University of Hawaii at Manoa

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March 18, 1994

Ms. Mary Kok
U.S. Department of Energy
1301 Clay Street, Room 700N
Oakland, CA 94612-5208

SUBJECT: USDOE Contract #DE-FG03-85SF15798
Puna Geothermal Research Facility Technology Transfer Program

Dear Ms. Kok:

As a follow-up of our March 4, 1994, letter enclosed is the final report summary to fulfill the close-out requirements for the subject contract. We have enclosed another set of the individual task reports as an attachment to the final report summary.

If you have any questions please contact Wendy Armstrong at (808) 956-8788 or fax (808) 956-2336. Thank you for your patience.

Sincerely,

Patrick K. Takahashi
Director

Enclosures
cc: Andrea Beck
Peter V. Garrod

DOE/SF/15798--T13

Puna Geothermal Research Facility
Technology Transfer Program

FINAL REPORT FOR U.S.D.O.E. CONTRACT DE-FG03-85SF15798
8/23/85 - 8/23/89

University of Hawai'i
Hawai'i Natural Energy Institute
Patrick Takahashi, Principal Investigator

SUMMARY

In August 1985, the Hawai'i Natural Energy Institute, University of Hawai'i at Manoa, was awarded a $75,000 geothermal energy technology transfer grant from the U.S. Department of Energy. Over the duration of the project, which ended in August 1989, funds from other sources were added: $26,500 from the County of Hawai'i and $52,000 from private business sources on the island of Hawai'i.

The bulk of the funds, $105,746, was used in a series of small grants to entrepreneurs demonstrating the direct use of geothermal heat supplied by the State of Hawai'i's HGP-A well. This effort was known as the Community Geothermal Technology Program (CGTP.) Additionally, funds were used in a variety of public information and technology transfer activities, such as: a Pacific Rim geothermal workshop held at the University of Hawai'i at Hilo; the publication of an issue of the *Geothermics* journal focusing on geothermal development in Hawai'i; the support of informative "open houses" at the Puna Geothermal Research Facility (Noi'i O Puna laboratory); and the creation of a permanent educational display about geothermal direct use at the Puna facility's visitor center.

Since the primary focus was the grants to direct use entrepreneurs, this report will emphasize the results of the Community Geothermal Technology Program. Individual reports for the completed projects are also attached.

COMMUNITY GEOTHERMAL TECHNOLOGY PROGRAM BACKGROUND

A total of nine small business ventures, artistic endeavors and experiments were funded by the Community Geothermal Technology Program (CGTP.) The program provided small grants for pre-commercial enterprises utilizing geothermal heat and byproducts. These grantees were the first and, thus far, the only direct heat users in Hawai'i, although their efforts have encouraged others to consider the ample heat resource in the Puna District.

The CGTP was jointly administered by the Hawai'i Natural Energy Institute (HNEI) of the University of Hawai'i at Manoa, and by the State of Hawai'i Department of Business, Economic Development & Tourism (DBEDT), with on-site supervision and facilities provided by the Natural Energy Laboratory of Hawai'i Authority (NELHA.) Initial funding was provided by the U.S. Department of Energy for technology transfer; it was supplemented by the County of Hawai'i and, later, by private businesses. Two phases of grants were awarded, the first in 1986 and the second in 1988.

The pilot phase of the CGTP awarded grants to five projects: 1) "Green Papaya Powder Drying" ($10,301); 2) "Bottom Heating System Using Geothermal Power for Propagation," ($11,350); 3) "Experimental Lumber Drying Kiln," ($10,800); 4) "Hawaii Glass Project," ($10,144); and 5) "Cloth Dying by Geothermal Steam," ($6,119).

The second phase of the CGTP also awarded five grants, including a continuation of the bottom heating project from the pilot phase, for an additional $3,610. The four additional projects were: 1) "Geothermal Aquaculture Project" ($15,000); 2) "Media Steam Sterilization and Drying" ($15,000); 3) "Silica Bronze" ($15,000); and 4) "Electrodeposition of Minerals in Geothermal Brine" ($8,422).

Several of the business-oriented projects were very successful and could expand into an incubator facility for geothermal enterprises, should one become available. Agricultural businesses are especially suitable.

It is unlikely that the art projects based on recovering geothermal silica will be commercially viable due to the difficulty in processing the silica and its ready availability as a bulk import. However, these projects did focus public attention on the creative use of what was perceived as a waste material, and did successfully incorporate the silica into art glass, sculpture, and painting.

NOI'I O PUNA (PUNA GEOTHERMAL RESEARCH CENTER)

Noi'i O Puna is a public geothermal laboratory established in Hawai'i to support direct use research, tapping the previously unutilized heat in brines from the State's HGP-A well. The HGP-A well and power plant were developed with support from the U.S. Department of Energy, the State of Hawai'i, the University of Hawai'i, and other agencies.

The HGP-A well was first flashed in 1976. In 1981, a nominal 2.5-megawatt power plant using energy from the well first came on line; by 1982 it was providing firm power to the local electric utility. Noi'i O Puna was built next to the HGP-A power plant and dedicated to direct use research in 1985. In 1986, the U.S. Department of Energy formally transferred ownership of the HGP-A facility to the State of Hawai'i; its management was assigned to the Natural Energy Laboratory of Hawai'i (now the Natural Energy Laboratory of Hawai'i Authority.)

The Community Geothermal Technology Program awarded its first grants in 1986. A second phase of grants were awarded in 1988. Research continued through the end of 1989, when the HGP-A well and power plant were closed. The power plant equipment has since been removed; the well remains closed but available for research.

The purposes of the CGTP were to encourage the use of waste heat and byproducts from HGP-A, to support small business enterprises in the Puna District, and to allow access to the geothermal resource by individuals, entrepreneurs, community groups and non-profit agencies who may not otherwise be able to take advantage of the laboratory. Since the HGP-A well produced a wet resource and the power plant did not make use of the liquid portion, much excess heat was available for economic use. In addition, approximately 500 lb/day of amorphous silicon dioxide precipitated out of the brine into disposal ponds, and was also available for experimentation.

Most of the work on grants funded by the CGTP took place at Noi'i O Puna. The resources available at Noi'i O Puna included: high pressure brine (160 psig at 370° F, or 188° C); low pressure brine (15 psig at 250° F, or 121° C); low pressure steam (15 psia at 250° F, or 121° C); and hot potable water (50 psig at 210° F, or 99° C).

C.G.T.P. PROJECT SUMMARIES

Fruit Dehydration

The use of geothermal heat to dehydrate tropical fruits and fruit products was successfully demonstrated. The main product, green papaya powder, was manufactured by drying the puree of mature, green papayas. Various other fruit products, such as pineapple and banana slices, were also dehydrated. Because of high community interest in dehydration, other local products, including fish, macadamia nuts, kukui nuts and coconut, were also dryed on a short-term basis.

A truck dryer was built at Noi'i O Puna. The 18-foot-long cabinet, built of plywood, had several chambers for the "trucks," which are wooden frames on casters which hold stacks of aluminum drying trays. There were 40 trays per truck and three trucks per dryer, for a total capacity of 120 trays.

Potable water was heated by the laboratory's heat exchanger, and a second heat exchanger and fan system within the cabinet provided warm air. The preferred temperature range was 120°-130° F (49° - 54° C), and the dehydration period typically lasted from 24 to 36 hours. The lack of automatic controlling instrumentation hampered the process, as did the absence of proper recording equipment.

Although the quality of the geothermally-dryed products was inconsistent due to the lack of automatic controls and the varying ripeness of the fruit when it was prepared for drying, the grantee was satisfied that, if priced competitively, geothermal heat can be easily substituted for conventional heating methods in a commercial facility. The high community interest in dehydration indicates that this would be one of the most promising of the geothermal direct-heat ventures, if fully commercialized.

Bottom Heating

The bottom-heating project demonstrated that heated growing media can significantly improve the growth of certain species of ornamental palms. In Phase One of the project, thirty-three varieties of palms and other ornamentals were planted at two sites: the bottom-heated greenhouse constructed at Noi'i O Puna, and the grantee's existing, unheated greenhouse at his main commercial facility, Leilani Foliage. With additional funding under Phase Two, 16 more species were tested.

The growing medium at the bottom-heated greenhouse was kept at 85° to 90° F (29°-32° C), while at the control facility it was approximately 70° F (21° C). Hot water, provided from the Noi'i O Puna heat exchanger, ran in tubes in the depressions of corrugated roofing material laid on raised benches. The flats of palm seeds were placed on this roofing material. Although this system worked effectively, the grantee feels that burying the hot pipes in perlite or a similar material may heat more evenly.

With some species, the heat made a dramatic difference, such as betelnut which had an 82 percent germination in the bottom-heated flats and 0 percent without heat. Twenty-eight of the plant varieties tested during this project showed significant improvements in growth rates and/or germination with geothermal bottom heating.

Bottom-heating was demonstrated to: 1) improve germination, which is particularly important because the seeds of some exotic palm species can be extremely expensive; 2) accelerate growth rates, so that palms can be transplanted and sold earlier; and 3) encourage healthier and more consistent growth.

Lumber Kiln

Another of the pilot projects involved the partnership of King Koa, which specialized in functional art such as inlaid cutting boards and cabinetry. There were no lumber kilns on the island when the pilot project began: lumber was air-dryed locally, a process which took between one and two years, or shipped out of state for kiln-drying. The grantees also used a dehumidified chamber, which was an improvement over air drying but offered no control over the final moisture content. Also unavailable was a drying schedule for koa dictating the varying temperatures and humidities required within the kiln.

A small experimental kiln was built at Noi'i O Puna, with a computerized control system and sensors. The heat from the geothermal brine was transferred to potable water at the laboratory's heat exchanger, and to the air by means of a simple coiled-pipe heat exchanger at the kiln, along with a circulating fan. Fresh water could be sprayed into the air circulating system to increase humidity, when the drying schedule called for it. The kiln held less than 1,000 board feet of lumber.

The grantees experienced problems with low air temperatures, due to heat exchanger inadequacies. Despite this and problems with adequate air circulation, charges of lumber were repeatedly dried with good results. The partnership continued to operate the kiln on a semi-commercial basis after the conclusion of tneir research, but decided not to pursue the project on a larger scale.

Glass Making

Identifying a use for the ample geothermal silica, and simultaneously encouraging the local community of hot glass artists, were the goals of the Hawai'i Glass Project. The grantees experimented with several formulas for the glass, finally developing a unique formula using 93 percent indigenous Hawaiian materials, primarily geothermal silica.

Recovering the silica was laborious, requiring digging it out of the disposal ponds at a certain stage of precipitation, and then washing it to remove the salts. The silica must also be free of other contaminants which could affect the color and workability of the glass formula.

Two dozen artists from across the state participated, creating pieces ranging from hanging sculptures to etched bowls, paperweights and jewelry. Their exhibition was held in October 1987 at the Volcano Art Center, and a partial exhibit was also on display during December at the Hawai'i County Mayor's office.

Cloth Dyeing

An experiment in technology transfer from Japan to the United States, the cloth dyeing project illustrated the viability of using untreated geothermal steam to fix and modify the dyes in fabrics. The two Japanese grantees had experience with a similar venture in Iwate Prefecture, Japan.

The grantees found that the steam from HGP-A seemed to result in brighter dyed colors than the steam used in Japan. A wooden chamber was built, and dyed fabric laid on shelves, constructed of criss-crossed string to allow steam circulation. Raw steam at pressures between 160 and 180 psi and a temperature of 266° F (130° C) was vented directly into the chamber. After approximately 30 minutes, the steam was shut off and the chamber opened. This process also fixes the dyes permanently in the fabric.

All fabric was hand-dyed, with an eye toward the boutique or wearable-art markets. Over 375 pieces of fabric were dyed during the experiment, with most pieces reflecting the abstract pattern and varigated colors typical of tie-dyed work. The two grantees indicated a strong interest in continuing work at Puna.

Aquaculture

The "Geothermal Aquaculture Project" expected to experiment with the low-cost propagation of fin fish in geothermally-heated tanks. The low-input, recirculating system was to use a biofilter to allow a high-density population.

Tilapia were selected for the experiment. The tanks were simple, applicable to backyard aquaculture as well as commercial ventures. However, due to delays in the acquisition of suitable tank liners and other factors, the tanks were not constructed until late 1989, and the project was unable to be completed when the HGP-A well was closed. There is no final project report available for this work.

Growing Media Pasteurization

Untreated geothermal steam was used to pasteurize shredded coconut husks, replacing imported nursery growing media such as peat moss with an indigenous product.

Dual steaming chambers were constructed from used shipping containers. The first, connected to a two-inch brine pipe at Noi'i O Puna, was used to flash the brine to steam. Steam was conducted from the top of the first chamber into the second chamber by means of three six-inch ducts. A plywood plenum built at the bottom of the second chamber allowed steam and condensate to collect for disposal.

After coconut husks were shredded to a uniform half-inch size suitable for potting mix, they were mixed with screened black cinder, approximating the nursery's usual medium of 20 percent peat moss and 80 percent cinder. The husk/cinder mix was put into ten-gallon plastic pots, which were placed directly into the second steaming chamber.

The pasteurization treatment consisted of releasing steam into the chambers until the temperature reached 180° F. The average media temperature was 160° F, which was maintained for 30 minutes. Six batches of pots were pasteurized, for a total of 420 pots, before the HGP-A well was shut down.

The treated media mix was tested and certified free of harmful organisms by the State of Hawai'i Department of Agriculture. Other analyses revealed that the pH level of the media rose only slightly after steaming; salt levels doubled but remained at safe levels. Magnesium solubility increased after heating, but not to toxic levels. Field trials were conducted by planting ornamental palms in pots which were steam-treated, and comparing growth with the same palm planted in untreated media. After nine months, the plantings appeared equally robust, demonstrating that the use of untreated geothermal steam did not adversely affect the plants.

Bronze Casting

Geothermal silica was used as a refractory material in casting bronze artwork. The grantee, an established local sculptor, addressed the problem of recovering and washing the geothermal silica by building a structure to spray-wash and solar-dry the material. In contrast to glass making, the silica does not need to be pure to be useful as a refractory material for sculpture.

When casting bronze using the lost-wax method, it is essential to have a material which is unaffected by high temperatures and yet strong enough to support the wax form and the molten bronze which melts and replaces it. Geothermal silica was successfully used for this purpose in investment casting, although it had to be mixed with a coarser material, such as brick dust, to increase its strength.

In addition to casting a number of bronze sculptures, the grantee added silica to some of his other works, such as frescos, to create a unique product. A number of the works of art which employed geothermal silica were displayed in a one-man show at the East Hawai'i Cultural Center.

Electrodeposition

This basic research project intended to demonstrate whether useful compounds, such as calcium carbonate, will precipitate from the geothermal brine onto electrically-charged metals. Past international research has shown that calcium carbonate can be successfully precipitated from seawater onto metal structures, which may have a variety of economic uses. The chemical similarities between seawater and the geothermal brine were suggestive.

Electrodeposition occurs when a potential is applied across a cathode and anode in an electrolyte such as geothermal brine. The resulting potential difference induces a migration of ions through the electrolyte, enabling the depositing of certain ions at the cathode.

Geothermal brine at Noi'i O Puna was piped into three separate non-corrosive tubs which each held approximately 170 liters. The flow rate of the brine was maintained at approximately 32 liters per hour, and the temperature at approximately 140° F.

Identical carbon graphite anodes and stainless steel cathodes were suspended in the brine in each of the three cells. A 20-volt DC source supplied electricity, with individual cell voltages altered by load resistors. The cells were operated for approximately 30-day intervals. Aggregates which formed at the cathodes were removed and analyzed, determining their weight, crystalline structure and elemental composition.

Higher current densities were found to correspond to a greater accumulation of material on the cathode. The accumulated material consisted of halite, vaterite, calcite, amorphous silica and, in the cell with the highest current, aragonite. Interestingly, the accreted mass to expended power ratio for the geothermal brine was almost 150 times a typical value for seawater electrodeposition, possibly because of the silica content of the brine. The rate of deposition, however, is very slow. Any commercial potential has yet to be determined.