THE DEVELOPMENT OF LIQUID-FLUIDIZED BED HEAT EXCHANGERS FOR CONTROLLING THE DEPOSITION OF SCALE IN GEOTHERMAL APPLICATIONS

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Geothermal energy development has been slowed by the problem of scale formation on heat transfer surfaces. This is the case either in converting to electrical energy by using a secondary cycle, or in transferring heat for industrial processes. The object of our program is to develop an economically competitive heat exchanger in which scale formation on heat transfer surfaces is controlled.

Experiments conducted several years ago at our laboratory at the Idaho National Engineering Laboratory indicated that heat transfer coefficients between surfaces and a liquid fluidized bed were higher than when no bed was present. These same beds prevented deposition on cold surfaces near saturated solutions. These observations led to the suggestion that a fluidized bed heat exchanger could be developed which would prevent the usual deposition of scale from geothermal brines when cooled.

Initial studies were conducted with artificial brines at our laboratory, and with hot brines flowing directly from Geothermal Wells at Raft River, Idaho. The first experiments were performed in ∿4-inch diameter glass columns operating at atmospheric pressure. The heat transfer surfaces were made from 0.25-inch diameter tubing wound into spiral coils. Results from these tests showed that no scale deposited on heat transfer surfaces covered with a fluidized bed of sand particles, and that bed-to-tube coefficients doubled. These coefficients ranged from 4000 to 4500 w/cm^2-°C, the higher coefficients obtained at the higher superficial fluidizing velocities which ranged from 0.02 to 0.045 m/sec.

Slightly higher coefficients were obtained in a 6-inch diameter pressurized exchanger using 0.5-inch diameter tubing wound into a spiral coil covered with a sand bed having 1.0 mm particles. The unit was operated for 60 days using Raft River water at a temperature of 135°C, containing ∿2000 mg/l of dissolved salts. No scale deposited on the surfaces of the coil that was covered by the fluidized bed of sand.

Near future tests include atmospheric pressure bench-scale studies using water from 6-1 at the Bureau of Reclamation East Mesa Test Site near El Centro, California, and tests under pressure in one stage of an 8-inch diameter horizontal exchanger located at Raft River. Preliminary data may be available to this conference on results obtained in the bench-scale unit at East Mesa.

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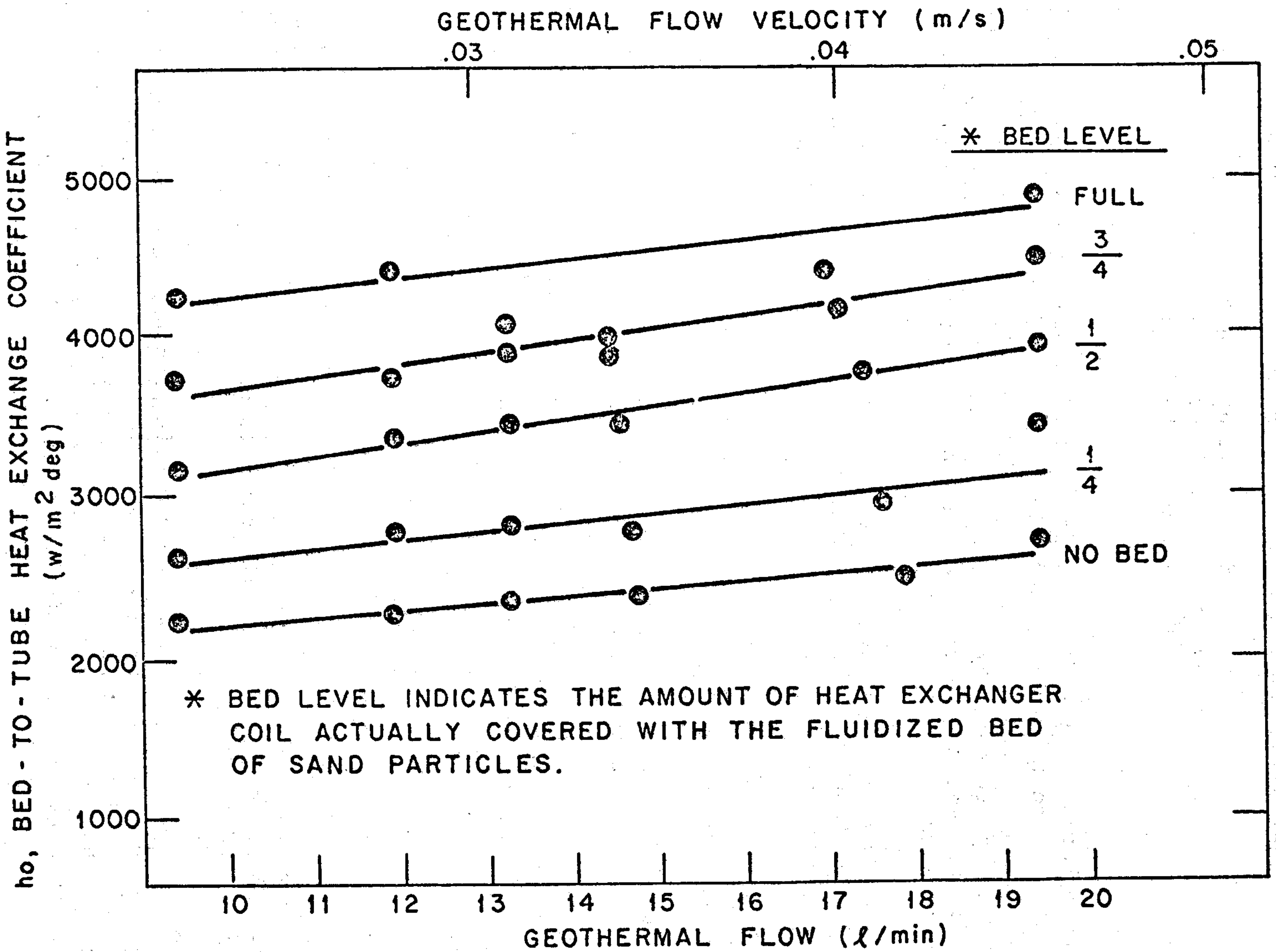

Figure 1. Effect of fluidized sand bed on bed-of-tube heat transfer coefficients.

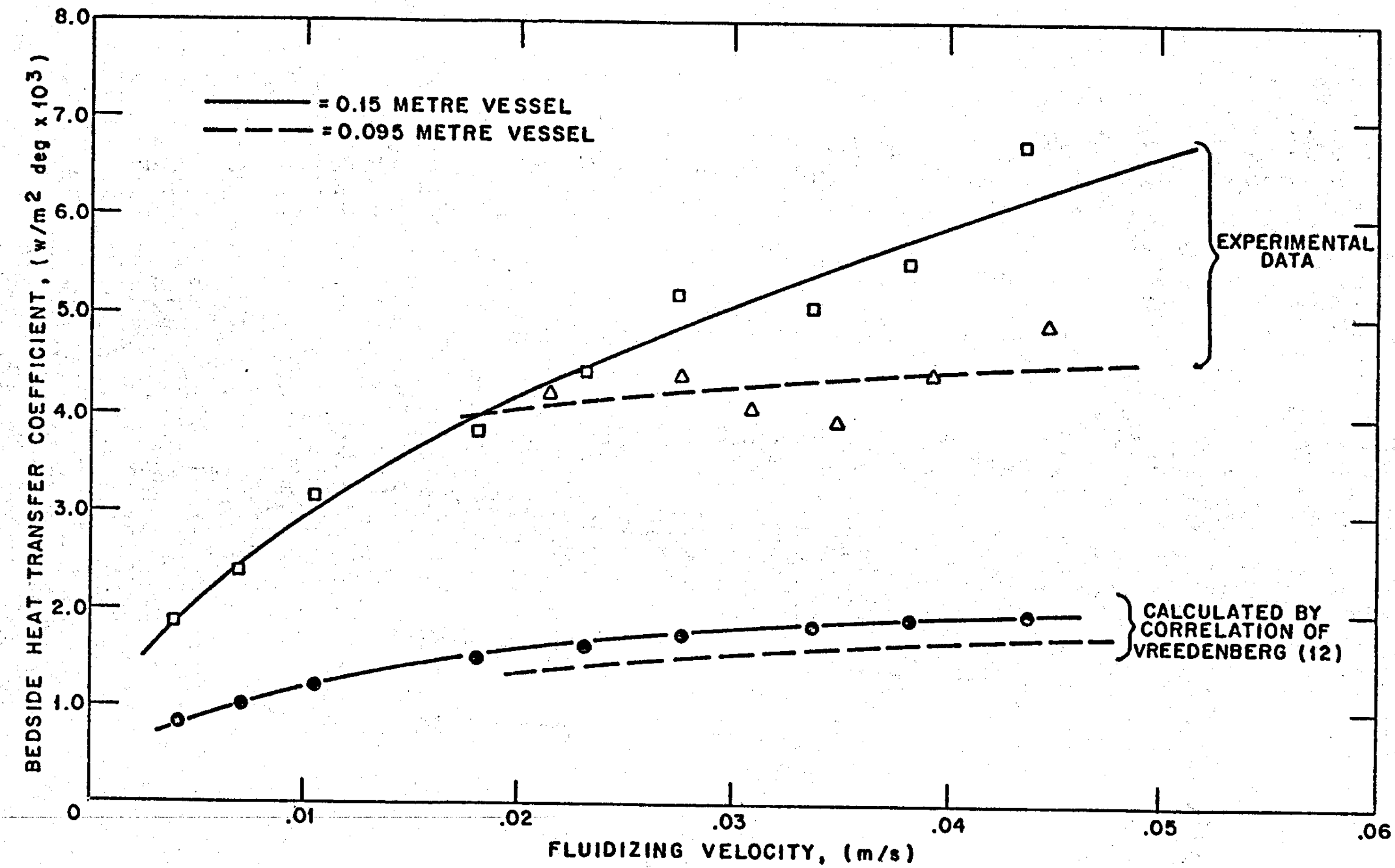

Figure 2. A comparison of bedside heat transfer coefficients obtained in 0.15 and 0.095 meter diameter vessels. Values calculated from correlation of Vreedenberg are shown also.

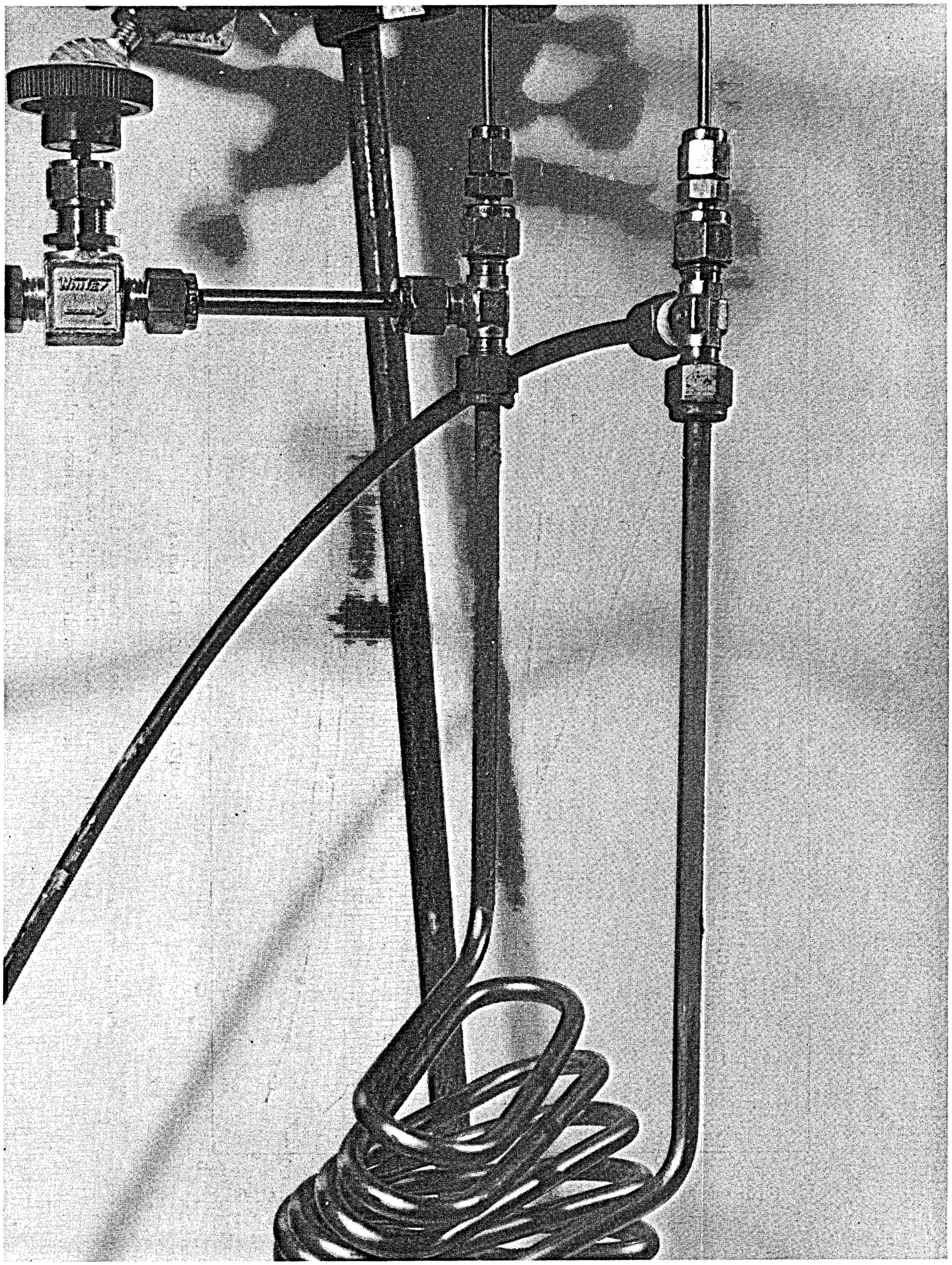

Figure 3. Scale deposited on cooling coil above level of fluidized bed of sand.

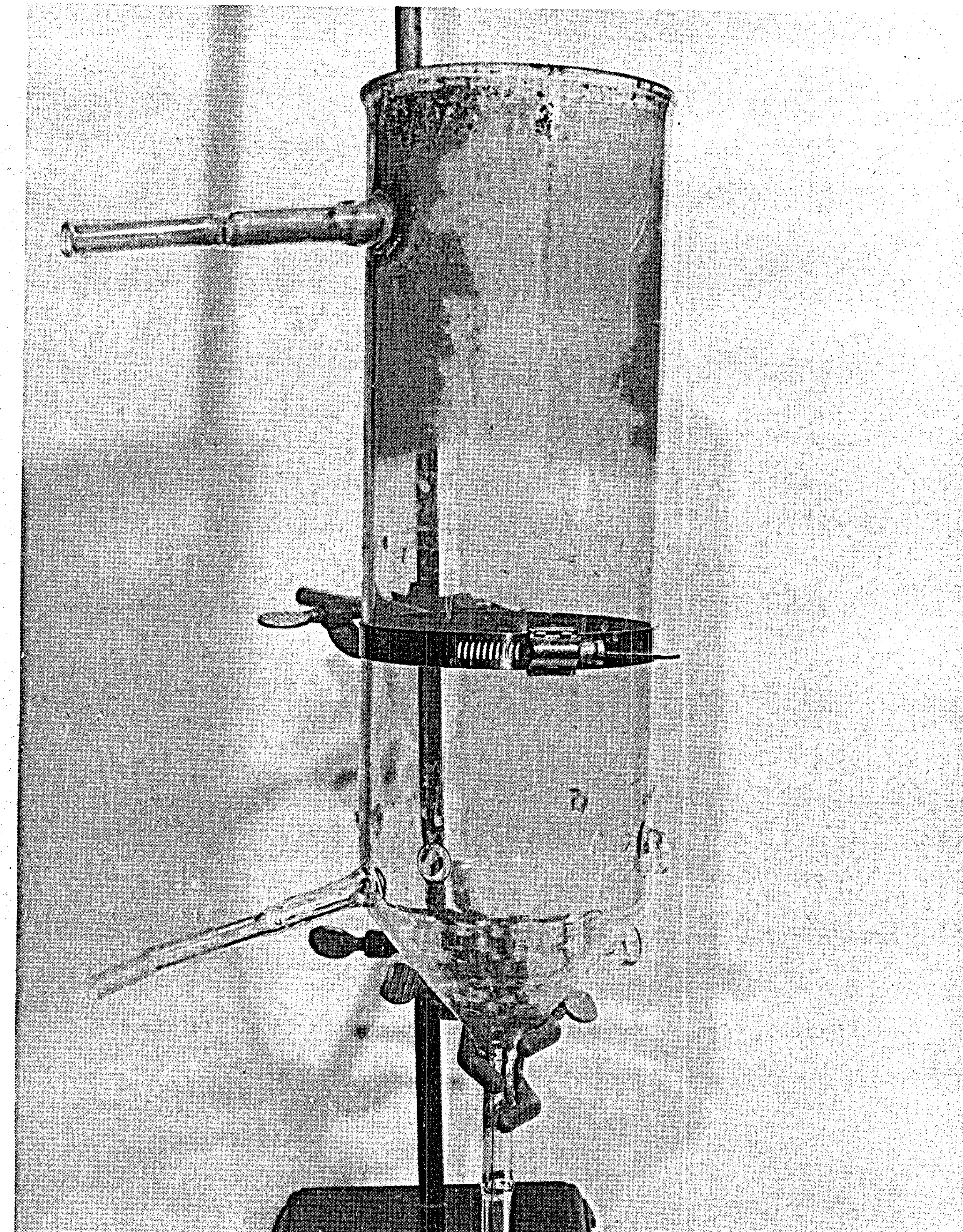

Figure 4. Scale deposited on wall of bench-scale exchanger above level of fluidized bed of sand.

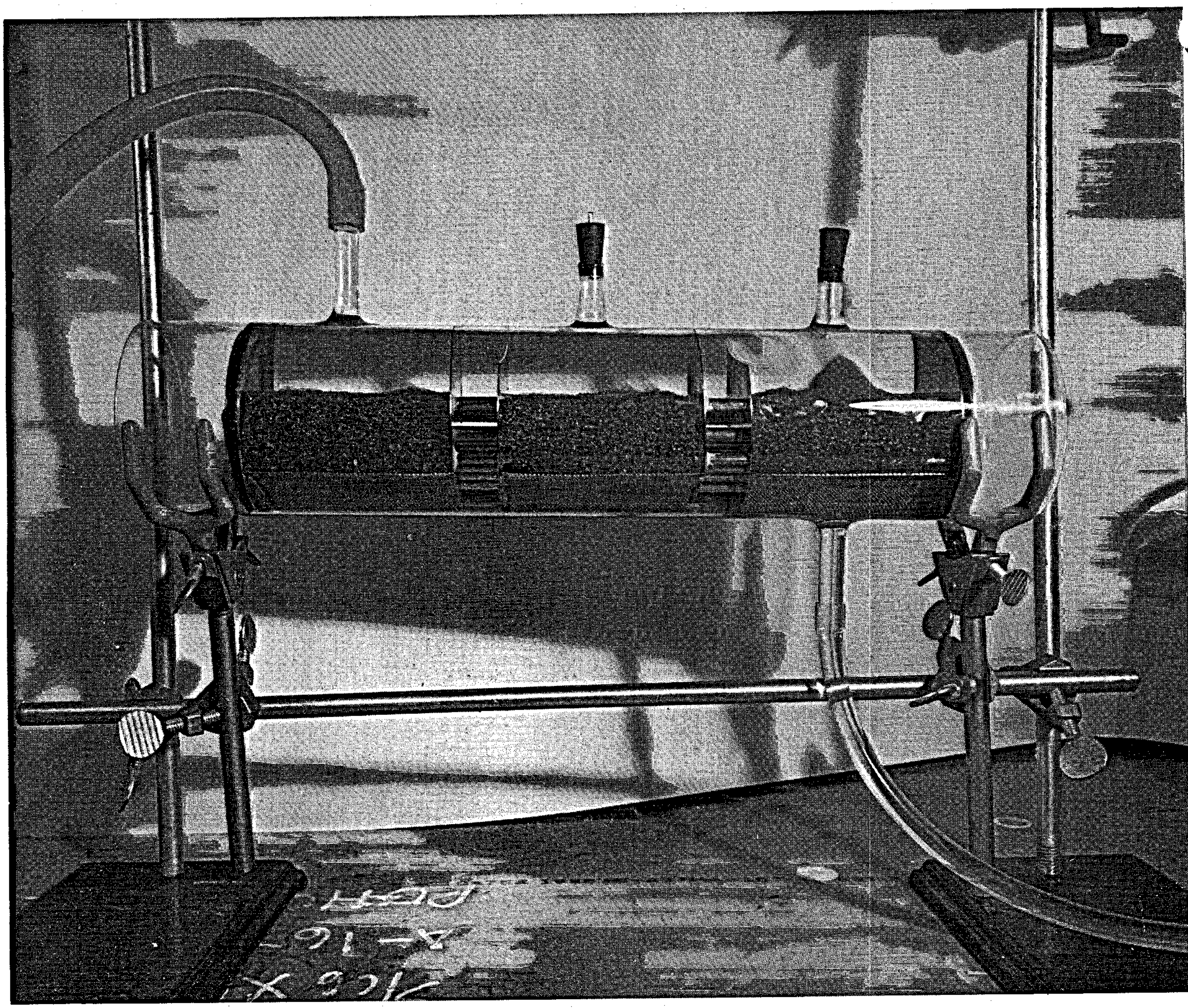

Figure 5. Conceptual model of multi-stage horizontal fluidized bed heat exchanger.

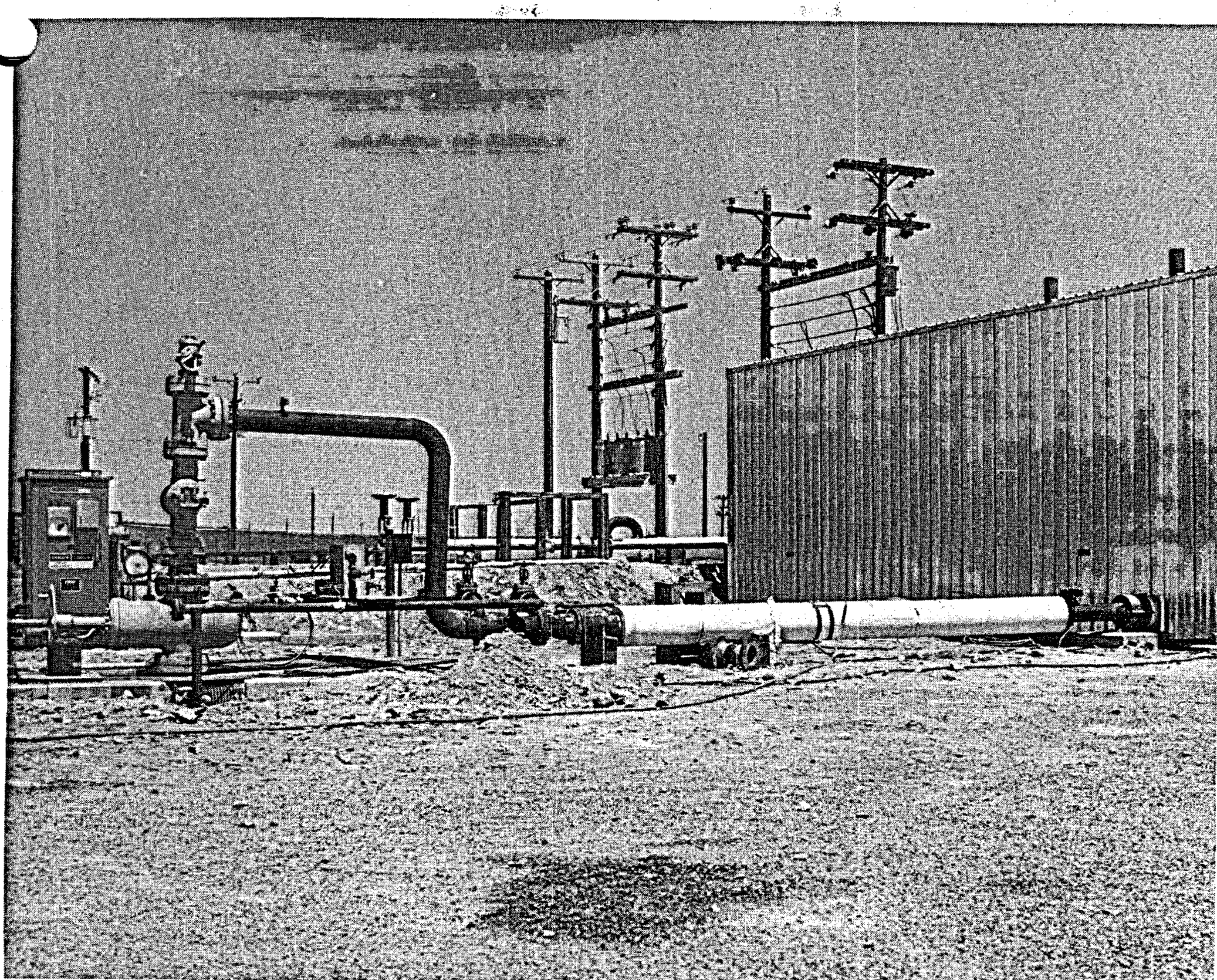

Figure 6. Wellhead No. 1 at Raft River Geothermal Project in Idaho.

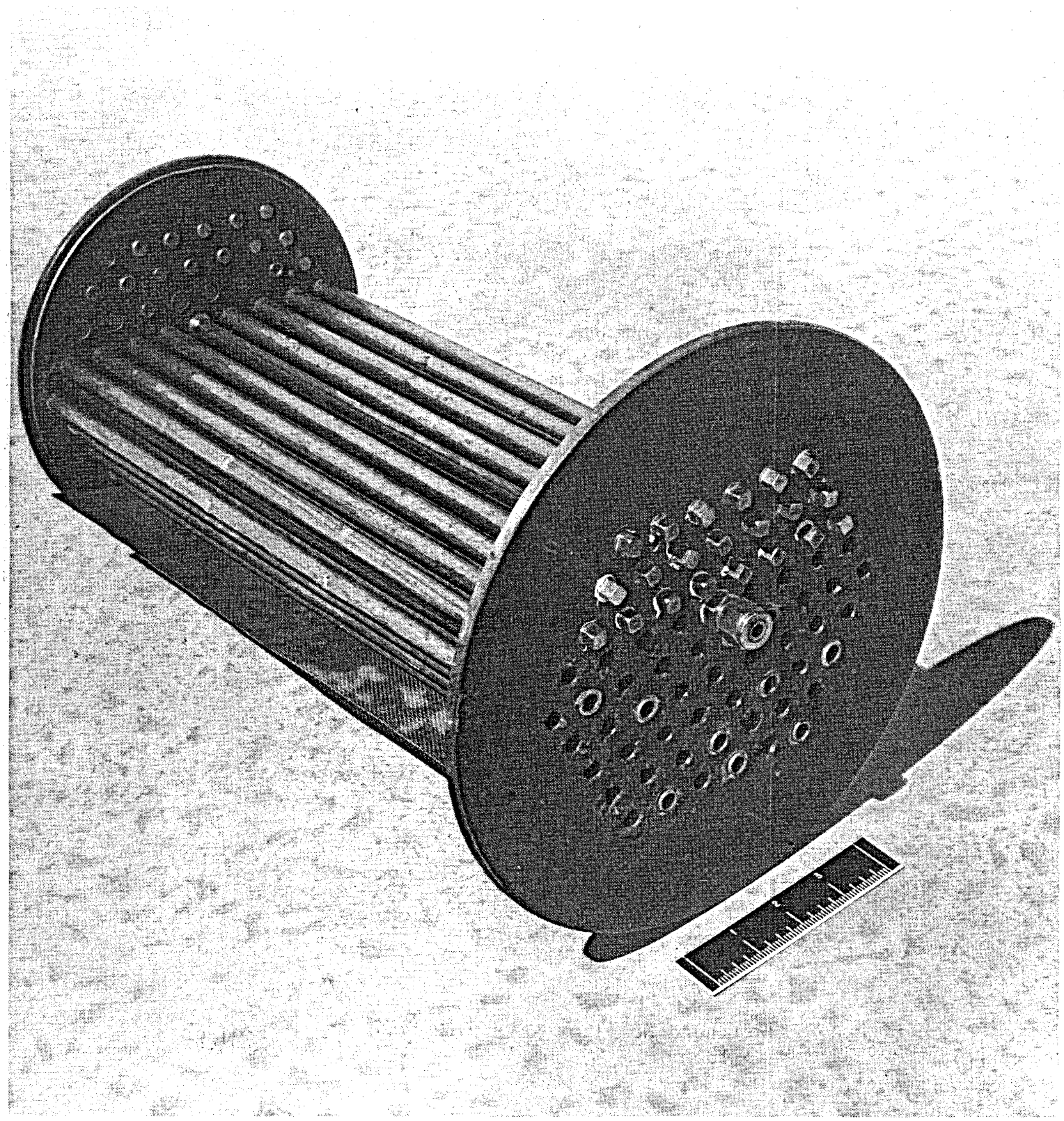

Figure 7. Experimental tube bundle for single-stage, 8-inch diameter heat exchanger.

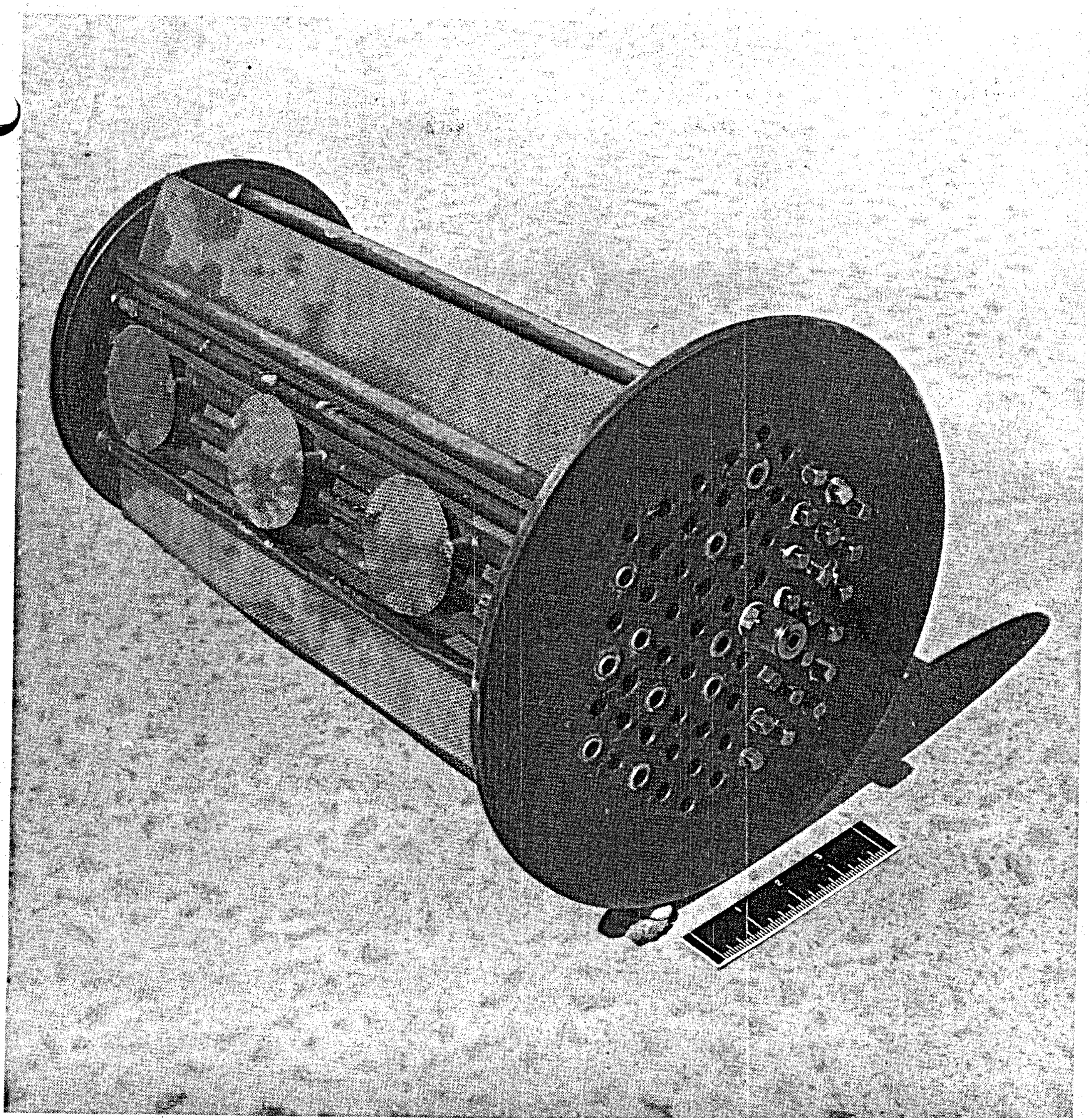

Figure 8. Bed support plate for single-stage, 8-inch diameter heat exchanger.

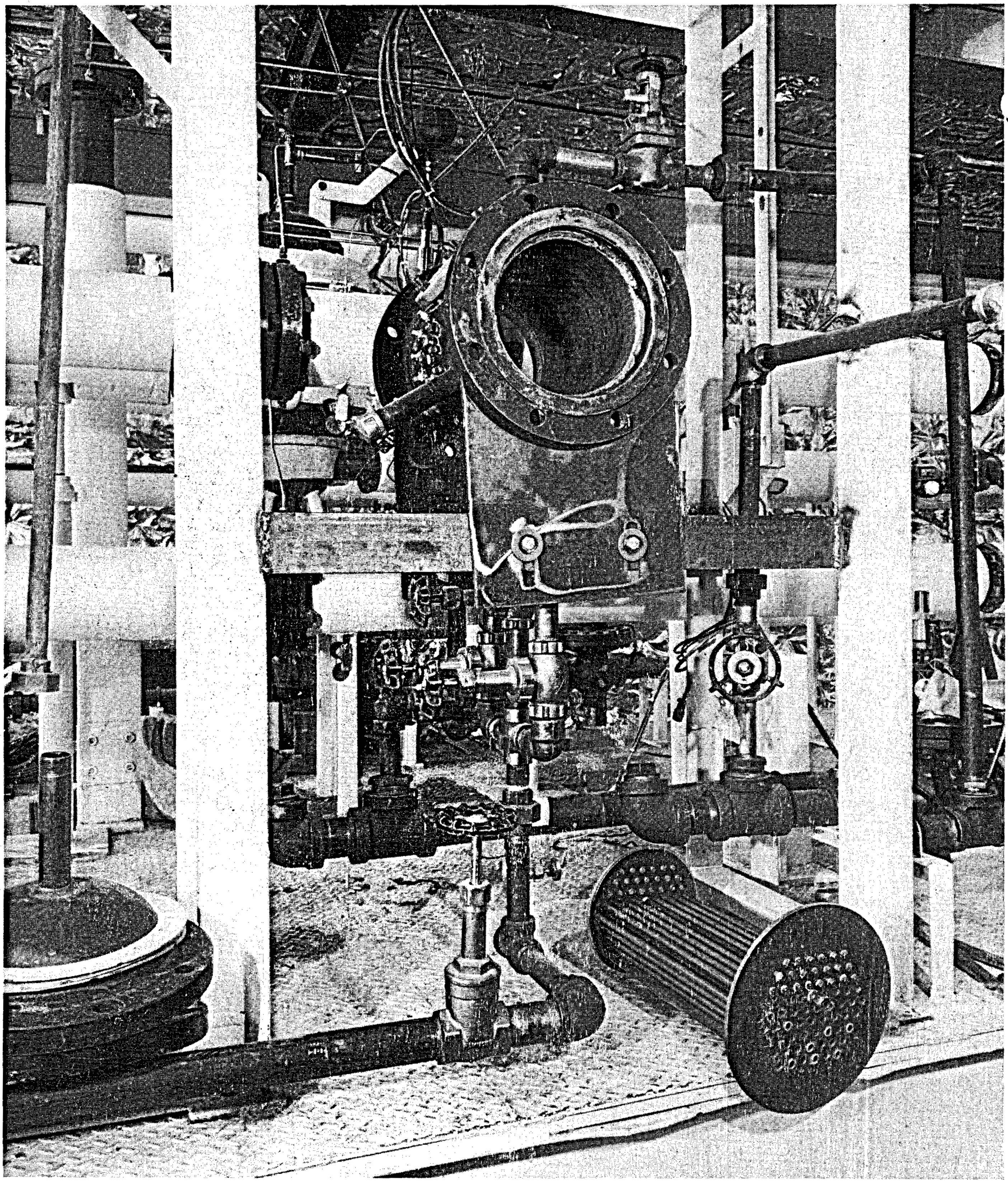

Figure 9. Shell and tube bundle of single-stage, 8-inch diameter heat exchanger ready to be installed at Raft River Geothermal Test Stand.

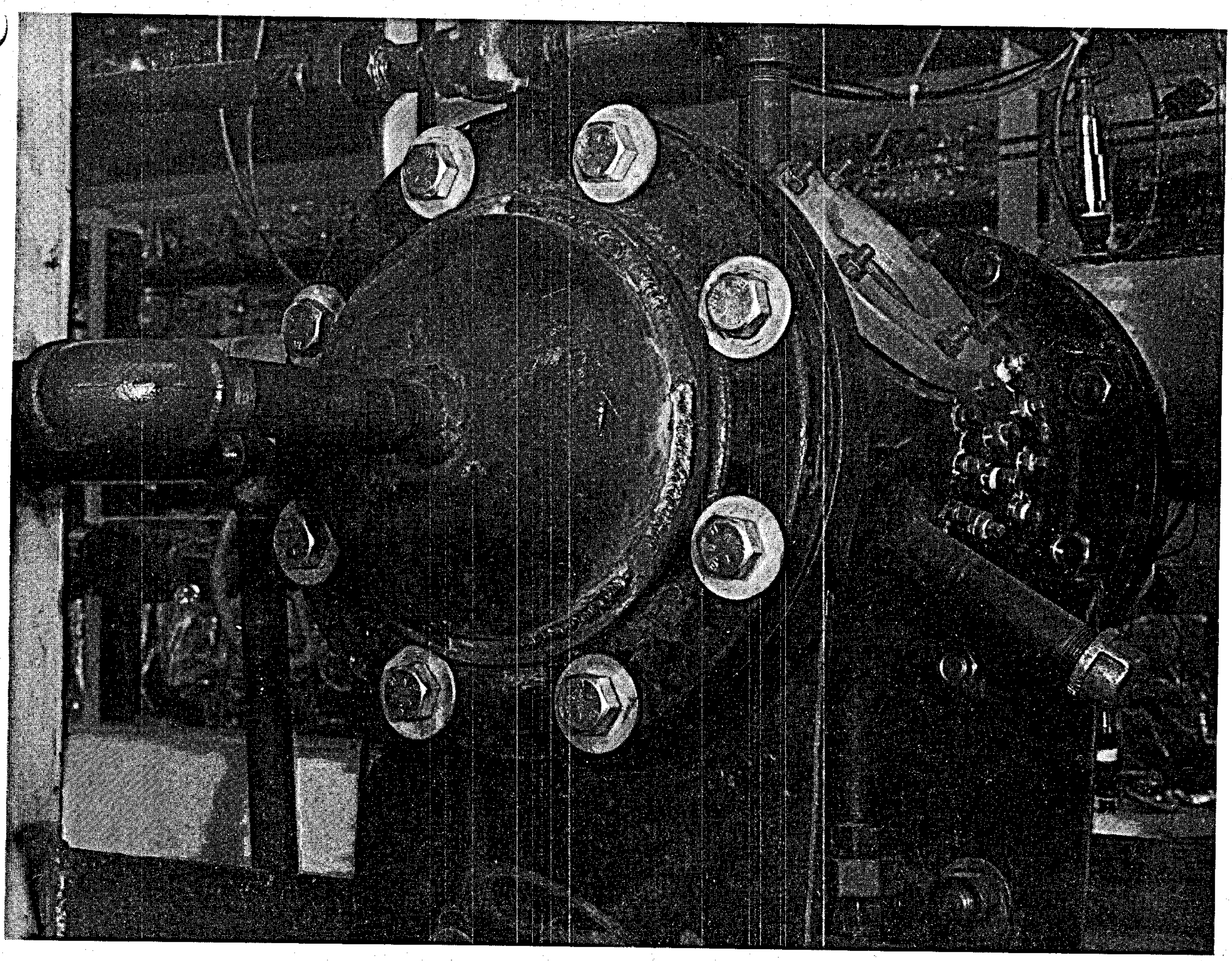

Figure 10. Installed fluidized bed heat exchanger at Raft River Geothermal Test Stand.