The Natural Energy Laboratory of Hawaii

1984 annual report

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To:

The Honorable George R. Ariyoshi
Governor of Hawaii

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

The Honorable Henry H. Peters
Speaker of the House of Representatives

Aerial view of NELH, December 1983.

Board of Directors

June 30, 1984

John P. Craven
Professor of Ocean Engineering and Director of the Law of the Sea Institute, University of Hawaii at Manoa

Philip Helfrich
Director, Hawaii Institute of Marine Biology

H. Stuart Kearns, Jr.
Director of Research and Development, County of Hawaii

Kent M. Keith
Director of Planning and Economic Development and State Energy Resources Coordinator, State of Hawaii

Herbert T. Matayoshi
Mayor, County of Hawaii

Susumu Ono
Chairperson and Member, Board of Land and Natural Resources, State of Hawaii

Patrick K. Takahashi
Professor of Civil Engineering and Acting Director of the Hawaii Natural Energy Institute, University of Hawaii at Manoa

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Abalone Farm Groundbreaking, June 1984. L to R: Kent M. Keith, Mayor Herbert T. Matayoshi, Governor George R. Ariyoshi, John P. Craven, George S. Lockwood, Rev. Leon Sterling.

Preface

The Natural Energy Laboratory of Hawaii has continued to expand throughout Fiscal Year 1984.

The Laboratory remains unique in its ability to supply large volumes of both warm surface seawater at 24-28°C and cold deep seawater (from 600m depth) at 10°C. The seawater supply systems have functioned continuously throughout the year, amassing totals of 1076 days and 792 days of flow for the warm and cold water, respectively.

The closed-cycle OTEC biofouling and corrosion experiments at NELH have continued with Department of Energy (DOE) support. The consistently high quality data from these experiments has demonstrated the possibility of substantial cost savings in future OTEC plants. They have provided unique time series of biofouling and corrosion data for various materials in seawater and information on the effects of various countermeasures.

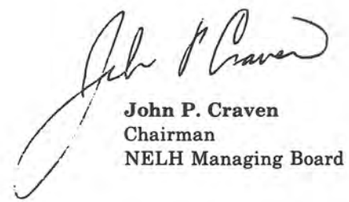
The open-cycle OTEC experiments begun in FY 1983 with funding from the Solar Energy Research Institute (SERI) have produced encouraging results indicating that the heat and mass transfer in open-cycle seawater systems approximates that predicted from previous experiments with fresh water. Gas desorption studies have provided a preliminary indication that the energy required to deaerate seawater may be 50% less less than had been anticipated based upon freshwater data. An experimental "mist-lift" apparatus has demonstrated the feasibility of generating a seawater mist and has indicated that the anticipated coupling exists between the mist and a rising vapor stream.

Several aquaculture experiments continue to demonstrate exciting possiblities for using the deep cold water. Salmon, rainbow trout, Maine lobster, nori and abalone have been grown successfully. Groundbreaking for a 21-acre commercial demonstration module for abalone production took place as the fiscal year drew to a close. A new project has shown the feasibility of using the "waste cold" from an OTEC plant to grow strawberries by irrigating with the cold fresh water which condenses from the air onto pipes carrying the cold seawater. Several other commercial aquaculture firms are now negotiating for sites at NELH. Proposed projects include production of oysters, clams, marine shrimp, spirulina and other marine algae.

Plans are being formulated for installation of a 30-inch cold water pipe to supplement the present 12-inch system. DOE laboratory personnel are developing designs for both open- and closed-system experiments to utilize the expanded seawater supply. The water will also be used downstream for aquaculture and agriculture experiments.

The NELH water quality laboratory has produced unique data on the characteristics of the water being pumped, and plans are now underway for a significant expansion and improvement of the water quality lab facilities. This expansion will allow both continued monitoring of the incoming water streams and improved service to the growing cadre of laboratory clients.

In summary, this fiscal year has again been productive and successful. The future promises continued expansion of research and development, demonstration and pilot-testing, and commercialization activities at NELH.



John P. Craven
Chairman
NELH Managing Board

Abbreviations

ANL	Argonne National Laboratory
BLNR	Board of Land and Natural Resources, State of Hawaii
CIP	Capital Improvement Projects (State of Hawaii)
CWP	Cold water pipe
DOE	U.S. Department of Energy
DOT	Department of Transportation, State of Hawaii
DPED	Department of Planning and Economic Development, State of Hawaii
EPA	Environmental Protection Agency
ERDA	Energy Research & Development Administration (Preceded DOE)
FRP	Fiberglass-reinforced plastic
GPM	Gallons per minute
HAF	Hawaiian Abalone Farms (affiliate of Monterey Abalone Farms)
HD&C	Hawaiian Dredging & Construction Co., A Dillingham Company
HECO	Hawaiian Electric Company
HIMB	Hawaii Institute of Marine Biology, UHM
HNEI	Hawaii Natural Energy Institute at UHM
HURL	Hawaii Undersea Research Laboratory
JHU/APL	John Hopkins University, Applied Physics Laboratory
LMSC	Lockheed Missiles and Space Company, Inc.
MAC	Marine Affairs Coordinator, State of Hawaii
NELH	Natural Energy Laboratory of Hawaii
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NSF	National Science Foundation
OTEC	Ocean Thermal Energy Conversion
RCUH	Research Corporation of the University of Hawaii
RDA	R & D Associates, Marina del Rey, CA
SERI	Solar Energy Research Institute
UHM	University of Hawaii at Manoa
UHSG	University of Hawaii Sea Grant Program

Introduction

This report summarizes the Fiscal Year 1984 activities at the Natural Energy Laboratory of Hawaii.

NELH was created by the Hawaii State Legislature in 1974 as a facility for natural energy research. It is presently located on 322 acres of state-owned land at Ke-ahole Point, adjacent to 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 insolation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. Ke-ahole Point uniquely meets all of these criteria.

NELH is governed by a Managing Board consisting of the Director of Planning and Economic Development of the State of Hawaii, the State Marine Affairs Advisor, the Chairperson 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 officials appointed by the Mayor of Hawaii.

The Board is responsible for maintaining NELH property, reviewing and approving proposals from prospective users, and planning and coordinating the development of the NELH site. While NELH personnel may provide technical assistance, the primary function of NELH is to make facilities and resources available for the research, development and pilot testing of innovative new technologies and businesses. As of May 1984, on-site commercialization is also possible for projects which successfully complete their research and development phases at the laboratory. The Board has engaged the services of the Research Corporation of the University of Hawaii to provide administrative services. Plans call for the NELH to become self-supporting through collection of users 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. Areas of planned expansion are closed- and open-cycle OTEC, cold water aquaculture and agriculture, solar ponds, direct solar energy applications, and marine materials and equipment testing. The Appendix contains the NELH Policy on Project Acceptance. Inquiries concerning NELH should be addressed to the Executive Director.

Abalone research facility with strawberry patch in foreground.

Summary of Activities

Institutional Developments

Legislation Changes

The 1984 Hawaii State Legislature passed Act No. 59, which ammends the NELH enabling legislation (Ch. 227 HRS) to include "commercialization" as one of the stated goals of the laboratory. This legislation, signed into law by the Governor in May 1984, allows the commercial development of research carried out at the laboratory.

Lease

A formal ground lease for NELH (No. S-4717) was approved by the Board of Land and Natural Resources and signed in May. This allows the NELH Board to negotiate and approve subleases with companies which want to pursue research and commercial projects on laboratory land, subject to final approval of BLNR.

Funding

State fiscal support of NELH continued at approximatelyconstatnt levels throughout fiscal year 1984. Federal DOE support has continued for the OTEC biofouling and corrosion and open-cycle expriments, however the funding came this year through the Solar Energy Research Institute (SERI) instead of the previous contracts with Argonne National Laboratory (ANL). User fees from aquaculture projects have begun to contribute to the operating budget. We anticipate that the proportion of support from smaller non-DOE projects will continue to grow.

Staff Changes

The laboratory staff has been augmented this year by the addition of a half-time Public Relations Officer. This position, funded with Federal money by the State Energy Extension Service, allows the provision of regular tours for the public and some backup assistance for the laboratory secretary/receptionist.

Dr. Takeshi Yoshihara has taken over as acting Executive Director until Mr. Jack Huizingh assumes the regular position in the fall of 1984. The core staff of the laboratory at Ke-ahole Point now consists of nine-and-one-half positions, including six personnel able to provide direct project technical support.

Facility Developments and Status

Coldwater Supply System

NELH remains the only facility in the U.S., and possibly the world, supplying a continuous flow of cold deep seawater. At year's end, our redundant pumping system is operating well. Continuous flow was maintained throughout the year, largely by a conscientious and responsive staff effort. As of 30 June 1984, coldwater experiments have run for 732 days, and there have been no interruptions exceeding 2 hours since Hurricane Iwa in November 1982. Following the lessons from the storm, a corrugated metal pipe cover installed over the onshore portions of the pipelines in early FY 1984 provides significant new protection from wave damage.

New Coldwater Pipeline

DOE plans to install a new coldwater pipeline at NELH with a diameter of approximately 30 inches (76 cm) and a pumping capacity near 6000 gpm. This will supplement the existing 12-inch (30 cm) 1300 gpm pipe. The new plans follow a failed attempt in October 1983 to deploy down the slope off Ke-ahole Point the 6000-foot (1800 cm) long, 48-inch (1.2 m) diameter polyethylene coldwater pipe from the OTEC-1 experiment. That failure resulted in the loss of a significant portion of the pipe. Subsequent meetings with potential future facility users arrived at 30 inches as a suitable diameter for a new pipe, and efforts are underway at year's end to establish a cooperative agreement between DOE and the state for the installation of such a pipeline.

Electrical Distribution System Improvements

NELH has obtained State CIP funds to install an electrical distribution panel to improve electrical energy supply capabilities to experimental facilities in the test pad area. Five metered 480 volt three phase circuits will be available when this sytem is installed early in FY 1985.

Visitor Program Improvements

Funding from the Energy Extension Service, a federal program administered by DPED, permitted the purchase of a 16 mm projector used to show films on OTEC and alternate energy to interested visitors. A special contract with the County of Hawaii through its Department of Research and Development has provided funds for the purchase of a videocassette recorder on which the various videotapes taken on submersible dives off NELH are viewed by visitors and researchers. The county contract is also funding the preparation of an "information kiosk" to be built at the highway entrance to NELH. This will include three sign panels describing, respectively, OTEC and its potential; the various past, present and future laboratory projects; and the rules for access to and use of the NELH property and the shoreline areas. The text and illustrations for these panels have been prepared, and this kiosk is due for completion early in FY 1985.

Shop Facilities

NELH has obtained several valuable new machine tools through the Department of Accounting and General Services Surplus Property Branch. A large lathe and bandsaw, a table saw and several work tables have greatly improved our fabrication capabilities at minimal expense. Surplus has also provided three 10 kw portable generators, two of which have been repaired to operating condition using parts from the third. These greatly improve our construction and repair capabilities, especially outside the laboratory compound.

Abalone Commercial Production Module Facilities

Success of the research performed at NELH over the last two years by Monterey Abalone Farms of California led to the signing in May 1984 of a long-term lease to develop a commercial production demonstration module on 21.3 acres of open land adjacent to the existing laboratory compound. Site preparation activities began in June, and many state, county and community officials attended a formal groundbreaking ceremony for "Hawaiian Abalone Farms" (HAF) on June 28. Initial construction will include two large million-gallon kelp tanks (each 15 feet high and 105 feet in diamater) and several acres of shade cloth structures which will cover the abalone growout tanks. Some of the facilities improvements required by this project have been funded by State CIP funds. Plans call for NELH to sell cold water to the project for the first year of operation, following which HAF will install their own pipeline to meet their future requirements.

Nori culture tanks.

Fish culture tanks.

Facility Capabilities

As of June 30, 1984, NELH had the following operational support capabilities:

Warm Seawater Supply

- 2,000 GPM
- 24°C to 28°C

Cold Seawater Supply

- 1,000 GPM (redundant 640 GPM pumps)
- Expandable to 1300 GPM
- 8.5°C to 10.5°C (constant, depends on total flow)

Water Chemistry Laboratory

- Flow
- Temperature
- Salinity
- Suspended Solids
- pH and Alkalinity
- Nutrients
- Dissolved Oxygen
- Biochemical Oxygen Demand (BOD)
- Residual Chlorine

Technician Support

- Mechanical
- Electronic/Instrumentation/Electrical
- Laboratory
- Diving

Facilities

- Laboratory Space (in & outdoor)
- Warehouse Space
- Office Space
- Shops: Electronics, Machine
- Large Vacuum Pumps and Open-cycle Experimental Chambers
- Aquaculture Tanks (all plumbed with warm and cold seawater):
  10 ea. 600-gallon fiberglass tanks
  5 ea. 1000-gallon plastic lined steel tanks
  10 ea. 3 cubic meter (800-gallon) rectangular tanks, each divided into 1 cubic meter sections
  Various tanks, larval basins and growout baskets designed for the culture of Maine lobster (housed in a 1000 sq. ft. inflatable building)
- Offshore Research Corridor
- 24-foot Workboat on Trailer
- Triply Redundant, Automatically Started Backup Diesel Generators
- 2 Trailer-mounted 10 kw Generators for Field Work
- PDP11-23 Computer for On-line Heat Transfer Processing
- IBM-PC with Graphics Printer, Color Monitor and Word Processing, Spreadsheet and High-level Language Software.

Vehicles

- 2 Fork Lifts
- 3 Trucks
- Electric Utility Vehicle
- Station Wagon

Communication

- Private VHF System with All Vehicles, Boat and Handheld Units

Environmental Monitoring

- Wind, Temperature, Rainfall
- Solar Insolation
- Multi-channel Data Logger

Permits in Place

- Offshore Research Corridor
- Conservation District Use Application
- Special Management Area Use Permit
- DOT Harbors Division Shore Waters Construction Permit
- EIS/EA
- NPDES Discharge Permit

Public Information

- Tours Available
- Public Lectures
- Brochures and Information Packets

Biofouling and corrosion test loops.

Research Activities and Results

Table 1: **Summary of Research Projects at NELH**

Project Name	Objectives	Sponsor Institutions(s)	Funding Source(s)	Investigator(s)	Dates	Results	Status 6/84
Buoy Fouling and Corrosion Studies	Study fouling and corrosion of OTEC Heat Exchanger Materials	UHM, HNEI, JHU/APL	HNEI, DOE, NSF/ERDA, UHSG, MAC	J. Larsen-Basse, F. Munchmeyer	76-79	Biofouling became significant after an initial incubation period of several weeks.	Completed
Mini-OTEC	Demonstrate net power production from OTEC	DPED, LMSC, Dillingham Corp.	State of Hawaii, various companies	E. Grabbe	1/79-12/79	First successful production of net power from OTEC. Generated more than 10Kw net on a floating platform moored in the NELH Offshore Research Corridor.	Completed
Argonne Test Project	Heat transfer monitoring and biofouling control Microfouling studies Corrosion studies Macrofouling studies Water Quality Analyses	UHM/ANL UHM/ANL UHM/ANL UHM/ANL NELH/ANL	DOE/DPED DOE funding via SERI since 7/83	J. Larsen-Basse L.R. Berger J. Larsen-Basse E.A. Kay T. Daniel	7/81-present	1. Biofouling in warm surface water repeatably reduces heat transfer to unacceptable level within 20 days. 2. Only 70 ppb chlorine applied for 1hr/day controls the biofouling. 3. No reduction in heat transfer (i.e. biofouling) has occurred over 2 years of continuous cold water flow. 4. Aluminum alloys do not show pitting corrosion in surface water, but do in deep water.	Continuing
Simplex Corrosion	Measure corrosion of samples installed on offshore buoy.	UHM	Simplex Wire & Cable Co.	J. Larsen-Basse	7/81-3/82	Measured corrosion on several alloys installed on offshore buoy.	Completed
UH Atmospheric Corrosion Project	Monitor and analyze corrosion of samples in NELH marine atmosphere	HNEI	UH Foundation	J. Larsen-Basse	7/81-3/83	Collected corrosion data on several aluminum alloys.	Completed
OTEC Aquaculture Fish	Investigate parameters of growing salmon and trout in deep cold water	HIMB	UHSG, MAC, DPED	A. Fast	1/82-11/84	1. Grew more than ½lb. fish per gallon deep water. 2. Found optimum temperatures, photo-periods and flow rates. 3. Studied smoltification parameters. 4. Spawned trout successfully in seawater.	Continuing
OTEC Aquaculture Macroalgae	Demonstrate culture of nori (Porphyra teneral) and ogo (Gracilaria spp.)	HIMB	UHSG, MAC, DPED	F. Mencher, R. Spencer	1/82-3/83	1. High nori growth rates (35% mass increase per day) initially and 40-60 gm/m^3/day in high density (2-3kg/m^3) tanks. 2. Optimum photoperiods and temperatures were determined.	Completed
Abalone Culture	Investigate feasibility of commercial ablalone culture in Hawaii	Monterey Abalone Farms	Monterey Abalone Farms	G. Lockwood	2/82-present	1. Abalone and kelp (Macrocystis) to feed them can be grown in the deep cold water. 2. The high nutrient content of the deep water results in high protein in kelp. 3. The lack of pathogens in the deep water permits its use without filtration. 4. A commercial development module has been initiated.	Continuing
OTEC Chlorination	Study the effects of low level chlorination on the marine food chain	UHM	HNEI	F.J. Sansone	6/82-6/83	1. Chlorine kinetics in tropical seawater differ markedly from results with other seawater. 2. Reaction of the chlorine with the water takes much longer than in temperate water. 3. Only trace levels of halogenated organics are produced in chlorinated NELH water.	Completed
Marine Lobster Culture	Validation of Hawaii as site for Northern Lobster (Homarus americanus) culture	Sanders Associates Inc.	Sanders Associates, DPED	M. Thays	9/82-10/83	1. Maine lobster grow well in the Sanders culture system using temperature control obtained by mixing surface and deep water. 2. Present economics indicated this culture would be unprofitable.	Completed
Cable Corrosion	Investigate corrosion of candidate materials for deep sea cables	Parson's Hawaii	DOE/HECO	J. Larsen-Basse	1/83-present	Various candidate cable materials show expected corrosion in seawater.	Continuing
ASTM Corrosion	Monitor corrosion of metals in the ocean offshore of Ke-ahole Point	ASTM	NELH	J. Larsen-Basse	6/83-6/89	First samples submitted to ASTM.	Continuing
Alcoa Corrosion	Study the corrosion of various aluminum alloys in flowing seawater	Alcoa	Alcoa	B. Liebert	1/83-present	Analysis of proprietary samples continues. Effects of brushing in warm and cold water are being studied.	Continuing
Open-cycle OTEC							
Heat and Mass Transfer Research	Study efficiency of spout evaporators and condensers by measuring heat and mass transfer in seawater system	UHM/HNEI	SERI/DOE	J. Larsen-Basse	6/83-present	1. Seawater results are similar to those with fresh water in Colorado. 2. Spout evaporators and condensers promise high efficiency for OC-OTEC.	Continuing
Gas Desorption Research	Use a packed column to study composition of dissolved gases in seawater heat and at various temperatures and pressures	UHM/Look Lab.	SERI/DOE	H-J. Krock	6/83-present	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 (to be combined with mass transfer study)
Mist-lift Process	Demonstrate operation of the mist-lift cycle with seawater	R&D Associates, Marina del Rey, CA	SERI/DOE	S.L. Ridgway	6/83-12/83	1. Mist generator works well without clogging. 2. Vapor-mist coupling approximates predictions - up to 100m. of lift may be available from 20°C.	On Hold
CWP/AST Phase III	Deploy and monitor 1/3 scale FRP CWP down slope off Ke-ahole Point.	HD&C/NOAA	NOAA/DOE	I. Sandison	4/83-5/84	Deployment successful. Data collection begun.	Continuing

OTEC Research

The ongoing biofouling and corrosion research initiated in 1981 by Argonne National Laboratory (ANL) has continued this year with support from the Solar Energy Research Institute (SERI) and technical direction from ANL and Dr. Jorn Larsen-Basse of UHM. That work has been supplemented by new research directed by SERI and Dr. Larsen-Basse into open-cycle processes. Additional projects have been initiated on cold water pipes and on the environmental impacts of proposed OTEC experiment expansion.

Closed-cycle OTEC

Heat Transfer, Biofouling and Corrosion — These experiments use 1 inch diameter piping loops in the NELH laboratory, each of which contains a heat transfer monitor and through each of which seawater flows continuously at 6 ft/sec. Project expansion at the beginning of FY 1984 brought the system up to its design capacity of 12 warm water and 6 cold water loops.

Warm Water — Warm seawater has flowed through 12 experimental loops throughout FY 1984. In addition to the 7 loops run since July 1981, 5 new loops contain heat transfer monitors and samples designed to test different alloys and new heat exchanger enhancements. Both spirally-fluted ("korodense"-enhanced) and rectangular cross-section ("Trane"-type) tubes are being tested. A new temporary intake with a submersible pump was installed more than 600 feet offshore in January, and water from this system has flowed through one loop since then. This experiment did exhibit an incubation period before the onset of the first biofouling cycle, as expected from earlier results obtained using an offshore buoy at Ke-ahole Point. Subsequent fouling cycles have initiated rapidly, however, indicating that the biofouling characteristics of the water from 600 feet offshore do not differ significantly from those of the water from 300 feet out which is pumped through the NELH primary warm water supply.

Biofouling Countermeasures — Continued experimentation in FY 1984 has further confirmed the efficacy of intermittently-applied low chlorine levels for effective biofouling control. Only 70 parts per billion (ppb) of residual chlorine applied for only one hour per day appears to almost completely control the biofouling of tubes made from several candidate heat exchanger materials. In addition, the same low intermittent chlorination schedule can remove established biofouling films. These results, combined with the improved understanding of the chemical dynamics of chlorine in tropical water obtained from Dr. Sansone's chlorination studies at UHM, continue to indicate that chlorine can control OTEC biofouling without adverse environmental effects. These results have also been confirmed for rectangular cross-section and spirally-fluted tubes used in enhanced heat exchanger designs.

Cold Water Results — FY 1984 saw the initiation of several new cold water loops for continued research on biofouling and corrosion. Cold water flowed uninterrupted throughout the year, allowing corroboration of the previously obtained results: no biofouling and significant pitting corrosion of aluminum alloys in the cold water. These results continue to indicate that biofouling will not be a serious problem in OTEC condensers and that corrosion of aluminum may preclude its use on the cold water side. Both rectangular cross-section and spirally-fluted tubes were also tested in the cold water.

Coupon Analysis — Dr. Jorn Larsen-Basse's study of the corrosion of candidate heat exchanger materials has continued to indicate that aluminum will work well in warm surface water, but may corrode unacceptably in the cold deep water. Dr. L. Ralph Berger's continued analysis of the biofouling films has produced spectacular electron micrographs of the fouling organisms and shown how they grow on the corrosion layers. Year-end results indicate that some skeletal forms may remain on the surfaces even after removal of all heat transfer resistance by chlorination.

Macrofouling Studies — A new facility for the study of corrosion and macrofouling under slow-flow conditions was constructed at the end of FY 1983 and has produced interesting data in FY 1984. Three warm water and three cold water troughs carry seawater at about 1 ft/sec (0.3 m/sec) past samples extracted periodically for both biofouling and corrosion analyses. Dr. E. Alison Kay of the UHM Zoology Department is responsible for the macrofouling analyses, while Dr. Larsen-Basse is combining these corrosion studies with those described below for the Deep Ocean Cable Materials study.

Kinetics of Chlorine in Seawater — Dr. Francis J. Sansone has continued research in FY 1984 at UHM using NELH seawater samples in attempts to understand the kinetics and fate of chlorine in tropical seawater. Results continue to indicate that potential environmental impacts of chlorination at an OTEC plant would be minimal, both because of the low levels required and because of the lack of significant production of the halogenated organics found when other seawaters are chlorinated.

Open-cycle OTEC

Three experiments testing open-cycle OTEC concepts have been operated at NELH in FY 1984 with DOE funding through SERI in Golden Colorado.

Heat and Mass Transfer — Experimentation has continued on the properties and efficiencies of spout evaporators and condensers using the apparatus assembled in FY 1983 from remnants of the mini-OTEC pipe. Data collected under Dr. Larsen-Basse's direction by researchers from UHM and SERI have mostly replicated the results obtained earlier at SERI with fresh water. These results indicate the potential for very high efficiencies in spout evaporators and condensers. At year's end, plans are being formulated for a major new experimental apparatus using much larger tanks and more sophisticated instrumentation to continue this experiment in combination with the gas desorption studies described below.

Mist Lift — Dr. Stuart Ridgway of R & D Associated in Marina del Rey, California ran several successful experiments with the apparatus which he brought to NELH from California and assembled with DOE funding through SERI. Successful operation of the experimental-scale mist-lift process using seawater was achieved for the first time in October, 1983. Results indicated that the fine (100 micron diameter) holes in the mist generator were not clogged quickly by the seawater and that the coupling between the rising vapor and the liquid mist droplets was very close to that predicted. In spite of these encouraging results, the follow on proposal to SERI for continued experimentation was not funded in FY 1984. The apparatus remains erected at NELH awaiting further funding.

Seawater Gas Sorption Kinetics — Dr. Hans-Jurgen Krock, Director of the JKK Look Laboratory of Ocean Engineering at UHM, has, with SERI funding, erected a packed column at NELH for studies on the gas content of seawater as a function of temperature and pressure. The apparatus was transferred to NELH from Oak Ridge National Laboratory early in FY 1984 and erected adjacent to the other open-cycle experiments. Input plumbing allows measurements of both the input and output warm and cold water streams from the other two open-cycle experiments. Since the vaccuum priming system on the primary NELH warmwater pumps removes an unknown fraction of the dissolved gases, an additional temporary warm water pumping system installed in September, 1983 provided surface water from a submersible pump through an independent 6-inch pipeline for this experiment. At year's end, preliminary results have been reported to SERI indicating that the energy required to remove the dissolved gases from seawater is approximately 50% of that predicted fom data obtained previously with fresh water. Though the thermodynamics behind this exciting observation are not yet understood, the data show that

pre-deaeration will be a much smaller parasitic loss in open-cycle systems than was previously expected.

OTEC Coldwater Pipe Test

NELH is the site of Phase III of the One-third Scale Cold Water Pipe At-Sea Test Program funded by DOE through NOAA's Office of Ocean Engineering. This program has been conducted under NOAA guidance by Hawaiian Dredging & Construction Company. Phase I involved construction of a 400-foot (122 m) long by 8-foot (2.4 m) diameter "test article" using fiberglass-reinforced-plastic (frp). Phase II, conducted off Waikiki, Oahu in April 1983, suspended the pipe from a surface platform and measured the forces and moments on it under various wave and current conditions. In Phase III, an 80-foot (24 m) long section of the pipe was deployed down a 40-degree sloping bottom off NELH in April 1984. A year-long program has begun monitoring the forces on the pipe and its foundation under varying environmental forcing. The environmental data on waves and currents off Ke-ahole Point will be particularly helpful to the ongoing efforts to understand and forecast the offshore environment. These data are being recorded by a stand-alone computer system, which is connected via a telephone modem with the Honolulu offices of Edward K. Noda and Associates, HD&C's subcontractor for data collection. This system allows complete control of the data acquisition system from Honolulu and minimizes requirements for work on-site at NELH. Systems of this type will allow this and future projects to minimize both the costs of doing research at NELH and also the direct involvement of NELH staff in the research.

Environmental Impact Studies

In support of DOE plans for using the ill-fated 48-inch coldwater pipe and subsequent plans for installing alternative new seawater systems, the University of California at Berkeley (UCB) Marine Sciences Group has been funded to study the environmental impacts of the installation and use of proposed facilities. A large experiment planned for the fall of 1984 will study the existing oceanographic conditions off Ke-ahole Point. These data will serve as input for modeling the effects of large-volume intakes and discharges on the nearshore region.

Coldwater "OTEC" Aquaculture Research

Potential economic benefits from aquacultural by-products which might be grown in the coldwater discharge from an operating OTEC plant have prompted the state of Hawaii to fund development of facilities or research into cold water aquaculture. These include the unique NELH cold seawater supply system and several types of tanks and other equipment for growing various species of plants and animals. These facilities have attracted a number of research projects from both the private and public sectors investigating the potential utilization of the deep cold water. The properties of low temperature, high nutrient content and lack of pathogens that are found in the deep cold water have pointed to the potential for commercialization of several species of aquatic plants and animals.

Fish — Dr. Arlo Fast and his associates from the Hawaii Institute of Marine Biology have continued their research on the growth of salmon and rainbow trout in the deep cold water. Major experiments this year have concentrated on studying environmental influences on the smoltification process in salmon and on the spawning of steelhead trout in seawater. Results indicate that photoperiod has little effect on salmon smoltification, but lower water temperatures appear to accelerate the process and minimize the time spent by the fish in freshwater. Manipulation of temperature and photoperiod induced steelhead trout to spawn in seawater, and in January 1984, the researchers milked the sperm and eggs from the fish and successfully produced offspring in fresh water. This is believed to be the first such hatching that has achieved a high percentage of viable offspring. This procedure further reduces the proportion of the fishes' early life cycle which must be spent in freshwater.

The researchers now feel that they have sufficient data to design fish aquaculture systems in conjunction with future OTEC plants. Present plans call for completion of these research projects in the fall of 1984. A publication will then be prepared summarizing the results of all the coldwater aquaculture research at NELH, including the previous projects which investigated growth of nori (seaweed) and Maine lobster. That report will include an analysis of the economics of raising the various species, both independently and in conjunction with an OTEC plant.

Abalone — In May 1984, Hawaiian Abalone Farms (an affiliate of Monterey Abalone Farms of California) signed a long-term lease for 21.3 acres of land adjacent to the NELH compound and began development of a "Commercial Demonstration Module" of an abalone production facility. This culminates more than two years of research at NELH which has indicated the suitability of the deep cold water for abalone culture. The company has announced plans to move its production operation from Monterey to Kona. At the end of the fiscal year they formally broke ground and began clearing land for the commercial demonstration module.

This company's research has successfully demonstrated the useful properties of the deep cold water being pumped at NELH for aquaculture of marine mollusks. The purity of the water permits successful larval growout without expensive water purification processes. The high levels of dissolved inorganic nutrients in the deep water provide rapid growth rates and high protein content in both the microscopic plants the mollusks consume in the larval stages and in the giant kelp which provide their food as adults. Since the deep water as delivered at the laboratory is always colder than required for the various stages of the culture process, temperature can be cheaply maintained throughout the systems by controlling the coldwater flow to balance heat gained from the Hawaiian climate. Several new proposals for utilizing these coldwater properties in culturing both shellfish and marine algae are being considered for research and development at NELH.

OTEC Agricutlure

Dr. Sanford Siegel of the Botany Department and Dr. Martin Vitousek of the Hawaii Institute of Geophysics at UHM have initiated research into the possiblity of using the cold freshwater which condenses on the pipes carrying cold seawater to irrigate agricultural crops such as strawberries. With funding from the UH SeaGrant program, several beds were constructed at NELH and plumbed with various combinations of coldwater piping running both above and below the soil. Initial results show that significant water condenses on the pipes even when they are well buried in the soil, and that sufficient water condenses from the ambient air at Ke-ahole Point to provide adequate irrigation for optimum strawberry growth. In addition, the strawberries grown using this cold condensed water consistently have about five times the sugar content of control plants watered with ambient temperature tap water. This six-month pilot project has demonstrated the usefulness of the coldwater agriculture concept, and plans are being formulated for expanded research in FY 1985.

Strawberry patch at NELH.

Water Analysis

The expanded program of weekly sampling and analysis of the surface and deep water supplies and of the mixed discharge from the laboratory has continued throughout FY 1984 with funding from DOE. In addition, NELH has contracted with Analytical Services of UHM to produce a computerized data base and a summary report presenting the unique three-year data set of water quality parameters measured at the laboratory. Plans include periodic updating of this report and data base for use by researchers at NELH and throughout the scientific community.

Other Research

Environmental Measurements

NELH remains an official National Weather Service observation station, reporting daily observations of temperature and rainfall. Hourly measurements of solar insolation are recorded and sent to HNEI at UHM for incorporation into the state-wide sensor network. A new data aquisition system to be purchased in early FY 1985 will facilitate direct compilation of these and other data in the NELH computer system for rapid preparation of charts and tables.

Deep Sea Cable Corrosion

This project, sponsored by DOE through contract with Hawaiian Electric Company and sub-contract with Parson's Hawaii, has contracted with Dr. Larsen-Basse of UHM to monitor corrosion of several candidate materials proposed for jacketing the deep sea cables required for inter-island power transmission. Measurements of the electric potential changes on samples installed in troughs which have warm and cold water flows of about one ft/sec (30 cm/sec) yield estimates of expected corrosion rates in the ocean. The troughs used for this experiment also serve as test vessels for the macrofouling analyses conducted by Dr. Kay in conjunction with the OTEC research program.

Alcoa Corrosion Project

Aluminum Company of America is funding Dr. Bruce Liebert of UHM Mechanical Engineering to conduct a three-year project to measure corrosion of some proprietary aluminum alloys in rapidly flowing seawater (6 ft/sec). Coupons of several alloys, some brushed periodically, are sampled on a regular basis and analyzed at UHM for corrosion. The program has reached the halfway point in June 1984, and it is proceeding well.

ASTM Corrosion Tests

NELH is participating in a five-year international inter-laboratory research program on the global variability of the corrosivity of seawater. ASTM has supplied a rack holding samples of steel, aluminum and copper-nickel which NELH personnel have deployed near the cold water pipe offshore of Ke-ahole Point. Specimens are collected at regular intervals and sent for analysis and comparison with similar samples deployed elsewhere. This research is being coordinated by Dr. Larsen-Basse of UHM, but no fees are being charged.

Solar Ponds

The design of a one-acre salt solar pond 30 kw power generating system for NELH was completed in FY 1983 by SETS, Inc. of Honolulu, The design, funded by DPED, proposed use of NELH's cold deep seawater on the condenser side to provide a higher temperature difference than that available in similar projects elsewhere. Construction funding for this project has not been obtained, so plans are being formulated to use the site for other projects.

Miscellaneous Aquaculture

Six of the 1000-gallon tanks constructed in 1982 for chlorine uptake experiments continue to be used for various aquaculture experiments. Some are being used for proprietary abalone experiments, while others contain cultures of Hawaiian limpets ("opihi"). These tanks and the 1,000 sq. ft. inflatable building erected to house the completed lobster pilot project remain available for use by new aquaculture projects.

Seawater pipes and aquaculture facilities.

Aquaculture specimens: (clockwise from top) - abalone, oyster, salmon, lobster, kelp, (center) - nori.

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Future Plans

Permanent Executive Director and Secretary

Early in 1985, Mr. Jack P. Huizingh will move to new offices in Honolulu to assume the post of Executive Director of NELH. The Hawaii State Legislature has established permanent positions for both the Executive Director and a secretary. Ms. Mae Nakamura is the new NELH secretary.

OTEC Research Associate

A new position is being added to the NELH on-site staff effective at the beginning of 1985. A Research Associate with responsibility for oversight and organization of the data collection procedures for the DOE-sponsored OTEC projects has been working at NELH under a UHM contract throughout FY 1984. This position will now become part of the NELH staff, reporting to the Laboratory Director.

Upgrade of Cold Seawater Supply System

New cold water submersible pumps ordered for delivery in mid-FY 1985 will bring the supply from the present 12-inch (30 cm) diameter coldwater pipeline to its maximum capacity of 1300 gpm (4900 l/m). These pumps, specified using the experience of more than two years of operation of the system, should improve the reliability significantly.

DOE has initiated planning for a significant expansion of facilities to be developed around a new cold seawater supply system at NELH. Present plans call for a pipeline approximately 30 inches (76 cm) in diameter to be installed at the laboratory by the end of 1986, along with associated pumping and plumbing. To implement this expansion, a draft Cooperative Agreement between the state and DOE is in preparation at the end of FY 1984.

Within about one year, Hawaiian Abalone Farms will require more water than NELH can provide from its present systems. The company plans to install its own seawater system to meet its needs, and NELH is cooperating in planning for the company's use of the existing Offshore Research Corridor. A cooperative agreement is anticipated for providing shared use of coldwater systems - at least to the extent of providing each entity with an emergency backup water supply.

Closed-cycle OTEC

NELH plans to continue the present biofouling and corrosion experiments through at least the remaining three years of a planned five-year program. Continued funding from DOE is anticipated to support this project. In addition, DOE is funding HNEI and Johns Hopkins University Applied Physics Laboratory (JHU/APL) for a new investigation of non-chemical biofouling control methods. Dr. Patrick Takahashi, Director of HNEI, will supervise research on ultra-violet irradiation and Dr. William Avery of JHU/APL will investigate the possibility of using ultrasonic radiation. Additional loops with heat transfer monitors and another computer will be installed on a new plumbing system for these experiments.

Open-cycle OTEC

SERI intends to fund a proposal fron HNEI for Drs. Larsen-Basse and Krock to construct a greatly expanded open-cycle test facility at NELH. This project will combine the previous heat and mass transfer project with the gas sorption kinetics research. Two large pressure vessels will be fabricated and assembled at NELH for experimentation with larger volumes of seawater and under more controlled conditions than are possible with the existing apparatus. These experiments will be designed to use up to 1000 gpm each of warm and cold seawater.

Pending Commercial Projects

Alcan Aluminium, Ltd. — After approximately one year of planning and discussion, Aluminium of Canada has decided to proceed with a large-scale test of aluminum heat exchanger elements. Several multi-tube heat exchangers of

various alloys will be installed in the laboratory for continuous monitoring of heat transfer and corrosion with 6 ft/sec (2 m/sec) flow of both warm and cold water. NELH will install new water supply lines for this experiment, which will be designed to eliminate the need for costly booster pumps to maintain the flow. Argonne National Laboratory has agreed to support this research by making the heat transfer instrumentation available to Alcan. Researchers at Alcan's British laboratory outside London will conduct the experiment, which is being designed so that both data and experiment control information will be transmitted automatically over the telephone. This should minimize the operational interaction required from the NELH staff. Plans call for initiation of the installation in the Fall of 1984.

Hawaiian Abalone Farms — As noted above (see p. 15), this company is constructing a commercial development module of an abalone culture system on land leased from NELH. They have announced plans to begin commercial production within six months. The operation will require its own deep seawater pumping and piping system within approximately one year. Full utilization of the 21.3 acres leased from NELH is expected within 5 years.

Cyanotech, Inc. — This company from Woodinville, Washington plans to develop production facilities at NELH for various marine microalgae. At year's end negotiations are nearly complete for their use of a 4-acre parcel of NELH land adjacent to that leased to Hawaiian Abalone Farms. Initial plans call for production of *spirulina*, a microalgae in great demand as a health food supplement. Though spirulina is normally grown in fresh water, Cyanotech scientists have demonstrated that it will do well in pure seawater. The company plans that the profit expected from spirulina sales will provide capital for their planned research into pharmaceutical derivatives from various microalgae.

American Sea Ranch, Inc. — This company plans to establish a shellfish hatchery at NELH, using the purity of the deep cold water to ensure the production of high quality larvae. The company is a successful producer of shellfish in the Pacific Northwest, and they also propose to establish a growout facility to serve the Hawaii market for live shellfish. At year's end, they are proposing initial experimentation within the existing laboratory compound, to be followed upon successful completion by a commercial scale development on adjacent land.

Other Aquaculture — Other companies have approached NELH about the possibility of growing algae, clams, scallops and other sea foods using the deep cold water at the laboratory. Negotiations have begun for several small projects. NELH foresees expansion which could rapidly utilize all its available land at Ke-ahole Point. The newly-created quasi-public High-Technology Development Corporation has been approached about the possibility of organizing an aquaculture park on land adjacent to NELH, and discussions of this possibility are progressing as FY 1984 closes. Such a park could serve projects which test their technology at NELH and subsequently want to enter into a long-term commercial lease.

DUMAND — The DUMAND (Deep Underwater Muon and Neutrino Detection) project plans to deploy a large array of sensors in the deep ocean off Ke-ahole Point in 1986. The power and data cables for the project will terminate at NELH, and plans are developing for a data collection and analysis facility at the laboratory. Instrumentation studies conducted off NELH in FY 1984 have aided in the design of the complete system, which will be one of the largest ocean engineering projects ever undertaken.

Budget Summary

Project Funding Support Summary FY 1984

	STATE	FEDERAL	OTHER
A. **Operational Support**			
Operational Support for NELH	$208,477/(DPED)		
B. **Site Studies**		None	
C. **Site Development**		None	
D. **Ocean Energy**			
1. OTEC Biofouling Experiments		$301,000	
2. Open cycle test		11,373/(SERI)	$7,149/(R&D Associates)
E. **Mariculture**			
1. OTEC Coldwater Fish Culture		13,515/(NOAA)	
2. Abalone			7,083/(Monterey Abalone Farms)
3. Lobster			113/(Sanders Associates)
F. **Other**			
1. Alcoa Corrosion			5,000/(Alcoa)
2. Deep Sea Cable Materials			8,129/(Parson's-Hawaii)
3. Miscellaneous			3,636/(various)
TOTALS:	$208,477	$325,888	$31,110
Total income: $565,475			

Appendix

NELH Policy on Project Acceptance

The criteria for acceptance of projects for pursuit at the NELH facilities shall be based upon the projects' relation to the development of natural energy resources and also upon their utilization of those resources that are available at the NELH facility at Ke-ahole Point. Projects that are only tenuously related to alternate energy development and/or do not require the resources that are available at Ke-ahole Point shall be referred to the appropriate governmental agency for action and recommendations.

Illustrative examples include:

OTEC research

High priority, alternate energy development plus uses available NELH resource (deep cold seawater).

Solar pond power systems

High priority, alternate energy development plus uses available NELH resource (high solar radiation).

Cold water aquaculture

Medium priority, may be an adjunct to OTEC research plus utilizes available NELH resource (deep cold seawater).

Solar desalination

Medium priority, indirectly energy related and utilizes available NELH resource (high solar radiation).

DUMAND

Medium priority, tenuous relation to energy but need proximity to undisturbed deep ocean.

Note: The 1984 Hawaii State Legislature enacted changes to the NELH legislation which allow commercialization of projects at the laboratory. Leasing of NELH land for commercial purposes can now be approved by the Board of Directors. The Board has determined to encourage those commercial projects which first perform research and development work at the laboratory.

Kelen Dunford conducts a tour.

Staff

June 30, 1984

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Seattle, Washington

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