SCALING TESTS ON A SALTON SEA GEOTHERMAL BRINE

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As part of the Penn State scaling project sponsored by the U. S. Bureau of Mines, we designed a field test to determine scaling rates from homogeneous geothermal fluids. This technique has been used on the concentrated brines of the Salton Sea K.G.R.A. The principle adopted for the test was to cool the brine abruptly to a controlled temperature and then to maintain flow until sufficient scale was deposited to determine scale composition and amount deposited along the flow path.

Figure 1 is a schematic diagram of our experimental apparatus. A selected proportion of the geothermal brine is mixed with irrigation or other water at ambient temperatures to produce a mixed fluid at the required temperature. The remainder of the geothermal brine flows through a small heat exchanger where it is cooled to the chosen temperature and maintained as a single phase. The small-volume heat exchanger (Figure 2) was constructed from a two-foot length of six inch-diameter pipe. Both end plates are identical and contain ports for entry and exit of both the geothermal brine and the cooling fluid. The brine is quenched within a 25-foot, helical coil of 1/4 inch-diameter copper tubing. The coil has a four-inch outside diameter which gives each turn a total length of approximately one foot. Flow rates were determined by measuring the time to collect measured volume of effluent in a barrel.

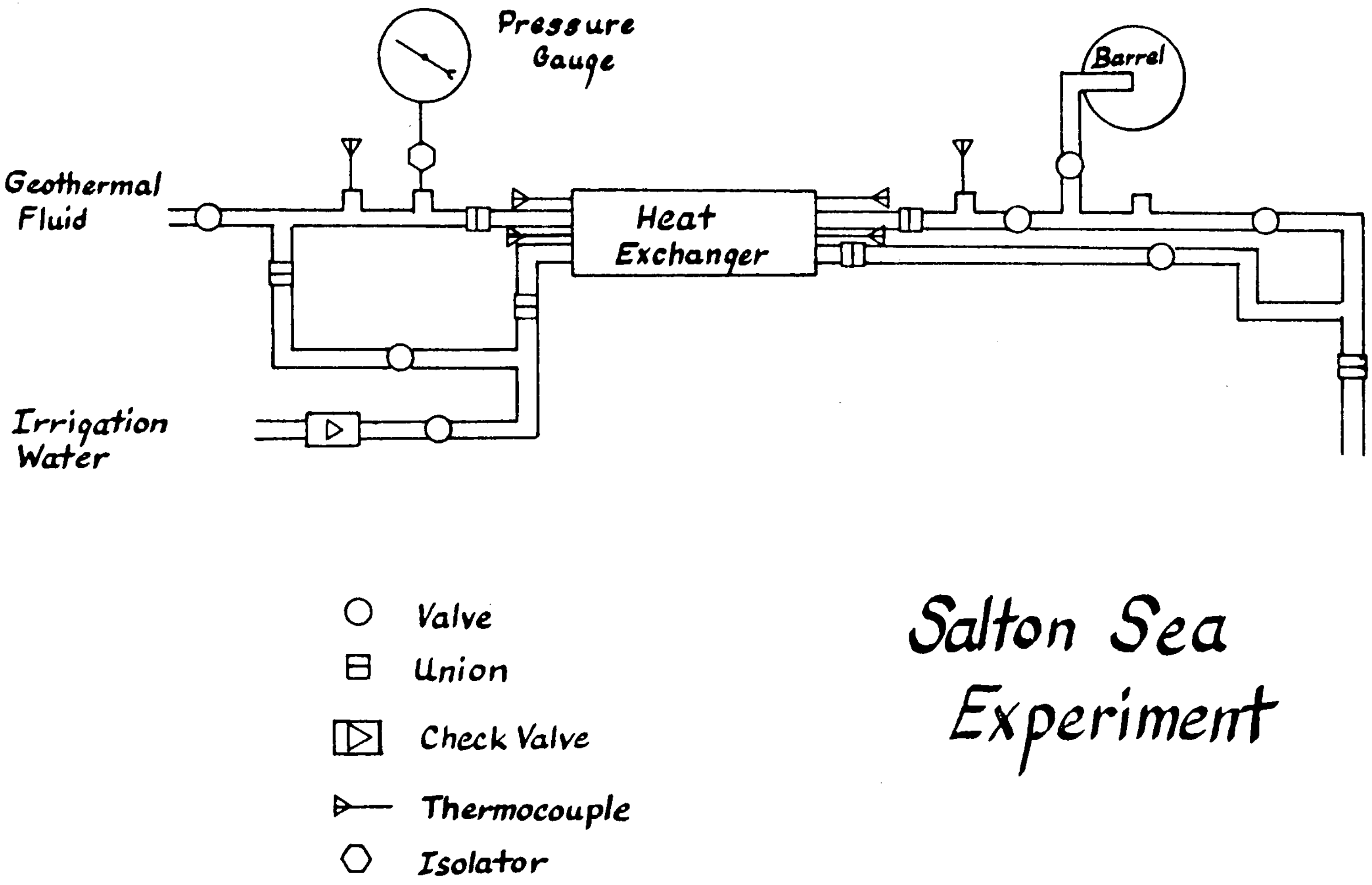
The brine from Magmamax I (courtesy of San Diego Gas and Electric Company) was introduced into the heat exchanger at 225°C and 25 bars. A constant flow rate of 1 ± 0.1 gallons per minute was maintained for the four hour duration of each run. Experiments were repeated at intervals of 25°C for quench temperatures between 225°C and 75°C. Temperatures were monitored every 15 minutes and flow rates every half hour. Due to scaling within the tube and fluctuations in the flow rate of the well, minor periodic adjustments had to be made to maintain the constancy of temperature and flow rate. During the course of individual experiments, the chloride content of the incoming brine was monitored to determine whether upstream flashing was significantly altering the composition of the incoming brine. Any runs which included flashed brines were discarded. Upon completion of the experiment, the coils were removed, weighed and stored.

When the entire suite of coils were returned to our laboratory, they were dried in a nitrogen stream, any exterior scale from the cooling fluid was removed and the coils were reweighed. Figure 3 is a plot of the total weight of the cleaned coil as a function of quench temperature. The maximum amount of scale was formed at quench temperatures between 125 and 150°C. At higher temperatures, the brine was only slightly supersaturated and at lower temperatures, the rates of precipitation were slow enough that only a relatively small amount of scale was precipitated during flow through the tube.

The coils were cut into individual loops and the distribution of scale along the coils was determined by weighing. Several scale samples from different coils were mounted and analyzed by x-ray diffraction, scanning electron microscopy--including x-ray emission spectroscopy, and standard polished section microscopic techniques. Scales formed from the Salton Sea Brines are a complex mixture of carbonate, sulfide and silicate minerals. The majority of the scale is composed of Pbs and copper-iron sulfide phases dispersed in a carbonate matrix--largely aragonite. The crystal habit of the aragonite and the abundance of copper-iron sulfides is a function of both the rapidity of the quench and the quench temperature.

The resulting easily acquired data show the dependence on temperature decrement and distance, of the amount and composition of scale that is likely to form during geothermal development of a well. These data apply to a fluid of fixed initial composition being cooled, either before or after, but not during flashing. The kinetics of flashing, where volatile components are partially removed, may be significantly different both in rates and in composition of resulting scale. Further experiments have been designed to determine the effects of flashing on the kinetics of scale formation.

FIGURE 1. TOP VIEW OF A SCALING TEST APPARATUS.



Salton Sea Experiment

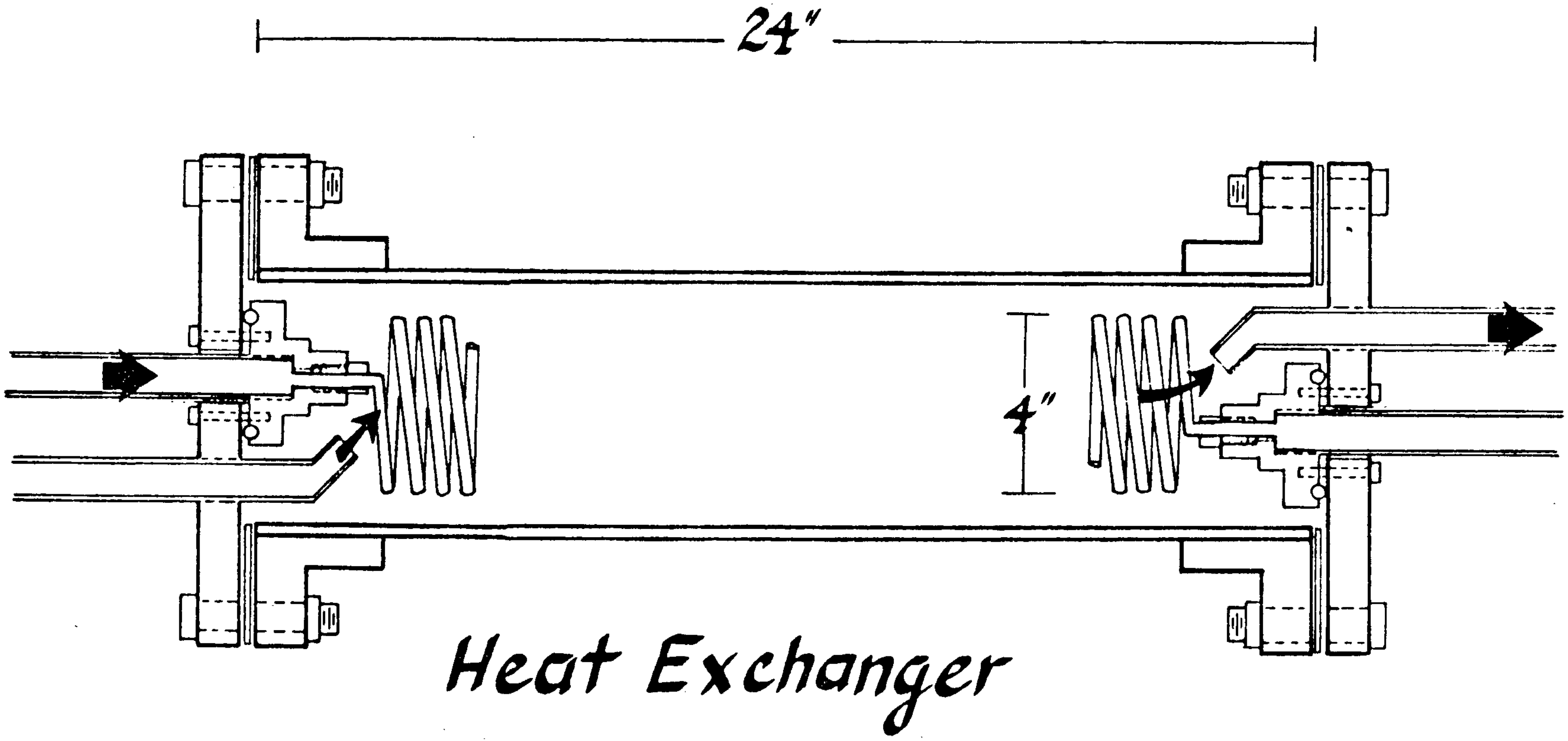


FIGURE 2.

FIGURE 3. Weight change of coils as a function of quench temperature. The 175°C experiment was duplicated and both values are plotted.