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PRELIMINARY RESULTS OF GEOTHERMAL DESALTING OPERATIONS AT THE EAST MESA TEST SITE IMPERIAL VALLEY, CALIFORNIA

Sus H. Suemoto
U. S. Bureau of Reclamation
Holtville, California

Ken E. Mathias
U. S. Bureau of Reclamation
Boulder City, Nevada

The Bureau of Reclamation has erected at its Geothermal Resource Development site two experimental test vehicles for the purpose of desalting hot fluids of geothermal origin. Both plants have as a feed source geothermal well Mesa 6-1 drilled to a total depth of 8,030 feet and having a bottom hole temperature of 400°F. Formation fluid collected at the surface contained 24,800 mg/l total dissolved solids. The dissolved solids consist mainly of sodium chloride.

A multistage distillation (3-stage) plant has been operated intermittently for one year with no operational problems. Functioning at steady-state conditions with a liquid feed rate of 70 g/m and a temperature of 221°F, the final brine blowdown temperature was 169°F. Product water was produced at a rate of about 2 g/m; average total dissolved solids content of the product was 170 mg/l. A product quality of 27.5 mg/l at a pH of 9.5 was produced from the first stage.

The second distillation test vehicle, a vertical tube evaporator, consists of two units: a single-effect unit and a three-effect unit. All components are constructed of carbon steel. The single-effect unit was operated a total of 50 hours for intermittent shakedown tests. After inspection and chemical cleaning, the unit was operated continuously for 100 hours. During the last 24 hours of steady-state running, the unit was operated with a 302°F steam feed at a ΔT of 16°F, producing a concentration factor of 1.07. A heat transfer coefficient has been calculated as 405 Btu/hr-sq ft-°F; this value remained constant during the last 24 hours. The product (steam feed condensed at a rate of 0.8 g/m) had a total dissolved solids content of less than 10 mg/l. Inspection indicated minor corrosion products with no visible evidence of carbonate or silica scale. The three-effect unit is currently undergoing shakedown operations.

I. INTRODUCTION

The Bureau of Reclamation is currently exploring the geothermal resources of Imperial Valley, California. The primary objectives of the program are to demonstrate the feasibility of desalting geothermal fluids for development of needed high-quality water supplies in the southwest and to investigate the production of electric energy concurrently with desalted water. These aspects are reported in more detail elsewhere in this proceedings (Ref. 1). As a part of this geothermal resource development program, two types of test desalting units have been installed at the Bureau of Reclamation East Mesa test site.

Current research at the East Mesa test plants has not only direct application to desalting of geothermal fluids, but also direct application to heat exchanger design for power development using geothermal fluids.

The Imperial Valley test production wells, desalting plants, and a brief review of desalting data will be described.

II. THE IMPERIAL VALLEY

The Imperial Valley is an extensive sedimentary basin characterized by high heat flow. The valley is part of a structural depression known as the Salton trough that extends northwest from the Gulf of California. Late tertiary sediments filling the depression consist predominantly of unconsolidated sand, silt, and clay with some gravel. As these sediments are saturated to within a few tens of feet of the land surface, the Imperial Valley constitutes a large potential geothermal reservoir. Rex described geophysical work done in the Imperial Valley (Ref. 2), and a summary of more recent geophysical work done in the East Mesa area is reported elsewhere in this proceedings (Ref. 3).

III. TEST WELLS

Based on data collected for the Mesa anomaly (Ref. 4), a deep production well was drilled to 8, 030 feet in 1972. A bottom hole temperature of about 400°F was measured. The initial method of completion was by hanging a slotted seven-inch liner below the 7262-foot depth. The liner was slotted at intervals opposite electrical log-determined sand horizons. At a later date, the casing was inhole perforated uphole between 6809 and 7151 feet opposite Saraband-selected sand horizons. Prior to uphole perforation, liquid temperature of about 300°F could be produced at very low flow rates. Since perforation, a liquid at substantially greater temperature and flow rate may be produced at the wellhead. Before and after perforation flow data for Mesa 6-1 are illustrated by Mathias (Ref. 5). Mesa 6-1 has provided feed for past and current desalting operations. A second well, Mesa 6-2, was drilled in 1973, and three more wells, Mesa 5-1, Mesa 8-1, and Mesa 31-1, were drilled in 1974. The last four wells were drilled to about 6000 feet. All wells are self-starting and can produce either steam and liquid or all liquid at the surface, depending upon surface-controlled back pressure.

IV. THE TEST SITE

Figure 1 shows installation of the two desalting plants at the East Mesa test site. On the left is the multistage flash (MSF) distillation plant, which was designed, constructed, and erected by the Envirogenics Company. The plant on the right is the vertical tube evaporator (VTE) distillation unit. It was designed by W. L. Badger Associates, Inc., Burns and Roe, Inc., and constructed by Aqua Chem, Inc. Both test vehicles were designed and built under contracts issued by the Office of Saline Water (now the Office of Water Research and Technology). The Bureau of Reclamation has responsibility of operating and developing the desalting test program.

V. THE MULTISTAGE FLASH PLANT

A schematic diagram of the MSF plant is outlined in Fig. 2. The unit operates on liquid fed from the nearby separator. Liquid is introduced into a flash vessel (A), where a pressure at less than saturation is maintained. A percentage of liquid is flashed, and the steam passes through an entrainment separator (to eliminate entrained liquid droplets) and on to be condensed to a distilled product. The remaining liquid in the flash vessel passes to the next vessel, where a lower ambient pressure is maintained. This procedure is performed in three vessels. System pressures are maintained by an external vacuum pump.

The unit was originally designed to function at a maximum feed rate of 1600 pounds per minute liquid at 400°F. During tests by Envirogenics Company at its Wrightsville Beach Test Facility using synthetic geothermal fields, the inlet conditions were widely varied with feed temperatures ranging from 250 to 395°F and blowdown temperatures ranging from 140 to 250°F. The unit has been operated intermittently in the Imperial Valley for one year with minimal problems. Operating at a liquid feed of 600 pounds per minute at 221°F and a final blowdown temperature of 169°F, product water was produced at a rate of about 17 pounds per minute. Average total dissolved solids (TDS) content of the product was 170 milligrams per liter (mg/l). A product quality of 28 mg/l TDS at a pH of 9.5 was produced in the first stage. The product from the second and third stages was always more saline, ranging from 85 mg/l to 360 mg/l TDS. This was due to the lower temperature operating parameters, where brine entrainment is more likely and to other hydraulic problems of operating at less than designed temperatures. These tests were performed before the uphole perforation in Mesa 6-1.

VI. THE VERTICAL TUBE EVAPORATOR PLANT

A schematic diagram (Fig. 3) has been prepared showing the vertical tube evaporator single-effect unit in the upflow mode. The VTE test vehicle has, also, installed in parallel, a three-effect VTE unit, which has been operated for only short periods to date. The single-effect unit is constructed of carbon steel with eighteen 3/4-inch, 13 gage smooth carbon steel (A-106 GrB) tubes 20 feet long.

The VTE also operates on the flash principle. Hot geothermal liquid (after separation from steam near the wellhead) flows upward through a bundle of tubes located inside the evaporator. As liquid flows through the tubes, it flashes down to a lower temperature and pressure, thus generating vapor. At the same time, steam surrounding the tube bundles evaporates an additional quantity of vapor from the brine. As steam transfers heat to the brine, it condenses to product water. In the single effect, generated vapor is vented, and the brine blowdown goes to waste; however, in the multi-effect VTE units, these fluids are fed to the next effect and the process is repeated. Initial operations have been in the upflow mode, but later tests will be run in the downflow mode as the equipment has been designed to be operated either way with only minor modification.

The unit has been operated over three different test periods using fluids from Mesa 6-1 after it was uphole-perforated. Fifty hours of intermittent operation were logged over a period of one year. The vapor head was then removed for inspection. An analysis of material taken from within the tubes showed it to be an iron corrosion product with no evidence of scale deposit. The unit was cleaned with a 20 percent inhibited hydrochloric acid solution and operated on a continuous basis for 100 hours. The first 76 hours of operation were not extremely stable due to minor control problems. The last 24 hours of operation were steady with a ΔT of 23°F. Liquid entering the tubes was subcooled, and a heat transfer coefficient of 221 Btu/hr-ft^2-°F was calculated using a log mean-temperature difference. This value was raised to 241 Btu/hr-ft^2-°F by increased venting. It is, therefore, possible that excess noncondensable gases were present in the shell side of the unit.

After a 100-hour continuous run, the evaporator head was removed. Inspection revealed a small amount of corrosion product within the tubing, but no scaling was discernible. The unit was then started for a continuous test run of several hundred hours. After operating for 800 hours with only a few hours of shut-down time for instrument calibration, the trend of heat transfer coefficient values had not decreased noticeably. ΔT was increased in an attempt to promote scaling, but buildup was not evident from the data. A partial outline of operating conditions for both the 100-hour test and the long-term test is presented in Table 1.

VII. WATER CHEMISTRY

A chemist and laboratory are maintained at the East Mesa site for all geothermal-associated chemical work. A consistent technique of fluid sampling has been employed in the Bureau's geothermal work. Samples are collected by jetting the sampled fluid in neutral, basic, and acidic ice water solutions. This method prevents the precipitation of soluble components, such as silica, bicarbonate, iron, etc., that precipitate under cooling.

The water chemistry has been seen to vary at the wellhead. At high flow rates, during downhole flashing, less silica and bicarbonate are seen at the wellhead than at low flow (liquid at the surface) conditions (Ref. 5). During the long-term VTE operations, well flow rate remained constant; therefore, little changes in wellhead chemistry were evident.

A brief summary of water chemistry from the steady-state portion of the VTE single-effect 100-hour test run is illustrated in Fig. 4. It is interesting to note the trends of TDS, pH, and alkalinity as fluids are passed from the wellhead through the system. TDS increases slightly from the wellhead to the separator outlet to the brine blowdown as would be expected due to liquid concentration as vapor is generated. The TDS of less than 10 mg/l of condensate water is not a true measure of VTE system efficiencies, but a measure of the wellhead separator efficiency. At this time, an analysis of generated vapor has not been made.

The pH measurement shows an increasing trend from the wellhead to the brine blowdown. This is due to evolvement of CO_2 from waters in the separator and VTE as pressures are reduced. The condensate water pH of 6.6 suggests that steam from the separator carried an amount of CO_2.

Alkalinity is shown in terms of equivalent parts of $CaCO_3$. A decrease in alkalinity from wellhead to brine blowdown implies that CO_2 is being evolved at both the separator and VTE. The high alkalinity of condensate water is again an indication that CO_2 was transported with steam from the separator. This high alkalinity would soon drop significantly if the water were aerated or allowed to stand for a period of time.

VIII. SUMMARY

The Bureau of Reclamation has successfully operated a multistage flash-type distillation unit and a vertical tube evaporator-type distillation unit on geothermal fluids. The MSF unit has operated satisfactorily at intermittent service for over one year with low-temperature liquids and should operate more efficiently on higher-temperature liquids now available. The plant will be used in the overall test program to monitor scaling and corrosion in flash vessels. The single-effect vertical tube evaporator unit was operated continuously for 100 hours and intermittently for 50 hours with no detectable tubing scaling and some formation of corrosion products. The unit was recently shut down after a continuous test run of about 800 hours with the data indicating no systematic decrease in heat transfer coefficient. A nonscaling operation of the tubing is necessary in order to maintain heat transfer and thus insure the feasibility of using geothermal fluids in heat exchange applications. As the unit is constructed of carbon steel, the corrosion problem could be solved with correct application of various alloys or coatings.

REFERENCES

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Table 1. A summary of operating conditions: vertical tube evaporator, single effect

Test series	100-hour test		Long-term test							
Feed rate, lb/hr	3,400	3,400	2,062	2,561	2,305	2,367	2,385	3,233	3,187	2,621
Condensate, lb/hr	417	420	383	394	306	378	399	430	667	512
Concentration factor[a]	1.07	1.07	1.23	1.18	1.15	1.19	1.20	1.15	1.27	1.24
ΔT, °F	25.8	22.7	14.6	18.7	17.7	15.6	12.7	20.7	33.7	24.7
Heat transfer coefficient, Btu/hr-ft^2-°F	211	241	348	280	229	320	413	275	264	273
Test date, 1974	8-8	8-9[b]	9-17	9-20	9-22	9-24	9-26	9-28	10-1	10-4

[a] Determined from chemical concentration.

[b] Increase drip pot venting from 8-8 data.

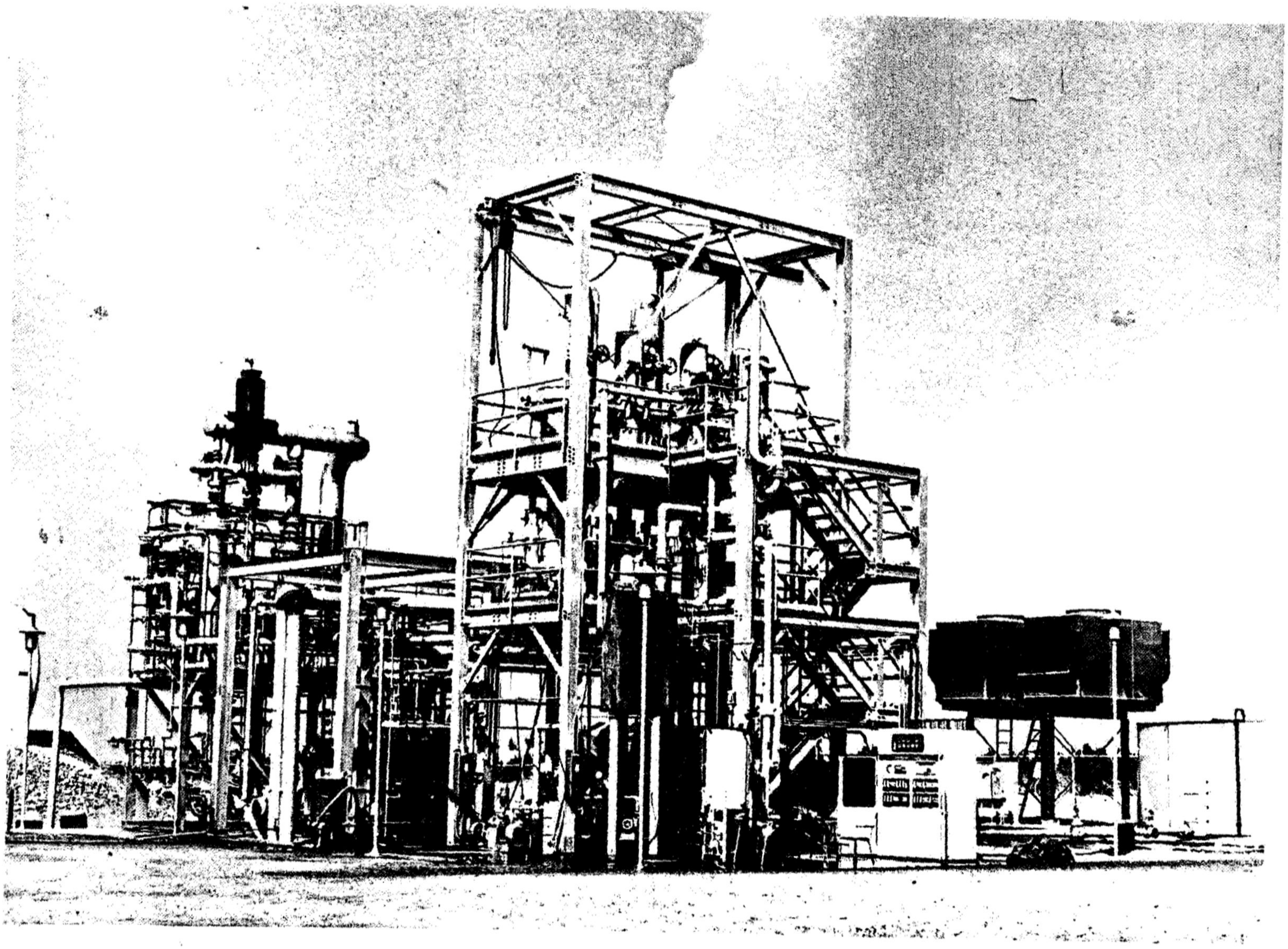

Fig. 1. Geothermal test site, Imperial Valley, California (photo by Bureau of Reclamation, U. S. Department of the Interior)

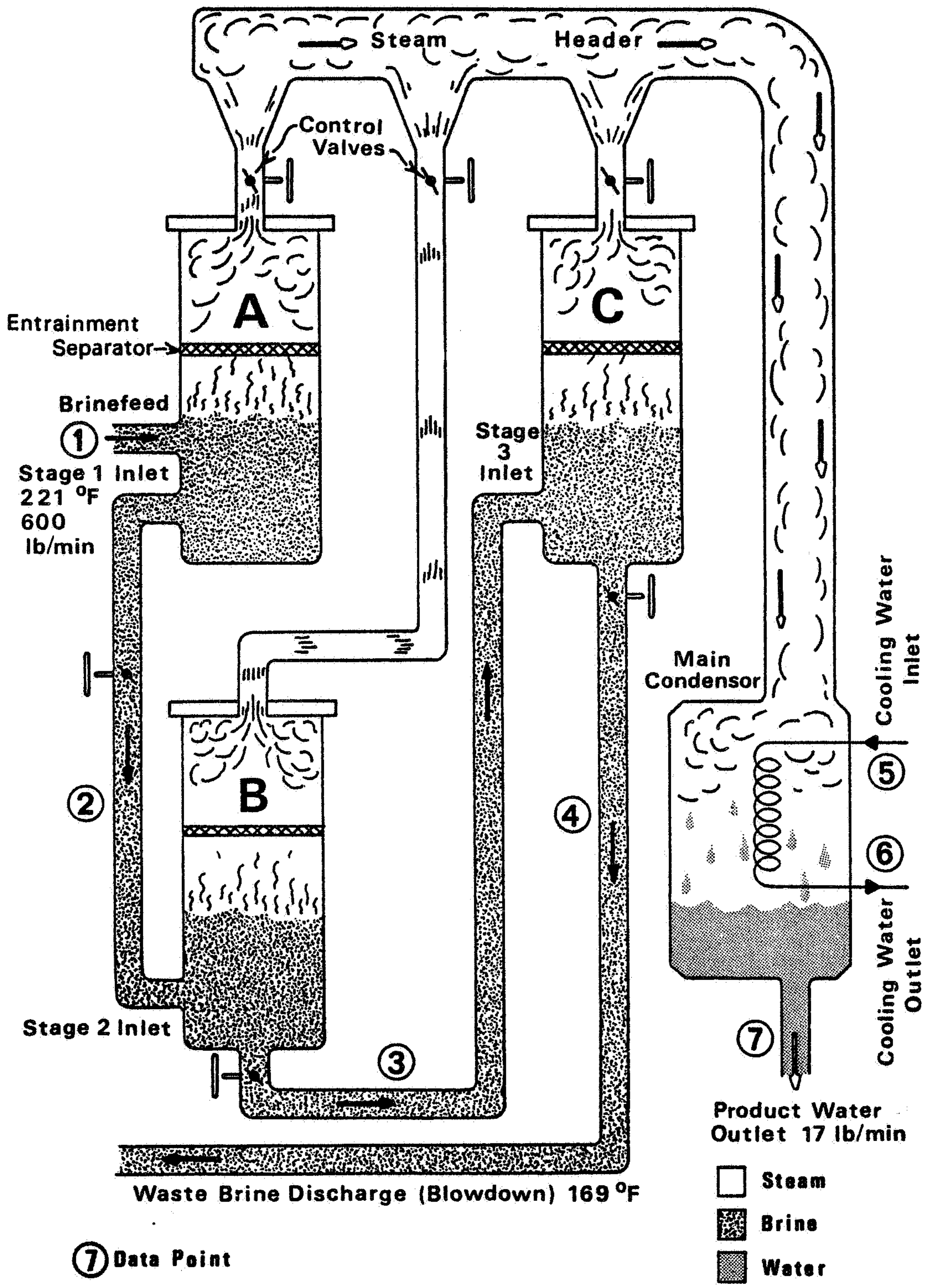

Fig. 2. Multistage flash distillation process

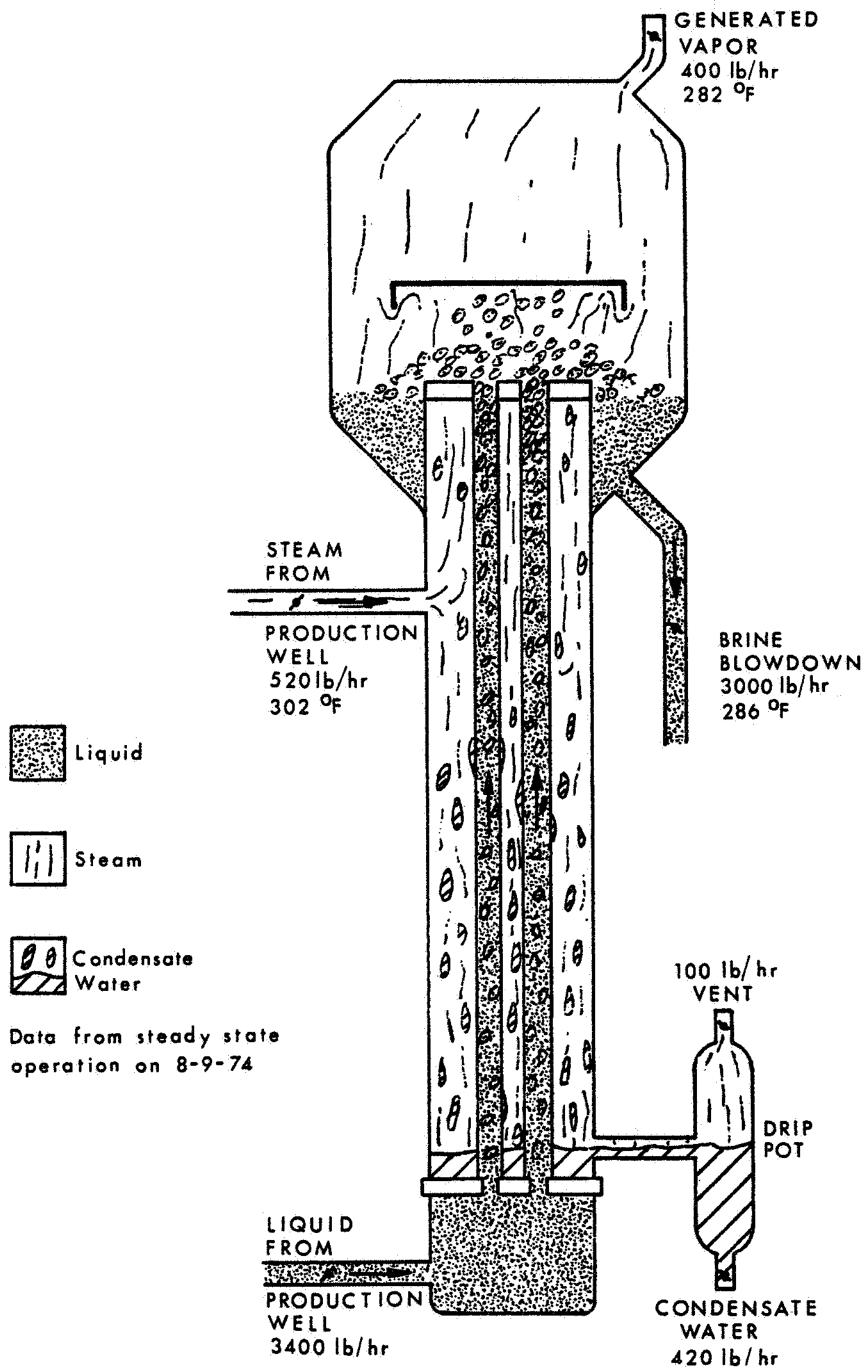

Fig. 3. Vertical tube distillation process

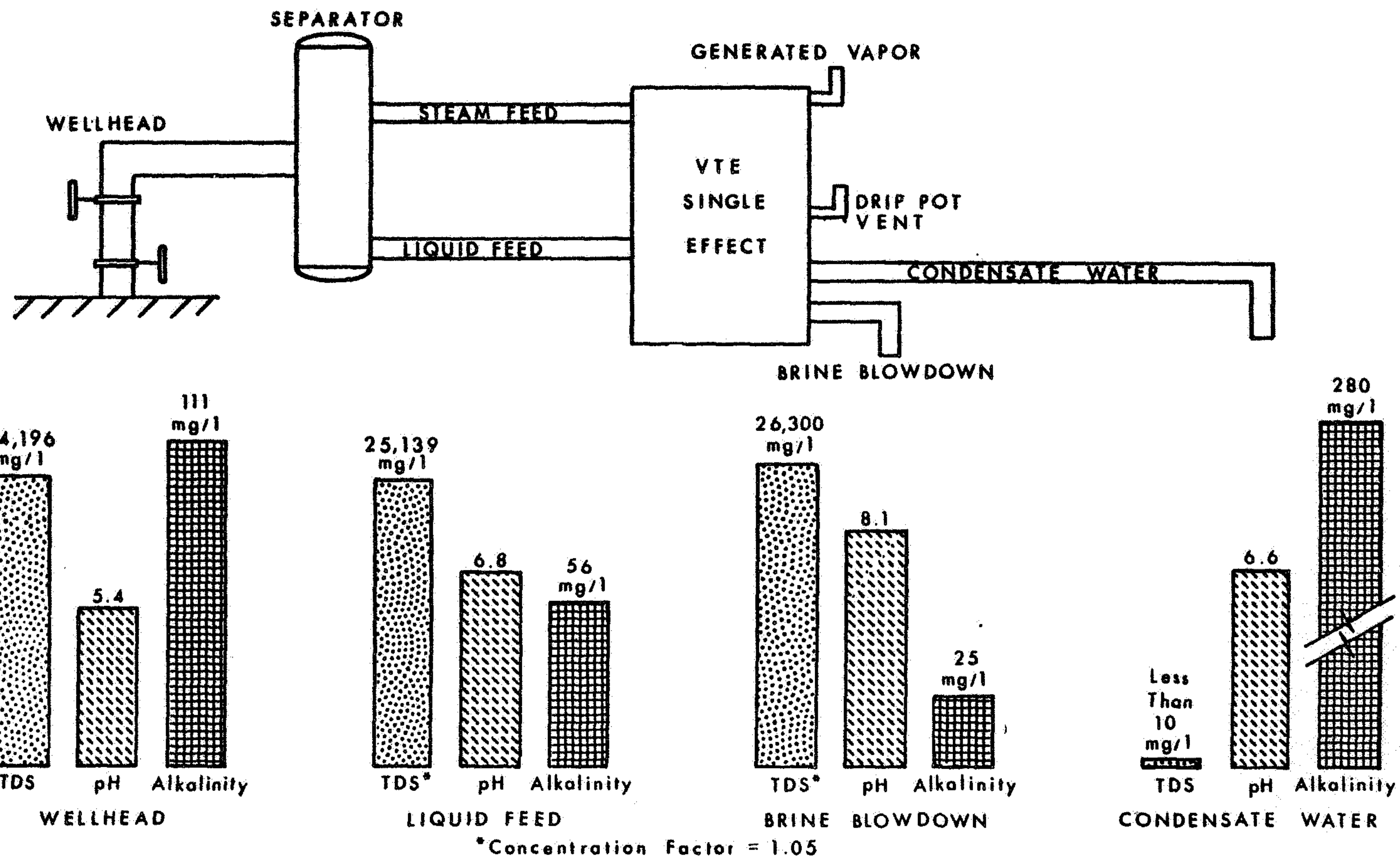

Fig. 4. Water chemistry of single-effect VTE operations