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HEAT EXCHANGER FOULING TESTS AT RAFT RIVER

G.L. Mines & J.F. Whitbeck

EG&G, Idaho, Inc.
Idaho National Engineering Laboratory

ABSTRACT

Heat exchanger fouling tests were conducted at Raft River to establish the geothermal fluid side fouling factors to be used in the Raft River thermal loop design. The tests were first conducted with materials that would not corrode severely to determine the effect of potential mineral deposition. These tests are currently being repeated using carbon steel and Monel 400.

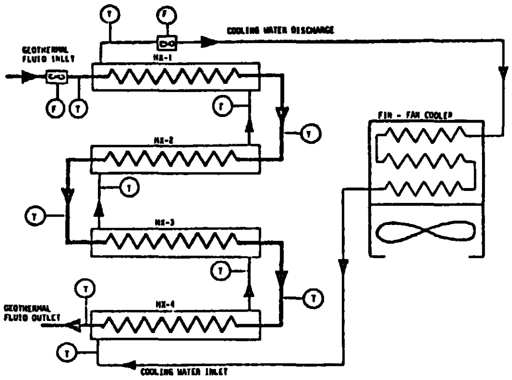
This report describes the test system and test results.

INTRODUCTION

The moderate temperature resources, such as Raft River, which have relatively low amounts of dissolved carbon dioxide are expected to have a low mineral scaling potential. This of course is very important with respect to the selection of heat exchanger fouling factors and thus heat exchanger cost. Preliminary design of the Raft River facility assumed that carbon steel heat exchanger tubes would be used and that the fouling due to corrosion and mineral deposition would be about 0.003 hr-°F-ft^2/Btu.

Concurrent with the preliminary design work for the thermal loop, a test system was designed using double pipe type heat exchangers in which four - twenty foot lengths of heat exchanger tubing could be installed. The heat exchangers could be operated in either series or parallel.

A closed cooling water system, filled with treated demineralized water, was used to remove heat from the geothermal fluid. This heat was in turn rejected in a small fin-fan radiator. A schematic of the system is shown in Figure 1.



HEAT EXCHANGER TEST SYSTEM
FIGURE 1

TEST PROGRAM AND TEST RESULTS

The initial phase of the test program consisted of a long term test with tubes made of titanium and type 304 stainless steel. The materials were selected because they were not expected to form a heavy corrosion scale which would retard the transfer of heat (the use of titanium or 304 SS did not imply a tentative material selection). Thus any significant fouling that might occur could be primarily attributed to mineral deposition and not a corrosion process.

This initial test was run with all four tubes in series so that a temperature drop approximately corresponding to that in the Raft River thermal loop could be achieved. The geothermal fluid inlet temperature was limited to the 275°F provided by the RRGE 1 well under artesian flow of about 200 gpm. Geothermal fluid pressure was maintained at about 150 psig at all times. This pressure was sufficient to ensure that the dissolved gases remained in solution. The goethermal fluid velocity was established at 5 fps (preliminary design velocity for the thermal loop).

Following an inadvertent shutdown caused by a site power outage, the heat exchanger tubes were removed for inspection for possible scale build-up due to boiling on the outer tube surface. It was discovered that, in spite of extensive pre-test cleaning of the cooling water system and chromate treatment of the cooling water, a film existed on the outside of the heat exchanger tubes. This film was not tenacious and could be easily wiped off. This wiping of the outer tube surface resulted in the over all heat transfer coefficient returning to essentially initial conditions. The initial build-up of fouling resistance and the return, after wiping the outer surface, to near initial conditions are shown in Figure 2. Since extremely low (or no) fouling was apparently occuring, it was decided to wipe the outer tube surface at intervals to obatin inside fouling factors which would be otherwise indistinguishable from the total of the inside and outside fouling factors.

The overall heat transfer coefficient was obtained by dividing the total quantity of heat transfered by the total outside tube surface area and the log mean temperature difference. The total heat transfered was determined from the test data as the product of mass flow rate and temperature drop for the geothermal fluid. In order to compensate for the temperature and velocity variations on both the cooling water and geothermal fluid side of the heat exchanger tube, a technique was developed to correct the initial overall heat transfer coefficient to fluid conditions at any data reading. This technique involved the derivation of "weight factors", which reflected the contribution of the inside and outside film coefficients to the initial heat transfer coefficient. These weight factors were applied to ratios of fluid properties and velocities which provided a correction factor to be applied to the initial overall heat transfer coefficient. The difference in the total thermal resistance (1/U)at each data reading and the corrected initial resistance was the fouling resistance at the time of that data reading.

Figure 2 shows the total fouling resistance for all four tubes over a period of 108 days. The data obtained immediately following the wiping of the outside tube surface is shown as a "square" in each case. Also shown for reference are points which represent various values of fouling resistance per year (assuming fouling resistance is linear with time). From this data it appears that fouling resistance is considerably less than the initial design value of R_f=0.003 hr-ft^2-°F/Btu, probably closer to R_f=0.001 hr-ft^2-°F/Btu.

The next phase of tests consist of installing tubing that would exhibit two different degrees of corrosion. Carbon Steel and Monel 400 tubing were selected for parallel operation. These tests are currently under way, however, 45 days of data have been obtained. This data is shown in Figure 3 (Carbon Steel) and Figure 4 (Monel). It is interesting to note that the carbon steel tubing shows very little fouling after wiping ($R_f \cong$0.001/yr hr-ft^2-°F/Btu) at this time although carbon steel corrosion coupons being evaluated in a corrosion test have shown severe corrosion. The Monel 400 tube seems to indicate a fouling rate slightly more than carbon steel (R_f between 0.001/yr and 0.0015/yr hr-ft^2-°F/Btu), although the Monel corrosion coupons did not appear to have as severe corrosion attack as the carbon steel coupons.

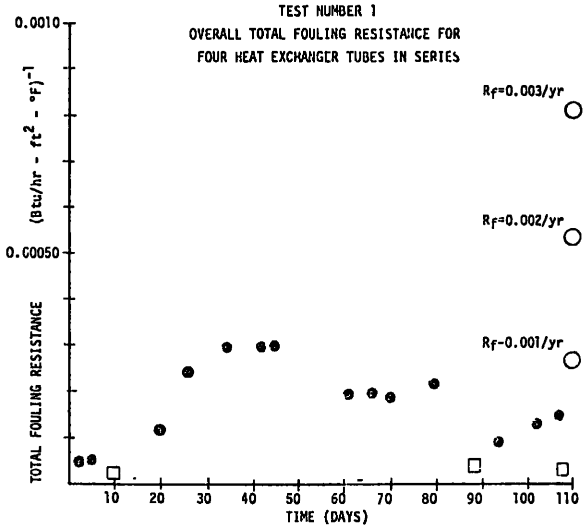


FIGURE 2

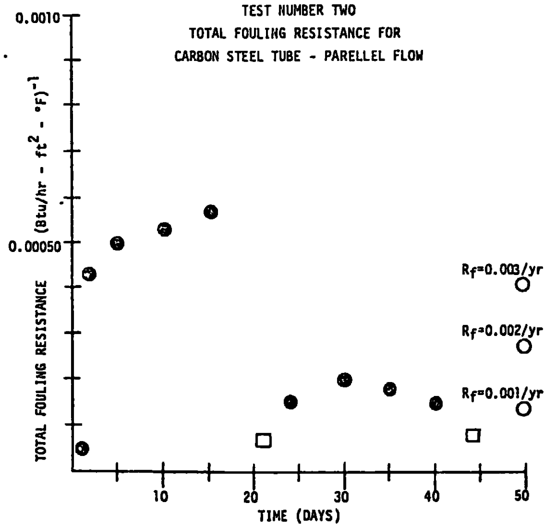


FIGURE 3

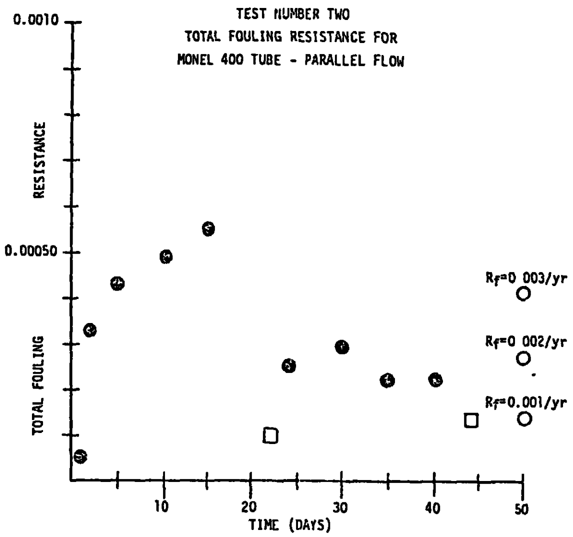


FIGURE 4

FUTURE TEST PLANS

Materials for use as tubing in the Raft River heat exchangers are being evaluated by exposure to the geothermal fluid as corrosion coupons and as simmulated tube-tube sheet connections. Results of these tests presently indicate that admiralty brass or a similiar copper alloy is the best selection for the tube material. Therefore, subsequent heat transfer tests will be conducted using admiralty metal.

CONCLUSIONS

As a result of this test program the design fouling factor has been reduced by 50% which will result in a reduction of approximately 20% in the total geothermal fluid heat exchanger area.

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