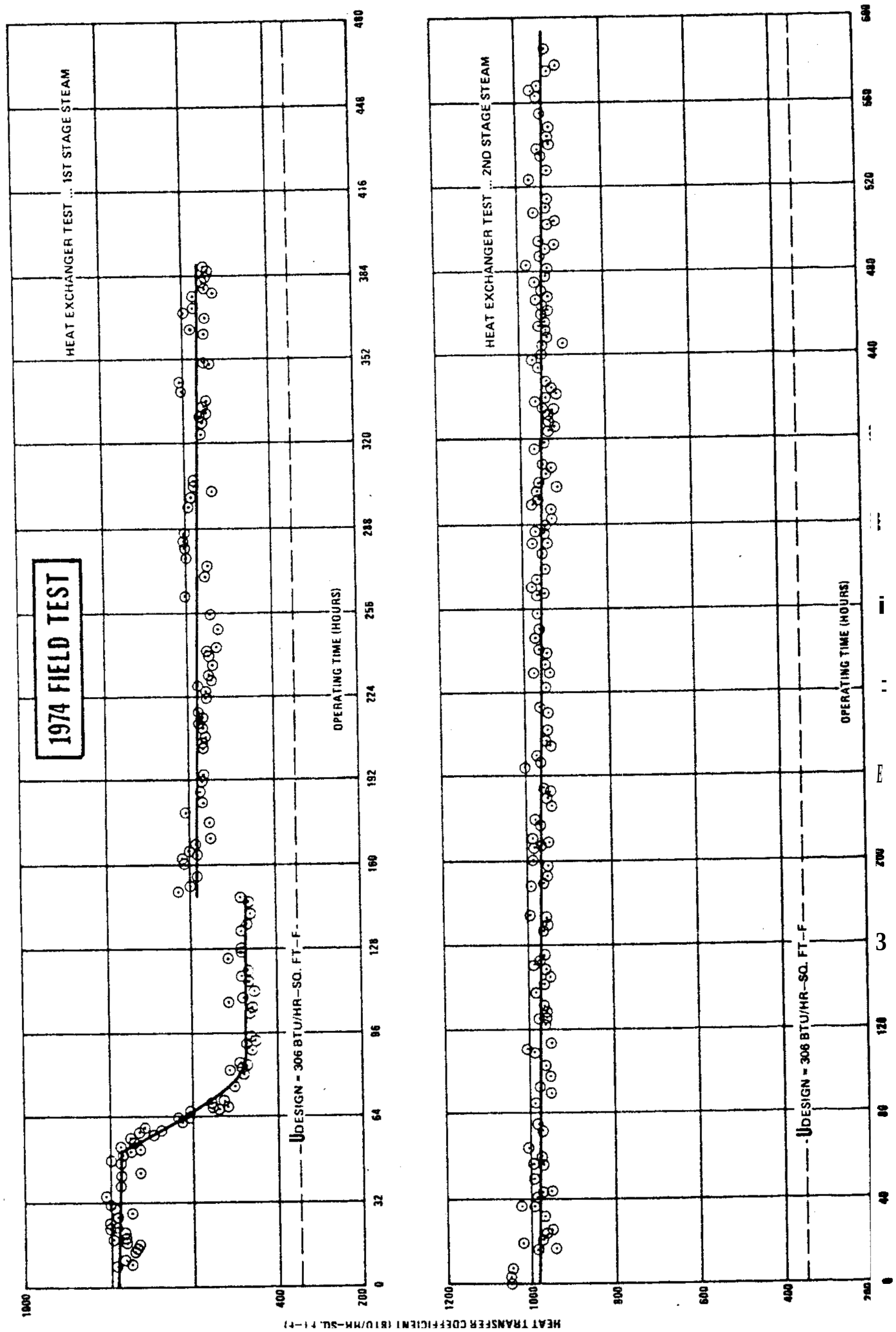


FIGURE 3.



1974 FIELD TEST
HEAT EXCHANGER TEST ... 1ST STAGE STEAM
HEAT EXCHANGER TEST ... 2ND STAGE STEAM
UDESIGN = 306 BTU/HR-SQ. FT-F
OPERATING TIME (HOURS)
HEAT TRANSFER COEFFICIENT (BTU/HR-SQ. FT-F)

FIGURE 4

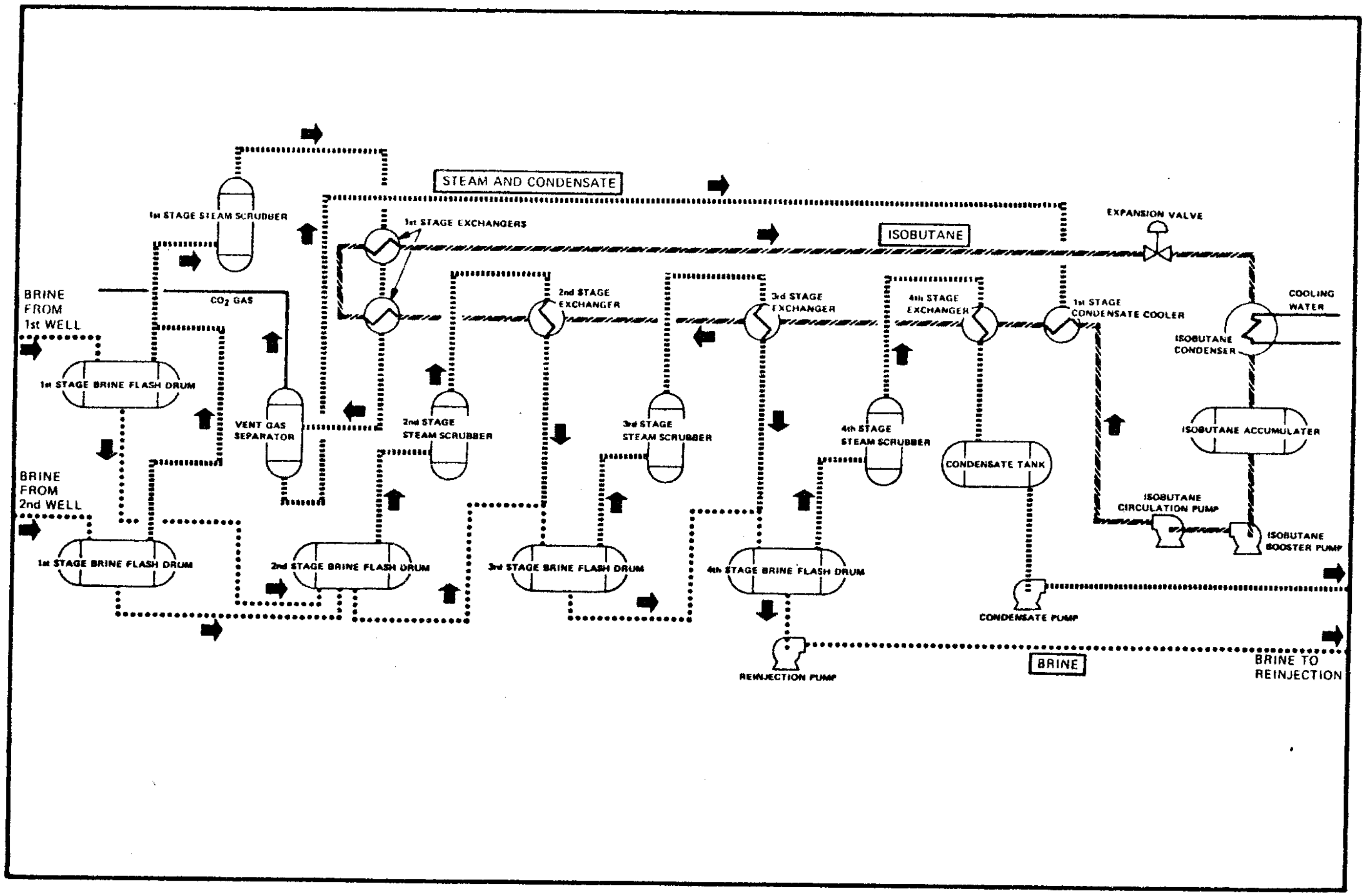

STEAM AND CONDENSATE
ISOBUTANE
BRINE
1st STAGE STEAM SCRUBBER
1st STAGE EXCHANGERS
BRINE FROM 1st WELL
BRINE FROM 2nd WELL
CO_2 GAS
1st STAGE BRINE FLASH DRUM
1st STAGE BRINE FLASH DRUM
VENT GAS SEPARATOR
2nd STAGE STEAM SCRUBBER
2nd STAGE BRINE FLASH DRUM
2nd STAGE EXCHANGER
3rd STAGE STEAM SCRUBBER
3rd STAGE BRINE FLASH DRUM
3rd STAGE EXCHANGER
4th STAGE STEAM SCRUBBER
4th STAGE BRINE FLASH DRUM
4th STAGE EXCHANGER
REINJECTION PUMP
CONDENSATE TANK
CONDENSATE PUMP
1st STAGE CONDENSATE COOLER
EXPANSION VALVE
COOLING WATER
ISOBUTANE CONDENSER
ISOBUTANE ACCUMULATER
ISOBUTANE CIRCULATION PUMP
ISOBUTANE BOOSTER PUMP
BRINE TO REINJECTION

FIGURE 5