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APPLICATIONS OF GEOTHERMAL RESOURCES IN THE EVAPORATION/CRYSTALLIZATION INDUSTRY

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ABSTRACT

A survey of major industries utilizing the evaporation/crystallization process was carried out in order to select three industries for consideration for utilization of geothermal energy. From among each of the selected industries, an example case was chosen for technical and economic evaluation. This evaluation included use of the "feed-and-bleed" process for energy extraction from the low-temperature geothermal brine.

This study concludes that, under certain conditions, geothermal energy could be used economically in the evaporation and crystallization industry. The factors that would most affect cost include geothermal resource characteristics; the energy extraction process chosen; and the duration of the evaporation/crystallization operation.

INTRODUCTION

The objective in this study was to determine the technical and economic feasibility of using low-temperature geothermal energy (hot brines) in place of steam from conventional sources for industrial use. Industrial use was restricted to users of multiple-effect evaporation and crystallization, a key industrial operation which consumes significant amounts of low-level energy. The key aspect of the study was that a "multiflash feed-and-bleed" system, would be incorporated with the evaporation and crystallization process to make efficient use of the geothermal resource.

The study investigated that phase of development classified by ERDA as "non-site specific, general industrial use of geothermal energy."

The evaporation and crystallization industry is a large user of low-grade heat. This paper discusses the technical considerations of applying geothermal brine at 300°F to the three selected industries - tomato paste processing (preserved fruits and vegetables); sugar beet refining (sugar and confectionary) and sodium chloride production (chemicals). These industries were selected based upon their potential use of geothermal brine, actual or possible location near geothermal resources, significant energy requirements for their evaporation/crystallization operation, and demonstration of the broad range of evaporation/crystallization conditions prevalent in the industry. The economics of using geothermal brine is presented for both the retrofit of an existing plant and the construction of a new plant.

PROCESSES

The processes for extracting heat energy from geothermal brine that were studied include simple flashed steam, a liquid-liquid heat exchange, and a feed-and-bleed process. Based on this study, it was determined that the feed-and-bleed process minimizes the brine flow requirements in addition to providing other process benefits. The feed-and-bleed process shown in Figure 1 consists of a series of flash tanks, one for each effect. The vapor generated from the geothermal brine in each flash tank then supplements the heat delivered to the associated effect from the preceding effect. In this manner, the heat content of the incoming geothermal brine is most effectively employed in the evaporator.

A further advantage in the use of flashed steam is that the heat transfer coefficient from condensing vapor is superior to that attainable in liquid-liquid heat transfer. Scale-forming brines that would foul heat exchangers have minimal effect in this process. The brine itself never contacts the heat exchange surfaces. Should any scale deposit in the flash vessels, it will do little harm; and if the deposit becomes thick enough to interfere with fluid flow, it can be removed readily from the large, smooth surfaces.

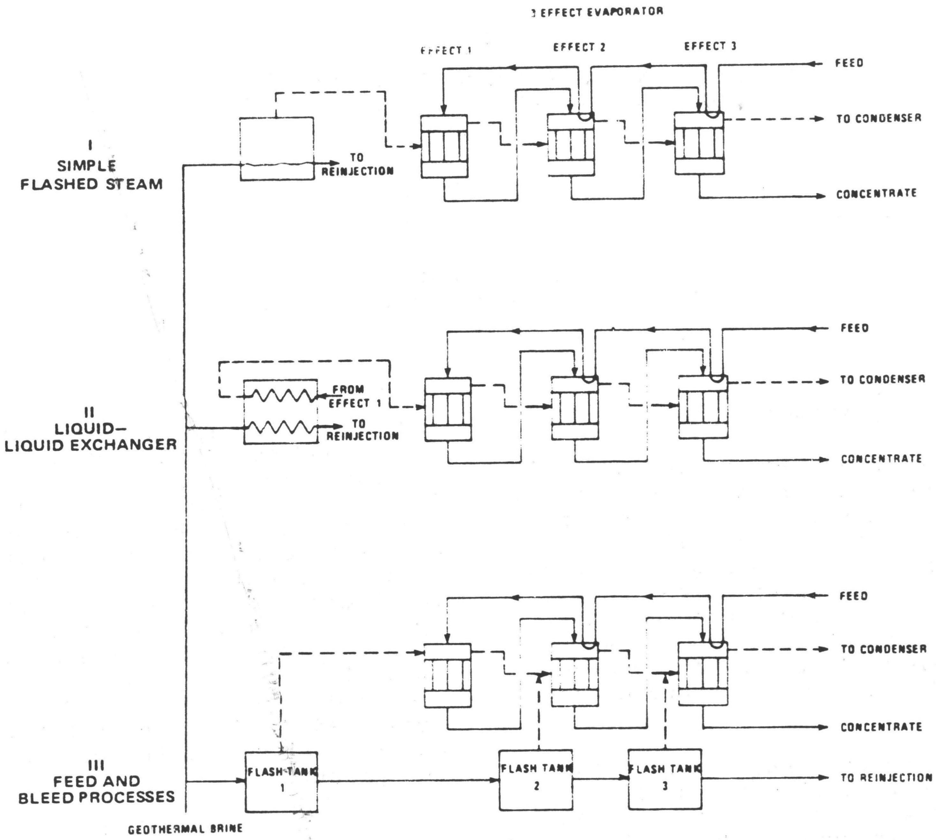

Fig. 1. Energy Conversion Process Comparison

SELECTED INDUSTRIES

The following is a description of the results for the selected industries. Discussed are the major equipment changes and opportunities for implementation.

Tomato Paste

In order to apply geothermal energy to tomato paste processing, new plants should be located near geothermal resources or the manner in which tomatoes are processed should be modified. Either an existing plant or a new plant can be adapted to the use of geothermal brine, but approximately 7 percent of the required steam flow must still be generated by a fossil-fueled boiler as the boiler is used for an aseptic system for sterilization and vacuum production.

For existing plants major equipment changes are required and include the following:

- Addition of heat exchanger area
- Conversion of pump drives from steam turbine to electric motor drives
- Modification of hot breaks to use lower temperature steam
- Addition of a small packaged boiler
- Addition of 3,700 kW of electrical power

Beet Sugar

Beet sugar and cane sugar production requires large amounts of energy. For the typical 4,000 tons/day plant, a substantial amount of electricity is cogenerated by the steam from the boiler prior to supplying the evaporators. As a result, after conversion to geothermal energy, there is a substantial increase in the electrical power requirement.

The use of geothermal energy in sugar beet and cane sugar production requires major changes including the following items:

- Redistribution of the number of vessels in each effect
- Addition of a concentrator prior to the crystallizers
- Modification of the plant liquid and vapor piping
- Increase in cooling system capacity
- Addition of 8,100 kW of electrical power

In the Hawaiian Islands the cane sugar industry appears to offer the best potential for utilizing geothermal brine due to operation throughout a substantial period of the year and the recent discovery of geothermal resources.

Sodium Chloride

About 10 percent of sodium chloride (salt) is produced by multiple effect evaporation and crystallization. Salt crystallization is similar to many other inorganic salt production processes as, for example, caustic soda concentration in chlorine-caustic production. The capacity of the selected typical plant is 500 tons per day and it uses the vacuum pan processes. For a retrofit plant, the changes required are:

- Replacement of the heat exchanger tube materials
- Conversion of the turbine pump drives to electric motor drives
- Addition of 760 kW of electrical power

Nine different types of inorganic salt production facilities were located with respect to geothermal resources. As a result, twelve inorganic salt production facilities were found to be located near "probable geothermal resource" areas.

Other Areas of Application

Although three processes were studied in detail, geothermal brine can be utilized in many other areas of evaporation/crystallization. Among these applications are the pulp and paper industry, dairy industry, and waste concentration.

SUMMARY OF RESULTS

Heat and material balances, equipment specification lists showing all the significant equipment additions or deletions, and a revised electrical energy requirement list are used as a basis for an economic analysis for each of the processes studied. The cost of geothermal energy is expressed as dollars per million Btu in terms of the equivalent fossil requirement for the process, i.e., the annual cost for the geothermal energy divided by the annual fossil fuel requirement. These results are summarized in Table 1.

Some of the more significant cost considerations are discussed in the final report. However, two of the more significant parameters are shown in Figures 2 and 3 for the tomato paste plant. Figure 2 shows the effect of plant operating time of the equivalent energy cost while Figure 3 shows the increasing cost as a result of increasing geothermal brine transportation distance.

CONCLUSIONS

Some of the most significant factors affecting the cost of utilizing geothermal brine are shown parametrically in this report and include the following:

- Geothermal Resource. For the processes considered, characteristics of the resources such as well temperature and cost, distance to the point of use, and flow will significantly affect the economics of the processes. For example, transportation of the brine more than 25 miles is not economical and a drop in brine temperature from 300°C to 250°F doubles the cost of the brine system.
- Energy Extraction Process. The feed-and-bleed process significantly reduces the brine flow requirements. As an example, the sodium chloride plant requires twice the brine flow when using a simple flashed steam process.
- Evaporation/Crystallization Process. Geothermal brine is most cost-effective when it is used throughout most of the year. In addition, the best equivalent energy cost will be obtained in a plant with the least amount of cogeneration of electricity (or its equivalent), as in tomato paste and sodium chloride production.

With favorable conditions, the equivalent energy cost can be less than $1/MMBtu. In all cases studied, there is a higher capital cost associated with a new plant using geothermal brine as compared to a plant using an oil- or gas-fired fossil

Industry	Tomato Paste	Beet Sugar	Sodium Chloride
Size (tons per day)	4,800	4,000	500
Typical Season (Days/year)	70	160	270
Retrofit Cost:			
Capital - MM$	7.04	8.74	2.07
Energy - $/MMBtu	3.88	3.21	1.64
New Plant Cost:			
*Capital - MM$	2.15	3.24	1.02
Energy - $/MMBtu	1.93	2.06	1.10

M = 1,000   MM - 1,000,000

*As compared to an oil or gas fired system

Table 1. Summary of the Economics Results for the Selected Industries

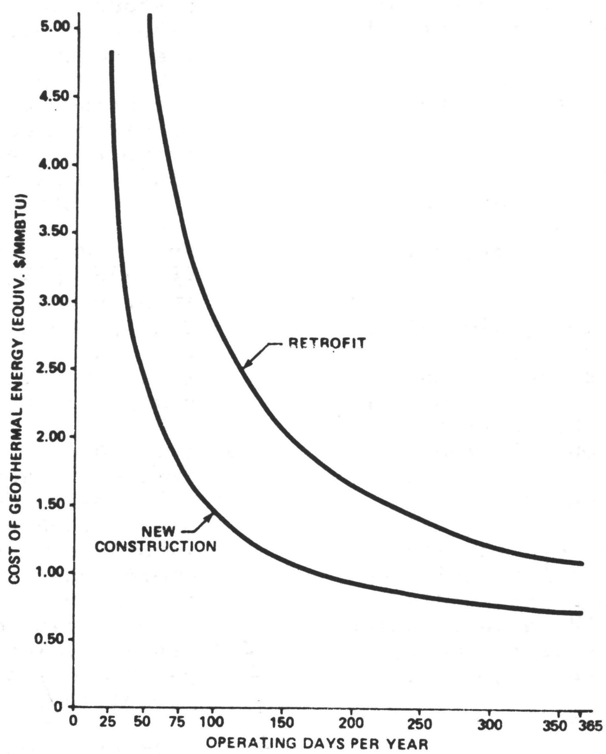

Fig. 2. Tomato Paste Plant (One Mile from Geothermal Wells) Cost as Function of Use

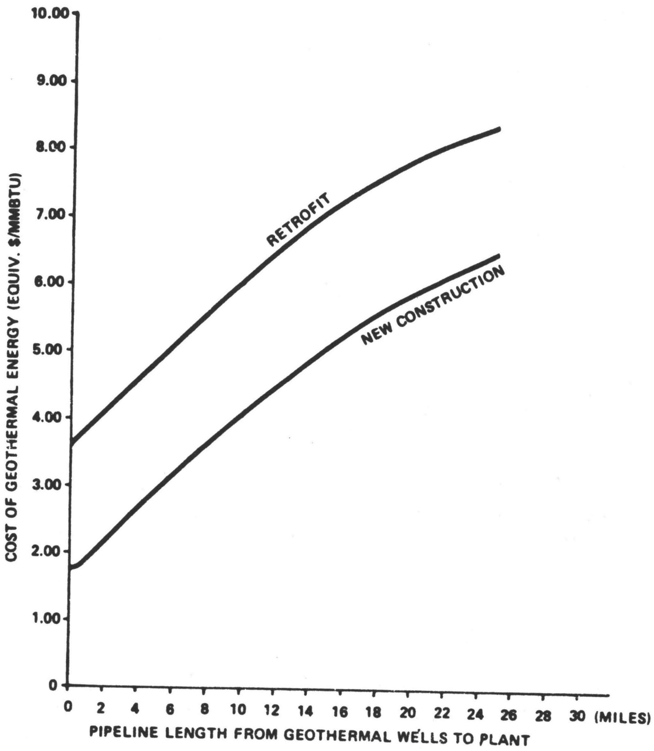

Fig. 3. Tomato Paste Plant (70 Operating Days Per Cost as a Function Distance

fuel. This results from the increased costs of equipment primarily associated with the geothermal energy supply system which exceeds the cost credit for the equipment no longer required, e.g., steam generator, turbine, etc.

RECOMMENDATIONS

No industries in the United States are presently using geothermal energy for evaporation and crystallization, even though many industries that are identified in this study can economically do so.

The lack of resource definition, technical knowledge, and operating experience are current obstacles to the development of geothermal energy. To assist in overcoming these obstacles and implementing the use of geothermal energy in the evaporation and crystallization industry, a demonstration program appears essential. The most promising process resulting from the contracts with industry and energy producers would be selected for additional study. This study would be site specific and would include a study to show the economic advantage of using geothermal brine followed by the construction of a demonstration plant or retrofit of an existing plant.

ACKNOWLEDGEMENT

Work was performed under the auspices of the U. S. Energy Research and Development Administration, Contract No. EX-76-C-03-1328.