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RECOVERY OF GEOPRESSURED ENERGY USING THE BIPHASE ROTARY-SEPARATOR TURBINE

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ABSTRACT

The Rotary-Separator Turbine (RST) is a concept of Biphase Energy Systems that has been developed for geothermal applications by Biphase and the Electric Power Research Institute (EPRI). The RST can provide an efficient method for extracting energy from geopressured brines. In this application the RST would develop shaft power from the thermal and pressure energy of the brine and would recovery chemical energy as methane available for distribution. A comparative analysis of conceptual designs for an RST system and a two-stage flash system indicates that the RST system could deliver electricity at a cost about seven percent lower than a two-stage flash system. Use of the Biphase Rotary Separator may result in more complete recovery of methane than is possible with gravity gas-liquid separators.

INTRODUCTION

Geopressured energy is one of four recognized forms of geothermal energy. The other forms are dry steam, hot water, and hot rock. Geopressured energy differs from the other forms in that the reservoirs which serve as its source are under extremely high pressures (>10,000 psi), are located deep beneath the earth's surface (≥12,000 ft), and contain large amounts of dissolved natural gas (CH_4). The temperatures of these reservoirs vary from 100 to 555°F and have an average temperature that has been estimated at >300°F. Mechanical energy is recoverable from the thermal and pressure energy of the brine. Chemical energy is recoverable from the dissolved methane. The largest geopressured region is in the Gulf of Mexico basin in Texas and Louisiana.

Commercialization of geopressured energy will require:

1. Greater knowledge of the quantity of methane in place in the geopressured reservoirs and the fraction produceable.

2. Greater knowledge of the fraction of the geopressured energy that is economically recoverable at the wellhead.

3. Improved drilling technology for operating at the high pressures and great well depth involved.

This paper describes the Biphase system and evaluates its usefulness in processing the brine at the wellhead by comparing its performance to that of a two-stage, flashing-steam turbine system (Helgeson and Cerini, 1981).

BIPHASE TURBINE SYSTEM DESCRIPTION

Data are not yet available to fully characterize either geopressured resources or geopressured well performance. Therefore this study is based on an assumed set of parameters which characterize the geopressured brine: temperature, 325°F; wellhead pressure, 2000 psia; methane content, 40 SCF/Bbl brine; and well production rate, 40,000 Bbl/day. The values chosen agree satisfactorily with the wellhead parameters reported for the Pleasant Bayou Well No. 2, in Brazoria County, Texas.

The Biphase wellhead conversion system which takes advantage of the three forms of geopressured energy is shown in Figure 1. The three stages of the process are (several gas purification steps are not shown):

1. A first-stage hydraulic turbine for power recovery,

2. A second-stage Biphase turbine for power and methane recovery,

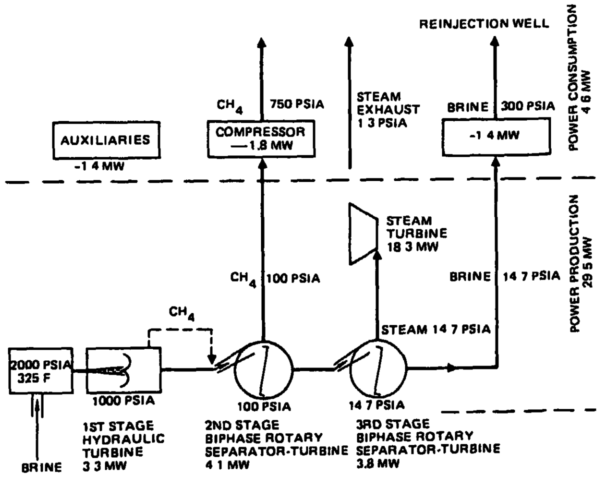

Figure 1. Schematic of Biphase geopressured energy-recovery system.

3. A third-stage Biphase turbine for power recovery from the remaining hot liquid, together with a steam turbine.

Hydraulic energy is recovered in the first-stage turbine. Mechanical energy is produced from the expansion of the two-phase brine stream in the second-stage Biphase turbine. The formation of small brine droplets and the high centrifugal forces developed in the Biphase rotary-separator turbine also assist in the recovery of methane from the brine in this stage. In the third stage the thermal energy of the brine is converted to mechanical energy.

It it is assumed that the geopressured brine is saturated with methane at a bottom-hole pressure of 10,000 psia and 300°F, it contains ~40 SCF/Bbl of methane. As this pressure is released to 1000 psi (first-stage turbine) approximately 80 percent of the methane becomes thermodynamically insoluble. If the methane evolves from solution in the hydraulic turbine, it will be reinjected as a gas phase to the second-stage Biphase turbine (see dashed line in Figure 1). If it does not evolve from solution by the time the brine exits from the hydraulic turbine, the methane is carried, in solution, to the second-stage Biphase turbine.

For the second-stage outlet a pressure of 100 psia is assumed. Subtracting the partial pressure of water, the equilibrium partial pressure of the methane is 40 psia. Assuming thermodynamic equilibrium, 99.6 percent of the natural gas could be recovered at the exit of the second-stage turbine.

The third stage is similar to a geothermal stage where the thermal energy of the brine is used to generate mechanical energy (Cerini, 1979). The brine is expanded from 100 psia to 14.7 psia, producing power in the Biphase rotary separator/turbine. Separated steam (and non-condensable gas) are expanded from 14.7 psia to 1.3 psia in a conventional steam turbine.

It has been assumed that vapor-liquid equilibrium will be achieved in each stage. In fact, this may not be true. For the third stage (brine/steam, single-component system) phase equilibrium is achieved within 2°F. For the first and second stages, however, where both the temperature and the methane content of the phases must be considered, data are not available to quantify the departure from equilibrium that may occur. Difficulty in separating the natural gas from the brine is anticipated, and it is believed that the high g-forces generated in the rotary separator may aid in achieving a closer approach to equilibrium than is possible in gravity separators. If so, this would increase the fraction of natural gas recoverable from geopressured brine.

In the proposed Biphase system, energy is consumed at the wellhead by the requirements to compress the natural gas to pipeline pressure, elevate the used brine to reinjection pressures, and power miscellaneous wellhead equipment.

BIPHASE TURBINE

Generation of power with the Biphase turbine depends upon the creation of a high-velocity jet by expansion of a gas-liquid mixture through a nozzle (Cerini, 1980). For the third-stage turbine this calculation is made using a two-phase (gas-liquid), one-component (water) computer program. These calculations have been discussed in detail (Cerini, 1980).

For the second-stage turbine a separate computer program for a two-phase, two-component (water-methane) system was used. After determination of the jet velocity exiting the nozzle, the power recoverable from the Biphase turbine can be determined from

$$P = \eta_{st}\,\eta_G\,\frac{\dot{m}_L\,V_j^{\,2}}{2g}$$

where η_{st} = combined efficiency of the liquid separator and liquid turbine (~0.80),

η_G = geometric correction factor (~0.9),

$\dot{m}_L$ = liquid mass flow-rate, and

V_j = jet velocity at nozzle exit.

The nozzle-exit jet velocity for the second-stage turbine was calculated as a function of gas content of the geopressured brine. The results of these calculations for an assumed second-stage inlet pressure of 1000 and an outlet pressure of 100 psia are shown in Figure 2. The amount of

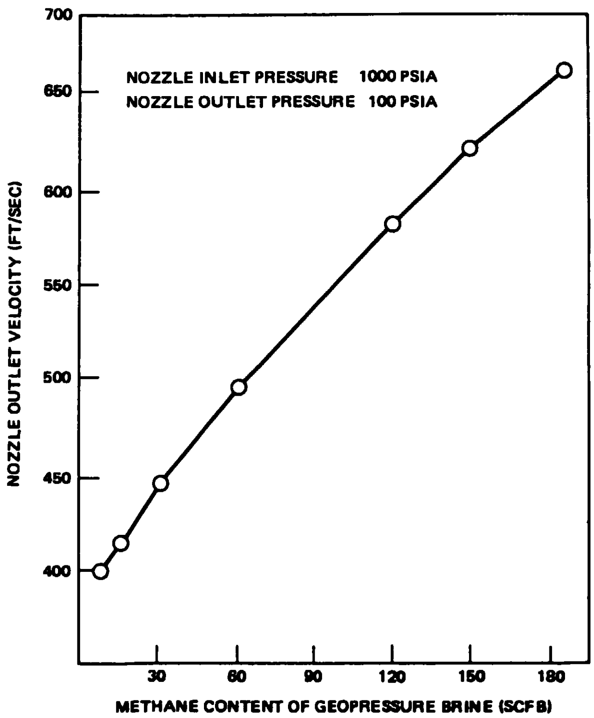

Figure 2. Calculated second-stage nozzle outlet velocity vs. methane content of brine.

natural gas present in the brine is indicated in terms of standard cubic feet per barrel of brine (SCFB). The results show that a significant increase in jet velocity results from increased gas content of the brine. Note that power increases as the square of the jet velocity. The calculations were extended over a wide range of gas content to account for the possibility of supersaturated concentrations of gas in the brine. The gas content of the brine used for the economic portion of this study was 40 SCFB. The effect of varying Henry's contsant, K (for dissolution of methane in the brine), was determined to be of secondary importance in determing the jet velocity.

The stated conditions and the power recoverable from the Biphase system are shown in Table 1, together with results of a two-stage flash system (Wilson, 1977). The energy required to compress the methane, to elevate the waste brine to reinjection pressure, and for various other wellhead-processing operations is also reported.

		TWO-STAGE FLASH (WILSON, 1977)	BIPHASE
ELECTRICAL POWER GENERATION			
BRINE TEMPERATURE	°F	325	325
HYDRAULIC TURBINE	MW_e	5 6	3 3
STEAM TURBINE GENERATOR	MW_e	20 8	18 3
2ND-STAGE BIPHASE TURBINE	MW_e	–	>4 1
3RD-STAGE BIPHASE TURBINE	MW_e	–	3 3
TOTAL	MW_e	26 4	29 5
METHANE AT 35% EFFICIENCY	MW_e	(58 0)	(58 0)
ELECTRICAL POWER CONSUMPTION			
METHANE COMPRESSION	MW_e	0 4	1 8
BRINE REINJECTION	MW_e	1 4	1 4
AUXILIARIES	MW_e	1 4	1 4
TOTAL	MW_e	3 2	4 7
NET ELECTRICAL POWER PRODUCTION	MW_e	23 2	24 8
ANNUAL ELECTRICAL ENERGY PRODUCTION (kW x 365 x 24 x 0 9) (METHANE EXCLUDED)	10^6 kWh/YR	182 1	195 5

Table 1. Summary of power generation and consumption.

SYSTEM POWER RECOVERY AND ECONOMIC ANALYSIS

According to available studies the costs for producing, distributing, and disposing of the brine are the major cost items in producing energy from geopressured resources. Wilson (1977) estimated capital costs for the brine system at $37.0 million of a total $60.00 million investment for a two-stage flashing 25-MWe geopressured facility.

To compare the Biphase rotary-separator turbine with this system, all costs, except for the wellhead processing equipment, are assumed constant. Capital costs of the Biphase system (using the same basis as used by Wilson) were estimated at $60.6 million.

The electrical power generated, the electrical power consumed, and the net electrical power produced by the two processing approaches is shown in Table 1. An auxiliary power debit of 1.4 MWe was assumed for both cases. The additional electrical power that could be generated if all the methane recovered were used for that purpose is shown in parentheses (a thermal efficiency of 35 percent for conversion of the chemical energy of the methane to electrical power was assumed).

To determine the cost of the geopressured energy, assumptions were made consistent with those of Wilson (1977), and included a 12.8 percent return-on-investment, a five percent depreciation rate on a straight-line basis, four percent for general administrative overhead and taxes, and an operating cost at eight percent of the capital. The natural gas was assumed to have a value of $2.00/MCF. The total annual cost, the credit obtainable from the natural gas recovered and the net annual costs are shown in Table 2. The cost of electricity in mills/kWh was determined from this and the annual kWh produced. The cost of electrical energy as determined by Wilson (1977) was six percent greater than that calculated for the Biphase case.

METHANE CONTENT OF BRINE – 40 SCF/Bbl METHANE VALUE – $2 00/MSCF			
		TWO-STAGE FLASH (WILSON, 1977)	BIPHASE
GROSS ANNUAL OPERATING COSTS (CAPITAL INV) x (0 128 + 0 05 + 0 04 + 0 08)	(10^6 $)	18 01	18 05
VALUE OF NATURAL GAS ($2 00 x (MSCF/YR)	(10^6 $)	8 94	8 94
NET ANNUAL OPERATING COST	(10^6 $)	9 04	9 11
ANNUAL ELECTRICAL POWER PRODUCTION (FROM TABLE 1)	(10^6 kWh)	182 1	195 5
COST OF ELECTRICAL ENERGY	(MILLS/kWh)	49.6	46 6

Table 2. Summary of costs for producing electrical power from geopressured brine reservoirs.

CONCLUSIONS

A process utilizing the Biphase rotary-separator turbine for recovery of the methane and for generation of electrical power at the wellhead has been analyzed. Energy calculations were performed and an economic analysis has shown that the cost of electrical energy generated by the Biphase system is 46.6 mills/kWh compared to that of 49.6 mills/kWh when a two-stage flash system is used. In addition to this advantage in power generation, the Biphase rotary-separator turbine may also provide an advantage for separating the evolving methane from the brine.

ACKNOWLEDGEMENTS

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