DEPARTMENT OF ENERGY

DIVISION OF GEOTHERMAL ENERGY

Contract No. ET-78-S-06-1102

FINAL REPORT

15 June 1978 through 30 June 1979

EXPANSION OF THE GEO-HEAT QUARTERLY BULLETIN

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Oregon Institute of Technology
Klamath Falls, OR 97601

DISCLAIMER

DISCLAIMER

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OBJECTIVE OF THE PROJECT

The purpose of the Geo-Heat Utilization Center is to disseminate information on the direct use of geothermal energy.

This objective is accomplished by:

1. Publishing a quarterly bulletin which contains the technical and economical aspects of direct geothermal utilization from both national and international sources.
2. Sending information packets to persons requesting materials on specific applications for space conditioning and low-temperature process use.
3. Conducting tours of geothermal use sites in the Klamath area.
4. Presenting talks (papers) on the direct use of geothermal energy.

The Center also conducts applied research in the areas of resource planning, systems engineering and economic feasibility for space and process heating. In addition demonstration projects located on campus are aquaculture (breeding and rearing of giant prawns) and geothermally heated greenhouse.

PROJECT SUMMARY

The Geo-Heat Utilization Center was activated in April 1975 at Oregon Institute of Technology (OIT) as an interdisciplinary, interdepartmental agency, with the Center director reporting to the president through the assistant to the president, who has been assigned coordinator of the Center. The Center was originally organized to continue the exchange of information begun with the International Conference on Geothermal Energy for Industrial, Agricultural and Commercial/ Residential Uses, held at OIT October 1974. Since that time the public's interest and response to the Center's services have increased dramatically.

The Center provides a central focus and coordination for projects involving: 1) public information dissemination service on direct heat applications of geothermal energy, 2) Technical Assistance to developers, 3) Regional Resource Planning, and 4) Applied Research Projects. A brief description of these projects follows:

1) Information Dissemination Service - A Quarterly Bulletin reports on the progress and development of the direct utilization of geothermal resources. The Bulletin is mailed at no charge to subscribers in 50 states and 30 foreign countries. The Center also provides field trips of geothermal sites in Klamath Falls, personnel for speaking engagements, and other outreach activities.

2) Technical Assistance - Under the technical assistance program up to 100 man hours of consultation can be provided, at no cost, to private, public, or corporate entities intending the direct utilization of geothermal energy. Application areas include but are not limited to, space heating and cooling, district heating, aquaculture, food production and processing, drying, chemical and pharmaceutical processes, animal husbandry, etc. Assistance will be given primarily for projects in the Pacific Region states of Alaska, Washington, Oregon, California, Nevada, Arizona, and Hawaii.

Consultation may be in the form of limited resource evaluation, engineering feasibility and economic studies, materials selection and corrosion problems, conceptual design, consultation with private engineering or consulting geologists, etc.

The program is intended to provide assistance to persons with little or no experience in the geothermal field in order to promote the rapid development of geothermal resources. The program is not intended to compete with consulting engineers and geologists and Geo-Heat personnel will not provide detailed plans, specifications or services when qualified private consulting is available.

Requests for assistance are prioritized based on proposed implementation dates. Existing fossil fuel users considering conversion to geothermal energy are provided early assistance.

3) Regional Resource Planning - The objective of this program has been to develop realistic scenarios for the development and commercial utilization of geothermal energy resources in the states of Alaska, Idaho, Montana, Oregon, Washington and Wyoming. To facilitate data collection, as well as input from each state's appropriate agencies, our organizational structure has included a geothermal specialist working out of the energy office of each state. This arrangement has proved exceedingly useful, providing on-site access of data for the project and a visible access point in each state for transferring information back to interested parties, both in the public and private sectors.

4) Applied Research - Demonstration projects on the Oregon Institute of Technology campus include the raising of giant fresh water prawns in geothermal waters, an OIT/OSU experimental greenhouse project and a program to monitor the effects of using geothermal fluid in the campus heating system. In addition studies have been completed on the hydrology and geochemistry of the Klamath Falls urban area, district heating for the City of Klamath Falls, extraction of heat from wells by means of downhole heat exchangers, and the application of geothermal energy to agribusiness industries in the Klamath and Western Snake River Basins.

The Center staff consists of four full time personnel located on campus and three staff members located in energy offices of the states of Alaska, Washington, and Oregon. In addition, seven faculty (scientists and engineers) are devoting from 25 to 50 percent of their time to various projects. Two full time secretaries are employed by the Center.

TASKS ACCOMPLISHED

The work accomplished according to the task statement is as follows:

Task 1: Geo-Heat Quarterly Bulletin.

The Bulletin reports the progress and development of direct heat applications covering projects throughout the U. S. Articles on Regional Resource Planning (Operations Research) have been included for three regions of the U. S. The Bulletin is mailed at no charge to 3,500 subscribers in 50 states and 30 foreign countries. Appendix A contains Bulletins published during the period of this contract.

Task 2: Information Packets.

Requests for information packets were mailed to 291 individuals in 29 states and 4 foreign countries. An information packet usually includes:

.Bulletins - back issues

.Publications -
Lienau, P. J. and Lund, J. W., Ed.
"Multipurpose Use of Geothermal Energy" proceedings of the International Conference on Geothermal Energy for Industrial, Agricultural, and Commercial-Residential Uses, Oregon Institute of Technology, Klamath Falls, Or, 1974.

Geothermal Resources Council
"Direct Utilization of Geothermal Energy: A Symposium"
San Diego, CA, 1978.

Culver, G. G.,
"Optimization of Geothermal Home Heating Systems",
Oregon Institute of Technology, Klamath Falls, OR, 1976.

.Papers - Potential utilization, food processing, downhole heat exchangers, space heating and economics.

Information packets were mailed to individuals in the following states:

Alabama	1
Alaska	9
Arizona	3
California	73
Colorado	12
Connecticut	3
Florida	3
Hawaii	2
Idaho	21
Illinois	2
Kentucky	1
Louisiana	1
Maryland	1
Minnesota	1
Missouri	3
Nevada	16
New Hampshire	2
New Mexico	5
New York	11
Ohio	2
Oregon	74
Pennsylvania	4
South Dakota	1
Tennessee	2
Texas	6
Utah	2
Virginia	1
Washington	8
Washington DC	12
Denmark	2
India	1
Kenya	1
Nigeria	1

Task 3: Tours.

There were 62 tours conducted of Klamath geothermal sites. A tour usually includes OIT, Merle West Medical Center, residence, school, creamery, commercial building, and an industrial plant. The listing below is for April 1979 through July 1979.

10 April	Aquaculture Henley 5th grade Klamath Falls, OR
20 April	Aquaculture Sacred Heart School Klamath Falls, OR
2 May	F. Hammer Sorensen B & S Rorteknik Denmark Jens Peder Jensen Indus. Attache, Vice Council New York, N.Y.
10 May	Aquaculture Henley 5th Grade Klamath Falls, OR
11 May	Society of American Foresters (32 Northwest
16 May	Japan Geothermal Energy Development Center (36)
	Ralph Carlson Brown & Caldwell Eugene, OR
21 June	Theron Blackeslee Verdant Vales School Middletown, CA
22 June	Jim Scherrer University of Pennsylvania Philadelphia, PA

5 July	Garretts Bend, OR	27 July	Geologic Society of Oregon (40) Oregon
27 July	Postmasters (45) Northwest		

Task 4: Speaking Engagements.

Center personnel have presented 15 papers on geothermal direct heat applications to conferences and groups.

The following papers were presented during the reporting period April 1979 to July 1979:

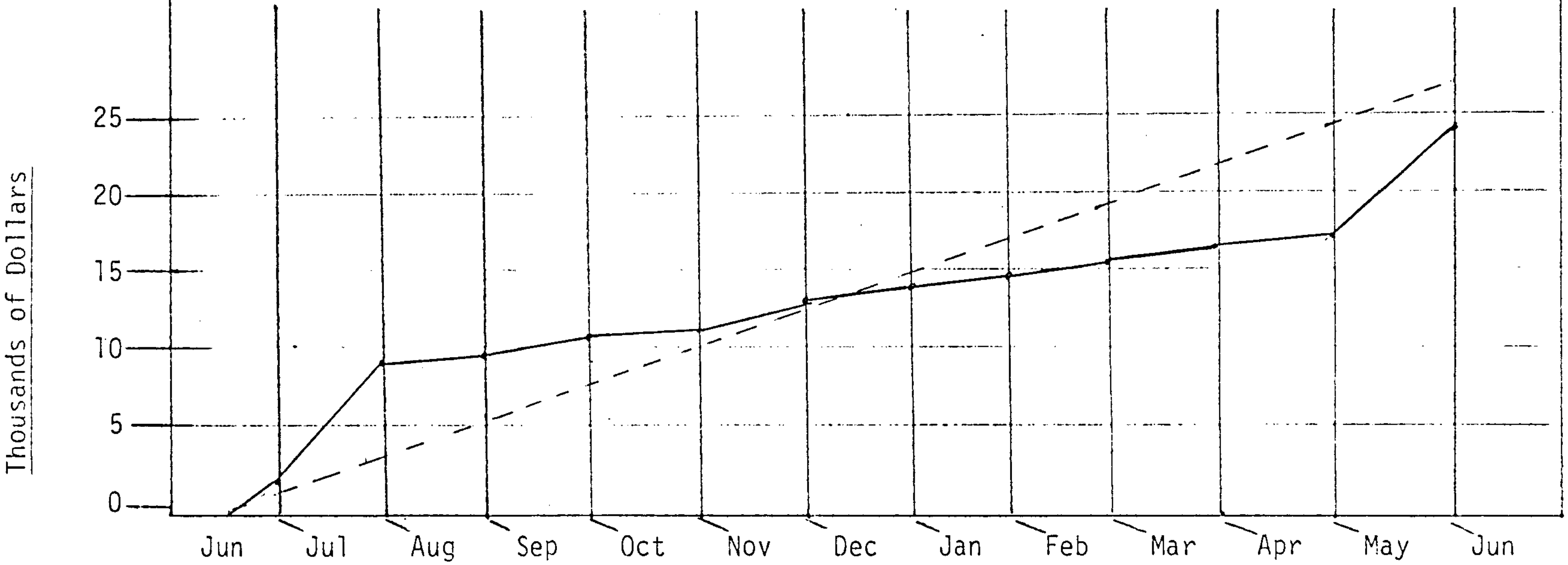
5 April	John Lund "World Wide Uses of Geothermal Energy" A Symposium of Geothermal Energy and its Direct Uses in the Eastern United States, Roanoke, VA.
16 April	John Lund "Uses and Potential of Geothermal Energy in Oregon" Earth Week, Corvallis, OR
8 May	John Lund "Overview of Nonelectric Uses of Geothermal Energy" Geothermal Resources Council Short Course, San Francisco, CA.
9 July	John Lund "Overview of Geothermal Energy" GASOHOL Symposium Klamath Falls, OR
17 July	Gene Culver "Space and Process Heating with Geothermal Energy" National Association of Industrial & Office Parks Seattle, WA.

PROJECT COSTS

The cost summary report for the project for the period 15 June 1978 to 30 June 1979 is shown on the following page.

COST SUMMARY REPORT

Organization	Contract Number	Reporting Period
Geo-Heat Utilization Center Oregon Institute of Technology	ET-78-S-06-1102	15 June 1978 to 30 June 1979



Incremental	Forecast		2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
	Actual		2,723	5,899	386	1,412	1,340	1,997	462	521	1,398	536	1,279	5,533
Cumulative	Forecast		2,160	4,320	6,480	8,640	10,800	12,960	15,120	17,280	19,440	21,600	23,760	25,921
	Actual		2,723	8,622	9,008	10,420	11,760	13,757	14,219	14,740	16,138	16,674	17,953	23,486

LEGEND Forecast-----
Actual_____

APPENDIX A

Geo-Heat Utilization Center

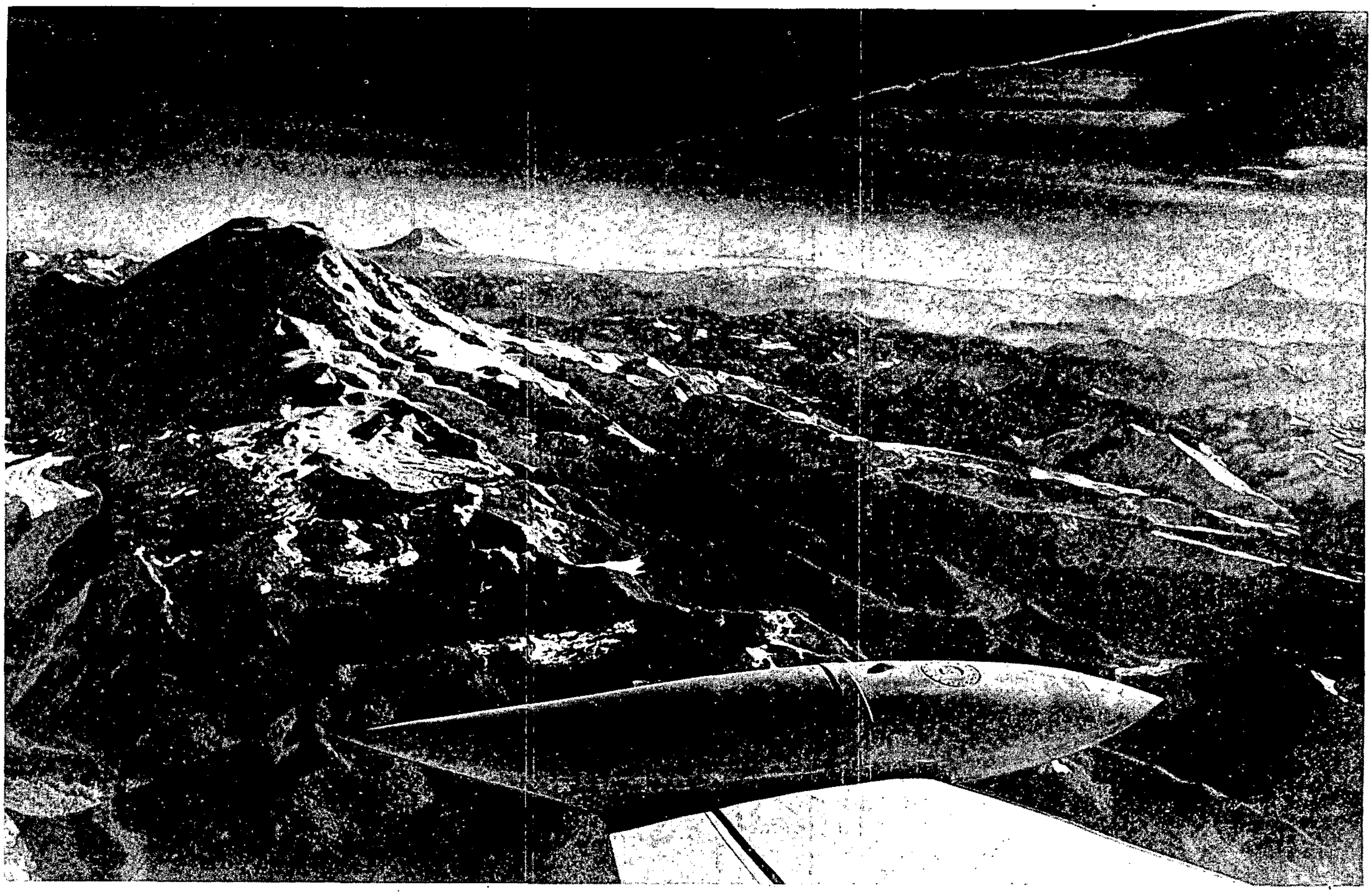
Quarterly Bulletin

GEO-HEAT UTILIZATION CENTER

Quarterly Bulletin

OREGON INSTITUTE OF TECHNOLOGY – KLAMATH FALLS, OREGON 97601

Vol. 4, No. 3 Supported by the U. S. Department of Energy June, 1979



Strato Volcanoes Rainier, Adams, Hood, and St. Helens indicate geothermal potential in Washington and Oregon Cascades.

GEOTHERMAL ENERGY IN WASHINGTON

by
R. G. Bloomquist

Among the most critical of problems facing our nation is energy resources. Though there may be minor disagreement about the specifics, magnitude, and solutions to these problems, there can be no question about their urgency and of the necessity for immediate action. In an effort to in part resolve these energy shortages by accelerating utilization of one of our renewable resources, the U. S. Department of Energy has developed a program of National and Regional Planning and Operations Research of geothermal energy resources.

The OIT Geo-Heat Utilization Center, under contract to USDOE, has been evaluating the geothermal energy resource development potential of the six northwest states of Alaska, Idaho, Montana, Oregon, Washington, and Wyoming. Our goal has been to summarize for this region, on a site-specific basis, the various factors affecting development including resource data, base, geological description, reservoir *characteristics, environmental character, lease and development status, institutional factors, economics, population and market, and finally, to estimate the site potential for development. These reports summarize the known geothermal data base for each state, and in this sense should be exceedingly useful for planners, policy and decision-makers formulating programs to develop this resource, as well as for the developers who will ultimately do the job.*

The continuation of this project now underway is attempting to complete this core of site information and identify data on new significant sites, provide accurate information and recommendations to policy and decision-makers, and ultimately to assist in evolving more effective regional and national geothermal energy programs.

Future articles will appear in the bulletin dealing with the geothermal development potential of the other northwestern states.

- Editor's Note -

Geothermal Development in Washington

Factors which have affected and will continue to affect geothermal development of potential sites in the state of Washington have been identified. Eight potential sites were chosen for detailed analysis by the author in consultation with the Washington Energy Office and the Washington Division of Geology and Earth Resources. The eight sites include: Indian Heaven KGRA (Known Geothermal Resource Area), Mount St. Helens KGRA, Kennedy Hot Springs KGRA, Mount Adams PGRA (Potential Geothermal Resource Area), Mount Rainier PGRA, Mount Baker PGRA, Olympic-Sol Duc Hot Springs, and Yakima.

Interest in geothermal energy in Washington began in the early 1970s and reached a high point in 1971 with the First Northwest Conference on Geothermal Power which was held in Olympia and chaired by Bert Cole, Commissioner of Public Lands for the State of Washington. The conference was attended by delegates from throughout the Pacific Northwest and by several delegates from other areas of the United States.

This initial surge of interest was followed by considerable interest by industry, and a total of 238 lease applications were filed with BLM. Overlapping lease applications in the Indian Heaven and Mount St. Helens areas resulted in portions of these areas being classified as KGRA's by the U. S. Geological Survey. In addition to the Indian Heaven and Mount St. Helens areas so classified, Mount St. Helens and Kennedy Hot Springs were designated as KGRA's on the basis of geological evidence. Much of the Cascade Range "Geological" Province was designated as a PGRA by the survey (Figure 1). Two areas in Okanogan County also received PGRA status because of the presence of recent volcanics.

Since the initial filing of lease applications for some 491,728 acres, little interest has been shown in the state by private industry and many of the lease applications have been withdrawn. Amax Exploration, Inc., is the only company known to have done exploratory heat-flow drilling in the state. Burlington Northern has maintained a low-profile program to assess the geothermal potential of company-owned properties in Washington.

The Washington Division of Geology and Earth Resources has continued to assess the geothermal potential of the state since 1972. As part of this assessment work, the division has attempted to sample all of the known thermal and mineral springs in the state and to do detailed geochemical analyses of the sampled waters.

These geochemical data have been used to estimate reservoir temperatures for each spring system sampled. Many of the assumptions made as to the geothermal potential at any of the areas covered in detail by this report have been made on the basis of these geochemical data.

In 1975, the Division of Geology and Earth Resources was engaged in the drilling of seven heat-flow holes in the Indian Heaven area of the southern Cascades and results of this study comprise the most detailed information available concerning heat flow in the state and especia[illegible] in the Cascade Range. In addition, the Divis[illegible] has supported and/or cooperated in the following: (1) measuring thermal gradients and heat flows in mineral exploration drill holes and water well;

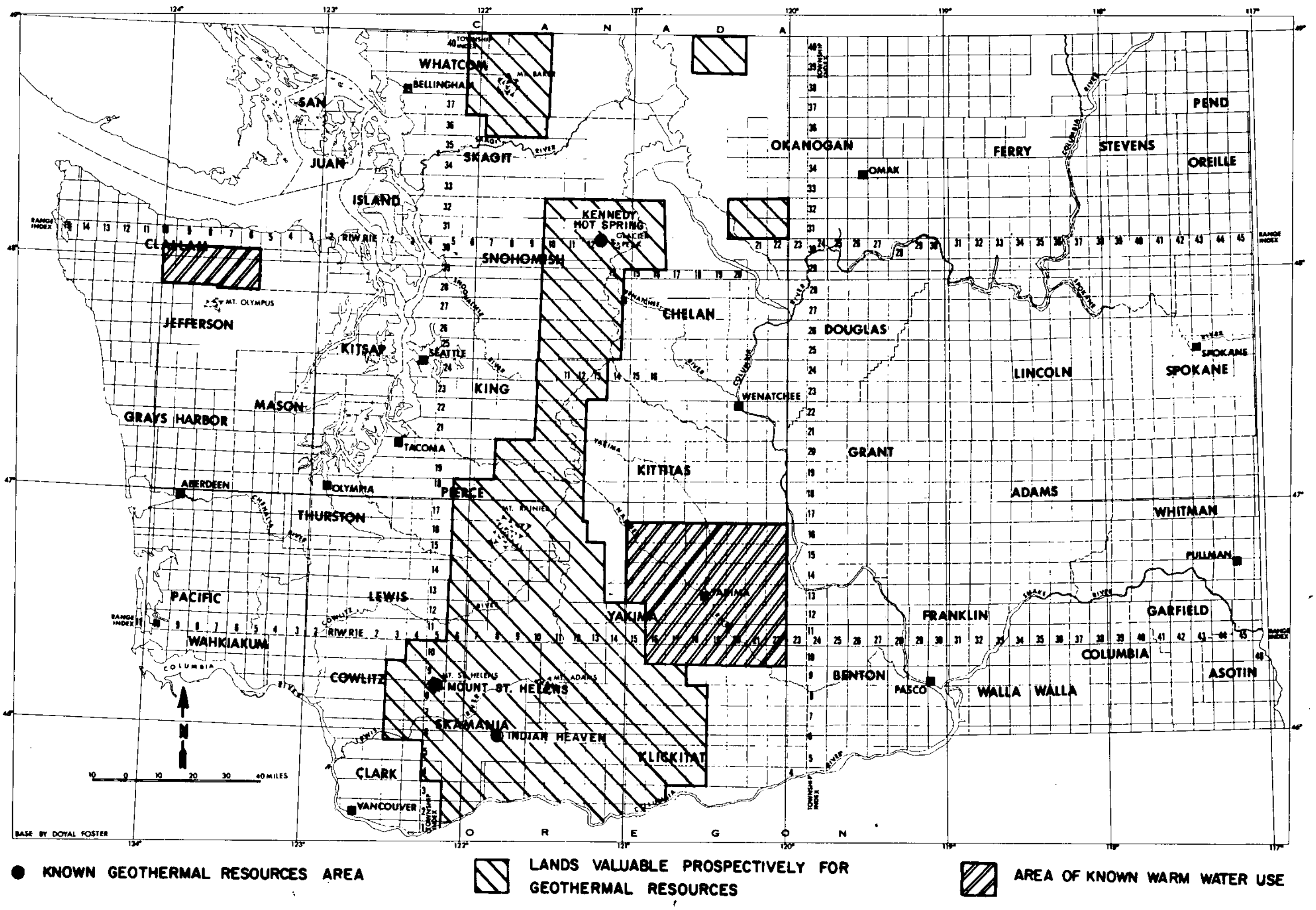


Figure 1. Geothermal Land Classification Map of Washington State

(2) compiling existing geologic mapping and conducting detailed reconnaissance geologic mapping in the southern Cascades; (3) assessing the use of ground noise measurements as a geothermal exploration tool; (4) publishing reports on the locations of earthquake hypocenters; (5) producing an aeromagnetic map of a large part of the southern Cascades; (6) publishing a gravity map of the state; and (7) sponsoring a project designed to measure gravity in the Indian Heaven areas.

In f.y. 1978 the Division of Geology and Earth Resources in cooperation with Battelle [illegible] attempted to accelerate the assessment of the state's geothermal resources with a special emphasis on the Cascade Range. Unfortunately, due to lengthy contract negotiations and the late arrival of funds, the effort was confined to the resampling of known thermal and mineral springs, obtaining information on existing wells, and reviewing the literature.

Plans for f.y. 1979 include the development of the Cascade Range Geothermal Assessment Program involving the U. S. Geological Survey and the Washington Division of Geology and Earth Resources. A portion of the funding for this program will be provided by the U. S. Department of Energy, Division of Geothermal Energy.

The Division of Geology and Earth Resources intends to continue the geochemical assessment of the thermal and mineral springs in the state, while emphasizing those springs in the Cascades. A great aid in this work will be the acquisition of laboratory facilities and equipment for geochemical analysis. The division will also become increasingly involved in geological and geophysical assessment of Mount St. Helens as a portion of the first year of the program which is expected to continue for the next 3 to 5 years.

Lack of industry commitment to geothermal in the state and lack of industry sponsored assessment work can be attributed to the absence of highly promising surface manifestations close to potential service areas, the lack of access to potential geothermal resources underlying national forest lands through failure of the Forest Service to open the lands for leasing, and the location of several of the promising geothermal prospects in the national parks or wilderness areas.

Of the known thermal and mineral springs in the state only six spring systems exhibit Na-K-Ca temperatures of over 100°C (212°F). The seven spring systems include Mount Baker Hot Springs, Sulphur Hot Springs, Kennedy Hot Springs, Garland Mineral Springs, Ohanapecosh Hot Springs, Gamma Hot Springs, and Summit Creek Mineral Springs (Soda Springs). None of these spring systems exhibits a significant flow. These seven springs do, however, have a definite spatial relationship to the stratovolcanoes (Schuster *et al,* 1978).

As can be clearly seen from Figure 2, major population centers are all at considerable distances from the known surface manifestations in the state, and this is especially true of the seven spring systems listed above.

Of all factors affecting the assessment and development of geothermal resources in Washington, the most serious has been lack of access

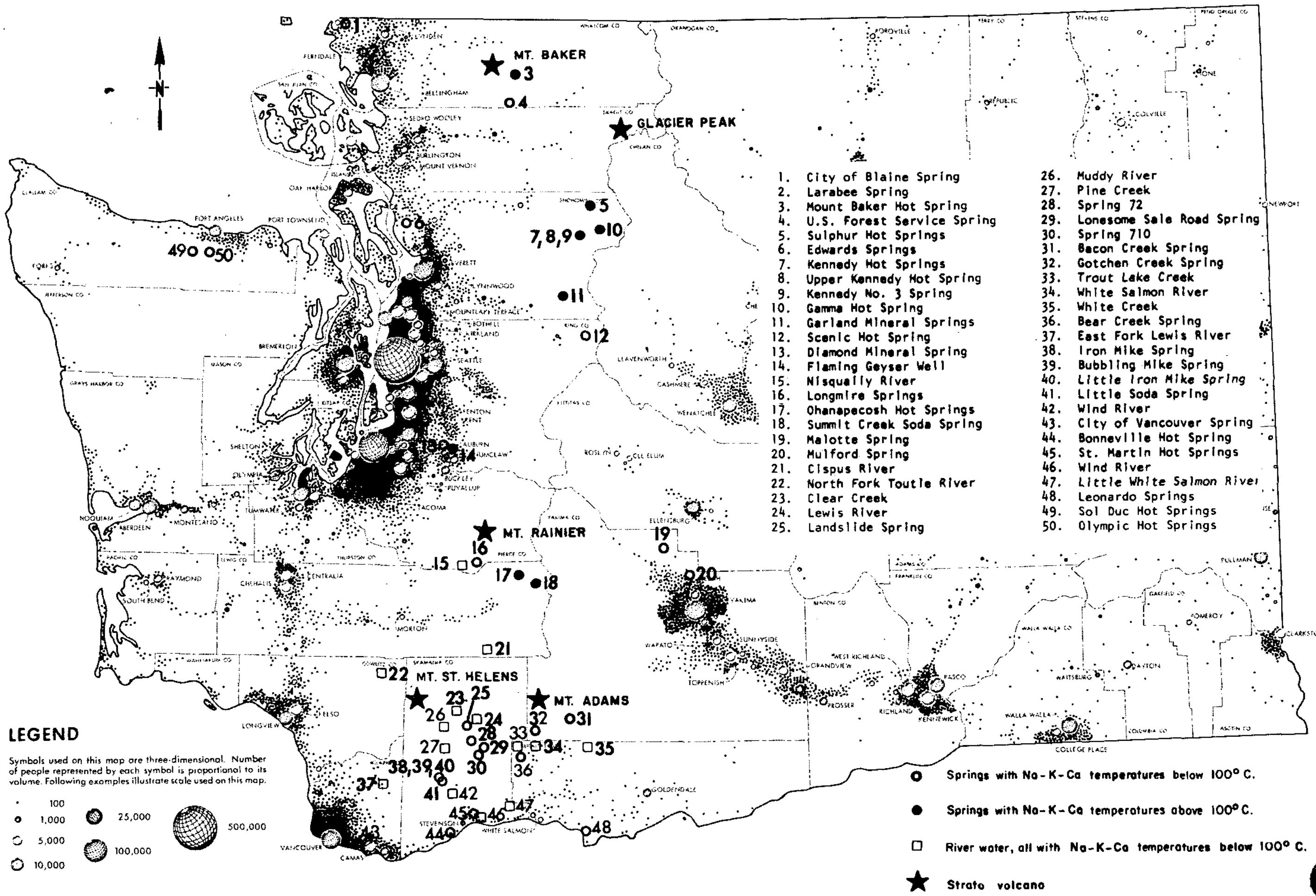


Figure 2. Location of Chemically Analyzed Springs and Rivers in Relation to (1968) Population Distribution in Washington

to federal lands. Lands classified by the U. S. Geological Survey as valuable prospectively for geothermal resources are almost exclusively Forest Service administered lands. As of January 1, 1978, 238 lease applications had been filed on Forest Service lands in Washington. Of this total, 92 were withdrawn primarily because of the failure to grant the leases within a reasonable period. One hundred and forty-five are still awaiting action. In addition, no lease sales have been held on lands in the three KGRA's in the state. The first lease sale is tentatively scheduled for March 13, 1979, and will be for lands in the Indian Heaven KGRA. A date for lease sales in the Mount St. Helens KGRA has not, as of this time, been set. The Kennedy Hot Spring KGRA is within the boundaries of the Glacier Peak Wilderness Area and therefore not open to leasing.

The issuing of leases awaits the completion and acceptance by the Forest Service of environmental statements concerning the potential impacts of geothermal exploration and development upon the lands for which lease applications exist. The first environmental statement in regard to geothermal was released in draft form by the Forest Service for public review and comment in January, 1978 (Wheeler, 1978).

The EAR (Environmental Analysis Report) covered 334,448 acres in the Gifford Pinchot National Forest. The EAR was rewritten and released for review and comments in October, 1978. Final acceptance is expected in early 1979.

Thus, the issuing of both competitive and noncompetitive leases should begin during 1979 or, at the latest, 1980.

The granting of leases should serve as a catalyst in generating renewed interest in the geothermal potential of the state by industry. A renewed interest and commitment in the state by industry in conjunction with the accelerated assessment program conducted by the U. S. Geological Survey and the Washington Division of Geology and Earth Resources is expected to result in the orderly and timely assessment and development of the state's geothermal resources, but remains dependent upon the receipt of adequate funding by the state and federal agencies involved.

References

1. Schuster, J. E. *et al.*, 1978, Heat Flow Studies in the Steamboat Mountain—Lemei Rock Area, Skamia County, Washington: Washington Division of Ceology and Earth Resources Information Circular 62, page 56.

2. Wheeler, B., 1978, Geothermal Leasing and Development, Giffor Pinchot National Forest Draft Environmental Analysis Report: U. S. Forest Service Gifford Pinchot National Forest, page 401.

The Geo-Heat Utilization Center Bulletin
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Editor, Paul J. Lienau

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CALISTOGA, CALIFORNIA
- HISTORICAL SPA COMMUNITY -

by
John W. Lund

Located approximately 75 miles from San Francisco, the delightful community of Calistoga is situated at the northern end of famous Napa Valley. This is the heart of the wine country and of numerous geothermal phenomena. The Geysers Geothermal Field is located just to the northwest where over 600 MW of electrical power is presently being generated from a "dry steam" geothermal resource. Calistoga is located on the southern extension of this famous field, where geothermal hot water around 200°F exists at shallow depths.

Geologically, the area consists of a northwest-southeasterly trending anticlinorium (a large upwarp) which forms the central core of the Coast Ranges. Numerous faults also parallel this trend, locally called the Mayacmas Mountains. Mount St. Helena, created by erosion of volcanic tuff-breccia, is located at the southern end of the range overlooking the Napa Valley and Calistoga. These folded pliocene sonoma volcanics lie uncomformably on rocks of the Franciscan Formation. The area is noted for numerous geysers, hot springs, and warm pools.

Early History

The area was originally settled by the Pomos and Mayacmas Indians. These early people, called Wappo by settlers, came from miles around to use the natural hot springs, fumaroles, and heated muds to soothe aches and pains. To them, this area was "the beautiful land" and the geothermal Spring Ground "the oven place." As with many geothermal areas of the west such as Klamath Falls and Calistoga, the Indians were the original geothermal users and appreciated this natural energy resource. They also used the local cinnabar for red war paint. Later on, this mercury ore would also be mined by white men.

In the early 1800s, the Spanish explorers visited the area looking for a possible Mission site. Naturally, they referred to the site as "Aqua Caliente." These missionaries did not establish a mission here, but it is believed that they planted the first grape vines to be used for sacramental wines, and the golden mustard which even today is found in the orchards and vineyards in early spring.

The person who had the greatest influence on the geothermal development of the community was Samuel Brannan. A Mormon and eastern Yankee, he was to become one of the first geothermal entrepreneurs. He first saw the geothermal springs and marsh in 1852. He envisioned a resort and spa similar to Saratoga Hot Springs of New York and the famous spas of Europe. The name Calistoga resulted from Brannan's combination of California and Saratoga. He also had the money to carry out his plan, having become prosperous through apparent misuse of funds from the Mormon church, from prospectors returning from the gold fields of Claifornia, real estate, and investments in Hawaii.

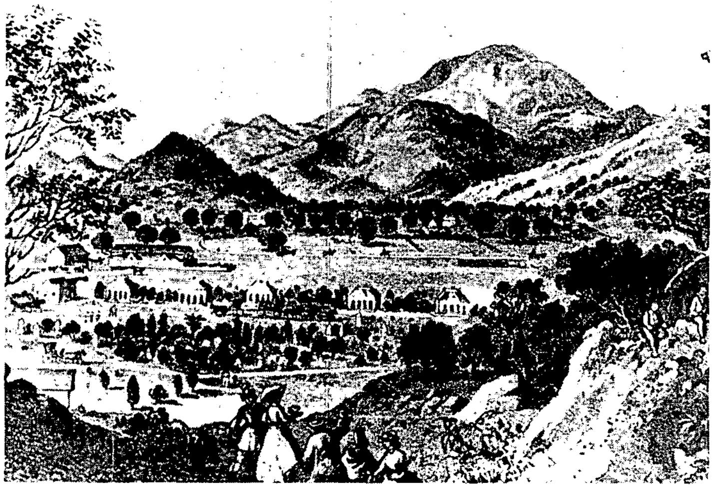

Figure 1. Spring Ground and Race Track (1865)

Sam Brannan poured an estimated half a million dollars into his "resort", first by purchasing about 2,000 acres of the Indian Hot Springs and then building the Hot Springs Hotel, which was opened in 1862. Twenty-five cottages occupied the grounds, one of which was later to be occupied by Robert Louis Stevenson. Only one of the original cottages exists on the grounds today, designated as a historical monument. Numerous miniature geysers and hot springs were located on the grounds, including at a later date, the "Chicken Broth Springs" with a sign reading "The Devil's Kitchen. Cook for Yourself." Patrons from the Bay Area traveled by ship to Suscol (now Vallejo) and then by carriage or stagecoach to Calistoga. By 1865, a railroad was constructed from Suscol to Napa, and after much controversy it was completed to Calistoga in 1868. In addition to promoting the railroad, Brannan also laid out a new town to attract customers to his resort. It is reported that this area was being considered as the location of a University by Leland Stanford and James Lick.

During the 1870s, over 1,000 people were guests at the Hot Springs in a single month. -ing this time the grounds consisted of over 2,000 acres, extending to the base of Mount St. Helena Included in this sprawling layout was a Japanese tea garden, a mulberry orchard, a brandy distillery, the hotel, bathhouses and five-room cabins connected by wide circular avenues and an elaborate park, a reform school, a skating pavilion, a race track and stables, and the railroad terminal.

The resort eventually ran into financial difficulties, mainly due to mismanagement of the funds by Brannan and competition by other resorts. In 1875, the property was sold, and has since gone through several owners. Around 1911, it was purchased by Jacques Pacheteau and today is called Pacheteau's Original Calistoga Hot Springs, Inc. Sam Brannan died in 1889, out of debt, but penniless. Today, a museum located in town has a three-dimensional diorama of Brannan's resort and the early town based on a photograph made around 1862.

Figure 2. Bathing Pavilion and Skating Rink, Spring Grounds

Another person who had significant influence in the area was the writer, Robert Louis Stevenson. In the summer of 1880, he and his recent bride moved to Calistoga for health reasons. Initially, the Stevensons lived in one of the cabins on the Hot Springs Hotel grounds. Here he could use the hot baths, the smaller chemical baths, or the large enclosed swimming pool. The cost of the cottage, meals, and mineral baths were an "economical" $10 dollars per week per person. Later on, to save expenses, the couple moved to a deserted mining camp (The Silverado Silver Mine) on the slopes of Mount St. Helena. It was during this time that he developed the story for the book, "The Silverado Squatters" and ideas for settings of "Treasure Island." In his writings he noted that the area around Mount St. Helena "is full of sulphur and boiling springs." He described Brannan simply as "the man who found the springs", for he never met Brannan as he was in Mexico at the time. Today his silverado residence is a State Park and a museum devoted to his life and works, and is run by the Vailima Foundation in the town of St. Helena.

Around the turn of the century, over 30 resorts existed in the surrounding area. Bath houses, mineral springs and resort hotels occupied each of these sites. These were devoted to health and relaxation, much as they are today. With the rise of city-oriented entertainment, by 1930, many of these resorts closed due to financial hardships. Fire and lack of maintenance finished others. Those that remained in operation catered mainly to older people, especially of recent European origin. This situation existed until approximately ten or fifteen years ago, as it did in similar resorts throughout the country.

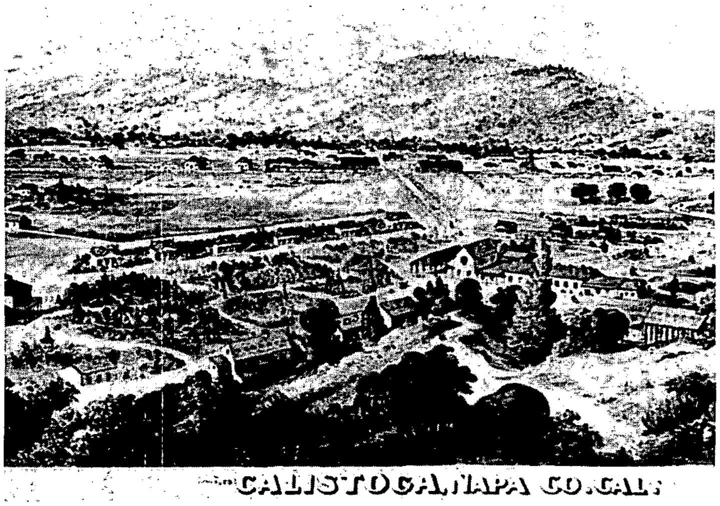

Figure 3. Calistoga As Stevenson Saw It (T. W. Morgan, 1871)

Today

Calistoga has become a "boom" town in recent years. In the past five years it has doubled its population to about 6,000 people, and during the summer its streets are crowded with visitors.

The revival of the spas has contributed to this growth.

Approximately six major spas and resorts are in operation. Most notable are Pacheteau's Hot Springs mentioned earlier, Calistoga Spa, Dr. Wilkinson's Hot Springs, Golden Haven Spa, Nance's Hot Springs and Roman Spa. All of these will provide many of the following services: mud bath, massage, steam bath, blanket wrap, mineral bath, hot mineral pool, and accommodations. Prices range from around $2.50 for the mineral pool to around $20 for the complete treatment. Rest and relaxation are the theme. A large public mineral water swimming pool also exists in town. All of these resorts have their geothermal water supplied from shallow wells around 200 feet deep with temperatures from 170° to 200°F. The water for the pools and baths is cooled to 80° to 105°F, with some resorts having several pools at different temperatures.

Figure 4. Mineral Bath

The mud bath is one of the most unusual geothermal treatments to undertake. To place your nude body in a large bathtub full of black mud is, to say the least, difficult. However, once immersed in the approximately 105°F mud for the recommended 10 to 15 minutes, the effort is well worth it. The mud bath, consisting of 50 percent local white volcanic ash and 50 percent peat moss and heated by geothermal water, is like a big warm blanket. It seems to remove all the tensions and worries of the day. After the mud bath, a relaxing whirlpool bath, blanket wrap, and mineral bath provides the ultimate in relaxation. Try it—you'll like it.

Figure 5. Author And Son Enjoying A Mud Bath

Figure 6. Mixing The Mud

The end of a long and stressful day can be spent soaking in one of the outdoor mineral pools, sipping your favorite Napa Valley wine or lo[illegible] mineral water, and enjoying the starlit sky. This is a favorite pastime of many Bay Area residents during the weekend.

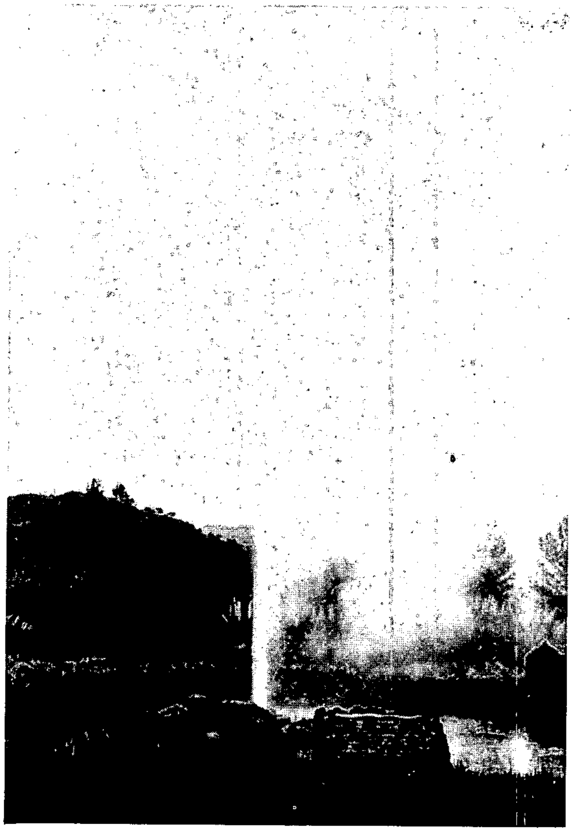

Figure 7. Old Faithful Geyser

In the shadows of Mount St. Helena on the north edge of town is the spectacular Old Faithful geyser of California. The water, 350°F hot, shoots approximately 60 feet into the air for a period of three or four minutes, then recedes. This performance is repeated every 40 minutes on the average. Howard and Olga Cream, owners of the property, tell us that this is one of only three "Old Faithful" geysers in the world. For a one-dollar admission, you can visit and photograph the eruption.

Calistoga has another unique industry, the bottling and sale of mineral water. Three plants distribute the mineralized underground water heated by volcanic processes. It is predicted that just as the wines of the Napa Valley have come to be recognized as the equal of the best French wines, so will the waters of the Napa Valley gain recognition in relation to their French counterpart. The companies presently producing the mineral water are Calistoga Water Company, Napa Valley Water, and Crystal Geyser Sparkling Mineral Water.

Figure 8. Mineral Water

The only application of this low-temperature geothermal resource that has not been developed to its fullest extent is space conditioning. There is some space heating in the spas, but this consists of very inefficient radiation from steel pipes running along the walls. The resource has potential for both space heating and cooling. In fact, the entire community could probably be provided with geothermal energy. With the energy "crunch", this may occur very soon.

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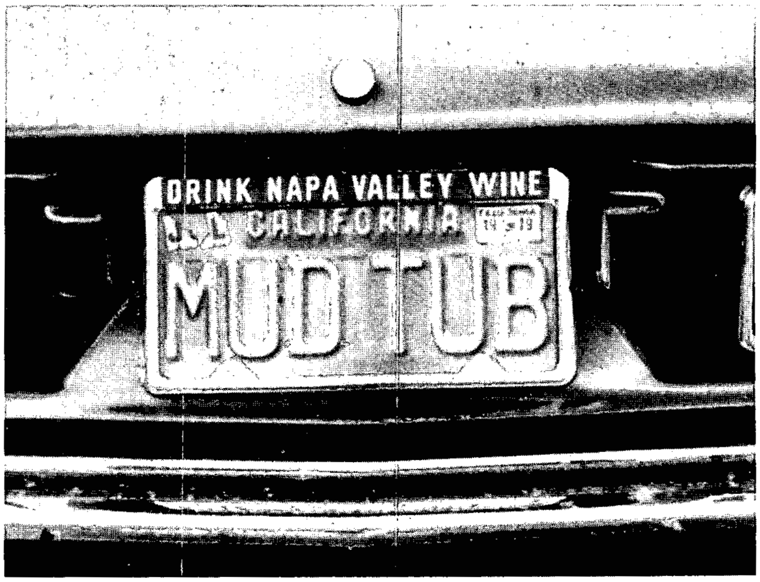


Figure 10. Wine and Geothermal
—A Good Combination—

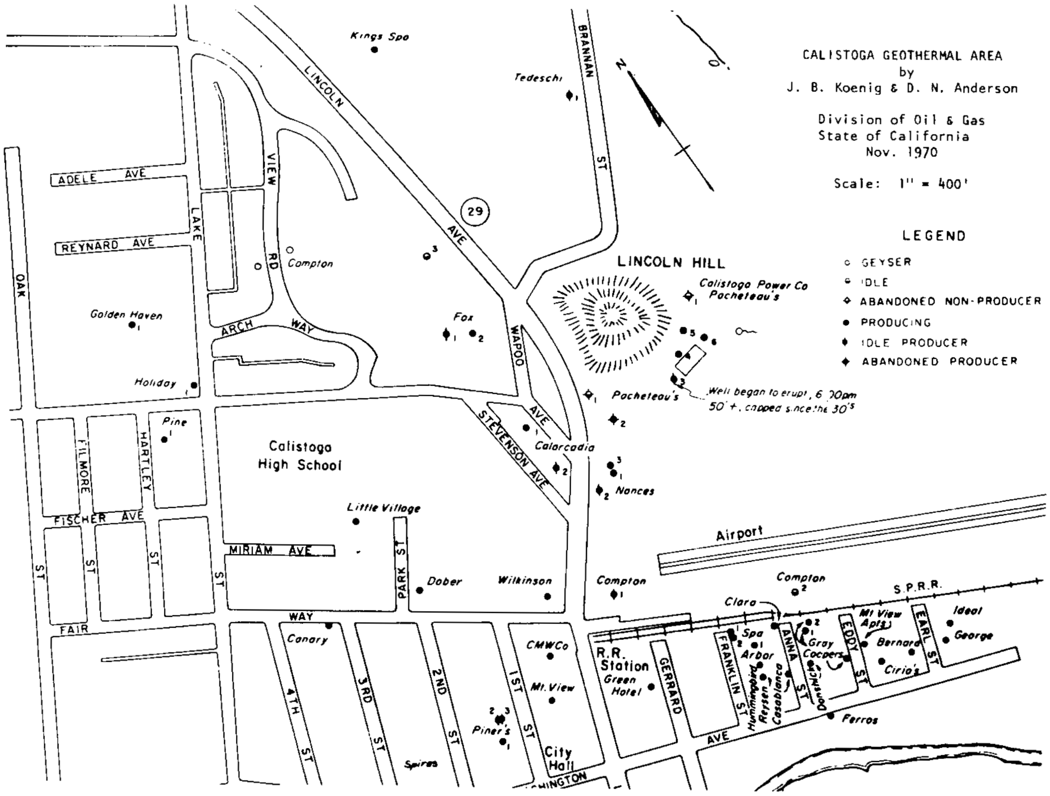


Figure 9. Geothermal Well Locations in Downtown Calistoga

MATERIALS PERFORMANCE STUDY OF THE OIT GEOTHERMAL HEATING SYSTEM

By Paul J. Lienau

A cooperative testing and analysis program of materials exposed to geothermal fluids in the Oregon Institute of Technology (OIT) geothermal heating system is being conducted by Radian Corporation, Pacific Northwest Laboratories (PNL) and the OIT Geo-Heat Utilization Center.

In addition, APV Company, Inc. has provided a plate heat exchanger for testing and Gordon and Associates, Inc., campus engineers for new construction, are cooperating in the project.

The purposes of this cooperative study are: (1) perform failure analysis on samples obtained from various components of the OIT heating system, and (2) understand geothermal fluid characteristics which affect performance in the OIT geothermal heating system and an experimental plate heat exchanger. The in-line corrosion testing station and plate heat exchanger are shown in Figures 1 and 2.

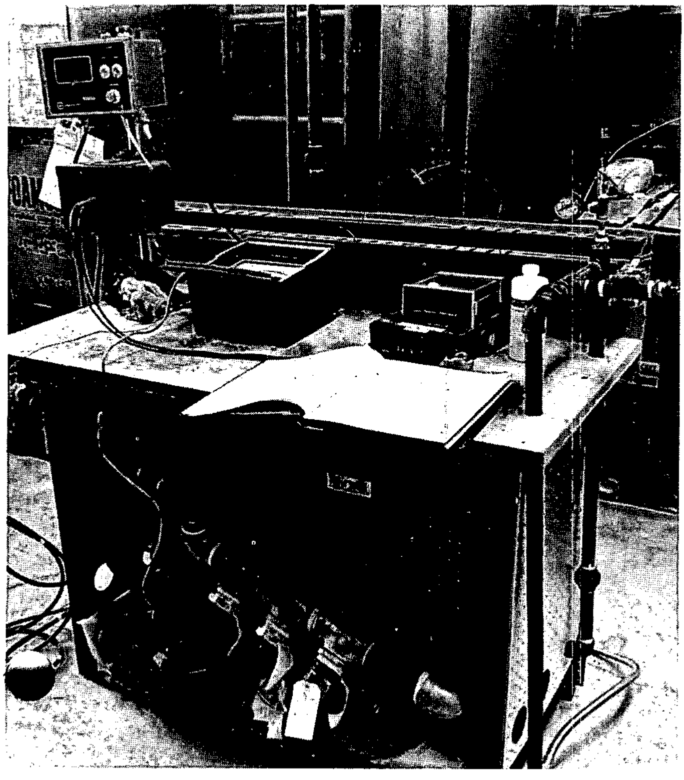


Figure 1. In-Line Corrosion Testing

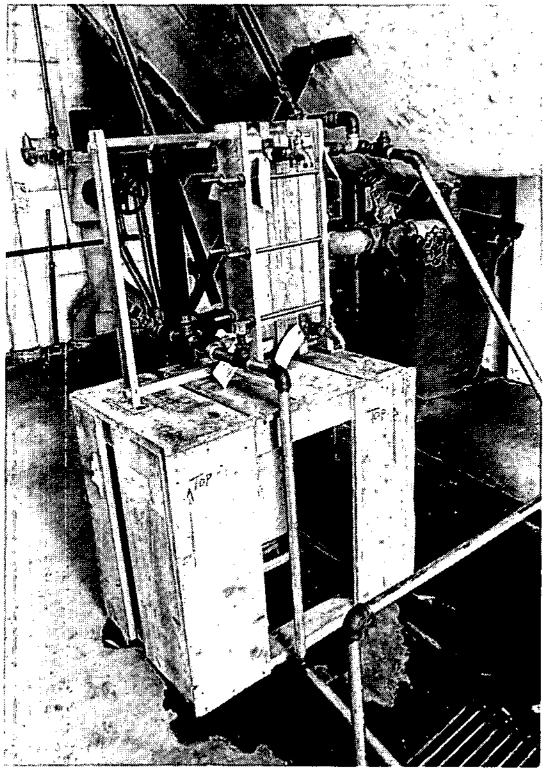


Figure 2. Experimental Plate Heat Exchanger

The campus of OIT was constructed in 1963 to take advantage of geothermal energy. The buildings and domestic water are heated by geothermal hot water (192°F) through a heat exchange system in each building. The building arrangement is shown on Figure 3.

Three wells of 1,288-, 1,716-. and 1,800-foot depths are equipped with variable speed drive deep well turbine pumps. Geothermal fluid is at 192°F and a maximum flow of 750 gpm at peak loads is pumped to a vented settling tank. It then flows by gravity to the ten buildings.

Various buildings use different schemes to make use of heat available from the geothermal fluid. For example, in the Residence Hall, individual rooms are heated by finned pipe convectors. Other buildings use more centralized systems with heated air ducted to the various rooms. In some cases, warm inside air is reheated using the geothermal fluid.

Spent geothermal fluid is disposed of by discharge to the campus storm drain system. The average temperature of the discharge fluid

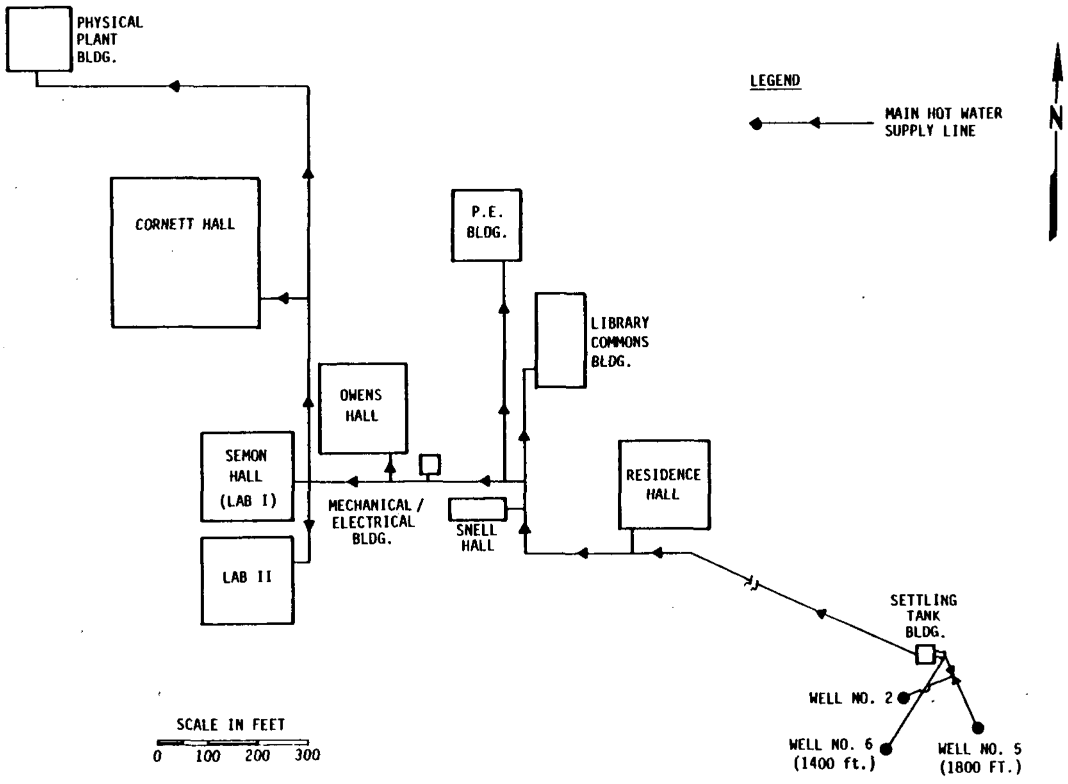


Figure 3. OIT Geothermal Heating System

is 120°F to 130°F. This system saves approximately 11,000 bbl of oil or $225,000 each year in fuel costs when compared to conventional heating systems.

The main distribution lines are direct buried insulated carbon steel and the heat exchangers primarily are made of copper and cast iron. Brass valves are used and copper piping is used extensively in the buildings. Component failures have occurred occasionally, however, the causes were not firmly established. A question has been raised about the suitability of copper for the application, since ammonia (1.3 mg/ℓ) and H_2S (1.5 mg/ℓ) are present in the water which is corrosive to copper and brass.

Failure Analysis

Radian Corporation has examined 17 samples (steel supply pipe, hot water coils, copper pipe and valves) obtained from various components of the OIT heating system. The samples obtained for this study were selected to represent several materials of construction and equipment ages of the various components in this system. Failures in these components have taken the form of leakage at solder joints, tubing perforation, scaling, or valve seizure. Most components evaluated have been in service for 14 years. The overall effort includes establishment of a geothermal failure data base and development of materials selection guideline for all types of geothermal systems.

Examination Procedure

Standard laboratory techniques were employed to evaluate the many components considered in this examination. Each sample was documented as part of a visual examination of that component. When deposits were found on the inside of a sample, analysis of that deposit was performed using X-ray diffraction (XRD) for compound identification. In all cases, c[illegible]per Ka radiation was used. Energy dispers[illegible] X-ray spectorscopy in conjunction with scanning electron microscopy was used to perform elemental analysis of deposits and materials of construction.

Metallographic examination was performed when necessary, using standard polishing and etching techniques. The methods described above were applied as appropriate to the samples considered in this examination.

Examination Results

Each material class will be discussed below with mention of the tests performed to obtain the results. The chemistry of the geothermal fluid (shown in Table I) must be considered in the evaluation of these tests.

TABLE I.
Chemistry of OIT Geothermal Fluid

Species	Concentration (ppm)
pH	8.5 - 8.7 (pH units; not ppm)
Total Dissolved Solids	79
$c1^-$	51
CO_3	15
SO_4^{-2}	330
HCO_3^-	20
NO_3^-	4.9
H_2S	1.5
NH_3^+	1.3
Ca	26
F	1.5
Fe	0.3
K	4.3
Si	48
F^-	1.5
Na	205
O_2	0 - 0.02

Resource Temperature - 192°F
Fluid tested at room temperature.

Ferrous Samples

Iron-based samples consist principally of steel supply piping and cast iron headers from copper heat exchangers. The steel piping extends from wellhead to each building and is generally insulated and buried. Steel pipe samples considered in this examination have suffered little external corrosion. The interior of the piping was found to have a deposit (SiO_2 and Fe_3O_4) build-up with a thickness of 1/16" to nearly 1/4". The rough internal surface of the pipe is due to the formation of corrosion tubercles. Beneath these tubercles the pipe wall thickness has been reduced by up to 1/3 of its original thickness.

Where system leaks have occurred, a heavy white deposit of sodium sulfate (Na_2SO_4) has formed on the external surfaces of the components. Cast iron headers found in larger heating coil samples evaluated in this study confirm the nature and degree of this attack. As most of the pipe is buried and therefore difficult to sample, it is not possible to assess the system-wide distribution of this corrosion.

Non-Ferrous Samples

Due to their accessibility, the majority of samples evaluated are made of copper or copper alloys. These components are joined by threaded joints or tin/lead soldered connections. Failures in the form of leaks have occurred at solder joints. The form of this attack is a dissolution of the solder by the fluid. The most severe attack in the samples examined was from the Cornett Building where a solder joint was adjacent to a noninsulated steel/copper joint. The galvanic couple may have accelerated the corrosion of the joint.

All copper-bearing components exposed to the geothermal fluid were found to be coated with a copper sulfide deposit. This black loosely adherent scale is the product of corrosion of the copper by H_2S gas. In addition, samples from Lab II Building and Cornett Hall were found to contain oxides of copper and other elements. Based on the few samples containing oxides, there is insufficient data to determine the oxygen source.

Metallographic examination of the copper samples revealed no degradation in the form of cracking. In the case of a plug valve, some corrosion at the attachment of the valve stem to the plug was observed. While no formal records have been maintained, multiple failures of this design have occurred. This attack is attributed to galvanic corrosion caused by the brass/stainless steel combination. Many of these valves have failed by separation of the valve plug from the stem.

Discussion

The primary cause of component failures is corrosion. Two concurrent mechanisms have led to the various leaks which have occurred at OIT. Copper and copper alloy components will suffer attack when exposed to H_2S. To alleviate this problem, it will be necessary to eliminate the H_2S and/or chlorides or not use these materials in contact with the geothermal fluid.

In a similar manner, oxygen is entering the geothermal heating system at the well, or the settling tank, or possibly other parts of the system. An incompatibility exists between the ferrous materials and the oxygen in the system. As long as oxygen exists within the system, corrosion can be expected to continue to occur.

Corrosion rates in the OIT system range from an average of about 1 to 4 mils per year. The components at OIT have lasted longer due to greater wall thickness, 50/50 tin/lead solder and a generally lower corrosion rate. At OIT, the highest corrosion rates occur in areas where copper and steel are closely coupled. This explains leaks at tube/manifold interfaces. The generally lower corrosion rate is attributed to two factors: (1) decreasing corrosion rate with respect to time, and (2) the species HS^- and Oxygen tend to counteract the corrosive effect of each other.

In the presence of oxygen, copper oxide can be formed. In this manner, the copper tubing may be protected by the oxide film. Any future modifications to the OIT system should be consistent with the effects of both H_2S and oxygen on both the copper and steel.

In all, the 14-year life of most of the components examined seems consistent with the materials of construction and fluid chemistry that exists. Significantly longer lifetime can be expected if alternate materials or process changes are studied, selected, then installed. In addition, a decision as to the acceptable level of allowable maintenance must be made. Such analyses, while beyond the scope of this report, clearly affect future materials selections.

Conclusions and Recommendations

1. The copper and copper alloy materials are not compatible with the H_2S (or equivalently, HS^-) in the geothermal fluid. Copper should be prevented from contacting sulfide bearing geothermal fluid.
2. The ferrous materials should not be allowed to contact oxygen-bearing geothermal fluid. The source of oxygen should be found and the oxygen eliminated to increase ferrous component life and minimize system deposits. Alternately, chemical treatment to remove the oxygen should be studied as a means to successful operation.
3. The settling tank should be modified to more effectively minimize silt and sand carry-over to the system piping. The oxygen intrusion (if any) due to this component should also be studied and corrected, if necessary.
4. An evaluation of solders in Klamath Falls geothermal fluid should be made. It is known that 1% silver solder has a very short life in similar fluid. Alternate compositions should be examined to determine the most suitable formula for use in these geothermal systems.

In-Line Corrosion and Scale Tests

PNL has designed and installed a portable in-line package to characterize the fluids and measure the effects of fluids on materials through the use of advanced electrical probe methods. Figure 4 is a schematic of the test loop and Figure 5 details a test section.

Probe outputs are studied as functions of flow velocity and oxygen content of the geothermal fluid. In-line probes offer unique advantages, since continuous output is available and, in general, much less time is required to take measurements. The continuous output offers the advantage of detecting transient conditions

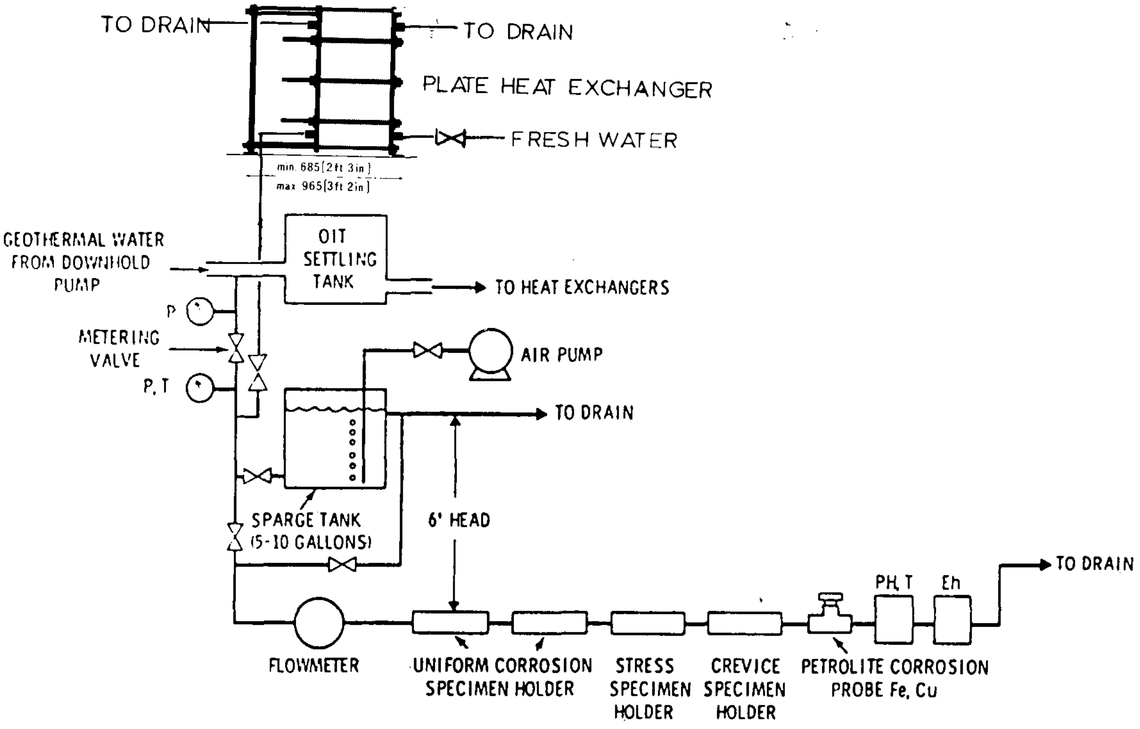


Figure 4. Schematic of Test Loop (not to scale, built of ½-inch pipe)

that would go unobserved by conventional methods.

The instrument probes which are being field tested include an in-line Eh probe (oxidation potential), pH probe, and corrosion probes which measure instantaneous corrosion rates using the linear polarization technique. Figure 5 is a diagram of the corrosion probe which shows the basic relationship between the three electrodes, an ammeter, a voltmeter, and an adjustable current source. To compensate for normal variations in the surface conditions of the Test and Reference electrodes, the meter is adjustable so that all readings can be measured from a preselected base position. Applying the current causes a small flow of electricity between the Test and Auxiliary electrodes. This current, depending on the direction of flow, either slightly cathodically protects or anodically accelerates the corrosion of the Test electrode. The change in corrosion rate caused by the polarizing current results in a change in potential of the Test electrode as measured against the nonpolarized, freely corroding Reference electrode. Current flow becomes directly proportional to the Corrosion rate of the Test electrode, while a constant voltage of 10 mV is maintained between the Test and the Reference electrode. The PNL probe differs from the commercial Petrolite probe in that the electrodes are heat exchanger tube samples. Thus, instantaneous corrosion rates can be obtained on specimens of the same material and flow geometry used in

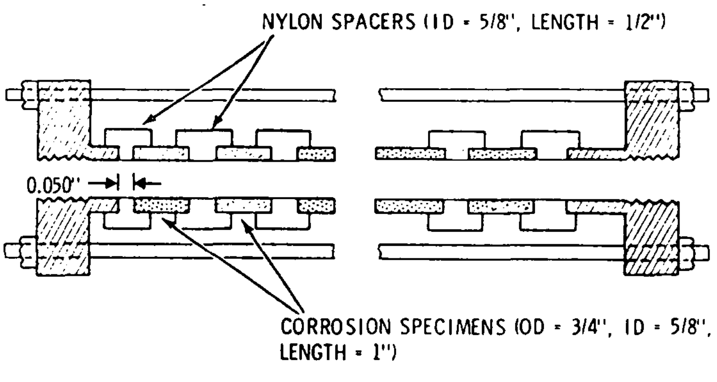
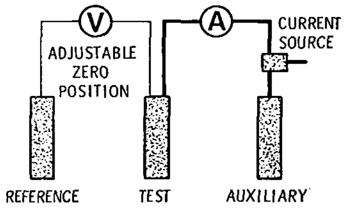


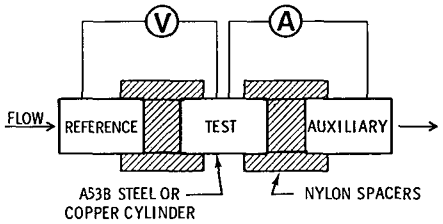
Figure 5. Cross-Section of Specimen Holder

the geothermal heating system. The diameter of the cylinders can be varied to match the conditions in the heating system heat exchangers. Two Petrolite probes, Cu and Fe, will also be tested along with the PNL designed corrosion probes, DHP copper and A53B steel. To verify the probe output for both the PNL and Petrolite probes, weight loss samples will be checked.

Weight loss corrosion specimens were furnished by Radian (for uniform corrosion studies, Figure 6) and are pipe sections 1-inch long (ID = 5/8"). Materials are DHP copper, A53B carbon steel, 316 stainless, titanium (Grade 2), DHP copper in contact with graphitized cast iron, and Admiralty brass (type 433 used in valves). In addition, specimens will be studied for stress cracking and crevice corrosion.



(A) COMMERCIAL PETROLITE PROBE SYSTEM



(B) PNL CORROSION PROBE SYSTEM

Figure 6. Comparison of Petrolite and PNL Corrosion Probes

The chemistry of the geothermal water will be monitored throughout the test series. The geothermal water will be analyzed at the beginning and completion of each test along with recording of electrical measurements of Eh, pH, and corrosion rate. If some tests are of long duration, such as four weeks, at midpoint throughout the test an additional water sample will be collected and analyzed for just the important corrosion controlling species such as oxygen, H_2S, NH_3, sulfate, silica, and dissolved CO_2.

A Model Junior Plate Heat Exchanger has been furnished by APV Company, Inc. Geothermal water (192° to 90°F) at 10 gpm flows through the product side and fresh water (60° to 162°F) flows through the service side. Ten plates each of T-316-SS, Titanium and T-316-SS are arranged in series with taps at each junction for chemical analysis.

One plate from each section will be removed three months after the test began for a nondestructive analysis by Radian Corporation. The test will continue for an additional three months on the remaining plates. Deposition and corrosion analysis will be performed on the plates. Results of the in-line test series and experimental plate heat exchanger will be reported in future bulletins.

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GEOTHERMAL SNOW MELTING AT SAPPORO, JAPAN*

by

Mamoru Sato[1] and Mitsuru Sekioka[2]

Since 1966, a snow-melting system for roads in Sapporo, Japan, has been in operation using water from the Jozankei Spa. As of December, 1978, the system covers 1,328 m

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[1] Minami Public Work Station, Sapporo City Office, Sapporo, Japan.

[2] Institute of Meterology, The Defense Academy, Yokosuka, Japan.

* See Vol. 1, No. 3 (Jan., 1976) and Vol. 1 No. 4 (April, 1976).

($10,400m^2$), and provides snow- and ice-free conditions. The initial construction of 240 m ($1,440m^2$) for the Mikaerizaka Hill was undertaken in December, 1966, and consisted of four 50- to 75-mm diameter pipes embedded 30-cm deep at 140-cm spacing. External corrosion, not caused by the internal geothermal fluid, required gradual replacement of the steel pipe with 25-mm diameter polybutene pipes after September, 1973. In February, 1976, the extension of the system by the Sapporo municipal authorities, changed the hot spring source from a private one belonging to several hotels, to a municipal one.

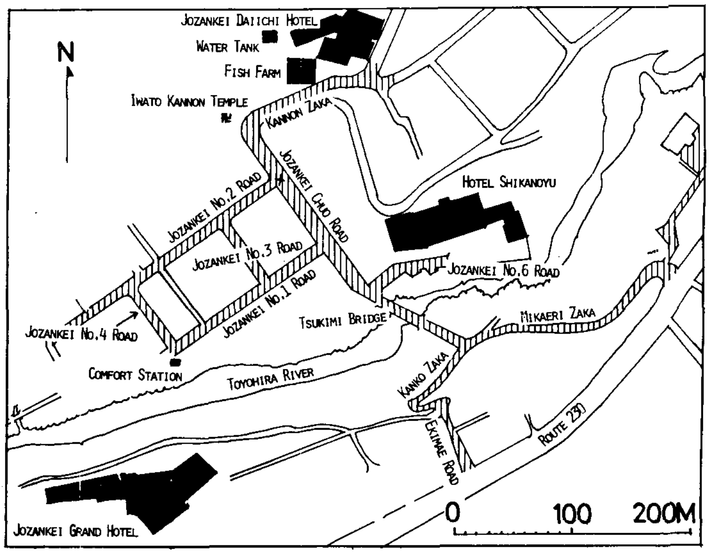

Figure 1. Sapporo Snow-Melting System

Hot spring water is circulated by three 10-hp pumps through three separate loops of polybutene pipe embedded approximately 8- to 12-cm deep at 30-cm spacings and then discharged to Toyohira River at 25°C. The hot water flow in the three loops is 180, 180, and 150 1/min at an inlet temperature of 76°, 83°, and 78°C respectively, resulting in a total heat supply of 1.65×10^6 Kcal/hr (6.91×10^9 J/hr or 1.92 MWt). Assuming lateral and downward heat loss of 20%, the effective heat supply to the road surface is 130 $Kcal/m^2$-hr (5.44×10^4 J/m^2 hr), which is in good correlation with the calculated load of 132 $Kcal/m^2$-hr required for a continuous snowfall of 1 cm/hr (ASHRAE).

No insulation is used under the roadway base except on the Tsukimi Bridge bottom, which is exposed to the air.

The geothermal fluid has a pH of 7.7 and consists mainly of sodium (995 mg/ℓ), chloride (1620 mg/ℓ), and bicarbonate (375 mg/ℓ). Hydrogen sulfide varies from 0.51 to 2.21 mg/ℓ and carbon dioxide from 75 to 88 mg/ℓ.

The construction expenses are about 9000 yen/m^2 including the cost of polybutene pipes, while the maintenance expenses are 115 yen/m^2 year, which is mainly due to electricity for the pumps ($1 = 200 yen).

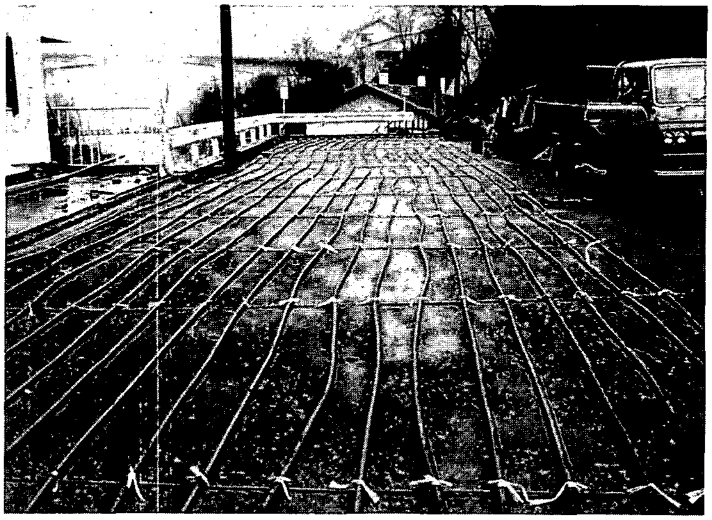

Figure 2. Laying Polybutene Pipes At A Parking Area In Jozankei, Sapporo

Figure 3. Jozankei Chuo Road embedding snow melting system. No snow is seen on carriage way and sidewalk.

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COSTING OF GEOTHERMAL HEATING SYSTEMS IN NEW ZEALAND

by

David W. L. Cooke*

Scope

The use of geothermal heat for comfort heating in residential, commercial, and institutional premises, as well as for process heating, is well established in Rotorua and the surrounding areas and to a lesser extent, in other geothermally active areas in New Zealand. Apart from the heat source and the geothermal heat exchange equipment, conventional heating system technology is used for the actual heating installation.

The costing information prepared is based on the Rotorua area.

Geothermal Heat Source

There has been a steady increase in the usage of geothermal heat in Rotorua over the past thirty years and the accompanying increase in scientific and practical knowledge of the extent of the geothermal field, now permits wells to be sunk with a degree of predictability. As a result, the likely cost of the production and associated soak bores is well known.

The ready availability of a source of geothermal heat, together with the ability to dispose of the effluent is the initial factor to take into account when carrying out a cost feasibility investigation into the use of geothermal heat as compared with conventional fuels. The quality of the geothermal heat should also be taken into account and whilst, a calorimeter test can be taken to establish the amount of heat available, it cannot always be predicted whether the bore be clean or dirty. It is also important to take into account the location of the bores with respect to the heat exchanger plant room, as this can have considerable influence on cost.

In New Zealand, central and local Government regulations cover the drilling of geothermal bores, and the direct use of geothermal water or steam within a closed building is not permissible because of the risk from dangerous gases which are found in thermal water being released in the building. Costing should take into account the cost of complying with such regulations.

Although the heat is available free of charge, there are additional costs associated with the geothermal bores, the distribution pipework, and the heat exchangers, which are peculiar to geothermal heating systems.

Much of the maintenance, however, is dependent upon whether or not the bore is clean or dirty and the resultant build-up of calcite and other mineral deposits. Maintenance costs should be allowed for servicing the bores, maintaining valves, and controls for removing the excessive build-up of deposits in pipelines and on heat exchange surfaces.

In addition, allowance should be made for replacement of pipework and heat exchangers at more frequent intervals than with conventional boiler plant.

Bores and Boreheads

Each installation requires a production bore and a soak bore, although in domestic and smaller commercial installations it is the practise for groups of users to share a common bore to reduce the owning and operating costs. In all cases, the bores should be located as close as practicable to the Plant Room to minimise the distribution cost. There are also several large installations where a number of buildings are fed from one or more bores such as at the Government Centre. However, these more complex installations require individual costing, as the quality of the geothermal heat as well as the

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* Managing Director, Cooke Heating Ltd., Auckland, New Zealand.

as the number of bores and the site layout and conditions can differ considerably.

It is a good practise to operate production bores at less than full capacity, as this reduces the build-up of calcite and the need for maintenance. Soak bores require venting to above adjoining buildings to disperse the H_2S gases present in the thermal water, and provision should be made for the cost of this vent pipe.

Distribution

As previously stated, the bores should be located as close as practicable to the Plant Room to minimise the distribution cost. The distribution costs can vary widely depending on whether they are run below ground in concrete ducts or exposed above ground, and whether the pipes are insulated or bare. It is common practise to insulate the delivery pipes to minimise heat losses and the danger of exposed hot pipes, as well as to provide weather protection where the pipework is exposed. It is desirable, however, for the effluent pipe to be left uninsulated to provide additional cooling for the effluent entering the soak bore. A common form of insulation is preformed fibreglass pipe insulation sections with aluminum cladding. In more heavily built-up areas, it is often necessary to run the pipework below ground, and in such cases, it is desirable to install the thermal pipework in concrete ducts provided with removable lids for maintenance access. Precast or cast in-situ ducts are used with drainage points to disperse surface water entering the duct.

Plant Rooms

Heat exchanger plant rooms are generally at ground level, in or alongside the building being heated, although, in simple installations, the equipment is mounted outside in the open air. The specific requirements of good ventilation, reasonable access, and adequate space for maintenance, are similar to those for typical plant rooms and require no special allowance.

Heat Exchangers

As the regulations do not permit the use of geothermal water within a closed building, it is necessary to transfer the heat-by-heat exchangers into a secondary medium, which is usually the water in the closed circuit heating system or into the domestic hot water supply.

The heat exchangers are generally of conventional shell and tube mild steel construction, and typical costs are listed below. Heat exchangers are usually conservatively rated to allow for considerable fouling to occur on the geothermal side. Control of the heat input to the heat exchangers is usually by manual adjustment of the delivery valve at the borehead, however, automatic controls are used in the larger and more complex installations.

Ancillaries

Various ancillary components are used according to the quality of the geothermal water and the type of usage. Typical examples of these which must be costed separately are: 1) Controls—for automatic control of the geothermal water, 2) Calcite Traps—to minimise calcite deposits in pipework and heat exchangers, and 3) Air Compressors—to provide air to assist with raising the geothermal water on some low-temperature production bores.

Costing

It is difficult to be specific on account of the varying factors, however, typical costings for the heat source installations are listed below.

Typical costs are:

Production Bore	\$4000 - \$8500
Soak Bore	\$ 600 - \$1000

Distribution Pipework

Bare	50mm	\$17m
	80mm	\$28m
	100mm	\$36m
Insulated	50mm	\$30m
	80mm	\$50m
	100m	\$65m

Concrete Trench (300 x 450) \$90m

Operating Costs

The operating cost for a geothermal heating system is particularly dependent on the maintenance and replacement costs which vary from installation to installation. Comparative operating costs based on current alternate fuel costs are:

Geothermal		Less than 1¢/kWh
Oil Fuel		2.0¢/kWh
Electricity -	Domestic	2.8¢/kWh
	Commercial	3.7¢/kWh

Summary

The preceding notes cover the wide range of factors which should be taken into account when costing geothermal heat sources for heating systems. In the Rotorua area, companies engaged in this field have developed considerable expertise, and as a result typical costs can be narrowed down for specific locations.

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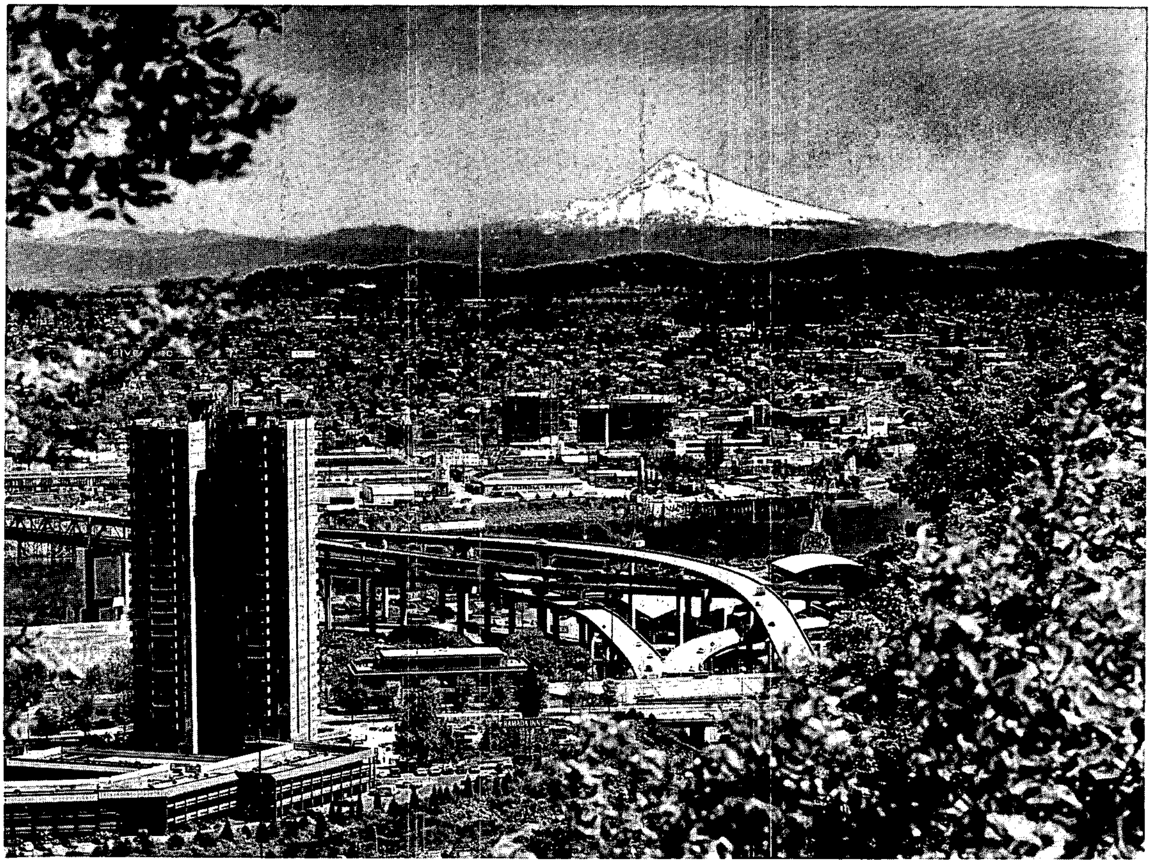
Quarterly Bulletin

OREGON INSTITUTE OF TECHNOLOGY – KLAMATH FALLS, OREGON 97601

Vol. 4, No. 2 Supported by the U. S. Department of Energy March, 1979

A Quarterly Progress and Development Report
on the Direct Utilization of Geothermal Resources



The Mt. Hood volcano is currently being investigated for geothermal resources that may in the near future supply energy to the city of Portland.
(Photo courtesy of Oregon Department of Transportation)

MOUNT HOOD, OREGON

by Debra Justus
Geo-Heat Utilization Center
Salem, Oregon

Mount Hood is more than meets the eye. For decades the mountain's year-round mystique has enticed Portlanders to spend energy traveling to her slopes. Now there are indications that the mountain's energy can be brought to Portland to heat homes and fuel industries. Geo-scientists are speculating that geothermal heat, Mount Hood's long-kept secret, may be a new motherlode energy resource.

Mount Hood peers over the Cascade Mountain Range from the crest of the High Cascade region in northern Oregon. The Columbia River Gorge borders the north side of the mountain and the Willamette Valley lies to the west. At 3,427 meters elevation, Mount Hood is Oregon's highest peak. It serves as a landmark from Portland to the west as well as from the high desert country to the east.

The designated Mount Hood Known Geothermal Resource Area (KGRA) and surrounding vicinity is federally owned and is managed by the Mount Hood National Forest. Land use is focused generally on the area's natural resources and on timber production, recreation and watershed in particular. The Forest Service land management plan proposed to increase timber production and recreational opportunities while maintaining the scenic qualities of the mountain area. The natural attributes have met the criteria for inclusion into the National Wilderness Classification System. The Mount Hood Wilderness Area includes most of the mountain proper and encompasses the entire KGRA.

Population levels in the Mount Hood area are low, but tend to fluctuate seasonally. The small percentage of private land available for residential development is concentrated along Highway 26 which results in population densities approaching urban or suburban levels in the existing communities. The population in these areas is expected to double or triple in the next 20 years. Although the Hood area is sparsely populated, more than a million persons live within a 1- to 2-hour drive. To some the mountain is a symbol of the earth's power.

Natural forces are reflected in the complex geology of the area which shows evidence of the volcanic history and glaciation of Mount Hood and recent stream deposition. The profile of the mountain has been evolving for millions of years as regional uplift, structural deformation, and erosion by stream and ice action accompanied the accumulation of volcanic materials, flank sediments, and alluvium. The result of these processes has been highly varied and discontinuous rock types.

The oldest exposed rock is Columbia River Basalt of Miocene age. Outcrops around the mountain suggest that Columbia River Basalt underlies the Hood volcano.

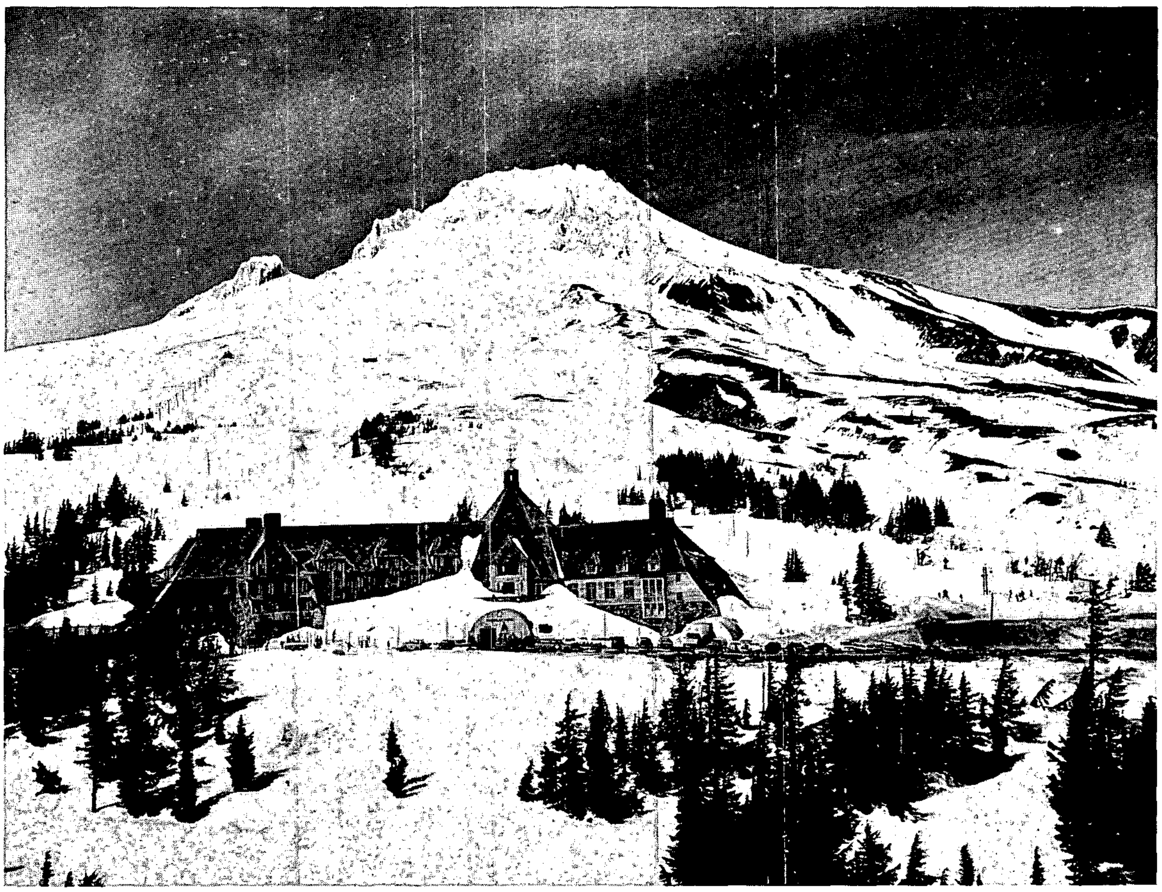
The Rhododendron Formation unconformably overlies the Columbia River Basalt and is composed of volcaniclastic debris and interbedded andesite flows. Contemporaneous with this formation is the Dalles Formation of mid-Pliocene age. The formation is made up of volcanic debris with some interbedded lava flows. Andesites of early Pliocene age rest conformably on the Rhododendron Formation. Above, these units are found: Mount Hood volcanics, glacial and mudflow deposits, gravels, alluvium, and intrusives.

The mountain itself is an andesitic stratovolcano of Pleistocene age. The composite cone consists of olivine andesite, pyroxene andesite and hornblende dacite flows and pyroclastic debris with an estimated volume of 45 cubic miles. The cone rises over 2,134 meters above the surrounding area and is approximately 70 percent lava flows. The entire cone was flanked with glaciers during Fraser Glaciation but dissection was not extensive.

Since the end of glaciation, a considerable quantity of material has been added resulting from andesite flows and the intrusion of a plug dome. Crater Rock, near the summit, is the only remnant of the plug, but debris still covers much of the southwestern slope of the cone. Much of the surface geology has been mapped as Pleistocene Mount Hood clastic debris, primarily pyroclastic, but with considerable postglacial transported detritus on the surface.

In conjunction with the geology of the mountain, surface manifestations of thermal activity at Crater Rock and Swim Warm Springs have encouraged scientists to question the possibility of geothermal energy potential at Mount Hood. If a sufficient resource were discovered and could be developed in an environmentally responsible manner, it seems clear that the demand for heat is present given the adjacent population concentrations. This explains why exploration at Mount Hood has been active and represents the largest geothermal research effort to date in Oregon.

An extensive geothermal resource assessment of Mount Hood was begun in 1977. The research program was established as a cooperative effort between the U. S. Department of Energy, U. S. Geological Survey, U. S. Forest Service, and the Oregon Department of Geology and Mineral Industries. During 1977, resea[illegible]ers began conducting geophysical surveys, drilling shallow temperature gradient holes and modeling heat flow of the volcano. Deep



Timberline Lodge, constructed of massive timbers and stone masonry, was dedicated by Franklin D. Roosevelt in 1937. (Photo courtesy of Oregon Department of Transportation)

drilling, continued geophysical studies, and additional gradient hole drilling were accomplished in 1978. In early 1979, 15 papers focusing on the assessment project were informally presented to other members of the research team. Much of the field data has yet to be fully interpreted. Results of the investigations should be forthcoming by late 1979. These conclusions will not only supply meaningful data on the realistic potential of the Mount Hood geothermal resource, but will serve to broaden the knowledge and understanding of other Cascade volcanos.

Preliminary results of electrical surveys completed by Lawrence Berkeley Laboratory have indicated an anomaly south of the cone near Swim Warm Springs and another in the area of Cloud Cap. In its most recent estimate, the U. S. Geological Survey estimates that the Mount Hood geothermal resource could yield 0.058×10^{18} joules of beneficial heat and speculates a mean reservoir temperature of 122°C ± 12. These indications have lead to a keen interest in developing the potential Mount Hood geothermal resource.

It was on Mount Hood in September, 1977, that the U. S. Forest Service issued its first geothermal lease on public land to the operator of Timberline Lodge. The lease was issued on a non-competitive basis with no-surface-occupancy stipulations. In 1977, a shallow gradient hole was drilled east of the lodge, but difficulties in drilling caused subsequent abandonment.

As part of the federal-state resource assessment program, a second test hole was drilled near the maintenance shed at the lodge in August, 1978. The well was permitted to 610 meters, drilled to 421 meters, and completed as a

224-meter observation hole due to serious drilling problems. Temperatures were isothermal to 195 meters, but the bottom 30 meters yielded a gradient of 180° to 200°C/km with evidence of hydrothermal alteration. Water samples were relatively ambiguous with high levels of calcium and chloride possibly from cement used during the drilling operation and high levels of sodium and potassium. Additional sampling and analysis is needed. Future plans for more geochemical analysis and continued test drilling at Timberline await further funding.

If sufficient temperatures and flow rates are indicated from exploratory drilling, the proposed plan is to supply space heating to Timberline Lodge and the anticipated facilities expansion, swimming pool heating, and for snow melting on roads and parking areas at the lodge. The new day lodge is being designed to accommodate both a conventional fuel and geothermal heating system. Timberline Lodge ranks as the largest single-building oil consumer in Oregon. A geo-heating system could displace 38,000 gallons of oil per month currently used at the lodge.

The Northwest Natural Gas Company has also exhibited an interest in development of the Mount Hood geothermal resource. The company holds assigned non-competitive no-surface occupancy leases on the west side of Hood.

In late 1977, Northwest Natural Gas drilled a temperature gradient hole to a depth of 564 meters at Old Maid Flat west of Mount Hood. In mid-1978, the hole was deepened to 1,220 meters as a joint effort by the U. S. Department of Energy and Northwest Geothermal Corporation, a subsidiary of Northwest Natural Gas Company. An initial temperature probe indicated a bottom hole temperature of 80°C. After several months had lapsed, the temperature was recorded as 81.5°C equilibrium temperature. The average geothermal gradient was 65.5°C/km.

The drilling at Old Maid Flat encountered Columbia River Basalt at a depth interval from 618 meters to 991 meters, similar to the Columbia River Basalt exposed in the Clackamas River area. From 24 meters to 618 meters the drilling encountered andesitic tuffs and lava flows of the Rhododendron Formation. More stratigraphic, petrologic, and geochemical studies are continuing and will be released in future reports.

To continue the Hood assessment activities, Northwest Geothermal plans to carry out additional temperature gradient drilling on the west side of the mountain. Water quality and quantity will be tested in the deep Old Maid Flat hole during early 1979.

As results of the resource assessment activities are evaluated, Northwest Geothermal will measure the feasibility of their proposed geothermal heating project. The objective is to find a sufficient resource to justify construction of a 48-inch pipeline over the 70 km distance to Portland for industrial processing and space heating. The company has estimated that if a resource capable of producing 25,000 gpm of clean water at 74°C is discovered, it can be delivered to major users in the Portland area at less cost than the equivalent energy from natural gas or fuel oil.

Thus far, the results from test drilling appear favorable, but there are yet too many unanswered questions to confidentially postulate development. If and when the resource is proven capable, its development must be planned to be compatible with established environmental standards. It is too early to tell, but Portlanders may one day see Mount Hood as the power that heats their homes, businesses and fuels their industry.

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OPERATIONS RESEARCH FOR GEOTHERMAL DEVELOPMENT IN CALIFORNIA AND HAWAII

by

Robin Witkin, Jeffrey Wiegand, Fred Rigby, Monica Dussman, Tod Larson

Science Applications, Inc. (SAI), of La Jolla, California, recently completed a Department of Energy-sponsored contract entitled "Regional Operations Research for Geothermal Energy Resources in California and Hawaii." The study, which was cosponsored by the states of California and Hawaii, involved the preparation of development scenarios for the site-specific geothermal energy utilization. Factors constraining development were identified and recommendations made to accelerate resource utilization. The scenar were revised iteratively through comment by federal and local government agencies, utilities, and private developers to ensure the maximum level of realism. Finally, a methodology was developed to monitor progress of both direct use applications and electric power generation toward the goals DOE has set for the Pacific Region.

Factors Constraining Geothermal Development

SAI's work characterized permitting procedures which are radically different according to whether the resource lies under federal, state, or private land. With the plethora of government agencies involved in geothermal development, substantial permitting delays occur due to unspecified review times or duplicative permitting requirements. Therefore, it is crucial that interagency cooperation and coordination be established, specific time constraints on institutional processes be imposed, and duplicative functions be identified and removed. Funding support should also be provided to counties from DOE or the states to enable identification and organization of local permitting processes.

Other recommendations included instituting a procedure for monitoring leasing activity within the USGS in order to accelerate the processing of lease applications, convening an ad hoc workshop to determine the impact of the Public Utilities Commissions' rate setting policy on motivating utilities toward geothermal development, and establishing a formal nominating procedure for classifying federal lands as KGRAs, thus serving to expedite lease or no-lease decisions and guide the location of competitive lease sales.

Potential Markets for Direct Use and Electric Applications in California and Hawaii

The SAI-developed computer model "GEYSER" was utilized to determine the economic feasibility of electric power production and certain direct use applications. As a result of this study, it was determined that geothermal energy is capable of being cost competitive, marginally competitive or cost prohibitive depending upon site, application and market. Concern over rising energy costs and heavy reliance upon imported petroleum products in both states enhance the attractiveness of geothermal energy. The market for electric power production in California is adequate to absorb the resources as they are projected to come on-line by the year 2000; however, in Hawaii, the market is dependent upon an influx of new industries or shortages of petroleum products. In both states, proven geothermal resources for direct industrial heat application do not coincide with urban market locations.

Suggested areas for exploration for direct-use geothermal resources in California are shown in Figure 1. These areas were selected, utilizing a point system based on surface evidence of resources and potential users. (The maximum count achievable was 10.) Four aspects of direct use applications were considered in assigning a point value: potential for process heat utilization, space conditioning, agricultural activity, and population growth.

Estimates were made of potential energy supply and associated requirements in the near-term based on industrial and demographic patterns and resource data. Given an aggressive program, an annual supply of 0.1 quads or more might be achieved in the near-term in California. If fossil fuels costing over $2.00/MMBTU are displaced, the savings would be approximately $200 million.

Of the possible potential direct uses examined in Hawaii, two major viable prospect-user pairs were identified—sugar mills and aquaculture farms. Both industries are important to the Hawaiian economy and both are large users of process heat. The resort industry was also identified as having a significant potential for utilization of medium grade resources for space conditioning, health spas and water and swimming pool heating.

Recommendations evolving from the direct use and market analyses included exploration for resources in proximity to major markets, enactment of tax incentives, assessment of industrial attitudes, studies of the food processing and lumber industries in California, studies of the chemical industry in both states, demonstration of industrial uses and of liquid-dominated electric power production.

Scenario Development for Imperial Valley, California and Puna, Hawaii

Integrated scenarios were generated for geothermal development in the Imperial Valley, California, and Puna, on the Big Island of Hawaii. The Imperial Valley subregion has the potential to become the leading center of development of hydrothermal resources within the continental United States—4500 MW power-on-line is achievable by the year 2020. (Figure 2) It is expected that development within Heber, Brawley, East Mesa and the Salton Sea KGRA's will result in approximately 1000 MW on-line by 1986.

During construction of the scenario, several issues were identified which affect the speed of commercial geothermal development in the Imperial Valley, such as effects of development on the local economy and local tax revenues, effects of inflation and costs of delay, the value of well logging to identify fractures and assist unitization, the impacts of geothermal development on the Salton Sea, solid waste management, extraction technology, new drilling methods, effect of the BLM Desert Plan, the value of anomaly-wide EIR's, KGRA nomination and direct use considerations. Specific recommendations were made to address these issues, such as development of a regulatory process to include direct use development, expansion of the seismic monitoring system and the water impact study, and preparation of anomaly-wide EIRs.

Puna, on the Big Island of Hawaii, is the site of one of the hottest geothermal wells in the world and has near-term prospects for development. These include the ongoing wellhead-generator program, a possible direct use application with the Puna Sugar Company, and recent interest in constructing a 20-MW power plant (the Tokyu Land Development Company and GEDCO both are giving consideration to development, if adequate financing becomes available). The DOE cost-shared wellhead-generator will be on-line in 1981, the direct use process could be operational by late 1982, and the power plant could be on-line in 1983.

In addition to near-term uses, development by energy-intensive industrial operations, including manganese nodule and aluminum reduction facilities, was considered in the formulation of the scenario. Near-term development is limited because the growth rate of the market [illegible] slow, and development in the long-term will be dependent upon an influx of more energy-intensive industry. In addition, several

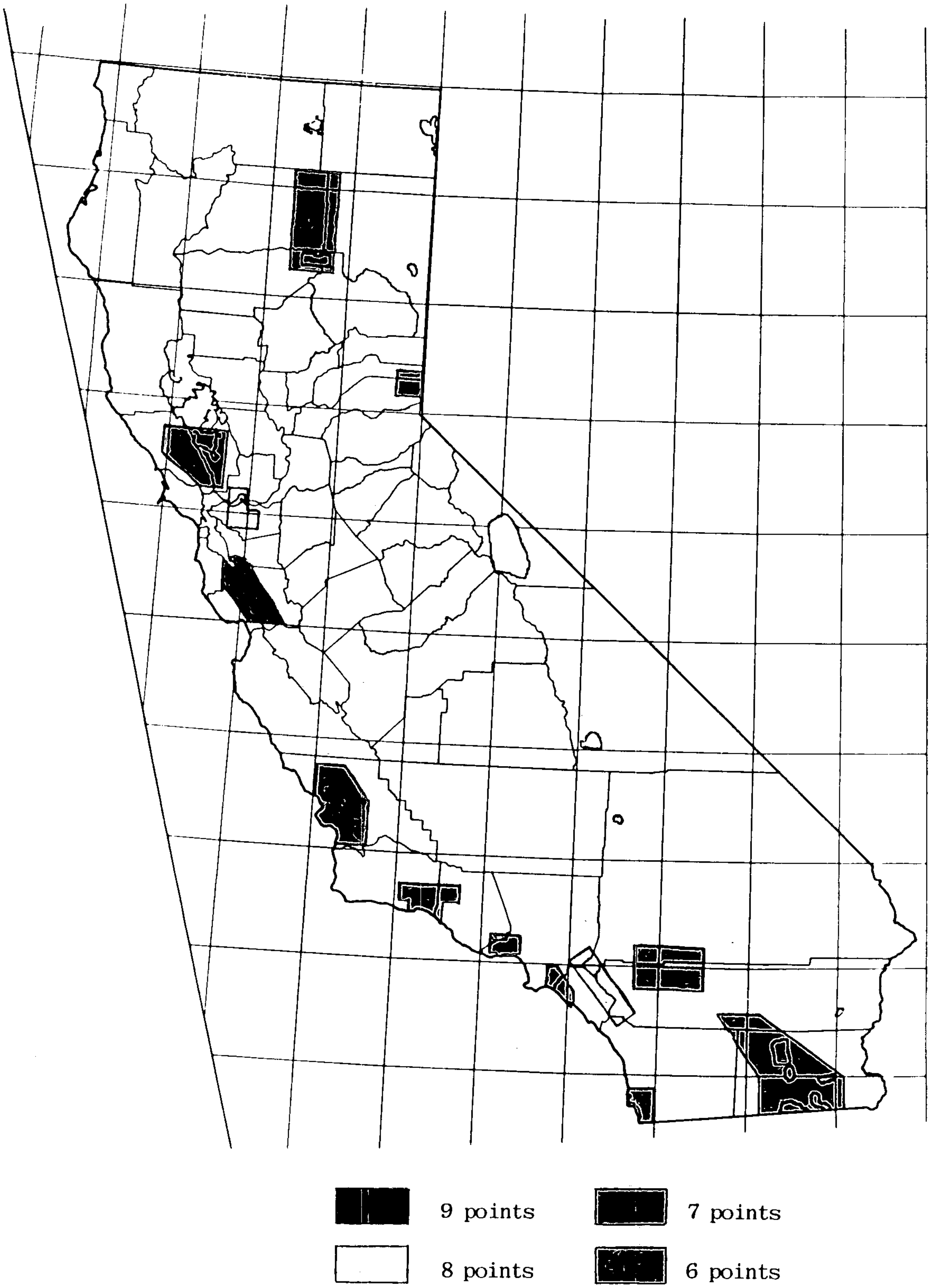

Figure 1. Suggested Areas for Exploration for Resources for Geothermal Direct Use Based on Potential for Applications and Favorable Geology.

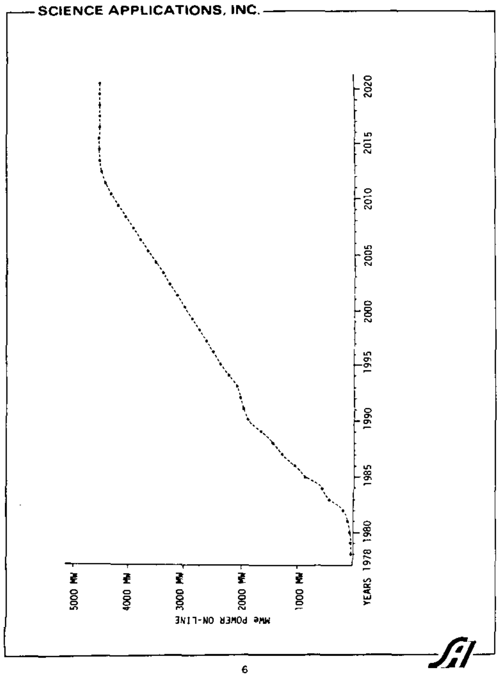

Figure 2. Cumulative Power On-Line in Imperial Valley to the Year 2020.

impediments to commercialization were identified, including native rights disputes, resource ownership issues, regulatory requirements, and limited demand for energy on the Island of Hawaii. The programmatic needs suggested to accelerate development included government encouragement of further resource exploration and exploratory drilling, an economic and marketing analysis of the potential uses of the resource (emphasizing energy-intensive industrial processes), provision of tax and relocation incentives, clarification of conflicts between state and private ownership, and clarification of native claims issues.

Regional Progress Monitor

A methodology was established which will allow DOE to monitor the progress of geothermal development. Three stages of geothermal development were defined—Identification, Exploration and Utilization—and indicators of progress were defined for each stage. The monitor is based on a site-by-site analysis of the developmental process, with site-specific scenarios serving as the standard against which progress is measured. A model was developed by which deviations from the projected scenarios may be detected, and the effects of actions to accelerate development may be evaluated.

In summary, it is evident that a potentially significant geothermal resource exists in the State of Hawaii and its utilization could significantly enhance the State's energy independence. California, as well, has a substantial geothermal potential, which is the process of being realized. However, achievement of timely commercialization of the geothermal resources within California and Hawaii requires a bold commitment to support the industry and to resolve the various issues identified as constraining development.

GEOTHERMAL ENERGY DEVELOPMENT IN THE SOVIET UNION

by

Philip R. Pryde*

The Soviet Union, in common with a great number of other countries, is actively pursuing the development of geothermal energy as a renewable (or at least semi-renewable) substitute for increasingly scarce fossil fuels. As oil, coal, and natural gas become more depleted and expensive, geothermal resources will look more and more attractive. Until the mid-1960s, the Soviet Union maintained a relatively low profile in geothermal research, but in recent years interest there appears to have quickened, particularly in the area of utilizing some of the lower-temperature resources.

Distribution of Geothermal Resources in the USSR

Surveys on subsurface temperature gradients have been conducted throughout the Soviet Union over a number of years, although some remote areas (most notably northern East Siberia) have been little surveyed and gradient values are largely inferred. These surveys have resulted in the compilation of a subsurface

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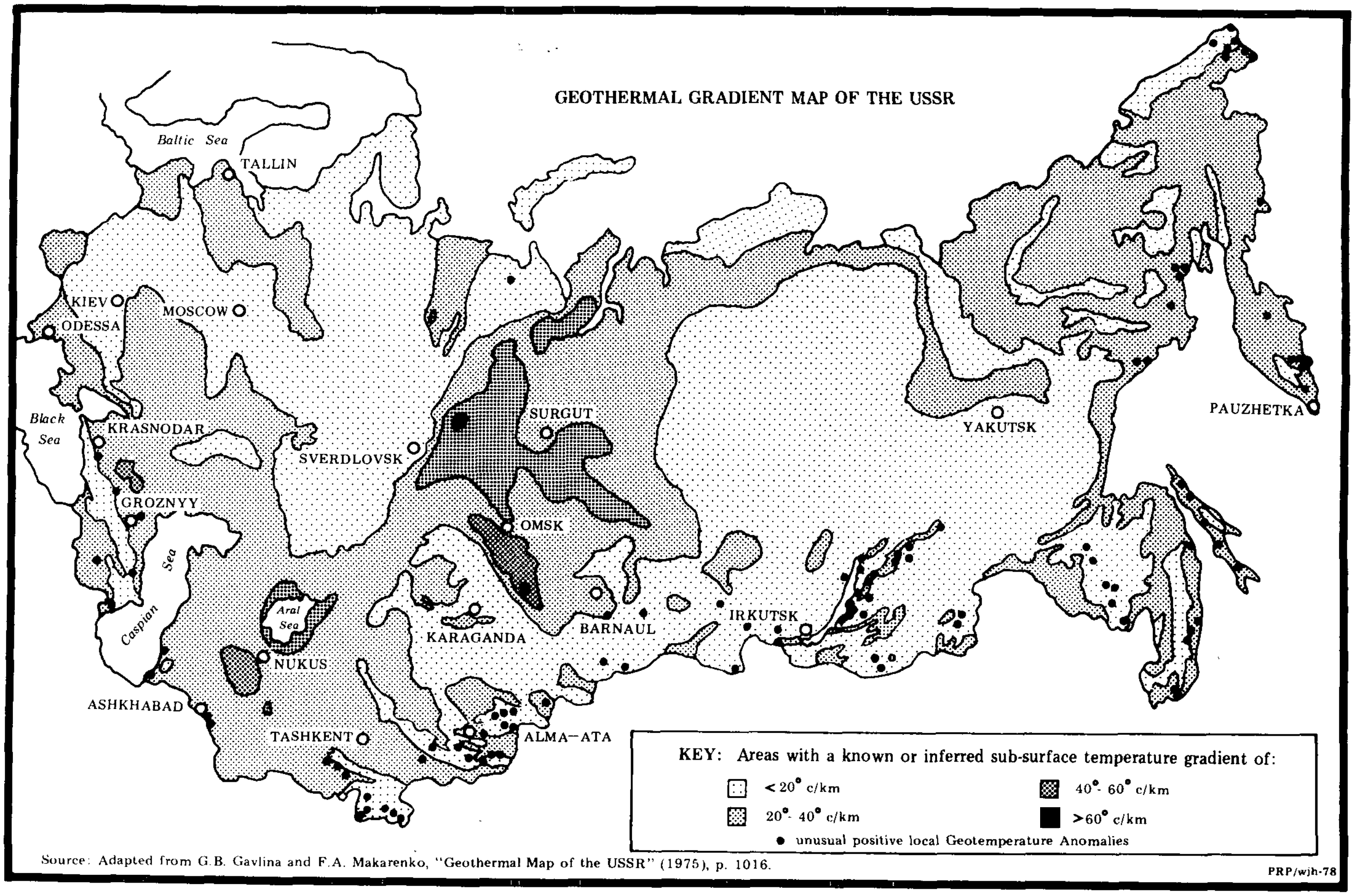
*Professor of Geography, San Diego State University. The complete paper is presented i Soviet Geography: Review and Translati Scripta Publishing Co., Washington, D.C., Feb. 1979, p. 69-81.



Source: Adapted from G.B. Gavlina and F.A. Makarenko, "Geothermal Map of the USSR" (1975), p. 1016.

Figure 1. Geothermal Gradient Map of the USSR.

temperature gradient map for the country as appears in Figure 1. From Figure 1 it can be seen that the general areas of the country exhibiting the steepest gradients are West Siberia (especially the western portion near the Ural Mountains), both the North and Trans-Caucasus, northern Kazakhstan, the Turanian basin plus adjacent portions of the Tadzhik and Kirgiz republics, the Carpathian Mountains, and the Kamchatka Peninsula (plus the Kurile Islands). Discrete locations having very steep temperature anomalies are widely scattered throughout the country (as shown by dots on Figure 1), but specific gradients for these sites are not given in available sources.

Only two extensive areas having gradients in excess of 60°C per kilometer of depth are shown on the USSR geothermal map, one near Serov on the east flanks of the Urals, and one near Pavlodar in northern Kazakhstan (the blackened areas on Figure 1). Neither of these are discussed as likely locations for electrical power plants, suggesting marginality of the resource base in these areas for this purpose. It is probable that in areas near active volcanic or seismic features, local temperature gradients in excess of 60°C/km may be encountered.

The areas of thermal anomalies in the southern part of East Siberia lie near the route of the new Baikal-Amur Mainline, the USSR's important second trans-Siberian rail line. It has been suggested that these geothermal resources be developed along with the other natural resources of the region as the new Mainline opens the area up to economic development (Pravda, Feb. 3, 1978, p. 6).

To date, the Kamchatka Peninsula (and possibly the Kuriles, where there is very little demand) is the only area which seems to be undergoing serious study for the production of electricity from geothermal steam. Several other areas have been identified by economic geologists, however, as potentially promising areas for using hot geothermal waters for space heating. The North Caucasus and the Georgian republic are regions where 1 Gcal of heat from geothermal sources costs from 1 to 3 rubles, which is 2 to 3 times less expensive than the cost from conventional sources. On Kamchatka, the cost of 1 Gcal is in many places only about 1/2 a ruble. Also promising are the previously mentioned areas of Kazakhstan, southern West Siberia, and Central Asia where the cost of 1 Gcal of heat ranges from 2 to 3 rubles and is also somewhat less than the rate for conventional thermal heat (Fomin et al., 1975).

These geothermal resources have been put to five main types of uses in the USSR. These uses are:

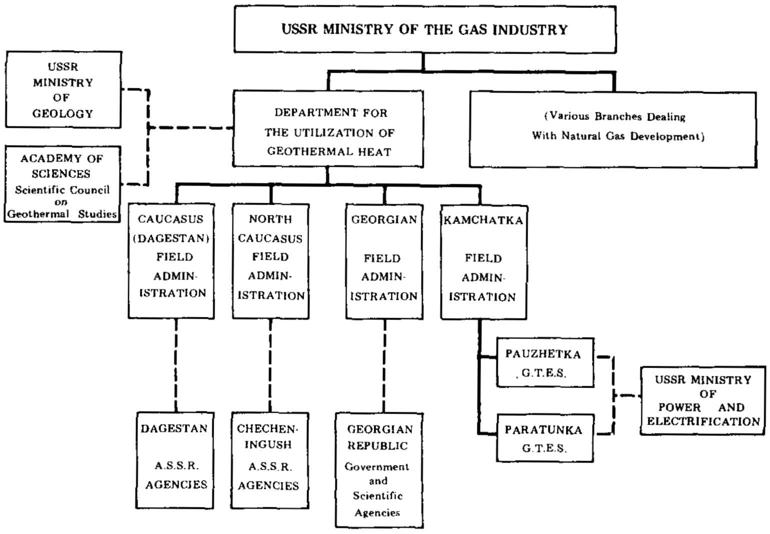
1. Balneological spas and sanatoria;
2. Chemicals extraction;
3. Space heating (including community applications);
4. Agricultural applications);
5. Electrical energy production.

The development of these geothermal resources is the responsibility of the Ministry of the Gas Industry, and its regional subdivisions. In addition, some republics have a set of auxiliary organizations of their own, such as the Georgian republic's Administration for the Utilization of Undergound Heat (Pravda, Dec. 8, 1973, p. 3). In addition, there exists a Scientific Council on Geothermal Studies within the USSR Academy of Sciences (Figure 2).

Geothermal applications for space heating, agriculture, and electrical energy are of primary interest in the context of USSR development, and are reviewed in the following sections.

Geothermal Energy Conversion to Electricity

The Kamchatka Peninsula has been the location of all Soviet efforts to date to utilize geothermal energy for electrical production (under the Ministry of the Gas Industry). Kamchatka is well known as an extremely active tectonic and volcanic region, and in addition to volcanoes, has a large number of thermal springs and geysers. The Kronotskiy geyser basin is considered to be in a class with those in Iceland, New Zealand, and Yellowstone.



SOURCE: Gadzhiev (1977)

Figure 2. Organization of Geothermal Development.

The first area in the Soviet Union to be developed for geothermal electric power was at Pauzhetka, near the southern tip of the Kamchatka Peninsula. Exploratory drilling began at the site in 1957, and eventually resulted in a total of 21 wells ranging in depth from 220 to 480 meters. The temperature of the fluids produced ranged from 150° to 200°C (300° to 390°F), and their mineralization varied from 1.0 to 3.4 g/1 (1000 to 3400 ppm). Preliminary estimates of the total potential from the Pauzhetka geothermal anomaly are on the order of 30 to 50 MW (Dvorov, 1976, p.71). These characteristics were deemed satisfactory for the construction of a geothermal electric power station, and work was begun in 1964. This station went into operation in 1967 and uses flashed steam (15 to 20% flashover), with an electrical outp[illegible] of 5000 KW (Koenig, 1973, p. 42). It provides electricity at a lower cost per kilowatt-hour than that produced by fossil fuel electrical generators located in the same area of Kamchatka.

In 1968, the Soviet Union constructed a small binary geothermal power plant at Paratunka, near Petropavlovsk-Kamchatskiy. Here, the hot water source (not steam) is at a temperature of only about 80°C (176°F) (Dvorov, 1976, p. 68). The secondary fluid used is freon-12, which has a boiling point of -29.8°C (-21.6°F). However, it is utilized at a pressure of 13.8 atmospheres, at which it boils at 55°C, and is thus easily vaporized by the geothermal fluids which surround it in the heat exchanger (Shubin, 1974, p. 16). The freon drives two 340-KW turbines, which went into routine operation in 1970. Excess heat from the plant is used to warm greenhouses, and warm water irrigation is also a by-product of the facility (Koenig, 1973, p. 43).

Although these two pilot-sized projects on Kamchatka appear to be successful operations, there seems to be little priority given to creating more or larger scale geothermal electric power plants. None are known to be under construction at the present time, although the possibility of building more is often discussed.

Use of Low-Temperature Fluids for Space Heating

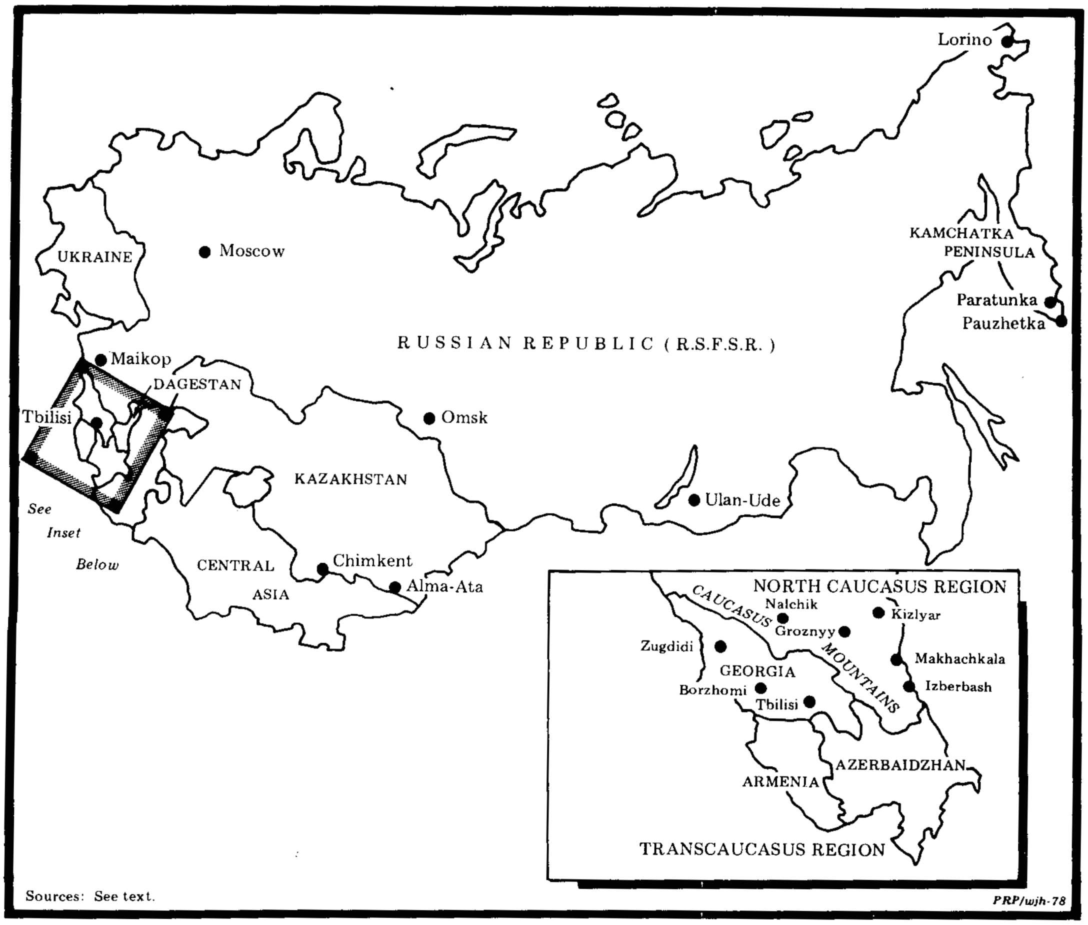
The primary use of geothermal heat in the Soviet Union to date has been for space heating and industrial applications. In 1976, of all the hydrothermal fluids extracted in the USSR, 62% went for space heating, spas, and industrial applications, 25% went into agricultural applications (mostly hothouses), and 13% was used in the two geothermal electrical generating stations on the Kamchatka Peninsula. The total amount of fluids extracted in 1976 was 26.4 million cubic meters, with an average temperature of 70°C (Nurshanov, et al.). The Soviet Union's development of geothermal resources for space heating purposes to date appears to somewhat exceed the scope of development for these purposes in the United States.

The region where hydrothermal resources have been most extensively developed for space heating is the Dagestan Autonomous Republic, which lies between the northeast flanks of the Caucasus range and the Caspian sea. The capitol and largest city of Dagestan is Makhachkala, with an estimated 1978 population of about 250,000 (Figure 3). Portions of Makhachkala have been heated with geothermal steam since the late 1940s, and today about 60% of the city's hot water needs are geothermally supplied. The several producing wells that are used to generate hot water have temperatures ranging from 60° to 70°C, and at least one has been in use for over a quarter of a century without showing any change in flow rate or temperature (Dvorov, 1974).

Two other Dagestan cities where hydrothermal heating has been widely developed are Kizlyar and Izberbash. The latter is entirely heated by geothermal fluids, while Kizlyar provides geothermal heat for all new buildings and plans to convert older buildings at a future date. The Kizlyar wells produce 17,000 m^3/day at 100° to 105°C, with 10 to 12 grams/liter of solids, and 18,000 m^3/day at 60°C and 3 to 4 g/l (Dvorov, 1976, p. 115). Elsewhere in the North Caucasus, the cities of Nalchik and Groznyy, which are respectively the capitols of the Kabardino-Balkar and Chechen-Ingush Autonomous Republics, also enjoy the benefits of geothermal heat. In Nalchik (unlike some other areas of the Caucasus), the fluids are highly mineralized, up to 18 to 20 grams per liter. Here, a heat exchange system is used, to provide hot fresh water for domestic heating, industry, and greenhouses. After exiting the heat exchanger, the feed water (now at 37° to 38°C) is used in public baths and a balneological hospital (Dvorov, 1976, p. 104).

South of the main Caucasus range, the Republic of Georgia has been the principle area of hydrothermal space heating development. In the Saburtalo district of the republic capitol of Tbilisi, some 25,000 persons receive domestic heat from hydrothermal fluids (Nurshanov, et al.). By 1980, it is planned that one-third of Tbilisi's population will have their hot water needs supplied from geothermal sources (Pravda, Aug. 10, 1976, p. 6). Also in Georgia, hot water is used for industrial purposes in the city of Zugdidi at a tea plant and a pulp-and-paper mill.

Elsewhere in the country, many state and collective farms, such as the Kaplanbek state farm near Chimkent, use hydrothermal fluids for the joint warming of hothouses and other



Sources: See text.

Figure 3. Areas of Geothermal Development in the Soviet Union.

farm buildings (see following section). For the future, a very promising region for geothermal space heating is West Siberia. Here, in the vicinity of the major city of Omsk, for example, there are large reservoirs of geothermal waters at 70° to 80°C at a depth of 2500 meters. Further north, the town of Tara could be similarly supplied (Dvorov, 1976, p. 118). Another very promising region for such development is Kamchatka, where some buildings are already being heated around the Paratunka geothermal electric station.

Use of Hydrothermal Resources for Agriculture

Geothermal fluids are used for agriculture in many parts of the Soviet Union. The volume of such use in 1976 reached approximately 6 1/2 million cubic meters of fluids. The heating of hothouses and greenhouses is the main use of these fluids. Greenhouses are very important in the USSR, where so many cities are located in northern latitudes. The current five-year plan envisions a sizable increase in greenhouse construction near major cities in order to increase the supply of fresh vegetables.

In most cases, the geothermal heating of greenhouses is very economical and explains the great interest shown in this approach in the Soviet Union. One article suggests that the construction costs of a geothermally heated greenhouse farm can be recouped in the first three to four years (Izvestiya, Jan. 13, 1976, p. 2). It has been estimated that 1500 to 1600 hectares of greenhouses could be heated by hydrothermal fluids throughout the Soviet Union (Dvor 1976, p. 134).

The most extensive development of geothermally heated greenhouses is in the Caucasus region, especially in the North Caucasus republics and in Georgia. Geothermally heated hothouse farms exist in the vicinity of Groznyy and Maikop (near Karsnodar), both in the North Caucasus. A very large greenhouse farm exists near Makhachkala and at several other locations in the Dagestan Republic. In Georgia, the main location of geothermally heated greenhouses is around the cities of Zugdidi and Okhure.

Elsewhere in the USSR, major geothermal hothouse operations are found in southern Kazakhstan, east of Lake Baikal, and on Kamchatka. In Kazakhstan, greenhouses heated by geothermal fluids can be found on state farms in the Chimkent and Alma-Ata regions (Kalmykov, p. 85). The greenhouses on the Chimkent farms cover an area of 12,000 m^2. At Ulan-Ude in East Siberia, hothouses fed by underground heat have been producing fresh vegetables for that city's residents since 1969, and now cover 20,000 square meters. The hot springs at Lorino on the Chukot Peninsula heat hothouses and chicken coops, as well as a swimming pool (Tikhonov, p. 1076). On the Kamchatka Peninsula, the largest operation is in association with the Paratunka geothermal electrical station, where discharged hydrothermal fluids are used to heat 60 greenhouses covering 60,000 m^2 that produce over 1000 tons of vegetables a year. At Pauzhetka, the waste heat from the power plant could be potentially used to heat 100,000 m^2 of hothouses (Dvorov, 1976, p. 138). At Omsk in West Siberia, a different use is made of geothermal heat. Here, along the Irtysh River, warm water is used to breed carp during the winter months, which then are harvested subsequently as an important food crop.

It is clear that the Soviet Union is very much interested in the increased use of geothermal fluids for greenhouse heating as a means of expanding the fresh food base of its major cities, wherever such cities are located near exploitable hydrothermal resources.

Other Present and Prospective Uses of Geothermal Resources

Besides space heating, agricultural, and electrical applications, the other two common uses of hydrothermal fluids in the USSR are for balneological and chemical extraction purposes. The former is by far the most important.

The Russians and the peoples of the Caucasus, in common with those of Central and Eastern Europe, are very fond of mineral spas, and balneological uses of hydrothermal fluids, especially mineralized ones, are quite common. In 1970, it was reported that health resorts and bottling works in the USSR used 280 springs and wells with a combined yield of about 100,000 liters per minute. Thermal water bottling was being done in 22 separate factories (Tikhonov, p. 1077).

The North and Trans-Caucasus are the main centers of this activity. The well known Borzhomi mineral waters, which exit the ground at 40°C, are typical of the many balneological uses of geothermal waters in this area. The thermal springs near Tbilisi have been used for centuries. Although these *in situ* uses of hot mineral waters are of considerable regional economic importance, they are sometimes overlooked. They are reported on in detail for the Georgian republic in Buachidse *et al.*, 1970, and for the North Caucasus region in Sukharev *et al.*, 1970.

The extraction of chemicals from hydrothermal fluids is not practiced on a large scale at present in the USSR (although chemicals have been extracted from normal temperature saline waters, such as the Caspian Sea, for years). As an example of a potential resource base, the Cheleken area of western Kazakhstan contains thermal waters with the following mineralization (in mg/1): iodine, 26.3; bromine, 579; lithium, 7.8; rubidium, 0.65; lead, 3.24; zinc, 3.7; copper, 2.4; cadmium, 1.48; arsenic, 0.36; and strontium 715 (Dvorov, 1974, p. 66). Other areas rich in geothermal minerals include specific locations within the North Caucasus and Kamchatka.

A final application of hydrothermal fluids which is being researched in the Soviet Union is their use to assist in thawing frozen ground in northern regions in connection with mining operations.

In summary, it appears that geothermal resources are the subject of a slow but steadily expanding interest in the Soviet Union. Although the USSR presently has adequate reserves of fossil fuels, they, like the United States, have passed out of the era of the inexpensive and easy exploitation of these resources. Their rising cost of development coupled with the need for ever increasing absolute amounts of energy in a variety of forms will necessitate the development on nontraditional forms of energy resources, one of the chief of which will be geothermal.

The USSR presently has only two small geothermal stations producing electrical power, both on Kajchatka, and little effort is being expended to develop more. However, low-temperature (<160°C) uses of geothermal energy have been widely developed in the Soviet Union, especially in the North Caucasus, Georgia, southern Siberia, and Kamchatka. These uses include space heating of buildings, the operation of greenhouses, and balneological applications. There seems to be considerable interest in expanding these types of low-temperature uses in the future, with a lesser emphasis on the transformation of geothermal steam or brine into electrical energy.

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POTATO PROCESSING

by Paul J. Lienau
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The food processing industry has many possibilities for the use of geothermal to satisfy their energy demand. Potato processing is one specific area of interest with the recent agreement signed between Ore-Ida Foods, Inc., Ontario, Oregon, and the U. S. Department of Ener This paved the way for exploration of geothermal water and use of the source as energy in food production. Ore-Ida will supply land, facilities and personnel; the DOE will share costs of original development. CH_2M Hill will manage the technical aspects of the energy system.

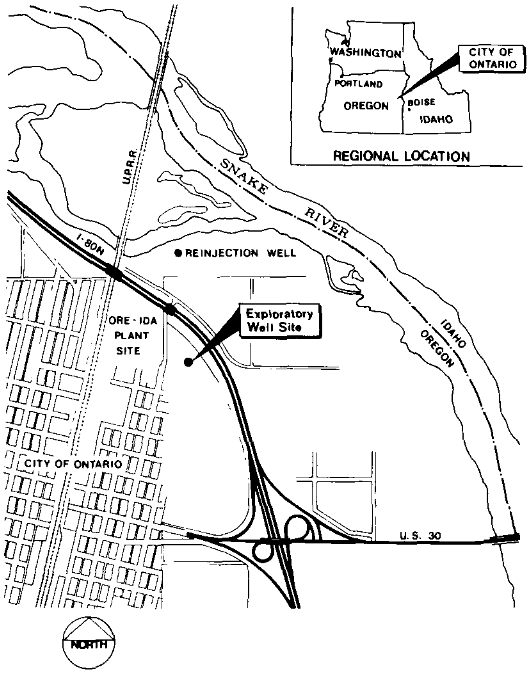

Figure 1. Location of Ore-Ida/U.S. DOE Geothermal Energy Project

Potato processing at the Ore-Ida, Inc. plant was studied by the Geo-Heat Center in a recent agribusiness study of the Klamath and Western Snake River Basins in Oregon. A description of this study is as follows:

General Description

There are two prime french fry potato lines and several by-product lines at the Ore-Ida plant processing over two million pounds of potatoes per day resulting in over one million pounds of 13 frozen potato products. Potatoes for processing are conveyed to a preheater which softens the peel making it easier to remove chemically by a 15% lye solution. Heat for peeling, 24.5 million Btu/hr is supplied by direct injection of steam at 100 psi, maintaining the solution at a temperature of 140° to 175°F. After the potatoes are trimmed for defects and cut to the desired style of nch fries, they pass through a hot blanch at 200°F, requiring 16.5 million Btu/hr and a warm blanch at 150°F requiring 8.9 million Btu/hr. After blanching, the potatoes are dewatered and fed through a sugar drag, which will impart a golden color when the potatoes are fried. They then pass through a dryer which removes the surface moisture prior to a two-stage frying process. The first stage cooks the product more completely, while the second stage gives it the golden color. The oil in the fryers is heated to 375°F by heat exchangers receiving steam at 275 psi. The frying process requires 43.1 million Btu/hr. The heat consumption rate, which largely determines the extent of geothermal resource required, totals 106.5 million Btu/hr. This includes all potato processing and plant heating. Of this amount, 43.1 million Btu/hr are used in the fryers. The anticipated geothermal resource temperature of 300°F precludes the direct use of geothermal energy for frying, which is at 375°F. However, the remaining 63.4 million Btu/hr can readily be satisfied geothermally.

To avoid any possible contamination of the product by geothermal fluid, or the need for treatment of the fluid, energy is supplied to the process via intermediate heat exchangers. The geothermal fluid passing through these exchangers will transfer energy to a secondary fluid, primarily water, which delivers energy to the process. The secondary fluid, circulating in a closed system, then returns to the intermediate heat exchanger to be reheated.

After processing, the product is Individually Quick Frozen (IQF) in Lewis continuous freezing systems powered by Sullair and Mycom compressors. Freezing temperatures are maintained at a constant -30°F. The products, 13 different varieties, are now ready for packaging and cold storage.

Geothermal Application

The processes to be supplied by geothermal fluids are distinguished in Table I by their functions and temperature requirements.

With an anticipated temperature drop of 170°F for the geothermal fluid used to supply the 63.4 million Btu/hr needed for processing, roughly 370,000 lb/hr will be required. This should be readily available from two wells, with adequate margin for load variation or delivery rate fluctuation. The wells would be pumped to minimize temperature losses. A third well would be required for injection of the waste fluid.

TABLE I.
Heat Loads and Secondary Fluid Temperatures

Function	Heat Rate (10^6 Btu/hr)	T-in (°F)	T-out (°F)
Peeling	4.12	260	200
Peeling	5.63	200	150
Peeling	14.6	150	100
Hot blanch	16.52	200	100
Warm blanch	8.92	150	100
Water heating	2.62	150	50
Plant heat	11.00	150	100

The geothermal water will be carried from the wellhead to the Ore-Ida plant through a 1-mile, 10-inch pipeline. The pipe will be installed above ground level set upon concrete pillars which support the pipe on rollers to allow for pipe expansion and contraction. The pipe will be insulated with 2 inches of rock wool and finished with an aluminum weatherproof jacket.

Figure 2 suggests one possible routing of the geothermal fluid through the intermediate heat exchangers for maximum extraction of energy. Energy requirements for the high-temperature (200°F or more) processes are satisfied by dropping the geothermal fluid temperature from 300°F to 190°F. The lower-temperature processes are then supplied partially by this cooled-off geothermal fluid and partially by fresh geothermal fluid.

The actual amount of energy required for each process wil be controlled by pneumatic valves located in the geothermal inlet to each heat exchanger. These valves will be modulated to maintain a set process water temperature. All heat exchangers will be instrumented with continuous pressure and temperature recorders and flowmeters to accurately record and calculate the actual amount of energy being derived from

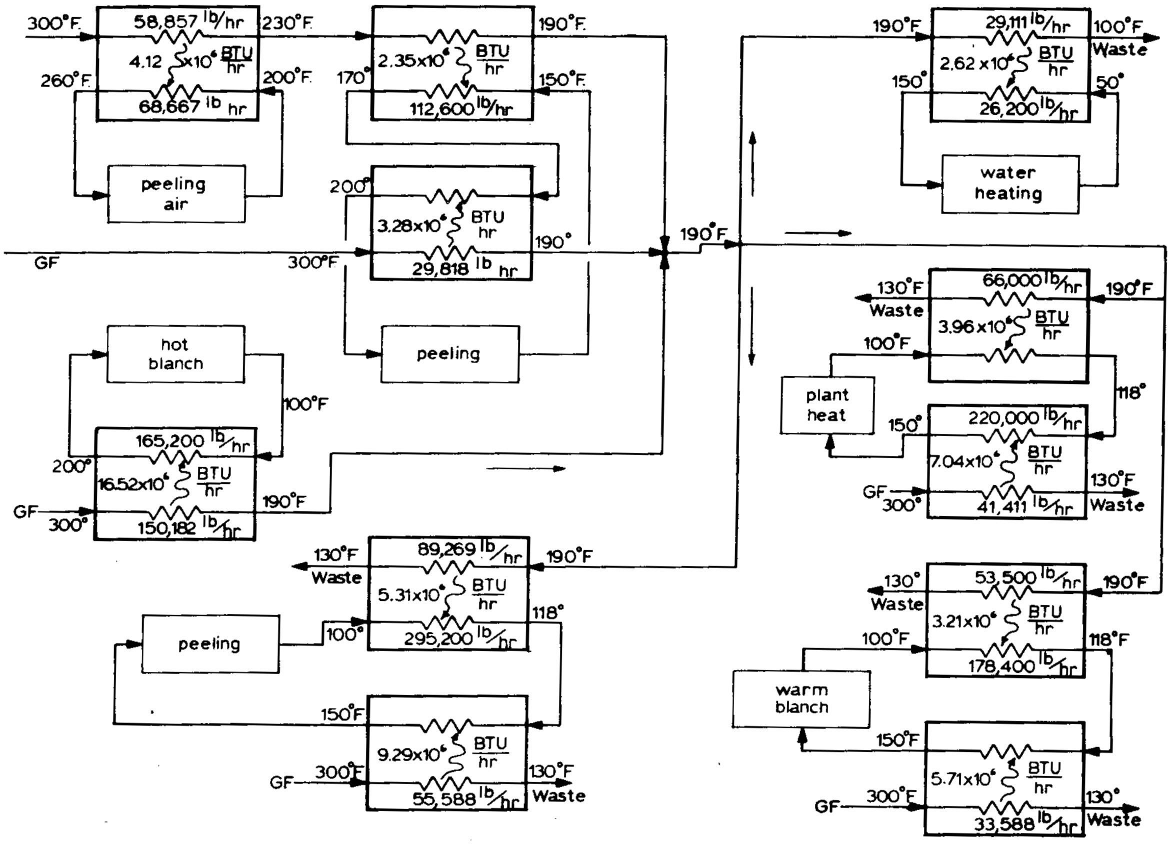

Figure 2. Flow Diagram for Geothermal Conversion.

the geothermal source. This information gathered from the various sensors and recorders could be fed directly into a microprocessor to calculate efficiencies, total energy use, and energy cost.

Economic Analysis

The economic analysis for the geothermal conversion of Ore-Ida Foods, Inc. assumes a ten-year depreciation life for tangible assets. Throughout the economic analysis, Ore-Ida's method of cost analysis was used. This requires 200 percent declining balance depreciation, after-tax cash flows from operations, expensing intangible costs in the year incurred, and discounting the after-tax cash flow for each year, to arrive at a present worth.

The calculation of annual savings from operations were accomplished as follows:

1) The fuel mix of natural gas and fuel oil that occurred in the year ending July, 1977, was assumed to remain constant.

2) A 15-year projection of costs for natural gas to supply 100 percent space heating and 54.9 percent of process requirements was inflated at a rate of 11.2 percent annually through 1986, and 7.5 percent thereafter.

3) Costs of fuel oil were inflated at 7.5 percent annually for the 15-year projection.

4) Increased electrical power costs due to wellhead pumps and other components of the geothermal system were inflated at 8.5 percent annually through 1986, and 7.58 percent thereafter.

5) Maintenance and repair costs were inflated at 6 percent annually, which is the projected economic inflation rate.

All of the above inflation rate projections were obtained from the Oregon Department of Energy.

Annual costs of the geothermal system were subtracted from the projected annual costs of conventional fuels to arrive at a total annual savings before taxes.

Depletion allowances were applied to these annual savings as follows:

1979 and 1980 - 22 percent
1981 - 20 percent
1982 - 18 percent
1983 - 16 percent
1984 on - 15 percent

The depletion allowance was subtracted from annual savings and the result was multiplied by 48 percent to determine the increase in federal income tax due to cost reduction. This percentage (.48) is used by Ore-Ida in calculating after-tax cash flow.

The total capital outlay of $2,848,451 includes intangible costs after taxes of $1,321,840, and tangible costs of $1,526,611. On these latter costs, a 20 percent investment credit was taken at the end of year one.

All cash flows due to after-tax savings from operations, annual asset depletion and reduced federal taxes due to tax credits and tangible asset depreciation, were discounted at a rate of 20 percent compounded continuously, assuming uniform cash flow throughout each year to arrive at a present worth total of $4,389,908. A second present worth calculation was done at a rate of 30 percent compounded continuously, to provide Ore-Ida with a more accurate ROI.

The cost of drilling a productive well based on total intangible estimated costs would be $2,542,000 ÷ 3 = $847,333. The after-tax cost would be .52($847,333) = $440,613. In drilling a nonproductive well, these costs would be substantially reduced due to the fact that the well would require only surface casing and would not incur mobilization and demobilization cost. The estimated after-tax costs of a nonproducing well are estimated to be (.52)($658,000) = $342,000. Ore-Ida requires only two producing wells and one return well and the total after-tax dollars available for intangible cost at 20 percent ROI are $1,321,840 + $1,541,457 - $2,863,297. Therefore, the company could afford to drill a total of eight wells to get two productive wells and use one of the nonproductive wells as a return well. In other words, with a confidence level of as low as 25 percent, they could still realize a 20 percent ROI.

DIRECT UTILIZATION WORKSHOP

by
John W. Lund
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During early February, a three-day workshop was held at Diamond Lake Lodge, just north of Klamath Falls. The purpose of the workshop was to develop four educational reports on the direct utilization of geothermal energy. These include a technical version of approximately 150 to 200 pages in length, a nontechnical version of approximately 50 to 100 pages in length, a series of articles for newspaper release, and a pricing parameter report. The technical version of the report consists of seven major sections:

I. Nature and Occurrence of the Resource
   Patrick Muffler, Chairman

II. Exploration, Confirmation and Evaluation of the Resource
   Jim Combs, Chairman

III. Reservoir Development and Management
   Jay Kunze, Chairman

IV. Utilization
   Paul Lienau, Chairman

   - Space Conditioning Subgroup, Gene Culver, Chairman
   - Process Heating Subgroup, Gordon Reistad, Chairman
   - Corrosion Subgroup

V. Economics
   Charles Higbee, Chairman

VI. Legal and Institutional Considerations
   Syd Willard, Chairman

VII. Financing
   Paul Rodzianko, Chairman

Each work group had from five to eight people participating in outlining and writing the initial draft at Diamond Lake. The group chairman then has the responsibility of completing and editing the material.

The workshop was funded by a Department of Energy grant and administered jointly by the Geo-Heat Utilization Center and Geothermal Resources Council with David Anderson and John Lund as principal investigators. Bev Hall was the project coordinator, Henry Curtis the public relations writer responsible for the serialized newspaper articles, Robert DeRosier the technical writer, Lorraine Smith the graphic artist, and Colleen Fry and Alma Kesler as typists. Charles Higbee is responsible for developing the pricing parameter publications.

The purpose of the workshop was to develop a comprehensive publication on direct thermal utilization of geothermal energy (nonelectric applications). Note: according to Syd Willard, the current terms are now: "direct" and "nondirect" uses as opposed to nonelectric and electric uses. These publications will be available by the middle of the summer from Geothermal Resources Council or the Geo-Heat Utilization Center. Approximately fifty-five people attended the workshop, which took place during rain, snow, sunshine, and a power outage. After the completion of the workshop, a geothermal tour of Klamath Falls and the Oregon Institute of Technology campus was conducted by Geo-Heat Utilization Center personnel.

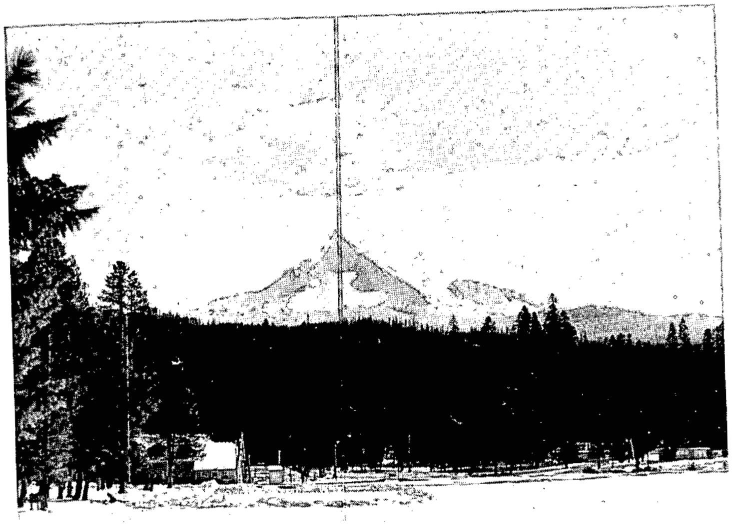
Legal and Institutional Workgroup
At Play

Workgroup Chairpersons and
Principal Investigators

Workshop Participants

Space Conditioning Subgroup
At Work

Dinner Discussions In The Lodge



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A Quarterly Progress and Development Report
on the Direct Utilization of Geothermal Resources

LAVA HOT SPRINGS IDAHO

By David McLain
Geo-Heat Utilization Center
Boise, Idaho

History

Lava Hot Springs is located along the Portneuf River in Central Bannock County in southeastern Idaho. A small resort community of 700 people, Lava Hot Springs has a long history of geothermal water production and usage. The geothermal resources of the area have been utilized for health and recreation purposes for decades. The temperature of geothermal waters in Lava Hot Springs (70°F to 140°F) indicates the resources could be utilized for space heat, and the city of Lava Hot Springs is exploring the idea of a district heating system.

Figure 1. Lava Hot Springs (1940s)

The development of Lava Hot Springs as a recreation and health center started over 200 years ago. The historic use of the hot springs dates back to early historical times when the Indian tribes of the region would set aside their differences to bathe at the springs and worship the "Great Spirit." The area was considered a spiritual location because of the hot waters that are found along the Portneuf River. The waters were used to heal wounds and clean animal hides.

Westward-moving fur trappers were the first non-Indians to discover the natural hot waters in 1812. Shortly thereafter, the site of the hot springs became a restful respite along the Oregon Trail. Lava Hot Springs, like a number of other locations along the Old Oregon Trail, shares in the romance of winning the West. It was here, over a century ago, that caravans of covered wagons enroute to Oregon, stopped to rest and recuperate after the arduous crossing of the Rocky Mountains.

For a number of years, there was a small settlement near the springs, and homesteading of nearby rich valleys by Mormon immigrants served as an impetus to the area's growth. By the 1890s, the Bannock and Shoshone Indians were largely confined to the Fort Hall Reservation, 45 miles to the north near Pocatello. In the late 1890s, the Indians signed over the title of the hot springs and 178 acres to the federal government. In 1902, the federal government gave the area to the State of Idaho by the Lava Hot Spring Land Grant Act.

As time passed, the wonders of the mineral springs became more widely known and gradually the settlement began to grow into a resort community. The Oregon Short Line Railway extended its mainline through Lava Hot Springs at the turn of the century. As a stop along the Harriman railway system, Lava Hot Springs began to grow rapidly and the fame of the mineral springs lured visitors from as far away as the East Coast. By 1925, the community had developed several private hotels, motels, spas and public swimming and bathing facilities.

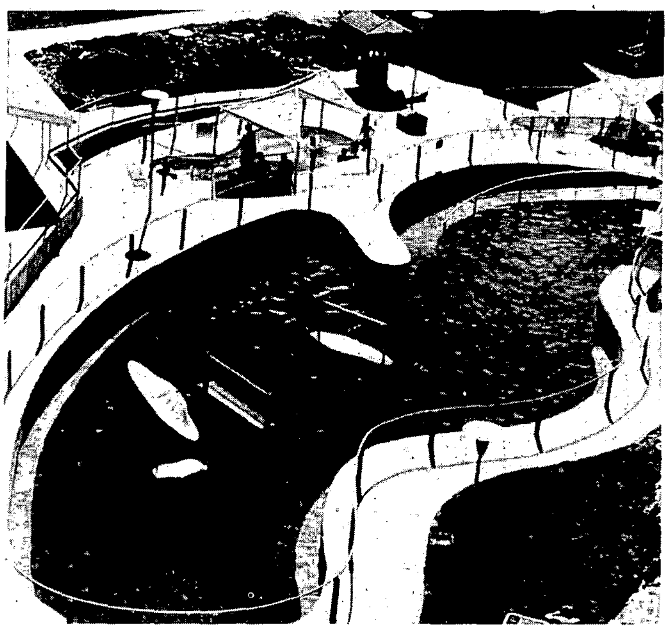

Figure 2. Lava Hot Springs Spa Today

In 1935, the State of Idaho passed the Lava Hot Springs Foundation Act. The Foundation objectives are to provide "health and recreation facilities with comfortable and aesthetic surroundings for enjoyment of the public." One hundred and twenty acres of the original one hundred and eighty acres under jurisdiction of the Foundation have been developed into a recreation spa, swimming facility, and park. In 1962, the City was struck by a disasterous flood which destroyed the Foundation's hot pools. The Foundation and the City quickly recovered and built new facilities. The most recent development was the addition of an olympic-size swimming pool and diving facility, and adjacent condominium units.

The Lava Hot Springs Foundation is self-supporting and relies on revenues generated to maintain its operation. At present time, the recreational usage of the hot water generates 10 full-time, and 50 part-time employment positions which are associated directly with the Lava Hot Springs Foundation. Besides the direct employment with the Foundation, there are other jobs created in supportive services relevant to the recreational economy of the city. Such things as hotels, motels, service stations, and restaurants are, to a large extent, dependent upon the tourist trade associated with the Lava Hot Springs Foundation. In 1977, over 252,000 visitors passed through the Foundation facilities.

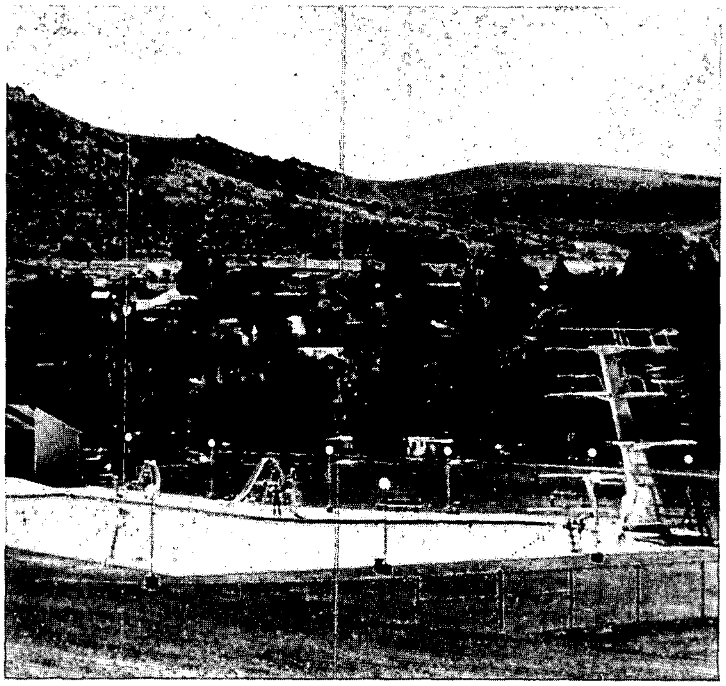

Figure 3. Lava Hot Spring's Swimming Pool

Origin of the Geothermal Water

Geologically, the Lava Hot Springs area is a complicated stratigraphic and structural location. The oldest rocks in the area are Precambrian and lower Cambrian quartzite. Units representing Cambrian through Pennsylvanian systems are present in the area. Most of the rocks in this section are carbonates. A major unconformity exists between the upper Paleozoic units and Tertiary units of the area. All of the Mesozoic and most of the lower Tertiary are unrepresented in the area. Pliocene units are present in the area and consist of sedimentary and volcanic breccias, tuffs, ash, and lava flows. Most of these rocks are valley fill materials which have been largely removed by erosion. The final stratigraphic unit deposited in the area are Pleistocene lava flows. Most of the Portneuf River Valley is underlain by this intervalley basalt flow.

During the Cretaceous and early Tertiary, major thrust faulting displaced the Precambrian and Paleozoic units eastward. The area experienced a period of structural quiescence during the early and middle Miocene which was followed by extensive high angle faulting during the Pliocene. This last period of tectonic uplift created the present fault block mountain range of the area.

Physiographically, the Lava Hot Springs area is in the northeastern most corner of the Basin and Range Province. The occurrence of thermal springs in the area appears to be related to the location of fault zones. The brecciated fault zones serve as permeable conduits leading the thermal water up from depth.

In the city of Lava Hot Springs, two major fault linears intersect. The Lava Hot Springs fault is a major north-south trending linear that is typical of the Basin and Range Province. Vertical displacement along this fault is several thousand feet creating the fault block mountain which dominates the relief of the area. A second fault cuts east-west through the Lava Hot Springs area offsetting the Lava Hot Springs fault to the east several hundred feet. It is at the intersection of these two faults that the thermal waters of the area are manifested. The relationship of the thermal waters to the thrust plain of the region is unclear.

The hot waters of the Lava Hot Springs area range in temperature from 70°F to 140°F. The major springs which feed the Foundation Spa are 110°F. The presence of fault zones can be easily determined in the area by extensive travertine deposits. These thermal waters are most logically associated with deeper sources of thermal fluids which are circulating up through the Paleozoic units along the fault intersection.

Most of the thermal springs and wells in the area occur from the basaltic rocks which underlie the Portneuf River Valley. Several shallow wells have been dug with backhoes to depths of less than 20 feet. Hot fluids are intersected along the bottom contact of the basalts. This may indicate that thermal water of the area is rising along the fault zones and spreading horizontally along the basalt contact.

Using the sodium-potassium-calcium geothermometer, a reservoir temperature of 410°F has been predicted, and using silica, a temperature of 176°F. In either case, the temperature would be sufficient for space heating. A surface temperature of 140°F has been reported on the bank of the Portneuf River just west of the spa. Investigations are presently being undertaken to determine the feasibility of designing a district heating project. The reported flow (over 400 gpm) and the location appears to favor this project. A district heating project would also avoid the present apparent interference between the very shallow individual wells in town.

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GEOTHERMAL RESOURCES IN THE EASTERN UNITED STATES

By J. Edward Tillman
Johns Hopkins University

Introduction

In the March, 1978, issue of GEO-HEAT, there was a brief summary of geothermal energy developments in the eastern United States. This article adds to and updates the data presented in that issue.

Interest has been increasing in the moderate to low temperature hydrothermal systems that are likely to exist in many of the sedimentary basins in the eastern United States. Areas underlain by sedimentary basins are attractive because: 1) the low thermal conductivity of the sediments insulates the heat source from loss of temperature to the surface resulting in above-average thermal gradients (1.6 > 2.0°F/100 ft); 2) water availability is easier to appraise in a well-layered sedimentary sequence than in a crystalline complex; and 3) drilling is less expensive in sediments than in crystalline rocks.

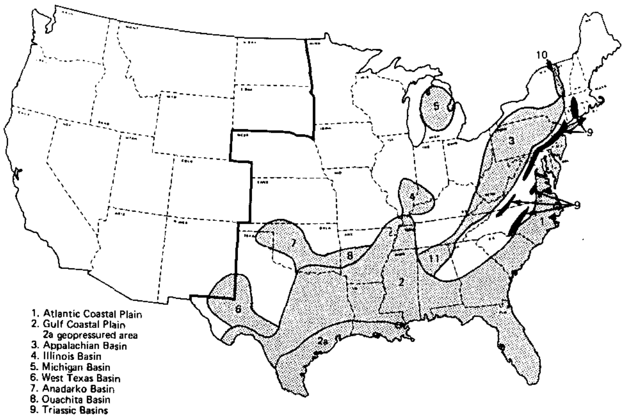


Fig. 1 Sedimentary basins within DGE eastern region.

Bottom-hole temperature data are known for all sedimentary basins which have been evaluated for their oil and gas potential. The thermal gradient map published in a joint effort by the American Association of Petroleum Geologists Survey (USGS) in 1976 illustrates the association of high thermal gradients with parts of the deep interior basins. This map is a compilation of bottom-hole temperatures (BHTs) and thermal gradient logs supplied by oil and gas exploration companies to the individual State Geologic Surveys. These data indicate that there are large areas in the east, associated with major demographic centers, that have useful temperatures at exploitable depths. If the conditions prove favorable for extraction, hot water between 120°F to 220°F will be available from 3,000-ft to 10,000-ft wells for a whole spectrum of direct heat applications (space heating, space cooling, food processing, certain industrial processes, etc.).

However, the key parameter (in addition to temperature) required for early utilization is water availability. If water occurs at the necessary depths to be heated to useful temperatures, and if it is easily extractable and rechargeable (high performance aquifer), then the economics for utilization of these resources become favorable. In the case where high thermal gradients are encountered with no water or with aquifers of low permeability, then the resource will have to wait for development as a Hot Dry Rock (HDR) site, if at all.

Conduction-dominated hydrothermal systems in the eastern United States are being evaluated in the Atlantic and Gulf Coastal Plains and in several of the interior basins (the Illinois and Michigan cratonic sags and the Appalachian foreland basin). The conduction-dominated systems are divided into geopressured aquifer systems, such as occur along the Gulf Coast, and simple aquifer systems that occur in most other areas. Convection-dominated systems are being evaluated at Warm Springs, Virginia, and Hot Springs, Arkansas, and possibly occur in the Champlain Valley and many of the Appalachian-Triassic Basins.

The following section identifies the DOE/DGE-sponsored programs and contacts if further information is desired.

Programs of Interest

The Department of Energy's Division of Geothermal Energy has divided the U.S. into three regions for purposes of stimulating the economic and enrironmentally acceptable development of geothermal energy. Mr. Bennie DiBona is the Manager of the Eastern Region, the 35 states east of the Rocky Mountains excluding the Dakotas and including Puerto Rico. Two divisions exist within the Eastern Region. The first consists of the geopressured regions of the Gulf Coast (Texas and Louisiana). This region is supervised by Mr. Keith Westhusing of DGE. The major contractors are The Center of Energy Studies, University of Texas, Austin, Texas 78712 (Dr. Dale C. Zinn), and the Petroleum Engineering Department of Louisiana State University, Baton Rouge, Louisiana 70803 (Dr. Bert Wilkins). The rest of the Eastern Region consists of hydrothermal resources and is under the supervision of Dr. David B. Lombard of DGE. The main effort for evaluation of hydrothermal resources at this time is in the Atlantic Coastal Plain. The geologic evaluation and targeting of hydrothermal resources beneath the Atlantic Coastal Plain have been underway at the Virginia Polytechnic Institute and State University (VPI & SU), 4044 Derring Hall, Blacksburg, Virginia 24061, under the direction of Dr. John Costain for the past several years. They have selected the sites for a series of thermal gradient wells and are performing back-up studies in support of the drilling program (e.g., gravity surveys, petrologic studies, geophysical modeling, temperature logging).

Gruy Federal, Inc. (Mr. Richard Lane, 2500 Tanglewilde, Suite 150, Houston, Texas 77063) is supervising the drilling program. The first pass of shallow (approximately 1,000 ft) thermal gradient wells has been completed in the northern half of the New Jersey to Georgia Resource Evaluation Area. A second pass, about 12 additional holes, is underway to gain better control on the extent of the above-average gradient areas encountered in the first pass, to be able to select the best sites for drilling deep pump-test wells. Energy Services, Inc. of Houston, Texas, is the drilling subcontractor for these wells.

Dr. Joseph Lambiase is the VPI & SU sedimentologist examining the cores taken from the shallow wells. These samples are logged and thermal conductivity measurements are made on them. After the holes are cased, a crew of VPI & SU geologists makes a series of thermal gradient logs in each well to establish the gradient under equilibrium conditions. Results of the VPI & SU program are published in their Quarterly Reports.

In support of the drilling program, the Delaware Geological Survey (Newark, Delaware), under the direction of Dr. Robert Jordan, the State Geologist, has been funded by DOE/DGE to conduct gravity studies in Delaware.

The USGS is publishing aeromagnetic maps of parts of the Atlantic Coastal Plain (Dr. I. Zietz, Reston, Virginia) and a revision of USGS Circular 726 (C-790) will be released in early 1979 (Mr. Edward Sammel, Menlo Park, California). The USGS Water Resource Division has been able to obtain some water well data from the shallow gradient wells (Dr. Leonard Wood, Reston, Virginia).

Aside from the Atlantic Coastal Plain studies, other areas of the East are also under investigation. Gruy Federal, Inc., Earth Science Division, has a DOE/DGE contract to perform geologic resource evaluation studies in Virginia, West Virginia, Pennsylvania, Illinois and Michigan, based on existing data (Mr. Joel Renner, 1911 Jefferson Davis Highway, Suite 500, Arlington, Virginia 22202).

Dr. James Maxwell of the Los Alamos Scientific Laboratory (LASL) in New Mexico, and Dr. Peter Geiser of the University of Connecticut at Storrs, are evaluating the resource at Hot Springs, Arkansas. Dr. Geiser is presently completing his study of the structural control of the warm springs in western Virginia. His reports can be found in VPI & SU Quarterly publications. Los Alamos also has expanded its hot dry rock program in the eastern United States. They now have a federal program in addition to the Fenton Hill study to look for sites in the east for a second HDT experiment.

The National Conference of State Legislatures (NCSL) has a contract with DOE/DGE to assist states in evaluating the necessity for new laws or regulations to facilitate the economic and environmentally acceptable development of geothermal energy. Mr. R. Harris (1405 Curtis Street, Denver, Colorado 80202) is conducting workshops in Delaware and Virginia this fall.

The Johns Hopkins University Applied Physics Laboratory (JHU/APL, John Hopkins Road, Laurel, Maryland 20810) is publishing its report of its work in South Dakota and has turned over all responsibility to Dr. J. Salisbury (Director of DGE Rocky Mountain, Basin and Range Region). A scenario for the development of geothermal resources in Delmarva will be available for use by local, state, and federal agencies and interested parties by the first of 1979. APL will continue to update their "roadmap" as new data become available. This manuscript incorporates local and state development plans, laws and regulations with the planned development of geothermal energy in order to identify the time phasing of necessary steps and initiatives. The scenario discusses problems of commercialization, storage, transport, space cooling, and resource management. An Energy Market Analysis for southern New Jersey; Norfolk, Virginia, to Stumpy Point, North Carolina; and Delmarva will also be completed by the first of 1979. This report identifies the potential users of geothermal energy in the three areas, the cost of application, and engineering methods of conversion. Economic studies performed by by the JHU Metro Center will show whether they can be competitive with current forms of energy in situations of high density site-specific usage if aquifers with good performance characteristics are encountered. JHU/APL publishes quarterly reports of its current activities in the energy field.

THE HONEY LAKE PROJECT

by K. L. Boren and K. R. Johnson
GeoProducts Incorporated

One year ago, GeoProducts Corporation (Oakland) began construction of their Honey Lake Farms Project near Wendel, California. Today, thirty units of a planned 205 geothermally heated hydroponic greenhouses are producing European cucumbers and tropic tomatoes. Cucumber production in 20 houses averages approximately 1,500 pounds per unit per week. Although the tomatoes are still in the primary stage of development, they are expected to produce an average of 850 pounds per unit per week. The purpose of this article is to describe the planned utilization of the geothermal resource in this project, to acquaint the reader with hydroponics in general and to describe the Honey Lake system in particular.

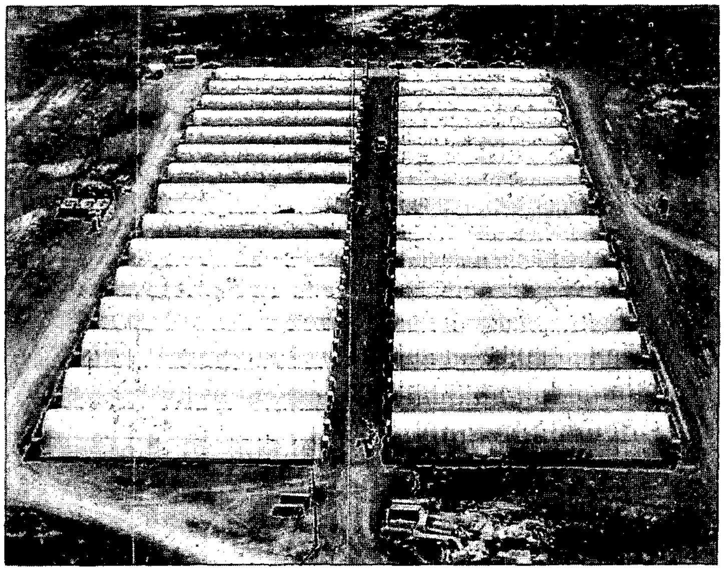


Figure 1. Hydroponic Greenhouses at Honey Lake

Located geographically 22 miles east of Susanville, California, and 80 miles north of Reno, Nevada, the Honey Lake Project is within the Wendel-Amedee KGRA. GeoProducts has extensive lease holdings in this area of which forty acres have been set aside for the hydroponic development. An additional forty acres have been donated to the Lassen

College Foundation. It is anticipated that this Foundation and/or Lassen Community College will, in the near future, plan to construct a research facility to explore problems related to hydroponics and geothermal development. The area's geologic environment has been described by extensive geological and geophysical surveys. Additional information is available from three thermal-gradient wells and from natural surface hot springs flowing boiling water. The geothermal water is of good quality, containing less than 900 mg/L of total dissolved solids. Water temperatures measured on the site are 206°F in the surface hot springs, 248°F in a deep well (4,100 ft), and an estimated 220°F at 400 feet in a shallow well used for greenhouse heating. Previous geochemical analysis of the hot springs indicated that high temperatures would be encountered at relatively shallow depths.

Pleistocene to recent volcanism exists near the geothermal area at the intersection of two major faults, suggesting existence of a deep-seated magma chamber. In addition to fossilized tuff mounds indicating an active geothermal history, ground water recharge into the Honey Lake Basin, large magnitude faults, and experience in previous drilling operations indicate that primary and fracture porosity are well developed on the surface and at depth. These geologic considerations, as well as geophysical surveys, suggest a large, deep-seated geothermal reservoir exists at the site. Shallow drilling to date also suggests the source of the geothermal fluids is deeper, perhaps 5,000 to 6,000 feet.

The project is being developed in three phases. Each phase comprises a construction stage, a geothermal supply stage, a planting stage, and a harvest stage. The numbers of greenhouses to be installed are 30 in Phase I (completed), 80 in Phase II, and 95 in Phase III. This schedule was designed to allow for any changes that might be required. The only non-geothermal energy used is electricity to operate lights, motors, pumps and automatic control systems.

Generally defined, hydroponics is the growing of plants in nutrient solutions with or without an inert medium to provide support to the plants and their root systems. To provide total environmental control and still benefit from available solar energy, hydroponic operations are usually conducted in translucent growing units equipped with heating and cooling facilities. Automatic controls maintain optimum growing temperatures and moisture conditions. The nutrients are circulated to the plants in water-based solutions that are carefully controlled to provide the plants proper minerals at the right time.

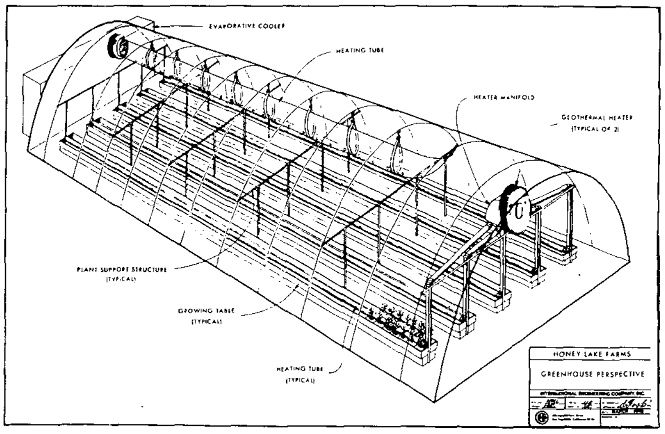


Figure 2. Honey Lake Farms--
Greenhouse Perspective

Each greenhouse at Honey Lake is 30' x 124' (Figure 2). They are of the Quonset design with heavy duty steel tubing, galvanized inside and out for greater longevity. The framework is anchored 2 feet in the ground with concrete to insure stability. The top cover is comprised of two layers of six mil, Monsanto 602 greenhouse sheeting. Monsanto 602 is an ultraviolet light inhibiting material designed to last a minimum of 2 years. A small electric air blower continually inflates the area between the two layers and maintains an air space of about 6 inches resulting in heat savings of approximately 40% over conventional coverings. Inside the greenhouse, a full concrete floor is poured incorporating various electrical plumbing blockouts.

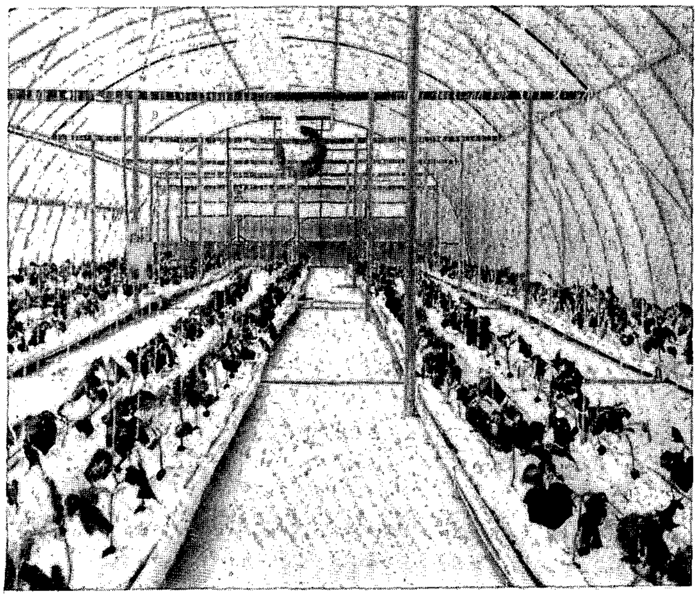


Figure 3. European Cucumbers Growing on Plant Tables

Five plant tables running the length of the house are built with a slope of 1-inch in 8 linear feet to provide drainage for the nutrient. Each of the five tables accommodates two flexible polyethylene growing tubes in which the plants are nurtured. There is no growing medium such as dirt, gravel or peat; instead, the plant roots are enclosed in the tube, with the plant stem protruding from a pre-cut slit. As the plant matures from the seedling stage to the production stage, it is supported by twine extended from an overhead support grid. As the vine crops grow, they are continually pruned to leave only one main growing stem thereby concentrating the plant's strength and production process in the budding area where the fruit is developing. During growth periods, the main stem of the vine is trained to lay along the growing table with only the last 3 or 4 feet rising vertically, supported by the overhead grid.

Each greenhouse has two, 450-gallon fiberglass tanks buried 12 inches below grade under the center growing tables. The nutrient solution is maintained in these reservoirs into the growing tube at one end and allowed to flow by gravity to the other. The flow of the nutrient is controlled by a time clock, with an interval of 10 minutes on, and 5 minutes off, permitting sufficient nutrient along with the necessary root areation. At the lower end of the tube, the solution flows into a return gutter and back into the reservoir. At approximately 8-day intervals, the solution is flushed and replenished. Virtually all the supply mains, fresh water, nutrient supply, return gutters, and evaporative cooling supply lines are below grade.

Each unit requires about 225 gallons per day of irrigation water to supply plant needs. This is less than 10% as much water as is required for field crops and about 1/2 of the water required for other hydroponic systems that use a growing medium. At the 205-unit level, 32 gpm will be required for the irrigation and 25 gpm for the evaporative cooling system. Total project usage would be 57 gpm or an average of 92 acre-feet per year. Water is supplied by an irrigation well on the northeast corner of the property, drilled to a depth of 110 feet and producing 100 gpm.

Ventilation and cooling within the greenhouse is provided by twin 42-inch exhaust fans mounted in the front, and a horizontal evaporative cooling system mounted in the rear of the greenhouse. When cooling is required, a control thermostat actuates a recycling pump that irrigates the cooling pads while the exhaust fans draw outside air across the wet cooling pads and through the greenhouse. The ventilating and cooling system is designed to replace the entire air capacity of the greenhouse 36,000 cubic feet every minute, when required. Humidity control is provided by motorized shutters which control the flow of outside air into the greenhouse.

Two Modine PT2540s, each delivering 12,500 CFM, are suspended from the rigid steel framework at each end of the house. The geothermal fluids are circulated through each heater. The heat removed from the geothermal fluids is distributed through a series of polyethylene convection tubes. The main heating tube is 10 feet above grade, attached to the rear heater, 24 inches in diameter with 2-inch holes punched in the lower hemisphere every 20 inches to distribute the heat evenly. Five smaller tubes (9-inch diameter) are positioned between the growing tubes at plant level, with perforation every 16 inches. Although the two heater fans run continuously for air circulation, the hot water delivered to the heater coils is controlled by motorized valves which are activated by thermostats positioned in the center of the house and vertically adjustable to fruit level. A 3° differential in the settings of the heating thermostats provides for an even heat flow. With the valves in the open position, the geothermal water passes through the heater coil at a design pressure of 25 psi. Maximum hot water usage rates during the coldest periods are estimated to be 10 gpm per house. After passing through the coils with a design temperature drop of 70°, the effluent flows into a 6-inch return main. Once the effluent has passed through the heater, it is in a free-flow system with no further energy requirements. It is piped for 1,280 feet and allowed to flow into an existing ditch thereafter, where it is made available for range cattle. Eventually, it flows underground into Honey Lake, an alkali sink devoid of aquatic life.

Marketing for the Honey Lake Project is arranged by C. L. Stratton and Son, the largest produce brokers in Los Angeles. Stratton has the responsbility of selling all produce from the project, arranging for trucking from Wendel and assisting in market expansion and product identification. Each cucumber is individually wrapped in shrink film to reduce dehydration and labeled with the Honey Lake Hydroponic Farms Label. The tomatoes are individually picked, labeled, and packed in Pan-a-Pac trays to insure they arrive at market with a minimum of damage.

Labor for the project is under the direct control of the Resident Manager. There is one unit manager for each 15 houses, and approximately two technicians for every three houses. Additional personnel are required for packing operations, maintenance, spraying and complex support. Total labor force at the 205-unit level is estimated to be approximately 150 employees.

An old Magma Power Company well drilled in the early sixties to a depth of 627 feet is totally cased with 12-inch (upper 400 feet) and 8-inch (lower 225 feet) perforated casing. Pumping requirements are met with a 40-hp submersible turbine pump specially designed by Valley Pump (St. Louis) for this application. Surface temperature of the produced water is 206°F and preliminary pumping tests indicate that the well should have a sustained pumping capacity of about 300 gpm. The well is located 175 feet from the first greenhouse, and is presently connected to the "in-house" supply system by a 4-inch transit main buried 36 inches below grade. Beginning in Phase II, the geothermal water will be first passed through an absorption refrigeration unit and then into the greenhouses.

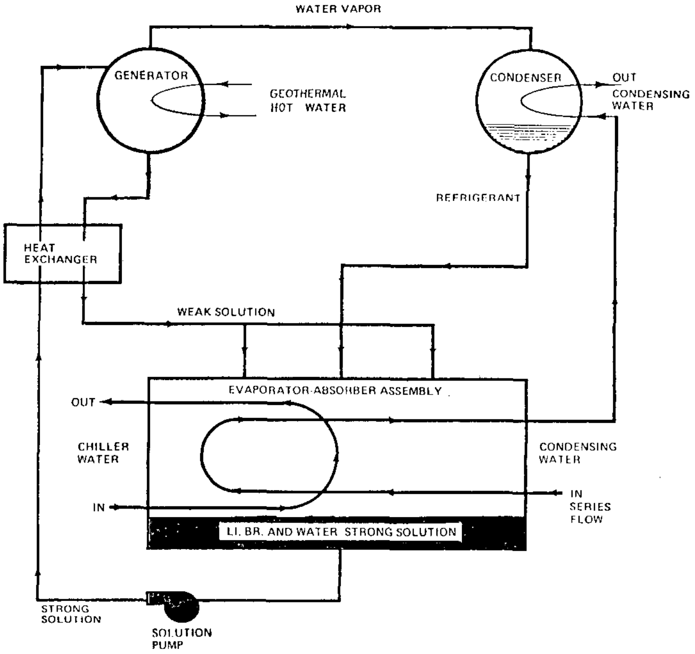


Figure 4. Absorption Refrigeration Cycle (Source: Arkla)

The geothermally operated absorption refrigeration unit will be installed in a cool room designed to maintain the harvested and packaged fruit and vegetables at about 55°F. Hot water with a design temperature of 190°F will be pumped from the geothermal well to the generator section of the refrigeration system (Figure 4). The effluent water, at 182°F will then be pumped into the geothermal system for use in the greenhouses. All heat energy absorbed in the refrigeration unit via the generator and evaporator sections must be ultimately rejected through the absorber and condenser sections. This project will use a spray pond to reject waste heat into the atmosphere by evaporative water cooling. The unit (Arkla WFB300) has a design rating to 20 tons of refrigeration capacity.

Preliminary cost studies indicate that although the geothermally energized refrigeration unit will have an initial capital cost approximately $3,000 greater than an electrically powered unit, the cost of energy used will result in a savings of $8,352 per year (based on 3.86¢/kwh, 50% cooling utilization and 3-phase 230V power), demonstrating that the capital cost differential could be recovered in the first year of operation.

Alternate space heating systems have been studied to serve as a basis for comparison with the geothermal system. Assumptions were that each system would be required to provide heat 1/3 of the hours each year, BTU requirements would be identical, and the system's cost would be amortized over 25 years at 10%.

SUMMARY - ALTERNATE SPACE HEATING SYSTEMS

System	Capital Cost of Installation	Yearly Fuel Costs	Yearly cost of fuel and amortization	
			Total	Per Greenhouse
1. Central Boiler-Woodwaste				
a) As retrofit system	$1,100,000	$220,752	$ 341,939	$1,668
b) As an original installation	1,677,770*	220,752	405,592	1,978
2. Central Boiler-Propane				
a) As retrofit system	200,000	981,120	1,003,154	4,893
b) As an original installation	777,770*	981,120	1,066,807	5,204
3. Individual Propane Heaters	282,900	883,008	914,175	4,459
4. Geothermal System	637,520	34,928	105,164	513

*Capital costs of the two central boiler systems, had they been used as the original installation instead of the geothermal system, would have included the ocst of the hot water delivery system ($275,600) and the cost of Modine hot water heaters ($302,170).

Table 1.

Using the above criteria, four systems were analyzed. The first two systems utilize the same heaters and hot water distribution system as the geothermal system being installed. Either of these two systems could, therefore, be installed on a retrofit basis to supply heat. The third system is an alternate to the geothermal system that would require a propane delivery system as well as propane heaters in each structure. The fourth system is the geothermal system actually being installed. Table 1 summarizes the analysis.

The Honey Lake Project, as seen in the foregoing, is a large-scale application of geothermal energy in a field that has traditionally been the victim of large overhead expenditures in the form of heating costs. The use of geothermal energy at Honey Lake, in a direct application, should provide a basis of experience upon which to draw information and ideas for future developments.

DIRECT USE GEOTHERMAL ENERGY WHAT PRICE?

By Charles V. Higbee
Geo-Heat Utilization Center

The price tag for direct use geothermal energy involves so many variables as to make the problem seem insoluble. The stock economic answer is "The price for geothermal energy is that price which is agreed upon between the supply and the demand." While this may be true in the final analysis, it fails to expound on the major factors that should be considered when trying to formulate a reasonable starting point for the cost of direct use geothermal energy. This article addresses itself to that task.

Unlike conventional fuels, the value of geothermal energy varies widely with the resource. One could question this comment stating that oil wells or coal mines vary greatly also, but these fuels can be sold on the open market from many different resources at a price that will recover these widely varying costs. Direct use geothermal energy must be priced at the resource for a demand that is in the immediate area. Pricing for a specific geothermal resource with specific users can be broken into four major categories: 1) the capital investment to develop the resource, 2) the cost of delivering the resource to the user of users, 3) the cost of maintaining the system for its economic life, and 4) the savings or cost benefit realized from utilizing the resource.

1) Capital Investment to Develop the Resource

In the development of a geothermal resource there are extremes in drilling cost related to geographic location, type of drill rig required, existing drilling conditions, well depth required to encounter the resource, and the probability that a resource will be found with sufficient temperature and flow to be usable. Some resources seem to yield a production well with every drilling; others require several drillings to obtain a single production well. Therefore, the probability of encountering the resource is a major factor and the price of energy would vary greatly depending on whether the supplier or the user bears this risk.

A number of users demand an uninterruptable source of energy. This requires 100% redundancy which could nearly double the capital investment required. Typically, the supplier would like 100% utilization of the resource on a continuing basis, while the user merely wants to satisfy his existing energy requirements as they occur. This dilemma results in a resource developed to supply peak demand with an average usage rate that may be as low as 10% of the resource available. Some compromise here seems inevitable. The supplier might consider several users whose seasonal demands occur at different times in order to better utilize the resource. The user should consider paying a premium if he expects a dedicated resource to supply peak demand with a low average rate of consumption. In many instances, conventional fuels are used in parallel with the geothermal resource to provide peaking. It goes without saying that many utilities hesitate to offer energy during peak demand periods of these periods occur at the same time that their regular clients consume maximum energy. Therefore, it is suggested that any peaking system utilize conventional fuel that can be stored on site, such as oil, propane or coal.

2) Cost of Delivering the Resource

Well head pumping costs vary greatly, depending upon the resource. Some geothermal resources have artesian flow in excess of 1,000 gal/min. Others with a high static water level require very little pumping. Still others have either low static levels or severe drawdown in production which drastically increases pumping costs.

Transmission lines require costly expansion joints and insulation is necessary to avoid heat loss. Transmission lines placed in concrete conduit have a high initial cost, however, such a system increases the life of the transmission line and lowers maintenance and replacement costs. Uninsulated pipe is less expensive but loses considerable energy as distance increases. Costs of transmission lines vary from $10 to $80/ft. Therefore, the distance from the well head to the user and the type of transmission line installed is another major cost factor. In this regard, if the well owner provides the transmission line, the temperature of the resource should be measured at the point of delivery. If, on the other hand, the user designs and pays for the transmission line, temperature should be measured at the well head. This method would encourage the design of optimum transmission lines, depending on the temperature of the resource versus the temperature required by the user.

3) Costs of Maintaining the System

Water quality greatly influences maintenance costs. Water which is excellent quality (low in chemical content and dissolved solids) can be pumped directly through the system. As water quality deteriorates, maintenance and replacement costs increase, more elaborate heat exchangers are required, and efficiency drops.

4) Savings or Cost Benefit Realized From Utilizing the Resource

The annual savings resulting from the application of direct use geothermal resources is largely dependent on the amount of energy available and the amount of energy extracted in the conversion system. The amount of energy available is related to the temperature and production rate or flow rate of the resource. Many wells yield only sufficient flow to heat a small residence and are rarely economically feasible. Conventional hot water heating systems typically supply temperatures of 200°F to 210°F and have a ΔT (change in temperature, or heat extracted) of 20°F. Many of these systems are overdesigned and could function with 180°F and 160°F supply temperatures. Assume geothermal water is supplied to such a system at 210°F with a 10°F approach temperature in a plate heat exchanger. The user could probably obtain a 40°F ΔT in the heating system. Compare this to a supply of 190°F water with a 10°F approach temperature in the heat exchanger. The user could only obtain a 20°F ΔT which would increase the flow required and consequently the pumping costs. A supply of 170°F would be useless without expensive retrofit costs in the heating system.

Warm Springs Water District in Boise, Idaho, provides an excellent example for analysis of cost benefit. The district sells 170°F water at a price of \$0.45/100 ft^3. For a heating system extracting 20°F, the cost per million BTU is \$3.69, which exceeds the current cost of natural gas. One of the primary users of this energy has designed a space heating system which extracts 57°F resulting in a cost of \$1.30 per million BTU. This cost provides the user more than 50% savings over the cost of natural gas. It is very likely, however, that the user's cost could be reduced by over half again by drilling his own well.

Given the variables involved in pricing geothermal energy for direct use, the only viable pricing formula would be one which would consider total capital investment, annual operating and maintenance costs, and some estimated life of the system. Using the cost of capital, these costs could then be calculated to arrive at an annual equivalent cost, which could then be subtracted from the annual equivalent benefit. With the rapid inflation of conventional energy, it might be more appropriate to project costs and savings cash flows by year over the life of the project and calculate the annual savings. Either method would require forecasting of inflation rates for conventional fuels and cash flows would have to be adjusted as these rates vary from year to year with the rates that were forecast. The supplier and user can agree on some percentage split of the cost savings.

Many resource owners try to compare geothermal energy to conventional energy when calculating the annual savings. Although this would appear to be an equitable starting point, it is the opinion of this author that it would be a serious error to tie the cost of alternative energy to the rapidly inflating costs of conventional fuels. If the cost of geothermal energy is maintained at the same cost as conventional fuel, there is no incentive for users to seek this energy until conventional fuel supplies are exhausted. Owners of geothermal resources are not sitting on oil wells. They cannot barrel it and ship it. They cannot transport it over hundreds of miles of transmission lines. They must find a user in the same geographic location and commit that user to their resource.

The national economic inflation rate is greatly influenced by the inflation rates of conventional fuels. It certainly seems appropriate to permit geothermal energy to inflate at the economic inflation rate, allowing for increases in electrical pumping costs, labor and maintenance. Such a pricing formula would hopefully provide the incentive to encourage potential users to seek geothermal resources to avoid the rising costs and increasing scarcity of conventional fuels.

ONION DEHYDRATION

By John W. Lund

Geo-Heat Utilization Center

The food processing industry has many possibilities for the use of geothermal energy to satisfy their energy demand. This is especially true in direct application such as for drying or dehydration. Onion dehydration is one specific area of interest, and with the recent dedication o the plant at Brady Hot Springs, Nevada, the interest is a reality. The Brady project, funded in part by a Federal Program Opportunity Notice, is operated by Geothermal Food Processors, Inc.

Onion dehydration was studied by the Geo-Heat Utilization Center in a recent agribusiness study of the Klamath and Snake River Basins in Oregon. A description of this study is as follows

General Description

All onions for processing are grown fro[illegible]pecific varieties best suited for dehydration. Specific strains of the Creole Onion, Southport Globe

Onion, and the Hybrid Southport Globe were developed by the dehydration industry. They are white in color and possess a higher solid content which yields a more flavorful and pungent onion.

Onion dehydration involves the use of a continuous operation belt conveyor using fairly low-temperature hot air from 100°F to 220°F. The heat originally was generated from steam coils, but now natural gas is more popular. Typical processing plants will handle 10,000 pounds of raw product per hour (single line), reducing the moisture from around 83% to 4% (1,500 to 1,800 pounds finished product). These plants produce 5 million pounds of dry product per year using from 0.15 to 0.20 therms per dry pound produced (+0.06 therms of electrical energy), or 4,000 BTU per pound of water evaporated.

An example of one type of processing equipment, the Proctor dehydrator, is a single-line unit 212 feet long and 12.5 feet wide, requiring 36,500 ft^3 of air per minute and up to 40 million BTU per hour. Due to the moisture removal, the air can in some cases only be used once, and thus is exhausted. Special silica gel--Bryair, desiccations units are required in the final stage. Approximately $200,000 in fuel are thus used for a single-line dryer in a year's operation (180 days).

In general, four stages (A through D) are preferred; however, if the ambient air himidity is below about 10%, stage D can be eliminated. This is not felt to be possible in the Klamath Basin. Also, temperature and number of compartments in each stage may vary. The details of each stage of a typical process are as follows:

Stage	Size (length)	Air Temp. °F	Air Volume CFM*	Depth of Onions	Moisture Content
Curing bins	100 x 100	100	variable	variable	
transfer					80-85
A (4 comptmts.)	73 ft	190-220	230,000	4"	
transfer					20-25
B (2 comptmts.)	25 ft	155-170	60,000	12"	
transfer					12-16
C (2 comptmts.)	25 ft	135	70,000	30-40"	
transfer					6-8
[illegible] 2 comptmts.)	25 ft	120	20,000	60-70"	
transfer					4-5

*Some air may be recirculated depending upon moisture content.

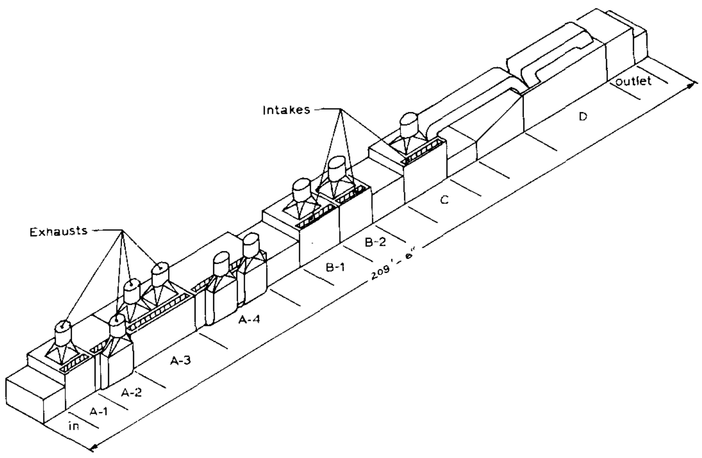


Figure 1. Single-Line Onion Dehydrator.

Power Production and Energy Requirements

The energy requirements for the operation of a dryer will vary due to differences in outside temperature, dryer loading, and requirement for the final moisture content of the product. A single-line Proctor dryer handling 10,000 pounds of raw product per hour (1,500 to 1,800 pounds finished) will require about 5.0×10^8 BTU/day, or for an average season of 150 days, 7.6×10^{10} BTU/season, using approximately 0.15 therms per pound of dry product. This is estimated to cost from 4¢ to 5¢ per pound of finished product.

The energy is provided by natural gas; air is passed directly through the gas flame in stages A and B, and over steam coils in stages C and D The steam coils are necessary to prevent turning of the onions in the last two stages.

In addition to the heating requirements, electrical energy is needed for the draft and recirculation fans and small amounts for controls and driving the bed motors. Total electric power required for motors is from 500 to 600 hp, or about 1×10^4 KWh/day, or 2×10^6 KWh/season. This amounts to 0.01 therm per pound of finished product and increases to about 0.06 therm per pound when all electrical requirements are considered.

Stage D, supplying desiccated air with a Bryair unit, reduces the moisture content of the product to a point below that of the ambient air. The unit is divided into two sides: the process side, which supplies desiccated air to the dryer after it has been passed through silica gel beds, and the reactor side in which heated air is passed over the silica gel beds in order to remove the moisture which had been absorbed in the process side.

The total energy requirements, using natural gas as a fuel, varies from 21 to 26 x 10^6 BTU/hr depending upon the ambient air varying from 65°F to 40°F. Air flows depend upon temperature and amount of recirculated air--which could only be estimated.

Geothermal Applications

Using a specific example, a design was made to convert a Proctor dehydrator to geothermal energy. Using a 20°F minimum approach temperature between the geothermal water and process air, a well with 230°F water is required.

The first-stage air temperature can be as low as 180°F; however, temperatures above 200°F are desirable, as indicated by people in the industry.

Figure 2 indicates Design I using 230°F water. The line has to be split between compartments A-1 and A-2, since both require 210°F air temperature. A total of 900 gpm is required. The Bryair desiccator requires 300°F on the reactor side, thus only half of the 1.0 x 10^6 BTU/hr energy requirements can be met geothermally. Geothermal heat will be used for preheating to 175°F, with natural gas or propane used to boost the air to 300°F. The waste water from the Bryair preheater has a temperature of 192°F, thus this could be used for space heating, greenhouses or other low-temperature energy needs. The waste water would be returned by an injection well.

Design I considers the ambient air to be 40°F (worst conditions). An alternate design considers a 65°F air temperature which will reduce the required flow to 760 gpm. A third design,

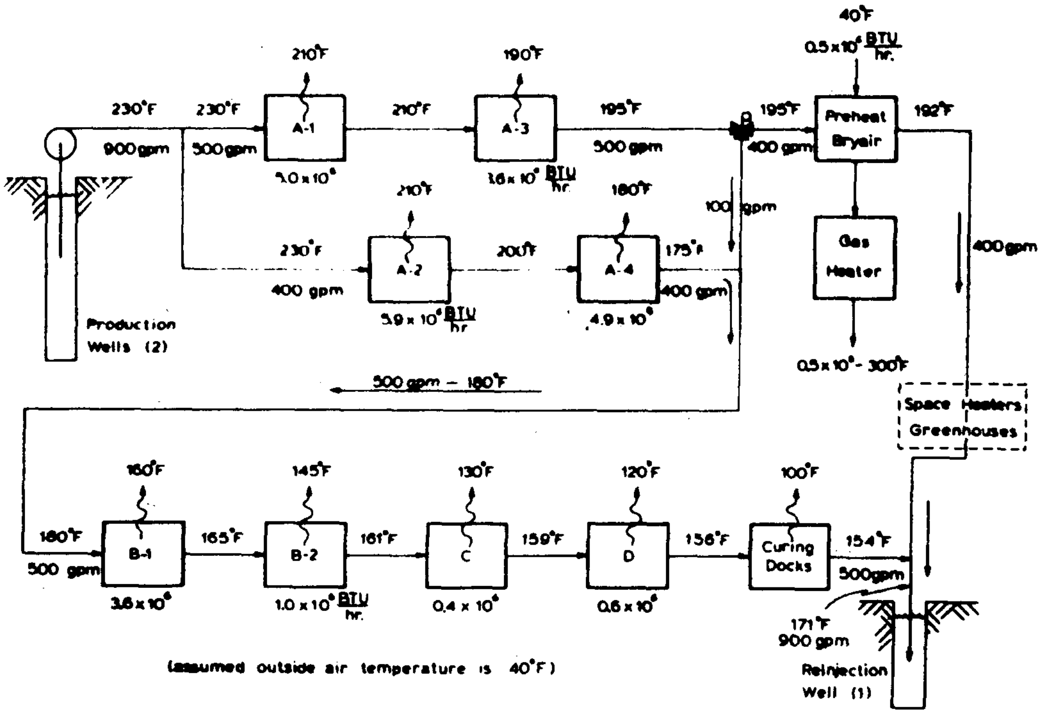


Figure 2. Design I—Single-Line Onion Dehydrator Using 230°F Geothermal Water and 40°F Ambient Air.

using 220°F geothermal water and 200°F air temperature for compartment A-1 sould require 975 gpm.

In compartments A-1, A-2, A-3 and A-4, four finned air-water heat exchangers in parallel would be required to satisfy the energy requirement and water velocity flows. The remaining stages would require from one to two heat exchangers in each compartment, depending upon the energy requirements.

If lower-temperature geothermal waters were encountered (below 200°F), then not all of the energy could be supplied to Stage A geothermally. Geothermal water would then be used as a preheater, with natural gas providing the energy for the final temperature rise.

Economic Analysis

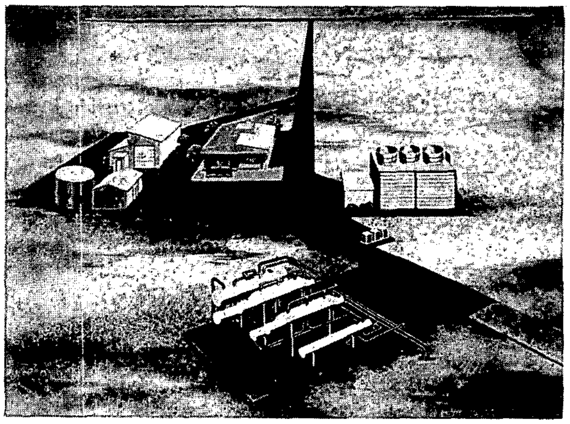
The economic analysis of onion dehydration does not consider investment tax credits on tangible costs, tax reduction due to write-off of intangible costs, depletion allowances, or tangible asset depreciation due to the fact that this project involves starting new facilities which could take up to 5 years to pay back the additional capital investment as compared to conventional systems. It is not known what kind of ownership or the tax structure that would be involved, nor what method of depreciation would be appropriate. Therefore, the analysis is ultraconservative and all federal tax incentives for capital investment and use of geothermal energy would increase the profit margins considerably over these figures. The cost analysis for an onion dehydration plant was done by investigating the cost difference in establishing a dehydration plant using conventional fuel (natural gas) versus geothermal energy. A plant and well layout was assumed for a typical operation. Two 2,000-ft deep production wells producing 500-600 gpm were used to supply geothermal fluid to the plant. The buried supply lines were insultated asbestos cement pipe. Well spacing was assumed to be 1,000 feet and one injection well was used.

In areas such as the Klamath Basin, the onion harvest season is only two weeks. Break-even analysis indicates that a dehydration plant would have to operate 180 hours per year in order to make the geothermal system competitive with natural gas. Assuming a two-week processing supply of onions, 24-hour operation for 14 days would be 336 hours of operation annually which would provide a $31,454 advantage to the geothermal system. Storage facilities could extend the processing period greatly and starting sets in greenhouses would provide an even longer processing season. It should be noted that the return fluid is very suitable for a large 15-acre greenhouse complex.

References

[1] Lienau, Paul J., et al., "Agribusiness Geothermal Energy Utilization Potential of Klamath and Western Snake River Basins, Oregon," (Contract No. EY-76-S-07-1621, DOE), Geo-Heat Utilization Center, Klamath Falls, March, 1978.

EG&G STARTS DEPARTMENT OF ENERGY GEOTHERMAL POWER PLANT PROJECT



EG&G GEOTHERMAL POWER PLANT PROJECT FOR D.O.E IN IDAHO. Architect's rendering depicts $6.68 million Raft River Valley Thermal Loop Facility for 5 MW pilot power plant in Idaho. Now being built, this EG&G-supported complex will perform geothermal power production experiments for the U.S. Department of Energy (DOE). In a binary cycle loop, geothermal water from the earth's depths will heat the isobutane driving fluid for a $1.2 million turbine generator. Construction, under the management of EG&G Idaho, Inc., EG&G's largest subsidiary, will be completed by early 1980.

TECHNICAL ASSISTANCE PROGRAM

By Gene Culver
Geo-Heat Utilization Center

OIT has recently entered into a contract with DOE/DGE to provide technical assistance for the development and commercial utilization of geothermal energy for space and process heating, aquaculture and agriculture in the states of Alaska, Washington, Oregon, California and Hawaii. The contract currently extends through July 14, 1979, and is being managed by Gene Culver.

Gene has given up his position as Department Chairman of Mechanical Engineering Technology and will devote full time to the project. He will be assisted by Paul Lienau, John Lund, Charles Higbee, William Johnson, and others as requested to provide a total of approximately 1 3/4 man years of effort.

Under the terms of the contract, the program can provide: on-site investigations, limited resource evaluation studies, help in matching the resource with applications, preliminary cost and economic analysis, information on institutional factors, help in materials and component selection, conceptual designs, consultation with consulting engineers or designers involved in final design, and provide technical personnel for informational seminars for trade and technical associations, speaking engagements, etc.

OIT's philosophy is that the program is intended to stimulate and accelerate the use of geothermal energy to replace fossil fuel by providing as much help as we can when and where it's needed. On the other hand, we don't intend to compete with consulting engineers and geologists by providing detailed plans, specifications, or other services when qualified private consulting is available.

Simply stated, we'll show you how, help you get started, and well down the road, turn you over to someone else for the final design, and show you how to make a profit to boot.

For further information or requests for assistance under the program, write to: Gene Culver Geo-Heat Utilization Center, Oregon Institute of Technology, Klamath Falls, Oregon 97601, or phone: (503) 882-6321.

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Quarterly Bulletin

OREGON INSTITUTE OF TECHNOLOGY – KLAMATH FALLS, OREGON 97601

Vol. 3, No. 4

Supported by the Oregon Department of Energy and
Pacific Northwest Regional Commission

July 26, 1978

A Quarterly Progress and Development Report
on the Direct Utilization of Geothermal Resources

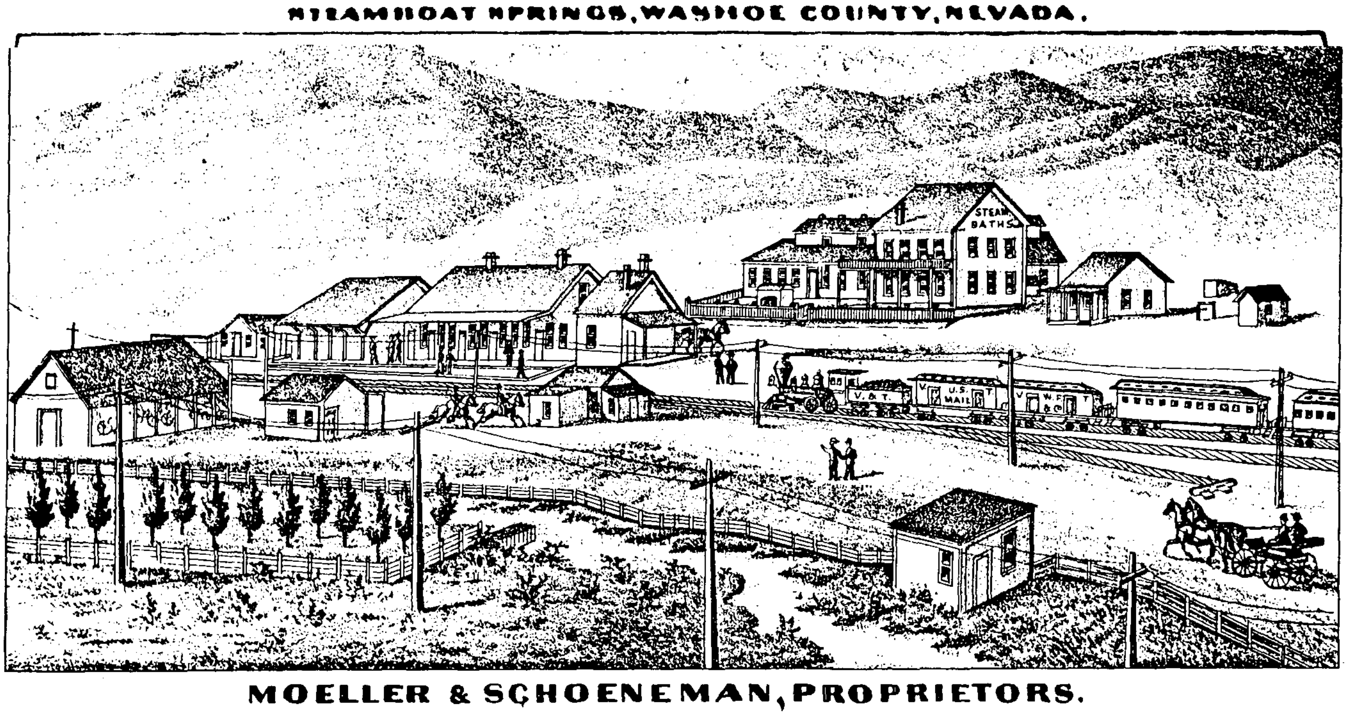

Figure 1. Early Woodcut from History of Nevada—1881

STEAMBOAT SPRINGS, NEVADA

By John Lund
Geo-Heat Utilization Center

Ten miles south of Reno, on U.S. 395 near the junction of the road to historic Virginia City, is Steamboat Hot Springs, a popular stop for travelers since the mid-1800s. Legend has it that Mark Twain named the geothermal area because it looked and sounded like a chugging Mississippi River paddle-wheeler. It is said when he first saw the stream rising from the ground he exclaimed, "Behold! A steamboat in the desert." Over the years, the area has been used for its relaxing and curative qualities by Indians, settlers, college students and geothermal experts.

A Nevada State Historical Marker near the springs states:

"These natural hot-springs are notable for their curative qualities. They were nationally acclaimed by President Ulysses S. Grant when he visited them in 1879.

"Early immigrants so named them because of their puffing and blowing. Located in 1860 by Felix Monet; a hospital, with adjacent bath-houses was subsequently added by a Doctor Ellis (1861-1862).

"The Comstock mining activities and the coming of the Virginia and Truckee Railroad in 1871, caused Steamboat to become a terminal. Here materials for the

> silver mines were transferred to freight wagons for the steep haul to Virginia City. The completion of the tracks abolished the need for a junction, but its resort popularity was to reach its peak with the bonanza days.
>
> "To its 'fine hotel, commodious dance hall, and elegant bar, came the legendary silver kings, politicos, gamblers, and news chroniclers, escorting the lovely ladies of stage and opera house.'
>
> "With borasca, attendance waned, fire destroyed the luxurious buildings (1901), but the therapeutic waters remained not only for health seekers, but for conditioning athletes—even producing mineral muds sought by cosmeticians and face house owners."

The active geothermal area is located within the north-south trending graben like trough between the Carson and Virginia Ranges at the southern end of Truckee Meadows. Hot springs and other geothermal features occur over an area of about 1 square mile. Dr. Donald White, a research geologist from the U.S. Geological Survey, called Steamboat "one of the outstanding geothermal areas in the world" during a tour of United Nations delegates from 20 foreign countries and the U.S. meeting at Steamboat in 1975. He explained to the delegates this was because evidence at Steamboat indicates it has been geothermally active "more or less as it appears now for one to three million years," making it the oldest-known geothermally active area in the world.

The midbasin location is controlled by faulting more or less parallel to the major mountain-front faults. It is believed that the heat source for the system is a cooling magmatic body at depth.

The quantity of water discharged by the geothermal system is estimated at between 800 and 900 gallons per minute. Recharge is from deep circulation of waters from the mountains to the east and west. The temperatures of the springs vary from 122°F (50°C) to 205°F (96°C)—boiling at that elevation. Temperatures of 367°F (186°C) have been found at depth, with 280°F (138°C) found in one well only 160 feet deep. Steam and geysers are associated with these high near-surface temperatures.

Extensive terrace-forming siliceous sinter deposits have been built up around the natural discharge sites. Associated with these deposits are cinnabar, stibnite, pyrite, and other sulfides. Gold, silver, antimony, mercury, and copper also occur in the deposits, mercury, silica and clay have been mined on a small scale, and an explosives manufacturing firm has used the water as a safe source of heat to maintain the explosives in an easily worked plastic state.

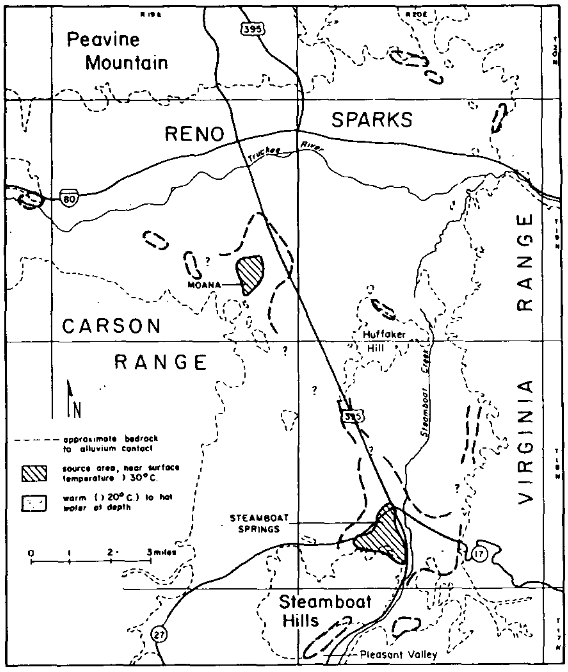

Figure 2. Areas of known thermal ground-water occurrence in the Truckee Meadows.

During the 1950s, Nevada Thermal Power Company considered Steamboat Springs as a possible site for electric power production, however, the minimum temperature (180°C) was not encountered. The water-steam mixture and the high concentrations of minerals also made the site less desirable. Future developments may make the site more attractive. At the present time, space heating of a nearby subdivision is being considered.

Some early comments on the hot springs as reported in the "History of Nevada—1881," is of interest.

". . .these springs are among the greatest natural curiosities of the State. . . . Nature, in an eccentric mood made these springs for the benefit of mankind, and in this, as in others of her wonderful creations succeeded admirably."

"Before reaching these wonderful springs the traveler is notified of their existence and locality by large wreaths of steam that wind in a serpentine manner towards the heavens, visible at a great distance."

"The Virginia and Truckee Railroad runs nearly through the center of this tract, the springs and buildings being on the west side of the road". . . . "The buildings consist of a fine hotel, with twenty rooms, also five cottages containing a like number of rooms. Connected with the main hotel is a bath-room building, containing fifteen separate sets of baths each, a set consisting of a steam bath from a hot sulphur spring, also tub and shower baths". . . . "Fifty thousand dollars in coin has been expended in improvements upon the buildings and land. . ."

"In 1873 Mr. Cullins fell into one of the springs, and was so severely scalded that he died soon after". . . . "In 1876 deposits of sulphur and cinnabar were opened near here . . . large quantities of pure sulphur have been taken from around the springs."

Today, the Steamboat Hot Springs spas are in operation providing "active hot mineral water and steam baths, massage and mudpacks." Manager Tonia Skrabak stresses that the spa features therapeutic supervised treatment providing easing for tired muscles after a tough day of driving. For $3, you can soak yourself in a private mineral bath, or for $6, have a bath and steam. A bath and massage costs $15. A heated mineral pool and cold mineral pool are also available. It is open every day except Monday, from 8 a.m. to 5 p.m. (Sunday, 10 a.m. to 4 p.m.).

The informational brochure from Steamboat Hot Springs states:

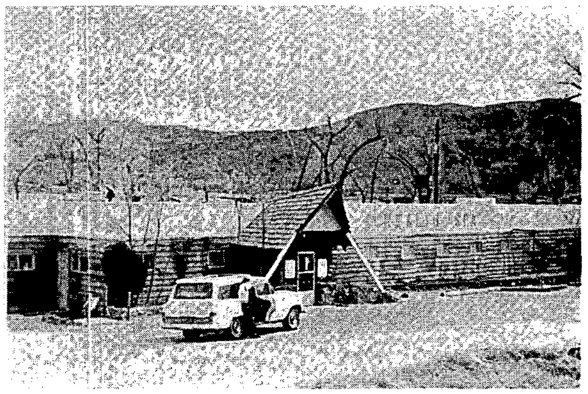

Figure 3. Steamboat Hot Spring Health Spa

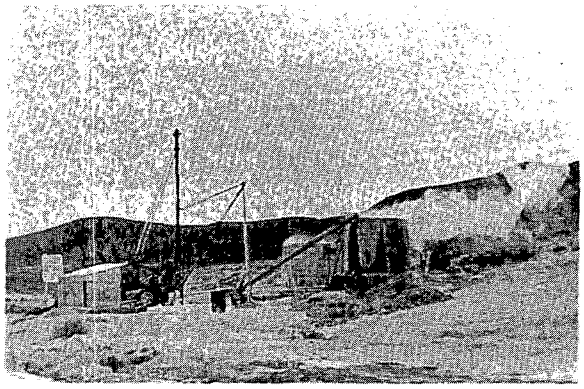

Figure 4. Well and storage tanks for geothermal water used in Health Spa.

"Steamboat Springs water has been known for many years for its remarkable healing power. It has been used successfully to relieve the discomforts of arthritis, neuritis, and intestinal conditions. It is not only the chemical content of the water which is beneficial, but the radiant heat action of the hot water relieves the pain of swelling of bone and joint discomforts. The water stimulates the natural agents of elimination. . . the skin, the bowels and the kidneys. To the excessively nervous individual or those lacking in nervous energy, the effect of the water and vapor baths is to restore normality."

> "The medicinal mud of Steamboat Hot Springs is a soft and creamy substance, bluish-gray in color, and is formed by precipitated minerals of the water. It lies in a 12-foot strata along Steamboat Creek. This mud contains all of the minerals found in the water, plus a substantial amount of gold and silver. The mud is used at Steamboat Springs to reduce the swelling of arthritic joints and for skin conditions, sprains, and muscular discomfort."

The water has a total dissolved solid of about 2400 ppm (mg/1) of which the major constituents are bicarbonate (305), chloride (865), sulfate (100), sodium (653) and silica (293), with a pH of 7.9. Boron (49), hydrogen sulfide (4.7), calcium (5.0), arsenic (2.7), and lithium (7.6) also contribute to the dissolved solid content. Although these chemical constituents suggest the input of water of direct volcanic origin, actual contribution, based on isotopic evidence, is only on the order of 5 percent.

The well supplying water to the spa is fairly shallow, tapping 250°F water. The water is brought to the surface and cooled in large wooden vats, where it is then used for the baths and space heating. Due to the reduction in temperature and pressure, some of the silica and bicarbonates precipitate out, coating the well casing. This requires daily cleaning of the well with a drilling rig.

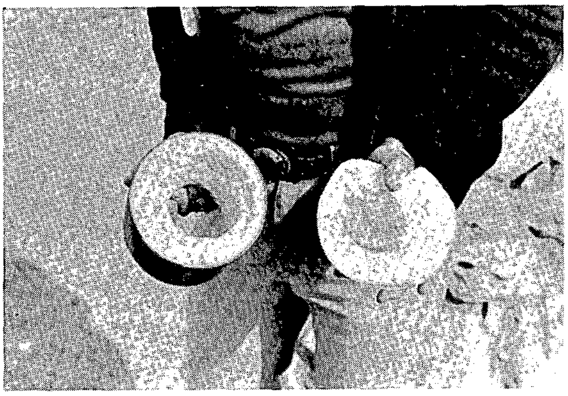

Figure 5. Bicarbonate and silica build-up in well casing from Health Spa.

A trip to the area is well worth the effort, the hot springs and spa are on the east side of the highway and natural fissures issuing steam on a small mound on the west side of the highway. Portions of the area are included in Bureau of Land Management geothermal lease sale area.

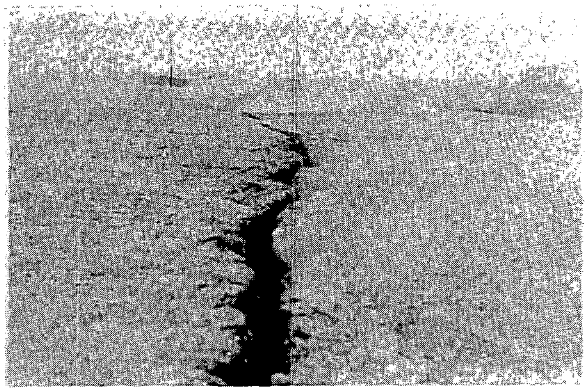

Figure 6. Fissures on west side of highway with geothermal steam issuing from them.

References

1. Bateman, Richard L. and R. Bruce Scheibach, "Evaluation of Geothermal Activity in the Truckee Meadows, Washoe County, Nevada," Nevada Bureau of Mines and Geology, Report #25, Reno, 1975.
2. "History of Nevada—1881,"—with illustrations and biographical sketches of its prominent men and pioneers, reproduction of Thompson and West's edition by Howell-North, Berkeley, California, 1958.
3. Several articles from the Reno Evening Gazette: "Everyone's Flocking to a Mineral Spa," by Tim Anderson, and "Scientists Tour Steamboat."
4. Informational pamphlets and personal conversations with Tonia Skrabak, Manager of Steamboat Hot Springs Health Spa.

KLAMATH GREENHOUSES

By Saul Laskin
Geo-Heat Utilization Center

Geothermal energy, which used to be somewhat of a nuisance at the Jack Liskey ranch near Klamath Falls, Oregon, is now finding commercial application in a new greenhouse venture. Once used for house heating and, after cooling in surface ponds, for stock watering and crop irrigation on the 300-acre ranch, the 195°F water now heats an expanding complex of greenhouses. Construction of the complex began at the end of 1977, and the present crop was planted in April, 1978.

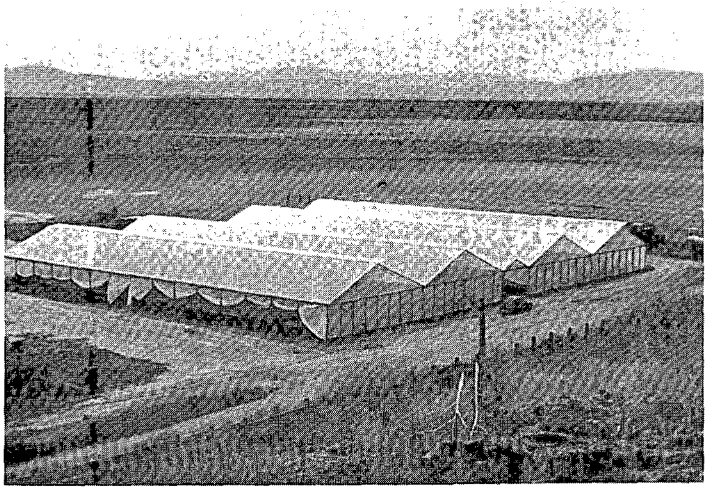

Figure 7. View of the greenhouse complex from the hill in which the water storage tank is buried. Not the roll-up siding.

The operation, called Klamath Greenhouses, is a partnership between Liskey Farms Inc., owner of the property and geothermal resource, and Phil Thorson, who owns Northwest Ground Covers and Nursery in Woodinville near Seattle, Washington. The partners, brought together by the Klamath County Economic Development Association, have established the county's largest greenhouse enterprise.

The complex presently utilizes one of the five geothermal wells on the property and lies just over 800 feet from it. This 12-inch well has a static water level 42 feet below the surface and can deliver 1100 gallons per minute with a drawdown of 20 feet. So far, peak usage has been 800 gallons per minute. Water from this well is pumped up to a tank (salvaged from a tank car) buried atop a hill overlooking the greenhouses. A rod connected to an internal float protrudes above ground from the tank, to visually indicate the water level in the 10,000 gallon capacity tank, and a float switch activates the well pump to charge the tank when the water level drops to a preset point. An emergency generator in the pump house is capable of driving the pump during power failures. A larger well on the property will be used for back-up purposes. This is a 270 foot deep, 24 inch diameter well capable of delivering 5,000 gallons per minute with a drawdown of only 2 feet from the 16-foot static water level.

Water from the tank flows by gravity to the greenhouses, arriving with about a 30-foot head and a temperature ranging from 188° to 190°F. The higher temperature occurs when the well pump is charging the tank.

The complex was designed by Balzhiser and Colvin Engineering, Inc. of Eugene, Oregon. It currently consists of four adjoining houses and a centrally located breezeway. Each house is 42 feet by 150 feet with 10 foot high walls and a peaked roof rising to a height of 21 feet. The breezeway is 15 feet wide and runs the length of the adjoining houses. It is topped by an inflated, plastic roof.

Ventilation is achieved through chain-operated roof vents and roll-up plastic sheeting which covers the periphery of the entire complex. Heating and cooling are now controlled manually but an automatic temperature control system is planned for the future. Expansion of the complex is also contemplated and will be implemented by the addition of breezeways on either side of the structure, paralleling the existing breezeway, followed by the erection of new greenhouses adjoining these added breezeways.

Nineteen tables, each measureing 6 by 41 feet, run the width of each house. Atop these tables rest trays containing the only crop now being raised. This consists entirely of reforestation seedlings, all of which are under contract to the U.S. Forest Service, the Federal Bureau of Land Management and private timber companies. Buyers of the crop are located in Oregon, Washington, and California.

Each seedling occupies its own individual plastic tube in one of the 200-tube trays. They are started from seeds which are inserted by automated equipment into the tubes, along with a special sterilized soil. It takes just 1 square foot of table top to hold 100 tubes, so each table supports about 24,600 seedlings. This amounts to some half million seedlings per house or two million seedlings for the entire complex. The various types being raised are Ponderosa pine, lodgepole, Douglas fir, Englemann spruce, and western larch.

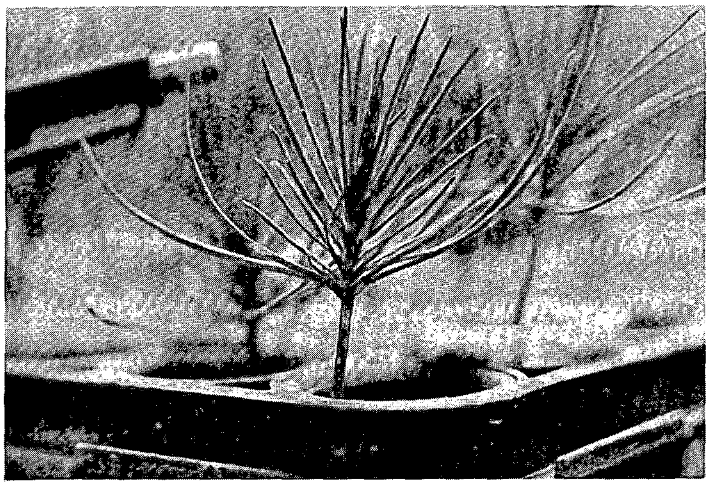

Figure 8. Size of this seedling may be compared to the pen cap.

The production cycle, from seed to the 6 to 8 inch tall end product, will take five to eight months. When full production is reached it is expected that 50,000 to 80,000 seedlings per day will be turned out by a crew of four or five people. This could possibly jump to 200,000 per day with 18 employees. Diversification into other crops is also planned, which could call for employment levels of 40 to 50 year around.

For the present crop, temperatures in the greenhouse are kept between 68° and 75°F during the night, and between 75° and 85°F during the day. A 40 foot long finned pipe runs the length of each table, resting underneath on cinder blocks, carries the heat-providing geothermal fluid. These 1 1/4-inch pipes with their moderately spaced 4-inch fins heat the air by natural convection. They are also placed beneath the rain gutters located in the valley formed by the sloped roofs of adjacent houses to prevent ice blockage. Gravity-driven hot water enters the main supply header at one end of the complex and flows toward the opposite end along distribution ducts. From these ducts, it branches off to both sides at various points to enter series of finned pipes which snake back and forth under the tables. Each branch point delivers heat to a block of six or seven benches. The spent water from each branch empties into a common drain line and is wasted from the house at the end opposite the main supply header. The exiting water must pass over a moderately high loop which serves to prevent emptying of the system when the main supply valve is closed. There are plans to extract additional heat from the spent water by passing it through fan coils, two per house, before it is wasted.

Figure 9. Watering operation in progress.

The rate of heating is controlled by a trial-and-error setting of flow control valves in each heating branch. The system then is simply turned on or off manually by operation of the main valve to full open or full close. With the current arrangement, a 26°F temperature drop of the geothermal water is achieved.

about 3 atmospheres pressure and a temperature of 80° to 97°C.

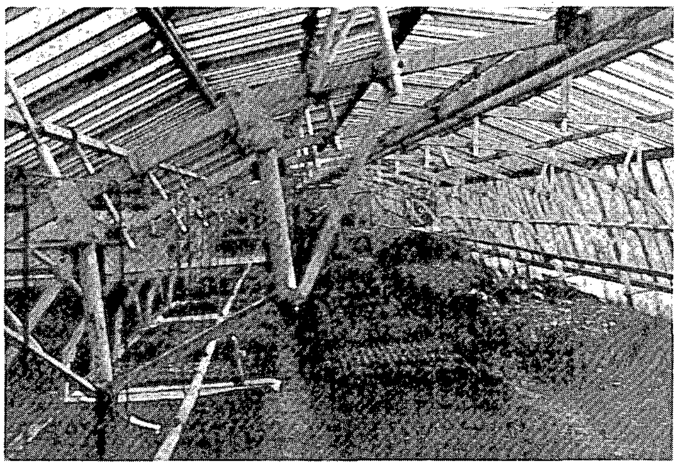

Figure 17. Greenhouse near Szentes where the structural members carry the geo-fluid.

Farther south, near the Yugoslavian border, the city of Szeged has a recent housing project heated geothermally. Since here the water is aggressive (but as yet disposed of on the surface), heat exchangers are used. Scaling occurs in the well lines, but is pretty well understood and handled by acid cleaning during the nonheating season. The University is heated geothermally from a single well. The following photo shows the 3-chamber basin of 1000 m^3 volume for storing and degasifying the geothermal water in Szeged, with the pumping station just below.

The Hungarian geothermal effort is apparently strong, healthy and growing. Dr. Jenõ Balogh is in direct charge of Hungarian geothermal engineering effort. His name should be familiar from his publications in this field. He is about to start reinjection experiments this summer. Near Szeged, he will reinject 60^3m /h of 87°C water into three old dry oil wells about 1.5 km apart, each terminating in a different horizon. With a layer permeability of only 200-300 millidarcies, this will probably require 80-100 atmospheres, which in turn will require about a 750-kw motor to drive the pumps. By this fall, injection data should begin to become available.

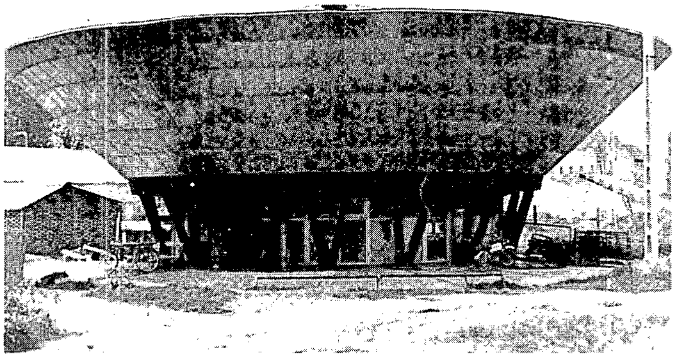

Figure 18. The geothermal fluid storage and degasifying chamber in Szeged.

DOE TO DRILL FIRST GEOTHERMAL WELL ON EAST COAST

The Department of Energy (DOE) has officially begun a major drilling program to locate geothermal energy resources on the East Coast.

East Coast geothermal resources are believed to consist of hot water trapped within rock formations at depths of a mile (1.6 kilometers) or more. It could potentially be drawn to the surface from wells and used to provide heat for buildings or for industrial processes.

A 1,000-foot well drilled at Fort Monmouth, New Jersey, is of about 50 to be drilled along the Atlantic coastal plain this year. The purpose is to measure the flow of the earth's heat. This information will be used to select the most promising site for a subsequent 7,000-foot well that would actually penetrate a geothermal reservoir.

The drilling projects will be conducted for DOE by Gruy Federal, Inc., Houston, Texas, under a $1.9 million contract.

Besides the well at Fort Monmouth, Gruy Federal and its subcontractor, Energy Service Co., will drill at least four more 1,000-foot wells at other sites in New Jersey, before moving the drilling operations successively to Delaware, Maryland, Virginia, North and South Carolina, Georgia, and Florida. The drilling should be completed within 12 months, but the scheduled program may be extended for an additional 12 to 24 months to drill 7,000-foot wells at several additional sites.

Most of the wells will be drilled on public lands. The sites have been selected by scientists for Virginia Polytechnic Institute and State University (VPI SU) in cooperation with the appropriate state agencies and the United States Geological Survey (USGS). VPI SU has been conducting detailed studies of potential East Coast geothermal sites under contract to DOE's Division of Geothermal Energy.

VPI SU will measure heat flow in each of the 1,000-foot wells, and still cooperate with geoscientists from state agencies in analyzing data from the wells. The USGS will make special geophysical measurements at some of the 1,000-foot well sites.

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conversion) and require 362 operating hours annually in order to break even with a fuel oil-fired system. By using geothermal energy, the harvesting and processing costs would be cut from $20 to less than $16 per ton providing a 13.6 percent profit margin per ton of product. A plant producing 10,000 tons annually would require five years of operation to pay back the capital investment costs of a geothermal system at 9 percent per annum.

A facility that has an annual output of between 25,000 and 30,000 tons of pellets would realize a savings of $100,000 per year over a conventional plant.

GEOTHERMAL IN HUNGARY

By A. M. Stone
Johns Hopkins University

Two thousand years ago, adventurous Romans bathed in and extolled the wonders of the marvelous natural hot springs on the banks of the great Danube River. Two hundred years ago, the medicinal virtue of Hungarian geothermal waters was already famous and a number of balneological institutes, founded in the 18th century, survive today.

Eastern Hungary overlies the Pannonian Basin, a Pliocene sandstone. Western Hungary overlies the Danubian Plain, which is of Triassic age and mostly dolomite in composition. Geothermal activity to date centers on the Pannonian Basin. There are more than 400 geothermal wells, averaging 200 gal/min per well. Basically, although there is a number of usable aquifers, the most productive are in the 2000 m depth range. The usual well casing sequence is followed, with 6 5/8" the final size.

The following figure is a hydro-geothermal province map of Hungary. The Pannonian Basin possesses gradients up to twice the "normal" value.

The Ministry of Building (Mélyépterv) is the responsible agency for geothermal heating, which has been prominent in Hungary since the 1930s and 1940s. The goal is 100,000 to 200,000 dwelling units (equivalent) heated by geothermal waters. At the moment, there are 6,000 dwellings so provided in Budapest itself, as well as greenhouses, apartments, hospitals and so on in other areas of eastern Hungary. In fact, they have the largest greenhouse complex geothermally heated in all of Europe.

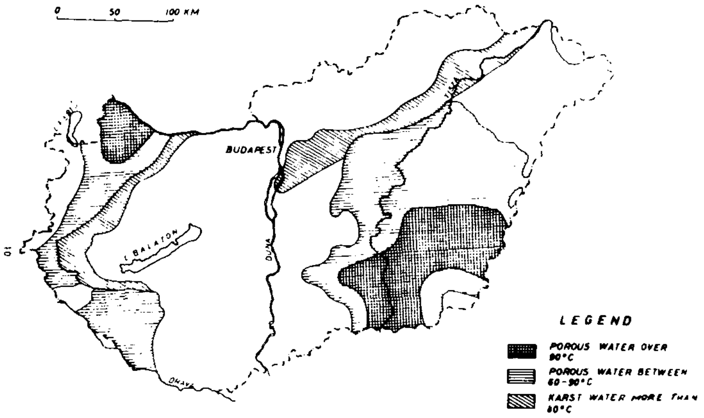

Figure 16. Distribution of Hungarian Geothermal Resources

The over 135 thermal baths pervade Hungary and are an important source of foreign exchange since treatment for the relief of rheumatic and arthritic conditions by geothermal fluids is well advanced in Hungary and well advertised in the world.

In southeastern Hungary, near the town of Szentes, geothermally heated greenhouses are fed from a 2400-m aquifer. The greenhouses cover 25-30 acres and additions are underway. Figure 2 shows the interior of a greenhouse at Szentes, where the structural members serve to pipe the geothermal water and to act as the heat exchange medium. For all of Hungary, about 125 acres of greenhouses are heated geothermally. The capital costs of the heating system are comparable with those of oil-fired systems, but obviously the lower operating costs make the installations attractive. The estimate is that operating costs are 20 to 30 percent of the cost of oil or natural gas heating. Well spacings are 1 to 2 km; reinjection is not yet practiced which may be the reason that flow rates diminish with time. The geothermal fluid arrives at the surface at

ALFALFA DRYING WITH GEOTHERMAL ENERGY

by Paul J. Lienau
Geo-Heat Utilization Center

Oregon Institute of Technology, Department of Geology and Mineral Industries, and the Department of Economic Development, recently completed an investigation of using geothermal energy for Agribusiness applications in Klamath and Western Snake River Basins, Oregon. In addition to resource assessment studies in the two areas, engineering and economic studies were completed for six industries in the Basins. Alfalfa drying with Geothermal Energy will be the first of the industries to be summarized in the Bulletin.

There are several reasons for fuel drying the final alfalfa product instead of complete sun wilting. Fuel drying produces a harder and heavier pellet, and retains a greater percentage of Vitamin A, and xanthrophyll. Ideally, 100,000 to 125,000 international units of Vitamin A and xanthrophyll are needed; however, this can only be achieved by complete fuel drying. By field wilting and then fuel drying, they can retain a minimum of 17 percent protein and an average of 55,000 international units of Vitamin A (xanthrophyll is assumed to be at about the same level as Vitamin A). In addition, a bright green color is maintained that appears to improve the sellability of the product. Complete dehydration at this time does not appear to be economical and no new plants are being built along this line.

A plant that uses a combination of field wilt and fuel drying will produce 80 to 110 tons of pellets per eight-hour shift. The alfalfa is purchased (or costs the company) $45 to $55 per ton standing (at 12 percent moisture), and costs an additional $20 per ton to harvest and pellet. Of the total cost, $2.50 is due to the actual drying, or about 6 gallons of fuel oil per ton of alfalfa. This fuel usage can range from 5 to 30 gallons per ton depending upon the moisture content and ambient conditions. The total cost of pellets is $65 to $75 per ton, of which about $5 per ton is the margin of profit. Thus, any fuel savings by converting to geothermal would have a significant percentage effect on the margin of profit.

A geothermal energy conversion design was made for the combination field wilt and fuel drying process using the rotary drum type dryer as shown below.

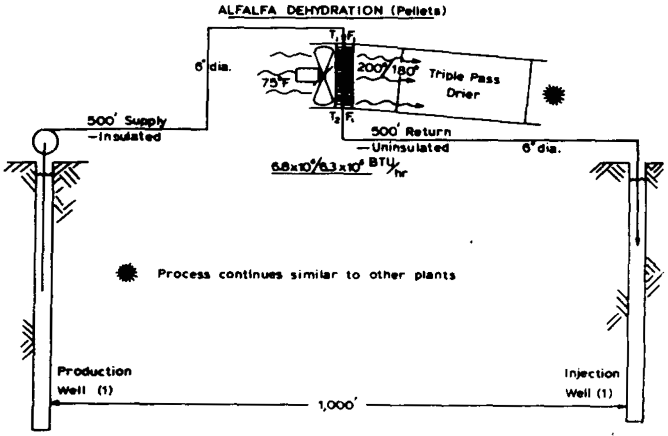

Figure 15. Rotary Drum Alfalfa Dryer

Using a 200°F air drying temperature fo the triple-pass dryer would require at least 220°F geothermal water. Assuming a combir tion of ambient air and 25 percent recycle ai at 75°F and 50,000 ft^3 per minute, 6.8 x 10^6 Bth/hr would be required. The following cc binations of flow rates and temperatures cou be used to provide the necessary energy:

Geo-Water Flow, gpm	Geo-Water Incoming temp, °F	Waste Geo· Water temp,
500	220	193
300	220	175
500	200	175
300	200	158

One well could then provide the require flow, with one injection well for the wastewa Due to the high energy requirements and flo rates, a four-pass fixed water-to-air heat e changer would be required.

Annual equivalent fixed costs for the ge thermal system are $16,583 (67 percent prod tion, 9 percent delivery, and 24 percent

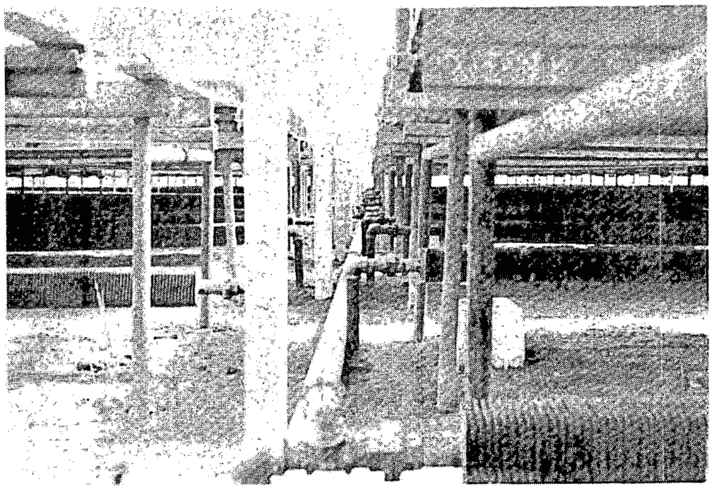

Figure 10. Under-table heating pipes.

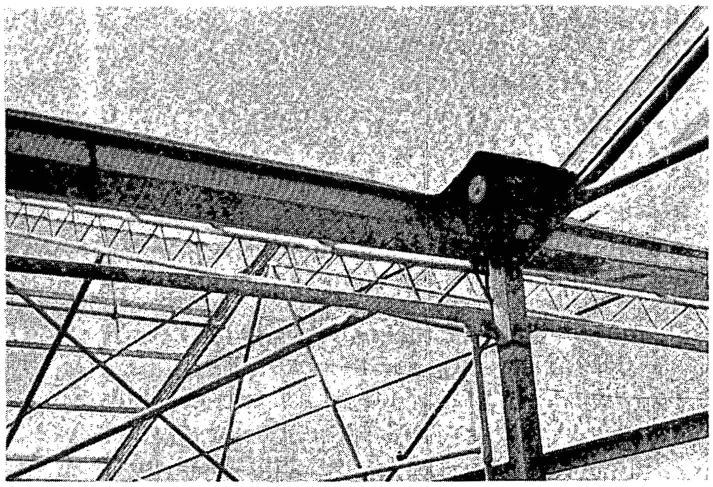

Figure 11. The only fan to be seen in the complex inflates the breezeway roof.

GEOTHERMAL UTILIZATION IN SOUTH DAKOTA

By D. D. Carda

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With the energy crunch on, a look at South Dakota's geothermal heating potential has been revived. The Madison limestone which is present in most areas of western South Dakota has long been known to produce water in the 120° to 160°F temperature range with relatively good water (Table 1). The Madison waters have been utilized as heat sources in limited quantities in two communities of western South Dakota for nearly 15 years with moderate success. The Philip Municipal Water Treatment Plant has supplemented its heating requirements with "homemade" heat exchangers which have experienced severe corrosion. The Midland School District has been using a commercial shell and tube heat exchanger which also has been plagued by severe corrosion.

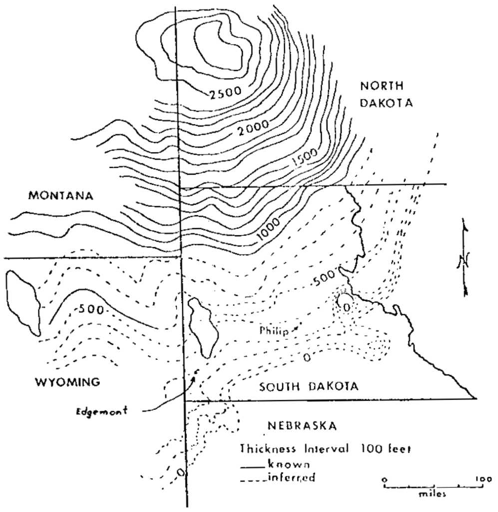

Figure 12. Thickness and extent of the Madison Limestone in South Dakota and adjacent states.

Table 1.
Madison Water Quality

Name	TDS	Temp	SO_4	C1	Ca	Na
Edgemont	1140	130°F	280	257	130	180
Philip	1172	153	633	21	221	15
Midland	1462	160	736	28	272	18
EAFB	1210	129	214	3	73	8
BHP&L #1	189	57	35	3	72	4

In the fall of 1976, the authors became involved in a feasibility study sponsored by the Energy Research and Development Administration to determine whether or not the Madison waters could be effectively utilized for low-temperature space heating and what chemistry and corrosion problems might be involved in its direct utilization.

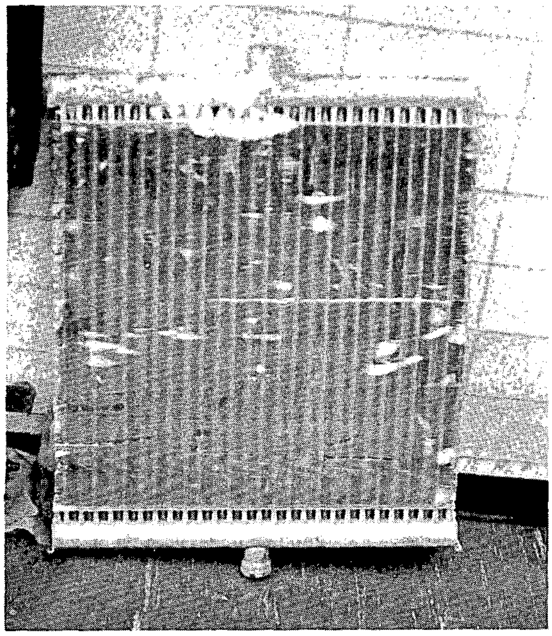

Figure 13. "Homemade" exchanger.

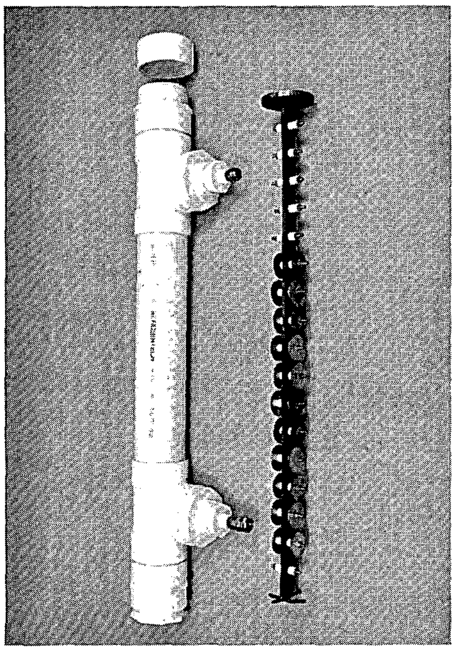

Figure 14. Corrosion Test Rack.

One area of investigation involved a detailed chemical analysis of the existing Madison waters. The second area of concern to the authors was the nature of the corrosion and its action on various metals. One of the main points observed was that the water was highly variable in chemical composition throughout the aquifer (Table 1).

Because of the variable chemical composition of the water, it was decided to examine the corrosive action at several different areas on various common metals used in piping and heat exchangers. Corrosion test racks were constructed of PVC pipe and brass support racks were prepared to suspend the metal coupons on teflon insulated plugs.

The corrosion exhibited on the test rack was immediately visible; within two weeks, a black powdery scale formed on all copper containing metal portions. This same powdery black scale was found on the "homemade" exchanger from the Philip Plant and also the shell and tube unit at Midland. X-ray diffraction identified this material to have the structure of bornite (Cu_5FeS_4).

The analysis of the gases in the waters at the two selected sites indicated a significant amount of sulfide present. The sulfide is apparently the active agent in the corrosion of the copper metal. Titanium and several stainless steels appear to exhibit good resistance to the corrosive actions of these two waters.

The examination of the Madison waters has been continuing and has been expanded to include another test rack and feasibility investigation funded by D.O.E. to determine whether or not the Edgemont School District can utilize its three existing Madison water wells at 130°F for space heating purposes. Four demonstration projects have also been awarded by D.O.E.—two school buildings, one hospital, and one agribusiness application. These demonstration projects will include two different methods of heat extraction for space heating, as well as several different water temperatures ranging from 120° to 160°F, and a grain-drying application. More information on these projects will be published as progress is made.