The Natural Energy Laboratory of Hawaii Annual Report 1981

THE NATURAL ENERGY LABORATORY
OF HAWAII
1978 - 1980 REPORT

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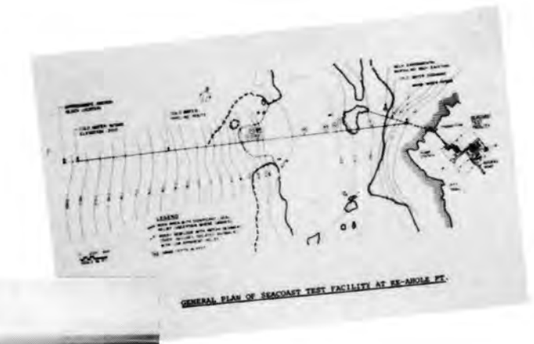
The Natural Energy Laboratory of Hawaii Annual Report

1978-1980

To Governor State of Hawaii, President of the Senate, Speaker of the House of the State of Hawaii



PREFACE

Since the 1977 Annual Report was issued, the Natural Energy Laboratory of Hawaii has experienced notable success and significant growth.

As indicated in this report for 1978-80, NELH has moved to formalize its legal status and obtain the necessary permits and rezoning to develop a research center. Ground was broken at the NELH site at Ke-ahole Point in January 1979, marking the beginning of property improvements to support the Seacoast Test Facility, NELH's first major onshore user.

We can be proud that Hawaii was chosen as the site of all three of the nation's major ocean thermal energy conversion (OTEC) activities: Mini-OTEC, the Seacoast Test Facility, and OTEC-1. It speaks well for NELH that it is the site of two of those activities. Mini-OTEC was positioned offshore of NELH and its experiments were supported by NELH operational staff. The Seacoast Test Facility is located at NELH itself. Thus, NELH is at the center of the nation's OTEC development efforts.

While our attention is rightly focused on OTEC, NELH has a mandate to serve as a research facility for all appropriate forms of natural energy research and ocean resource use. The tentative "Master Developmental Plan" reproduced on page 2 in this report sets forth areas for OTEC aquaculture and direct solar testing. We look forward to activities in these and many other areas in the coming years.

We hope that this report is a useful update on our growth and development.

John P. Craven
Chairman
NELH Board of Directors

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INTRODUCTION

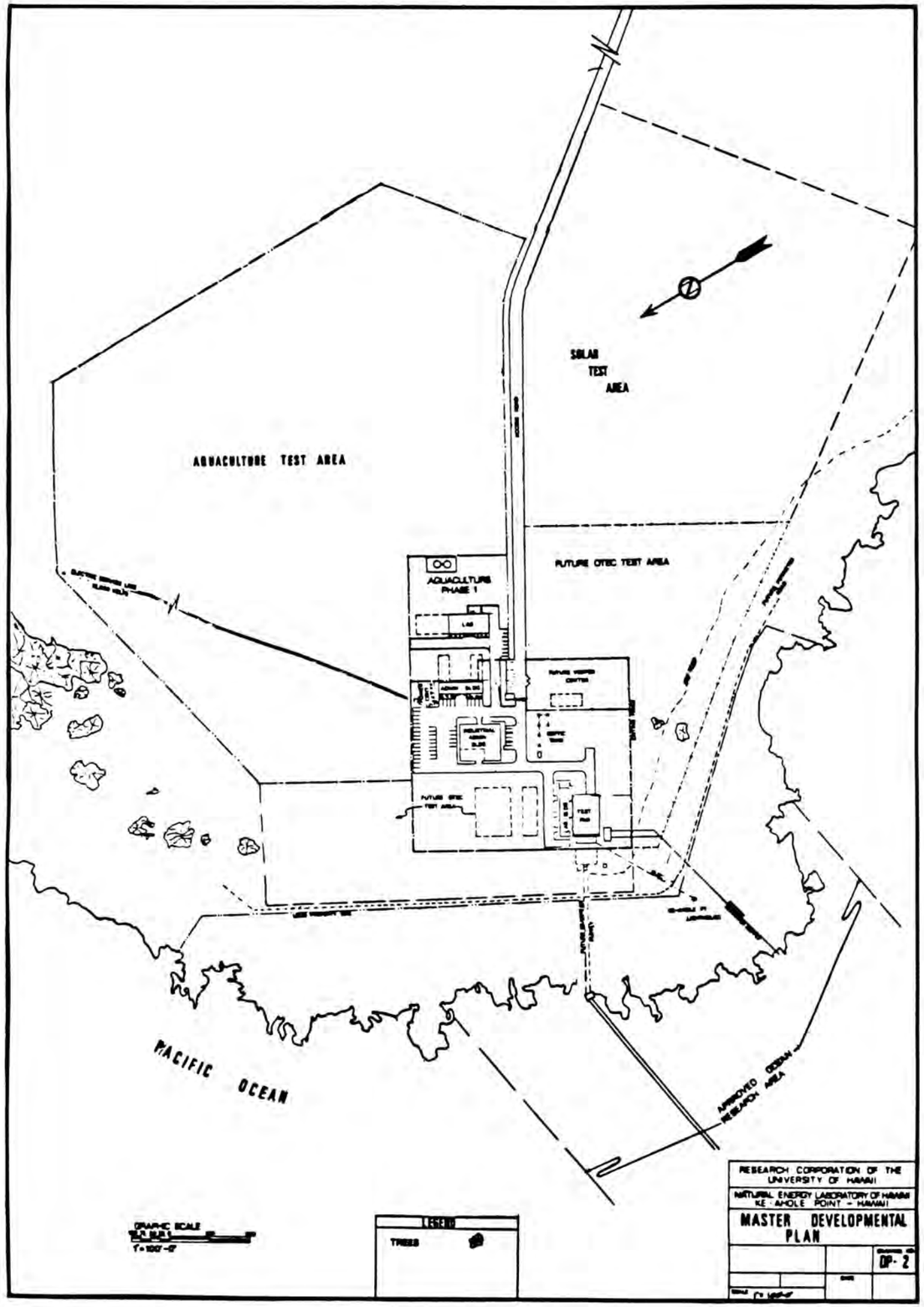
This report summarizes the 1978-80 activities and projects associated with the Natural Energy Laboratory of Hawaii (NELH). Earlier activities (1972-1977) are listed in Appendix B.

NELH was created by the Hawaii State Legislature in 1974 as a facility for natural energy research. It is located on 328 acres of state-owned land at Ke-ahole Point, adjacent to the Ke-ahole Airport on the Kona Coast of the Island of Hawaii. This site was chosen because of the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual solar radiation; accessibility to logistical support including major airports, harbors, and highways; and adequate quantitites of undeveloped land. Among the nine sites investigated, Ke-ahole Point is unique in meeting all of these major criteria.

NELH is governed by a Board of Directors consisting of the Director of the State Department of Planning and Economic Development, the State Marine Affairs Coordinator, the Chairman of the Board of Land and Natural Resources, two officers or employees of the University of Hawaii appointed by the President of the University, and two County of Hawaii officials appointed by the Mayor of the County.

The Board is responsible for maintaining NELH property, reviewing and approving research proposals from prospective users, and planning and coordinating the development of the NELH site. While NELH personnel may become directly involved in research, the primary function of NELH is to serve as the facilities manager for the research activities carried out by others. To date, NELH has been supported by State and County of Hawaii funds. It is expected that NELH operations will eventually be funded by user's fees.

NELH welcomes research proposals from both the public and private sectors. With the approval of the Board, researchers may arrange to share existing facilities or construct their own facilities. Areas of planned expansion are OTEC, OTEC-aquaculture, and direct solar energy applications research. Inquiries concerning NELH should be addressed to the Executive Director.



ACTIVITIES OVERVIEW

Institutional Progress

NELH experienced significant institutional progress in 1978-80. First, the necessary permits were obtained for the development of the Ke-ahole site. A "Master Developmental Plan" (see page 2) was drawn up and submitted with NELH's application for a Special Management Area Permit from the County of Hawaii. The Department of Land and Natural Resources approved the issuance of a lease to NELH for the Ke-ahole site in October, 1978. After public hearings, the property was rezoned "urban." Groundbreaking ceremonies for the construction of the new access road and other improvements were held on January 12, 1979.

Second, plans for NELH's first permanent onshore facility were developed. The State Energy Resources Coordinator, Director of the Hawaii Natural Energy Institute, State Marine Affairs Coordinator, and Managing Director of the County of Hawaii joined together to form the Seacoast Test Facility Development Group. The Development Group requested the Research Corporation of the University of Hawaii (RCUH) to prepare a proposal for the funding of an OTEC test facility by the federal government. The U.S. Department of Energy accepted that proposal in September, 1978.

Third, the organizational structure and powers of NELH were further defined. Act 236, Session Laws of Hawaii 1974, established NELH but did not set forth the specific powers or duties of its board and its relationship to other agencies. NELH thus sought clarifying legislation, which was passed as Act 213, Session Laws of Hawaii 1979. The text of Act 213 is presented as Appendix A. The Board also began consideration of appropriate policies, rules, and procedures for NELH users. In early 1980 the Board incorporated NELH as a non-profit corporation. The NELH Charter was issued by the Department of Regulatory Agencies on January 23, 1980, and By-laws were filed on February 28, 1980. Under Act 213, NELH was assigned to the Department of Planning and Economic Development (DPED) for administrative purposes. DPED, with the concurrence of the Board, contracted with the Research Corporation of the University of Hawaii to provide administrative services to NELH, a role in which RCUH has functioned from the beginning.

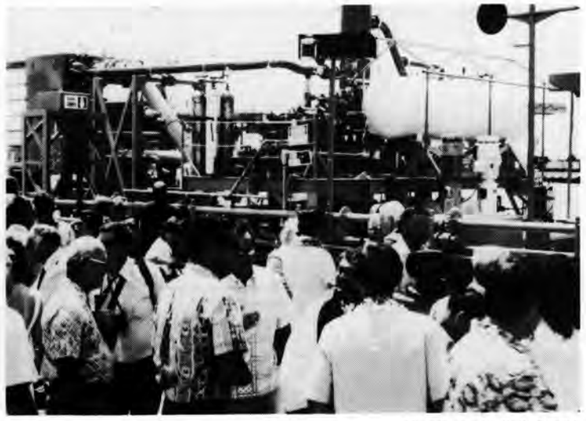
Onshore OTEC Experiment—1978

Research Activities

The first NELH-related research efforts consisted of initial studies covering ocean thermal energy conversion (OTEC), mariculture uses of OTEC discharge water, wave energy, corrosion and biofouling problems related to OTEC technologies, and environmental and socio-economic impacts of nearshore tropical ocean energy conversion plants. These led to a search for sites suitable for location of an OTEC plant or research facility. The Ke-ahole Point site was selected in 1975 based on the results of this study.

In the early years a series of studies were initiated relating to the biofouling and corrosion of OTEC heat exchangers. One of the most essential elements in demonstrating the economic feasibility of OTEC is establishing that scaling, biofouling, and corrosion can be held in check for the life of the plant without adding

Seacoast Test Facility Groundbreaking



Blessing of Mini-OTEC

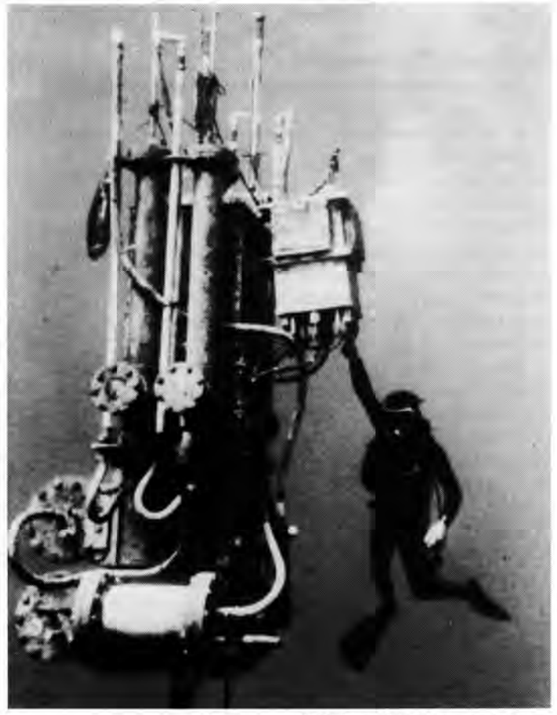
excessively to the costs. For this reason, agencies such as the National Science Foundation, the Energy Research and Development Administration (now U.S. Department of Energy), the Sea Grant Program, and the State of Hawaii undertook studies in this area.

Early research projects at the NELH site were somewhat limited by the access road which made four-wheel drive mandatory. However, significant scientific advances were made. For example, in 1976 a project was initiated by NSF and ERDA to investigate biofouling and corrosion problems in OTEC heat exchangers. Because such experiments must be conducted under conditions as close as possible to those an operating OTEC plant would encounter, the test apparatus was mounted on a buoy located fifty feet below the surface in about two hundred feet of water directly offshore Ke-ahole Point. Power to run the apparatus and data from the instrumentation were transmitted over cables connecting the buoy to a small portable laboratory building and a diesel generator onshore. Over the years this project has produced some of the best OTEC biofouling and corrosion information available anywhere in the world.

One major focus of activities during 1978-1980 was the Seacoast Test Facility (STF). STF is the first major project to be located at NELH. It is an onshore laboratory designed to conduct OTEC research in a variety of technological areas. The initial projects will be concerned with biofouling, biofouling countermeasures, and the corrosion characteristics of OTEC heat exchangers. STF will occupy approximately 5 acres near the tip of Ke-ahole Point.

In Phase I of STF, design of the pipeline system and onshore facilities was accomplished. A bottom current survey and visual reconnaissance were conducted early in 1979 to provide detailed bottom design data along the proposed cold water pipeline route. Construction in support of the STF began in January, 1979. The paved access road, grading of land, fencing, gatehouse and utilities were completed by December, 1979.

Another major activity in 1979 was the Mini-OTEC project. The Mini-OTEC project itself received no direct funding through NELH, but it was deployed under permits obtained by NELH for its research corridor, and received support from NELH staff. Also, NELH initiated a project to describe the biological impact on the marine environment of the deployment



Offshore OTEC Research Buoy

and operation of the Mini-OTEC system. Thus, Mini-OTEC is an NELH-related project. Under the agreement of the project participants the Mini-OTEC system became the property of the State of Hawaii at the completion of the first deployment, and is now considered to be an NELH facility.

Other research activities included a plan for a facility suitable for using OTEC water for aquaculture research; a study of the environmental variability at a benchmark site off Ke-ahole Point, and the construction of a 3-inch pipeline from the offshore biofouling and corrosion buoy to an onshore site, thus permitting experiments to take place simultaneously on and offshore. Details on 1978-80 research activities are presented in Appendix B.

THE MINI-OTEC SUCCESS

On August 2, 1979, Mini-OTEC became the world's first at-sea, closed-cycle OTEC plant to generate net energy. Hailed throughout the world, Mini-OTEC is a major breakthrough in ocean energy development.

Hawaii Governor George Ariyoshi said in his telegram to President Carter announcing Mini-OTEC's success, "I am delighted to send you the good news that Hawaii has achieved an historic first in energy production . . . Mr. President, I believe the Hawaiian peninsula named Ke-ahole Point deserves to be recorded in history as the site of this important technological turning point in America's war for energy independence." The Governor likened Mini-OTEC to the first flight by the Wright Brothers. The Mini-OTEC success has been described in newspaper and magazine articles, conference proceedings, and technical journals.

Mini-OTEC operated for three and a half months about 1 mile offshore Ke-ahole Point. It used ammonia as a working fluid to generate up to 52 kilowatts (kW) of electricity. Thirty-five to 40 kW were used to operate the pumps, compressor, and other equipment necessary to keep the system running, while the remaining 10 to 15 kW were consumed in test loads aboard the barge. Television sets, lights, and power tools were operated on this surplus power. Mini-OTEC was a proof-of-concept system built with off-the-shelf components to prove that OTEC plants really do work. With only 10-15 kW available for consumption out of the 50 kW that the generator was producing, net power available equaled 20-30 percent of gross power generated. This performance was significantly better than what was predicted. Predictions using these same analytical techniques indicate that a plant designed to generate 200 to 400 megawatts of electricity would deliver at least 70 percent of these levels to the utility grid or other end user.

From concept definition to successful operation, Mini-OTEC took only l5 months. It was a joint venture project which included the State of Hawaii and a number of private firms, each contributing a combination of equipment, time and financial support.

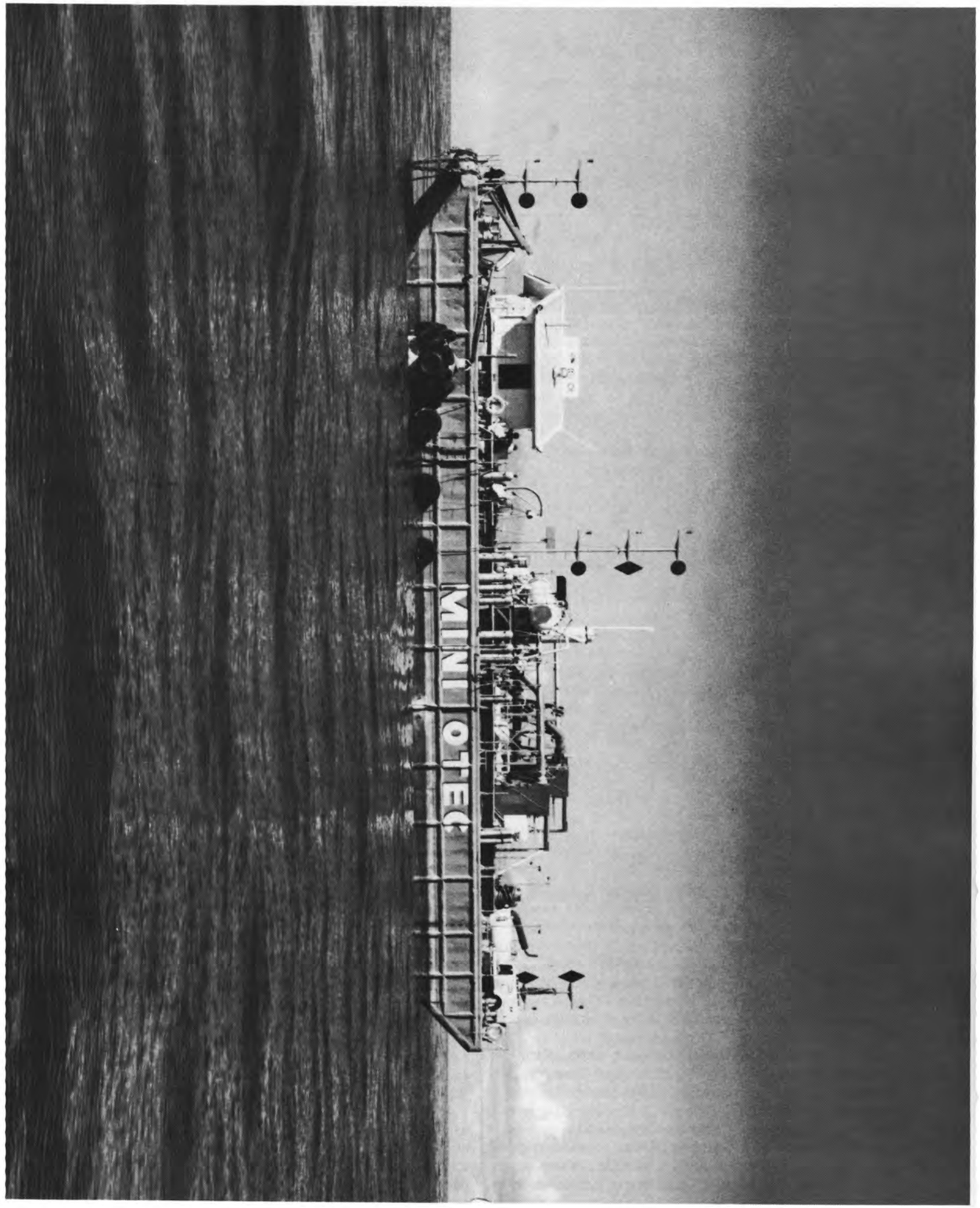
The OTEC plant itself was designed, built and installed by Lockheed Missiles and Space Company. Although assembled from many off-the-shelf components, considerable innovation and sound intuitive engineering was required to achieve a successful operation out of a theoretical concept. System construction and installation was done by the Dillingham Corporation. Major system components were provided by Alfa-Laval of Sweden, which donated the titanium plate heat exchangers and provided both instrumentation and expertise; the Rotoflow Corporation of Los Angeles, which constructed the turbine/generator assembly; and the Worthington Pump Company of Philadelphia, which provided the sea-water pumps.

Governor Ariyoshi Onboard Mini-OTEC

The State of Hawaii directed and supported operation of the system through RCUH, NELH and the State Department of Planning and Economic Development. The State Marine Affairs Coordinator funded modifications to the barge (on loan from the Navy through the help of the Department of Energy) which was used as the plant machinery platform, as well as the purchase of the 2,170-foot polyethylene cold water pipe (supplied by Phillips Driscopipe Inc. of Dallas), its mooring design, and installation. Dillingham Corporation of Hawaii contributed project management expertise during the construction and deployment phases, and did all the barge modifications and marine installations at cost.

The overall project objectives were to (1) develop an operating-at-sea OTEC system, (2) gain "real world" operating experience on an OTEC system, (3) provide a subsystem, component, and technology facility that can be used as a risk-reduction test bed, and (4) expand public awareness of the OTEC potential. All of these objectives were realized.

In mid-November, 1979, Mini-OTEC was returned to the University of Hawaii's Snug Harbor facility for evaluation and modifications before a second deployment. The second deployment, planned for late 1980 or early 1981 is expected to include OTEC-aquaculture research.

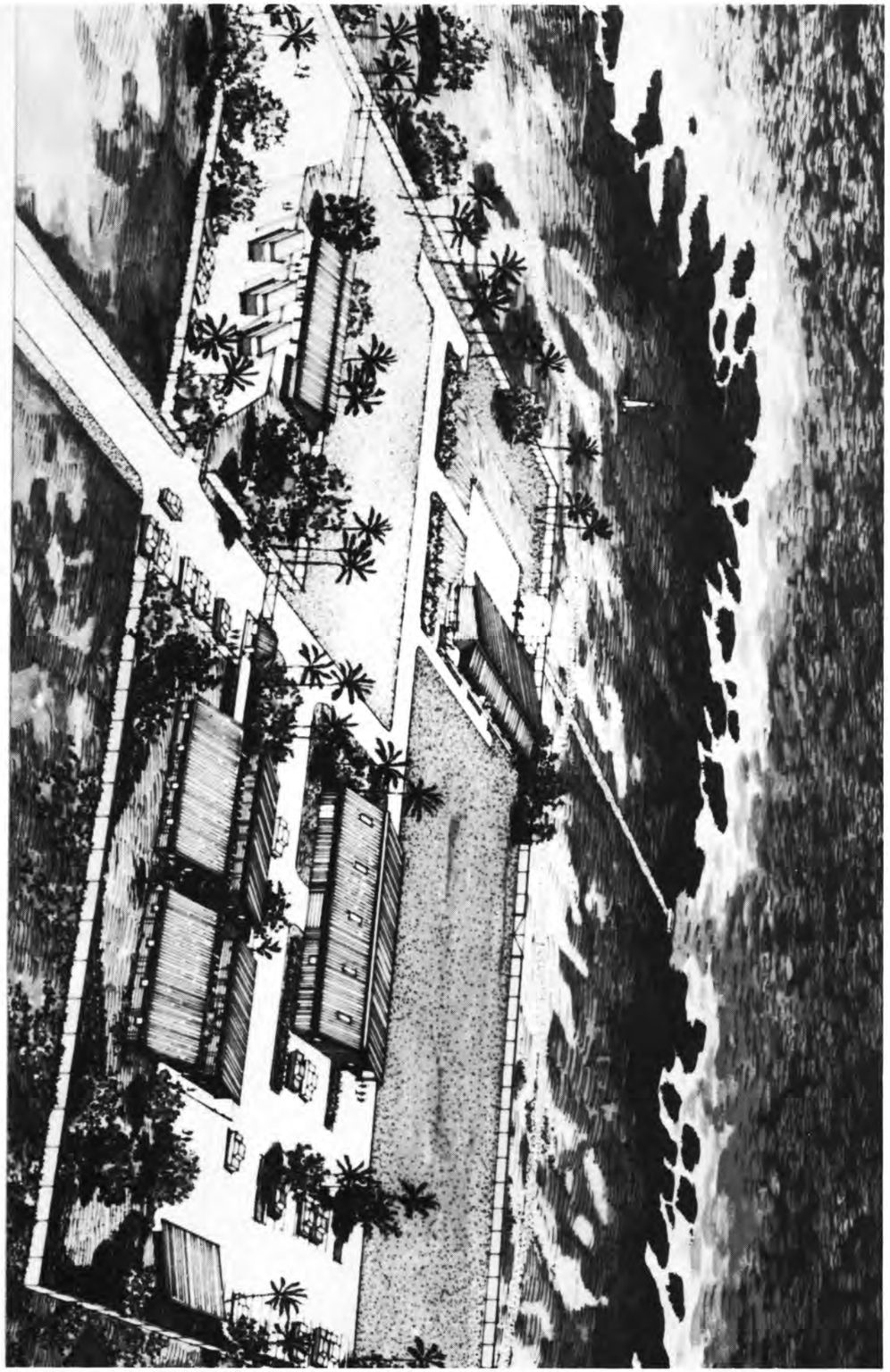


BUILDING THE SEACOAST TEST FACILITY

In September of 1978, Argonne National Laboratory (ANL), acting on behalf of the U.S. Department of Energy, accepted the proposal of the Research Corporation of the University of Hawaii (RCUH) acting as the agents for the Seacoast Test Facility Development Group to locate an onshore OTEC test facility at NELH. The first phase of the project, the design of the test and supporting facilities, was awarded to Hawaii, and Dr. Edward K. Noda was appointed Project Manager by the STF Development Group. Authorization to proceed with Phase I work was given by ANL, and Parsons, Brinckeroff, Quade and Douglas, Inc. was selected as the architectural-engineering firm. The final design was completed at the end of 1979. It is a result of extensive tradeoff studies dealing with pipe material characteristics, protection, deployment, risk analysis and costs.

Phase II, construction of the pipe system and shore facilities, is divided into two stages. Stage 1 includes the refurbishment of an existing state-owned temporary warm water supply, capable of pumping 2000 gallons per minute of nearshore water, and the construction of onshore test facilities. These facilities include a 60-by-100-foot concrete test pad, a laboratory building which includes a control and data acquisition room, an industrial building housing administrative offices plus shops and warehouse space, and a power center which contains standby diesel-electric generators and also serves as the power distribution center for the site. Both the test pad and the laboratory building are designed for easy expansion to meet added test requirements. The access road construction, site grading and fencing, security building, and utilities to the site, which were completed during 1979, are also considered to be part of the Stage 1 construction effort.

The major water supply system and an administration building will be provided in Stage 2 of construction. This seawater system utilizes an innovative design to provide the required volumes of warm and cold ocean water of adequate quality at the desired temperature differential. Current plans calls for a deep water pipeline supplying 6400 gallons per minute of cold seawater from a depth of 2100 feet and a warm surface water pipeline pumping up to 9600 gallons per minute of warm seawater from a depth of 50 feet. Design of the facilities has been funded primarily by the federal government while the early portions of the Stage 1 construction have been funded by the state.



OTEC SEACOAST TEST FACILITY - KEAHOLE POINT, HAWAII

BUDGET SUMMARY

ABBREVIATIONS

ERDA	Energy Research and Development Administration (now DOE)
DOE	Department of Energy
DPED	Department of Planning and Economic Development
HIG	Hawaii Institute of Geophysics
HNEI	Hawaii Natural Energy Institute
MAC	Marine Affairs Coordinator
NELH	Natural Energy Laboratory of Hawaii
NSF	National Science Foundation
OI	Oceanic Institute
SG	Sea Grant

BUDGET SUMMARY / 1972—6/30/79

	Year	County of Hawaii	State		Federal	
A. Operational Support						
Natural Energy Proposals	1976		$ 38,000	MAC		
Project Support for NELH	1975	$50,000	50,000			
Project Support for NELH	1976		58,000			
Operational Support for NELH	1977		92,000	DPED		
Operational Support for NELH	1978		97,000			
		$50,000	$335,000			
B. Site Studies						
Report on Aquaculture and Ocean Energy Systems for the County of Hawaii	1972	$ 5,000	$ 5,000	MAC		
An Evaluation of Oceanographic and Socioeconomic Aspects of a Nearshore OTEC Pilot Plant in Subtropical Hawaiian Waters	1975				$ 48,000	NSF/ERDA
A Further Evaluation of the Oceanographic Conditions Found off Ke-ahole Point, Hawaii and the Environmental Impact of Nearshore Tropical Energy Conversion Plants on Subtropical Hawaiian Waters	1975		10,000	DPED		
Environmental Survey Benthic Ecosystem at Ke-ahole Point	1977		25,625	DPED		
Environmental Survey Benthic Ecosystem at Ke-ahole Point	1978		21,710	DPED		
Field Observations of Ocean	1977		2,400			
Site Selection Bathymetry Survey Ke-ahole Point, Hawaii for Deepwater OTEC Pipeline	1978		35,670	DPED		
Engineering Studies and Land Surveys of the Ke-ahole Point—Site of NELH. Currents, Temperature Profiles, and Surface Plankton off Ke-ahole Point, Hawaii	1978		46,000	DPED		
		$ 5,000	$ 43,025		$ 48,000	
C. Site Development						
NELH Uncontaminated Surface Seawater Supply System	1977		$ 65,000	DPED		
Preliminary Design of Ocean Thermal Energy Conversion (OTEC) Deep, Water and Warm Water Pipeline Systems Proposed for Ke-ahole Point	1978		$ 24,928	DPED		

	Year	County of Hawaii	State		Federal	
D. Ocean Energy						
A Pilot Engineering Study of OTEC	1975		$ 6,686	HNEI		
The Oceanic Institute's OTEC Ocean Structure Model Project	1975		$ 9,625 $ 4,907	UH OI	$ 111,594	SG
Pipeline Survival Under Ocean Wave Attack	1975		$ 10,000	MAC	$ 37,000	SG
Operational Sea State and Design Wave Criteria for OTEC Projects	1976		$ 10,000	MAC	$ 39,000	SG
The Isaacs Wave Energy Pump: Tests off the Coast of Kaneohe Bay, Oahu, Hawaii	1976				$ 36,000	ERDA
Consolidated Oceanographic and Meteorological Data for Four North Pacific OTEC Sites	1977		$ 43,323	DPED		
Corrosion and Fouling Renewal	1977		$ 4,500			
Fouling and Corrosion in OTEC Heat Exchangers	1976		$ 7,598	HNEI	$ 114,000	NSF/ERDA
OTEC Heat Exchanger Biofouling Experiment	1977		$ 15,000	MAC	$ 246,000 $ 53,591	NSF/ERDA SG
Fouling and Corrosion in OTEC Heat Exchangers	1978				$ 294,000	DOE
OTEC Heat Exchanger Biofouling Experiment	1978		$ 23,716	DPED	$ 52,477	SG
E. Mariculture						
OTEC Mariculture/Algal Project	1977		$ 10,000	DPED		
F. No Funded Projects During These Years						
Other						
Mantle Conductivity Beneath the Hawaiian Ridge					$ 10,000	NSF
TOTALS		$55,000	$762,688		$1,041,662	

Year	County of Hawaii	State		Federal	
A. Operational Support					
Operational Support for NELH		$ 97,758	DPED		
B. Site Studies					
Phytoplankton Monitoring at Ke-ahole Point Related to OTEC Environmental Research Program		$ 32,000	MAC	$238,000	DOE
Bottom Current Survey		$ 31,733	DPED		
C. Site Development					
Seacoast Test Facility		$ 31,000	UH	$550,599	DOE
NELH—Facilities and Road Construction		750,000	DPED		
		330,000	MAC		
3-Inch Pipeline at NELH		35,700	MAC		
D. Ocean Energy					
OTEC Heat Exchanger Biofouling Experiment				$ 47,230	SG
Mini-OTEC		$ 600,000	MAC		
Environmental Impact of Mini-OTEC Operation		12,000			
		51,305	HNEI		
E. Mariculture					
Phase I of Aquaculture Component at NELH		$ 115,000	MAC		
F. No Funded Projects During This Year					
TOTALS		$2,086,496		$835,829	

ACT 213 **HB NO. 1680**

A Bill for an Act Relating to the Natural Energy Laboratory of Hawaii and Making an Appropriation Therefor.

Be it Enacted by the Legislature of the State of Hawaii:

SECTION 1.—Findings and purpose. The legislature finds that the State of Hawaii is generously endowed with a variety and abundance of natural energy resources, among which are geothermal, solar radiation, steady winds, ocean waves, biomass, and ocean thermal energy conversion (OTEC), and Hawaii has been chosen as the site for a number of significant demonstrations in the development of natural energy.

By Act 236, Session Laws of Hawaii 1974, the legislature provided that the natural energy laboratory of the State of Hawaii be located on the parcel of state-owned land makai of the Ke-ahole airport on the island of Hawaii and further provided that the laboratory is to be under the direction and management of a consortium that could be made up of several state and county entities and such foundations and enterprises as may be willing to provide funds, facilities, or research for the laboratory.

Following enactment of Act 236, a consortium consisting of representatives of the county of Hawaii, the office of the marine affairs coordinator, the University of Hawaii, the department of land and natural resources, and the department of planning and economic development has been providing for the direction and management of the natural energy laboratory at the Ke-ahole Point site.

In 1978 capital investment funds were released to provide for the development of the natural energy laboratory site and for facilities essential to its operation/ Funds were also released for demonstrating projects for participation by the State, the county of Hawaii, and the private sector in demonstrating the feasibility of OTEC. In addition, the United States Department of Energy has approved plans for the demonstration of OTEC concepts and related research and development projects to be located at the natural energy laboratory. Thus, Hawaii can become the international center for natural energy investigations utilizing the Ke-ahole Point site.

It is the purpose of this Act to provide for the formal organization and operation of the natural energy laboratory of Hawaii.

SECTION 2.—The Hawaii Revised Statutes is amended by adding a new chapter to be appropriately designated and to read:

CHAPTER

NATURAL ENERGY LABORATORY OF HAWAII

Sec.-1—Establishment of Natural Energy Laboratory of Hawaii; purpose. There is established a body corporate and a public instrumentality of the State of Hawaii to be known as the Natural Energy Laboratory of Hawaii. The Natural Energy Laboratory of Hawaii shall be placed within the department of planning and economic development for administrative purposes.

The Natural Energy Laboratory of Hawaii shall manage and operate an outdoor research facility on a parcel of state-owned land at Ke-ahole Point on the island of Hawaii. The outdoor research facility shall provide a site for research, development, and demonstration of natural energy resources and for other compatible scientific and technological investigations. For the purposes of such activities, the outdoor research facility shall include the land at Keahole Point, the waters offshore, and the structures constructed or erected thereon or therein, as determined to be required by the managing board of the Natural Energy Laboratory of Hawaii.

Sec.-2—Managing board; composition. The Natural Energy Laboratory of Hawaii shall be under the general control and management of a managing board consisting of seven ex officio voting members. The director of planning and economic development, the chairman of the board of land and natural resources, the marine affairs coordinator, two officers or employees of the Uniersity of Hawaii as designated by the president of the university, and two officials of the county of Hawaii as designated by the mayor of the county of Hawaii shall be the members of the managing board.

Sec.-3—Powers of the managing board. In the name of the Natural Energy Laboratory of Hawaii, the managing board may:

(1) Adopt, amend, and repeal bylaws governing its organization, the conduct of business, and the exercise of its powers and duties;
(2) Promulgate rules with respect to its projects, activities, properties, and facilities, which rules shall be in conformance with chapter 91;
(3) Promote the use of the Natural Energy Laboratory site for the purposes provided by law;
(4) Impose and collect fees pertaining to the use of properties and facilities of the Natural Energy Laboratory of Hawaii;
(5) Make and execute contracts and all other instruments necessary or convenient for the exercise of its powers and functions under this chapter;
(6) Contract for and accept gifts or grants in any form from any public agency or from any other source;
(7) Formulate budgets to provide for the operation of the laboratory;
(8) Appoint, hire, and remove, without regard to chapters 76 and 77, necessary staff for the laboratory, and establish the salaries therefor;
(9) Submit an annual report to the governor, the president of the senate, and the speaker of the house of representatives, which shall include, but not be limited to, progress and accomplishments made in the year, an accounting of funds received and disbursed, and the status of research projects; and
(10) Do any and all things reasonably necessary to carry out its purposes and exercise the power granted in this chapter.

Sec.-4—Special fund. Any other law to the contrary notwithstanding, there is established a special fund to be known as the Natural Energy Laboratory of Hawaii special fund, into which shall be deposited all moneys, fees, grants, and gifts made to the Natural Energy Laboratory of Hawaii and from which expenditures may be made to provide for the operation of the Natural Energy Laboratory of Hawaii."

SECTION 3.—Act 236, Session Laws of Hawaii 1974, is repealed.

SECTION 4.—This Act shall take effect on July 1, 1979.

APPENDIX B

NELH RELATED PROJECTS

The following section lists NELH-related projects over the past years. They are organized in major catagories which include:

A. Operational Support
B. Site Studies
C. Site Development
D. Ocean Energy
   General
   Biofouling and Corrosion
   Mini-OTEC
E. Mariculture
F. Other

Following the list of projects within these major categories the 1978-80 projects are described in greater detail.

A. OPERATIONAL SUPPORT

Title	Investigators	Year	Funding	Funding Agency
A-1 Natural Energy Proposals	Dr. John P. Craven, Marine Programs MAC	1975	$38,000	MAC
A-2 Project Support for NELH	Dr. James H. Jones, NELH	1975	$50,000	MAC
	Dr. John P. Craven Marine Programs, MAC		$50,000	County of Hawaii
	William Coops, RCUH	1976	$58,000	State of Hawaii
A-3 Operational Support for NELH	William Coops, RCUH	1977	$92,000	DPED
	1978	$97,000	DPED	
	1979	$97,758	DPED	

Project No.: A-1

Title: Natural Energy Proposals
Investigator: Dr. John P. Craven, Marine Programs, MAC
Year Funded: 1976
Funding: $38,000 (MAC)
Description:

Past efforts at establishing a major facility at the Natural Energy Laboratory of Hawaii focused on a land-based engineering test facility for ocean thermal energy conversion (OTEC) heat exchangers and subsystems. A major proposal to develop this facility was prepared under this project, and submitted to the Energy Research and Development Administration (ERDA) for funding, with the expectation that ERDA would proceed rapidly with an OTEC program. Although the content of the proposal was well received, it did not obtain funds because ERDA had not yet determined whether a land-based test facility was to be part of the its OTEC program plan.

Project No.: A-2

Title: Project Support for Natural Energy Laboratory of Hawaii
Investigators: Dr. James H. Jones, NELH; Dr. John P. Craven, MAC; William R. Coops, RCUH
Funding: 1975 $ 50,000 (State of Hawaii)
$ 50,000 (County of Hawaii)
$ 58,000 (State of Hawaii)
Description:

This project was established to assist the University of Hawaii, the State of Hawaii, and other institutions, in preparing proposals for submission to federal agencies or any other out-of-state sources concerned with the development of natural energy. These proposals were concerned primarily with the establishment of a landor sea-based ocean thermal energy conversion test systems and the establishment of complementary energy options as they may become appropriate. This project also provided funds to conduct analytical studies required to supply information for these proposals and to develop an NELH Master Plan and a state Environmental Impact Statement.

The "Ke-ahole Master Plan: Phase I" concluded that the lowest-cost solution for providing utility services to Ke-ahole Point was by connecting into the existing Ke-ahole Airport systems. The plan also recommended evaluation of potential environmental impacts of support facilities. The direct impacts of Phase I NELH development were found to be minor. The impact of greatest significance was the change in character of the land use, from unused to developed land. This change would result in minor losses of wildlife habitats and vegitation, none of which are endangered.

- Neighbor Island Consultants *Ke-ahole Master Plan*
- Towill, R.M. Corporation *Environmental Assessment of the Natural Energy Laboratory of Hawaii at Ke-ahole Point, Hawaii*

Project No.: A-3

Title: Operational Support for Natural Energy Laboratory of Hawaii (NELH)
Investigator: William Coops, RCUH
Funding: 1977 $92,000 (DPED)
$97,000 (DPED)
$97,758 (DPED)
Description:

Operational support provided under this project is to fund NELH in the following functions:

- Administration
- Grant solicitation
- Laboratory operations

The administration of NELH is continued under the auspices of the RCUH, while the NELH grant solicitation is continued as a joint HNEI/NELH effort with the NELH Board of Directors exercising final authority.

The laboratory operations include the cost of maintaining and operating facilities at the Kona field office, communications, and authorized support in project coventures.

B. SITE STUDIES

Title	Investigators	Year	Funding	Funding Agency
B-1 B-1Report on Aquaculture and Ocean Energy Systems for the County of Hawaii	Prof. Kaare R. Gunderson, Dr. Robert Q. Palmer, UH	1972	$ 5,000 $ 5,000	MAC County of Hawaii
B-2 An Evaluation of Oceanographic and Socio-Economic Aspects of a Nearshore Ocean Thermal Energy Conversion Pilot Plant in Sub-Tropical Hawaiian Waters	Dr. Karl H. Bathen, with R. M. Kamins, K. Kornreich, J.E.T. Moncour, UH, Ocean Engineering	1975	$ 48,000	NSF/RANN/ERDA
B-3 A Further Evaluation of the Conditions Found Off Ke-ahole Point, Hawaii, and the Environmental Impact of Nearshore Tropical Energy Conversion Plants on Sub-tropical Hawaiian Waters	Dr. Karl H. Bathen, UH, Ocean Engineering	1975	$ 10,000	DPED
B-4 Environmental Survey Benthic Ecosystem at Ke-ahole Point	Dr. James H. Jones, NELH Dr. R. S. Nolan, Dr. E. Alison Kay and Dr. Daniel P. Cheney, ORCA	1977 1978	$ 25,625 $ 21,710	DPED DPED
B-5 Field Observations of Ocean Currents, Temperature Profiles, and Surface Plankton off Ke-ahole Point, Hawaii	Dr. Karl H. Bathen, UH,	1977	$ 2,400	State of Hawaii
B-6 Site Selection Bathymetry survey, Ke-ahole Point, Hawaii, for Deepwater OTEC Pipeline	Dr. Edward Noda, UH J.K.K. Look Laboratory	1978	$ 35,670	DPED
B-7 Engineering Studies and Land Surveys of the Ke-ahole Point Site of NELH	William R. Coops, RCUH	1978	$ 46,000	DPED
B-8 Phytoplankton Monitoring at Ke-ahole Point, Hawaii Related to OTEC Environmental Research Program	Dr. Edward Noda, UH, J.K.K. Look Laboratory	1979	$ 32,000 $238,000	MAC DOE
B-9 Bottom Current Survey	Dr. Edward Noda and Lawrence E. Brower, UH, J.K.K. Look Laboratory	1979	$ 31,722	DPED

Project No.: B-1

Title: Report on Aquaculture and Ocean Energy Systems for the County of Hawaii
Investigators: Prof. Kaare R. Gunderson and Dr. Robert Q. Palmer, U.H.
Year Funded: 1972
Funding: $5,000 (County of Hawaii)
$5,000 (MAC)
Description:

This project was a state/county-supported survey of coastal areas on the island of Hawaii. It resulted in the selection of Ke-ahole Point as potentially the most suitable site for an ocean thermal energy pilot plant and aquaculture station. Factors which were considered included:

- Bathymetry and horizontal distance to deep water
- Suitability of adjacent coastal land for laboratory and for production plants
- Ownership of land and likely availability
- Stability of climatic conditions with maximum of yearly sunshine hours
- Closeness to transportation and lodging centers.

Of eight sites considered, Ke-ahole Point was found by far the most suitable. This state-owned land consists of more than 240 acres of fairly level, lava-covered coast land between the new Ke-ahole Airport and the shoreline. A depth of 700 meters is reacher 1.6 km offshore at this location. Several commercial flights daily connect Ke-ahole with Honolulu and Hilo within 45 minutes' flight time. Kailua-Kona, with hotels, service facilities, and a harbor, is located nine miles south on the sunny, low-precipitation Kona Coast. The coastal waters on this leeward side of the island are fairly calm and offer the maximum stability during installation of deep-water pipes and pumps.

Project No.: B-2

Title: An Evaluation of Oceanographic and Socio-Economic Aspects of a Nearshore Ocean Thermal Energy Conversion Pilot Plant in Subtropical Hawaiian Waters

Investigators: Dr. Karl H. Bathen, with R. M. Kamins, K. Kornreich, J.E.T. Moncour, U.H., Ocean Engineering

Year Funded: 1975

Funding: $48,000 (NSF/RANN/ERDA)

Description:

This study was concerned particularly with local bathymetry to the 2,000-foot depth, nearshore and offshore thermal density stratification to 1,500 feet, nutrient concentrations in the water column, local nearshore benthic biota, plankton community composition and productivity, seasonal circulation patterns around Ke-ahole Point, local wave and swell conditions, and the local meteorological conditions at Ke-ahole throughout the year. Results of the study indicate that Ke-ahole Point provides favorable bathymetry, annual sea state conditions, and meteorological conditions along with a diverse biota and a pristine environmental background.

The concluding part of the oceanographic work involved an evaluation of the potential environmental impact a 10-MW pilot plant located at or just off Ke-ahole Point would have on the local, characteristically subtropical waters. Environmental analyses were done on plume prediction, surface heat exchange and alteration, potential downstream heat storage changes in the mixed layer due to cold water discharge, effects of nutrient addition, potential of local plankton biostimulation, and estimates of the extreme conditions likely to occur off Ke-ahole Point.

A three-part socio-economic program was also conducted. It was concerned with examining the legal aspects of a nearshore OTEC plant, developing a socio-economic profile of the Kona area, and projecting the potential local socio-economic impact of a new potential power source.

Details of this project can be found in the report titled "An Evaluation of Oceanographic and Socio-economic Aspects of a Nearshore Ocean Thermal Energy Conversion Pilot Plant in Subtropical Hawaiian Waters" by Dr. Karl H. Bathen, published April 1975.

Project No.: B-3

Title: A Further Evaluation of the Oceanographic Conditions Found off Ke-ahole Point, Hawaii, and the Environmental Impact of Nearshore Tropical Energy Conversion Plants on Subtropical Hawaiian Waters

Investigator: Dr. Karl H. Bathen, U.H., Ocean Engineering

Year Funded: 1975

Funding: $10,000 (DPED)

Description:

This was an extension of a previous project providing further definition of existing oceanographic conditions off Ke-ahole Point and the environmental impact resulting from conducting nearshore tests for both a 100and 240-megawatt OTEC floating power plants. The environmental analyses were concerned with examining potential changes in the net exchange of heat at the surface, the changes in heat storage in the mixed layer, and potential biostimulation in the cold water discharge area.

Field efforts were completed to compare the 1974 and 1975 observations of summer thermal vertical structure and the profile of nearshore currents down to a depth of 550m (1,800-foot) depth.

The report on this project was published in November 1975 by the University of Hawaii.

Project No.: B-4

Title: Environmental Survey Benthic Ecosystem at Ke-ahole Point

Investigators: Dr. James H. Jones, NELH; Dr. R. S. Nolan,
Dr. E. Alison Kay, Dr. Daniel P. Cheney,
Ocean Research Consulting and Analysis, Ltd.

Funded 1977 $25,625 (DPED)
1978 $21,710 (DPED)

Description:

This study was designed to provide a portrait of the coral reef community adjacent to the Natural Energy Laboratory of the State of Hawaii. It represents an effort to provide baseline information in anticipation of aN NELH artificial upwelling test facility. This study IS THE a first step toward an integrated, comprehensive description of a coral reef ecosystem.

The study indicated that the assemblages of corals, macroinvertebrates, micromollusks and reef fishes at Ke-ahole Point are similar to those found on other undisturbed west Hawaiian reefs. It was also found that there are distinct assemblages of corals, fishes and micromollusks between the Reef Slope and the Surge Zone, and that a correlation exists between the abundance of these assemblages and reef depth, water conditions, coral cover and substrate quality. In this manner, fishes, corals, urchins and micromollusks are biological indicators of reef health and water quality. Details of this study may be found in the report "Coral Reef Survey . . ."

- Ocean Research Consulting and Analysis, Ltd. *Coral Reef Survey: Ke-ahole Point, Hawaii for the Natural Energy Laboratory OTEC Facility*

Project No.: B-5

Title: Field Observations of Ocean Currents, Temperature Profiles, and Surface Plankton off Ke-ahole Point, Hawaii

Investigator: Dr. Karl H. Bathen, U.H., Ocean Engineering

Year Funded: 1977

Funding: $2,400 (State of Hawaii)

Description:

Ocean currents, ocean temperatures, and plankton biota and productivity in the nearsurface and benthic waters off Ke-ahole Point were observed over a one-month period between mid-September and mid-October 1977. The intent of this work was to describe the flow characteristics off Ke-ahole Point as it occurs simultaneously in the nearshore and benthic depths and from the nearshore to offshore waters.

The results of this study show that nearsurface flows closest to the shore were strongest, decreasing with distance from the shore, and that temperatures in the nearsurface waters varied the most diurnally. The results also imply that, during the time of the study, the biological/planktonic parameters were very atypical. This was believed to be due primarily to heavy volcanic cloud cover which decreased incident solar radiation.

- University of Hawaii, College of Engineering *The Behavior of Nearshore Ocean Currents, Plankton Biology, Benthic Currents and Ocean Temperatures in Depths of 2200 Feet at a Potential OTEC Site off Ke-ahole Point, Hawaii*

Project No.: B-6

Title: Site Selection Bathymetry Survey, Ke-ahole Point, Hawaii for Deepwater OTEC Pipeline

Investigator: Dr. Edward K. Noda, J.K.K. Look Laboratory

Year Funded: 1978

Funding: $35,670 (DPED)

Description:

This field survey filled the need for detailed, precise information about the bathymetry off shore the NELH site. Specifically, this survey determined bottom conditions which would have a major impact on the design and construction of a deep water pipeline for the Seacoast Test Facility. Such questions as the existence of small canyons, cliffs, abrupt changes in slope, and the position of an optimum corridor were investigated carefully.

High accuracy positioning data are required to provide this information from a surface vessel survey. An Electronic Positioning System providing instantaneous readouts with an accuracy of plus or minus 3 meters was utilized. A shallow-water, high-frequency surface fathometer was used to depths of 70 meters, with a lower-frequency, towed fathometer used from depths of 70 meters to 900-meters. Detailed results are available in Technical Report No. 43.

- J.K.K. Look Laboratory of Oceanographic Engineering *Technical Report No. 43*

Project No.: B-7

Title: Engineering Studies and Land Surveys of the Ke-ahole Point Site of NELH

Investigator: William R. Coops, RCUH

Year Funded: 1978

Funding: $46,000 (DPED)

Description:

This project produced land survey maps, property maps, topographic maps, a preliminary utility routing study and other information needed to support the applications for the permits required for the development of the NELH site.

Project No.: B-8

Title: Phytoplankton Monitoring at Ke-ahole Point, Hawaii, Related to OTEC Environmental Research Program

Investigator: Dr. Edward K. Noda, J.K.K. Look Laboratory

Year Funded: 1979

Funding: $ 32,000 (MAC)
$238,000 (DOE)

Description:

This study involved the evaluation of the variability in physical, chemical and biological parameters at an OTEC benchmark site off Ke-ahole Point, Hawaii. Although the primary focus is the study of environmental variability, the long-range objective is to utilize the field results to aid in the design of subsequent OTEC monitoring programs. The measurements are intended to provide, at a specific location, one year of background data which will form the basis, in conjunction with previously obtained pertinent information for the region, for defining longer term and more extensive environmental surveys necessary to permit the siting and eventual operation of an OTEC plant in the region.

The present contract, which terminates in February 1980, is for the Kawaihae Ke-ahole Point area where the OTEC-1 platform is expected to be deployed in the Spring of 1980. This contract provided the baseline environmental data for the environmental impact statement for the OTEC-1 project.

Project No.: B-9

Title: Bottom Current Survey

Investigators: Dr. Edward K. Noda and Lawrence E. Rower,
J.K.K. Look Laboratory

Year Funded: 1979

Funding: $31,733 (DPED)

Description:

The conceptual design of the Seacoast Test Facility (STF) cold water intake pipeline involves an innovative design feature in which the pipeline is actually suspended 20 to 40 feet above the ocean bottom. The purpose of this feature is to isolate the pipeline from sudden changes in terrain characteristics and to avoid the abrasive effects of the hard, volcanic bottom material. In order to provide the pipeline with buoyancy, polyethylene material was selected, which has a specific gravity less than that of seawater. Of primary concern during the design of the STF pipeline was the magnitude of the ocean currents near the bottom along the pipeline route. If strong bottom currents are prevalent, the drag load on the pipeline due to the current could force it to theocean bottom, where the relatively soft, plastic pipe materialwould be abraded. Thus, a bottom current survey was conducted in order to provide bottom current design data along the proposed pipeline route.

Completed in September 1979, the bottom current observations in the waters off Ke-ahole Point indicated that the maximum recorded current speed (122 cm/sec) during the three months of observation was in the nearshore zone ending at the upper edge of the shallow dropoff. At deeper water locations, the maximum current speed was much less (25 cm/sec). Details of this study may be found in Technical Report No. 47.

- James K.K. Look Laboratory of Oceanographic Engineering *Technical Report No. 47*

C. SITE DEVELOPMENT

Title	Investigators	Year	Funding	Funding Agency
C-1 NELH Uncontaminated Surface Seawater Supply System	Dr. James H. Jones, NELH	1977	$ 65,000	DPED
C-2 Preliminary Design of Ocean Thermal Energy Conversion (OTEC) Deep, Cold Water and Warm Water Pipeline Systems Proposed for Ke-ahole Point	Dr. Edward K. Noda, HNEI	1978	$ 24,928	DPED
C-3 Seacoast Test Facility	Dr. Lawrence Hallanger, NELH	1979	$ 31,000	UH
	Dr. Edward Noda		$550,599	DOE
C-4 Manned Submersible Reconnaissance Survey	Dr. Edward K. Noda, J.K.K. Look Laboratory	1979		
C-5 NELH Facilities and Road Construction	William R. Coops, RCUH	1979	$750,000	DPED
			$330,000	MAC
C-6 3-Inch Pipeline at the Natural Energy Laboratory of Hawaii	Henry J. White, RCUH	1979	$ 35,700	MAC

Project No.: C-1

Title: NELH Uncontaminated Surface Seawater Supply System

Investigators: Dr. James H. Jones, NELH

Year Funded: 1977

Funding: $65,000 (DPED)

Description:

The initial impetus for this system was to supply water for the APL-OTEC heat exchanger biofouling experiment (A-9). However, the need for a large volume, reliable water supply system became clear as the OTEC program began to encourage experiments designed to obtain data on heat exchanger corrosion and biofouling with OTEC-type surface water. A system was designed consisting of two 12-inch PVC pipelines running from a depth of 10 feet below sea level to the pumping facility 270 feet inland. The seaward end of the pipes was protected by a seven-ton steel structure secured to the basalt cliff. Two high-capacity suction pumps provided a total of over 3,000 gpm of seawater.

Project No.: C-2

Title: Preliminary Design of Ocean Thermal Energy Conversion (OTEC) Deep, Cold Water and Warm Water Pipeline Systems Proposed for Ke-ahole Point

Investigator: Dr. Edward K. Noda, HNEI

Year Funded: 1978

Funding: $24,928 (DPED)

Description:

Preliminary designs for a pipeline system for Ke-ahole Point, including detailed drawings and basic specifications, were developed under this project. Also, firm cost estimates were obtained from local design and construction companies for the design and construction of the system, and the physical and mechanical characteristics, costs, and estimated delivery times of available "off-the-shelf" pipeline materials suitable for the proposed system were ascertained.

Project No.: C-3

Title: Seacoast Test Facility

Investigators: Dr. Lawrence Hallanger, NELH
Dr. Edward K. Noda

Year Funded: 1979

Funding: $ 31,000 (HNEI)
$550,599 (DOE)

Description:

The Seacoast Test Facility (STF), is an onshore research, development and demonstration laboratory which is being constructed at NELH at Ke-ahole Point. The STF Project will evaluate components of an OTEC system, as well as conduct related biofouling and corrosion research. When completed the facility will include an onshore laboratory building, administration space, electronic and machine shops, warehouse space, warm water pipes and deep cold water pipes. Because of funding limitations within the U.S. DOE, facilities construction is to be carried out in two separate stages. Stage 1, planned for 1980, will provide all of the onshore facilities with the exception of the administration building. During Stage 1, office space will be provided as part of the warehouse building. Stage 2 of construction, is planned for 1980 or 1981, and will consist of the adminitration building and the main seawater supply system. Until completion of the Stage 2 construction warm seawater will be supplied to the facility through a temporary seawater system which will be refurbished in 1980.

The completed facility will be operated for at least ten years and offers Hawaii the opportunity to become a world leader in OTEC research and development.

Project No.: C-4

Title: Manned Submersible Reconnaissance Survey

Investigator: Dr. Edward K. Noda, J.K.K. Look Laboratory

Year Funded: 1979

Funding:

Description:

A bathymetry survey was conducted in 1977 to define accurately the ocean bottom topography. This survey yielded optimistic data related to the design and construction of a cold-water intake pipeline for the STF. As a result, this visual reconnaissance survey, using a submersible, was performed in order to assess the micro-structure of the bottom bathymetry and to evaluate the characteristics of the bottom and sub-bottom materials which would affect the design and construction of the cold-water intake pipeline.

This submersible survey indicated that, along the survey route, no severe bottom conditions existed that would preclude the design and ultimate construction of a cold-water intake pipeline. In fact, along most of the surveyed route, bottom conditions were ideal for pipeline placement. In only one section was there any formidable problem. In this area, where the water depth was about 450 feet, rock outcroppings were observed as a continuation of the gently sloping shelf. Vertical drops of 10 to 20 feet were noted in this rock outcropping zone, as well as a jagged and rocky surface texture. Interspaced among the rock outcroppings were sand channels 10 to 20 feet in width which form a smooth transition from the gently sloping shelf to the major 30° offshore bottom slope.

Project No.: C-5

Title: NELH Facilities and Road Construction

Investigator: William R. Coops, RCUH

Year Funded: 1979

Funding: $ 750,000 (DPED)
$ 330,000 (MAC)

Description:

Under this project plans and specifications were prepared and a construction contract was awarded for facilities at Ke-ahole Point. These facilities include an access road, fresh water supply line, electrical power supply lines, telephone conduits, security gatehouses, site grading, and security fencing. Construction was completed in December 1979.

Project No.: C-6

Title: 3-Inch Pipeline at the Natural Energy Laboratory of Hawaii

Investigator: Henry J. White, RCUH

Year Funded: 1979

Funding: $ 35,700 (MAC)

Description:

A 3-inch flexible pipeline was installed from the offshore biofouling and corrosion buoy to an onshore site. Deployment of this apparatus permits experiments to take place simultaneously onshore and on the buoy. Results of the identical biofouling experiments at each location will be compared. If the outcome is favorable, this will permit the state to conduct experiments onshore with a high degree of confidence that the results are representative of true oceanic conditions.

It should be noted that this project is primarily for the installation of a facility and not the experimental operations associated with it. The operational phase of the project is being funded in 1980 under a DOE grant in association with current biofouling and corrosion projects. (see A-8)

D. OCEAN ENERGY GENERAL

Title	Investigators	Year	Funding	Funding Agency
D1-1 A Pilot Engineering Study on OTEC	Theodore T. Lee, UH Ocean Engineering	1975	$ 6,686	HNEI
D1-2 The Oceanic Institute's OTEC Ocean Structure Scale Model Project	Joe A. Hanson, Oceanic Institute	1975	$111,594	Sea Grant
			$ 9,625	UH
			$ 4,907	Oceanic Institute
D1-3 Pipeline Survival Under Ocean Wave Attack	Robert Grace, UH, Civil and Ocean Engineering	1975	$ 10,000	MAC
			$ 37,000	Sea Grant
		1976	$ 10,000	MAC
			$ 39,000	Sea Grant
D1-3 Operational Sea State and Design Wave Criteria for OTEC Projects	C. L. Bretschneider, UH Ocean Engineering	1976	$ 36,000	ERDA
D1-5 The Isaacs Wave Energy Pump: Tests off the Coast of Kaneohe Bay, Oahu Hawaii	Dr. James H. Jones, NELH Gerald L. Wick and David Castel	1977	$ 43,323	DPED
D1-6 Consolidated Oceanographic and Meteorological Data for Four North Pacific OTEC sites	Dr. Karl H. Bathen, UH, Ocean Engineering	1977	$ 4,500	State of Hawaii
D2-1 Corrosion and Fouling Removal	Dr. Jorn Larsen-Basse, UH	1976	$ 7,598	HNEI
D2-2 Fouling and Corrosion in OTEC Heat Exchangers	F. Munchmeyer, UH, Mechanical Engineering	1976	$114,000	NSF/ERDA
		1977	$246,000	NSF/ERDA
		1978	$294,000	DOE

D. OCEAN ENERGY GENERAL
(continued)

Title	Investigators	Year	Funding	Funding Agency
D2-3 OTEC Heat Exchanger Biofouling Experiment	Dr. Paul Yuen, HNEI	1977	$ 53,591	Sea Grant
	Dr. James H. Jones, NELH		$ 15,000	MAC
	Peter P. Pandolfini, APL, Johns Hopkins	1978	$ 52,477	Sea Grant
			$ 23,716	DPED
		1979	$ 47,230	Sea Grant

OCEAN ENERGY—MINI-OTEC

D3-1 Mini OTEC	Dr. Eugene Grabbe, DPEd	1979	$600,000	DPED
D3-2 Environmental Impact of Mini-OTEC Operation	Dr. John Caperon	1979	$ 12,000	State of Hawaii
			$ 51,305	HNEI

Project No.: D1-1

Title: A Pilot Engineering Study on OTEC

Year Funded: 1975

Funding: $6,686 (HNEI)

Description:

The materials and equipment for an OTEC working model were procurred with the help of funds from other sources, and fabrication was completed in February 1976. The model was used for determination of the dynamic response of a platform-pipe-mooring system, hydrodynamic aspects, and thermal diffusion under the combined action of wind, waves, and currents. Supporting analytical studies were also conducted.

- Lee, Theodore T. "Laboratory and Natural Investigation on Ocean Thermal Energy Conversion on Environment," Technical paper

Project No.: D1-2

Title: The Ocean Institute's OTEC Ocean Structure Scale Model Project

Investigator: Joe A. Hanson, Oceanic Institute

Year Funded: 1975

Funding: $111,594 (Sea Grant)
$ 4,907 (Oceanic Institute)
$ 9,724 (University of Hawaii)

Description:

There was concern with early floating OTEC installations following observations that the contained watermass of the structures were a large proportion of the total mass and that the water mass is in motion and in hydrodynamically coupled to the structure to a greater or lesser extent depending on the design employed. It was concluded that some preliminary scale model tests would help determine the extent of the coupling on an "OTEC Ocean Structure."

The term "OTEC Ocean Structure" used here, encompasses not only the platform, but also the water pipes and the station-keeping mechanism, whether it be mooring or dynamic positioning. These three components are so closely coupled hydrodynamically that they must be treated as one system in order to avoid a possibility of catastrophic seakeeping behavior in early floating OTEC installations.

Project No.: D1-3

Title: Pipeline Survival Under Ocean Wave Attack

Investigator: Robert A. Grace, UH, Civil and Ocean Engineering

Funding: 1975 $10,000 (MAC) $37,000 (Sea Grant)
1976 $10,000 (MAC) $39,000 (Sea Grant)

Description:

This project was a two-year study of wave forces on a pipe set parallel to wave fronts. The effects of wave forces on pipelines is especially vital to future ocean energy projects, as many different methods and ideas of tapping ocean energy, or using the ocean in connection with energy generation (for cooling, especially) require that pipeline be laid through shallow, nearshore surf zones.

The test site was in 37 feet of water, 1400 feet from the coastline adjacent to Honolulu, Hawaii. The coastline in the vicinity of the site runs approximately northwest-southeast so that trade wind waves are small at the test area. The important test waves arrives as swells from southern hemisphere winter storms. Such swells are typified by low deep water heights and long periods. A point of interest in connection with this project is that the Australian Bureau of Meteorology cooperated by sending reports of waves and swells they observed to be heading toward Hawaii.

Details of the results of this study was published in many reports, some of which follows:

- Grace, R. A., "Setting Up and Running Ocean Wave Force Equipment," A.S.C.E., *Journal of the Waterway, Port, Coastal and Ocean Division.*
- Grace, R. A., and Nicinski, S.A., "Wave Force Coefficients from Pipeline Research in the Ocean," *Proceedings,* Eighth Annual Offshore Technology Conference, Houston, Texas, May 1976, Vol. 3, pp. 681-694.
- Grace, R. A., "Surface Wave Heights from Pressure Records," *Coastal Engineering,* Vol. 2, pp. 55-67.
- Grace, R. A., Castiel, J. and Shak, A. T., "Pipe Forces Due to Perpendicular Ocean Wave Motion," Technical paper.

Project No.: D1-4

Title: Operational Sea State and Design Wave Criteria for Ocean Thermal Energy Conversion Projects

Investigator: C. L. Bretschneider, UH, Ocean Engineering

Year Funded: 1976

Funding: $36,000 (ERDA)

Description:

The objective of this project was to acquire environmental data on winds, waves, and currents for specified areas. The specific zones of interest include the Atlantic, Pacific and Gulf Coasts of the Continental United States, the Hawaiian Islands, and all other oceanic areas (including the Indian Ocean) situated between 20° North and 20° South latitudes. These locations have primarily to do with potential selections of ocean thermal energy conversion (OTEC) project sites.

Project No.: D1-5

Title: The Isaacs Wave Energy Pump: Tests off the Coast of Kaneohe Bay

Investigators: Dr. James H. Jones, NELH; Gerald L. Wick and David Castel, Scripps Institution of Oceanography, Institute of Marine Resources, University of California, San Diego

Year Funded: 1977

Funding: $43,323 (DPED)

Description:

The purpose of this study was to bring to Hawaii for testing a modified version of the Isaacs wave energy pump that had already been successfully tested off Southern California. The Hawaii tests provided performance information in a trade wind regime where the wave energy distribution is different and usually more consistent and greater than it is off California. The float was about 8 feet in diameter on the top and was shaped as a body of revolution having exponential sides. The float supported a cluster of three flexible polyethylene pipes, each 300 inches, 1.4 inches, and 2 inches respectively. On the buoy deck the pipes fed water through a nozzle to a Pelton wheel coupled to an electric generator. A telemetry system monitoring pertinent information transmitted data to a shore station on command. The results indicated that one to three foot seas produced a continuous jet flow to a height of about 20 feet. A sea-state with three to four foot waves, produced 225 watts of power through the buoy generator. With proper scaling and careful construction, this device could produce significant energy and could be designed to bring nutrient-rich water feom the 10,000 foot depth to the surface for an open-ocean mariculture system.

Project No.: D1-6

Title: Consolidated Oceanographic and Meteorological Data for Four North Pacific OTEC Sites

Investigator: Dr. Karl H. Bathen, UH, Ocean Engineering

Year Funded: 1977

Funding: $4,500 (State of Hawaii)

Description:

This project reviewed historical data and compared oceanographic conditions at potential OTEC sites in the eastern, central, and western tropical Pacific Ocean. The goal of this data review was to determine for each of four sites 5° latitude by 10° longitude, the characteristic annual limits and potential extreme conditions of local meteorology, change in temperature over the 0 to 3,000 foot depth, initial profiles of salinity and local circulation, sea state, bathymetry, tides and biota. A rough ranking of these four sites giving equal weight to each one of the eight criteria is: Southern Hawaiian Islands; Western Tropical Pacific; Central Tropical Pacific; and last Eastern Tropical Pacific.

Project No.: D2-1

Title: Corrosion and Fouling Removal

Investigator: Dr. Jorn Larsen-Basse, UH, Mechanical Engineering

Year Funded: 1976

Funding: $7,598 (HNEI)

Description:

Under this project, a laboratory test was designed to simulate the corrosion of a piece of metal on which the partially protective film of corrosion products is destroyed by mechanical action on only part of the surface. This sets up a corrosion cell between the "old" and the "new" surface. By measuring the potential difference, it is possible to determine the time it takes to re-form the film, and by measuring the amount of charge passing between the two parts of the surface—in this case, two separated specimens—it is possible to determine the amount of metal lost to re-form the film after each scrubbing cycle. For aluminum alloys, it is necessary to abrade with sharp abrasives in order to destroy the surface film. It therefore appears that corrosion-erosion will be of little importance in OTEC plants with aluminum alloy heat exchangers. However, the techniques developed here should be useful for studies of corrosion-erosion in other situations, such as coal conversion.

For comparison with the laboratory work, some exposure tests were conducted at Kaneohe Bay. Specimens were exposed to flowing seawater for 3.5 months. The degree of fouling and the nature of the corrosion attack for the different metals were essentially as expected, except for an aluminum-copper alloy. This alloy gave indications that the nature of the corrosion product film may have a profound effect on the degree of fouling, which may indicate a basis for alloy development for fouling resistance.

Project No.: D2-2

Title: Fouling and Corrosion in OTEC Heat Exchangers

Investigators: F. Munchmeyer, UH, Mechanical Engineering

Funding: 1976 $114,000 (NSF/ERDA)
1977 $246,000 (NSF/ERDA)
1978 $294,000 DOE)
1979 $250,000 (DOE)

Description:

One of the most essential elements in demonstrating the economic feasibility of OTEC is to establish that scaling, biofouling, and corrosion can be held in check for the life of the plant without adding excessively to the capital or operating costs. Studies of fouling and corrosion must be done in the ocean under conditions approximating those expected to exist in practice. A test apparatus, consisting of heat exchanger tubes operating under various conditions of water flow velocity and utilizing different materials, has been operated in the ocean at Ke-ahole Point. The studies are continuing.

The tests are done under conditions simulating those in the evaporator where, because of the higher temperature and greater abundance of sea life and dissolved oxygen in the surface waters, fouling and corrosion are expected to be most severe.

The first ocean data for the ERDA biofouling and corrosion program were obtained during the summer of 1976. These data gave the first known indications of the rate at which heat exchange, between ocean and an OTEC power loop, will degrade. The indications were favorable; the rate of degradation is believed to be low enough to yield favorable technical and economic predictions. The first experiments were conducted from a floating platform.

Since 1976, three long term experiments have been completed in the ocean on a submerged offshore buoy. A fourth submerged experiment has been prepared for execution in 1980. A parallel experiment onshore has been prepared for 1980 which will take water from the ocean at the site of the offshore buoy.

The six experiments, five in the ocean and one onshore, have been designed to investigate many questions which are of immediate and continuing importance to the national OTEC program. These include the degradation of the rate of heat exchange due to biological fouling and to corrosion, improvements in the rate of heat exchange after mechanical cleaning, the nature of the corrosion present, the nature of the biological film which degrades heat exchange performance and the nature of the seawater at the buoy site.

The heat exchanger tubes used in these experiments are fabricated from metals which are candidates for OTEC heat exchangers. As experience has been gained, increasingly perceptive studies have been made of the corrosion and of the biological film formations, and of their variations with tube materials. The data from these studies is provided continuously to designers of OTEC systems.

Concurrently, techniques for conducting such experiments in the hostile ocean environment have been improved.

The submerged buoy has been operated since February 1977. It has exceeded its expected life. The parallel experiments onshore will establish a connection between the two types of experiments. (The State of Hawaii funded the capital equipment for the onshore experiments.)

The 1980 plan is to discontinue the buoy after completing the parallel experiments.

Project No.: D2-3

Title: OTEC Heat Exchanger Biofouling Experiment

Investigators: Dr. James H. Jones, NELH; Peter P. Pandolfini, Applied Physics Laboratory, Johns Hopkins University; Dr. Paul Yuen, HNEI

Funding: 1977 $53,591 (Sea Grant)
$15,000 (MAC)
1978 $52,477 (Sea Grant)
$23,716 (DPED)
1979 $47,230 (Sea Grant)

Description:

This contract dealt with the investigation of the effects of biological fouling on the outside of APL-OTEC heat exchanger elements as tropical ocean water flows continuously through the test section. The Applied Physics Laboratory designed and built the test section and the experimental measuring equipment, while NELH provided a test site with uncontaminated tropical seawater typical of an OTEC environment, and operated and conducted the tests in cooperation with APL. The tests, which began in June 1977, measured the waterside heat transfer coefficient as a function of time at a flow rate of 3 fps under both light and dark conditions. The initial results of these tests indicate that the fouling coefficient built up to average values near 0.0005 in 6 weeks. These results are consistent with other experimental data taken independent of this project at the NELH site.

In 1978 the methods of study were modified as a result of data obtained during 1977. The time period for each measurement in the series were extended from three weeks to as long as four months. In addition, techniques for *in situ* cleaning of the water side during full-flow conditions and during no flow were investigated.

At the end of the project, the facility at Ke-ahole Point was placed in preserved storage for possible future use. The facility was in operation for approximately 18 months and maintained the stipulated water flow during the entire experimental period.

Project No.: D3-1

Title: Mini-OTEC

Investigator: Dr. Eugene Grabbe, DPED

Years Funded: 1978-1979

Funding: $600,000 (MAC)
(MAC) 1978
$450,000 (MAC) 1979

Description:

Mini-OTEC operated 1.3 miles off Ke-ahole Point. In August 1979 it became the first closed-cycle at-sea OTEC system in the world to produce net energy. It was therefore the first test of a complete present day operational system, Mini-OTEC spotlights Hawaii's potential as the ocean energy research laboratory of the world.

The Mini-OTEC demonstration was a joint venture of the State of Hawaii, Lockheed Missiles and Space Company of Sunnyvale, California, the Dillingham Corporation of Honolulu, and Alfa Laval Thermal Inc. of Sweden. The joint venture required no federal funds. Mini-OTEC went from conception to completion in only 15 months.

Mini-OTEC operated for three and a half months before returning to the University of Hawaii's Snug Harbor facility on Oahu for evaluation and modification prior to a second deployment.

Project No.: D3-2

Title: Environmental Impact of Mini-OTEC Operation

Investigator: Dr. John Caperon

Year Funded: 1979

Funding: $51,305 (HNEI)
$12,000 (State of Hawaii)

Description:

This project described the biological impact on the marine environment of the deployment and operation

of the Mini-OTEC system. Data from field surveys and laboratory tests was developed to describe quantitatively the effects of discharged water on marine phytoplankton, zooplankton and nekton populations. The discharge of relatively large volumes of deep ocean water directly into the euphotic zone is without precedent, and this activity provided an opportunity to contribute to an understanding of the natural upwelling enrichment process. The availability of this deep water in quantity also makes possible the analysis of the enrichment process under controlled laboratory conditions to help interpret the field observations.

E. MARICULTURE

Title	Investigators	Year	Funding	Funding Agency
E-1 OTEC Mariculture/Algal Project	Dr. James H. Jones, NELH	1977	$ 10,000	DPED
E-2 Phase I of Aquaculture Component at NELH	Dr. John P. Craven, Marine Programs, MAC William Coops, RCUH	1979	$115,000	MAC

Project No.: E-1

Title: OTEC Mariculture/Algal Project

Investigators: Dr. James H. Jones, NELH; M. S. Doty, UH

Year Funded: 1977

Funding: $10,000 (DPED)

Description:

This project was intended to identify seaweed algae that can economically be grown in the State of Hawaii. The first step was to determine the basic ecological and physiological responses of three of the most common seaweeds found in Hawaii; *Sargassum*, *Eucheuma*, and *Gracilana*. The first two genera are the best choices for the bioconversion of sunlight to a gas such as methane or alcohol. Four factors influencing fertility were identified: light, water motion, temperature, and water quality. The total fertility is a complicated function of all four of these factors. the primary thrust of this program was to compare methods of measuring growth by standard respirometric methods and by weight change and how these methods can best be used to predict the success of a commercial algae production pond using OTEC waste water.

Project No.: E-2

Title: Phase I of Aquaculture Component at the Natural Energy Laboratory of Hawaii

Investigators: Dr. John P. Craven, Marine Programs, MAC
William R. Coops, RCUH

Year Funded: 1979

Funding: $115,000 (MAC)

Description:

Aquacultural products, such as prawns, oysters, and ophihi, must be cultivated in cold waters. The temperature of Hawaiian surface waters, therefore, makes it difficult to raise these and other foods. The OTEC concept, utilizing deep, cold ocean water, offers the possibility of a beneficial union between OTEC and aquaculture. Because of this, a preliminary study of the possibility of installing an aquaculture system at Ke-ahole Point was initiated.

The objectives of this study were to provide administration, planning and design of a facility suitable for using the cold, deep, nutrient-rich water from OTEC and readily available surface waters from the Seacoast Test Facility for aquaculture research, thus developing the potential and economic values of cultivating ocean plants and animals. This study will make NELH a more complete and useful facility to carry out ocean-energy research and development projects, and will also fill the state's critical need for outdoor aquaculture research and demonstration facilities.

F. OTHER

Title	Investigators	Year	Funding	Funding Agency
F-1 Mantle Conductivity Beneath the Hawaiian Ridge	Dr. Charles E. Helsey, HIG	1978	$10,000	NSF

Project No.: F-1

Title: Mantle Conductivities Beneath the Hawaiian Ridge

Investigator: Dr. Charles E. Helsley, HIG

Year Funded: 1978

Funding: $10,000 (NSF)

Description:

Measurement of the earth's electric field by means of sensors placed in a hole drilled into the surface rock was conducted under this project. The data gathered at Ke-ahole Point was used in conjunction with magnetic field measurement data taken at other sites on the island to provide a sounding of the earth's mantle beneath the island of Hawaii. This project also included work on Oahu and Midway Islands. Total funding was $73,400, with about $10,000 being spent for the Ke-ahole Point portion of the work.

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