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MODEL DEVELOPMENT FOR CYCLE ANALYSIS IN ADVANCED HEAT REJECTION STUDIES

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KEY WORDS

computer-aided model, binary cycle, flash steam system, geothermal power plant, heat rejection system, economic evaluation, thermodynamic evaluation, off-design performance

PROJECT BACKGROUND AND STATUS

Determining the best heat rejection system for power plants using liquid-dominated hydrothermal resources is a crucial issue in producing low-cost energy. The resources being considered are generally in the low to moderate temperature range and, therefore, the power plant must reject a large amount of heat. In addition, most of the resources are located in areas where water is scarce and total wet cooling may not be possible. It is then imperative to investigate heat rejection systems to produce economical electrical energy.

In FY1994, we developed models to evaluate cycle performance and impact on the levelized cost of energy (LEC) produced from binary plants. This procedure included a computer program to perform the cycle analysis and component sizing for binary systems with dry cooling (air-cooled condensers) and a spread sheet in which the economic data was calculated. The method of computing the levelized energy cost was an incremental method to determine the percentage change from a base case. The method is a an updated version of a method proposed by Demuth and Whitbeck in Report EGG-GTH-5821. Results have been used to consider base cases as defined by Barber Nichols for small, low temperature plants (4 production wells and <300°F). Additional baseline data will be incorporated during the next year into the model from the Next Generation Geothermal Power Plant Study currently being carried out under the direction of the Electric Power Research Institute (EPRI) and the U.S. Department of Energy (DOE).

Studies of heat rejection systems and their impact on cycles was carried out during FY1995. The tool mentioned above was updated to include different types of heat rejection temperatures and also to predict "off-design" performance of a system if the ambient conditions were changed from the design values. These enhancements have made possible studies on different types of heat rejection systems and their response to changing ambient conditions. In FY1996, the tool will be further expanded in its database of working fluids and economic data on different systems. In addition, dual-flash steam systems will be included in the model.

PROJECT OBJECTIVES

Technical Objectives

- Produce a computer-aided method to rank systems with different configurations by evaluating their impact on LEC.
- Update the model to consider more working fluids (including pure fluids and binary mixtures) for the binary cycle.
- Analyze heat rejection system performance, working fluid performance for mixtures in binary systems with and without internal recuperation and comparison of binary with flash steam systems.

Expected Outcomes

- A computer-aided method to be used by the Geothermal Power Program to evaluate advanced systems.
- Different operating strategies to minimize water consumption along with LEC.
- Other studies involving binary cycles with different types of working fluids, with and without recuperative preheat of the working fluid with turbine exhaust, comparisons between binary and flash steam systems.

APPROACH

The approach taken is to apply a computer-aided "Value Analysis" as described in the Background section to binary cycles with various types of heat rejection systems, with and without internal recuperation. Flash steam systems will also be considered in the method. The value analysis is a simplified screening method that provides a means of comparing one concept with another by evaluating the impact of the concept on the change in the levelized energy cost. The procedure lends itself to "ball-parking" at the value of possible research paths as well as providing an accurate estimate of the value of the more fully developed concepts.

During FY1994, a computer program was developed which allowed changes in the levelized energy cost (LEC) to be determined for changes in small air-cooled, binary geothermal power plants with air-cooled condensers. The effects of component size change and their impact on LEC were determined for some low temperature applications.

In FY1995, this work was extended to include different types of heat rejection systems. Additional systems to be considered are:

- Shell-and-tube condensers with water cooled in an evaporative cooling tower,
- Shell-and-tube condensers with water cooled in an air cooler and then in an evaporative cooling tower,
- Series combinations of one of the air cooled systems over an evaporative water cooled system,
- Parallel combinations of the systems mentioned above.

This work will be extended in FY1996 to include studies involving binary cycles with recuperation, and dual flash steam systems. In addition, the binary working fluid database will be expanded and the economic database will be extended to include some of the results of the EPRI/DOE Next Generation Geothermal Power Plant Study (NGGPP). (The final report on this study will be available at the end of calendar 1996.)

The methodology will be updated to include economic data from the NGGPP study for higher temperature resources and larger plants. More choices of binary cycle working fluids will be available including many binary mixtures. Binary cycles with internal working fluid preheating with turbine exhaust and dual-flash systems will be added to the method.

RESEARCH RESULTS

Last year, the initial model was used to compare with some more detailed conceptual designs of small, low temperature power plants using air-cooled condensers done by Barber Nichols, Inc. The results compared favorably to the degree of accuracy of this simplified model. These results are described in a draft report mentioned in the References section.

FUTURE PLANS

In FY1996, the computer-aided model will be expanded to include: 1) Binary systems with recuperative preheating of the working fluid with turbine exhaust, 2) Greater choice of working fluids including binary mixtures, 3) Expanded economic data to include higher temperature resources and larger plants with data from the NGGPP study, and 4) Dual-flash systems.

Studies will be made on the effect of recuperation on LEC of binary systems, selection of binary working fluid to fit particular resource and ambient conditions, and comparisons between advanced flash steam and binary systems.

INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

The computer program will be made available to industry when it is completed. The use of the NGGPP Study will give a baseline with which industry is familiar. The results of the studies will produce some "rules-of-thumb" in components such as heat rejection systems, the type of

working fluid to use in binary cycles at different resource conditions and the comparison of flash steam to binary systems.

The intermediate results of this project were presented at the 1995 Geothermal Program Review and comments were solicited from the industrial participants.

REFERENCES

The original "Value Analysis" work for geothermal power plants is discussed in the following report:

Demuth, O.J. and J.F. Whitbeck, "Advanced Concept Value Analysis for Geothermal Power Plants," EGG-GTH-5821, March 1982.

Bliem, C. J., "Computer-Aided Value Analysis for Small, Low-Temperature Binary Systems," Report CJB-NREL94-01 submitted to NREL December 1994.

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