# HAWAII NATURAL ENERGY INSTITUTE

1992
ANNUAL REPORT

School of Ocean and Earth Science and Technology
University of Hawaii at Manoa



soest
university of hawai'i

## DISCLAIMER

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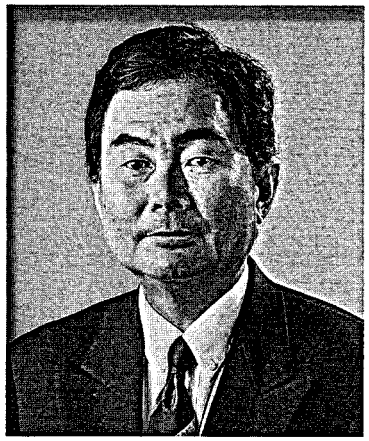
# MESSAGE FROM THE DIRECTOR



Just about every convenience we enjoy today had its beginnings in the research laboratories of yesterday. Many we recognize as products of painstaking research: the solid-state transistors in our televisions and radios, satellite and fiber optic systems that link us instantaneously with places around the world, silicon chips that drive our computers, laser discs and cellular telephones, plastics in our tools and appliances, metal alloys in our jet aircraft and spacecraft, sophisticated medicines and medical technologies. Many others we take for granted: the abundance of fresh food and clean water, the quality of our manufactured goods, our very quality of life. And still others are being developed and refined in the research laboratories of today: the next generation of computers, new communication media, cures for cancer and diseases, and myriad discoveries yet unknown to the public.

At the University of Hawaii's Hawaii Natural Energy Institute, researchers are developing the fuels, materials, and technologies that will someday take their place among those things we now consider commonplace.

The year 1993 will mark the 20th anniversary of the first oil embargo and the genesis of HNEI. In the time since the institute's formation in 1974, much of the promise of the research begun in the aftermath of that crisis has been fulfilled. The Hawaii Geothermal Project in Puna, which HNEI spearheaded, has led to the construction of the islands' first commercial geothermal plant. Tests of solar energy technologies and the identification of the best solar insolation locations state-wide have led to Hawaii having the highest per capita usage of solar water-heating systems in the nation. HNEI contributed to the early research on the ocean thermal energy conversion system, a pilot plant of which is now being tested at Keahole Point on the Big Island. Early research on biomass led to the use of sugarcane and other biomass as promising bio-products feedstock.

Today, HNEI researchers are seeking new ways of generating electricity and producing methanol from sugarcane waste and other biomass. They are finding ways to encourage the expanded use of methanol as a transportation fuel. They are creating innovative and cost-efficient methods of producing and storing hydrogen gas, considered the "fuel of the future."

HNEI's pioneering ocean energy research has evolved into an expansion of the institute's mandate to include serving as the ocean technology research and development arm of the University of Hawaii's School of Ocean and Earth Science and Technology. HNEI researchers are now developing the techniques and technologies that will enable us to tap the unlimited mineral resources of the oceans that surround us. They are testing methods of using the oceans to reduce the amount of carbon dioxide being discharged into the atmosphere. And they are mapping the strategies by which the seas can become a major source of food, precious metals, and space for living and for industry.

Moreover, the coming years will see a shift in national spending priorities from military to civilian purposes. A new administration in Washington, D.C., has signaled its interest in sustainable resource development. The outcome of the Earth Summit reaffirmed the world's desire for environmentally benign energy alternatives. The globalization of the economy has stimulated interest in producing food, energy, and materials that enhance our competitiveness and standard of living. And this very global competitiveness has led to the realization that cooperation among nations will be essential to universal human progress. HNEI's international research and development work will continue to play an instrumental role in this changing environment.

Some of the technologies and techniques being developed by the Hawaii Natural Energy Institute will find everyday application in the very near future. Others may not enter the marketplace for many years. Some will succeed commercially and find their way into our lives; others may be too costly or impractical for widespread use. That is the nature of research.

But whatever the future of any particular idea or research project, what is essential is that new ideas are being examined and old ones reevaluated, hypotheses are being tested, technologies are being developed and refined—and progress is being made. The cadre of graduates to lead the quest for expanded utilization of sustainable resources is being trained. The Hawaii Natural Energy Institute is contributing to the betterment of our lives by testing these ideas, creating the technologies of tomorrow, and maintaining Hawaii's international leadership in the fields of renewable energy and ocean resources development.

Our progress, as expressed by the achievements described in this annual report, can be attributed to the experience, creativity, painstaking study, perseverance, and sacrifices of HNEI's dedicated corps of researchers, both past and present, an exceptional staff, and the generous support of the University of Hawaii administration, industry, members of the legislative and executive branches of our state and federal governments, and all who share a commitment to HNEI's goals.

In particular, HNEI has enjoyed and appreciated strong ties with the Hawaii Department of Business, Economic Development & Tourism, Pacific International Center for High Technology Research, local and national utility organizations, such national laboratories as the National Renewable Energy Laboratory, the U.S. Departments of Energy, Commerce, Defense, and the Interior, National Science Foundation, national resource centers such as the Florida Solar Energy Center, industry, and the public and private sectors of other nations.

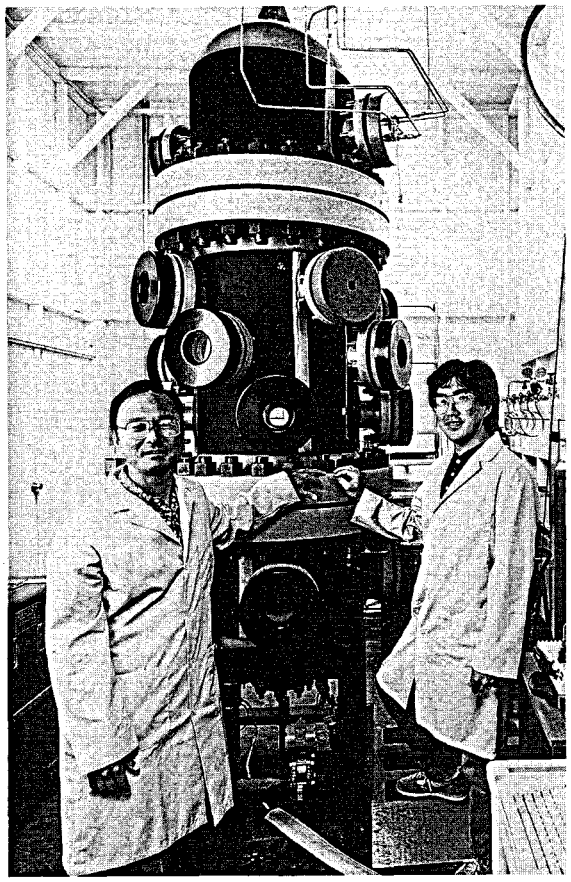
The Hawaii Natural Energy Institute will continue to build on this outstanding research record in the years ahead, and we look forward to your continued interest in and support for our endeavors.◀

*Patrick K. Takahashi*
Director, Hawaii Natural Energy Institute

## Injection of Carbon Dioxide in Deep Ocean Water

Researchers from HNEI and the Pacific International Center for High Technology Research (PICHTR) have constructed an experimental facility to test the feasibility of deep ocean disposal of carbon dioxide as a means of mitigating global warming.

While the scientific community has yet to reach any agreement on global warming, the potential environmental consequences of increased greenhouse gas emissions have spurred the development of strategies to control the level of these gases. One potential means of controlling atmospheric carbon dioxide is liquefying carbon dioxide emitted by industrial fuel combustors and disposing of it in the deep ocean.



*Researchers Charles Kinoshita (left) and Steve Masutani are analyzing the feasibility of disposing of greenhouse gases in the sea. This device (background) simulates 600-meter ocean depths.*

A laboratory test of this idea is being conducted by engineers from HNEI and PICHTR. Their general objective is to examine the physics of mixing liquid carbon dioxide and sea water. Toward this end, they have constructed a facility that simulates ocean depths of 600 meters. Their results will be applied to the development of predictive models that can be used to validate the concept and engineer a viable disposal system.

## Engineering Research Needs for Off-Shore Mariculture Systems Workshop

The National Science Foundation sponsored a Hawaii Natural Energy Institute workshop to identify the research needs that would be a precursor to successful open-ocean mariculture, i.e., the cultivation of fish at sea rather than in land-based aquaculture systems.

This workshop was proposed because natural, wild stocks of fish are being depleted by over-fishing, pollution, and other factors; the U.S. is far behind other nations in open-ocean mariculture research and commercialization; and open-ocean mariculture presents an opportunity for development as a new industry. Open-ocean mariculture also holds special significance for Hawaii because of Hawaii's pioneering aquaculture work and the potential adaptation of artificially upwelled water to sea-based fish farming.

The workshop was held to assess the progress and problems experienced in nations with major mariculture industries, then identify the research required for the U.S. to proceed in this area. The participants made research recommendations in four key areas: (a) materials that can be used in a rough marine environment and construction techniques for off-shore cage systems; (b) anchoring, mooring, and positioning

of fish cages or other confinement systems; (c) the engineering and biological operational needs of fish farming; and (d) the potential use of deep ocean water and artificially upwelled sea water for mariculture.

Sixty participants from around the world attended the September 1991 event, which was held in Honolulu.

## Stockpile 2000

Thirty specialists in marine minerals technology, representing government, industry, and academia, participated in a workshop in September 1991 to define the technology needed for the delineation of ore reserves and the recovery of chromium and platinum from off-shore placers and cobalt and platinum from crusts and nodules. The event was funded by the National Science Foundation.

The goal is to create a U.S. marine mineral reserve base which would serve as an alternative to the existing national defense minerals stockpile, reported to have a deficit of $7.5 billion. The specific objective of the Stockpile 2000 participants was to define the technical needs to delineate and recover strategic and critical minerals from the marine environment.

Results of the workshop revealed that opportunities exist for encouraging commercial marine mining, but which would require improvements in resource assessment technology, particularly geotechnical measurement, the design and development of mineral recovery and extraction equipment, and a better understanding of the environmental impact of this activity. Participants held there was too little cooperation between government and industry and that this condition had slowed the advancement of seabed resource recovery. The participants recommended that global sharing in exploration, technology, and environmental data be promoted to overcome the obstacles inhibiting industrial growth.

## U.S. Ocean Resources 2000

Top experts from industry, government, and academia met in Hawaii in June 1992 to map a strategy for the utilization and management of the nation's ocean resources.

The conference was convened to plan ways in which the U.S. can reestablish its global competitiveness through its leadership in ocean resources development and related technologies. The planning meeting, which featured representation from the Pacific, Atlantic, and Gulf states, was sponsored by the National Science Foundation and National Oceanic and Atmospheric Administration.

The U.S. has the largest Exclusive Economic Zone in the world, and many contend that this resource base can provide seafood, one-half of which is now imported; strategic minerals, again imported in large quantities; major sources of renewable energy; and space for floating cities, artificial islands, and off-shore facilities for waste treatment and manufacturing. Despite the abundance of resources in the seas and the designation of EEZs, the U.S. has continued to lag behind other nations in ocean resources development.

The participants proposed two approaches to address this need. The first calls for congressional oversight hearings on the establishment of a national oceans initiative. These hearings would focus attention on the necessity of a national program, investment in technology

development, and the assignment of these tasks to a federal agency, probably in the U.S. Department of Commerce.

The second approach, to be pursued in parallel with the first, was the establishment of a university-industry, non-profit organization to serve as a focus for ocean resources and dire technology development activities. Government would provide administrative and management oversight and foster cooperative research and development programs.

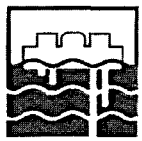
At a minimum, the national program would provide information on the economic potential of the oceans, assess the actual need for new technology, and develop a plan for the systematic application of these technological advances in resource development. Some of the ideas proposed for demonstration projects included multipurpose incubators or large-scale industrial floating platforms, environmental and climatological monitoring systems, seabed observatories, and ocean fish farms.

The participants also adopted a National Ocean Policy Proclamation that expressed the goals of the group. It reads:

*"Participants in Ocean Resources 2000 found that the United States is in dire and immediate need of new direction with respect to a national ocean policy and that the most pressing need is for the establishment of partnerships among industry, government, and academia, partnerships which will restore the United States to a position of leadership in the use and protection of our oceans and our ocean resources. Participants further found that the most important step in furtherance of this objective is the provision of a clear focal point for the coordination of such partnerships and accordingly recommends that the Congress, by legislation, inclusive of adequate funding, combine all non-military U.S. oceanic research, development, resource assessment and management, and environmental control within the purview of a single agency, and that further the agency of choice be located within the U.S. Department of Commerce."*

A copy of the U.S. Ocean Resources 2000 proceedings can be obtained from HNEI. ◄

***Ocean Resources 2000:*** *Experts from throughout the nation attended this gathering to map a strategy for ocean resource utilization.*



As the marine technology arm of the University of Hawaii, HNEI's Marine Minerals Technology Center/Ocean Basins Division directs its research efforts at developing equipment and techniques for seabed mineral exploration, characterizing marine mineral deposits, and assessing the environmental impacts of such development.

The MMTC/OBD complements the research of the MMTC/Continental Shelf Division based at the University of Mississippi. The Hawaii center cooperates with the Hawaii Institute of Geophysics, Hawaii Undersea Research Laboratory, Look Laboratory, various UH academic and research units, the Universities of Mississippi, Michigan, and Georgia, various companies, and other organizations throughout the world.

**Deposit Characterization:** Studies are targeted at exploring for coastal deposits of carbonate sand and deep seabed manganese crusts.

Techniques have been developed to characterize near-shore sand deposits and forecast the potential environmental effects caused by offshore mining. Numerical models have been created to support this effort, and field tests will be conducted to verify the models. Preliminary tests were done in the vicinity of the Halekulani sand channel off Waikiki Beach.

Plans are underway, in cooperation with the Hawaii Undersea Research Laboratory, to characterize manganese deposits near Johnston Island. A preliminary set of manganese crust samples was analyzed for platinum content to determine the relationship between that metal and the phosphorite layers between and below the platinum enrichments. The ability to date the seamount age and individual phosphorite layers will greatly increase our understanding of the formation of platinum.

**Exploration Equipment and Technique Development:** Work has concentrated on improving the acoustic profiling technology being used to map island sand deposits. A seabed corer and other equipment have been acquired for this effort.

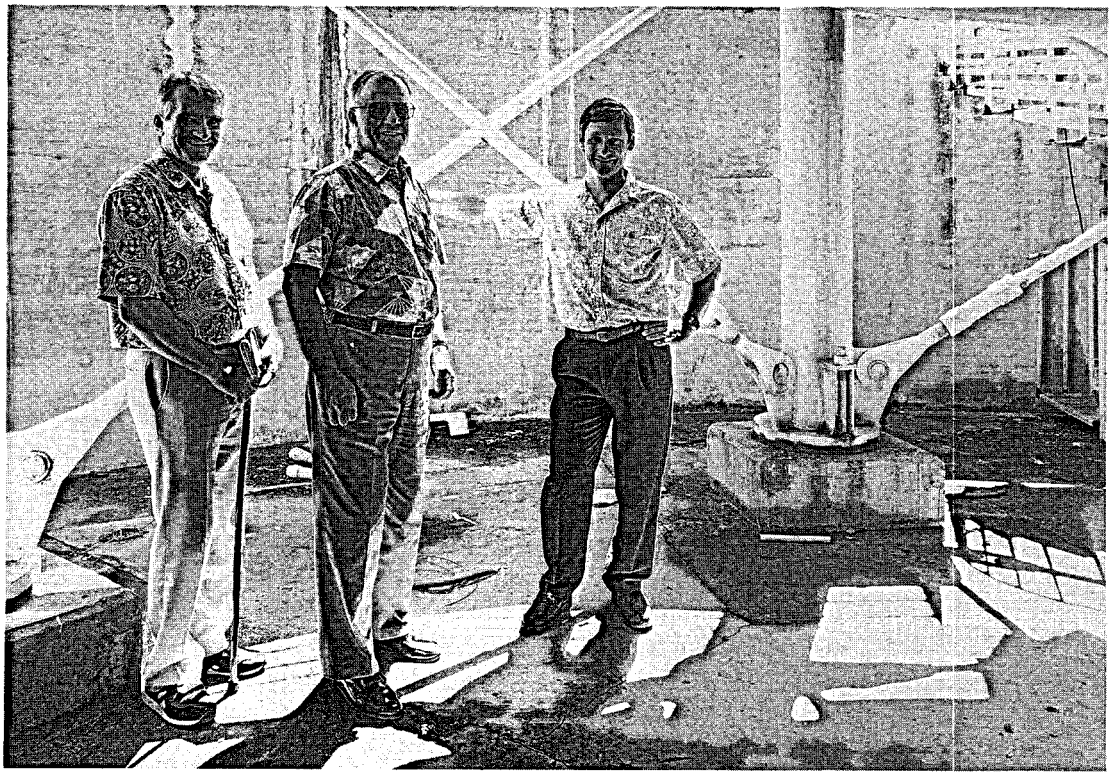
The design and fabrication of a vibratory sand corer was completed during the year. It will be used for sampling purposes to verify geophysical data off the southern Oahu coast. A simplified non-percussion gravity corer was fabricated and tested. Five new gravity corers will be evaluated during a research cruise in the North Atlantic.

Research continued on the production of a high-definition, side-scan sonar system which can be accurately calibrated using stereo photogrammetry. The tool will be used for seabed microtopography purposes.

**Environmental Impact Assessment:** Two computer numerical models have been developed to assess the environmental impact of near-shore sand mining. A field simulation will be conducted to provide the data to calibrate the models.

## Rapid Reconnaissance Sampling of Hard Mineral Deposits on the Seabed

The MMTC has been cooperating with the Analytical Services Company (ASC) on the development of a free-fall, hard-substrate percussion corer that will enable the efficient recovery of samples of hard minerals and other sea floor materials.



*Left to right: Michael Cruickshank, Harry Olson and Charles Morgan of the Marine Minerals Technology Center.*

Free-fall grab samplers have been used with great success by marine miners and researchers in their evaluation of manganese nodule deposits. These samplers, deployed simultaneously in multiples, allow the collection of large numbers of samples from specific sites using a minimum of ship time. ASC, meanwhile, has pioneered the use of percussion coring to sample hard sea floor materials, including ferromanganese crusts and ridgecrest basaltic glass. The combination of these two methods with a free-fall capacity promises to result in a highly efficient tool that will find wide use in marine geological research.

Three samplers have been fabricated and tested. The corer has operated successfully in tank tests and trials in shallow off-shore waters. ◀

The Hawaii Integrated Biofuels Research Program, now in its fifth year, undertakes basic and applied research on the production and conversion of biomass into gaseous and liquid fuels.

Biomass has been targeted because it is the most flexible renewable resource available. Biomass can be burned for heating in industrial and domestic applications, produce steam for electricity generation, and be converted into gaseous or liquid fuels for various purposes, including transportation fuel. Hawaii is well-suited for expanded biomass use because of the absence of fossil fuels, ideal plant growth conditions, and wealth of expertise in the agricultural industry and academic community.

The Hawaii Integrated Biofuels Research Program, funded by the U.S. Department of Energy through the National Renewable Energy Laboratory, is organized into three components: biomass production and feedstock preparation, biomass conversion, and biomass systems integration.

**Biomass Production and Feedstock Preparation:** Research has included field trials of various woody and herbaceous crops in a variety of environments, modeling of their productivity potential, and selection of seedlings for propagation. HNEI researchers, in collaboration with the Hawaiian Sugar Planters' Association and the university's College of Tropical Agriculture and Human Resources, have identified varieties of sugarcane and other grasses with maximum energy potential, investigated eucalyptus and other tropical hardwoods as energy crops, and studied methods of improving yields. They have also analyzed harvesting, handling, transporting, and processing techniques.

**Biomass Conversion:** Research in biomass conversion is directed at analyzing and testing thermochemical processes to covert biomass into fuel gas and methanol, and biochemical processes to convert biomass into ethanol.

*HNEI researcher Charles Kinoshita (standing) outlines the progress of the Hawaii Integrated Biofuels Research Program to members of the technical review committee.*

Solvolysis studies have examined the production of sugars from biomass by flash, acid-catalyzed hydrolysis, as well as the influences of reaction conditions on glucose yield from cellulose and pentose yield from sugarcane bagasse. Steam pre-treatment (i.e., steam explosion) studies have yielded information on the use of this technique to provide feedstocks for biomass-to-ethanol processes from sugarcane and other crops. Experiments on the pyrolytic gasification of biomass in supercritical water have tested the use of this method in producing gas from high-moisture-content biomass. Catalytic gasification studies have focùsed on reforming tars and oils in gasified biomass for the production of biofuels and electricity. Other work has involved biomass gasification technology tests and experiments to prepare for the scale-up of a biomass gasifier plant on Maui.

**Biomass Systems Integration:** Integrating the many components of the biofuels research program is the objective of this component. Various analytical tools have been developed to plan large-scale biomass production and conversion systems, assess biomass resource potential in Hawaii, aid in determining the most

cost-effective methods of production, and analyze the economics of methanol and ethanol production based on Hawaiian feedstocks and specific technologies being developed in the state.

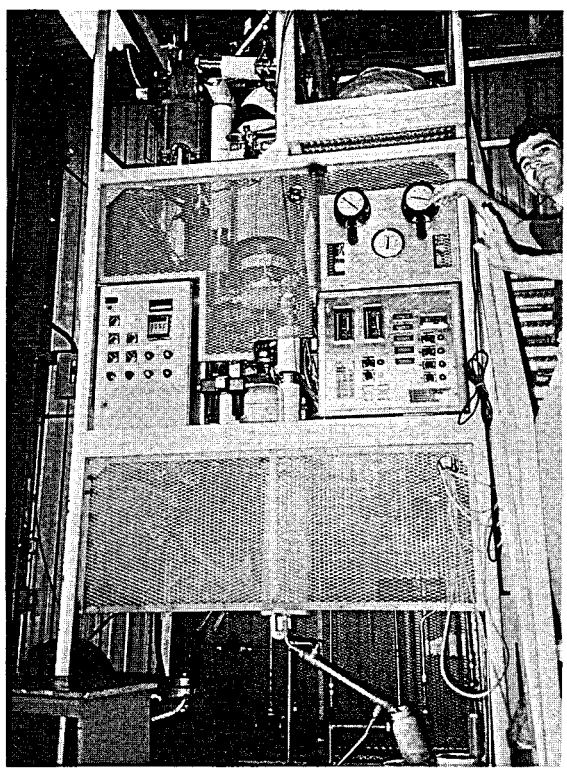
## Hawaii Biomass Gasifier Scale-Up Facility

The Hawaii Natural Energy Institute has joined the Pacific International Center for High Technology Research, Institute of Gas Technology, The Ralph M. Parsons Company, and Hawaiian Commercial & Sugar Company (HC&S) in a multimillion-dollar project to build a scale-up biomass gasification plant, with the ultimate objective of using the technology to produce electrical power and transportation fuels.

Funding to the Pacific International Center for High Technology Research is being provided by the U.S. Department of Energy, which selected Hawaii in a nationwide competition, and the State of Hawaii. The cost of the first phase is nearly $10 million, of which the federal government is providing $5 million, the state government $4 million, and the participants the balance in in-kind support.

The project is in the first of its planned three phases. Phase one includes the design, construction, and preliminary operation and testing of the biomass gasification plant at HC&S' sugar factory in Paia, Maui. This reactor, which is based on the Institute of Gas Technology's Renugas design, will be capable of gasifying 100 tons of biomass per day, although that amount will be halved for the initial tests. In the first phase, sugarcane bagasse will be used as the feedstock. Subsequent phases may include the gasification of other feedstocks.

The second phase calls for the generation of electricity from gas turbines coupled with the biomass gasifier. The third phase will involve the conversion of the biomass gas into methanol for transportation fuel.



*William Kaar adjusts the steam explosion vessel being used to convert biomass into pulp and other useful products.*

## Steam Explosion of Sugarcane and Other Biomass Feedstocks

Steam explosion, a technology developed in the 1920s, is being resurrected and refined throughout the world as a means of producing marketable commodities from biomass in an environmentally benign way.

Steam explosion is a process in which biomass, contained in a reaction vessel, is treated with saturated steam, then rapidly discharged through a constricting orifice. This technique turns biomass into pulp without the addition of chemicals. Researchers are now hoping it can be used to produce paper, fermentable saccharides for liquid fuels, furfural, or animal feed.

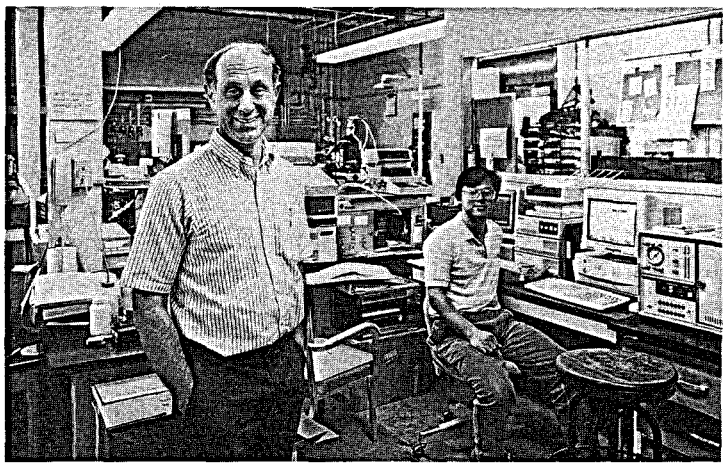
A 10-liter steam explosion unit was installed in October 1991 at a site in Waipahu provided by Oahu Sugar Company. Performance tests and modifications were made to improve its performance. Such biomass feedstocks as bagasse, cane leaves and tops, banagrass, eucalyptus, and waste newspaper and office paper have been treated. The samples are being evaluated for their suitability for conversion into marketable products. Future work will include testing Norfolk pine and residues from macadamia nut and coffee plantations.

The project, involving a team of researchers from HNEI and the Hawaiian Sugar Planters' Association (HSPA), is being sponsored by the University of Hawaii's Office of Technology Transfer and Economic Development, HSPA, and Governor's Agriculture Coordinating Committee.

## Renewable Resources Research Laboratory

Several innovative energy technologies are under development in the Renewable Resources Research Laboratory ($R^3L$).

Research on charcoal production has led to the development of a charcoal reactor that has a yield of nearly 50 percent from biomass feedstocks, about double that of existing systems. Furthermore, the reactor can produce chunk charcoal from dry logs in less than 40 minutes, as compared to current practice which takes eight to 10 days. A patent application for this energy-efficient system has been filed by the University of Hawaii, and CNRS Laboratories plans to commercialize the technology in France. The success of the charcoal project has now led to an examination of the use of charcoal, from wood, as an alternative renewable gasification feedstock. A bench-scale reactor has been designed and funds are being sought to fabricate and test the invention.

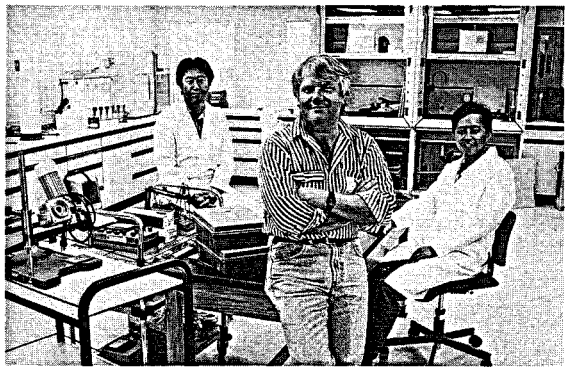


*Michael Antal (standing) and Sheldon Xu in the Renewable Resources Research Laboratory.*

Hydrogen, considered by many to be the fuel of the future, is being produced by the steam reforming of wet biomass in supercritical water (water at extremely high temperature and pressure). The technology developed in the $R^3L$ has been the subject of a patent disclosure filed with the University of Hawaii and there have been expressions of interest by industry. Current work focuses on the gasification of algae, kelp, water hyacinth, banana tree trunks, and other wet biomass.

Researchers are also producing high-value chemicals and liquid fuels using supercritical water reactors. ETBE, methacrylic acid, furfural, ethene, acrylic acid, butene, and methyl ethyl ketone are some of the valuable products being derived from fermentation products through this process.

A biomass fractation (i.e., solvolysis by hot, compressed liquid water) technology developed in the laboratory separates biomass into a liquid containing simple sugars and a solid cellulosic residue. The method being tested uses only water (no acids or costly solvents), with a reaction time of under two minutes. The results of a bench-scale test have led to the fabrication of a pilot plant that will be used to study the commercialization potential of the solvolysis process.◀



*Kelton McKinley (center) with post-doctoral fellows Noriyuki Nakamura (left) and Kunshan Gao in the Bioresources Laboratory.*

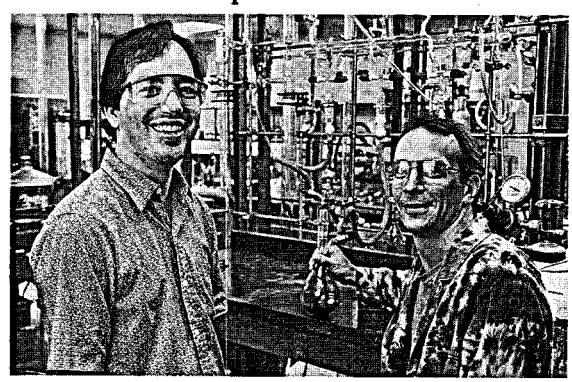
The Hawaii Natural Energy Institute's hydrogen research and development program has been described in the National Hydrogen Association's National Aeronautics and Space Administration technology assessment as the only program in the nation that has "the type of balance between mission, research activity, and practical goals that [could serve as] the foundation of [a] national hydrogen [effort]." The Hydrogen from Renewable Resources Research Program, now in its sixth year, is funded by the U.S. Department of Energy through the National Renewable Energy Laboratory.

HNEI's research balances the competing needs of long-range innovation and short-term return. Achieving this balance has meant that two areas of technology development have been the focus of the institute's program: production and storage. At present, the program consists of three tasks: (1) improved hydrogen storage through the use of nonclassical polyhydride metal complexes, (2) photoelectrochemical production of hydrogen through the use of coated silicon electrodes, and (3) solar conversion and the production of hydrogen with cyanobacteria. A fourth task, hydrogen production from high-moisture-content biomass through the use of supercritical water, will rejoin the program early in 1993.

**Nonclassical Polyhydride Metal Complexes:** A major roadblock to the use of hydrogen as an energy carrier or fuel has been storage. Hydrogen traditionally has been stored as a compressed gas or cryogenic liquid. The disadvantages of these methods are the extreme pressure, weight, and volume requirements. Storage of hydrogen as a liquid is particularly impractical because of the extreme low temperature requirements and high energy demands needed to liquefy the gas. These storage methods also entail safety risks. "Solid hydrogen" storage systems based on metal hydrides are safer and require far less volume than either high pressure or cryogenic storage systems. Unfortunately, conventional metal hydrides contain inadequate quantities of hydrogen, often less than 2.0 percent weight. The resulting high weight of these metal hydride storage systems has severely restricted their practical application.

An alternate class of metal hydrides, called nonclassical polyhydride metal complexes, is being developed at the University of Hawaii. This new class of metal hydrides, in which hydrogen bonds to a metal center while concurrently retaining a significant amount of hydrogen-to-hydrogen bonding, undergoes complete and reversible loss of hydrogen under mild conditions. These compounds also hold the promise of significantly improved percent weight hydrogen content.

During the year, researchers synthesized and characterized novel cobalt group nonclassical polyhydride complexes and have gained increased understanding of the metal-hydrogen interaction. This aspect of the research has



*Craig Jensen with graduate student Jack Belli: investigating nonclassical polyhydride metal complexes.*

attracted national attention and the University of Hawaii has entered into collaborative research projects with Los Alamos National Laboratory, the Universite de Paris-Sud, and Yale University. Research is now being directed toward examining practical storage materials using low-cost iron complexes.

**Photoelectrochemical Production of Hydrogen:** Semiconductor-based photoelectrochemical cells are a promising means of directly producing hydrogen from water using sunlight for energy. While calculations indicate that conversion efficiencies of sunlight to hydrogen exceeding 20 percent are possible, development lags behind that of solid state cells. Improvements in the efficiency and stability of these photoelectrochemical systems require a multidisciplinary approach that addresses both the fundamental chemistry of the semiconductor-electrolyte interface, and total system engineering to quantify and minimize the losses responsible for poor performance.

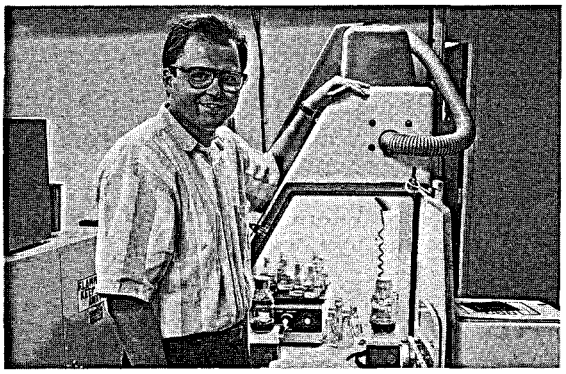
An interdisciplinary team has been formed, combining the fields of chemistry and physics, and chemical, mechanical, and electrical engineering. Thus far, the group has developed a sophisticated, solid state and electrochemical laboratory for the fabrication of semiconductor-based electrodes. It has also developed a computer-based solar simulator for automated measurement and equivalent circuit models for the characterization of solid state and photoelectrochemical devices.

The team has verified the models using prototypical metal-semiconductor and metal-insulator semiconductor devices with ultra-thin metallic films, which have shown improved performance over existing electrodes. Other team members have developed improved impedance spectroscopy techniques to characterize semiconductor-electrolyte interfaces and developed advanced surface analytic techniques, including micro-Raman spectroscopy, x-ray photoelectron spectroscopy, and photoluminescence, to study the chemical and electronic characteristics of semiconductor-metal-electrolyte interfaces. Efforts are currently directed at the development of high-efficiency systems using high-voltage, multi-junction amorphous silicon photoelectrodes. Reactor systems models are also under development.

**Photobiological Production of Hydrogen:** Hydrogen production by cyanobacteria, or blue-green algae, is particularly attractive because these organisms are capable of generating their own organic substrates using only light energy and carbon dioxide, while using water as their ultimate source for hydrogen produced.

Three basic enzyme systems are involved in hydrogen metabolism in these organisms: nitrogenase, uptake hydrogenase, and reversible hydrogenase. Nitrogenase reduces protons to hydrogen, a by-product that accompanies nitrogen fixation, which is the capture of atmospheric nitrogen toward its ultimate conversion to fertilizer in the form of ammonia. Hydrogenases generally function to recapture the hydrogen produced during nitrogen fixation, thus saving the organism significant losses of chemical energy. The diversion of that hydrogen for human uses is the goal of the research effort.

Employing state-of-the-art genetic engineering, researchers have selected a well-characterized alga, *Anabaena* PCC 7210, to examine the molecular mechanisms of hydrogen metabolism.



*Edward Bylina: studying the photobiological production of hydrogen.*

Tentative identification has been made of the hydrogenase genes for the alga, and that has led to the construction of a DNA library. At present, researchers are studying *Spirulina pacifica*, an alga grown commercially for dietary supplements, as another potential source of hydrogen production.

**Hydrogen Production from "Wet" Biomass:** Hydrogen can be produced by the gasification of biomass, making biomass the most cost-effective renewable source of hydrogen. Production costs could be substantially reduced, and quantities of hydrogen increased significantly, if "wet" biomass could be used for the production of medium Btu gases and hydrogen, in addition to the more conventional "dry" forms. It is the high water content that has made these materials unattractive, despite the fact that wet herbaceous or "fleshy" land plants and high-moisture-content aquatic plants grow at rates equalling or exceeding the rates achieved in land plants in intensive agricultural practices. It is simply too costly to remove the water from these plants before using them in conventional conversion technologies.

A new process in which wet materials can be used for hydrogen production involves the use of supercritical water, or water at high temperature and pressure. High-moisture-content organic materials exposed to supercritical water are destroyed by pyrolitic gasification to form hydrogen, carbon dioxide, carbon monoxide, and methane.

*James Gaines: solid hydrogen for applications in space exploration.*

HNEI's efforts have been directed at designing several supercritical fluid reactors and making improvements in design, materials, and performance with each generation. A slurry-feed reservoir has also been designed to facilitate the feeding of biomass to the reactors. Future work will concentrate on catalysts which improve the gasification efficiency.

The future for hydrogen research and development is improving at the national level, as significant increases in financial support were received in 1992-93 and the coming years promise a doubling or even tripling of funding. HNEI hopes to continue to do its part in bringing the promise of tomorrow closer today.

## Energy Storage and Conversion in Solid Hydrogen

The U.S. Air Force Astronautics Laboratory is funding another hydrogen-related research project, this one to study novel, high-energy density materials that could find use in rocket propulsion engines.

The specific goal has been to assess solid hydrogen containing "unstable" additives (e.g., hydrogen atoms) as a fuel with the highest possible energy density. The successful development of such a fuel would permit travel in deep space, something now considered impractical. Research has been directed at creating high atom densities and seeking ways of triggering the release of the energy stored there. The latter objective will solve the practical problem of recovering the stored energy for use in propulsion.

## Thermal and Optical Response of Atoms in Solid Hydrogen

The National Aeronautics and Space Administration is the sponsor of a study of the storage of energy in solid hydrogen in the form of atoms, and the conversion of that stored energy into other forms of useful energy. This research differs from the aforementioned Air Force project in that it involves an investigation of the optical and thermal response of a hydrogen host solid containing unpaired atoms, rather than the study of solid hydrogen containing hydrogen atoms.◀

Hawaii has long been at the forefront of the push for new transportation fuels to combat air pollution and reduce petroleum consumption, and HNEI researchers, with support from the U.S. Department of Energy, are leading the research effort to produce biofuels as a gasoline substitute.

Methanol, in particular, has been targeted because of the potential cost benefits. One method of production is from the gasification of biomass and the conversion of that gas into methanol through a catalytic synthesis process. The gas itself can also be used in combustion turbines to generate electricity. Biomass used in this dual system of electricity generation and methanol production could increase its commercial appeal.

HNEI's research has been divided into three tasks: (1) a practical demonstration of methanol use in the community, (2) identification of corrosion-resistant storage materials, and (3) improvement of the visibility of the methanol flame.

**Methanol Economy Demonstration:** *Molokai has been proposed as the site for a* demonstration of a "methanol economy." That island was selected because of the large potential for agricultural biomass, limited population, and manageable energy demands. HNEI researchers will identify obstacles to the transition to a methanol system, plan a demonstration project involving methanol use, and also plan a more extensive transition plan to convert Molokai entirely to alternative fuels.

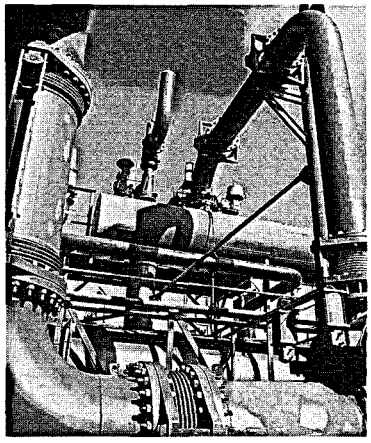
Two flexible-fuel vehicles that run on methanol have been ordered for an initial demonstration program on Oahu. HNEI and the Department of Business, Economic Development & Tourism will test the vehicles. DBEDT will use its vehicles in its public education outreach program.


*HNEI operates a small fleet of methanol-fueled vehicles.*

**Corrosion:** The corrosiveness of methanol has led researchers from HNEI and the university's Departments of Chemistry and Mechanical Engineering to study the effects of methanol on various metals and alloys that could be used in methanol vehicles and examine the role of methanol impurities in the corrosion of metals. Such materials as Armco iron, zinc, 1018 mild steel, 6061 aluminum, and Zamak3 were tested using electrochemical impedance and molecular x-ray fluorescence spectroscopy as the means of determining the rate and chemical nature of the methanol corrosion processes.

The researchers hope that their investigation will facilitate the judicious selection of materials in the retrofitting and designing of methanol-fueled vehicles through the quantitative ranking of materials, recognizing that the stainless steel coating of all components that may come in contact with methanol may not be the best solution. They also expect that their findings will support the development of corrosion inhibitors to permit existing vehicles to use methanol with minimum alteration.

**Flame Luminosity:** The invisibility of methanol flames in daylight could pose potential fire safety problems should this fuel find wider use. Luminosity tests have been conducted and HNEI researchers have determined that certain additives containing higher carbon-to-hydrogen ratios, when mixed with methanol, increase flame luminosity.◀



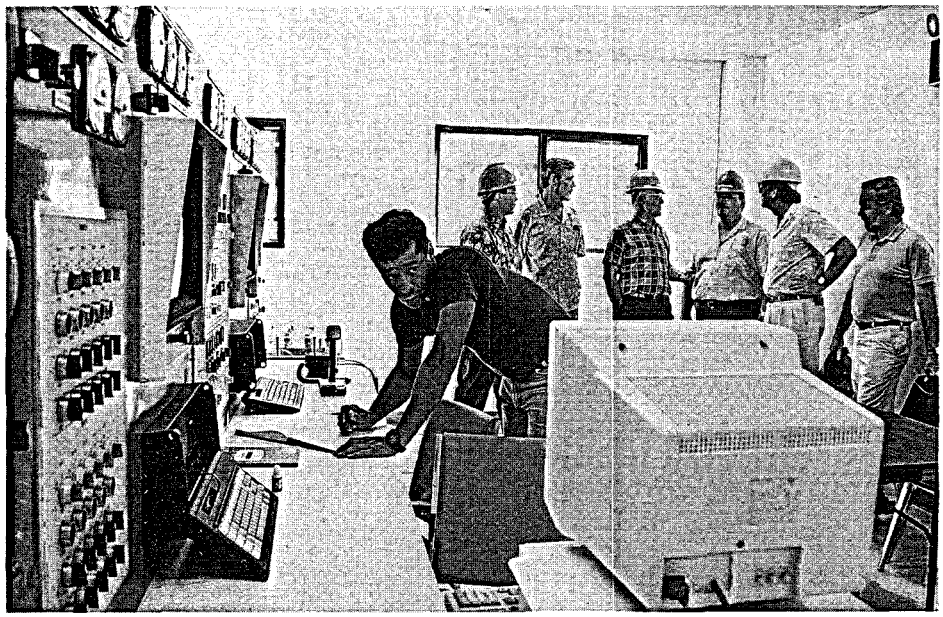
*Steam pipes of the electrical generation unit at Puna Geothermal.*

With the completion of drilling three Scientific Observation Holes in June 1991, attention turned to analyzing the gathered data and core samples.

University of Hawaii researchers have investigated the geochemical, hydrogeological, and reservoir engineering data from the SOH and HGP-A wells, which were equipped with monitors to collect baseline ground water and reservoir data. Geochemical studies covered major and trace elements, water levels, temperatures, and ground water. The hydrogeological research has focused on developing various numerical models on fluid flow. Reservoir engineering studies have focused on long-term monitoring of the reservoir pressures, particularly as they are affected by commercial geothermal development.

The Electric Power Research Institute project on slim hole drilling was completed during the year. The project was successful in demonstrating the value of this technique in assessing geothermal resources. A Bonneville Power Administration project on resource optioning strategies, also involving slim hole drilling, was completed as well.

The Scientific Observation Holes were drilled to a depth of approximately 2,000 meters, and bottom hole temperatures ranging from 206° to 350° C were recorded. These results proved instrumental in confirming the geothermal resource potential of the Kilauea East Rift Zone and stimulating commercial development in that area.◀



*Electrical control room at Puna Geothermal.*

## Demonstration of a Pumped Hydro Facility at the HNEI/Kahua Wind Energy Storage Test Facility

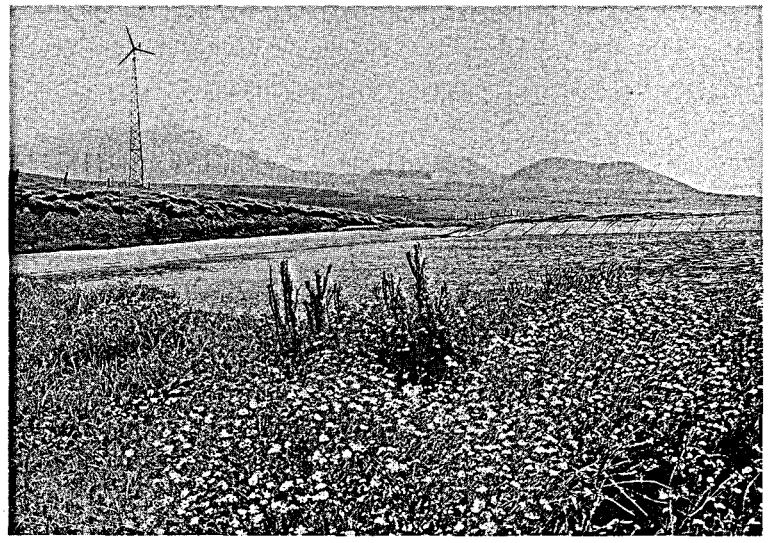
The pumped storage hydro project, an imaginative combination of wind energy, hydropower, and battery technology, marked its first year of operation during the year.

Dedicated in the summer of 1991, the project consists of three Carter 25-kilowatt wind turbines, two reservoirs, and a variety of energy storage technologies, including batteries and a hydrogen system containing an electrolyzer, metal hydride and standard storage tanks, and fuel cells.

A typical pumped hydro system can use cheaper, off-peak utility power or excess electricity from other sources to pump water from a low reservoir to a higher one. When electricity is needed, water is released from the upper reservoir and electricity is generated through a motor-generator as the fluid flows to the lower reservoir. The batteries aid in storing electricity for use when additional power is needed.

This novel system, located at the Wind Energy Storage Test (WEST) Facility at Kahua Ranch on the Big Island, uses wind energy exclusively to pump the water, making it totally renewable. The goal is to make wind energy a consistent source of power, even during times when the winds are intermittent or non-existent.

The motor-generator used in this project can operate at constant or variable speeds. It is equipped with a throttle valve to control the water flow rate from the upper to the lower reservoir. It also has controls so the generator turbine speed operates at the highest possible efficiency at any number of flow rates. During the year, successful tests of the motor-generator were conducted to evaluate its performance at different speeds.



*Kahua WEST Facility.*

The next phase of the project involves the transfer of the WEST Facility and the pumped storage hydro system from HNEI to the Pacific International Center for High Technology Research, reflecting the transfer of this technology from research to pre-commercialization. Future work will include the design and installation of a master controller that will integrate all elements of the system.

The Bonneville Power Administration and Hawaii Department of Business, Economic Development & Tourism (DBEDT), the primary sponsors, have expressed their support for the continuation of the project. PICHTR and DBEDT are now developing a three-year implementation plan for the WEST Facility, which includes installing the master controller, coordinating work with the electric utilities, and seeking additional funding.

## Residential PV Demonstration Project: Phase II

The original experimental residential photovoltaic (PV) demonstration project, funded

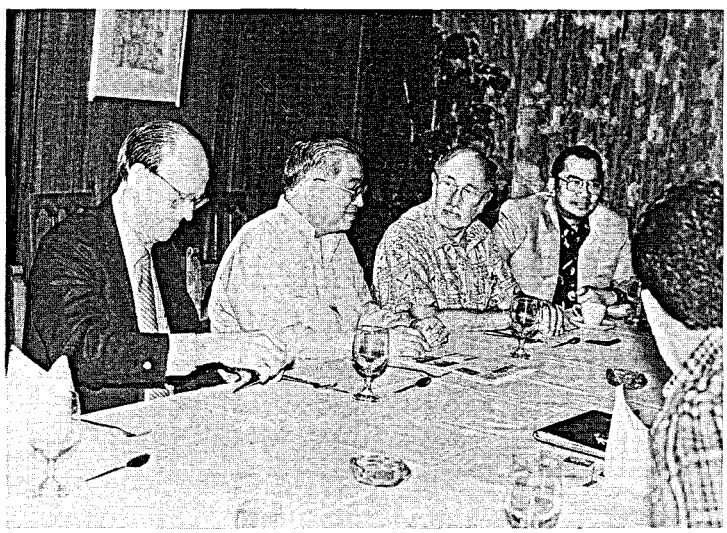
by the U.S. Department of Energy, ended in 1992. The PV modules were sent to the Wind Energy Storage Test Facility on the Big Island, and were also used to promote international cooperation.

The PV units to be installed at the WEST Facility will add to the mix of renewable energy systems now employed there. The units will provide electricity for data collection systems and serve as a back-up source of power.

## Pacific Area Cooperative Renewable Energy Development Program (PACRED)

Renewable energy research and development received a major boost with the formation in 1991 of the Pacific Natural Resources Network (PNRN), a seven-nation association formed to explore greater international cooperation in this field.

The signatories to the agreement establishing the network included representatives from Australia, Hong Kong, Indonesia, Papua New Guinea, the People's Republic of China, Philippines, and Hawaii.



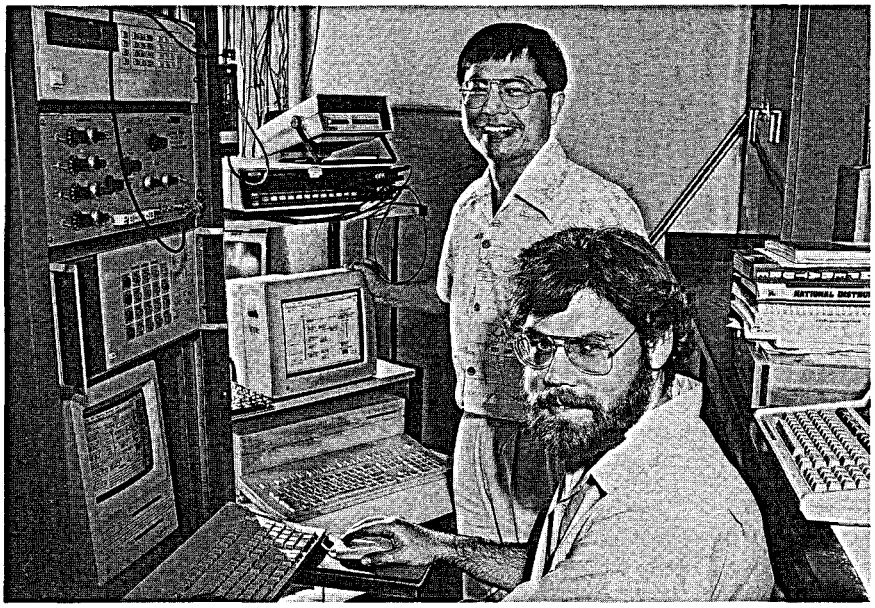
*Left to right: Milton Staackmann, Ambassador Alejandro Melchor, H. M. Hubbard, and Marcelino Espino discuss the Pacific Natural Resources Network and other cooperative ventures in Manila.*

In 1992, HNEI researchers traveled to the Philippines, Indonesia, and Thailand as a follow-up to the initial meeting in Hawaii. The Philippines expressed the strongest interest in a cooperative project, the details of which will be discussed at the next PNRN meeting planned for 1993.

Support for such a project may come through the proposed Pacific Sustainable Resource Systems Program. This program is a consortium of the U.S. Department of Energy's Pacific Region Office, Hawaii Department of Business, Economic Development & Tourism, East-West Center, Hawaiian Electric Company, Pacific International Center for High Technology Research, and HNEI. The consortium will submit a funding proposal to the U.S. Department of Energy for renewable energy projects in the Asia-Pacific region.

The catalyst for these international efforts has been the Pacific Area Cooperative Renewable Energy Development Program (PACRED), funded by the Hawaii Department of Business, Economic Development & Tourism. The goals of PACRED are to foster international cooperation and ultimately to establish Hawaii as a Pacific Solar Technology Transfer Station and develop a Pacific Region Education for Marine and Indigenous Energy Resources (PREMIER) program to position the state as an international center for technical assistance and education in the fields of marine and renewable energy resources.

Other projects completed under the auspices of PACRED have included a study of the social and environmental costs of energy use, the transfer of HNEI's Wind Energy Storage Test Facility to PICHTR, sponsorship of the Pacific Rim Workshop on renewable energy (that led to the formation of the Pacific Natural Resources Network), and a renewable energy technology trade mission to Guam.



*Bor Yann Liaw (standing) and Larry Schmitt in the Materials Research Laboratory.*

## Virtual Instrumentation

Advancements in computer technology have made computers essential to research. However, the application of computers in laboratory instrumentation has lagged, resulting in a growing need for software to automate standard lab activities.

Researchers at the Hawaii Natural Energy Institute are developing instrumentation control and data acquisition software for such widely used platforms as the Macintosh, IBM PC, and Sun Workstation systems. The software will provide a unified, graphical programming environment based on a language called LabVIEW, developed by National Instruments to serve as a dynamic link between instruments and end-users. The packages developed through this effort will be used to control electrochemical measuring instruments through a user-friendly interface for data acquisition and real-time, on-line data analysis and presentation. With this link, instruments in a laboratory could be controlled with one software system and data will be available from initial logging to final publication of the results.

A key feature of the software is its flexibility. The software will be written in easy-to-understand graphical modules, while plug-in boards will be used to control data acquisition through instruments. The software can be transported from one platform to another.

The project is being supported by a grant from the University of Hawaii's Office of Technology Transfer and Economic Development. ◄

## Reproducible Excess Heat Generation

Research continues on the Fleischmann-Pons "cold fusion" phenomenon, with HNEI's efforts focused on a novel method of excess heat generation using molten salt electrochemical techniques.

This research has recorded excess heat generation of 600 percent over the input energy. The objective now is to consistently reproduce this heat generation. Evidence shows that harnessing energy from this method produces little harmful radiation, making it potentially a cost-effective and abundant energy resource.

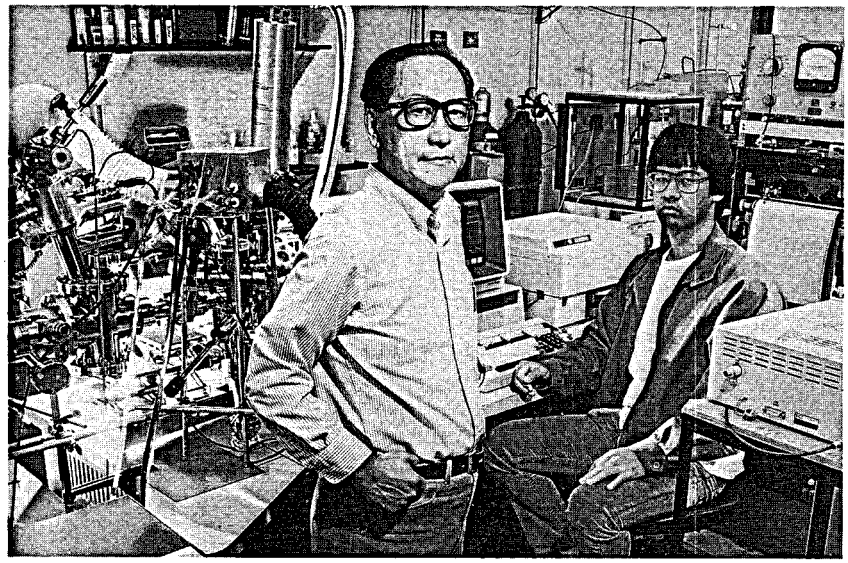
Funding is being provided by the Office of Naval Research and Fusion Resources, Inc.

## ESCA Study of Refractory Concrete Samples

The deterioration of airport runways caused by jet blasts, fuel leakages, and other stresses is the subject of a study by UH researchers using electron spectroscopy for chemical analysis (ESCA).

The researchers have analyzed concrete samples in the hopes of determining the chemical composition of the surface and the change in the material's electronic structure after thermal and chemical treatments. Results of the study may lead ultimately to heat- and chemical-resistant concrete.

This work is being conducted in cooperation with the U.S. Navy Materials Science Laboratory.



*William Pong (standing) and student Derek Yamamoto with the electron spectroscopy for chemical analysis system.*


*Richard Rocheleau in the Thin Films Laboratory.*

## Thin Films Laboratory

The School of Ocean and Earth Science and Technology provided funding for a permanent home for the Thin Films Laboratory, enabling researchers to consolidate their equipment, construct several new deposition systems, and expand their studies.

Thin films are widely used as anti-corrosion and wear-resistant coatings and as active components in electronic and electrochemical devices. Thin films are of special interest to HNEI because of their application in solar cells, batteries, thermo-electric transducers, and gas sensors.

HNEI researchers are collaborating with colleagues from other UH departments on thin films projects. Ongoing efforts include the use of thin films for the protection of materials from marine and high-temperature environments, the development of improved thin film electrolytes for sensor and fuel cell applications, and the development of novel oxygen chemical sensors using thin film tetragonal zirconia polycrystals.◀

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Peter R. Ziegler
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Thomas Lo
Nasrin Mohamed
Craig Monden
Milton Oka
Matthew Okubo
Fung Wa Or
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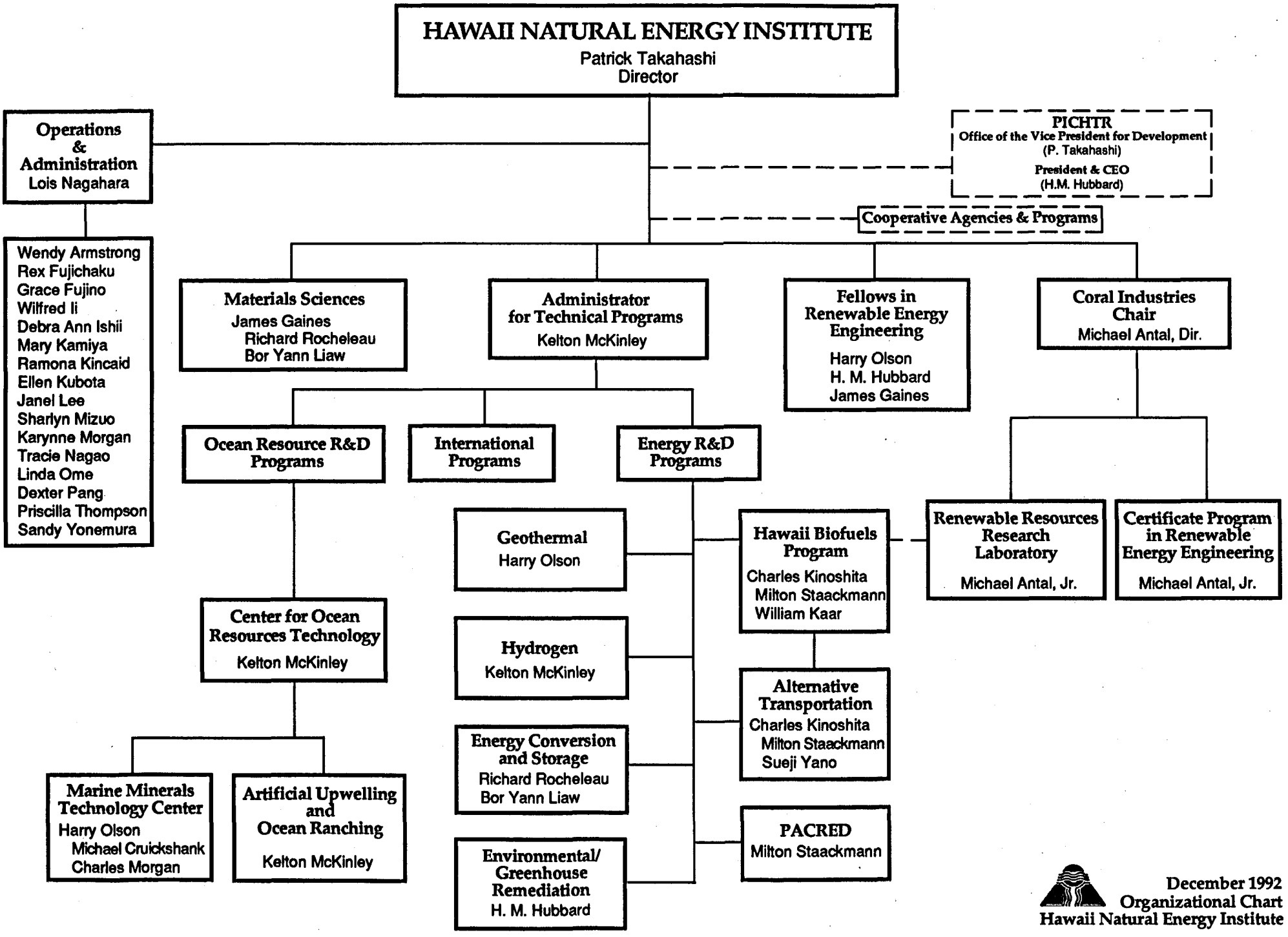
Sheila Taketa
Kimberly Thomas
Leigh Watanabe
David Wilson




December 1992
Organizational Chart
Hawaii Natural Energy Institute

## SEMINARS

***Separation of Ethanol-Water Solution by Supercritical $CO_2$ in the Presence of a Membrane***
Professor Chung-Sung Tan
Department of Chemical Engineering
National Tsing Hua University
August 29, 1991
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***Small Business Innovation Research (SBIR) Program***
William M. Bass
High Technology Development Center
October 18, 1991

***Influence of Ionic Strength on Xylose to Furfural Reaction Rate and Yield***
Chunchang Fang
Furfural Technology Group
QO Chemicals, Inc.
October 22, 1991
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***Chemical Reactions in Thermal Decomposition of Coal***
Dr. Wolfgang Wanzl
DMT-Gesellschaft Für Forschung und Prüfung MBH
October 24, 1991
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***A Short Introductory Course in Carbohydrate Chemistry***
Professor G.N. Richards
Wood Chemistry Laboratory
University of Montana
November 18-22, 1991
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***Direct Liquefaction of Wood: The Effect and Role of Additional Alcohol on Liquefaction***
Tomoko Ogi
National Institute for Resources and Environment
Ministry of International Trade and Industry
December 9, 1991
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***Surprising Supercritical Water From Solvent to Reactant: A Changing View***
Prof. Dr. J.M.L. Penninger
Akzo Salt and Basic Chemicals
Netherlands
December 20, 1991
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***What Nonequilibrium Thermodynamics and Nonlinear Dynamics Tell Us About the Origin of Life***
Professor Richard J. Field
Department of Chemistry
University of Montana
February 7, 1992
Sponsors: Coral Industries Chair of Renewable Energy Resources, HNEI and UH Department of Chemistry

***Patterns in Energy Systems Evolution***
David Sanborn Scott
Institute for Integrated Energy Systems
University of Victoria
February 28, 1992

***Renewable Energy Development in the Pacific***
Dr. John W. Shupe
Pacific Site Office
U.S. Department of Energy
March 20, 1992
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***Production of Polyvinyl Chloride and Polyethylene from Fermentation Ethanol***
Dr. L. Davis Clements
U.S. Department of Agriculture
Cooperative State Research Service
April 3, 1992
Co-sponsor: Coral Industries Chair of Renewable Energy Resources

***Isothermal Flow Calorimetric Investigations of the D/Pd System***
Dr. Michael C.H. McKubre
SRI, International
June 26, 1992

## WORKSHOPS

***Marine Geology Research and Applications Techniques***
August 10-31, 1991

The U.S. Geological Survey and the University of Hawaii's Marine Minerals Technology Center, in cooperation with the United Nations Development Programme, offered a series of workshops on marine geology that would be helpful to maritime countries. Nineteen participants gathered to hear presentations of state-of-the-art techniques and methodologies that are used in the investigation of energy and mineral resources in the oceans.

***Stockpile 2000***
September 1991

Thirty specialists in marine minerals technology, representing government, industry, and academia, gathered to define the technical needs to find and recover strategic and critical minerals from the marine environment. The meeting was funded by the National Science Foundation.

***Engineering Research Needs for Off-Shore Mariculture Systems Workshop***
September 26-28, 1991

The National Science Foundation funded an HNEI workshop to identify the research needs that would be a precursor to successful open-ocean mariculture. Sixty participants from around the world gathered to assess the progress and problems experienced in nations with major mariculture industries, then identified the research required for the U.S. to proceed in these areas.

***22nd Annual Underwater Mining Institute***
September 29 - October 2, 1991

This forum, sponsored by the University of Wisconsin's Sea Grant Institute and hosted by the Marine Minerals Technology Center, provided international leaders from government, industry, and academia in ocean mining, research, and resource management a unique opportunity to discuss the status of and prospects for ocean mining.

***Ocean Resources 2000***
June 9 -11, 1992

The National Science Foundation and the National Oceanic and Atmospheric Administration co-sponsored a planning meeting of 35 top experts from industry, government, and academia, representing the Atlantic, Gulf, and Pacific communities, to discuss and map a strategy for the utilization and management of the nation's ocean resources.

# PUBLICATIONS

**The following publications and reports may be obtained by writing directly to the author in care of:**

**Hawaii Natural Energy Institute**
University of Hawaii
2540 Dole St., Holmes Hall 246
Honolulu, Hawaii 96822

**M.J. Antal, Jr., W.S.L. Mok, P. Szabo, G. Varhegyi, and B. Zelei**
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1992. Uncatalyzed Solvolysis of Whole Biomass Hemicellulose by Hot Compressed Liquid Water. *Ind. Eng. Chem. Res.* 31:1157-1161.

**M.J. Antal, Jr., W.S.L. Mok, and G. Varhegyi**
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**J.E. Bardach, M.A. Champ, and P.K. Takahashi**
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**J.H. Barry**
1991. Problems in Characterization of Sand Deposits in a Carbonate Reef Environment. Presented at Oceans '91, October, Honolulu, Hawaii.

**J.H. Barry**
1991. Characterization of Deep Sand Deposits in the Tropical Reef Environment in Hawaii. In *MTS '91 An Ocean Cooperative: Industry, Government & Academia Proceedings.* 1:579-585. Nov. 10-14, New Orleans, Louisiana.

**G.N. Baturin, T.A. Demidova, E.A. Kontar, and M.J. Cruickshank**
1992. Prediction of Benthic Disturbances from Nodule Mining in Areas of Benthic Currents. In *Proceedings of PACON 92.* Pacific Congress on Marine Science & Technology, June 1-5, Kona, Hawaii.

**R. Bregman and P.K. Takahashi**
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**R. Bregman and P.K. Takahashi**
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**R. Bregman, F. Gerritsen, and P.K. Takahashi**
1991. Redevelopment of Coastal Hawaiian Fishponds for Mariculture. In Proceedings of Oceans '91 Conference, *Ocean Technologies and Opportunities in the Pacific for the 90's,* 1431-1437. Institute of Electrical and Electronics Engineers, October 1991, Honolulu, Hawaii.

**M.J. Cruickshank**
1992. Around the World in Mining News. *Sea Technology* 33(6):79.

**M.J. Cruickshank**
1992. Licensed Companies Lead Few Exploration Activities. *Sea Technology* 33(2):101-102.

**M.J. Cruickshank**
1992. Marine Mineral Resources. Chapter in *Encyclopedia of Earth Systems Science,* ed. William A. Nierenberg, 3:113-123. San Diego: Academic Press.

**M.J. Cruickshank**
Marine Mining. Chapter in the *SME Mining Engineering Handbook,* ed. H.L. Hartman. New York: Society of Mining Engineers.

**M.J. Cruickshank**
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**M.J. Cruickshank**
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**W. Kaar**
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**Y. Mori, S.M. Masutani, G.C. Nihous, L.A. Vega, and C.M. Kinoshita**
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**Inquiries about the following papers should be directed to the author(s) in care of the department listed. Unless otherwise indicated, the address for all departments is: University of Hawaii, Honolulu, Hawaii 96822**

**A.S. Chitrapu and R.C. Ertekin**
1992. Effect of Nonlinear Drag Forces on the Low- and High-Frequency Response of Floating Platforms. In the *Proceedings of the 11th International Conference on Offshore Mechanics and Arctic Engineering*, 1(Part A):97-104.
Department of Ocean Engineering

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Department of Chemistry

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**M. Lee**
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**H. Mahesh**
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Department of Ocean Engineering

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Department of Oceanography

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Department of Oceanography

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Department of Physics & Astronomy

**M. Prasad**
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Marine Minerals Technology Center/ HNEI

**C.M. Staehle, J.E. Noakes, and J. Spaulding**
1991. Survey and Analyses of Deep Water Mineral Deposits Using Nuclear Methods. In *Proceedings of Oceans '91*, 3:1316-1318. October 1-3, Honolulu, Hawaii. Marine Minerals Technology Center/HNEI

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1991. Application of Ferromanganese Marine Minerals Tailings in Concrete and Ceramics. Presented at the Underwater Mining Institute, Sept. 29-Oct. 2, Kahuku, Hawaii.
Department of Oceanography

**J. Wiltshire and G. McMurtry**
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Department of Oceanography

**L. Wisniewski, K. Zilm, M. Mediati, and C.M. Jensen**
1992. Mechanism of the Interconversion of Hydride and Dihydrogen Ligands in $IrH_2Cl(H_2)(PPr^i_3)_2$. Submitted to *J. Am. Chem. Soc.*
Department of Chemistry

## PUBLISHED REPORTS

**The following publications and reports may be obtained by writing directly to HNEI:**

***Hawaii Natural Energy Institute, Hawaii Integrated Biofuels Research Program, Final Subcontract Report, Phase III,*** Published by the National Renewable Energy Laboratory, May 1992

***Hawaii Natural Energy Institute, Hawaii Integrated Biofuels Research Program, Final Subcontract Report, Phase IV,*** Published by the National Renewable Energy Laboratory, (in press)

***National Science Foundation Engineering Research Needs for Off-Shore Mariculture Systems Workshop Proceedings***
G. Hirata, K. McKinley, and A. Fast (editors) Honolulu: Hawaii Natural Energy Institute, University of Hawaii, 1992

***U.S. Ocean Resources 2000: Planning for Development and Management,***
K. McKinley and G. Hirata (editors) Honolulu: Hawaii Natural Energy Institute, University of Hawaii, 1992

| Project | Principal Investigator(s) | Funding Agency | Budget | Expended This Period |
|---|---|---|---|---|
| **OCEAN** | | | | |
| • Development and testing of a wave-driven artificial upwelling device | C. Liu | NSF | $57,083 | $5,079 |
| • Engineering research needs for off-shore mariculture systems | P. Takahashi | NSF | 54,545 | 37,499 |
| • Injection of carbon dioxide in deep ocean water | C. Kinoshita | PICHTR | 167,521 | 92,993 |
| • Integrated ocean resource applications workshop | P. Takahashi | NSF | 20,000 | 0 |
| • Marine Geology Research and Applications Techniques Course | M. Cruickshank | tuition collected. | | |
| • Marine Minerals Technology Center, Ocean Basins Division Contract #G1105128 | H. Olson | BOM/UM | 555,357 | 225,466 |
| Program administration | H. Olson | | | |
| Development of a free-fall seafloor hard substrate corer | J. Toth | | | |
| Quantitative determination of seabed microtopography | C. Morgan | | | |
| Computer-aided design methodology for power, communication and strength umbilicals | R. Knapp | | | |
| Sand for Hawaiian beaches: phase II and III study | F. Gerritsen/H. Krock/M. Cruickshank | | | |
| Maximizing the returns from 20 years of deep seabed minerals exploration | C. Morgan | | | |
| A detailed analysis of the origin and distribution of platinum in manganese crusts | J. Wiltshire | | | |
| Chracterization of a cobalt-rich crust deposit in the Johnston Island exclusive economic zone | A. Malahoff | | | |
| MMTC/OBD support of the development of a deep seabed gamma ray detector | M. Cruickshank | | | |
| • Marine Minerals Technology Center, Ocean Basins Division Contract #G1115128 | H. Olson | BOM/UM | 579,069 | 126,075 |
| Program administration | H. Olson | | | |
| Development of a free-fall seafloor hard substrate corer | J. Toth | | | |
| Quantitative determination of seabed microtopography | C. Morgan | | | |
| Sand for Hawaiian beaches: phase II and III study | F. Gerritsen/H. Krock | | | |
| Maximizing the returns from twenty years of deep seabed minerals exploration | C. Morgan | | | |
| • Rapid reconnaissance sampling of hard mineral deposits on the seabed | M. Cruickshank | NSF | 99,985 | 35,215 |
| • Stockpile 2000: Marine alternative for domestic reserves of critical minerals | M. Cruickshank | NSF | 40,027 | 35,509 |
| • 22nd Underwater Mining Institute | M. Cruickshank | tuition fees | | |

| Project | Principal Investigator(s) | Funding Agency | Budget | Expended This Period |
|---|---|---|---|---|
| **BIOMASS** | | | | |
| • Acid-catalyzed formation of ethyl-butyl ethers in near- and supercritical water | M. Antal | NSF | $78,820 | $42,556 |
| • Catalytic dehydration of carbohydrates in near and supercritical water | M. Antal | NSF | 151,444 | 151,444 |
| • Charcoal reactor modifications to accept natural gas as a heat source | M. Antal | OTTED | 12,500 | 4,049 |
| • Fundamental studies of charcoal formation from biomass at elevated pressures in a stagnant gas environment | M. Antal | NSF | 29,799 | 10,481 |
| • Hawaii biomass gasifier scaleup | C. Kinoshita | PICHTR | 394,345 | 8,317 |
| • Hawaii Integrated Biofuels Research Program, Phase IV<br>Task 1A: Biomass Sites<br>Task 1B: Economic Analysis<br>Task 2A: Isozyme Research<br>Task 2B: Nitrogen-Fixing Trees<br>Task 3A: Pyrolytic Gasification<br>Task 3B: Parametric Testing<br>Task 3C: Wastewater Engineering<br>Project Management | P. Takahashi<br>V. Phillips<br>V. Phillips<br>V. Phillips<br>J. Brewbaker<br>M. Antal<br>C. Kinoshita<br>P.Y. Yang<br>V. Phillips | NREL | 340,000 | 245,087 |
| • Hawaii Integrated Biofuels Research Program, Phase V<br>Task 1A: Biomass Economics<br>Task 1B: Inventory of RD&D Activity<br>Task 2A: Genetic Characterization<br>Task 2B: Nitrogen-Fixing Trees<br>Task 2C: DFSS Establishment<br>Task 2D: Macroalgal Culture<br>Task 3A: Solvolytic Pretreatment<br>Task 3B: Pyrolytic Gasification<br>Task 3C: Catalytic Gasification<br>Task 3D: Dilute Biomass Engineering<br>Task 3E: Pretreatment for Ethanol<br>Project Management | C. Kinoshita<br>D. Singh<br>M. Staackmann<br>V. Phillips<br>J. Brewbaker<br>H. Hubbard<br>K. McKinley<br>M. Antal<br>M. Antal<br>C. Kinoshita<br>P. Yang<br>W. Kaar/K. McKinley<br>C. Kinoshita | NREL | 654,891 | 135,351 |
| • Investigation of steam explosion technology | C. Kinoshita | OTTED | 130,000 | 47,758 |
| • Methanol pilot plant | P. Takahashi | DBEDT | 2,000,000 | 2,000,000 |
| • Study of acid catalyzed dehydration of fermentation products in supercritical water | M. Antal | NREL | 135,000 | 69,546 |
| • Survey of land-use, agricultural, and biomass resource recovery and energy conservation in the Pacific Rim | C. Kinoshita | NREL | 14,916 | 14,345 |
| • Systems survey of pressurized feeding of biomass | C. Kinoshita | Winrock | 29,960 | 16,215 |
| • Thermogravimetric studies of charcoal formation from biomass at elevated pressure | M. Antal | NATO | 8,516 | 8,499 |

| | Principal Investigator(s) | Funding Agency | Budget | Expended This Period |
|---|---|---|---|---|
| **HYDROGEN** | | | | |
| • Energy storage conversion in solid hydrogen | J. Gaines | AFSOR | $471,904 | $74,342 |
| • Hydrogen Energy with Renewables | P. Takahashi | PICHTR | 9,227 | 4,762 |
| • Hydrogen from Renewable Resources Research, Phase III (modification) | P. Takahashi | NREL | 389,000 | 162,775 |
| Task 1A: PEC Materials | W. Pong | | | |
| Task 1B: PEC Stability | S. Sharma | | | |
| Task 1C: PEC Impedance | B. Liebert | | | |
| Task 1D: PEC Fabrication | R. Rocheleau | | | |
| Task 2A: Cyanobacteria | S. Patil/E. Bylina | | | |
| Task 2B: Cyano Strain | K. McKinley | | | |
| Task 3: Polyhydrides | C. Jensen | | | |
| Management | K. McKinley | | | |
| • Hydrogen from Renewable Resources Research, Phase V (modification) | K. McKinley | NREL | 251,999 | 54,759 |
| Task 1: Partial Oxidation of Biomass in SC Water | K. McKinley | | | |
| Task 2A: Cyanobacterial Production, Part A | E. Bylina | | | |
| Task 2B: Cyanobacterial Production, Part B | K. McKinley | | | |
| Task 3A: Nonclassical Polyhydrides, Part A | C. Jensen | | | |
| Task 3B: Nonclassical Polyhydrides, Part B | K. McKinley | | | |
| Task 4: Photoelectrochemistry | R. Rocheleau | | | |
| • Hydrogen-OTEC project | P. Takahashi | PICHTR | 15,213 | 15,097 |
| • Studies of the thermal and optical response of H atoms in solid hydrogen | J. Gaines | NASA | 275,000 | 92,407 |
| **ALTERNATIVE TRANSPORTATION** | | | | |
| • Alcohol transportation fuels demonstration program | C. Kinoshita | USDOE | 299,995 | 100,809 |
| • State or local government demonstration of electric and hybrid vehicles | P. Takahashi | USDOE | 577,706 | 14,847 |
| • Variable speed pumped hydro demonstration with series resonant converter | P. Takahashi | USDOE BPA | 164,931 | 20,753 |
| **GEOTHERMAL** | | | | |
| • Agreement for drilling support services for PICHTR Downhole Coaxial Heat Exchanger experiment | P. Takahashi | PICHTR | 50,000 | 48,309 |
| • Agreement for HGP-A well workover | H. Olson | NELH | 60,000 | 48,199 |
| • Geothermal reservoir assessment based on slim hole drilling | H. Olson | EPRI | 400,000 | 71,956 |

| Project | Principal Investigator(s) | Funding Agency | Budget | Expended This Period |
|---|---|---|---|---|
| **GEOTHERMAL , continued** | | | | |
| • Optioning geothermal resources - the slim hole project | H. Olson | Bonneville USDOE | $148,320 | $7,009 |
| • Scientific observation hole | H. Olson | DBEDT | 250,000 | 3,978 |
| • Scientific observation hole program - geothermal resource development, Hawaii | H. Olson | DBEDT | 5,601,000 | 511,040 |
| **OTHER** | | | | |
| • Cold fusion | B.Y. Liaw | T. Chubb | 2,000 | 0 |
| • Demonstration of a pumped hydro facility at the HNEI/Kahua Wind Energy Storage Test facility | P. Takahashi | DBEDT | 267,000 | 22,600 |
| • ESCA study of refractory concrete samples | W. Pong | Dept. of the Navy | 5,000 | 4,699 |
| • Mechanistic study on catalytic behavior on rare-earth intermetallics | B.Y. Liaw | URC | 6,000 | 2,000 |
| • Molten salt techniques for reproducible excess heat | B.Y. Liaw | ONR | 25,000 | 1,184 |
| • Pacific area cooperative renewable energy development program | P. Takahashi | DBEDT | 258,000 | 110,376 |
| Develop strategies and implement them | G. Hirata | | | |
| Establish Hawaii as the Pacific solar tech transfer station | M. Staackmann | | | |
| Initiate the PREMIER program | J. Woodruff | | | |
| Gain cooperative involvement | M. Staackmann | | | |
| Begin implementation of economic devlopment programs | P. Takahashi | | | |
| • Polymer liquid crystals and polymer/liquid crystal composites | P. Crooker | RCUH | 23,830 | 23,600 |
| • Reproducible excess heat generation | B.Y. Liaw | Fusion Resources, Inc. | 25,542 | 22,745 |
| • Review and evaluation of selected renewable energy resource assessments in Hawaii | R. Rocheleau | R. Lynette & Assoc. | 16,022 | 14,942 |
| • Residential PV demonstration project termination | P. Takahashi | MIT | 12,000 | 5,732 |
| • Virtual instrument library | B.Y. Liaw | OTTED | 64,929 | 15,005 |