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Summary of Section X
Other Single and Multipurpose Developments

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INTRODUCTION

The papers in this section may be summarized with the observation that geothermal resources may be utilized primarily for electrical purposes and, secondarily, for nonelectrical purposes. Exceptions to this ordering will occur in areas where the geothermal resource is plentiful or where the exploration risks, and hence anticipated costs, are minimal. The electrical-nonelectrical priorities have been assigned in the context of a geothermal resource producing the energy equivalent of tens or hundreds of thousands of barrels of oil per day. The geologic criteria and economic parameters for the generation of electricity are described in the next section.

The electrical generation prerequisite is emphasized by Yuhara and Sekioka (p. 2249); Fernelius (p. 2201); and Palmer, Forns, and Green (p. 2241). The strictly nonelectrical utilization of geothermal energy is reported on by Gutman (p. 2217); Delisle, Kappelmeyer, and Haenel (Sec. XI, p. 2283); and Minohara and Sekioka (p. 2237). The papers by Forbes, Leonard, and Dinkel (p. 2209) and Barnea (p. 2197) discuss both electrical and nonelectrical utilization but give no preference to either. The papers by Lindal (p. 2223) and Lúdvíksson (p. 2229) of Iceland describe multipurpose utilization in areas where the resource is both abundant and exploration risks (costs) are minimal.

DISCUSSION

Yuhara and Sekioka (p. 2249) have used linear programming for an economic analysis of multipurpose utilization of a vapor-dominated reservoir in the Siramizu-gawa area near Sounkyo, Hokkaido, Japan. Utilization is shown in three stages. The primary stage is for electrical generation; the secondary stage for space heating, greenhouses, and snow-melting on roads; and the third stage for mineral baths. The most important elements for the commercialization of a geothermal system are the quality and quantity of geothermal resources, transportation of geothermal fluid, utilization for power generation, utilizations other than power generation, waste disposal, and environmental conservation.

The paper describes the linear-programming model and summarizes the results of the analysis based on actual cost data. Although the authors do not mention mineral recovery, they conclude that utilization is difficult to economically justify without electric power generation.

Water desalinization at the East Mesa field in the Imperial Valley of California conducted by the U.S. Bureau of Reclamation is described by Fernelius (p. 2201). Information is provided on the five deep exploration wells at the East Mesa anomaly, together with results from production tests and information dealing with scaling and corrosion. Two distillation desalting units have been installed at East Mesa, together with a multistage flash unit and a vertical-tube evaporator. The design criterion for this equipment is 200°C; however, the maximum temperature of the geothermal waters is 166°C.

Work to date indicates that electric power generation will most likely be required to supplement the costs for the desalinization program. It is not clear whether the desalinization program would have been economical had the temperatures of the resource been 200°C rather than 166°C.

Palmer, Forns, and Green (p. 2241) consider the concept of locating a geothermal electric power plant on the sea floor at continental-shelf depths. The waste heat would be contained in the sea floor, which in turn would provide a preferred site for certain species of fish and crustacea such as the rock oyster, shrimp, and the "spiny lobster."

The basis for the proposition of locating geothermal power plants on the sea floor is derived from studies for siting nuclear power plants in coastal zones. Using the United States as an example, studies indicate that within a coastal belt 80 km wide, 40% of the population lives on 8% of the land and that land contains job sites for 42.6% of the industrial sector. Because siting a nuclear power plant in a coastal zone precludes multiple uses of this land, it is contended that an offshore, underwater geothermal plant would permit multiple uses of the coastal lands. Offshore experience in oil and gas drilling and heat pipe technology developed by the Hughes Aircraft Company is cited in support of the required underwater technology.

The compatibility of an onshore geothermal power plant with multiple uses may be envisioned from the other papers in this section.

Gutman (p. 2217) describes the use of geothermal waters for the soilless growing technique called hydroponics. No wells were required. The chemical constituents of the water are described, as is their effect on the types of viruses and bacteria which affect various plants. A chart which describes the impact of boron on different types of crops is included.

Under the heading "Environmental Impacts" Gutman states, "The spent water with some nutrients is discharged into the natural drainage system where it irrigates the natural alkaline soil and induces growth of grains and grasses from windborne seed, which previously were unable to germinate due to the toxicity of the alkaline soil." This is particularly thought-provoking when one considers that many of the areas of geothermal potential throughout the world are located near deserts where soil conditions are likely to be similar to those described by Gutman. Because these areas are both toxic and arid, production of geothermal waters or brines which are predominately acidic could serve to neutralize the toxicity and make the lands fruitful. Evaporation of the geothermal waters into the atmosphere could increase rainfall by adding moisture to the air. Soil conditions in many areas of the world, including the United States, could perhaps be enhanced by the drilling and flowing of geothermal wells.

Delisle, Kappelmeyer, and Haenel (Sec. XI, p. 2283) list the limiting conditions for economic utilization of geothermal energy. These, combined with the lack of accessible high-temperature geothermal potential in Germany, make major economic development of geothermal energy in Germany appear unlikely at this time, although some exploration to find resources for space heating is under consideration.

The impact of water temperatures slightly higher than normal for the breeding and incubation of crocodilians is described by Minohara and Sekioka (p. 2237). Difficulties were encountered in making direct body-temperature measurements, but this was overcome by using an infrared thermometer capable of remote measuring. The remote sensing device was not described, although it may have application in the exploration for geothermal energy.

The paper by Forbes, Leonard, and Dinkel (p. 2209) illustrates one of the problems often encountered in geothermal development, namely, transportation. While electricity can move long distances between major population centers or from isolated areas to population centers, nonelectrical applications require that the resource be used on-site. Forbes, Leonard, and Dinkel examine geothermal development in Alaska, where the remoteness of geothermal resources from population centers and the sparseness of the population centers themselves weigh against large-scale development. The potential for geothermal development at Circle and Chena hot springs, Manley Hot Springs, and Pilgrim Springs is described. Additional studies which include space heating, refrigeration, agriculture, controlled-environment plant systems, sewage disposal, and fish farming are being conducted at the three spring locations cited.

The paper by Lúdvíksson (p. 2229) explains the concept of multiple uses of geothermal energy for electrical production at temperatures between 180 and 200°C and for processing agricultural products, marine products, and various raw materials using geothermal steam at temperatures ranging from 100 to 180°C. At temperatures from 40 to 100°C, geothermal hot water may be used for horticulture, animal husbandry, health resorts, and space heating. At temperatures less than 30°C, fish farming may benefit.

Lúdvíksson presents an operating analysis for an electro-horticultural complex. This includes a market analysis for vegetables, flowers, and so on, both for domestic consumption and export, and the capital costs for constructing a growing facility. The principal cost of the growing facility is the glass and framework. It may be interesting to learn whether a low-quality glass could be manufactured using the electricity from the complex and the silica precipitate from the geothermal brine. The analysis excludes the costs for electrical generating facilities but assumes that one-half of the electricity produced will be sold in the marketplace. The electrical production is considered necessary for artificial lighting. The description of the complex will be drawn upon in the conclusions for this section.

The Reykjanes Peninsula in Iceland is an area of abundant and readily accessible geothermal resources as evidenced by the many surface manifestations. Lindal (p. 2223) describes the activities of the Sea Chemicals Complex on this peninsula, a project initiated by the National Council of Iceland in 1966. The project was designed to coordinate the exploitation of indigenous Icelandic resources. Principally, these are hydraulic power, heat from geothermal energy, sea water, and industrial raw materials which are found in goethermal fluids. Presently under consideration by the Icelandic government are facilities for the commercial recovery of salt, potash, and calcium chloride from the geothermal brines.

During the last four years of the investigations a well was kept flowing in order to observe production rates and possible changes in the chemical composition of the brine. The depth of the well is not given. The rate of production the first year was 85 kg/sec. The production then declined to 68 kg/sec in the second year, 57 kg/sec in the third year, and remained the same thereafter. The chemical composition did not change. Mineral recovery was achieved through separation by evaporation and fractional crystallization. The minerals present in the brines were found to attain a solid form in the following order: silica, sodium chloride, potassium chloride, and calcium chloride. An evaporator was constructed to assist in removing the water in order to concentrate the fluid. Geothermal steam from the test well was the source of heat for the evaporator. Silica and calcium sulfate build-up of scale commonly associated with geothermal production is not considered to be a problem. Build-up of scale did, however, inhibit the heat-transfer coefficient in the evaporator when oxygen was permitted to enter the system. By purging the oxygen, the heat-transfer coefficients are expected to remain satisfactory.

The most extensive technical work accomplished by the Sea Chemicals Complex is the preparation of magnesium chloride from sea water as a feed to electrolytic magnesium cells for the ultimate manufacture of magnesium. Inexpensive soda ash processed by geothermal steam is a key component in the manufacturing system envisioned. The production of sodium metal, chlorine, and caustic soda have also been studied. Because magnesium and sodium metal as well as other products such as ammonia can be produced using electrolytic processes, additional attention should be given to electrolysis using power generated by geothermal energy.

GEOTHERMAL DEVELOPMENT COMPLEX

A geothermal development complex conceptualized from the papers contained in this section might consist of an electric-power generating facility, with a portion of the electricity used internally and the balance sold into a transmission grid. The electricity would be used within the complex conventionally by residents and for many energy-intensive manufacturing processes such as smelting and electrolysis for the manufacture of ammonia. Some steam could be diverted from the power station for process use or water desalinization. Hot waste water could be used for space heating in buildings, greenhouses, and/or to hydroponically produce food. Low-quality greenhouse glass could possibly be produced with precipitated silica in electric ovens. Otherwise arid lands could be made tillable with waste waters and ammonia-based fertilizers from the electrolytic processing plant. Perhaps the hot water could be piped under intercomplex roads to keep them snow-free. Mineral baths would be an ideal place for residents to contemplate other productive activities for the geothermal development complex.

While the vision of a geothermal development complex is appealing, the demand (value) for electricity and associated costs may economically preclude multipurpose uses in areas such as the United States. In such areas it may be desirable to reinject the geothermal fluids at their highest temperature in order to maintain or prolong reservoir life. Reinjection would also maximize individual well lives and inhibit production declines. Until more wells are drilled and permitted to flow, this question will remain unanswered.