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MASTER

A 500 kW DIRECT CONTACT PILOT PLANT FOR EAST MESA

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September 1979

Prepared for the U.S. Department of Energy
under Contract W-7405-ENG-48

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A 500 kW DIRECT CONTACT PILOT PLANT FOR EAST MESA

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ABSTRACT

A 500 kW powerplant utilizing a direct contact heat exchanger (DCHX) between the geothermal brine and the isobutane working fluid is nearing completion at the East Mesa Component Test Facility. The primary purpose of the plant is to evaluate the performance potential of the direct contact system in a size much larger than the small exploratory units that have been tested to date. Thermodynamic performance of DCHX binary power systems has been demonstrated in small 10 kW research test rigs (Refs. 1, 2, and 3), however, characteristics that affect the economics and practicality of long term operation need to be evaluated. Three factors influencing plant performance and cost are: 1) the control of noncondensables that contaminate the power cycle condenser, 2) the equipment required to limit working fluid losses, and 3) the control of scaling or performance robbing deposits in critical components. These factors are not unrelated and control of one often impacts control of the other two. Operating data and research with the 500 kW pilot plant should demonstrate a solution to all three of these factors and provide design guidelines for larger plants.

INTRODUCTION

The plant design is for a system that will produce a net 500 kW with the highest utilization factor consistent with proven concepts and previous experience utilizing brine from East Mesa well 8-1. Utilization factor refers to the power produced per pound of brine (W-hr/lb).

Thermodynamic cycle analysis was performed to select the most promising working fluid and cycle state point conditions. The cycle studies were supported by independent groups with DCHX experience to assure a maximum experience input into the cycle selection. The cycle studies were based on the pilot plant utilizing 340°F brine from East Mesa well 8-1. The cycle selected for the pilot plant uses isobutane at a peak cycle temperature of 250°F. The selected cycle will have an efficiency of 8.9% with a 94°F condenser and will produce 5.5 W-hr/lb of brine flow.

The plant brings the incoming brine through a sand trap and CO_2 separating vessel, boosts the pressure of the brine for injection into a spray column configuration DCHX and returns the brine, after passing it through a working fluid recovery system, to a facility pond for reinjection. The isobutane (IC_4) working fluid is pumped from the hot well to a high pressure for injection at the bottom of the DCHX. As the IC_4 flows to the top of the DCHX through the descending brine, the IC_4 is heated, then boiled, and taken off the top of the heat exchanger as a vapor. The IC_4 vapor passes through a single stage radial inflow turbine and on to the condenser where it is condensed and returned back to the hot well. The high speed turbine is coupled through a gearbox to a 60 cycle, 480 v, 3-phase generator. The output from the generator is used to power the pumps and other support equipment, the excess being the net plant output of 500 kW.

The plant is being constructed in modular form so that it can be moved from the East Mesa site to other designated sites for additional testing.

CYCLE STUDIES

A study of thermodynamic cycles for this direct contact geothermal pilot plant was made. The intent of the cycle studies was to define a baseline system that would provide the highest utilization factor consistent with proven concepts and previous experience. Three fluids were evaluated; isobutane, isopentane, and N-pentane. The cycle analysis was made for a system that would provide 500 kW net output accounting for all the support equipment power requirements and system efficiencies. The results of the cycle studies produced a brine utilization factor defined as the net W-hr output/lb of brine flow for cycle state points.

The results of these studies are shown in Figure 1. The curves show a distinct superiority in terms of brine utilization for the isobutane with the 340°F East Mesa brine. The curves also show that as condensing temperature is reduced, the cycle efficiency and system performance are improved further. Because the system may be tested at the Raft River facility, studies were also run using Raft River well conditions of 290°F brine and a 74°F condenser with the same system configuration and component efficiencies. At the lower brine source temperature the performances of isobutane and pentane cycles are nearly the same with isobutane being slightly higher.

The higher utilization factor of the isobutane, particularly at the higher well temperatures at East Mesa, indicate that it should be the selected working fluid. When plant costs are considered, the pentane system appears to be simpler and less expensive than an IC_4 system. The pentane cycles run at lower DCHX pressures, eliminating the need for the brine boost pump and the hydraulic power recovery turbine. The delivered pressure from the well is sufficient for achieving the optimum pentane cycle temper-

ature. Additionally, the required organic feed pump power is much less for the pentane than the IC_4 system. The resulting pentane systems thus can be designed for a lower gross power level and the required pressure vessels can be designed and built with lighter gage materials. Since initial investment costs have a strong effect on the price of geothermal generated energy, a cost differential for the two systems was evaluated to try to establish whether the higher utilization factor of the IC_4 system would justify its increased complexity. The cost comparison for the IC_4 system and the pentane systems were surprising in view of the complexity of the IC_4 system and its higher operating pressure levels. The anticipated savings of the pentane system over the IC_4 system were offset by higher costs for the pentane DCHX and turbine. The DCHX is more expensive as it is much larger in diameter and the turbine is much larger to handle the increased volume flow that results from the low condensing pressure.

The comparison between pentane and isobutane systems was based on selected operating temperatures of 240°F for the pentane and 250°F for the isobutane. The pentane temperature was selected slightly past the optimum point because of improved cycle efficiency and potentially lower condenser costs with a small reduction in utilization efficiency. The isobutane peak cycle temperature of 250°F was selected to limit the amount of power required by the pumps and, thus, the gross power level and the pressure levels in the system. The isobutane temperature appears to be below its optimum point from a utilization standpoint but at the higher temperatures and resulting higher pressures, the system cost is increasing. The cycle selected is felt to be near optimum considering both system cost and performance. The process diagram is shown in Figure 2. Additional details concerning cycle and process state points are covered in Reference 4.

PLANT LAYOUT

Construction of the pilot plant will be modular form to provide the portability required to move the system to various geothermal test sites. The plant layout is shown in Figure 3. There are seven modules including the DCHX component. The control and power modules are housed in trailers. The electrical equipment (i.e., generator, voltage controls, switch gear, etc.) are separated from the isobutane turbine by a barrier wall. The electrical side of the trailer is pressurized with ambient air to eliminate any isobutane vapors and thereby circumvent the requirement to use explosion-proof equipment. The control trailer is pressurized for the same reason. The hot well and brine handling modules are built on steel support frames and can be transported intact. The DCHX is a column forty inches in diameter and thirty-two feet high. The unit can be transported on a flatbed truck. The isobutane storage module is made up of four individual 1000 gallon tanks connected to a common manifold. The evaporative condensers make up the final module assembly.

The plant is being assembled on a concrete pad located at the DOE East Mesa Component Test Facility. The DCHX component is shown in Figure 4. This view is looking east and the condenser modules can be seen to the left of the DCHX. The modules are being fabricated at the Barber-Nichols Engineering Company's facilities in Arvada, Colorado, and then shipped to East Mesa.

ACKNOWLEDGEMENTS

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Fig. 1

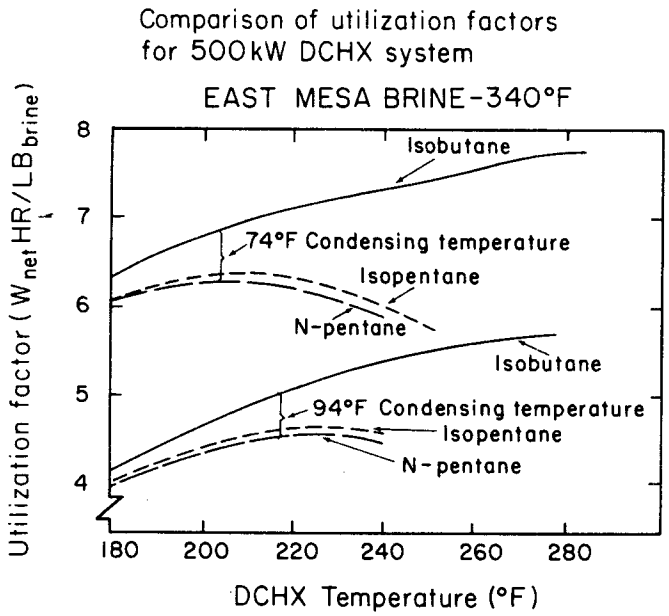

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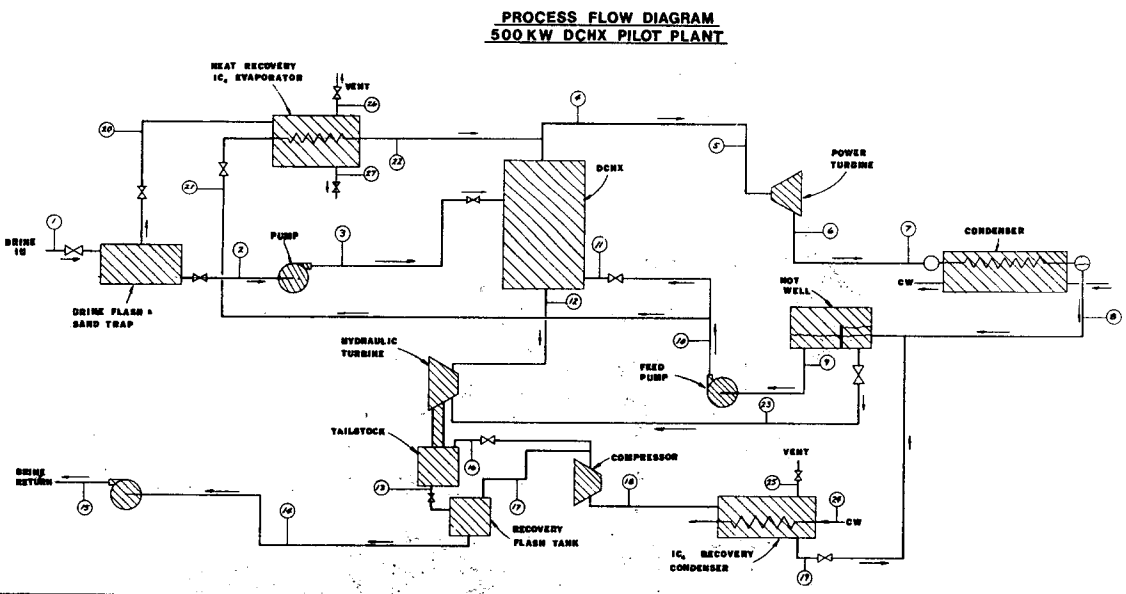
Fig. 2



MATERIAL BALANCE

PROCESS STREAM NUMBER

STREAM / PARAMETER	(1) GEOTHERMAL BRINE SUPPLY	(2) GEOTHERMAL BRINE TO BOOST PUMP	(3) GEOTHERMAL BRINE TO DCHX	(4) ISOBUTANE VAPOR FROM DCHX	(5) ISOBUTANE VAPOR TO TURBINE	(6) ISOBUTANE VAPOR TO CONDENSER	(7) CONDENSER INLET	(8) ISOBUTANE CONDENSATE TO HOTWELL	(9) ISOBUTANE LIQUID TO FEED PUMP	(10) ISOBUTANE LIQUID FROM FEED PUMP	(11) ISOBUTANE LIQUID TO DCHX	(12) GEOTHERMAL BRINE FROM DCHX	(13) GEOTHERMAL BRINE FROM HYD. TURBINE	(14) RETURN BRINE	(15) RETURN BRINE	(16) VENT FROM TAILSTOCK	(17) VENT FROM RECOVERY FLASH TANK	(18) FLOW TO RECOVERY CONDENSER	(19) CONDENSATE FROM IC$_4$ RECOVERY CONDENSER	(20) STEAM & CO$_2$ TO EVAPORATOR	(21) IC$_4$ TO EVAPORATOR	(22) IC$_4$ FROM EVAPORATOR	(23) WATER CONDENSATE FROM HOTWELL	(24) COOLING WATER TO IC$_4$ RECOVERY CONDENSER	(25) IC$_4$ RECOVERY CONDENSER VENT	(26) IC$_4$ EVAPORATOR VENT	(27) IC$_4$ EVAPORATOR DRAIN
FLOW RATE (LB/HR × 10^3)	97.8	97.2	97.2	99.4	99.4	99.4	99.4	99.4	98.0	98.0	95.4	95.4	95.8	95.8	95.8	.018	.006	.024	.021	0.633	2.6	2.6	1.4	16.0	.003	.144	.489
TEMPERATURE (°F)	340	335	335	255	252.4	148.6	140.6	94.0	94.0	95.0	95.0	148.8	144.8	144.8	144.8	144.8	144.8	250	76	335	95	260	94	74	76	270	225
PRESSURE (PSIA)	175	118	485.0	452.7	442.7	72.0	71.6	70.0	70.0	485	467	457	17.0	5.0	20.0	17.0	5	90	90	95	485	460	17	—	90	95	95
ENTHALPY (BTU/LBM)	311.4	306.1	306.6	581.0	581.0	607.7	607.7	776.1	788.9	787.2	787.2	114.1	112.98	112.98	112.98	—	—	—	—	417.3	-787.2	-610.8	62.0	42.0	—	—	—
DENSITY (LBM/FT^3)	56.0	56.1	56.2	6.46	6.32	0.692	.688	34.0	33.8	33.8	33.8	61.4	61.3	61.3	61.3	—	—	—	—	.224	33.8	7.0	62.1	62.3	—	—	—

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Fig. 3

500 KW PILOT PLANT SITE LAYOUT

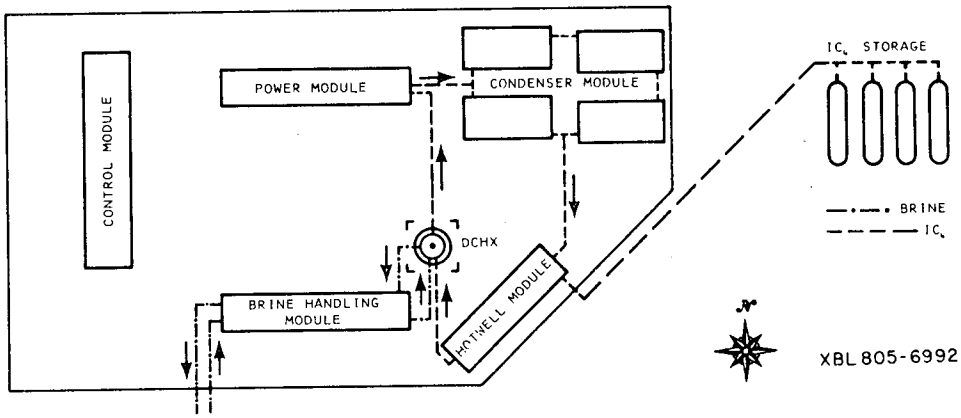
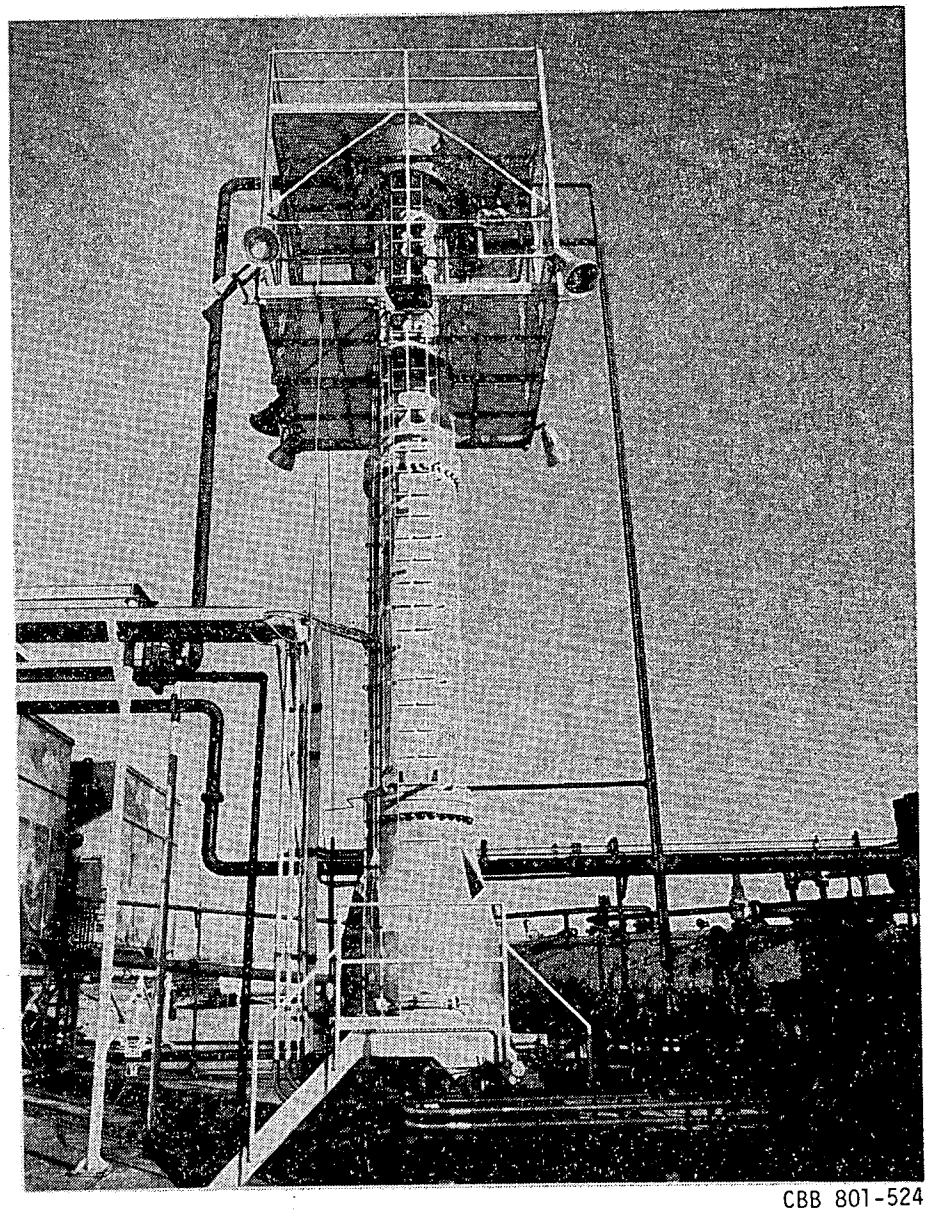


Fig. 4. DCHX installed at East Mesa



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