The Natural Energy Laboratory of Hawaii

1988 Annual Report

To:

The Honorable John Waihee
Governor of Hawaii

The Honorable Richard S.H. Wong
President of the Senate

The Honorable Daniel J. Kihano
Speaker of the House of Representatives

Board of Directors

FY1988

Dr. John P. Craven, Chairman
Marine Affairs Advisor, State of Hawaii, and Director, Law of the Sea Institute, University of Hawaii at Manoa.

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Chairperson, Department of Land and Natural Resources, State of Hawaii

Dr. Patrick K. Takahashi
Director, Hawaii Natural Energy Institute, University of Hawaii at Manoa

Mayor Dante Carpenter
Mayor, County of Hawaii

Mr. Gregory R. Mooers
Deputy Managing Director, County of Hawaii

Contents

In Memoriam

To honor two men active in the development of deep ocean resources in Hawaii whose lives were lost to the powers of the sea, pipeline dedication ceremonies were held at NELH-Kona on June 3, 1988. The new NELH 18" emergency back-up pipeline was dedicated to Mr. Patrick Wolter (1947-1987) of American Divers, Inc., and the existing NELH 12" pipeline was dedicated to Mr. Henry Horn (1924-1981) of Makai Ocean Engineering, Inc. Bronze plaques with the following inscriptions are to be installed onshore at Keahole Point in their memory.

This pipeline is dedicated to the memory of
Patrick Wolter
(1947-1987)
Who, with his company,
American Divers, Inc.,
Was a leader in the development
Of deep ocean resources in Hawaii

This pipeline is dedicated to the memory of
Henry Horn
(1924-1981)
Who, with his company,
Makai Ocean Engineering, Inc.
Was a leader in the development
Of deep ocean resources in Hawaii

This report recalls the events of the twelve months from July 1987 through June 1988 which included a number of historically noteworthy achievements in deep sea pipeline technology development at Keahole and culminated in the pipeline dedication ceremonies honoring Pat Wolter and Hank Horn in June. It is in the memory of their lifetime devotion to working in the sea that we would like to also dedicate this edition of the NELH 1988 Annual Report.

Message from the Chairman

Fiscal Year 1988 has been the year that the Natural Energy Laboratory of Hawaii came of age. Since it was first established by the State Legislature in 1974, NELH has matured into a world-reknowned research support facility. Since 1982, a single 12-inch pipe has delivered a continuous supply of the valuable deep coldwater and made possible a wide range of research and demonstration-scale projects

With only a single source of cold deep seawater, perpetual vigilance had to be maintained to keep systems operative. Rapid expansion of projects at NELH significantly increased the potential for the large product and financial losses due to cold seawater system failure or storm damage. The limited capacity of the water source also restricted the scale of the projects which could be tested.

In FY 1988, five new pipelines capable of delivering a total of 23,000 gallons per minute of deep ocean water were installed and became operational. Cold seawater availability has increased 15 times, but, more importantly, complete redundancy of seawater supplies has been achieved at Keahole Point.

Roger Ulveling (left) and John Craven (right) are all smiles as the first deep cold seawater flows from the new 18" emergency back-up pipeline during special dedication ceremonies held to initiate the new pipeline.

The deep cold seawater is employed in energy experiments at NELH in the temperature range of 6 to 9 degrees Celsius. Currently, research is being carried out in heat/mass transfer experiments and testing open-cycle OTEC plant components by the DOE, SERI, ANL and PICHTR. Closed-cycle OTEC experiments with aluminum heat exchangers are being conducted by the Aluminum Company of Canada.

The coldness of the water in the 9 to 13° C temperature range yields a variety of other novel and economically promising applications associated with cooling. In this range, the now "world famous" strawberry project has shown that a wide variety of temperate climate crops can be produced in a subtropical setting using coldwater pipe condensate for irrigation and cooling. Expansion of this OTEC agriculture project from several small test beds to a one acre experimental farm was authorized in FY1988. Other applications in this temperature range have been the successful air conditioning of the laboratory building using a simple deep water-chill water heat exchanger, the recovery of CO_2 from stack gases for use as an algal fertilizer,a proposed fresh water condensate generator, and others.

In the range from 13° Celsius and above, the nutrient characteristics of the water have permitted the development of polyculture by Ocean Farms of Hawaii, formerly the Hawaiian Abalone Farm. Originally specializing in abalone and kelp production, OFH has expanded its operation to grow oysters, sea urchins and salmon. Expansion is also taking place at Royal Hawaiian Sea Farms where the successful harvest of the seaweed *nori* has been supplemented by the production of the seaweed *ogo*. Cyanotech Corporation is similarly expanding its commercial production of Spirulina, Dunaliella, and other microalgal species useful as food supplements, pharmaceutical preparations, and biofertilizers.

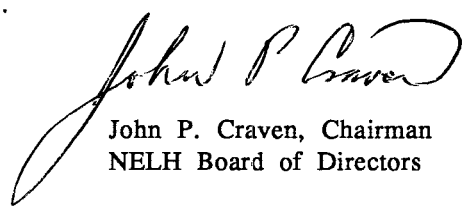
The rapid growth of these commercial enterprises has exceeded expectations and, as a consequence, a spillover of the expanding projects into the neighboring commercial HawaiiOcean Science and Technology (HOST) Park will take place sooner than anticipated. Recognizing the penumbral nature of projects moving from incubation to profitable commercialization, a merger of the NELH and HOST Park organizations will be proposed for consideration by the 1989 Legislature. Limited joint venturing between the two facilities leading to the merger is already in progress.

A further spinoff of success at NELH has been the national and international attention that has been focused on Keahole Point by the media, from television to the printed page. The laboratory and its products are the subject of a major article in the 1989 Year Book on Science and the Future of the Encyclopedia Britannica. As a result of this and other publicity, many visitors to Hawaii now regard a trip to visit the NELH Kona Seacoast Facility "a must." The visitor program, hosted 3500 persons in FY 1988. The program, is being expanded to satisfy this growing need.

The progress of ocean energy research and by-product development at the Kona Seacoast Facility is paralleled at the Puna Geothermal Facility where a geothermal well and power plant, a research laboratory, and a by-product technology development program is underway using another natural energy resource, geothermal energy. Although

reliance is still dependent upon the continued operation of a single geothermal well, by-product projects at the Noi'i o Puna Geothermal Research Center which include the drying of lumber and fruits, the making of glass, the heating of greenhouses and the use of warm mineral-rich waters in a geothermal spa have been progressing well. Negotiations have also been completed with a neighboring land owner to develop a geothermal mini-park which will provide needed land for commercialization of projects conducted at the research center. Possibilities also exist for integrations of the geothermal process and the ocean thermal process.

The ongoing formation of a policy framework shared by all who conceive of the individual projects within NELH, independent and proprietary as they must sometimes be, is an intrinsic and continuing part of the development of an NELH that serves Hawaii's future. NELH of tomorrow will function as a total system for the incubation, growth and maturation of industry focused around the development of Hawaii's unique ocean thermal and geothermal energy resources. As the twentieth century draws to a close, NELH will be well-prepared to lead the way in research and development for the coming technology-rich twenty-first century in Hawaii.



John P. Craven, Chairman
NELH Board of Directors

Executive Director's Report

NELH has made great strides forward in FY 1988. Six new projects were initiated in Kona and seven in Puna. Four new cold seawater pipelines were installed at Keahole Point by various public and private interests. Two of the pipelines were dedicated to the memory of Mr. Henry M. Horn, founder and President of Makai Ocean Engineering, and Mr. Patrick H. Wolter, owner and President of American Divers, both of whom were instrumental in the development and success of NELH-Kona. Major research achievements have been accomplished in OTEC experimentation and deep, cold seawater mariculture. New applications for utilizing the pure, cold seawater resources available at NELH continue to be demonstrated every year.

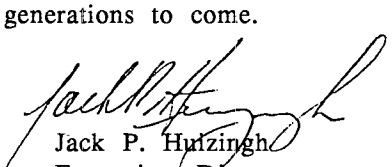
In Puna, the HGP-A geothermal plant received a major overhaul to extend its useful life and safety at the site. The HGP-A power plant has provided reliable electric power to over 2,000 homes in the Puna area since 1982. A major upgrade and expansion of the Noi'i o Puna geothermal research center is also underway. The direct use applications of the waste geothermal fluids for drying agricultural products, heating greenhouses, dyeing cloth, making glass and use in geothermal spas have demonstrated many new opportunities in geothermal resource development.

In addition to the many research successes that have been achieved by the users of NELH, we are especially proud of the progress that has been achieved in the area of economic development. There are currently over 80 people employed at NELH-Kona, of whom 65 are with private sector projects. Land use, capital investment, and operating revenues are at new highs and should continue to increase.

In the coming year, we anticipate many new projects for the Kona and Puna sites. Infrastructure improvements and expansion are planned for both facilities. We anticipate the consolidation of NELH and HOST Park which will mark a major milestone in the overall development of Keahole Point. We also anticipate commercial expansion of several of the demonstration projects in Puna into Hawaii's first geothermal industrial park.

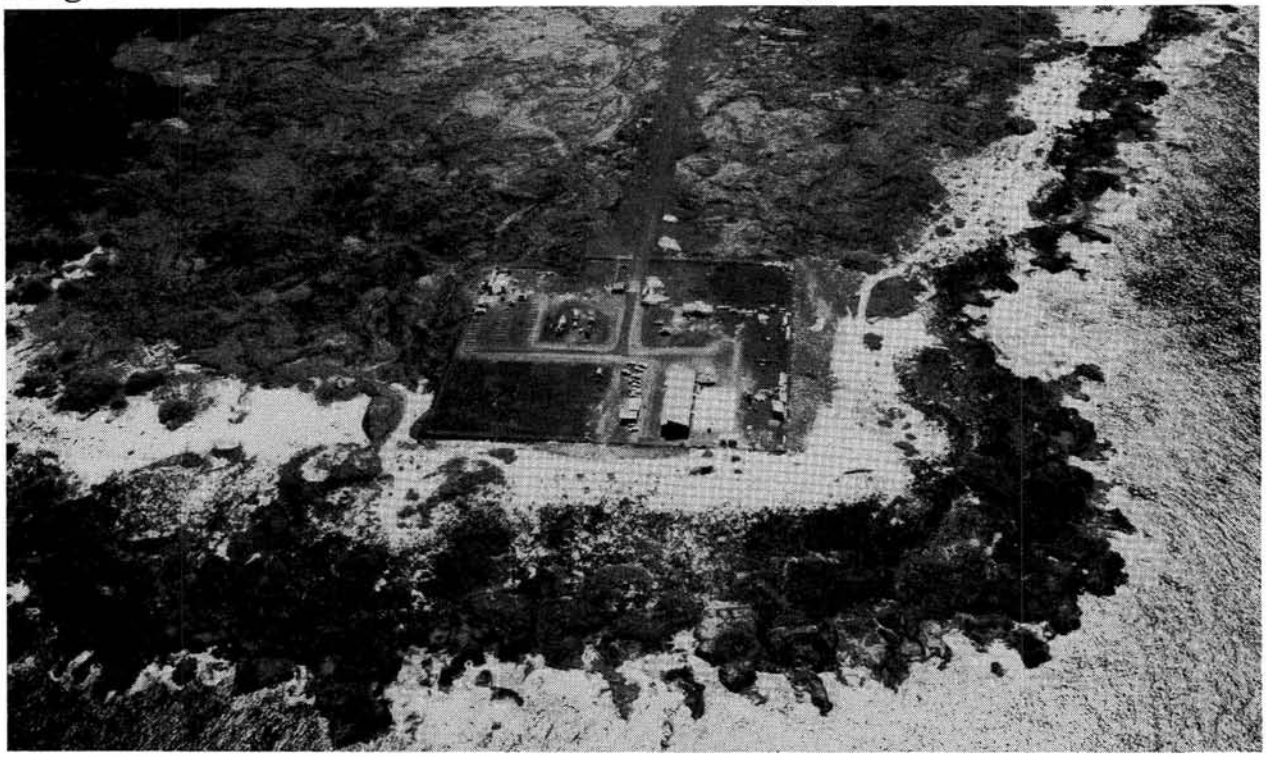
The future success of NELH will depend on maintaining a number of important balances. It is critical that marketing is responsive to the availability of resources, infrastructure, and utilities to assure that the needs of current projects and new projects can be met. The type and impact of projects on the local environment, on the quality of the natural resources, and on other projects must be evaluated, monitored, and controlled. Local participation in the projects at NELH must be rigorously encouraged. The State, County, NELH management, and respective tenants must work together to address areas of concern and develop policies of mutual benefit.

The unique opportunities presented to the people of Hawaii through the development of the State's natural ocean and geothermal resources are in the early stages of realization and demonstration at the NELH facilities. With continued sound and dedicated management, positive government and private support, and responsible monitoring and control, the development and viability of these economic opportunities and responsible utilization of these natural resources will serve many generations to come.

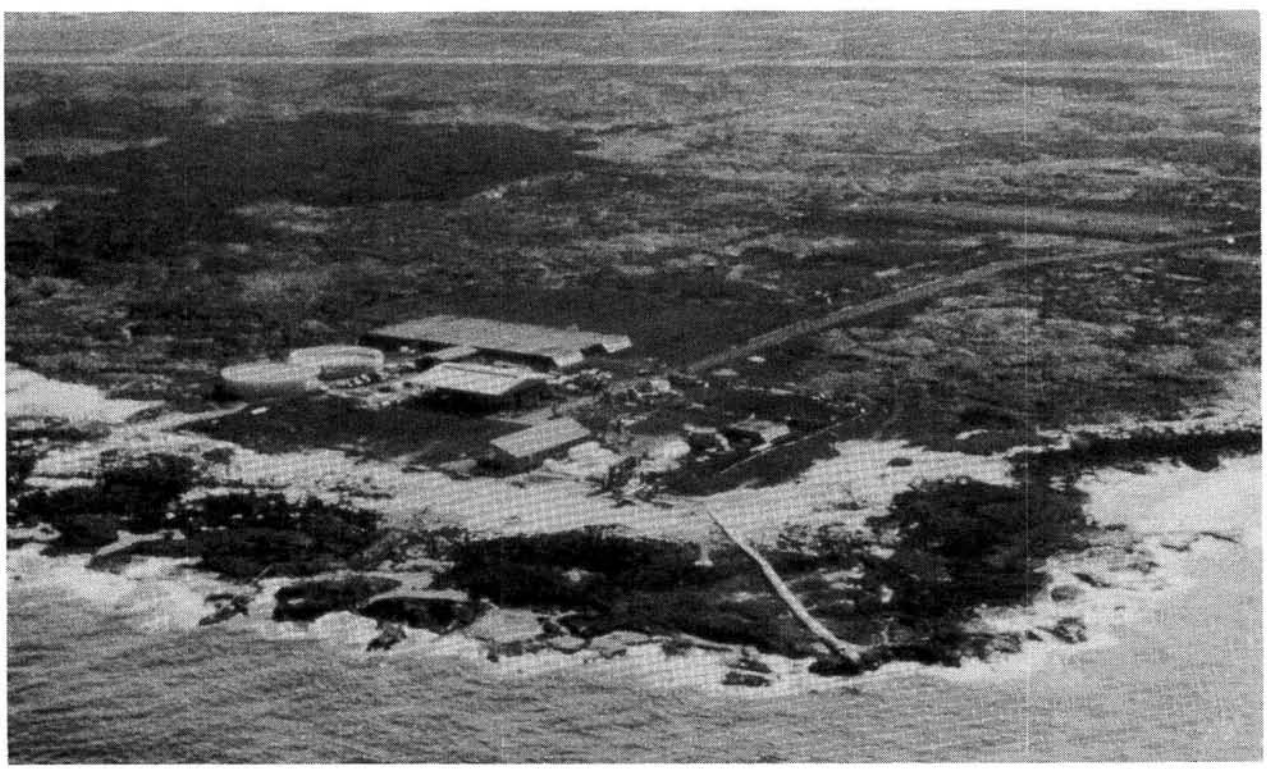


Jack P. Hunzinger
Executive Director

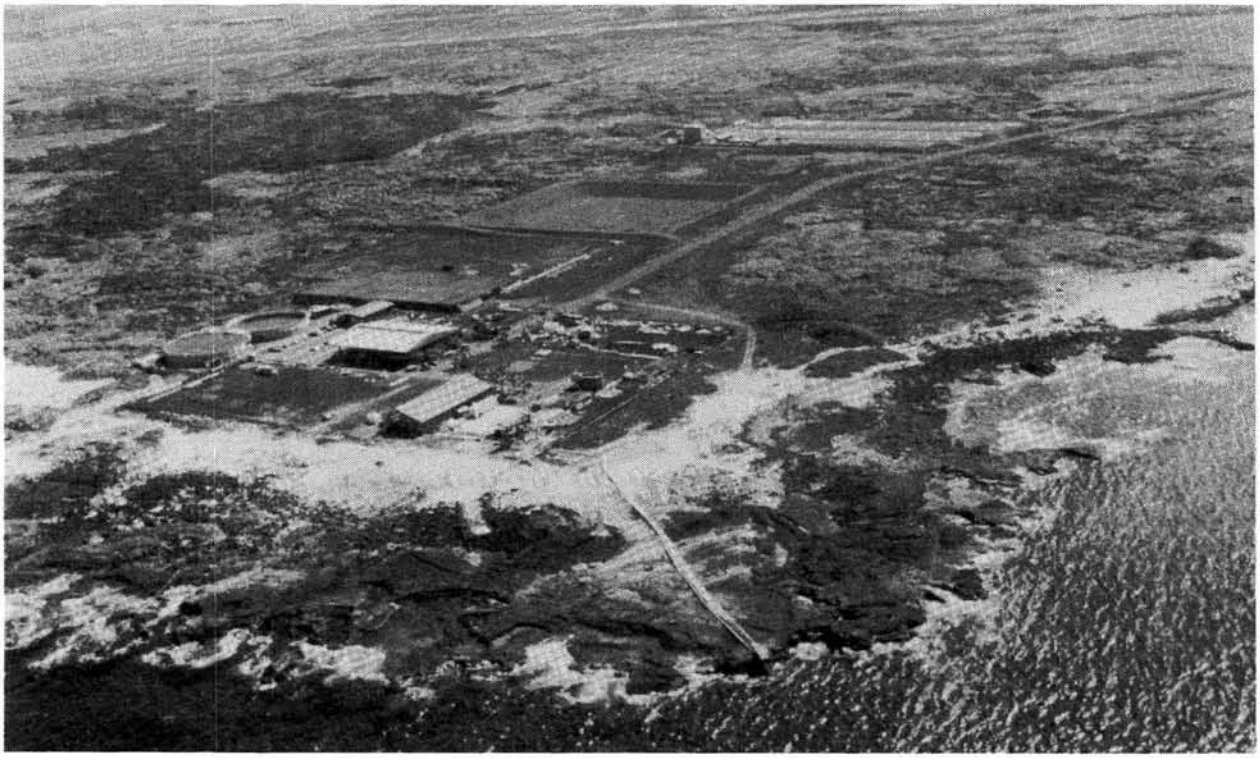
Progress at the NELH Kona Seacoast Facility, Keahole Point, Hawaii



1980



1985



1986

1987

Abbreviations

ADP	Aquaculture Development Program, DLNR
AE	Aquaculture Enterprises
ANL	Argonne National Laboratory, DOE
ASTM	American Society for Testing and Materials
BLNR	Board of Land and Natural Resources
CC	Cyanotech Corporation
CGTP	Community Geothermal Technology Program
CIP	Capital Improvement Projects
CSA	Community Service Agreement
CWP	Cold water pipe
DAGS	Department of General Services, State of Hawaii
DLNR	Department of Land and Natural Resources
DOE	U.S. Department of Energy
DOT	Department of Transportation
DBED	Department of Business and Economic Development
DUMAND	Deep Underwater Muon and Neutrino Detection Project
EES	Energy Extension Service, DBED
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
ERDA	Energy Research & Development Administration (preceded DOE)
FUA	Facilities Use Agreement
gpm	Gallons per minute
HAF	Hawaiian Abalone Farm
HCEOC	Hawaii Economic Opportunity Council, County of Hawaii
HECO	Hawaiian Electric Company
HELCO	Hawaii Electric Light Company, Hilo
HGP-A	Hawaii Geothermal Project-Well "A"
HIG	Hawaii Institute of Geophysics, UHM
HIMB	Hawaii Institute of Marine Biology, UHM
HNEI	Hawaii Natural Energy Institute, UHM
HOST	Hawaii Ocean Science and Technology Park, DBED
HTDC	High Technology Development Corporation, DBED
MOE	Makai Ocean Engineering
NELH	Natural Energy Laboratory of Hawaii, DBED
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSF	National Science Foundation
OFH	Ocean Farms of Hawaii
OTEC	Ocean thermal energy conversion
PICHTR	Pacific International Center for High Technology Research
PGF	Puna Geothermal Facility
PGRC	Puna Geothermal Research Center (Noi'i O Puna)
RCUH	Research Corporation of the University of Hawaii
RHSF	Royal Hawaiian Sea Farms
SERI	Solar Energy Research Institute, DOE
TPC	Thermal Power Corporation
UHM	University of Hawaii at Manoa
UHSG	University of Hawaii Sea Grant Program

Introduction

This report summarizes activities at the Natural Energy Laboratory of Hawaii for Fiscal Year 1988, July 1, 1987, to June 30, 1988.

The Natural Energy Laboratory of Hawaii (NELH) was created in 1974 by the Hawaii State Legislature as a facility for research, development and demonstration of natural energy resources and other compatible scientific and technological investigations. NELH is chartered as a not-for-profit corporation and is administratively attached to the state's Department of Business and Economic Development (DBED).

NELH's Kona Seacoast Facility is located on 322 acres of state-owned land at Keahole Point, adjacent to Keahole Airport on the Kona coast of the Island of Hawaii. The Keahole site was selected for the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual insolation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. Keahole Point uniquely meets all of these criteria.

In late 1985, NELH expanded its management responsibilites to include the Puna Geothermal Facility (PGF) located in the Puna District near Hilo, also on the Island of Hawaii. The PGF is comprised of the HGP-A geothermal well, a 3MW power plant and the Noi'i o Puna Geothermal Research Center.

NELH also maintains a Honolulu office which is responsible for the overall management and administration of the Kona and Puna facilities. Planning, marketing, facilities use agreements and subleases are handled through this office, as is coordination with government-related activities, funding sources, and regulatory permitting agencies.

NELH is governed by a Board of Directors which is responsible for managing and maintaining NELH properties, reviewing and approving proposals from prospective users, and planning and coordinating the development of NELH facilities. While NELH personnel may provide technical assistance, the primary function of NELH is to make facilities and resources available to researchers, inventors, and entrepreneurs for the research, development and pilot testing of innovative new technologies and businesses. Legislation passed in May of 1984 permits on-site commercialization of successful research and development projects.

NELH engages the services of the Research Corporation of the University of Hawaii (RCUH) to provide administrative services. Plans call for NELH to eventually become self-supporting through the collection of user fees.

NELH welcomes proposals from both the public and private sectors. With the approval of the Board, users may arrange to share existing facilities or construct their own. The Kona Seacoast Facility welcomes new projects which utilize or are related to the natural ocean and solar resources available at the site. The Puna Geothermal Facility welcomes new projects related to the geothermal resource and its by-products.

The appendices in this annual report contain the NELH Policy on Project Acceptance and a summary of publications resulting from research projects conducted at NELH. Inquiries concerning NELH should be addressed to the Executive Director at 220 South King Street, Suite 1280, Honolulu, Hawaii 96813.

Institutional Developments

Kona Seacoast Facility

The Kona Seacoast Facility has continued to grow and expand to fulfill the NELH mission of providing sites for research, development, demonstration, and commercialization of natural energy resources and other compatible scientific and technological investigations.

During FY 1988, a feature article detailing the history and future of OTEC was written by NELH Laboratory Director Tom Daniel and Terry Penney of the Solar Energy Research Institute (SERI) for the widely distributed Encyclopedia Britannica. Work at NELH was featured as an example of OTEC technology development.

Funding. Federal and State funding through the DOE and DBED respectively remained level for FY 1988. Contract arrangements with the DOE were changed from fixed price contracting to a cost reimbursable contract, resulting in the expansion of NELH efforts in cost accounting. User fees from aquaculture and other projects have continued to increase and contribute to the operating budget.

Staff changes. A number of personnel additions and changes occurred in FY 1988. The mechanical staff was expanded with the addition of Henry Hua as mechanical technician in September 1987.

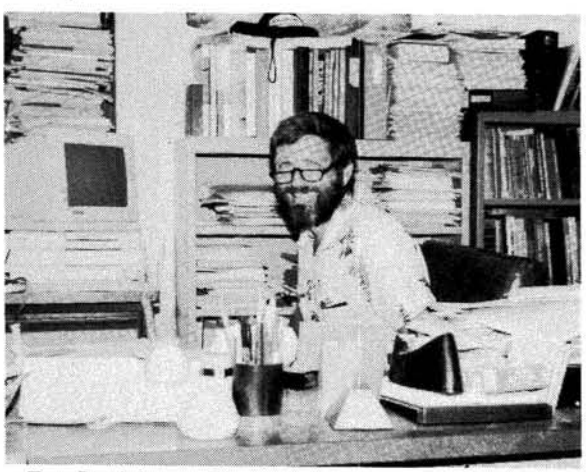
To assist the SERI staff on the HMTSTA project, Ernie Galt was hired as mechanical technician. He has a background in refrigeration, appropriate to the heat exchanger work vital to this experiment.

Carla Hannaford, Water Chemistry Technician, resigned in September 1987 to pursue a career in education. Carla's dedication and enthusiasm while part of the NELH staff is appreciated.

Ajay Bhargava, Data Analysis Engineer, left NELH in January 1988. Ajay's meticulous work during the last two years on the closed cycle OTEC research project was a significant contribution to the success of the six-year long project.

Cathy Yamashita was promoted to administrative assistant to fill the need for added accounting work on contracts and in April 1988, Genevieve Pickering was hired to fill the position of receptionist vacated by Cathy.

Employment. During FY 1988, employment opportunities at the Kona Seacoast Facility continued to grow through the further expansion of project operations. As of June 30, 1988, there were over 60 jobs in various technical, scientific, clerical and production areas at NELH and its tenant projects. (See Table 6.) Employment opportunities at NELH are expected to continue increasing throughout 1989.



Tom Daniel compiles seawater systems data at his computer.

Puna Geothermal Facility

In late 1985, NELH assumed management of the Puna Geothermal Facility (PGF). The PGF is dedicated to research, development and commercialization of alternate uses of geothermal resources. The overall development plan for the facility is similar to that of the Kona Seacoast Facility. The PGF provides for research, development, and commercialization of alternate uses of geothermal resources and for development of new technologies and businesses at the site. RCUH continues to manage the power plant operations subcontract with HELCO and also handles accounting for the research center and HGP-A.

Marketing materials, project initiation procedures, facilities use procedures have been developed to support the management and administration of the facility.

Funding. The state legislature has appropriated funds to NELH to operate the PGRC during its important startup years. As user projects develop, we anticipate their contribution to operating expenses to increase.

NELH contracts HELCO through RCUH to operate the HGP-A well and power plant at the site. Revenues from electricity sales essentially cover the operating costs of the power plant. The state contributes CIP funds to supplement the annual overhauls required to maintain the HGP-A well and power plant.

Staff Changes. Roy Nakanishi, initially hired as mechanical technician at the PGRC, has been promoted to Operations Supervisor. Jan War, who is Operations Manager at the Kona Seacoast Facility, also serves as Operations Manager for the PGRC.

Employment. During FY 1988, eight research projects were conducted at the PGRC, each staffed by one to three researchers who spent varying amounts of time at the site conducting experiments. As these initial projects move into commercial operations, permanent employment opportunities are expected to increase.

HOST Park

In November 1984 the High Technology Development Corporation, formed by the Hawaii State Legislature in 1983, began planning for the Hawaii Ocean Science and Technology (HOST) Park, located adjacent to NELH Keahole. HOST Park is a 547-acre state-owned facility which provides for the large-scale commercialization of projects which complete successful research and pilot-scale development at NELH. A major portion of the necessary infrastructure needed for development have been completed and include improvements to the access road and utilities corridor, grading of internal roads, basic utilities, and construction of a 40-inch cold seawater supply system.

Genevieve Pickering checks monthly budget status reports for NELH projects.

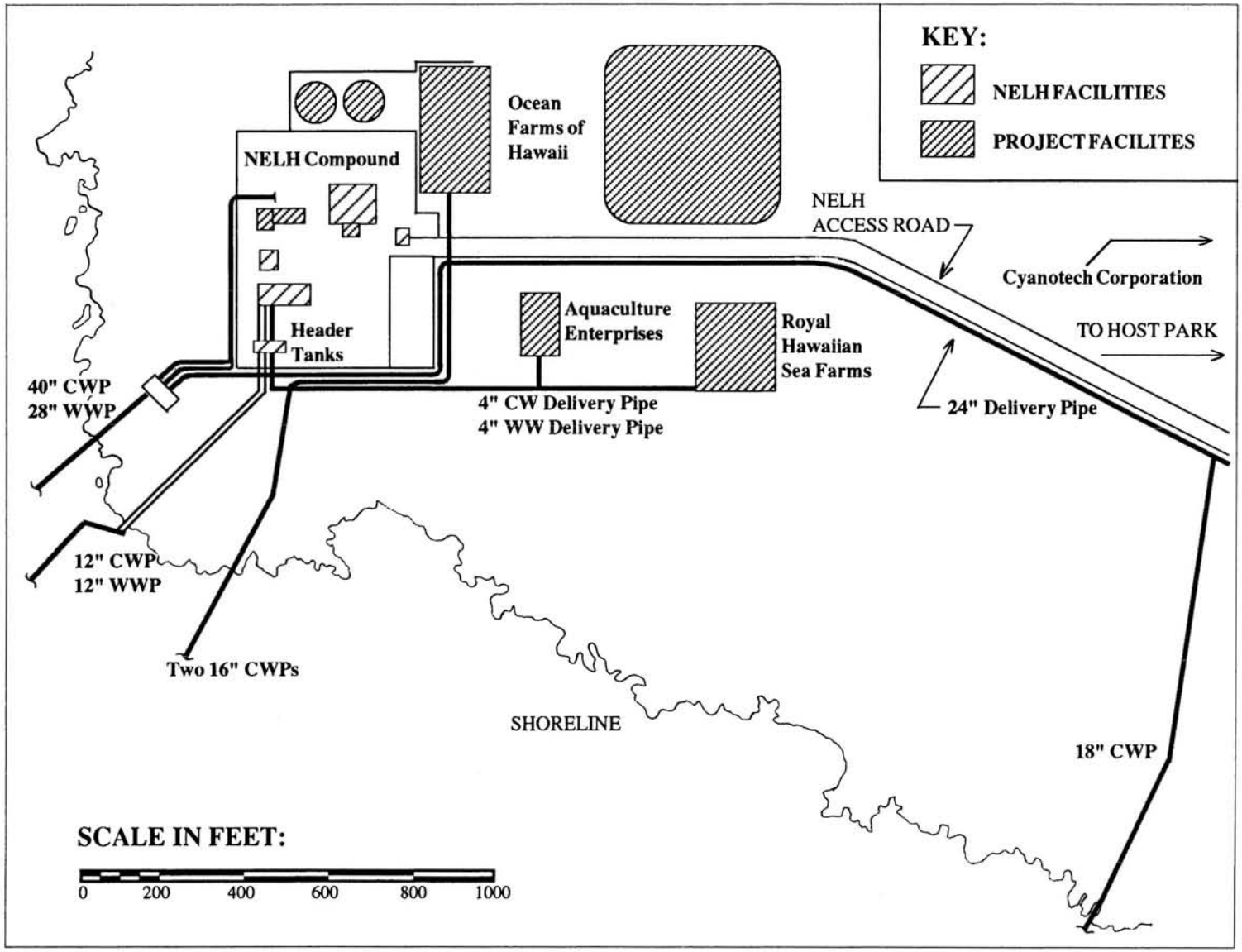


Figure 1: NELH SEAWATER SUPPLY SYSTEM
Kona Seacoast Facility at Keahole Point, Hawaii

Kona Seacoast Facility Developments and Status

Seawater System Improvements

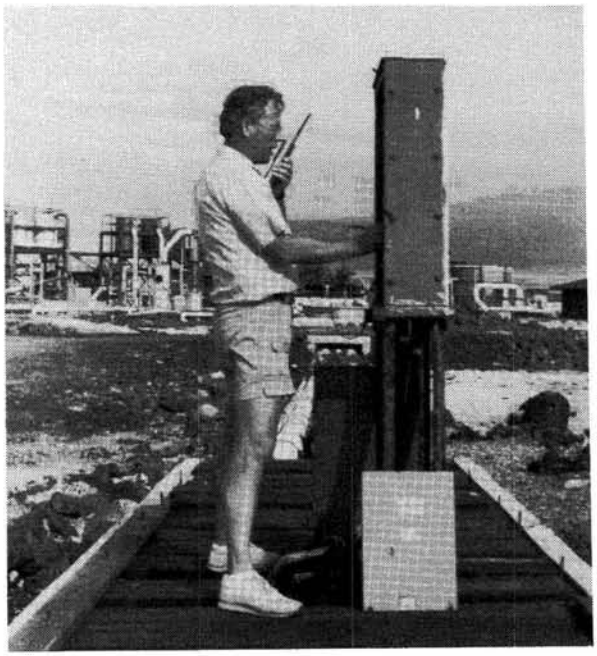
FY 1988 was the "Year of the Pipeline" for the NELH Kona Seacoast Facility. Major breakthroughs were made in pipeline engineering, design and deployment methods. Successful deployment techniques were developed through the efforts of Hawaiian Abalone Farm, Makai Ocean Engineering, American Divers, Inc., R.M. Towill, Kewitt Pacific, and the NELH staff.

Realignment of the 12-inch pipeline was completed in August 1987. This provided for a more wave-resistant design through the surf zone at Keahole Point. The anchoring system experiences severe testing in this area each winter. Makai Ocean Engineering designed the new anchoring system and American Divers, Inc., performed the installation.

Hawaiian Abalone Farm, now called Ocean Farms of Hawaii (OFH), installed two 16" pipelines to supply its new 4-acre, 16-million gallon kelp production pond. The two successful deployments were made in 1987. Since then, the new pipelines have supplied OFH with its own supply of cold seawater.

Makai Ocean Engineering (MOE) designed and American Divers, Inc. installed an 18" pipeline for NELH which provides an emergency backup supply for the 12-inch seawater system. Design and construction innovations incorporated into this pipeline

The newly installed 18-inch diameter emergency back-up pipeline snakes across the lava towards the sea. This pipeline will deliver 3000 gpm of deep cold seawater to NELH projects.



Underwater electrical cable installation is remotely directed by Aarne Haas.

resulted in significant cost breakthroughs for pipeline installation at Keahole Point.

The 18" pipeline was dedicated to the memory of Patrick Wolter, President and founder of American Divers, Inc., on June 03, 1988.

The DOE/HOST/PICHTR 40-inch pipeline and pump station were installed by Kewitt Pacific during FY 1988. The complex process of designing and constructing an on-shore pump station proved an engineering challenge. The pump station, tested in spring and summer of 1988, was the first of its type at Keahole. The system was accepted by project manager and system designer R.M. Towill for DAGS/HOST on June 13, 1988.

The 40-inch pipe began full-time operation on June 23, 1988. Two 88 hp pumps supply about 3200 gpm of very cold (less than 7° C) deep seawater. Long-term maintenance during the high surf winter seasons should be easier to accomplish in the protected shoreside pump station and buried nearshore intake piping. A new 28-inch warm seawater supply was also installed to support the DOE system.

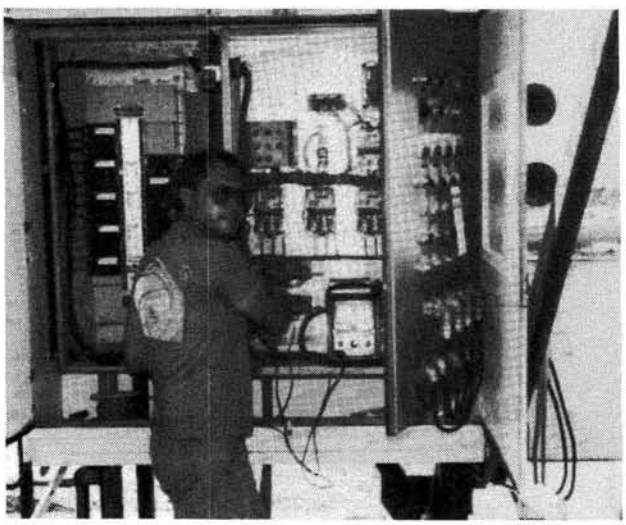
To provide for redundancy and increased reliability, the pipeline systems at Keahole Point have been cross-connected. Should one system fail, it is now possible to provide a backup supply from other systems to ensure continuity of the seawater supply.

Electrical Distribution System Improvements

The HOST Park underground electrical supply from new HELCO substation is being extended to NELH. This new connection will

Kent Merrill (left) and Jan War (right) prepare to jump into the foamy brine to secure underwater connections at the offshore pump station.

provide needed power for full-scale operation of the DOE/HOST pumps and continued laboratory expansion at NELH. It will replace the temporary feed from Keahole Airport that NELH has been using since its initiation. At the end of FY 1988, trenching and laying of conduit from the substation at the highway entrance was nearly complete. Switchgear for the connection of NELH systems and the DOE/HOST pumps are to be installed by November 1988.



Electrical panels at the header tanks undergo routine inspection by Bud Placek.

Water Quality Monitoring Program

The water quality laboratory at NELH continued to monitor incoming and effluent waters at the Kona facility. Regular samples were taken for nutrients, salinity, alkalinity, pH, total organic carbon, CHN and temperature analysis. This monitoring program, underway since 1982, has provided clear evidence of the consistent quality of the deep sea resource and has also remained as the only point-source deep sea sampling program in the ocean, a significant contribution to the oceanographic data base.

Data from the six-year long time series and supplementary concentrated sampling series on the deep water have yielded evidence of many scales of temporal variability. The variations of salinity and nutrients are highly correlated. The unexpected long-term variation is postulated to represent cyclic displacement of deep water masses in response to variation in the regional ocean circulation. (See *Nature* paper by Sansone et al, April 21, 1988.)

Plans are being made to further expand the analytical capabilities of the NELH water quality laboratory, enabling the lab to increase on-site seawater analysis as well as add groundwater and offshore monitoring to its capabilities. A supplemental $50,000 legislative appropriation will allow for the hiring of an additional technician and needed equipment and supply purchases in FY 1989.

A Cooperative Environmental Monitoring Program (CEMP) for the Keahole area, is being developed for the HOST Park and NELH by G.K. Associates. This program will establish baseline and long-term monitoring studies to assist in protecting the quality of seawater resources available at Keahole Point. The NELH water quality laboratory will play a key role in sample collection and analysis when this program is implemented.

Cold Seawater Air Conditioning

Air conditioning of the laboratory building using the cold seawater as coolant was installed in late summer 1987. The system

Henry Hua adds oil to an NELH air compressor during maintenance service.

has been used continuously during the year, saving a net average of $350 per month in electrical costs.

Interim Visitor Center

A proposal by NELH and ADP staff for the development of an informal center for visitors and tours was approved by the NELH Board in July 1987. In the past, public tours were orientated out-of-doors on a small grassy area near the laboratory building. Sun, wind and construction traffic made public speaking a challenge at times, yet requests for laboratory tours have continued to increase in number each year. Even though NELH was closed to visitors for several months during pipe construction for safety reasons, during FY 1988 over 3,500 visitors toured the Kona facilities through this program.

The upgraded program will help to make tour conditions more pleasant for both speaker and audience, providing amenities such as a portable audio system, hand-held visual aids, stationary exhibits, benches for 50 persons, and a shaded area for seating. As this interim visitor center is developed, approaches to effective information dissemination about NELH and its projects can be tested and perfected, someday to be transferred to a more formal visitor center to be developed in conjunction with the adjacent HOST Park facility. NELH staff have been working on implementing the interim visitor center plan in stages, with support provided by ADP of DLNR, the County of Hawaii, and the Energy Division of DBED.

Kelen Dunford shows a live abalone specimen to curious visitors during a tour.

Compound Expansion

A 7-acre expansion of the NELH compound is being constructed using State CIP funds. Plans call for the grading of the rocky area adjacent to the compound entrance and surrounding the current Aquaculture Enterprises site. This area will serve demonstration scale projects that require between one fourth and two acres of land.

Tenant Facility Expansion

The two major tenants at NELH, Ocean Farms of Hawaii and Cyanotech Corporation, continue to grow and develop as commercial capabilities are strengthened. Hawaiian Abalone Farm, now known as Ocean Farms of Hawaii, has continued to develop their commercial demonstration module on 21.3 acres of land at Keahole adjacent to the NELH laboratory compound. The first of four 4-acre kelp ponds has been put into production with the addition of two cold seawater pipelines to serve their increased seawater needs. OFH has also expanded culturing systems to include salmon, sea urchins, and oysters.

Cyanotech Corporation continues to develop their 15-acre site. During FY 1988, production pond acreage was increased by3.6 acres to bring them to a total 9 acres for the culture of Spirulina , Dunaliella and other microalgae species.

Royal Hawaiian Sea Farms expanded its project to a 1-acre site outside the NELH compound and has been grading and terracing. A large shadecloth structure to house production facilities was erected. Raceways and tanks for Porphyra and Gracilaria culture were also completed.

Aquaculture Enterprises, the newest addition at NELH-Kona, also developed a 9000 square foot site outside the compound for the production of Maine lobster. A shadecloth structure was erected, raceways installed, and an insulated laboratory building completed during FY 1988.

Table 1: KONA SEACOAST FACILITY

SEAWATER SYSTEM

PIPELINE DESCRIPTION	WARM SURFACE SEAWATER	COLD DEEP SEAWATER
12-inch diameter NELH	1200 gpm	1000 gpm
18-inch diameter NELH	N.A.	3000 gpm
40-inch diameter HOST Park	N.A.	6800 gpm
and DOE	N.A.	6500 gpm
28-inch diameter DOE	9600 gpm	N.A.
16-inch diameter OFH	N.A.	Proprietary
16-inch diameter OFH	N.A.	Proprietary
Total Capacities:	10800 gpm	17300 gpm + OFH
Temperature Ranges:	24° to 28° C	7° to 10° C

FACILITIES

- enclosed laboratory building
- outdoor wet laboratory
- concrete outdoor test pad
- warehouse storage
- offices
- electronics/wood/machine shops
- inflatable building (20 x 50 ft)
- fenced outdoor storage area
- electrical distribution panels for experimental areas
- dive locker (scuba, lift bags, broco torch, etc.)

VEHICLES

- 8-ton 4WD hydraulic crane
- 15-ton 4WD hydraulic crane
- 2 fork lifts
- 6 electric utility vehicles
- 1 mobile shop truck
- 1 station wagon
- 5 trucks
- 24-foot workboat with trailer
- 4WD surplus ambulance
- 1 back hoe

GENERAL EQUIPMENT

- large vacuum pumps
- open-cycle experimental chambers
- 3 automatically-started 125 kw diesel generators for facility back-up
- 2 trailer-mounted 10 kw field generators
- 1 trailer-mounted 100 kw 440V 3-phase generators
- 1 x 375 cfm trailer-mounted compressor
- portable pumps, welders, generators, compressors
- 2 x 600 cfm trailer-mounted compressors
- 2 PDP/11-23 computers for on-line heat transfer processing
- IBM PC and XT-compatible computer
- aquaculture tanks, plumbed for cold and warm seawater
  —10 ea 600 gal. fiberglas tanks
  —5 ea 800 gal. rectangular tanks each divided into 3 sections
  —various tanks, larval basins and growout baskets

OPERATIONAL SUPPORT CAPABILITIES

LABORATORY EQUIPMENT		
• analytical balance • top loading balance • stereomicroscope • muffle furnace	• particle counter • auto-analyzer • salinometers • drying oven	• amperometric titrators • pH meters • fume hood
TECHNICAL SUPPORT STAFF		
• systems engineering • electronic/instrumentation	• mechanical • electrical	• chemical laboratory • diving
MEASUREMENT CAPABILITIES		
WATER QUALITY MONITORING: • flow • temperature • analytical weights • salinity • suspended solids • residual chlorine		ENVIRONMENTAL MONITORING: • wind velocity • insolation • temperature • humidity • rainfall
COMMUNICATIONS		
• private VHF system for vehicles and boat as well as handheld units • Sharp FO-210 facsimile machine	• computer-based modem for electronic mail communications • Xerox machine	• NEC 1648 phone system with 6 CO lines and 16 extensions
PERMITS IN PLACE		
• Approved Offshore Research Corridor • Conservation District Use Permit for Coastal and Submerged Land • Special Management Area Use Permit for Coastal Lands	• DOT Harbors Division Shore Waters Construction Permit • Environmental Impact Statement/ Environmental Assessment for the whole Keahole facility	• NPDES Discharge Permit for Seawater Effluents • U.S. Army Corps of Engineers Permits • Federal Aviation Administration Permit
PUBLIC INFORMATION		
• site tours by appointment	• public lectures	• information packets
SECURITY		
• fenced research compound	• security guard service off-hours and holidays	

OTEC-Related Research Projects

Closed Cycle OTEC

Heat Transfer, Biofouling and Corrosion Project. These experiments consisted of 1-inch diameter piping loops in the laboratory, each of which contained a heat transfer monitor unit through which cold or warm seawater flowed continuously at 4.5 ft/sec or 6 ft/sec. Six of the original 12 warm water experiments and five of the original six cold water loops remained during FY 1988. This series of experiments drew to a close in FY 1988.

Data from these warm water experiments established a baseline on biofouling and corrosion in tropical surface seawater. Heat transfer measurements showed the need for biofouling countermeasures, however, corrosion analysis led to the unexpected discovery that most aluminum alloys do not develop corrosion pits in the warm water. Coldwater loops provided data which showed no significant biofouling but significant pitting corrosion in most of the aluminum alloys tested.

Biofouling countermeasures confirmed the efficacy of intermittently-applied low chlorine levels for biofouling control, to inhibit formation of biofouling films as well as to remove established ones. These results, combined with improved understanding of the chemical dynamics of chlorine in tropical seawater obtained from earlier chlorination studies, indicate that chlorine can be used to control OTEC biofouling without adverse environmental effects.

In accordance with DOE instructions, this program was terminated after six years of operation. The warm water loops were closed down in May and June and the final coldwater loops were shut off in September 1987. Detailed termination procedures were followed to allow complete data recovery from these unique samples, some of which had been in the seawater flow loops for more than six years. Experiments also demonstrated that an acetic acid solution will easily remove the aluminum hydroxide film which develops on aluminum alloys after prolonged seawater exposure. Analysis of remaining samples from this project continues by Oceanit Laboratories under the supervision of Dr. Bruce Liebert of the UHM College of Engineering.

ALCAN International Heat Exchanger Research. ALCAN continues to perform testing of heat exchangers fabricated from various aluminum alloys in both surface and deep seawater. On-going since April 1986, this experiment was installed for a large-scale test of aluminum heat exchanger elements. Both warm and cold seawater are run through several multitube heat exchanger elements made from various aluminum alloys which are continuously monitored for heat transfer and corrosion.

ALCAN International operates the data-collection system by telephone modem from its Kingston, Ontario, Canada, laboratory.

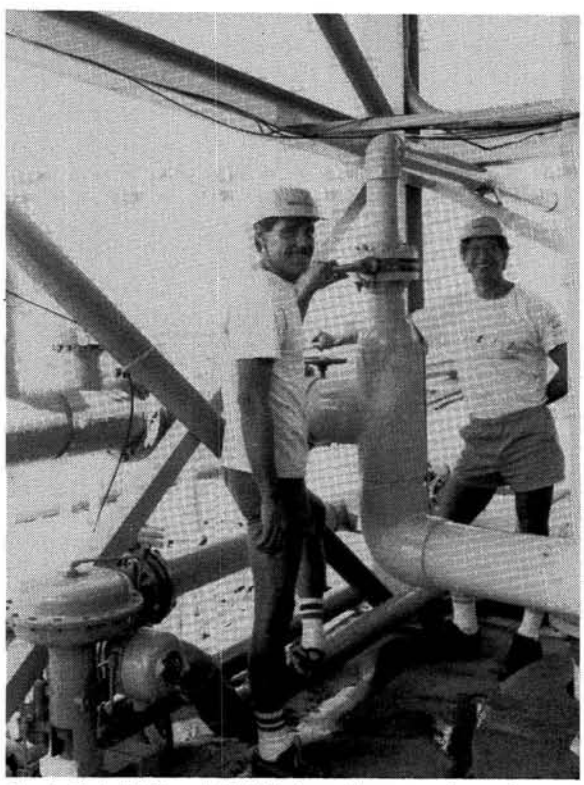
Open Cycle OTEC

Heat and Mass Transfer Scoping Test Apparatus (HMTSTA). The purpose of this project is to obtain initial data on open cycle OTEC spout evaporator and condenser performances for input to an initial design of an OTEC pilot plant. Data collection began in late summer 1987. Site preparation had proceeded during the summer of 1987, with the first of two 36-foot towers erected in

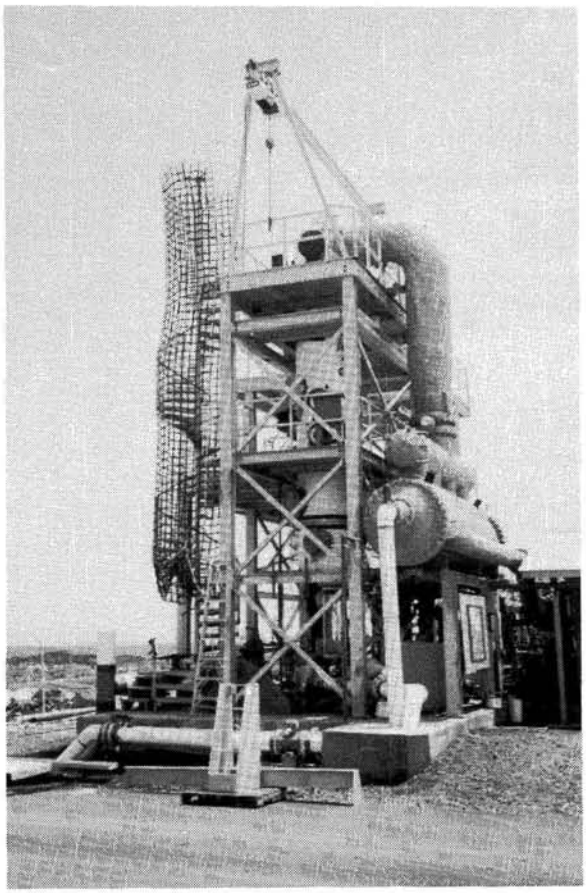
July and seawater hook-up completed in early August. Systems checkout, calibration and testing were completed soon thereafter.

The first potable freshwater from this open cycle OTEC experiment was produced on August 21, 1987. Seawater was flash-evaporated in a vacuum to demonstrate the production of one of the most valuable by-products of the open cycle OTEC process: fresh water.

Surface condenser experiments were carried out during "HMTSTA Phase I." Experiments measured the dissolved gas concentrations in seawater at the low pressures needed for open cycle OTEC operation. NELH personnel



Ernie Galt (left) and Hal Link conduct experimental runs to collect data on open cycle OTEC subsystem components.



The Heat and Mass Transfer Scoping and Test Apparatus experiment is housed in a 30-foot tower within the NELH compound.

completed the erection of the second tower for the direct contact condenser in June 1988. "Phase II" of the planned experiments awaits the arrival of the condenser chamber itself. These experiments will provide design parameters for the follow-on Net Power-Producing Experiment (NPPE), scheduled to begin in 1990.

Other Research

Environmental Measurements. NELH remains an official National Weather Service observation station, reporting daily observations of temperature and rainfall. Since January 1985, a data logger system has provided continuous measurements of many other environmental variables as well. Hourly averages of direct and diffuse insolation, air temperature and humidity, surface and deep water temperatures, and wind vector speed and direction, as well as daily averages, maxima and mimima of all these variables and daily total rainfall are recorded on tape cassettes. These data are processed to produce summary charts and tables for distribution to interested researchers and potential NELH users.

ASTM Corrosion Tests. NELH participated in a five-year international inter-laboratory research program on the global variability of the corrosivity of seawater. Tests were concluded in Spring of 1988. ASTM had supplied a rack holding samples of steel, aluminum and copper-nickel which NELH personnel deployed near the 12-inch coldwater pipe offshore of Keahole Point. Specimens were returned to ASTM for analysis and comparison with similar samples deployed elsewhere. This research has been coordinated by researchers from the University of Hawaii at Manoa.

Algal Carbon Dioxide Uptake Project. The Electric Power Research Institute (EPRI) has provided funding for an HNEI-sponsored project involving an innovative application of aquaculture. Dr. Edward Laws of UHM Department of Oceanography will be investigating the use of algae as scrubbers to remove carbon dioxide from stack gases, potentially reducing future emissions to the atmosphere from the burning of fossil fuels while producing a by-product for other uses.

Johns Hopkins Phytoplankton Project. From September 1986 through September 1987 NELH technicians collected phytoplankton samples for a project conducted by Dr. John Heinbokel of Johns Hopkins University in Baltimore, Maryland. He has been researching the occurrence of a symbiotic cyanobacterium in the cells of certain diatom populations.

The cyanobacteria are nitrogen fixers which may provide a significant contribution to primary production in the surface layers of the ocean. Investigations into the abundance and distribution of these species can add to understanding of optical effects in the water column as related to seasonal variations in these populations. The samples from NELH's point source seawater supply will be compared with samples taken by other groups during the same period.

Fish Drying Project. An application of solar drying proved to be a means of improving upon not only the economy but also the efficiency of a fish jerky producing project. A local company in Kailua-Kona, with assistance from DBED's Energy Division, designed and constructed a series of lightweight aluminum-framed solar drying units for use at the Kona Seacoast Facility. Electrical energy requirements were eliminated and test samples dried in a day as compared to several days with traditional drying ovens.

Cold Seawater Research & Development Projects

Left to right: Tablets of Beta-carotene, powdered Spirulina by the kilo, and other health food products against a backdrop of a paddlewheel pond; fresh salmon on ice; a ripe juicy strawberry; abalone in "mini-condominiums" are all products grown with the deep cold seawater at the NELH Kona Seacoast Facility at Keahole Point, Kona.

Potential economic benefits from aquacultural and other products which utilize the coldwater discharge from an operating OTEC plant have prompted research and development in aquaculture and agriculture. Support facilities at NELH include the unique cold seawater supply system and numerous tanks and other equipment for growing various species of plants and animals. A number of research projects from both the private and public sectors have found significant potential for commercialization of certain species of aquatic plants and animals, utilizing the properties of low temperature, high nutrient content and lack of pathogens of the deep cold seawater at NELH.

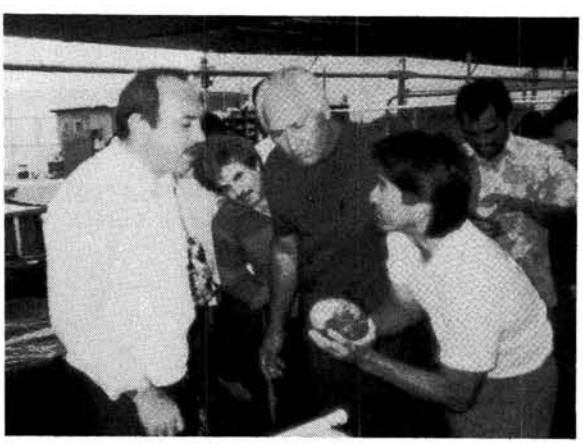
For example, the deep cold water being pumped at NELH is uniquely suited for aquaculture of many marine animals. The purity of the water permits successful growout of delicate larval stages without expensive water purification processes. High levels of dissolved inorganic nutrients in the deep water provide rapid growth rates for various algal species which serve as food for the animals. Temperature can be inexpensively maintained throughout complex systems by controlling the coldwater flow to balance heat gained from the Hawaiian climate.

A Sea Grant publication, now in press, summarizes the results of coldwater

aquaculture research at NELH to date. An analysis of the economics of raising the various species, both independently and in conjunction with an OTEC power plant is also included.

Abalone Production. Hawaiian Abalone Farm (HAF) has been conducting proprietary coldwater aquaculture experiments at the Kona Seacoast Facility since 1982 and began operating a commercial demonstration module in 1983. FY 1988 was an especially historic year for HAF.

In the forefront of pipeline deployment development, HAF installed two operational 16" pipelines in the summer and fall of 1987. Using a shore-based fabrication and deployment technique, each 6,000 foot long polyethylene pipe was set on a series of mounted rollers along the NELH access road and guided out to sea by a tug, assisted by several boats. The air-filled pipe was floated into position, then carefully flooded with water and allowed to sink. The installation of the new pipelines enabled HAF to initiate a 4-acre kelp pond, the largest such production pond thus far at Keahole, during the first half of 1988.



OFH biologist Mike Muranaka shows Governor Waihee and Pacific Island nation officials abalone broodstock.

Along with expansion of production facilities and seawater capabilities, HAF also diversified, changing its company name to Ocean Farms of Hawaii (OFH). In addition to abalone culture, OFH's menu of organisms now also includes sea urchins, salmon, and oysters.

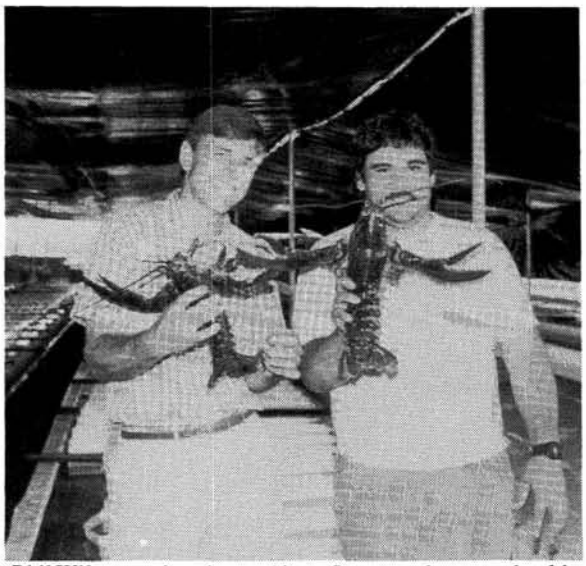
Microalgae culture. Cyanotech Corporation (CC) has successfully performed pilot research and development on advanced micro-algal culture and processing systems. This year, CC added six new raceways to its 15-acre site for the culture of Spirulina, Dunaliella and other microalgae species. New lab and office space were also completed.

The company introduced natural beta carotene products in the United Kingdom through Britannia Health Products, a wholly-owned subsidiary of Finnsugar Inc. of Finland, and a major U.K. distributor of nutritional supplements. Beta carotene is a precursor of vitamin A in the body and an essential component of a healthy diet.

Algal production of eicosapentanoic acid (EPA), significant in the prevention of cholesterol buildup in humans, continued under an agreement with American Cyanamid.

Maine lobster production. Aquaculture Enterprises (AE) began a new project in FY 1988 at the Kona NELH facility to develop a methodology for production of Maine lobster using the cold deep seawater.

AE commenced its project at NELH in July 1987. Within the short 12 months of its



Phil Wilson and assistant Ainoa Spencer show two healthy Homarus specimens from the AE broodstock.

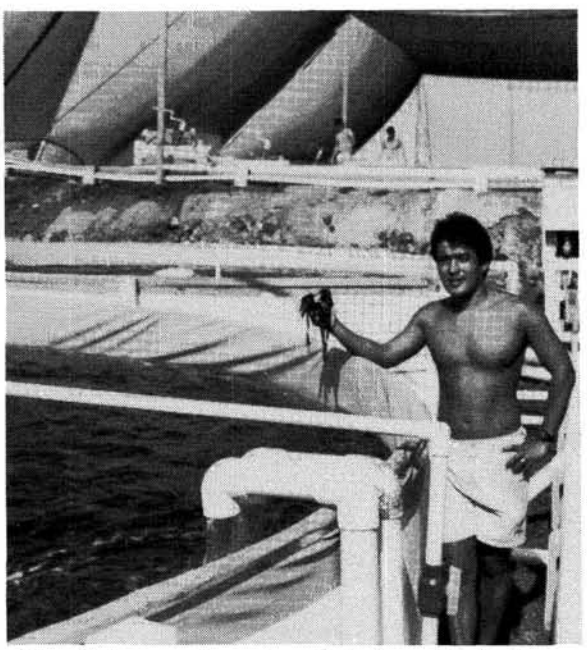
initial occupation of the one-acre site adjacent to the NELH compound, the demonstration project is already well underway. Grading and building on the 9000 square foot site and the shadecloth structure which houses the production facility and the laboratory building were completed in 1987. Raceway construction, plumbing, holding systems and seawater systems testing were completed to prepare for the arrival of the first lobsters in March of 1988. These lobsters were brought over from the AE Monterey facility in California with minimal losses.

AE is principally culturing the Maine lobster, Homarus americanus. Experiments are also being conducted on the European lobster, Homarus gammarus, and a hybrid cross of the Maine and European species.

Initial research proved the seawater and environment at the Kona facility provided excellent conditions for lobster survival. AE lobsters are comparable in taste to wild lobster, and the advantage of freshness in delivery to the local and Pacific area markets makes the product even more desirable. Today, the lobsters are doing well and production looks very encouraging. Initial markets for AE lobster include Big Island resort hotels and the local restaurant industry.

Nori Seaweed Culture. Royal Hawaiian Sea Farms (RHSF) continues to develop techniques for commercial nori growout in the deep cold seawater at NELH. Based on earlier Sea Grant-sponsored research conducted at NELH in 1982, this project completed pilot-scale growout and nursery tests and now is developing a commercial phase.

RHSF was established to begin commercial production of Porphyra tenera, commonly



Steve Katase samples nori *ready for harvest in the large growout tanks under the RHSF shadecloth.*

Table 2: SUMMARY OF RESEARCH PROJECTS

PROJECT NAME	OBJECTIVES	SPONSORS	FUNDING SOURCE
BUOY FOULING AND CORROSION STUDIES	• To study fouling and corrosion of OTEC heat exchanger materials	UHM, HNEI, JHU/APL	HNEI, DOE, UHSG, NSF/ERDA, MAC
MINI-OTEC DEMONSTRATION	• To demonstrate net power production from closed-cycle OTEC	DPED, LMSC, DC, VAR. CO.	State of Hawaii
ARGONNE TEST PROJECT	• To study heat transfer monitoring and biofouling control for closed-cycle OTEC • To study microfouling in OTEC systems • To study corrosion of candidate heat exchanger materials • To study macrofouling in OTEC systems • To analyze incoming seawater	UHM/ANL UHM/ANL UHM/ANL UHM/ANL NELH/ANL	DOE/DPED DOE Funding via SERI since 07/83
SIMPLEX CORROSION PROJECT	• To measure corrosion of samples installed on offshore buoy	UHM	Simplex Wire & Cable Co.
UH ATMOSPHERIC CORROSION PROJECT	• To monitor and analyze corrosion samples in NELH marine atmosphere	HNEI	UH Foundation
OTEC AQUACULTURE: TROUT AND SALMON	• To investigate parameters of growing salmon and trout in deep cold seawater	HIMB	UHSG, MAC, DPED
OTEC AQUACULTURE: MACROALGAE	• To demonstrate culture of *nori* (Porphyra tenera) and *ogo* (Gracilaria spp.)	HIMB	UHSG, MAC, DPED
ABALONE CULTURE	• To investigate the feasibility of commercial abalone culture in Hawaii	Monterey Abalone Farms/Hawaiian Abalone Farm/Ocean Farms of Hawaii	Monterey Abalone Farms/Hawaiian Abalone Farm/Ocean Farms of Hawaii
OTEC CHLORINATION	• To study the effects of low level chlorination on the marine food chain	UHM	HNEI
MAINE LOBSTER CULTURE	• To validate Hawaii as a site for northern lobster (Homarus americanus) culture	Sanders Associates, Inc.	Sanders Associates, DPED
CABLE CORROSION	• To investigate corrosion of candidate materials for deep sea cables	Parson's Hawaii	DOE/HECO
ASTM CORROSION	• To monitor corrosion of metals in the ocean offshore of Keahole Point	ASTM	NELH
ALCOA CORROSION	• To study the corrosion of various aluminum alloys in flowing seawater	Alcoa	Alcoa
HEAT AND MASS TRANSFER RESEARCH	• To study the efficiency of spout evaporators and condensers by measuring heat and mass transfer in a seawater system	UHM/HNEI	SERI/DOE
GAS DESORPTION RESEARCH	• To use a packed column to study composition of dissolved gases in seawater at various temperatures and pressures.	UHM/ Look Laboratory	SERI/DOE
MIST-LIFT PROCESS	• To demonstrate operation of the mist-lift cycle with seawater	R&D Associates, Marina del Rey, CA	SERI/DOE
CWP/AST PHASE III	• To deploy and monitor 1/3 scale FRP CWP down slope off Keahole Point	HD&C/NOAA	NOAA/DOE
OTEC AGRICULTURE	• To grow strawberries with freshwater condensing on pipes carrying cold seawater.	UHM	UHSG
MICROALGAE CULTURE	• To develop commercial microalgae culture techniques in seawater.	Cyanotech Corp.	Cyanotech Corporation
MACROALGAE STUDY	• To study growth of macroalgae in surface and deep seawater.	UHM	HNEI
GIANT CLAM CULTURE	• To study effects of Hawaiian environment on giant clam growth.	Marine Animal Assoc. Waikiki Aquarium	Private
NORI CULTURE	• To develop commercial nori culture techniques for Hawaii.	Aquaculture Concepts/ Royal Haw'n Sea Farm	Private
ALCAN OTEC	• To investigate corrosion behavior of various alloys and heat exchanger configurations	ALCAN Int'l.	ALCAN
OPIHI CULTURE	• To investigate and demonstrate growth of opihi (Hawaiian limpets).	W.H. Magruder	Private
MACROALGAE INVESTIGATION	• To investigate the potential use of macroalgae for removing excess nutrients from seawater return.	UHM Dept. of Tropical Agriculture	HNEI, ADP
PHYTOPLANKTON STUDY	• To study the occurrence of a symbiotic cyanobacterium in the cells of certain diatom populations in surface seawater	Johns Hopkins University	Office of Naval Research
MAINE LOBSTER CULTURE	• To test feasibility of commercial lobster (Homarus americanus) culture using deep cold seawater.	Aquaculture Enterprises	Aquaculture Enterprises
FISH DRYING PROJECT	• To test solar drying units for use with fish jerky production project.	Haw'n. Fish Distributors	DBED
ALGAL CO_2 UPTAKE	• To study uptake of carbon dioxide from stack gases by algal scrubbers.	UHM, EPRI	EPRI
HIRAME PROJECT	• To study the growth of *hirame* or flounder in deep seawater for commercial culture	Yonezawa Suisan	Yonezawa Suisan

AT THE NELH KONA SEACOAST FACILITY

INVESTIGATOR	DATES	RESULTS	STATUS 7/88
J. Larsen-Basse F. Munchmeyer	1976 to 1979	Biofouling became significant after an initial incubation period of several weeks.	Completed
E. Grabbe	1/79 to 12/79	First successful net power production from closed cycle OTEC. Generated > 10 Kw net electricity on a floating platform moored in the NELH Offshore Research Corridor.	Completed
J. Larsen-Basse L.R. Berger J. Larsen-Basse E.A. Kay T.Daniel	7/81 to 9/87	1. Biofouling in warm surface water repeatedly reduces heat transfer to unacceptable level within 20 days of flow. 2. Chlorine levels as low as 70 ppb for 1 hr/day can control biofouling 3. No reduction in heat transfer (biofouling) has occurred over 4 years of continuous cold seawater flow 4. Aluminum alloys do not show pitting corrosion in warm seawater, but do in cold seawater.	Completed
J. Larsen-Basse	7/81 to 3/82	Measured corrosion on several metal alloys installed on offshore buoy	Completed
J. Larsen-Basse	7/81 to 3/83	Collected corrosion data on several aluminum alloys.	Completed
A. Fast	1/82 to 11/84	1. Experiments yielded > 0.5 lb fish per gallon of deep cold seawater. 2. Identified optimum temperatures, photoperiods, and flow rates. 3. Studied smoltification parameters for salmon. 4. First to successfully spawn trout in seawater.	Completed
F. Mencher R. Spencer	1/82 to 3/83	1. Obtained high *nori* growth rates (35% mass increase/day) initially and 40-60 gm/m^3/day in high density (2-3 kg/m^3) tanks. 2.Optimum photoperiods and temperatures were determined.	Completed
G. Lockwood	2/82 to present	1. Abalone and kelp (Macrocystis pyrifera) to feed them can be grown in the deep cold seawater. 2. The high nutrient content of the deep seawater yields high protein content in the kelp. 3. The lack of pathogens in the deep water permits its use without filtration. 4. A commercial development module has been initiated.	Continuing
F.J. Sansone	6/82 to 6/83	1. Chlorine kinetics in tropical seawater differ markedly from results with other seawater. 2. Reaction of the chlorine with tropical seawater takes much longer than in temperate water. 3. Only trace levels of halogenated organics are produced in chlorinated NELH seawater.	Completed
M. Thays	9/82 to 10/83	1. Maine lobster grow well in the Sanders culture system using temperature control obtained by mixing surface and deep seawater 2. Present economics indicate this culture method would be unprofitable.	Completed
J. Larsen-Basse	1/83 to present	Various candidate cable materials show expected corrosion in seawater.	Continuing
J. Larsen-Basse	6/83 to 6/89	Submitted first samples to ASTM for analysis and comparison with samples tested elsewhere.	Completed
B. Liebert	1/83 to 1/85	Analysis of proprietary samples completed; effects of brushing in warm and cold seawater were studied.	Completed
J. Larsen-Basse	6/83 to present	1. Seawater results are similar to those with freshwater in Colorado tests. 2. Spout evaporators and condensers promise high efficency for open cycle OTEC	Continuing
H.-J. Krock	6/83 to 6/84	1. Dissolved gas compositions confirm predictions 2. The "height of transfer units" which measure the power required to remove dissolved gases are about 50% less with NELH seawater than predicted from freshwater data.	Continuing *(now combined with heat & mass transfer study)*
S.L. Ridgeway	6/83 to 12/83	1. Mist generator works well without clogging 2. Vapor-mist coupling approximates predictions—up to 100 m of lift may be available from 20° C.	On hold
I. Sandison	4/83 to 5/85	Deployment successful; data collection completed	Completed
S. Siegel, M. Vitousek	1/84 to 6/84	Strawberries and various vegetables grow well; seasonal cycling can be controlled by water flow rate.	On hold
G. Cysewski	7/84 to present	Spirulina, Dunaliella and other species grow well in seawater; commercial production begun.	Continuing
F. Mackenzie, C. Agegian	1/85 to 6/85	Macroalgae efficiently utilize high deep water nutrient concentrations.	Completed
M. Dailey	8/85 to 8/86	Preliminary: giant clams grow well in Hawaii.	Completed
S. Katase	8/85 to present	1. Nori spores will germinate and grow in NELH seawater. 2. Nori production seems commercially viable using the deep cold seawater	Completed
D. Goad	3/86 to present	Apparatus erected; experiments in progress.	Operating
W.H. Magruder	10/86 to present	Opihi reproduce and grow well in sprays of the deep seawater	Continuing
D. Robichaux	5/86 to 1/87	Algae mats can be used to remove most of the excess nutrients from return seawaters at NELH.	Completed
J. Heinbokel	9/86 to 9/87	Results pending.	Completed
P. Wilson, J. Wilson	7/87 to present	Preliminary: Lobsters do well in deep cold seawater.	Continuing
W. Kowalski	5/88 to 10/88	Test samples dried more quickly with good results in the solar drying units than in traditional ovens.	Completed
E. Laws	To begin 7/88		Continuing
H. Yonezawa	To begin 7/88		Continuing

known by its Japanese name, *nori*. The alga is grown using a tumble culture technique in which the cold seawater growth medium is kept moving continuously. This allows for maximum exposure to sunlight at the top of the tank, and therefore maximum growth. Harvesting is also facilitated since the plants do not have to be picked from a substrate as in nature.

During FY 1988, RHSF prepared a one-acre site and completed construction of production facilities and a laboratory. A large shadecloth structure houses a series of raceways and growout tanks. Spore-inoculated netting from Japan is agitated in specially designed raceways to simulate the moving waters of the natural environment of *nori*. The Agricultural Engineering Department of the University of Hawaii assisted RHSF in designing and building its mechanized system.

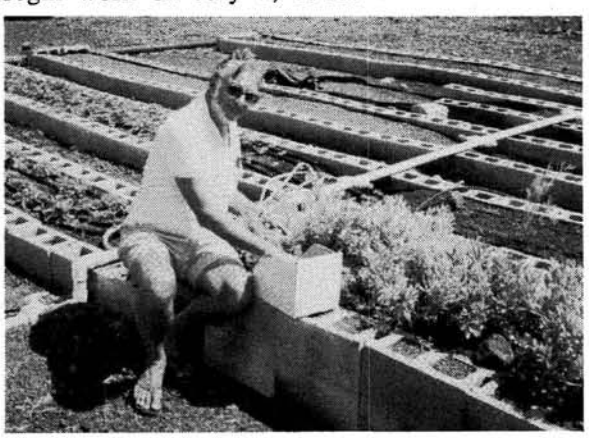
RHSF also expanded production to include the tumble culture of the popular alga, Gracilaria, commonly known as *ogo*. RHSF harvests and markets *ogo* weekly at the Keahole facility.

Opihi Culture. This project's goal is to collect the data necessary to design and build an opihi ranching operation. Several species of the limpets commonly known as *opihi* continue to thrive in the experimental set up at the NELH Kona facility. Deep seawater is applied to substrates, including lava rock and concrete blocks, in various test conditions. Algae which grow on the substrates form a mat upon which the opihi feed. Growth rates are encouraging, and the project looks forward to development of a commercial demonstration phase in the near future.

OTEC Agriculture. Temperate food and other high market value plant species can be grown in sub-tropical Hawaii using the cold freshwater which condenses on pipes carrying the cold sea water. The use of cold seawater to irrigate and cool land plants is an unusual but innovative application of this coldwater resource.

So far, several species of plants from temperate climates have been successfully propagated at NELH in a simple demonstration project initially funded by UH Sea Grant. Cold seawater is run through small pipes across the soil, providing moisture and coolness to the growing plants. Strawberries (Fragaria chiloensis sequoia), Alstroemeria flowers, asparagus, and several gourmet lettuces have done well in the small cinder-filled raised beds located within the NELH compound. Expansion to a commercial development stage is being planned for a site located outside the NELH compound.

Hirame Project. A Japanese-based firm has proposed to grow a type of flounder, known in Japan as *hirame* in the cold deep seawater at NELH in Kona. The project will begin work on July 1, 1988.



Marty Vitousek counts up his coldwater-enhanced crop of Alstroemeria.

Puna Geothermal Facility Developments and Status

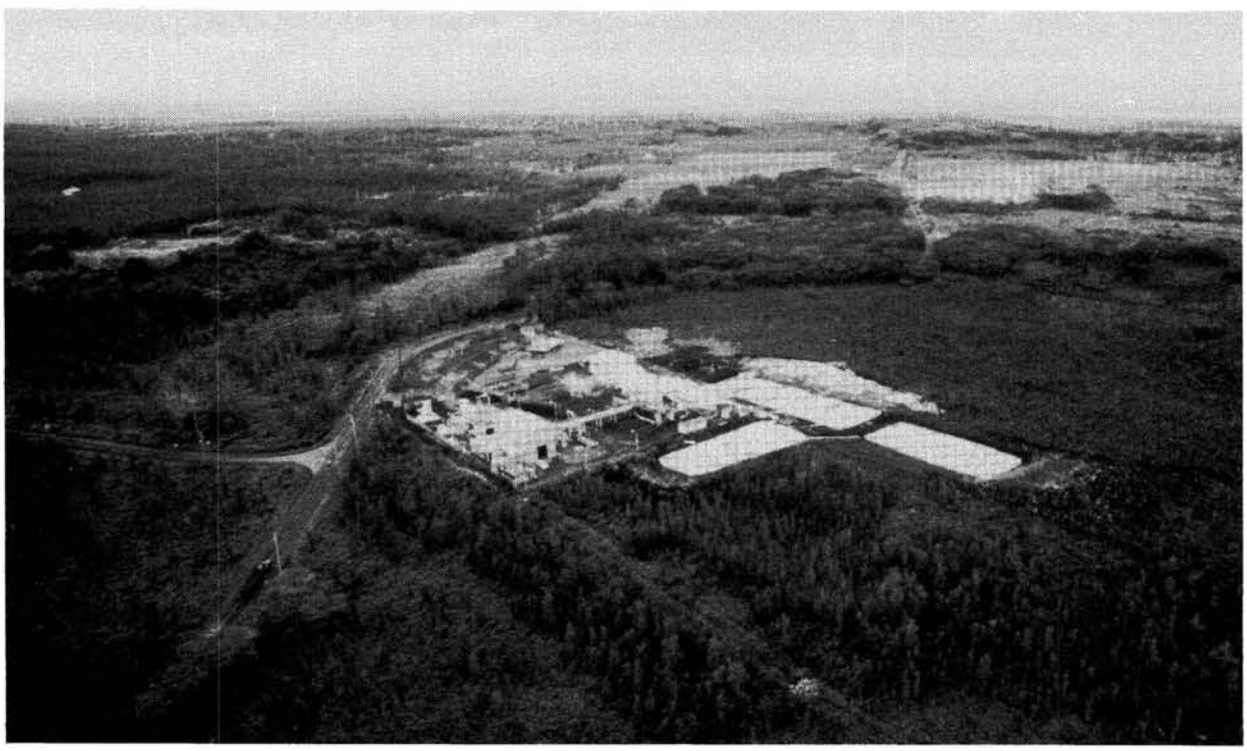
Background

The Puna Geothermal Facility consists of a geothermal well, a three-megawatt electric power plant and a research facility located on four acres in the Kilauea East Rift Zone of the Puna District, 25 miles south of Hilo on the Big Island of Hawaii.

The HGP-A geothermal well produces about 80,000 pounds per hour of mixed steam/liquid flow and the power plant generates an average power of between 2.0 and 2.5 megawatts. Noi'i O Puna geothermal research center is comprised of 2000 square feet of laboratory space, 1400 square feet of test pad, and 25,000 square feet of compound area which is available for geothermal-related research and demonstration projects.

History. The HGP-A geothermal well was started in December 1975, completed in April 1976, and successfully flashed steam in July 1976. In June of 1978 a contract was signed with the DOE for development and construction of a geothermal power plant. Following completion of the plant and several months of trials, commercial operation commenced in early 1982.

Specifications. The depth of the well is 6450 feet (1966 meters) and has one of the world's hottest bottom hole temperatures at 676° F (358° C). The well produces approximately 80,000 lbs/hr of a mixed phase fluid (57% liquid and 43% steam) at a wellhead pressure of 175 psia and a surface temperature of 365° F (186° C).



The NELH Puna Geothermal Facility is located in the district of Puna at Pohoiki in the middle of a lush ohia forest on the slopes of Kilauea Volcano.

Table 3: PUNA GEOTHERMAL FACILITY OPERATIONAL SUPPORT CAPABILITIES

GEOTHERMAL RESOURCE SUPPLY		
TYPE OF RESOURCE*	DELIVERY PRESSURE	TEMPERATURE
High pressure brine	160 psig	370° F
Low pressure brine	15 psig	250° F
Low pressure steam	15 psig	250° F
Hot potable water	50 psig	210° F
* Disposal system available for all fluids		
BRINE CHEMISTRY PARAMETERS		
• total dissolved solids (TDS): 15,800 mg/l	• pH: 6.6	• conductivity: 23,000 µmhos/cm
FACILITIES		
• research laboratory space, enclosed and outdoors • office space • chemistry laboratory, (lab benches, glassware, balances, fume hood, etc.) • mechanical shop	• electrical distribution panel (70 kva): —480 vac single- and three-phase —240 vac single- and three-phase (30 amp and 50 amp receptacles) —120 vac single-phase (20 amp receptacles	• instrumentation and shop • 40 x 40 ft concrete test pad • rest room • potable water • trash receptacle • post office box (Pahoa)
GENERAL EQUIPMENT		
• air compressor (100 psi at 50 cfm) • trailer-mounted air compressor (375 cfm at 100 psi) • heat exchangers (shell and tube, air exchangers)	• surplus supplies (valves, pipe fittings, temperature/pressure devices, etc.) • trailer-mounted 10 kw electrical generator	• IBM PC/XT computer system and Okidata printer • Telephone-Fax • Copy machine
PUBLIC INFORMATION		
• covered visitor center with restrooms and self-guided exhibit panels	• public lectures on request	• facility tours by appointment
SECURITY		
• fenced research area	• security coverage during off-hours and holidays	

Environmental Concerns. Maintaining the environment was a major consideration in the plant design. As a result, hydrogen sulfide and other noncondensible gases are extracted from the main condenser and burned in an incinerator. Burning hydrogen sulfide produces sulfur dioxide gas which is quenched and absorbed by water. The sulfur gases from the incinerator are finally neutralized in an abatement scrubber with caustic soda.

A comprehensive environmental program is being carried out to monitor the air quality as well as the noise level from the facility. After the steam and water mixture exits the well and goes through the separator, the water travels through a pipe to a series of drainage ponds where it percolates back into the earth.

Management. NELH assumed management responsibility for the facility in December 1985, and in November 1986 the federal DOE formally transferred title to NELH. Roy Nakanishi is Puna Operations Supervisor.

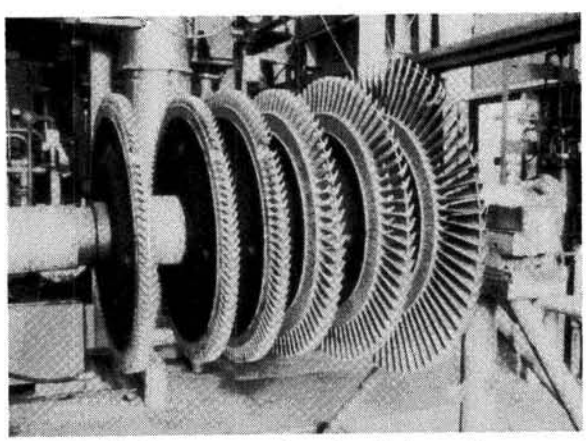
The Puna Geothermal Facility provides for by-product development through support of research projects which utilize the heat, steam, brine, and other geothermal resources available at the site. Like its sister facility in Kona, PGF encourages the further commercialization of successful research projects.

Power Production. Of the 2500 kw produced by the turbine, 200 kw is used to operate the power plant and 2300 kw net energy is delivered to the local HELCO grid for transmission to HELCO customers. Over the past six years which HELCO has been contracted to maintain and operate the power facility, the plant has generated over 120,000,000 kw hours of electricity.

Benefits and Economics. Annually, power production at the plant reduces the island's need for fuel oil by 30,000 barrels of oil while providing electricity for 2,000 homes with an availability factor exceeding 95%. The power plant has not only provided operational experience and research data on Hawaii's geothermal resource but revenues from the sale of electricity also have contributed to covering operating costs and maintenance expenses of the facility.

The operation of the Puna Geothermal Facility has demonstrated that the production of electricity from the geothermal resource in the Kilauea East Rift Zone is not only technically possible, but environmentally and economically viable.

Plant upgrade. In late 1987, the HGP-A power plant was upgraded and overhauled with funds appropriated by the 1987 State Legislature. Power generation has increased from 1.8 to 2.2 mw net power since the overhaul.



Turbine blades are exposed to view during maintenance at the power plant on the NELH Puna Geothermal Facility site.

Geothermal Research & Development Projects

Puna Geothermal Research Center

Hawaii has been blessed with one of the hottest geothermal resources in the world suitable for conventional electric power production. Many applications of geothermal energy, however, are non-electric.

In order to more fully explore the potential of geothermal energy in Hawaii, the Noi'i O Puna Geothermal Research Center (PGRC) was constructed in 1985 by the Hawaii Natural Energy Institute of the University of Hawaii at Manoa to support innovative approaches toward direct heat use. A small grants program was jointly initiated by DBED's Energy Extension Service and the UHM in 1985. The Community Geothermal Technology Program (CGTP) was created to encourage local entrepreneurs to experiment with non-electric uses of the discarded hot fluids and other by-products from the power plant. Since then, a number of projects have been conducted, some of which are ongoing, with applications ranging from the drying of food products to the fixing of dyes on silk.

In Hawaii, direct use of geothermal heat could be applied to agricultural and food processing,
materials drying, packaging, refrigeration, health spas, household water heating, and much more.

Elsewhere in the world, geothermal heat is in use daily for a wide range of applications. Geothermal energy supplies home heating and hot water requirements for more than 200,000 residents in Reykjavik, Iceland. An Oregon dairy uses geothermal heat for milk processing and pasteurization.

The PGF electrical power plant uses only a portion of the available heat energy produced by the well. The heat value of the untapped "waste heat," if properly developed, could actually exceed that of the steam currently used in the generation of electricity.

The power plant control room at the Puna Geothermal Facility.

Community Geothermal Technology Program Projects

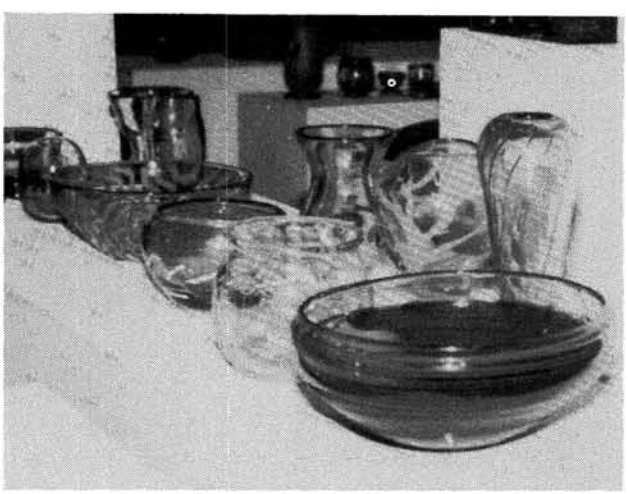
The Community Geothermal Technology Program (CGTP) is managed jointly by DBED's Energy Extension Service in Hilo, Hawaii, and UHM's Hawaii Natural Energy Institute. Funding for the program has been provided by the U.S. Department of Energy, the County of Hawaii, and a number of private donors.

Since 1986, the CGTP has annually requested proposals for research and development projects requiring up to $15,000. In FY 1987, five projects were funded and successfully conducted at the Noi'i O Puna Geothermal Research Center. Of these, several have inquired about the possibility

of commercial expansion and have entered into preliminary negotiations with NELH to do so.

A second round of funding was awarded by the CGTP in FY 1988. Five projects were selected for funding from eleven proposals submitted. The projects all make use of the the PGRC and represent a wide variety of uses of geothermal heat and silica, a by-product of the well fluids. The five new projects funded under the CGTP are currently in various stages of development and operation.

Hawaiian Glass Making. The silica which is deposited after the geothermal brine dries seemed a potential source for an unusual geothermal product. Norman Miller and Bill Irwin proposed to utilize the silica powder in a uniquely Hawaiian art glass. A formula was developed and art glass samples made with PGF silica were distributed to the University of Hawaii at Manoa art department and to other artists statewide for experimentation. Some of the art pieces produced from those trials were put on display at the Volcano Art Center in a special show during August 1987.



These pieces were produced by local artists using glass made from a special blend of PGF silica and other chemicals.

Lumber Drying. Bill Irwin and Denver Leaman found an excellent direct heat application: the drying of local hardwoods. Where drying is usually a months-long process in the high humidities of East Hawaii, with the drying ovens heated by geothermal brine the same process was shortened to five weeks. In addition to saving time, the energy costs were negligible.

Green Papaya Powder Drying. Dried agricultural products are normally energy-consuming products. However, using geothermal waste heat, Peter Allen and David Livingstone tested a number of products in a specially designed dryer with good results. Their primary interest was in the processing of green papaya which would give farmers one more alternative for harvests which could not be sold as fruit.

Cloth Dyeing by Geothermal Steam. A very unusual use of geothermal steam was first proposed by Japanese artist Yukie Kimura and Dr. Motoyuki Kawagoe in 1986. Heat is used in the dyeing process for natural fiber fabrics to fix the colors. The presence of minerals in geothermal steam was an added benefit, for it added brilliance to the colors as well as fixed them. Ms. Kimura has experimented with a variety of silks and dyes at the Puna facility in this project, with favorable results.

Bottom Heating. This project has been continuing since the first round of CGTP funding and is being conducted by James Downing, owner of Leilani Foliage of Puna. Plastic tubing containing water heated by the brine from the HGP-A well is run in

James Downing shows how heated water is piped through small tubes under each planter tray.

parallel rows beneath germination trays. Mr. Downing has found that this application of "bottom heating" allows soil temperatures to be regulated and elevated, dramatically improving plant germination success and subsequent growth.

Certain species of palms are especially difficult to sprout when compared with other types of plants and, consequently, nursery operators are often reluctant to culture these species. In a small greenhouse constructed by Mr. Downing at the PGRC, experiments were conducted comparing germination rates of palm seeds sprouted with and without bottom heating. Several types of ornamental palms have been tried in the past year resulting in enhanced seed germination and growth rates. The success of this project has been so encouraging that Leilani Foliage would soon like to expand their nursery operation to a full-scale business using geothermal heat.

Media Steam Sterilization and Drying. Robert D'Anna of D'Anna B'nana had an on-going problem of what to do with coconut husks he had accumulated in his business of providing coconuts for various markets. He recognized the potential of using this as a growing medium for plant growth and propagation but needed a means to provide heat for sterilization. Mr. D'Anna submitted a proposal to the CGTP which would utilize the geothermal heat to accomplish this. His proposal has recently been accepted.

The company plans to shred, steam, and dry the coconut husks and a variety of organic materials to be used as a medium for plant growth. Utilizing the brine/steam available at the PGRC, they hope to provide a certifiable growing medium for the local nursery industry as an alternative to importing sterile soil for plant shipment to the mainland.

Geothermal Aquaculture Project. Robert Taylor of Hawaii Aquafarms has proposed a research test program to utilize geothermal heat and power to run a low input recirculating aquaculture system for growing tilapia at the PGRC. He plans to develop a heating and feeding schedule to determine the optimum temperature and population concentration for fingerling grow-out to marketable size fish.

Silica Bronze Casting. Henry Bianchini, a well-known local sculptor, has proposed a research program to develop techniques to separate, dry and wash silica from the geothermal brine for use as a refractory material in bronze casting. He currently

uses imported brick dust as his refractory material and will be investigating the possibility of using the silica as a viable substitute to save on the costs of importation of other materials.

Roy Nakanishi examines pineapple slices drying in an oven powered by waste geothermal heat.

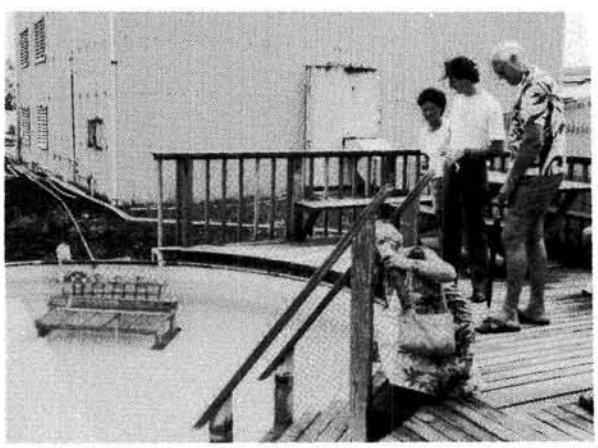
Electrodeposition of Minerals in Geothermal Brine. Dr. Patrick K. Sullivan of Oceanit Laboratories, Inc. has proposed to conduct research at the PGRC using samples of liquid brine to produce mineral deposits via electrolysis. It is believed at this time that there are sufficient trace minerals in the brine to produce calcium deposits on test specimens by this method.

Other Research

Silica Recovery. Dr. Donald Thomas of the UHM's Hawaii Institute of Geophysics (HIG) has been investigating the possibility of constructing a prototype silica handling recovery system. In order to utilize the commercial value of the silica-laden geofluids, an economically viable recovery process will have to be developed. Dr. Thomas is currently monitoring the performance of a small heat exchanger in order to develop baseline information on silica scaling.

Fiber Optics Sensor. Researchers at the University of Hawaii at Manoa and Lawrence Livermore Laboratory have been working on using fiber optics in the development of a technique to measure chemical properties in operating geothermal wells. Preliminary laboratory results indicate temperatures can be measured using a ruby crystal.

Geothermal Spa Demonstration. A portable swimming pool has been rigged with a small heat exchanger which uses geothermal waste heat to warm the water. The pool may be filled with plain water or with mineral waters from the geothermal resource, much like mineral springs used around the world by the health conscious.



DBED Energy Extension Agent Steve Holmes explains how the PGF demonstration spa is heated with a submerged heat exchanger using geothermal heat.

Table 4: SUMMARY OF RESEARCH PROJECTS

PROJECT NAME	OBJECTIVES	SPONSORS	FUNDING SOURCE
BOTTOM HEATING SYSTEM	• To utilize geothermal waste heat to enhance seed propagation and growth	HNEI, DPED, CGTP	DOE, Private Donations
GREEN PAPAYA POWDER DRYING	• To dry agricultural products using geothermal waste heat	HNEI, DPED, CGTP	DOE, Private Donations
LUMBER DRYING	• To develop methods and drying schedules for local hardwoods	HNEI, DPED, CGTP	DOE, Private Donations
CLOTH DYEING BY GEOTHERMAL STEAM	• To utilize flashed brine to dye silks • To experiment with local dye sources	HNEI, DPED, CGTP	DOE, Private Donations
HAWAIIAN GLASS MAKING	• To make glass from silica produced as a by-product from HGP-A well	HNEI, DPED, CGTP	DOE, Private Donations
ATMOSPHERIC CORROSION	• To identify corrosiveness of geothermal environment for better material selection	UHM	UHM
FIBER OPTIC SENSOR	• To develop a technique for measuring chemical properties in operating geothermal wells	UHM	Lawrence Livermore National Laboratory
SILICA RECOVERY	• To develop a means of recovering silica from geothermal brines	HIG, NELH	DPED
AQUACULTURE	• To utilize geothermal heat for a low input recirculating aquaculture system	HNEI, DPED, CGTP	DOE, Private Donations
MEDIA STEAM STERILIZATION AND DRYING	• To steam sterilize and dry organic material used for plant growing media	HNEI, DPED, CGTP	DOE, Private Donations
ELECTRODEPOSITION OF MINERALS	• To produce deposits via electrodeposition	HNEI, DPED, CGTP	DOE, Private Donations
SILICA BRONZE CASTING	• To use silica as a refractory material	HNEI, DPED, CGTP	DOE, Private Donations
GEOTHERMAL SPA	• To demonstrate the use of waste heat for a geothermally heated spa	NELH	NELH

AT THE PUNA GEOTHERMAL FACILITY

INVESTIGATOR	DATES	RESULTS	STATUS 7/88
James Downing Ken May	4/86 to present	Seed propagation and plant growth are significantly accelerated with heated soil; commercial potential high.	Continuing
Peter Allen David Livingstone	4/86 to present	Experimental dryer works well with all types of fruits; cost savings is ideal; commercial potential high.	Continuing
Bill Irwin Denver Leaman	4/86 to present	Drying lumber possible within four to five weeks; more data required to develop schedules for other hardwoods.	Continuing
Yukie Kimura Dr. M. Kawagoe	4/86 to present	Hawaiian steam produces brilliant colors and sets dyes fast in Japanese silks	Continuing
Norman Miller Bill Irwin	4/86 to present	Formula developed produces excellent art glass; formula distributed to UHM and artists statewide.	Continuing
S. Quazi B. Liebert	12/86 to 4/87	Corrosion at HGP-A is uniquely determined by physiochemical conditions of site environment; corrosion rate accelerated by presence of hydrogen sulfide, chloride and sulfate ions at site.	Completed
A. Seki S. Sharma	9/87	Preliminary lab results indicate that temperatures can be measured with a ruby crystal; continuation pending future funding.	Completed
D. Thomas	4/87 to present	Project beginning; results pending.	Continuing
Robert Taylor	3/88 to present	Project beginning; results pending.	Continuing
Robert D'Anna	3/88 to present	Project beginning; results pending.	Continuing
Patrick Sullivan	3/88 to present	Project beginning; results pending.	Continuing
Henry Biancini	3/88 to present	Project beginning; results pending.	Continuing
NELH Staff	10/87 to present	Concept successfully demonstrated; commercial potential shows promise.	Continuing

Future Plans

Kona Seacoast Facility

Open Cycle OTEC. The DOE-HMTSTA experiments will continue using the direct contact condenser in the second of two towers at NELH-Kona. The next stage of this experimental series is the construction of the Heat and Mass Transfer Experimental Apparatus (HMTEA) which will test a full-scale evaporator and condenser for the final stage of these OC-OTEC experiments, the Net Power Producing Experiment (NPPE). Construction of the NPPE is planned for 1991 and the energy-producing system should be operative by 1992.

Closed Cycle OTEC. Plans for one or two demonstration plants to produce power using closed cycle OTEC are being considered for the NELH Keahole site. A feasibility study is underway for testing of a 500 kw gross closed cycle OTEC plant integrating power production with desalination. The potential for freshwater production through this process economically enhances the OTEC concept.

ALCAN. Following the encouraging results of their initial research, ALCAN has extended their experiment at NELH for another two years. They have been conducting materials and subcomponent testing at the Kona laboratory since 1985.

ALCAN has also contracted GEC/Marconi of the United Kingdom to prepare a feasibility study for a pilot scale closed cycle OTEC plant and desalination facilty for possible implementation at NELH.

Desalination. The Hawaii County Economic Opportunity Council (HCEOC) has proposed a solar desalination project and research facility is proposed for the NELH-Kona site. Desalination equipment planned for use in Milolii will be tested at NELH-Kona.

DUMAND. A major international project to deploy an array of underwater neutrino and muon sensors offshore of Keahole Point is planned. Initial tests of instrumentation have been conducted. NELH will serve as shore base for the experiments.

Mariculture. NELH is in various stages of discussion with a number of prospective mariculture ventures that would like to utilize the unique and seawater resources that are available at Keahole Point.

Puna Geothermal Facility

Through the NELH Board, the State DBED-Energy Division, the Hilo Energy Extension Office, HNEI, HIG, the County of Hawaii, and NELH staff, the facility is actively being marketed for research and development projects using the geothermal resources available at the site.

Commercial Expansion. NELH has been approached by several of the CGTP researchers for additional space for commercial expansion of their projects. Currently, NELH is limited to accepting projects which have minimal space requirements. The need for additional land adjacent to the PGF is required if further support is to be provided for commercial expansion of successful projects at the PGRC. At this time, NELH has negotiated with an adjacent land owner for provision of an additional 10-15 acres to serve as a pilot or "mini"-geothermal industrial park.

If successful, the mini-park and lessons learned in its development and operation would be used to develop larger geothermal industrial parks. The result would be new businesses, jobs, and tax base for the residents of the Puna area.

HGP-A Power Plant. NELH will continue to operate the HGP-A power plant until another source of geothermal fluids is available to support the geothermal research center. Annual overhauls are being scheduled by HELCO and NELH to assure that safety and performance of the well and power plant as well as environmental quality are maintained.

Honolulu Office

The Honolulu Office has been approached by numerous companies and projects desiring to utilize the unique resources available at NELH. The future promises more unique and innovative applications of the natural energy resources of both the NELH-Kona and Puna facilities. Major efforts in planning, organization, and coordination will be required if NELH is to meet the needs of its rapidly expanding projects and demands on its resources and infrastructure.

NELH has requested funds from the State to expand the Honolulu office to meet the dramatically increasing work load. In order to provide centralized administrative services to the Kona and Puna facilities, an administrative assistant and fiscal officer will be added to the office staff.

Merger with HOST Park. During the next legislative session, the Department of Business and Economic Development will submit a plan to merge the two complementary facilities under one administrative body. The park was modelled after the successful commercial developments at NELH. The planned merger of the commercial park and research facility promise to foster continued growth and development at Keahole Point.

Figure 2: EMPLOYMENT AT NELH

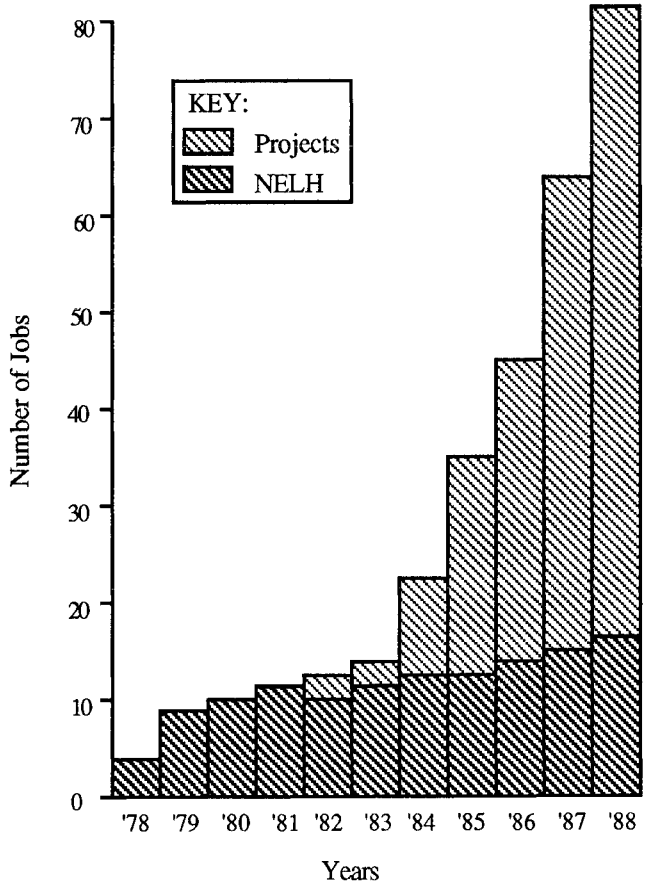


Figure 3: NUMBER OF PROJECTS

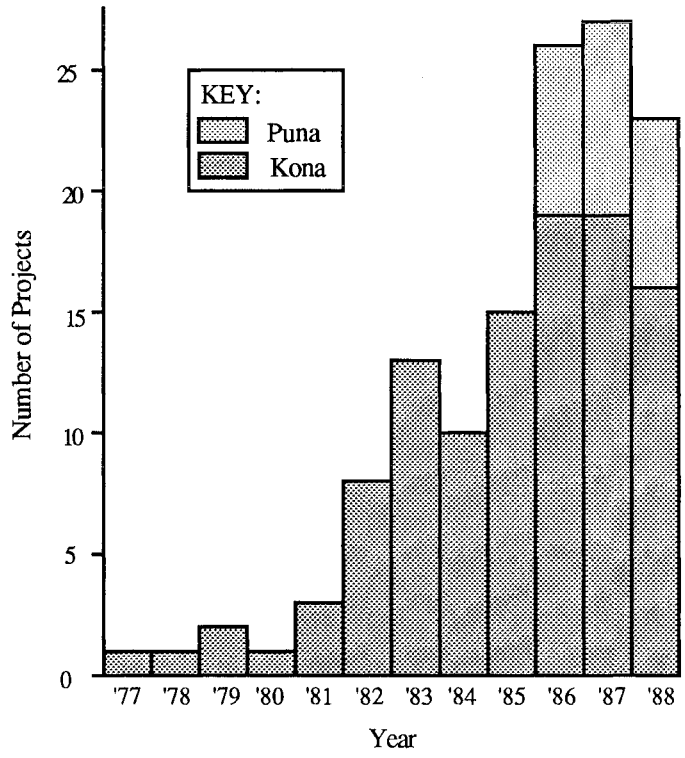


Figure 4: CUMULATIVE CAPITAL INVESTMENT KONA SEACOAST FACILITY

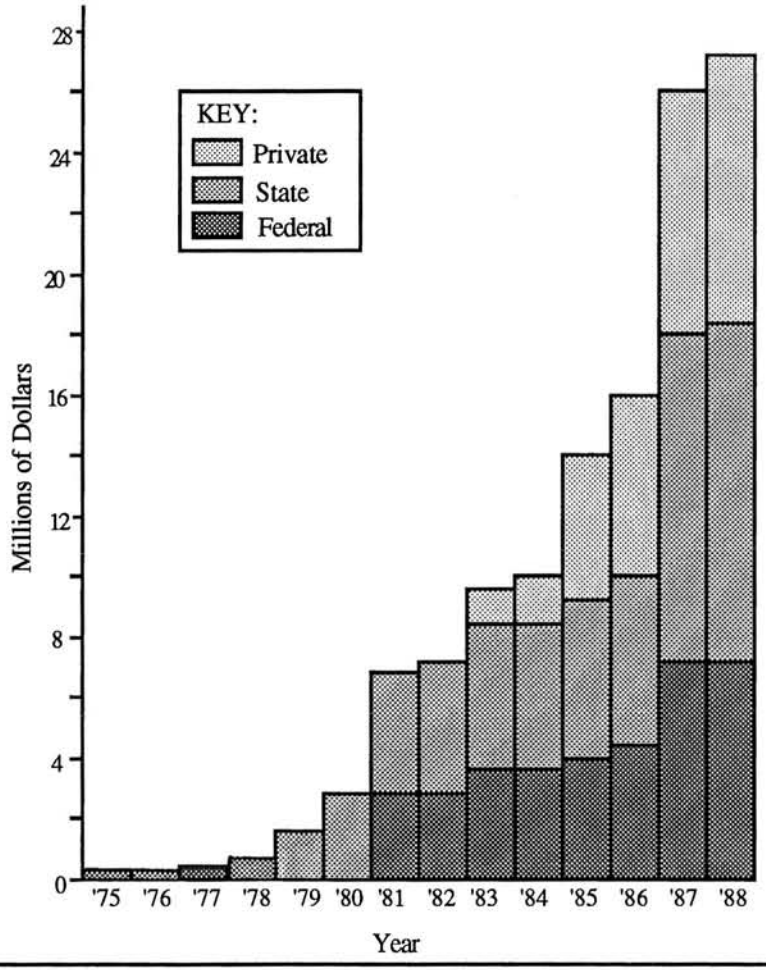
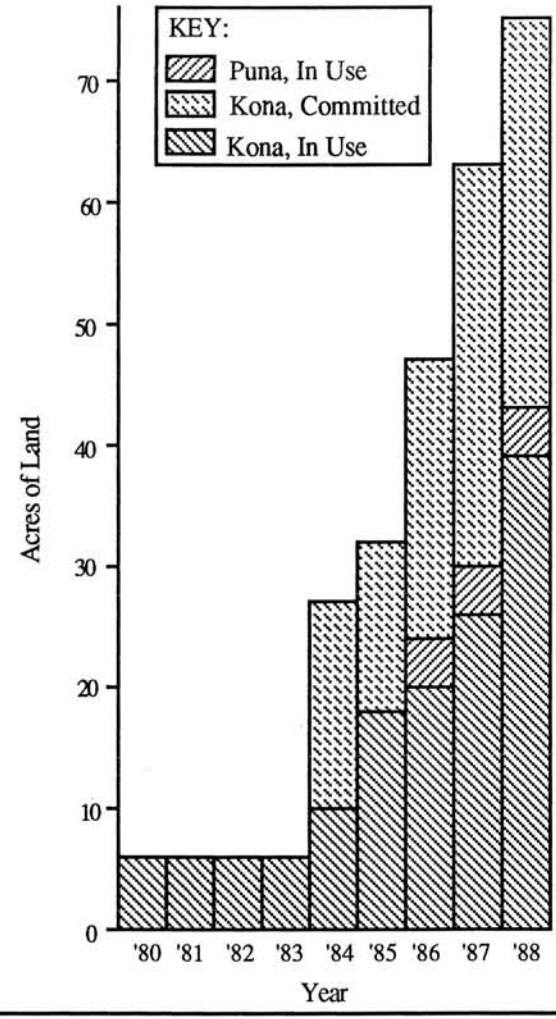


Figure 5: LAND UTILIZATION



Funding Summary

I. Operating Funds

	FEDERAL	STATE	USER FEES	TOTAL
A. KONA SEACOAST FACILITY				
1. Operational Support		$251,611		
2. Project Funding				
a) OTEC Experiments	$431,000		$28,781	
b) Aquaculture Projects			$177,695	
c) Other Projects			$2,637	
3. Transfers		-$10,000		
KONA SUBTOTALS:	*$431,000*	*$241,611*	*$209,113*	*$881,724*
B. PUNA GEOTHERMAL FACILITY				
1. Operational Support		$60,000		
2. Project Funding				
a) CGTP			$3,000	
b) Other Projects				
3. Transfers		-$5,350		
PUNA SUBTOTALS:		*$54,650*	*$3,000*	*$57,650*
C. HONOLULU OFFICE				
1. Operational Support		$14,905		
2. Funded Positions		$73,624		
3. Transfer		$15,350		
HONOLULU SUBTOTALS:		*$103,879*		*$103,879*
TOTAL OPERATING BUDGET:	**$431,000**	**$400,140**	**$212,113**	**$1,043,253**

II. Capital Improvement Funds

	FEDERAL	STATE	PRIVATE	TOTAL
A. KONA SEACOAST FACILITY				
1. Supplemental EIS		$140,000*		
2. 18" CW Pipeline		$1,498,000		
3. Compound Expansion		$180,000		
4. 40" CW/WW DOE/HOST Pipelines	$3,000,000	$5,500,000*		
5. Environmental Monitoring Wells		$63,000		
6. Project Expansion and Improvements (estimated)			$1,000,000	
KONA SUBTOTALS:	*$3,000,000*	*$7,201,000*	*$1,000,000*	*$11,201,000*
B. PUNA GEOTHERMAL FACILITY				
1. Research Center Expansion		$115,000		
2. HGP-A Plant Overhauls		$350,000		
PUNA SUBTOTALS:		*$465,000*		*$465,000*
TOTAL CAPITAL IMPROVEMENTS:	**$3,000,000**	**$7,666,000**	**$1,000,000**	**$11,666,000**

*Funding by HTDC

Appendix A

NELH Policy on Project Acceptance

The criteria for acceptance of projects at NELH shall be based upon the projects' relation to the development of natural energy resources and upon their utilization of those resources that are available at the NELH sites in Kona and Puna. Projects that are only tenuously related to alternate energy development and/or do not require the resources that are available shall be referred to the appropriate governmental agency for action and recommendations.

The 1984 Hawaii State Legislature enacted changes to the NELH legislation which allows commercialization of projects at NELH facilities. Leasing of NELH land for commercial purposes can now be approved by the Board of Directors, provided that some initial phases of the research are accomplished at the laboratory.

Appendix B

Publications Resulting from Research at the Kona Seacoast Facility

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Brewer, William A., Jack P. Huizingh and Jane E. Sexton, "Hawaii's OTEC Park Triggers High-Tech Aquaculture Development," *Info-Fish Marketing Digest*, No. 1/85, pp. 18-21.

Daniel, T.H., "Ongoing Experiments at the Natural Energy Laboratory of Hawaii, Keahole Point," presented at the 7th Big Island Science Conference, UH Hilo, April 1983.

Daniel, T.H., "OTEC and Cold Water Aquaculture Research at the Natural Energy Laboratory of Hawaii," *Proceedings of the Pacific Conference on Marine Technology--PACON 84*, Marine Technology Society, April 1984, pp. MRM2/47-52.

Daniel, T.H., "Aquaculture Using Cold OTEC Water," Oceans '85 Conference Record, Marine Technology Society, San Diego, Ca., November 12-14, 1985, pp. 1284-89.

Daniel, T.H., "Deep Ocean Water Uniquely Suited for Tropical Aquaculture," presented at the 8th Big Island Science Congress, University of Hawaii at Hilo, April 1985.

Daniel, T.H., "Food and Energy from the Sea: Research at the Natural Energy Laboratory of Hawaii, presented at the First Sigma Xi Mini-Conference, University of Hawaii at Hilo, 22 April 1988.

Daniel, T.H., "Operational Experience with the Cold Water Pipe at the Natural Energy Laboratory of Hawaii," *Oceans '86 Conference Record,* Marine Technology Society, Washington, D.C., September 23-25, 1986, pp. 185-90.

Daniel, T.H. and Terry R. Penney, "Energy from the Ocean: A Resource for the Future," *Science and the Future: 1989 Year Book, Encyclopaedia Britannica,* Chicago, 1988, p. 98-111.

Fast, Arlo W. and Karen Y. Tanoue (eds.), *OTEC Aquaculture in Hawaii*, Honolulu, UNIHI-SEAGRANT-MR-89-01, in press for publication in 1988.

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Hallanger, L.W., "Capabilities and Potential of the OTEC Seacoast Test Facility," presented at the 8th Ocean Energy Conference, Washington, D.C., June 1981.

Kearney, T.J., "Analysis and Formation Mechanisms of N-Halomethylamines: Application to Seawater Chlorination," M.S. Thesis in Oceanography, UHM, August 1983.

Kearney, T.J. and F.J. Sansone, "Analysis and Formation Mechanisms of Mixed N-Halogenated Methylamines," presented at the Fifth Conference on Water Chlorination, Williamsburg, Va., June 3-8, 1984, in *Water Chlorination: Environmental Impact and Health Effects*, Vol 5, R.L. Jolley et al (eds.), 1985.

Krock, Hans-Jurgen and Manfred J. Zapka, "Gas Evolution in Open Cycle OTEC," *Proceedings of 5th Symposium on Offshore Mechanics and Arctic Engineering*, Tokyo, Japan, April 1986, pp. 612-17.

Larsen-Basse, Jorn, "Corrosion of Some Aluminum Alloys in Cold and Warm OTEC Waters," presented at Corrosion '83, Paper no. 66, NACE, April 1983.

Larsen-Basse, Jorn, "Effect of Biofouling and Countermeasures on Heat Transfer in Surface and Deep Ocean Hawaiian Waters--Early Results from the Seacoast Test Facility," presented at ASME/JSME Thermal Engineering Joint Conference, Honolulu, March 1983, Vol. 2, pp. 285-89.

Larsen-Basse, Jorn and T.H. Daniel, "OTEC Heat Transfer Experiments at Keahole Point, Hawaii, 1982-83," presented at Oceans '83, San Francisco, Ca., August 1983.

Larsen-Basse, Jorn and Sanjeev Jain, "Aluminum Alloys as Potential OTEC Heat Exchanger Materials," *Oceans '86 Conference Record,* Marine Technology Society, Washington, D.C., September 1986, pp. 191-95.

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Larsen-Basse, Jorn, N. Sonwalkar and A. Seki, "Preliminary Seawater Experiments with Open Cycle OTEC Spout Evaporation," *Oceans '86 Conference Record*, Marine Technology Society, Washington, D.C., September 1986, pp. 202-6.

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Appendix C

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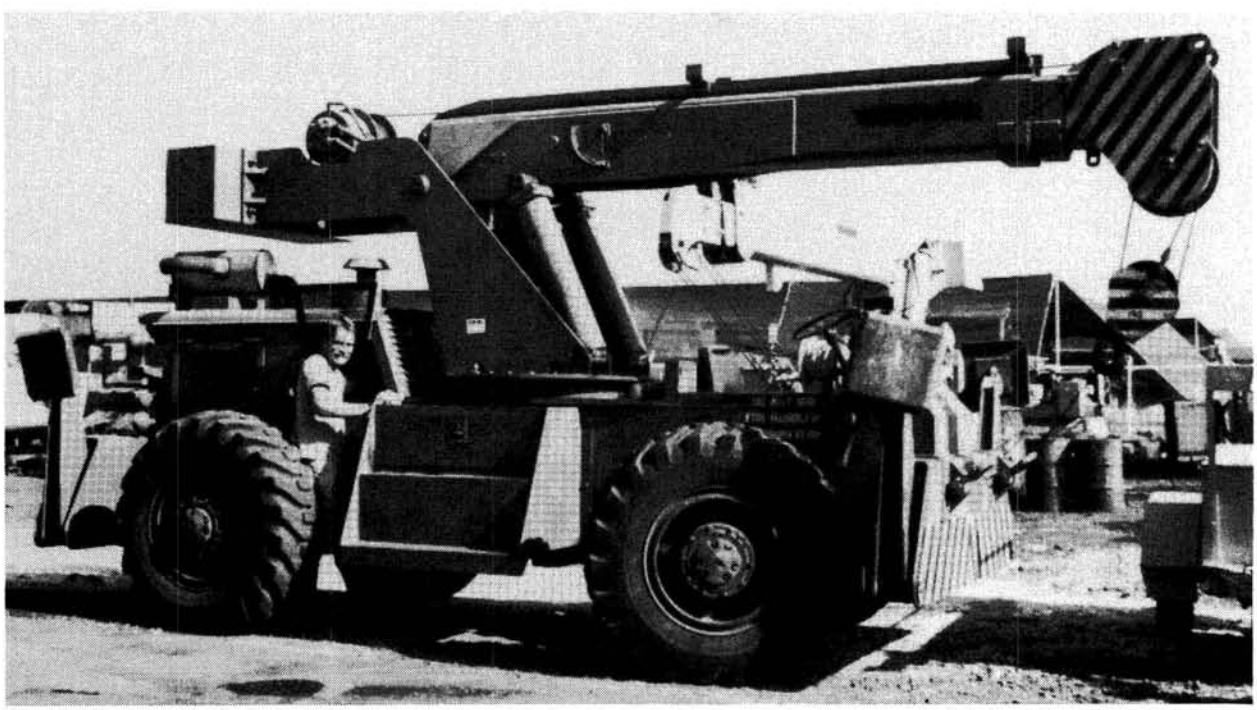

Steve Wilson is dwarfed by the 15-ton hydraulic crane used to move machinery, install pumps offshore, lift vehicles and other heavy-duty tasks at the NELH Kona Seacoast Facility at Keahole Point, Kona.