COMMUNITY GEOTHERMAL TECHNOLOGY PROGRAM

CLOTH DYEING BY GEOTHERMAL STEAM

Conducted by

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CLOTH DYEING BY GEOTHERMAL STEAM:

AN EXPERIMENT IN TECHNOLOGY TRANSFER

FROM JAPAN TO HAWAII

Final Report on the Cloth Dyeing Experiment
Submitted to the
Community Geothermal Technology Program

Augustine S. Furumoto
Administrative Assistant to the
Cloth Dyeing Experiment

December 31, 1987

NOTICE

PREFACE

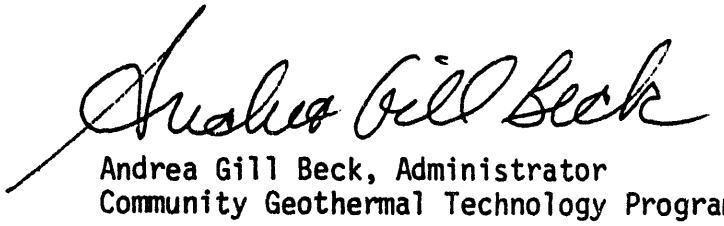
This is a report of work performed for the Community Geothermal Technology Program, a small grant program administered jointly by the Hawai'i Natural Energy Institute and the State of Hawai'i Department of Business and Economic Development.

This project was one of five funded under the pilot phase of the program. The grantees all began in 1986, and completed their work between October 1987 and April 1988. Funds for the pilot phase were provided by the U.S. Department of Energy and the County of Hawai'i.

The five Community Geothermal Technology Program projects were the first attempts to make direct use of geothermal heat and byproducts in Hawai'i. The success of these five grants has encouraged others to consider the use of geothermal energy in their businesses. A second round of grants was awarded in early 1988, and will demonstrate further applications of geothermal heat, brine and silica.

The opinions expressed in this report are those of the author, and are not necessarily shared by the program administrators, funding agencies, or others involved in the program. Responsibility for the accuracy of the data provided in this report lies with the author.

The enthusiasm, talents, and efforts of the grantees are much appreciated, and I look forward to continuing to work with them and with future recipients of grants from the Community Geothermal Technology Program.



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INTRODUCTION

An experiment to test whether cloth dyeing using geothermal steam, a technology already proven in Japan, would be feasible in Hawaii was conducted as one of the five initial projects of the Community Geothermal Technology Program at the Puna Geothermal Research Center (Noii O Puna) in Pohoiki, Hawaii. The principal investigator of the dye project was Mrs. Yukie Kimura of Tokyo, Japan, with Dr. Motoyuki Kawagoe, a dentist in the city of Morioka, Japan, as co-investigator. As both principal investigator and co-investigator were residents of Japan, Dr. Augustine S. Furumoto of the Hawaii Institute of Geophysics, University of Hawaii at Manoa, assisted them as administrator and local representative. The actual experiments were, however, conducted by the principal investigator and co-investigator.

In October 1985 a proposal for the experiment was submitted to the Community Geothermal Technology Program in response to a request for proposals by the Program. After due review by peers, the project was accepted by the Program and was funded in April 1986. The project was officially terminated in October 31, 1987, after a no-cost extension of six months.

The cloth dyeing project may be viewed as an experiment in technology transfer from Japan to Hawaii. However, this attempt at transfer differs from other attempts very significantly. Other transfer attempts are usually of advanced technology accompanied by capital investment in multi-million dollars. Geothermal cloth dyeing was and still is a cottage industry in Matsukawa Village in Iwate Prefecture of Japan, and the objective was to transfer the technology to Hawaii as a cottage industry. Such an industry is appropriate in the rural to semi-urban environment of Puna, Hawaii.

1. GOALS AND OBJECTIVES

The principal investigator, Mrs. Yukie Kimura, had been successful in Matsukawa Village, Iwate Prefecture, Japan, in

pioneering the application of geothermal steam to dye cloth for use in handkerchiefs, neckerchiefs, neckties, furoshiki and boutique type dresses. Her objective in undertaking the project at Puna Geothermal Plant was to duplicate, if not surpass, the success she enjoyed in Japan.

Specifically, the principal investigator wanted to try out different dyes on cotton, silk and synthetic cloth material, using geothermal steam. Among the dyes considered were chemical dyes and natural dyes extracted from leaves, flowers and stems of plants growing in Hawaii. Another factor to be experimented with was the quality of steam issuing from the geothermal vent. The brine from geothermal vents contain impurities: appreciable amounts of silica and traces of various chemicals, ferric, mercuric and others. These impurities alter the hue and brilliance of dyes. The alterations caused by these impurities may be desirable. The proper use of impurities may become advantageous in marketing of dyed cloth.

At the beginning, the plans to carry out the project consisted of the following:

1. To build a steam vat in Hilo and ship it to the geothermal plant at Puna.
2. Attempt dyeing with chemical dyes at first.
3. Experiment with herbs and plants.
4. Experiment with different lengths of time in steaming.
5. Explore the market in Hilo and Honolulu.

The above plans deviated somewhat from what were stated in the proposal. The proposal had called for shipping a steam vat from Japan, but it was found that there was no vat in good condition for shipping from Japan. Hence it was decided to build one in Hilo. The vat was simple in design anyway.

2. CONCLUSIONS DERIVED FROM THE EXPERIMENT.

The results of the experiment are the following:

1. With the simple equipment of a fabricated steam vat, cotton, silk and synthetic cloth material can be dyed with appropriate chemical dye. The resulting dyed material received high grades for steadfastness and permanency under dye testing carried out in the laboratories of Industrial Research Center of Iwate Prefecture at Morioka City, Japan.

2. Different techniques for dyeing that were succesful in Matsukawa were tried out in Puna. All techniques were replicated. Some of the techniques are described in Section 3-E below.

3. Attempts to embed leaf patterns on cloth by using natural leaves were unsuccessful. Attempts to extract

natural dyes from Hawaiian plants were also unsuccessful. The color of natural dyes deteriorated in a matter of hours. Either the extraction techniques were not appropriate or the mordants (fixing agents) used were not effective.

4. Chemical dyes gave brilliant hues or shades in this experiment. The results differed from those in Japan where the steam there gave subdued tones to the cloth.

5. The production aspect of geothermal dyeing was proven by this experiment to be feasible in Hawaii. The remaining problem is to develop a market for the product by attractive public relations. This can be done if there is anyone willing to risk venture capital of several thousands of dollars.

6. The most important conclusion is that geothermal dyeing can be a viable cottage industry in Puna, Hawaii.

3. DESCRIPTION OF WORK

3-A. Pre-Project Experiments.

Even before the project was funded, trials were conducted whether the geothermal steam at Puna could fix dyes satisfactorily. Pieces of cotton and silk cloth a few square feet in area were dyed and placed in a stainless steel container having an intake pipe and an exhaust pipe. Steam coming off the safety valve in the geothermal electric power plant was introduced into the intake pipe. The used steam from the exhaust stem was allowed into the atmosphere. The resulting product showed that dye was permanent on the cloth samples.

With the knowledge that the steam from the Puna well was good enough to dye cloth, application was filed for a grant from the Community Geothermal Technology Program.

3-B. Construction of a Steam Vat.

The first step in the project after funding was to construct a steam vat for dyeing purposes. From a simple drawing by Kimura giving only rough dimensions, a more detailed drawing was constructed by A. S. Furumoto. Furumoto had traveled to Morioka, Japan, in March 1986, to examine steam vats which were in use there for geothermal dyeing. The vats he inspected were in disrepair and were far from being satisfactory models to copy. The plans that finally resulted were mostly due to Furumoto, with the size of the vat determined by the sketches of Kimura. The vat was planned to be 36 inches wide, 48 inches high and 72

inches long. From this drawing a carpenter at Hilo, Marc M. Lee, constructed the vat.

One of the requirements of the vat was that it had to be leak proof while steam is injected from one end and exhausted from the other. To accomplish this, Marc Lee suggested that the vat be double walled with boards, with one layer of boards arranged perpendicular to the boards in the other layer. The suggestion was accepted and the vat was so constructed.

Another matter that required attention was the prevention of dripping of condensed water drops from the roof of the vat to the cloth samples below during the dyeing process. To prevent dripping, the roof of the vat was sloped so that drops of condensed water will run down the slope rather than drip.

The vat was installed at the Puna Geothermal Facility and was in operation by August 22, 1986. (See plates at end of report.)

3-C. Schedule of the Investigators.

The two principals in the project, Yukie Kimura and Motoyuki Kawagoe, are residents of Japan with professional commitments there. Hence they could not remain at Puna for a prolonged stay. Instead they made up for it by frequent visits of short duration. The following are the list of times that they came to carry out the experiments.

June 25, 1986.	Kawagoe and Kimura together about ten days.
October 20, 1986.	Kimura for about a week.
January 6, 1987.	Kawagoe for about a wweek.
January 21, 1987.	Kimura for eight days.
March 24, 1987.	Kawagoe for about a week.
April 10, 1987.	Kimura for ten days.
July 9, 1987	Kawagoe for three days.
July 22, 1987.	Kimura for a week.
October 5, 1987.	Kimura for 17 days, present at No'i O Puna open house.
October 27, 1987.	Kawagoe for about ten days.

3-D. Experiments with Chemical Dyes.

The experiments performed can be divided into two general categories: (1) dyeing of various kinds of fibers with chemical dyes and (2) dyeing of cloth with extractions from plants.

For chemical dyes, the dye known by the brand name of Regina Color, manufactured and marketed by Toyo Ink Co., a subsidiary of Fuji Chemical Industries Inc. was used. In conjunction with dye, acryl binders were used for color fastness. Regina Color was selected because of permanence and brightness of the hue.

During all the experiments, the incoming steam pressure was kept within the range of 160 to 180 psi. The temperature was kept at a steady 130^{o} C. In fact the pressure had to be varied from time to time to keep the desired steady temperature.

3-E. Different Methods for Dyeing.

In using chemical dyes, relying on past experience from Japan, both Kimura and Kawagoe tested out different ways of dyeing. Some of the ways tested were (1) straightforward dyeing; (2) pattern dyeing, (3) tie dyeing, and (4) fold dyeing. These different techniques will be explained.

(1) Straight forward dyeing.

At the very beginning, cloth material was soaked in Regina Color dyes with acryl binder and placed in the steam vat without any other variation of technique. Different combinations of steam pressure and time of application of steam were attempted to seek the optimum effect.

When placed in the vat, silk material and other thin cloth material required a lowering of steam pressure and the length of application was about 40 minutes. For cotton and thick material, steam pressure was raised and time in the vat was reduced.

(2) Pattern dyeing.

In this method, the cloth is first soaked in a dye of primary choice. Then a pattern is placed over the cloth. A second dye is next brushed on. The combination is then placed in the vat and steam is applied. The procedure is illustrated in Figure 1.

(3) Tie dyeing.

The cloth is first soaked in a dye that will be the base dye. A portion of the cloth is twisted together and dye is applied to the twisted part as shown in Figure 2. The material is placed in the vat as twisted. After steam applications, radial patterns will appear in the cloth (Figure 3).

(4) Fold dyeing.

Several pieces of cloth were dyed, each piece with a different color. The cloths are folded and placed one upon the other. The combination is placed in the vat and steam

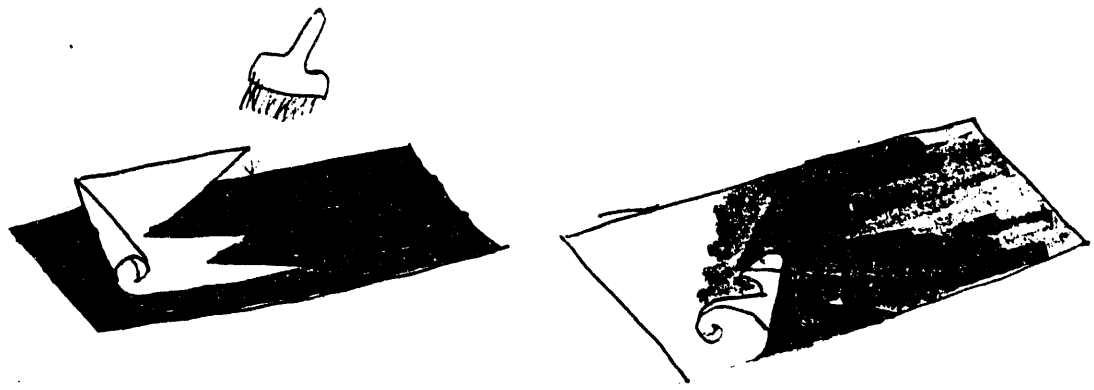


Figure 1. Steps in pattern dyeing. Left: place pattern over a fabric already soaked with dye. Then brush on second dye. Right: remove pattern.

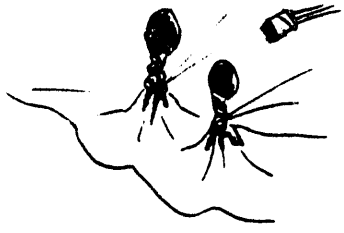
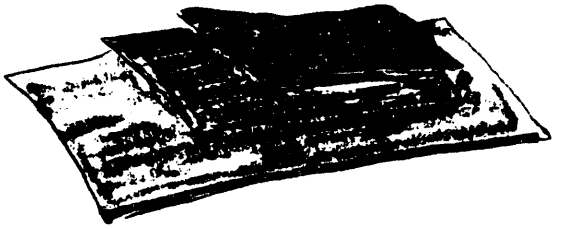


Figure 2. Brushing on dye in tie dyeing.

Figure 3. Radial patterns in tie dyeing.



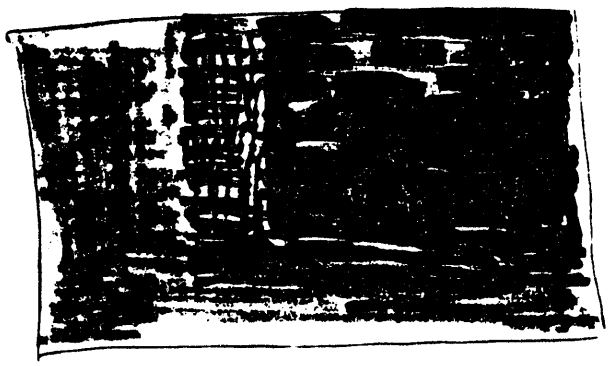


Figure 4. Fold dyeing. Three layers of cloth (upper diagram). Result after dyeing (lower diagram).

is applied (Figure 4). Dye from the upper layer seeped down into the lower layers to give different color patterns to the lower layers.

3-F. Experiments with Plant Extracts.

Kawagoe attempted to extract natural dyes from several types of colorful flowering plants. The difficulty he encountered was that colored fluids from plants faded or changed their colors even in the process of extraction. Even if the color was preserved after extraction, the original color could not be maintained after subjection to steam. For the sake of a complete record, experiments with natural dyes from plants are described here.

(1) Anthuriums.

From anthurium plants, flowers were cut from the stems and 100 g of flowers were crushed to extract fluids. The light red color from the flowers dissolved readily in 100 cc of water.

At first pieces of cloth of silk and cotton were soaked in the fluid. Even after 1 hour, the cloth did not soak up the red fluid. After 24 hours of soaking the bright red color turned brown. Nevertheless, the cloth was put through the steam vat.

In a second attempt, 100 g of flowers were again crushed and 120 cc of water was added. The mixture was boiled until the content was down to 100 cc. The color was bright red at first, but as boiling was prolonged, the color changed to dull red and then to brown.

(2) Birds of Paradise.

In the bird of paradise experiment, extraction was attempted from the blossoms, stems and leaves.

Taking about 150 g from yellow and orange parts of blossoms, the parts were soaked in 800 cc of water for 2 hours. Then the mixture was boiled for 10 to 15 minutes until all color was extracted.

A mordant, alum, was added. Cotton and silk fabrics were soaked in the mixture. The fabrics were sent through the steam vat, but the colors were altered.

300 g of stems were put in 1000 ml of water and boiled for 2 to 3 hours. The water turned a light green color. This used as a dye and subjected to the usual steaming process but the color did not remain.

300 g of leaves were left in 1000 ml of water for 10 hours. Leaves were removed and cotton and silk cloth were put in. Over low flame the combination was warmed for one hour. The cloth was cooled, and then placed in the steam vat. The cloth dyed a light green color.

(3) Red Ginger.

From the red ginger plant attempts were made to extrct colors from the blossoms and roots.

Flowers. 100 g of flowers were ground up and 150 cc of water was added. The water was boiled for 10 to 15 minutes. A light red color was obtained, but not an attractive color.

Roots. Only the roots of the ginger plant were used in this experiment. The roots were soaked for 10 hrs in water. After 2 or 3 hours of boiling a brown color resulted. This was used in dyeing.

In all of these experiments, dyes extracted from plants lacked brilliance and contrast was not good. The colors were not resistant to depredation by light and washing.

3-G. Product List.

In the following table the types of cloth articles and the quantity produced are listed.

Article	Material	Size	Number
Furoshiki	Silk	80 cm x 80 cm	24
Scarf	Silk	90 cm x 90 cm	40
Blouse	Silk	92 cm x 180 cm	2
Yukata	Cotton		2
Scarf	Synthetic	92 cm x 90 cm	2
T shirt material	Cotton	380 cm x 140 cm	1
Scarf	Cotton		5
Handkerchiefs			300

Photographs of fabric samples after dyeing are shown in Figure 5.

4. DISCUSSION OF PROJECT; PROBLEMS AND CHANGES.

The geothermal dye process involves the fixing of dyed cloth by geothermal steam. The dye is applied to the cloth first, in patterns or design as desired. The dyed cloth is then placed in a vat, and the vat is sealed. Geothermal

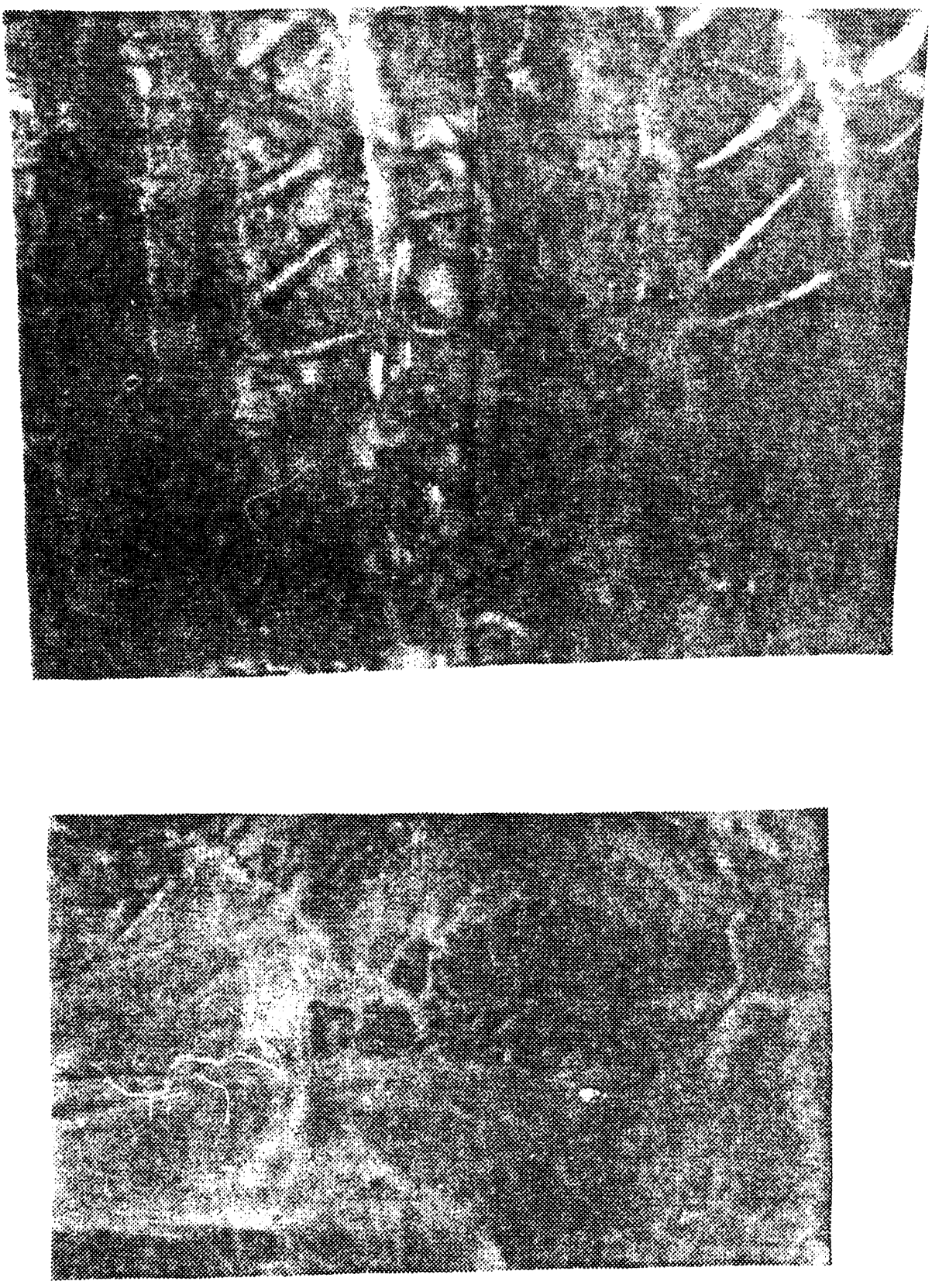


Figure 5. Two samples of non-reproducible patterns by geothermal dyeing. [Originals in color - ed.]

steam is introduced into the vat under pressure. The steam fixes the dye into the cloth fiber.

Depending upon the impurities in the geothermal brine, the dye is affected differently. For example, iron compound impurities (ferric) have the effect of making the color of dyes darker. Fourteen different chemical impurities have been identified in the geothermal brine at Matsukawa, Japan. There, ferric compounds give a subdued tone to the fabric.

On the other hand, the geothermal steam from the well at Puna has a quite a different effect. The steam makes the colors brighter. Data on chemical analysis of Puna geothermal steam are available, but the comparison between chemical inclusions of Matsukawa and those of Puna has not been made. Perhaps the topic of the effect of chemical impurities on dye could be one for a future project. That question was not addressed in this project.

One of the common chemicals present in most geothermal steam, whether in Hawaii, Japan, California or Italy, is hydrogen sulfide. In fact, there is a always a pervading characteristic odor of hydrogen sulfide in geothermal areas, the odor of spoiled eggs. Hydrogen sulfide discolors dyed cloth by reduction and produces white patches in dyed material. The discoloring can be used to advantage in producing fascinating designs.

The fixing process in geothermal dyeing differs from fixing in other dyeing processes. Care must be used in selecting dyes. The dye used in this project was produced and sold by Toyo Ink Co. under the brand name Regina Color. In their experiments at Matsukawa in Japan over the years, both Kimura and Kawagoe, especially Kimura, has experimented with different types of dyes and found that Regina Color has greater persistence and retention of brilliance than other dyes tested.

In the fixing process, geothermal steam is used under slight pressure. This fixes the dye into the fiber of the cloth, which gives for durability even through multiple washings.

One of the experiments performed was the interaction between two different dyes. A piece of cloth was dyed red and another dyed blue. They were placed together in the vat and geothermal steam was introduced. The interaction between the two dyes brought about mixing of colors. On top of that hydrogen sulfide in the steam discolored part of the mixed section to produce a design or pattern that was unique.

Not only for mixing of two dyes, but even for straight forward dyeing and fixing by geothermal steam, the

interaction of the dyes with impurities in the geothermal steam produces non-reproducible patterns or designs each time. No two designs are the same. Even with a repetition of steps exactly, the end results are different. The non-reproducible feature is an advantage in the dress industry. As fashion conscious women go through great lengths to be different from everybody else, the ability to churn out unique patterns and designs in quantity is a strong point for geothermal dyeing.

During the exhibition on October 17, 1988, at the Noi'i O Puna open house featuring the results of the Community Geothermal Technology Program grantees and their products, products of the geothermal dye project were displayed. The prevailing comment received at this exhibition was the desire for more brilliant colors. Based on these comments, experiments with different types of dyes should be carried out to find dyes that will produce brilliant colors under geothermal fixing.

5. FISCAL REPORT.

In the matter of finances there were two components in the dye project: the funds received from Community Geothermal Technology Program as a grant, and matching funds provided by the investigators. It must be remembered that the investigators are residents of Japan and they had to come to Puna, Hawaii, many times to carry out the project. As this was a project to develop local industry for the local community, it was understood at the outset that travel to and from Japan and sustenance while in Hawaii cannot be charged to the grant. We will discuss the grant portion first then the matching funds.

The amount of the grant awarded by the Community Geothermal Technology Program was $6119. Of this amount $3671.40 were made available in June 1986 at the beginning of the project and in February 1987 after the acceptance of a progress report $2141.65 became available. The remainder is to be received after the final report is accepted.

The expenditures from the grant funds and from personal funds by the investigators for the project were as follows:

Category	From CGTP	Cost Sharing	Total
1. Equipment	0	0	0
2. Materials, supplies supplies			
a. cloth material	2557.00	3000.00	5557.00
b. lumber, labor (steam vat)	1501.00		1501.00
c. dye	29.03		29.03
d. fixing agent (mordant)	158.00	254.00	412.00
3. Other costs			
a. salaries	0	0	0
b. inter-island travel	89.90		89.90
c. car rental	367.07	1176.00	1543.07
d. report writing stationery computor time	280.00		280.00
e. telephone	30.00		30.00
4. Additional Allowable costs			
a. insurance(2 yrs)	417.00		417.00
b. facility use	690.00		690.00
5. Travel, Japan-Hawaii		2200.00	2200.00
6. Sustenance in Hawaii		2200.00	2200.00
Total	6119.00	8830.00	14949.00

The matching funds were to include travel to and from Japan and sustenance while in Hawaii. Altogether 11 trips were undertaken and just for Mrs. Kimura, hotel bill of $2200 was incurred for her 64 days. The hotel bill for Dr. Kawagoe has not been tabulated as of this writing.

In the proposal $2688 were budgeted for hiring casual help in carrying out the project. As it turned out, Mrs. Kimura made friends in Hilo who helped out in the project without compe sation, either because of Mrs. Kimura's personality or out of curiosity. In this way the salary portion was allocated to other categories.

As of this writing the expenses involved in writing the final report and other minor expenses for closing the project have been only partially tabulated.

As obvious from the table of expenditures, the cost sharing part far outweighs the amount received in the grant. The amount contributed by friends of Mrs. Kimura in time and material goods, if ever tabulated, will raise the cost sharing portion to twice that of grant amount. The amount of cost sharing is being looked upon by those concerned as initial investment in starting a new enterprise in Puna.

7. CONCLUDING REMARKS

The technology transfer of geothermal cloth dyeing as a cottage industry has been shown to be readily feasible by this experiment. The techniques involved are relatively simple to be replicated in Hawaii. The intangible factors, such as imagination to create novel designs for a discriminating market and initiative to mount aggressive advertising campaigns to nurture a sustained market, will have to be left to private capital entrepreneurs who wish to transform geothermal dyeing into a viable commercial enterprise.

REFERENCE

Krohn, Val F. Hawaii Dye Plants and Dye Recipes. University of Hawaii Press, Honolulu, Hawaii, 135 pp. 1980.

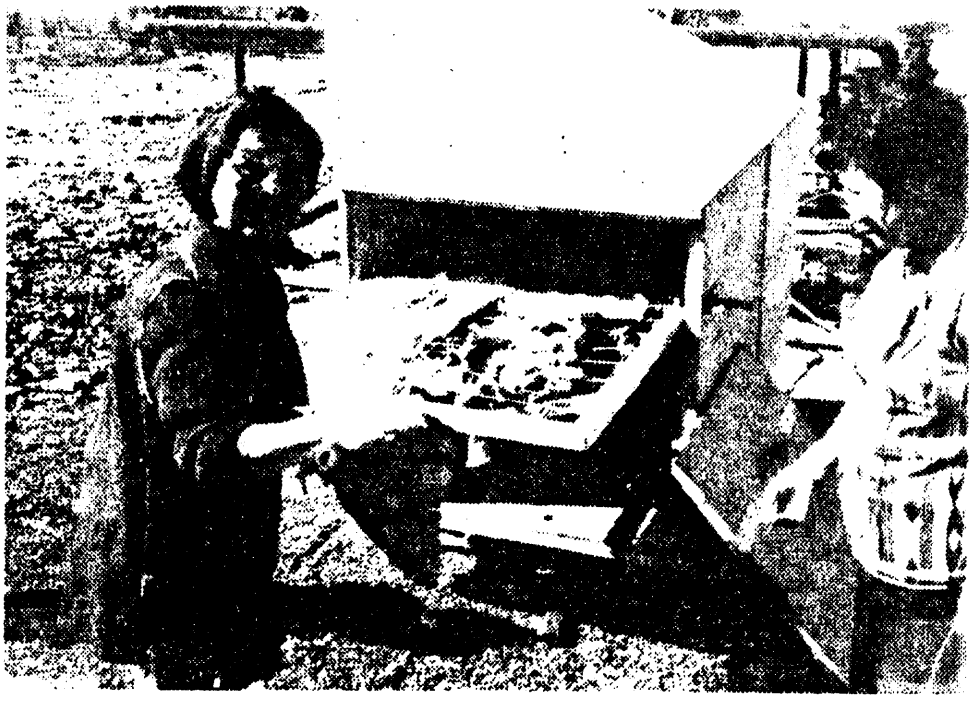


Plate 1. Mrs. Kimura (left) with some of her products.

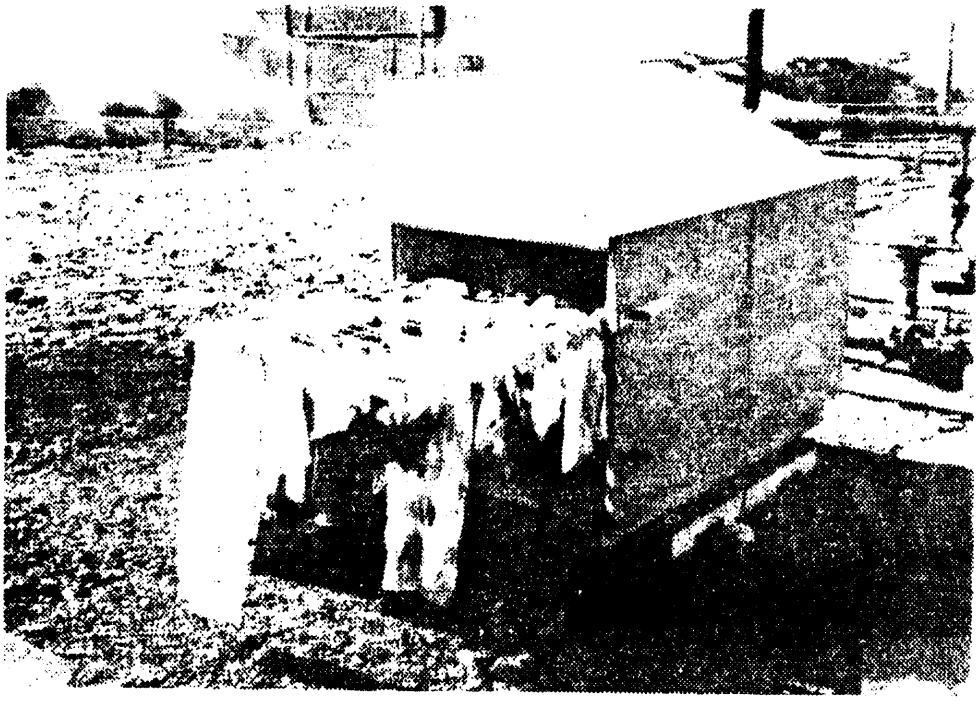


Plate 2. The steam vat used in dyeing.

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