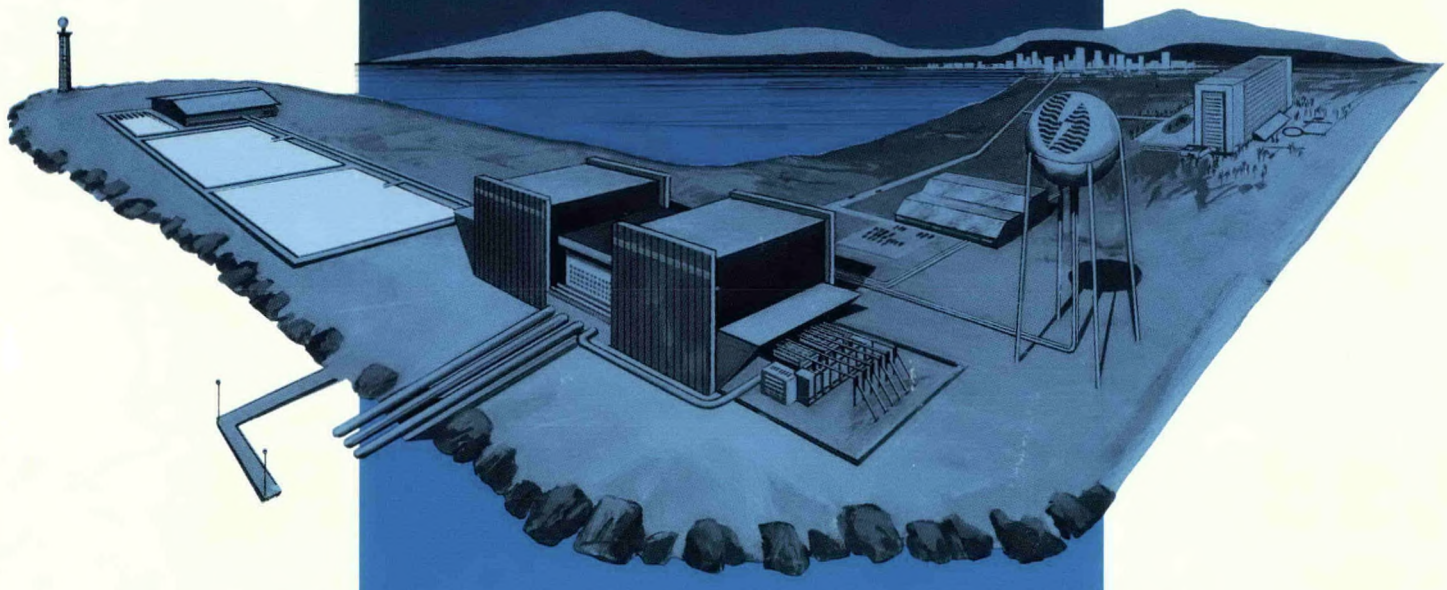
Federal Ocean Energy Technology



Program Summary for Fiscal Years 1984 and 1985

Prepared for:
U.S. Department of Energy
Wind/Ocean Technologies Division
Solar Electric Technologies
Assistant Secretary, Conservation and Renewable Energy
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Program Summary for Fiscal Years 1984 and 1985

September 1986

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Table of Contents

Introduction

Technology Development

The oceans are the world's largest solar energy collector and storage system. For centuries, human beings have harnessed part of this energy — in the form of winds and currents — for transportation. Today, the Department of Energy's (DOE) Ocean Energy Technology Program (OET) is looking for cost-effective ways to harness ocean energy to help power tomorrow's world. Federally sponsored researchers are studying methods to transform the solar heat stored in the ocean's surface waters into electricity as well as new ways to convert wave energy into mechanical energy or electricity.

Ocean Thermal Energy Converson (OTEC), the most promising of the ocean energy technologies, takes advantage of the temperature difference between warm surface water (25° - 27° C) and deep, cold water (5° C) in the tropics. This difference, as French physicist Arsene d'Arsonval first suggested in 1881, can be used to generate electricity — in a process that is essentially the reverse of a household refrigerator cycle.

D'Arsonval proposed a closed-cycle conversion system: Warm seawater, flowing around a heat exchanger, boils a working fluid, such as ammonia or Freon, which then drives electric turbines. A second heat exchanger, using cool, deep ocean water, recondenses the working fluid, which then recycles through the system.

The first OTEC experiments, however, tested an open-cycle OTEC system — so-called because it uses seawater directly as a non-recycled working fluid. French inventor Georges Claude — well-known for his invention of the neon lighting sign — demonstrated this new concept in Cuba in 1930. He showed that flash evaporating seawater in a low-pressure tank creates sufficient steam to drive turbines, producing electricity. In such open-cycle systems, the steam can be condensed by direct contact with cold seawater or indirectly to produce desalinated water.

In spite of Claude's success with the Cuban experiment, OTEC development has progressed slowly. Although a French team designed a 3 MW_e OTEC open-cycle plant for Abidjan, off the Ivory Coast of Africa in 1956, difficulties deploying a cold-water pipe in combination with competition from inexpensive hydropower kept the plant from being built. For a time, OTEC technology remained economically uncompetitive with conventionally generated electricity. This was due both to the high cost of plant construction and the availability of less expensive fossil-fuel generated electricity.

During the 1970s, however, impending worldwide energy shortages spurred a renewed interest in ocean thermal energy. A number of countries, including France, Japan, and the United States, began serious efforts to develop this technology. The Federal Ocean Energy Systems Program, initiated by the National Science Foundation in 1972, sought to develop reliable, cost-effective methods to transform significant amounts of ocean energy into electricity. To this end, the Program spent more than $200 million from 1975 to 1985 on OTEC research. In addition, it began modest studies in the mid-1970s to determine whether ocean waves, ocean currents, or salinity gradients could also be used to generate electricity. None of these technologies has shown the commercial potential envisioned for OTEC, however.

In 1979, Lockheed and the State of Hawaii, with assistance from the Dillingham Corporation, built the first closed-cycle OTEC demonstration plant, called Mini-OTEC, which generated 15 kWe net power. Japan followed with a larger-scale (32 kWe net) demonstration that operated intermittently on the island of Nauru during 1981. The same year OTEC-1, a floating, closed-cycle OTEC experiment on a modified Navy tanker, investigated 1-MW_e sized heat exchangers, OTEC's environmental impacts, and problems with biofouling, the films produced by microorganisms growing on metal surfaces in seawater.

Two laws passed in 1980 promote the commercial development of OTEC technology. The Ocean Thermal Energy Conversion Act (PL 96-320, modified by PL 98-623), established licensing procedures and authorized loan guarantees for OTEC facilities. The Ocean Thermal Energy Conversion Research, Development, and Demonstration Act (PL-310) authorized a comprehensive program to facilitate the early deployment of OTEC power plants. The law set goals for the installed capacity for OTEC systems, beginning with 100 MW_e by 1986 and reaching 10 GW_e by 1999.

Since these laws were enacted, however, fossil fuel prices, which had skyrocketed during the 1970s, stabilized and eventually declined. In 1981, in response to this changing economic environment, a new administration directed the U.S. Department of Energy (DOE), which had taken over the Ocean Energy Program in 1977, to shift the Program's emphasis to the high-risk, high-payoff research and development that private industry would be unlikely to pursue. With this expanded technology base, it is presumed that the commercial sector

could then make competent assessments of whether the concept would provide viable energy conversion alternatives, or supplements, to systems presently in use.

Under a new, and more modestly funded Federal Ocean Energy Program, scientists continued to make important strides in developing both closed- and open-cycle OTEC systems — strides that may make it possible for ocean energy systems to enter tropical island markets during the 1990s. During FY 1984, Ocean Thermal Corporation, in a project cost-shared with DOE and in association with the state of Hawaii and the Hawaiian Electric Company, completed the preliminary design, financial plan, and environmental description report for a 40 MW_e, closed-cycle OTEC pilot plant for Oahu, Hawaii. Plentiful oil supplies and falling oil prices have delayed construction of this plant for the time being, however.

DOE and the State of Hawaii have also begun efforts to upgrade the Seacoast Test Facility at the Natural Energy Laboratory of Hawaii, located on the Kona Coast of the Big Island of Hawaii. The major goal of the upgrade is to install a new cold-water pipe to support larger OTEC experiments. During FY 85-86, Hawaii completed the preliminary design and cost estimates for the project, which will be completed in FY 1987. Once the new pipe is installed, DOE will begin the design, construction, and testing of a series of scaled open-cycle OTEC experiments designed to test the feasibility of the open-cycle concept.

Economic analyses suggest that open-cycle OTEC systems in the range of 5 to 15 MW could be competitive with conventional power generation in tropical island markets if electricity were produced in conjunction with the production of desalinated water, often a scarce commodity in these locations. Other OTEC spin-offs, including using cold-water effluents for refrigeration or air-conditioning, could also enhance OTEC's economic prospects in the near future while oil prices remain low.

However, the central thrust of the Federal Ocean Energy Program is to develop OTEC technology to the point where industry can engineer reliable, cost-effective power plants that can compete with other conventional and renewable technologies in tomorrow's energy marketplace. Parallel efforts continue to address both closed- and open-cycle OTEC systems, taking full advantage of the technical commonality that exists between the two.

This Program Summary reviews research and development for OTEC sponsored by the United States Department of Energy during fiscal years 1984 and 1985.

Federal Ocean Energy Program

History of the Program

Ocean Thermal Energy Conversion (OTEC) was one of six solar technologies in the original U.S. solar energy program, which began under the sponsorship of the National Science Foundation in 1972. The Federal Ocean Energy Systems Program — as the Ocean Energy Technology Program was known until 1981 — was transferred to the Energy Research and Development Administration (ERDA) in 1975 and to the newly created Department of Energy (DOE) in 1977. Ocean energy research was part of a national strategy to reduce U.S. dependence on oil imports.

During the 1970s, the Federal Ocean Energy Program envisioned a significant role for OTEC in the U.S. energy economy, setting goals that would have culminated in an electrical power-production capability of 20 GW_e by the year 2000. Scores of OTEC power plants, with capacities ranging from 100 to 1000 MW, were to be deployed in the Gulf of Mexico off the coast of the United States as well as near tropical island communities around the world. Fueled by a nearly limitless supply of solar energy, these enormous OTEC facilities would transmit electricity via cable to shore-based utility grids or use the electricity on-site for such energy-intensive chemical process applications as ammonia or methanol production.

The Program began a comprehensive effort to bring this vision to reality. On the technical side, the development of closed-cycle OTEC became a top priority as analysts and planners decided that this technology showed the greatest potential for achieving the rapid breakthrough needed for such ambitious performance goals. (Open-cycle OTEC was also evaluated, but only for second-generation applications.) The Program undertook to develop critical components technologies and system materials for closed-cycle OTEC as well as to evaluate the legal, social, and environmental impacts of large OTEC facilities. In addition, it sought to demonstrate the economic viability of OTEC systems and assess their potential markets.

As the OTEC R&D effort progressed during the mid-1970s, the Federal Program began looking at whether ocean waves, ocean currents, or salinity gradients could also be used to generate electricity. The Program placed most of this new emphasis on a wave energy systems study, which yielded an experimental 125 kW_e pneumatic wave energy conversion turbine by the early 1980s.

Ocean energy research efforts led to other important accomplishments in the late 1970s and early 1980s. At-sea testing with Mini-OTEC (in 1979) and OTEC-1 (in 1981) demonstrated the technical feasibility of closed-cycle OTEC systems and provided data on heat exchanger thermohydraulics, environmental impacts, cold-water pipe deployment, and systems operations. These studies also indicated, however, that the technical and economic barriers to OTEC commercialization were far more significant than anticipated.

At the same time, the world's energy supply and the U.S. political climate were changing. In 1981, DOE's mission changed from directly promoting the commercialization of ocean energy technologies to supporting the high-risk, potentially high-payoff research that industry would be unlikely to pursue. The Department developed a new program strategy that focused on the technical uncertainties associated with near-shore OTEC systems in the range of 5 to 15 MW_e. This strategy has had the advantage that engineering experiments and cold-water pipe R&D can be undertaken at acceptable costs for both closed-cycle and open-cycle plants in this size range. The Program also continued limited research on such selected alternatives to ocean thermal energy conversion as wave energy.

Since OTEC plants in the 5 to 15 MW_e range are the ideal size to enter tropical island utility markets, private interest in this technology should increase as technical problems are solved. Whether industry actually undertakes the commercialization of OTEC, however, depends on whether energy costs for this technology can compete with those of conventional systems. This, in turn, depends on energy economics, technical advances, and geographic location.

OTEC's first commercial markets are expected to open in such tropical islands as Hawaii and Puerto Rico. Tropical areas not only depend on relatively expensive imported oil for their electricity, but also contain the best ocean thermal resources. As a result, DOE is currently selecting research activities that will help meet the Department's goal of attaining a cost-of-service for OTEC comparable to the cost of oil-fired power in entry island markets by 1989 and comparable to coal-fired baseload power in selected mainland markets by the late 1990s.

Projections of energy costs in tropical island areas and in the Gulf and Atlantic coastal areas on the U.S. mainland indicate that OTEC plant costs of \$7200/kW_e and \$3200/kW_e, respectively, must be achieved before

OTEC is cost-competitive with conventional energy sources. Operating and maintenance (O&M) costs are also important in such calculations since low O&M cost allows higher-priced facilities to be attractive.

Several factors may contribute to low operating costs for OTEC systems. There are no fuel costs and ocean energy systems are simple enough to lend themselves to low-cost automation. Although maintenance costs may be somewhat higher, due to the humid, corrosive, and sometimes stormy marine environment, the major economic hurdle for OTEC remains plant capital costs, in particular, the cold-water pipe and heat exchangers.

A number of recent discoveries may enhance the economic prospects for both open- and closed-cycle OTEC systems. These include

- Researchers have determined that plentiful and relatively inexpensive aluminum alloy can be used in lieu of the more expensive titanium for making heat exchangers.
- Biofouling appears not to be a problem in cold seawater systems and can be controlled with intermittent chlorination in warm seawater systems.
- Scientists are developing cost-effective evaporators and condensers for open-cycle OTEC systems.

In summary, the Federal Ocean Energy Technology Program has made significant advances in both closed- and open-cycle OTEC systems as well as important progress in the development of a pneumatic wave energy conversion turbine. The effort now underway will develop OTEC systems to the point where industry can assess whether OTEC is a viable renewable energy alternative, or supplement, to systems presently in use. The Program hopes to resolve the major technical issues of OTEC technology by 1989 and define or reduce major risks associated with the deployment and operation of OTEC plants designed for island energy economies.

Current Research Focus

Presently, the Federal Ocean Energy Technology (OET) Program focuses primarily on developing land-based or near-shore OTEC systems ranging in size from 5 to 15 MW_e. Researchers are looking at ways to make both the closed- and open-cycle OTEC systems work more efficiently — by designing smaller plants that produce more power, use smaller volumes of water, and incorporate less expensive materials and components. As this work progresses, the Program increasingly emphasizes laboratory and field testing of vital system components.

The Program is also defining cold-water pipe technology to provide industry with a base from which it can evaluate promising applications for a range of OTEC plant sizes. Industry needs information on materials, design, deployment, and installation before it can project whether current pipe technology can be scaled up for commercial installations.

The Program's increasing involvement with representatives of the private sector interested in OTEC development is not restricted to cold-water pipe technology. Since 1981, the OET program has sought university and industry participation in many aspects of ocean energy research and development. As a result, industry now assists the Program in identifying research tasks needed to resolve current OTEC issues, in assessing progress, and in recommending future directions for government research.

Although it heavily emphasizes the development of OTEC systems, current ocean energy research goes beyond engineering OTEC systems. Efforts are underway to understand OTEC design impacts on the ocean itself, including the temperature gradients that drive the process. Researchers are also studying such environmental issues as OTEC's effect on marine ecosystems. Finally, drawing from the growing experience with OTEC and from preliminary studies of other ocean energy technologies, the Program continues to identify and evaluate advanced concepts for ocean energy extraction and conversion.

The FY 1984 and 1985 Program focused on closed- and open-cycle OTEC systems as well as on technologies common to both options. Researchers studying large cold-water pipes completed shallow-water and at-sea testing of a 70-ft long section of an 8-ft diameter fiberglass reinforced plastic (FRP) cold-water pipe near Keahole Point, Hawaii. Other OET scientists completed preliminary design, cost estimate, and environmental studies for the planned Seacoast Test Facility Upgrade Project. Highlights of DOE's closed-cycle studies included developing a PC-based OTEC plant model for cost and performance calculations, proving that intermittent chlorination of 50 to 100 ppb for I hour each day controls biofouling in warm seawater, and completing seawater tests on smooth aluminum materials, which can be extrapolated to 10-15 year service

lifetimes. For open-cycle OTEC, researchers built and tested single-stage evaporators and condensers and developed mathematical models to study these components.

Program Organization and Responsibilities

The DOE Headquarters Wind/Ocean Technologies Division manages the Ocean Energy Technology Program. The Division, part of DOE's Office of Solar Electric Technologies, ensures that research sponsored by the Program is consistent with national energy research policies and allocates technical and budgetary resources for Program activities. The Division also sets operating policy for its two field research centers, The Solar Energy Research Institute (SERI) in Golden, Colorado, and Argonne National Laboratory (ANL) in Argonne, Illinois. The centers are responsible for day-to-day management and research activities. These research activities are outlined in Table 1.

Table 1
Ocean Energy Technology Program Research Centers

Research Center	Technical Responsibilities
Solar Energy Research Institute (SERI)	Claude Cycle Mist-Lift Cycle Advanced Turbines Oceanographic/Seabed Assessments Environmental/Legal Compliance Wave Energy Conversion OTEC Systems Analysis/Integration Alternate OTEC Power Cycles Ocean Engineering
Argonne National Laboratory (ANL)	Advanced Heat Exchanger Development Heat Exchanger Materials Research Advanced Heat Exchanger Fabrication OTEC Systems Analysis/Integration Alternate OTEC Power Cycles

Program Elements and Highlights for Fiscal Years 1984 and 1985

During FY 1984 and 1985, the Federal Ocean Energy Technology Program focused primarily on the technical uncertainties associated with near-shore OTEC systems in the range of 5 to 15 MW_e. These efforts attacked a variety of technical problems whose resolution is crucial to demonstrating the viability of OTEC technology. To spur continued technical advances and enhance opportunities for ocean technology transfer to industry, the Program was restructured into four research elements: (1) Thermodynamic Research and Analysis, (2) Experimental Verification and Testing, (3) Materials and Structural Research, and (4) Oceanographic, Environmental, and Geotechnical Research.

Thermodynamic Research and Analysis. A key thermodynamic research effort during FY 1984 and 1985 pushed the development of high performance evaporators and condensers for open-cycle OTEC systems. Advanced evaporators and condensers are the key to bringing costs for this technology to the point where it can compete with conventionally generated electricity in selected markets. During the past two years, researchers at the Solar Energy Research Institute (SERI) refined and tested their vertical spout evaporator, which *Industrial Research and Development* named as one of 1984's 100 most significant achievements. The evaporator increased the heat transferred in a given evaporator chamber by more than 70 times over the best commercial design. SERI began similar efforts to develop a new, efficient direct-contact condenser in 1985.

In addition to designing and testing these critical components, researchers developed and refined computer models to predict how efficiently these devices work singly and in combination with other system components. Systems analysis, using the Systems Analysis Language Translator (SALT) developed by Argonne National Laboratory, was employed to give the Program a clearer idea of the impacts of component

improvements on the performance and economics of the OTEC system. Along with experimental component studies, these results suggest that the new direct-contact exchangers will show an order-of-magnitude improvement over conventional devices.

Turbine rotors, another key component for open-cycle systems, received somewhat less attention during FY 84-85. However, researchers confirmed that turbines represent a significant portion of an open-cycle system's technical uncertainty and cost. Several factors are responsible for this. OTEC produces low-temperature, low-pressure steam that necessitates unusually large turbines, which may be subject to large, as yet undefined stresses. In addition, seawater droplets carried in the steam could affect turbine performance as well as contribute to corrosion problems. Program researchers hope to develop a turbine design that addresses these issues, test a prototype, and evaluate the long-term potential for advanced turbines by mid-1988.

Although open-cycle component and system research was the focus of the Thermodynamic Research and Analysis element during 1984 and 1985, this element also sponsored efforts to explore alternate OTEC power cycles. Researchers began efforts to improve closed-cycle OTEC system performance by using systems analysis to evaluate proposed improvements, including those which integrate both closed- and open-cycle concepts. In other efforts, scientists began the task of evaluating the feasibility of "mist-lift" OTEC systems, in which seawater is lifted in a two-phase fluid flow process. Steam generated in the evaporator entrains seawater droplets that are lifted against gravity to the condenser where the condensed steam droplets and entrained seawater are collected and provide a hydraulic head for a conventional hydroelectric turbine.

Experimental Verification and Testing. This element, whose activities range from component evaluation to research on innovative subsystems, determines how components or systems perform once they are built. By providing experimental verification of the predictions made by computer models, this element complements the thermodynamic research and analysis element discussed above. During 1984 and 1985, for example, SERI researchers used fresh water to study the vertical spout evaporator and the direct contact condenser. The results, which will be compared with similar seawater tests in the future, will assist engineers in understanding practical difficulties associated with building these components, in scaling up component designs, and in improving their analytical models.

Taken together, 1984-1985 experimental and analytical studies indicated that open-cycle OTEC is a promising alternative to the closed-cycle option. Consequently, researchers launched efforts in 1985 to design, build, and test a series of scaled open-cycle experiments at the Seacoast Test Facility at the Natural Energy Laboratory of Hawaii.

In related efforts, other scientists investigated new ideas for cold-water pipe conduits, joints, and methods of installation and deployment. As part of this project, they fabricated 8-ft diameter pipe segments that were tested in shallow water in Hawaii. In 1985, they also designed a set of scale-model tests that will allow them to assess various pipe design concepts.

Scale-model testing was also used in 1985 to evaluate a new tandem flap wave energy conversion device, developed as part of the Program's efforts to identify promising long-range ocean energy technologies. In addition, a pneumatic wave energy conversion system (PWECS) was tested as part of the International Energy Agency's wave energy program on the barge *Kaimei* in the Sea of Japan.

Materials and Structural Research. Research within this element has sought to discover the lowest-cost, highest performance materials for OTEC systems components. Activities range from materials analysis of cold-water pipes and heat exchangers to structural analysis of platform materials.

One of the major technical uncertainties in a 5-15 MW_e OTEC system is the cold-water pipe, which will be approximately 10-ft in diameter. The pipe, which will draw cold water from depths up to 1000 m, will be inaccessible for maintenance and repair once it is deployed. Hence, pipe materials must be understood as well as possible so that engineers can make accurate estimates of the pipe's functional lifetime. In 1985, the Program continued to identify and develop cold-water pipe design methods and analytical tools, construction materials, and deployment techniques. Materials testing should be completed in 1986.

In addition to pipe-materials research, the Materials and Structural Research element includes studies to find new materials for heat exchangers. Since 1981, the Seacoast Test Facility has been evaluating relatively inexpensive aluminum alloys, whose use in heat exchangers could result in a significant cost reduction for the system. Recent test results suggest that these materials would be an acceptable substitute for the expensive material titanium, used in earlier prototypes.

Oceanographic, Environmental, and Geotechnical Research. This element's objective is to foster a better understanding of the ocean environment, its impact on OTEC systems, and the impact of OTEC on the oceans. Oceanographic research seeks this knowledge through coastal zone interaction modelling and direct experiments to determine specific chemical and biological impacts within the water column. The environmental activity is responsible for determining whether a specific OTEC system complies with federal and local regulations governing its environmental impacts. Geotechnical research is responsible for characterizing the seafloor on steep slopes, and other near-shore areas as they relate to OTEC. Its findings will influence both cold-water pipe and platform foundation designs.

During FY 1984 and 1985, scientists made important strides in oceanographic, environmental, and geotechnical research. They analyzed and catalogued geotechnical data and methods for core sampling in seabed steep-slope areas; they developed a physical model of an OTEC mixed discharge outflow and used it to validate methods to analyze discharge plumes; they analyzed the potential environmental impacts of shore-based open-cycle OTEC plants; and they analyzed the redistribution of trace metals using biochemical methods.

Accomplishments by Field Laboratories in Fiscal Years 1984 and 1985

Argonne National Laboratory

- Developed and verified correlations for heat transfer and friction for waterside enhancements of heat exchangers. This will permit better predictions for the performance of heat exchangers using such enhancements.
- Demonstrated that intermittent, low-level chlorination is an effective biofouling control technique for enhanced waterside surfaces in OTEC heat exchangers.
- Obtained corrosion data to confirm that aluminum will be suitable for use in OTEC heat exchangers.
- Developed a design for a brazed-aluminum, baseline heat exchanger that is more cost-effective than earlier designs for OTEC.
- Developed and refined a computerized model, Systems Analysis Language Translator (SALT), for performance prediction and component integration of closed-cycle OTEC systems.
- Conducted a theoretical analysis for the open cycle surface condenser and developed a conceptual design for a full-scale condenser and a small-scale test unit.

Energy Technology Engineering Center (ETEC)*

- Instrumented and deployed an 8-ft diameter, 70-ft long fiberglass reinforced plastic (FRP) cold-water test pipe on a 40-degree slope off Keahole Point, Hawaii. Researchers used the test pipe to gather data to validate an analytical model predicting environmental loads.
- Initiated a comprehensive study to determine the feasibility of using a tunnel or large diameter drilling shaft as a conduit for transporting cold water from the deep ocean to shore-based plants.

Solar Energy Research Institute

- Showed that small OTEC plants (5-15 MW_e) that provide desalinated water and electricity have the potential to be cost-effective for tropical island applications.
- Verified, experimentally, that evaporators with a 3-ft head loss operate with 95 percent effectiveness.
- Received a patent and an IR-100 Award for the vertical spout evaporator.
- Investigated passive deaeration for OTEC system water intake with sorption kinetics experiments using seawater.
- Developed an analytical model that describes the performance of direct-contact condensers in the presence of significant fractions of noncondensible gases. The model was used to define condenser designs that can condense up to 98 percent of the steam entering them.
- In conjunction with an International Energy Agency (IEA) experiment, installed and operated a pneumatic wave energy conversion system (PWECS) experiment at sea on the *Kaimei* test barge.

*DOE phased out ETEC as an ocean energy field laboratory in 1985.

Future Program

The Federal Ocean Energy Technology Program plans to focus its future research on OTEC power and seawater subsystems. These two subsystems offer the most potential for performance improvement and cost reductions. Resolving the technical uncertainties is likely to lead to further cost reductions in the third subsystem, building and structures.

Parallel research activities in both closed- and open-cycle systems will address power conversion technology. These efforts will focus on system performance and lower-cost material analysis. The cold-water pipe will be the major research focus in seawater systems. Researchers expect to lower the cost of pipe by reducing water flow requirements and using low-cost construction materials and innovative design approaches. This research will be applicable to both the closed-cycle and open-cycle options.

The series of scaled open-cycle experiments currently being designed for the Seacoast Test Facility in Hawaii is expected to provide invaluable information by the end of the decade for determining the commercial potential of open-cycle OTEC. In theory, open-cycle technology should show both cost and performance advantages from eliminating conventional heat exchangers from the cycle. The Hawaii experiment will demonstrate whether this is true as well as determine whether open-cycle OTEC can generate net electrical power. Researchers also hope to gather valuable data on seawater flows and component behavior in a tightly coupled system. They plan to study and define the crucial turbine technology, too, with an eye to reducing power system costs. The next five years may be crucial in proving open-cycle OTEC's feasibility.

In contrast to open-cycle, the closed-cycle power system option is already close to implementation by the private sector. The preliminary design for a 40 MW_e pilot plant to be located off Kahe Point on Oahu, completed by Ocean Thermal Corporation, is evidence that commercialization can proceed once financial support becomes available. This design, which employs conservative design and equipment choices, represents a point of departure for government-sponsored research, which aims to provide the technological base for the evolution of advanced generation, low-cost closed-cycle power plants.

In the future, closed-cycle research will focus on improving heat exchanger performance and increasing the life expectancy of system materials. The next generation of heat exchangers will likely be made of aluminum alloy, an inexpensive construction material, and incorporate advanced waterside heat-transfer enhancements, which make possible more compact heat exchangers. In addition, these improvements should reduce the amount of cold water needed, allowing for a smaller, less expensive cold-water pipe. The result should be increased plant output and lower costs.

Similarly, government-sponsored research in all areas of ocean energy research will continue to focus both on technical improvements and cost-effectiveness. Top priority will be given to those research projects that offer the greatest potential for reducing the cost-of-service for electrical energy.

Thermodynamic Research and Analysis

Researchers plan to continue developing and testing open-cycle evaporators and condensers. A key task will be to develop condensers with low vapor and liquid-side pressure losses. By the end of 1987, they hope to attain new methods for advanced component design and performance analysis. These methods can in turn be used to make better system components.

In the future, the Program will step up its efforts to develop advanced open-cycle turbine rotors as well. The evaluation of advanced turbine rotor concepts will concentrate on those areas in which this technology deviates from established industrial practice. These include analyzing stresses in large turbine blades, modelling of steam distribution and flow, and studying the effect of seawater on blade corrosion and degradation. By mid-1988, these efforts should lead to the design and testing of a new prototype turbine.

At the end of each major phase in the open-cycle research program, Argonne National Laboratory's Systems Analysis Language Translator (SALT) will be used to determine the trade-offs among efficiency, cost, and parasitic power consumption of individual components. Similar analyses will also explore research opportunities for improving both open- and closed-cycle system performance.

Finally, by the end of 1988, systems analysis in combination with specific experiments will be used to establish or reject the feasibility of a cost-effective mist-lift plant.

Experimental Verification and Testing

In the near future, researchers will begin testing direct-contact evaporators and condensers with seawater and comparing their results with fresh-water experiments. In related efforts, they will begin scaling up evaporator, condenser, and turbine components for future open-cycle OTEC experiments at the Seacoast Test Facility. These scaled experiments will be designed to provide a comprehensive look at the power system by 1989 or 1990. As part of this experiment, investigators will analyze the interaction of power system components, determine the system's net-to-gross power output, and test the predictions made by their computer models. In addition, they will study the mechanical properties of a new prototype turbine rotor (including stress, strain, vibration, erosion, corrosion, and fatigue) as it operates in the unique open-cycle OTEC environment.

The successful operation of this OTEC experiment will verify the technical feasibility of the Claude power cycle — approximately 60 years after the French inventor first proposed his idea. Once the initial experiment works, industry is expected to support extended testing and commercialization of open-cycle OTEC.

To support these experiments, DOE, in cooperation with the State of Hawaii, plans to upgrade the Seacoast Test Facility at the Natural Energy Laboratory of Hawaii, located on the Kona Coast of the Island of Hawaii. This activity will ensure that the facility has a sufficient supply of cold and warm seawater to conduct the experiments. The improvements will include the design, purchase, and installation of piping systems, pumping equipment, computer monitoring equipment, and support features. A second cold-water pipe, which will add an additional cold-water pumping capacity of 13,300 gallons per minute (gpm) to the facility's present 1300 gpm, will be installed. The new pipe will deliver 6500 gpm of cold seawater to the OTEC experiments and the remaining 6800 gpm to other experiments, including mariculture.

DOE will share the costs of the upgraded facility, which will begin operation in mid 1987, with the State of Hawaii. DOE will use the new facility to conduct open-cycle component and system experiments, closed-cycle component and materials tests, biofouling and corrosion tests, and advanced OTEC concepts experiments. DOE researchers plan to use the facility in 1988 and 1989 to test advanced heat exchangers fabricated by new, state-of-the-art techniques. Concurrently, the State of Hawaii will explore mariculture, solar ponds, and other OTEC-related applications at the facility.

Materials and Structural Research

Materials and structural research will continue to focus on cold-water pipes and heat exchangers. Experiments to qualify cost-effective aluminum alloys for use in heat exchangers will be completed by 1986. At that time, DOE will decide whether this research should be continued.

An effort to develop the 10-ft diameter cold-water pipe required for a 5-15 MW_e OTEC system will accelerate in the near future. The task, which began in 1985 with a concept design analysis, will develop design methods, construction materials, and techniques for installation and deployment. Because cold-water pipes are inaccessible for repair and maintenance, cold-water pipe materials testing, which enables researchers to predict life expectancy, will be an important part of this project.

Oceanographic, Environmental, and Geotechnical Research

Oceanographic studies will continue to provide information to all areas of the ocean energy technology research effort on the impacts of OTEC on the environment and the impacts of the ocean on OTEC operation. Researchers will refine computer models of OTEC's interactions with marine ecosystems as well as monitor the chemical and biological effects of OTEC operations on the ocean.

In addition to oceanographic research, researchers will conduct required environmental assessments for Claude-cycle and alternative ocean energy systems by 1987 and 1989, respectively. These efforts will ensure that OTEC designers accurately predict environmental impacts and create designs that comply with federal and local regulations. Researchers are developing their computer models to reflect this commitment to meeting these regulations.

In the future, researchers will study the geology of the seafloor near potential OTEC installations. This information will be invaluable in designing the cold-water pipe and OTEC plant foundation, both of which sit atop steep slopes or continental shelves near land.

Contract Descriptions

Argonne

Title: Ocean Thermal Energy Conversion (OTEC) Systems Modeling

Contractor:
Purdue University
Mechanical Engineering Dept.
West Lafayette, IN 47907

Directing Organization:
Argonne National Laboratory

Principal Investigator: A. McDonald
Telephone: (317) 494-5621

Project Monitor: D. Hillis
Telephone: (312) 972-6607

Contract Number: 51752401

Contract Funding:

Year	Amount	Source
FY 85	$74,000	ANL

Current Contract Period From: 8/1/85
To: 9/1/86

Research Area: Thermodynamic Research and Analysis

Objectives: To develop a PC-based, user-friendly executive ocean thermal energy conversion (OTEC) system code for making scoping calculations of a 10 MW_e shore-based plant cost and performance.

Approach/Present Tasks:

- Develop a simulation and design code using a shell-and-tube heat-exchanger configuration.
- Develop an estimated plant capital cost code from relationships furnished by Argonne National Laboratory (ANL) from Systems Analysis Language Translator (SALT) cost data.
- Design and check out test apparatus for laminar flow condensation in the presence of non-condensibles in a single channel.

Status/FY 1984 and FY 1985 Accomplishments:

- Contract executed.

FY 1986 Milestones:

- Design experiment to study laminar film condensation in surface condenser.
- Complete PC-based executive OTEC system code and deliver final report.

Major Project Reports: None to date.

Argonne

Title: OTEC Thermal Energy Conversion (OTEC) Systems Optimization Study

Contractor:
Applied Physics Laboratory
The Johns Hopkins University
Johns Hopkins Road
Laurel, MD 20810

Directing Organization:
Argonne National Laboratory

Principal Investigator: W. Avery
Telephone: (301) 953-5000

Project Monitor: D. Hillis
Telephone: (312) 972-6607

Contract Number: 51352402

Contract Funding:

Year	Amount	Source
FY 85	$84,900	ANL

Current Contract Period From: 6/1/85
To: 3/1/86

Research Area: Thermodynamic Research and Analysis

Objectives: To customize the Argonne National Laboratory (ANL) developed Systems Analysis Language Translator (SALT) systems code specifically for Ocean Thermal Energy Conversion (OTEC) applications.

Approach/Present Tasks:

- Develop work breakdown structure (WBS) and cost algorithms usable with SALT for the 40 MW_e Proof of Concept Experiment (POCE) plant.
- Add a WBS and cost algorithm for the ANL 10 MW_e OTEC plant design.
- Combine the SALT code with the PC model which will permit optimized cases to be cross-checked with the PC-based system models.

Status/FY 1984 and FY 1985 Accomplishments:

- SALT code modified to include the WBS and cost algorithms for 40 MW_e POCE plant.
- SALT code modified to include the WBS and cost algorithms for the ANL 10 MW_e plant.
- OTEC system broken down into power system and cost modules for fast optimization.

FY 1986 Milestones:

- Submit final report.

Major Project Reports: None to date.

Argonne

Title: Waterside Enhancement Study

Contractor:
Iowa State University
School of Science and Technology
Ames, IA 50011

Directing Organization:
Argonne National Laboratory

Principal Investigator: A. Bergles

Telephone: (515) 294-6943
Contract Number: 40792401

Project Monitor: D. Hillis
Telephone: (312) 972-6607

Current Contract Period From: 9/1/83
To: On-going

Contract Funding:

Year	Amount	Source
FY 84	$35,000	ANL
FY 85	$15,000	ANL

Research Area: Experimental Verification and Testing

Objectives: To develop generic heat transfer coefficient and friction factor correlations for waterside heat transfer enhancements from an experimental data base which is applicable to Ocean Thermal Energy Conversion (OTEC) flow and temperature range.

Approach/Present Tasks:

- Develop engineering correlations for heat transfer and friction for enchanced tubes.
- Validate the correlations with selected single tube tests.
- Review literature for heat transfer and friction factor correlations for rectangular channels and plates.

Status/FY 1984 and FY 1985 Accomplishments:

- Comprehensive heat transfer and friction factor correlations for tubes have been developed for OTEC flow and temperature range.

FY 1986 Milestones:

- Complete experimental validation of correlations in four tube samples.

Major Project Reports:

- Ravigururajan, T. S.; Bergles, A. E. (1985). "General Correlations for Pressure Drop and Heat Transfer for Single-Phase Turbulent Flow in Internally Ribbed Tubes." *Augmentation of Heat Transfer in Energy Systems, HTD Vol. 52*, Bishop, P. J., ed. New York: The American Society of Mechanical Engineers; pp. 9-20. Presented at the ASME 1985 Winter Annual Meeting; Miami, Florida, November 16-21, 1985.

Argonne

Title: Materials Corrosion and Fouling Studies

Contractor:
Research Corporation of
University of Hawaii
1110 University Avenue
Honolulu, HI 96826

Directing Organization:
Argonne National Laboratory

Principal Investigator: J. Larsen-Basse
Telephone: (808) 948-6332

Project Monitor: C. Panchal
Telephone: (312) 972-8070

Contract Number: 52492401

Contract Funding:

Year	Amount	Source
FY 84	$ 95,000	ANL
FY 85	$230,000	ANL

Current Contract Period From: 9/1/83
To: On-going

Research Area: Materials and Structural Research

Objectives: To provide a test facility and a reliable supply of seawater for the collection of Ocean Thermal Energy Conversion (OTEC) corrosion and fouling data which are subsequently evaluated and reported.

Approach/Present Tasks:

- Samples are prepared and installed in the test loops and are removed according to a prescribed test plan.
- Supporting water temperature and water sample data are collected.
- Corrosion and fouling samples are evaluated and the data reported.

Status/FY 1984 and FY 1985 Accomplishments:

- For warm surface seawater, intermittent chlorination of 50 to 100 ppb employed for 1 hr/day can maintain the biofouling resistance within acceptable limits.
- Biofouling film can be effectively removed and the heat-transfer performance restored by intermittent or continuous chlorination.
- The uniform rate of corrosion, measured as loss of metal, is less than 0.0125 mm (0.0005 in.) per year for the typical test period of two years.

FY 1986 Milestones:

- Continue investigations with the Argonne National Laboratory test matrix.

Major Project Reports:

- Larsen-Basse, J. (March 1985). "Performance of OTEC Heat Exchanger Materials in Tropical Seawater." *Journal of Metals* (36:3), pp. 24-27.
- Panchal, C. B.; Larsen-Basse, J.; Little, B. (1984). "Biofouling Control for Marine Heat Exchangers Using Intermittent Chlorination." *Fouling in Heat Exchange Equipment, HTD Vol. 35*, Suitor, J. W. and Pritchard, A. M., eds. New York: The American Society of Mechanical Engineers; pp. 97-103. Presented at the 22nd ASME/AIChE National Heat Transfer Conference, Niagara Falls, New York, August 1984.

Title: Advanced OTEC Systems Integration

Contractor:
Argonne National Laboratory
9600 S. Cass Avenue
Argonne, IL 60439

Directing Organization:
Department of Energy

Principal Investigator: A. Thomas
Telephone: (312) 972-8071

Project Monitor: L. Lewis
Telephone: (202) 252-6263

Contract Number: 495-52

Current Contract Period From: 1/1/77
To: On-going

Research Area: Thermodynamic Research and Analysis

Contract Funding:

Year	Amount	Source
FY 84	$200,000	DOE
FY 85	$276,000	DOE

Objectives: To develop methodology and data base for the analysis and optimization of engineering concepts of integrated OTEC systems on cost/performance basis.

Approach/Present Tasks:

- Compare OTEC options based on common assumptions and data base.
- Identify areas with high potential for cost reduction toward multi-year program plan (MYPP) goals.

Status/FY 1984 and FY 1985 Accomplishments:

- Developed PC-based OTEC plant models that can be used for the cost and performance calculations of a closed-cycle OTEC plant.
- Integrated the performance and cost models into a PC-based code for single-point calculations of closed-cycle OTEC plant cost/kilowatt ratio.
- Modified SALT mainframe system code for rapidly converging optimization of closed-cycle OTEC systems.

FY 1986 Milestones:

- Complete OTEC closed-cycle system performance/cost code draft.
- Develop PC-based hybrid closed-cycle performance code.
- Complete comparison table and letter report for generic closed- and open-cycle 10 MW_e shore-based plants.

Major Project Reports:

- Shelpuk, B.; Thomas A.; Avery, W. H. (1984). *Prospects for Advanced OTEC Technology*. Paper No. MRM 2/1. 11 pp. Presented at the Pacific Congress on Marine Technology (PACON), Honolulu, Hawaii. April 1985. Available from: PACON, c/o Sea Grant College Program, University of Hawaii, 1000 Pope Road, Honolulu, HI 96822.
- Stevens, H. C.; Genens, L; Panchal, C. B. (1984). *Conceptual Design of a 10 MW_e Shore-Based OTEC Plant*. 84-WA/Sol-31. New York: The American Society of Mechanical Engineers; 6 pp. Presented at the ASME 1984 Winter Annual Meeting, New Orleans, Louisiana, December 1984. Available from: Engineering Societies Library, 345 East 47th Street, New York, New York 10017.

Title: Innovative Heat Exchanger Fabrication Techniques

Contractor:
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Directing Organization:
Department of Energy

Principal Investigator: A. Thomas
Telephone: (312) 972-8071

Project Monitor: M. Kim
Telephone: (202) 252-6262

Contract Number: 495-48

Current Contract Period From: 3/1/83
To: On-going

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$100,000	DOE
FY 85	$305,000	DOE

Objectives: To develop and test new and innovative methods for low-cost fabrication of advanced surface heat exchangers.

Approach/Present Tasks:

- Develop and test adhesive bonding methods for heat exchanger assembly.
- Develop and test high corrosion resistance brazing and diffusion bonding techniques.

Status/FY 1984 and FY 1985 Accomplishments:

- Mechanical strength of epoxy-bonded joints have proven to be adequate for OTEC applications, provided the joints are not subjected to tensile or peeling loads.
- After six months of immersion in seawater, epoxy-bonded titanium coupons have shown little or no degradation of joint strength.
- Laboratory scale diffusion-bonded aluminum joints have shown much less metallurgical discontinuity than brazed joints and therefore are believed to be less susceptible to localized corrosion attack.
- Contacts with industry have confirmed existing capability to braze modular-size stainless steel and titanium heat exchangers as well as to metallurgically bond aluminum fins to stainless steel panels.

FY 1986 Milestones: None

Major Project Reports:

- *Ocean Thermal Energy Conversion Annual Report, Fiscal Year 1984.* (March 1985). ANL/OTEC-TM-4. 54 pp. Available NTIS: Order No. DE85012291.

Title: 40 MW_e Pilot Plant — Preliminary Design

Contractor:
Ocean Thermal Corporation
595 Madison Avenue
New York, NY 10022

Directing Organization:
Department of Energy

Principal Investigator: J. Yaffo
Telephone: (212) 758-1990

Project Monitor: L. Rogers
Telephone: (202) 252-6265

Contract Number: DE-AC01-82CE30716

Current Contract Period From: 4/29/82
To: 11/28/84

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$5,000,000	DOE
FY 84	$2,028,000	OTC

Objectives: To conduct research for the development of a design and a credible cost estimate for construction and operation to enable assessment of the commercialization potential for a land-based plant sited at Kahe Point, Oahu, Hawaii.

Approach/Present Tasks:

- Prepare a conceptual design of a 40 MW_e Ocean Thermal Energy Conversion (OTEC) plant.
- Characterize the site to establish the features in which the design and construction must accommodate, and to enable an environmental impact assessment to be made.
- Prepare a preliminary design, equipment, specifications, procurement and construction plan.
- Prepare a total project financial plan.

Status/FY 1984 and FY 1985 Accomplishments:

- Completed preliminiary design, environmental description report, and financial plan.

FY 1986 Milestones: None

Major Project Reports:

- *40 MW_e OTEC Power Plant Final Technical Report.* (1984). Ocean Thermal Corporation. New York, NY. 4 Volumes.

Title: Ocean Cold-Water Pipe (CWP) Technology

Contractor:
Energy Technology Engineering Center
P.O. Box 1449
Canoga Park, CA 91304

Directing Organization:
Department of Energy

Principal Investigator: P. Pekrul
Telephone: (818) 700-5010

Project Monitor: C. Castellano
Telephone: (202) 252-6265

Contract Number: DE-AC02-76-SF00700

Current Contract Period From: 10/1/78
To: On-going

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$400,000	DOE/SAN
FY 85	$294,000	DOE/SAN

Objectives: To investigate the design, construction, and deployment of cold-water pipe systems with the intent of providing credible capital-cost estimates that achieve the Program goals.

Approach/Present Tasks:

- Complete scale-model tests to confirm design prediction techniques for waves and currents.
- Investigate alternative materials, configurations, and deployment techniques.
- Estimate costs of new concepts, sub-assemblies, and components.

Status/FY 1984 and FY 1985 Accomplishments:

- Completed 8-foot diameter, shallow-water, steep-slope testing in Hawaii.
- Completed 6-foot diameter, wave tank testing at Chicago Bridge & Iron Co.
- Drilling/tunneling appears to be a cost-effective alternative for cold-water pipes larger than 10 feet in diameter.

FY 1986 Milestones:

- Issue drilling/tunneling and geology reports.
- Complete work and issue reports of scale-model data analysis.
- Issue close-out summary report.

Major Project Reports:

- Robinson, K. S. (October 1985). *Tunnelling and Drilling for OTEC Cold-Water Pipes.* CWP-XR-0001. Canoga Park, CA.
- Robinson, K. S. (October 1985). *Preliminary Geologic Model-Keahole Point, Hawaii.* CWP-XR-002. Canoga Park, CA.

Title: 40 MW_e Pilot Plant — Project Management

Contractor:
Energy Technology Engineering Center
P.O. Box 1449
Canoga Park, CA 91304

Directing Organization:
Department of Energy

Principal Investigator: A. Klein
Telephone: (818) 700-5513

Project Monitor: L. Rogers
Telephone: (202) 252-6265/5540

Contract Number: DE-AC03-76-SF00700

Current Contract Period From: 10/1/78
To: On-going

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$ 61,000	DOE/SAN
FY 85	$286,000	DOE/SAN

Objectives: To provide project management and technical assistance to DOE/HQ in execution of the 40 MW_e Pilot Plant Project. Ocean Thermal Corporation (OTC) was contracted to prepare a preliminary design of a 40 MW_e OTEC plant at Kahe Point, Oahu, Hawaii.

Approach/Present Tasks:

- Monitor OTC's compliance with the technical and administrative requirements of its contract with DOE.
- Evaluate and assess the technical adequacy of the designs, procedures, and estimated costs.
- Provide assistance to DOE.

Status/FY 1984 and FY 1985 Accomplishments:

- Reviewed and provided assessment of documents issued by OTC.
- Conducted workshops and led government technical team to ensure technology transfer.
- Prepared summary of project activities.
- Acquired and managed major technical support subcontractors.

FY 1986 Milestones: None. (Project terminated in FY 85.)

Major Project Reports:

- Klein, A. (April 1985). *OTEC Pilot Plant Project: Phase II Summary Report*. 85ETEC-DRF-1212. Canoga Park, CA: Energy Technology Center.

Title: Heat Exchanger Performance Improvement

Contractor:
Argonne National Laboratory
9600 S. Cass Avenue
Argonne, IL 60439

Directing Organization
Department of Energy

Principal Investigator: A. Thomas
Telephone: (312) 972-8071

Project Monitor: M. Kim
Telephone: (202) 252-6262

Contract Number: 495-48

Current Contract Period From: 3/1/83
To: On-going

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$150,000	DOE
FY 85	$300,000	DOE

Objectives: To study the development of integrated heat transfer enhancements that allow the reduction of the heat transfer area and the water flow demand for a given amount of power.

Approach/Present Tasks:

- Develop engineering correlations for heat transfer and friction in enhanced plate heat exchangers.
- Identify optimum enhancement geometries.
- Experimentally validate the thermohydraulic performance of enhanced channels.

Status/FY 1984 and FY 1985 Accomplishments:

- The conceptual design and performance specifications for the baseline compact cross-flow heat exchangers were completed. This was an extruded channel aluminum unit of brazed construction.
- Comprehensive generic performance equations have been developed for shell-and-tube heat exchangers operating under Ocean Thermal Energy Conversion (OTEC) conditions.
- The performance equations have been partially validated in limited experiments with warm water flowing inside the tubes.

FY 1986 Milestones:

- Complete progress report for waterside performance correlations for plates.

Major Project Reports:

- Ravigururajan, T. S.; Bergles, A. E. (1985). "General Correlations for Pressure Drop and Heat Transfer for Single-Phase Turbulent Flow in Internally Ribbed Tubes." *Augmentation of Heat Transfer in Energy Systems, HTD Vol. 52*, Bishop, P. J., ed. New York: The American Society of Mechanical Engineers; pp. 9-20. Presented at the ASME 1985 Winter Annual Meeting; Miami, Florida, November 16-21, 1985.
- Panchal, C. B. (1985). "Condensation Heat Transfer in Plate Heat Exchangers." *Two-Phase Heat Exchanger Symposium, HTD Vol. 44*, Pearson, J. T. and Kitto, J. B., Jr., eds. New York: The American Society of Mechanical Engineers; pp. 45-52. Presented at the 23rd ASME/AIChE National Heat Transfer Conference, Denver, Colorado, August 1985.
- Panchal, C. B. (1984). "Heat Transfer with Phase Change in Plate-Fin Heat Exchangers," *AIChE Symposium Series No. 236, Volume 80, 1984*, Farukhi, N. F., ed. New York: American Institute of Chemical Engineers; pp. 90-97. Presented at the 22nd ASME/AIChE National Heat Transfer Conference, Niagara Falls, New York, August 1984.
- Panchal, C. B.; Hillis, D. L. (April 1984). *OTEC Performance Tests of the Alfa-Laval Plate Heat Exchanger as an Ammonia Evaporator.* ANL/OTEC-PS-13. 39 pp. Available NTIS: Order No. DE85009985.

Title: Seacoast Test Facility Upgrade — Design and Construction

Contractor:
Department of Planning &
Economic Development
State of Hawaii
335 Merchant Street
Honolulu, HI 96813

Directing Organization:
Department of Energy

Principal Investigator: T. Yoshihara
Telephone: (808) 548-4150

Project Monitor: L. Lewis
Telephone: (202) 252-6263

Contract Number: TBD

Current Contract Period From: TBD
To: TBD

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$1,400,000	DOE/SAN*
FY 85	$ 601,000	ETEC†
FY 85	$1,400,000	DOE/SAN‡

Objectives: To provide an upgraded physical environment in which to conduct experiments to verify ocean thermal energy conversion (OTEC) component functional feasibility and operational characteristics of the Seacoast Test Facility (STF) of the Natural Energy Laboratory of Hawaii (NELH), Keahole Point, Hawaii. Principal elements of the work involve providing a conduit for transporting at least 6500 gallons per minute (gpm) of cold seawater [in addition to 6800 gpm of cold seawater in the same conduit for the Hawaii Ocean Science and Technology (HOST) Park experiments] from a depth of approximately 2100 ft to the proposed test area at NELH, an ocean-based conduit length of approximately 7000 ft; providing a conduit for transporting at least 9500 gpm of warm seawater from a depth of approximately 60 ft to the proposed test area at NELH, an ocean-based conduit lenth of approximately 500 ft; providing a conduit for transporting at least 16,000 gpm of seawater from the proposed test area at NELH to a discharge structure; providing the associated land-based seawater lines, pumps, and control equipment for the seawater systems; and providing the associated structures and utilities to enable operations.

Approach/Present Tasks:

- The STF Upgrade Project will be accomplished through a DOE/State of Hawaii cost-shared cooperative agreement. Hawaii will manage the design and construction, which is expected to be completed in FY 87.

Status/FY 1984 and FY 1985 Accomplishments:

- Previous efforts at Energy Technology Engineering Center (ETEC) and Solar Energy Research Institute (SERI) to carry out this STF Upgrade Project were terminated because of lack of funds for completing a fully separate DOE seawater system.

FY 1986 Milestones:

- Hawaii will prepare a preliminary design and government cost estimate, and, with DOE approval, will bid and award a final design and construction contract at the end of FY 86.

Major Project Reports:

- Quinby-Hunt, M. S.; Sloan, D.; Dengler, A. P.; Wilde, P. (1985). *Environmental Assessment of Construction of Air Expanded Facility for the Seacoast Test Facility Stage-2 [Stage-2] at the Natural Energy Laboratory of Hawaii [NELH]*. MSG-85-024. Berkeley, CA: University of California; 225 pp.
- *Seacoast Test Facility Upgrade Project Conceptual Design Study*. (July 1985). STFU XR-0002. Canoga Park, CA: Energy Technology Engineering Center; 198 pp.

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*FY 84 funds transferred from DOE to ETEC.
†FY 85 funds used by ETEC; $1,400,000 transferred from ETEC to SERI.
‡FY 85 funds to be transferred from SERI Area Office to State of Hawaii.

Title: Heat Exchanger Materials Life-Cycle and Biofouling Research

Contractor:
Argonne National Laboratory
9600 S. Cass Avenue
Argonne, IL 60439

Directing Organization:
Department of Energy

Principal Investigator: A. Thomas
Telephone: (312) 972-8071

Project Monitor: M. Kim
Telephone: (202) 252-6262

Contract Number: 495-19

Current Contract Period From: 10/1/82
To: On-going

Research Area: Materials and Structural Research

Contract Funding:

Year	Amount	Source
FY 84	$30,000	DOE
FY 85	$42,000	DOE

Objectives: To generate experimental biofouling and corrosion data necessary for the design of advanced heat exchangers containing waterside enhancements and assembly joints.

Approach/Present Tasks:

- Identify generic fabrication joints applicable to aluminum heat exchangers for OTEC service.
- Identify waterside enhancements most likely to be employed in OTEC heat exchangers.
- Test samples containing typical joints and enhancements at the Seacoast Test Facility (STF).

Status/FY 1984 and FY 1985 Accomplishments:

- Short-term scoping biofouling tests with waterside-enhanced surfaces have suggested that they can be kept clean by similar environmentally acceptable dosages of chlorination as used for smooth surfaces.
- Initial screening tests with commercially brazed aluminum joints have shown no localized attack in warm water but rather severe pitting in cold water.

FY 1986 Milestones:

- Complete interim report on corrosion and fouling in aluminum heat exchanger joints.

Major Project Reports:

- Panchal, C. B.; Stevens, H. C.; Genens, L. E.; Hillis, D. L.; Larsen-Basse, J. (1984). "Biofouling and Corrosion Studies at the Seacoast Test Facility in Hawaii." *Oceans '84 Conference Record, Washington, D.C., September 10-12, 1984.* New York: Institute of Electrical and Electronics Engineers; Vol. 1, pp. 364-369.
- Panchal, C. B.; Larsen-Basse, J.; Berger, L. R.; Berger, J. A.; Little, B. J.; Stevens, H. C.; Darby, J. B.; Genens, L. E.; Hillis, D. L. (July 1985). *OTEC Biofouling and Corrosion-Protection Study at the Seacoast Test Facility: 1981-1983.* ANL/OTEC-TM-5. 59 pp. Available NTIS: Order No. DE86002148.
- Panchal, C. B. "Heat-Transfer Monitor for Measurements of Fouling of Industrial Heat Exchangers." Presented at the Condenser Biofouling Control Symposium: The State-of-the-Art. Lake Buena Vista, FL. June 18-20, 1985; 13 pp. The Electric Power Research Institute.

Title: Aluminum Alloys Qualifications

Contractor:
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Directing Organization:
Department of Energy

Principal Investigator: A. Thomas
Telephone: (312) 972-8071

Project Monitor: M. Kim
Telephone: 52-6262

Contract Number: 495-19

Current Contract Period From: 9/1/78
To: On-going

Research Area: Materials and Structural Research

Contract Funding:

Year	Amount	Source
FY 84	$400,000	DOE
FY 85	$180,000	DOE

Objectives: To select and test aluminum alloys and coatings that would lead to low-cost ocean thermal energy conversion (OTEC) heat exchangers with a 25-30 year service life.

Approach/Present Tasks:

- Identify aluminum alloys with optimum seawater corrosion resistance.
- Identify aluminum alloys with optimum fabricability and low-cost potential.
- Identify protective coatings to mitigate corrosion.

Status FY 1984 and FY 1985 Accomplishments:

- Three years of seawater tests with smooth aluminum surfaces have indicated that the surface corrosion and pitting rates are extrapolative to 10-15 year service lives.
- Although aluminum alloys are susceptible to pitting in deep seawater, no pitting has been observed in bare 5052; Alclad 3003 also has shown no pits penetrating into the base metal.

FY 1986 Milestones:

- Update aluminum qualification report.

Major Project Reports:

- Panchal, C. B.; Larsen-Basse, J.; Little, B. (1984). "Biofouling Control for Marine Heat Exchangers Using Intermittent Chlorination." *Fouling in Heat Exchange Equipment, HTD Vol. 35*, Suitor, J. W. and Pritchard, A. M., eds. New York: The American Society of Mechanical Engineers; pp. 97-103. Presented at the 22nd ASME/AIChE National Heat Transfer Conference, Niagara Falls, New York, August 1984.
- Larsen-Basse, J. (March 1985). "Performance of OTEC Heat Exchanger Materials in Tropical Seawater." *Journal of Metals* (36:3), pp. 24-27.
- Darby, J. B. (September 1984). "Ocean Thermal Eenrgy Conversion - Materials Issues." *Journal of Materials for Energy Systems* (6:2), pp. 130-137.
- Panchal, C. B.; Larsen-Basse, J.; Berger, L. R.; Berger, J. A.; Little, B. J.; Stevens, H. C.; Darby, J. B.; Genens, L. E.; Hillis, D. L. (July 1985). *OTEC Biofouling and Corrosion-Protection Study at the Seacoast Test Facility: 1981-1983*. ANL/OTEC-TM-5. 59 pp. Available NTIS: Order No. DE86002148.

Title: Ocean Thermal Energy Conversion (OTEC) — Facilities

Contractor:
ETEC
P.O. Box 1449
Canoga Park, CA 91304

Directing Organization:
Department of Energy

Principal Investigator: A. Klein
Telephone: (818) 700-5513

Project Monitor: C. Castellano
Telephone: (202) 252-6465

Contract Number: DE-AC03-76-SF00700

Current Contract Period From: 10/1/78
To: On-going

Research Area: Seacoast Test Facility Upgrade

Contract Funding:

Year	Amount	Source
FY 84	$1,400,000	DOE/SAN*
FY 85	$ 601,000	DOE/SAN†

Objectives: To upgrade the state of Hawaii's Seacoast Test Facility at Keahole Point to enable DOE to conduct large-scale experiments on OTEC components, systems, materials and structures. To define the project, establish requirements, prepare preliminary designs, prepare baselines, develop budgets and schedules, and implement the test plan.

Approach/Present Tasks:

- Draft DOE/Hawaii cooperative agreement.
- Develop project requirements.
- Prepare conceptual design and cost estimate.
- Define work to complete project.
- Obtain necessary technical assistance in areas of marine engineering/naval architecture/environmental engineering.

Status/FY 1984 and FY 1985 Accomplishments:

- DOE/Hawaii agreement accepted and executed.
- Project design requirements document issued.
- Project management plan document issued.
- Issued statement of work for final design and construction.
- Conceptual design and cost estimate of facility upgrade completed.

FY 1986 Milestones: None.

Major Project Reports:

- Quinby-Hunt, M. S.; Sloan, D.; Dengler, A. P.; Wilde, P. (1985). *Environmental Assessment of Construction of Air Expanded Facility for the Seacoast Test Facility Stage-2 [Stage-2] at the Natural Energy Laboratory of Hawaii [NELH]*. MSG-85-024. Berkeley, CA: University of California; 225 pp.

*FY 84 funds transferred from DOE to ETEC.
†FY 84 funds used by ETEC; $1,400,000 transferred from ETEC to SERI.

ETEC

Title: Seacoast Test Facility Upgrade — Project Management

Contractor:
In-house

Principal Investigator: F. A. Blake
Telephone: (303) 231-7102

Contract Number: DE-AC02-83CH10093

Current Contract Period From: 5/1/85
To: 3/31/86

Research Area: Experimental Verification and Testing

Directing Organization:
Solar Energy Research Institute

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Funding:

Year	Amount	Source
FY 85	$120,000	DOE

Objectives: To provide an upgraded physical environment in which to conduct experiments to verify Ocean Thermal Energy Conversion (OTEC) component functional feasibility, performance demonstration, and operational characteristics at the Seacoast Test Facility (STF) of the Natural Energy Laboratory of Hawaii (NELH), Keahole Point, Island of Hawaii.

Approach/Present Tasks:

- Complete the STF upgrade project in two subcontracted phases: (1) a seven-month design phase early in 1986, and (2) a one-year procurement/fabrication/construction phase to be completed in 1987.

Status/FY 1984 and FY 1985 Accomplishments:

- DOE funded conceptual design performed by Rockwell's Energy Technology Engineering Center (ETEC).

FY 1986 Milestones:

- Contract effort terminated in lieu of a cost-shared DOE/Hawaii upgrade program. The DOE portion will be managed by DOE/HQ and the DOE/SERI Area Office.

Major Project Reports:

- *Seacoast Test Facility Upgrade Project Conceptual Design Study*. (July 1985). STFU XR-0002. Canoga Park, CA: Energy Technology Engineering Center; 198 pp.

ETEC

Title: Cold-Water Pipe (CWP) Technology — At-Sea Testing

Contractor:
Hawaiian Dredging & Construction Co.
614 Kapahulu Avenue
Honolulu, HI 96815

Directing Organization:
Energy Technology Engineering Center

Principal Investigator: F. McHale
Telephone: (808) 735-3276

Project Monitor: P. Pekrul
Telephone: (818) 700-5010

Contract Number: R54PJZ853565509

Current Contract Period From: 11/15/84
To: 9/27/85

Contract Funding:

Year	Amount	Source
FY 85	$172,000	ETEC

Research Area: Experimental Verification and Testing

Objectives: To conduct the at-sea testing of a 70-ft section of an 8-ft diameter cold-water pipe (CWP) to provide engineering data on the waves and currents upon a CWP located on a steep-slope in shallow water.

Approach/Present Tasks:

- Expose an instrumented 8-ft diameter CWP section to the worst (winter) storm season in Hawaii.
- Measure the current and wave environment and the induced loads.
- Reduce and analyze the resulting data to compare with predictions.

Status/FY 1984 and FY 1985 Accomplishments:

- ETEC took over on-going experiment (initiated by NOAA) in 1984 and completed at-sea experiment in 1985.

FY 1986 Milestones:

- Complete the at-sea test data analysis and issue final report.

Major Project Reports:

- Noda, E. (April 1985). *At-Sea Down-Slope Experiment on a Fiberglass Reinforced Plastic Pipe at Hawaii.* Canoga Park, CA. Hawaiian Dredging and Construction Co.
- Cotter, D. (April 1985). *Model Tank Experiment on the Small-Scale Cold-Water Pipe (CWP) on the Sloping Beach.* Chicago, IL: CBI, Inc.

ETEC

Title: 40 MW_e Pilot Plant — Project Monitoring

Contractor:
Gibbs & Cox, Inc.
1235 Jefferson Davis Highway
Suite 700
Arlington, VA 22202

Directing Organization:
Energy Technology Engineering Center

Principal Investigator: E. Midboe
Telephone: (703) 979-1240

Project Monitor: A. Klein
Telephone: (818) 700-5513

Contract Number: R22PNA00340087

Current Contract Period From: 8/12/82
To: 9/30/85

Contract Funding:

Year	Amount	Source
FY 84	$387,000	ETEC

Research Area: Experimental Verification and Testing

Objectives: To assist the Energy Technology Engineering Center (ETEC) to ensure that Ocean Thermal Corporation (OTC) design and construction plans are technically sound from a naval architect/marine engineer's perspective.

Approach/Present Tasks:

- Review documents selected by ETEC and attend workshops and meetings to assure that technology transfer occurs.

Status/FY 1984 and FY 1985 Accomplishments:

- Reviewed all pertinent documents from OTC and issued comments and recommendations to ETEC.
- Attended meetings and workshops.

FY 1986 Milestones: None. (Project terminated in FY 85.)

Major Project Reports: None.

ETEC

Title: Seacoast Test Facility Upgrade — Project Management

Contractor:
Gibbs & Cox, Inc.
1235 Jefferson Davis Highway
Suite 700
Arlington, VA 22202

Directing Organization:
Energy Technology Engineering Center

Principal Investigators: E. Midboe
K. Picha
Telephone: (703) 979-1240

Project Monitor: A. Klein
Telephone: (818) 770-5513

Contract Number: R22PNA00340087

Contract Funding:

Year	Amount	Source
FY 85	$310,000	ETEC

Current Contract Period From: 8/12/82
To: 9/30/85

Research Area: Experimental Verification and Testing

Objectives: To prepare preliminary design of off-shore facilities to upgrade the state of Hawaii's Seacoast Test Facility at Keahole Point, Hawaii.

Approach/Present Tasks:

- Define off-shore environment for establishment of design criteria.
- Prepare design and deployment procedure for use as basis for budget request.
- Begin work at start of FY 1985.

Status/FY 1984 and FY 1985 Accomplishments:

- Prepared design report and cost estimates presented to Energy Technology Engineering Center (ETEC) and Department of Energy (DOE).
- Defined environmental design criteria.

FY 1986 Milestones: None. [Project reassigned to Solar Energy Research Institute (SERI) by DOE.]

Major Project Reports:

- *Seacoast Test Facility Upgrade, Offshore Pipe Systems Conceptual Design.* (July 1985). [19532-2(4-KGP-3258)]. Arlington, VA: Gibbs & Cox, Inc.
- *Seacoast Test Facility Upgrade, Offshore Pipe Systems Conceptual Design.* (July 1985). [19532-2-(4-TJH-3089)]. Arlington, VA: Gibbs & Cox, Inc.
- Evans/Hamilton, Inc. (June 1985). *Design and Operational Meteorological/ Oceanographic Criteria for the Seacoast Test Facility Seawater Pipeline.*

ETEC

Title: 40 MW_e Pilot Plant — Performance Assessment

Contractor:
Purdue University
Mechanical Engineering Dept.
West Lafayette, IN 47907

Directing Organization:
Energy Technology Engineering Center

Principal Investigator: A. McDonald
Telephone: (317) 494-5621

Project Monitor: A. Klein
Telephone: (818) 700-5513

Contract Number: R42PNA0034216

Current Contract Period From: 3/1/84
To: 12/21/84

Contract Funding:

Year	Amount	Source
FY 84	$128,000	ETEC

Research Area: Experimental Verification and Testing

Objectives: To assist Energy Technology Engineering Center (ETEC) to investigate and evaluate technical improvements to the Ocean Thermal Energy Conversion (OTEC) process which may be of benefit to the pilot plant.

Approach/Present Tasks:

- *Identify candidate features where improvements may be made and evaluate feasibility.*
- Develop a mathematical analysis technique that can be operated on a desktop computer to enable system improvement studies.

Status/FY 1984 and FY 1985 Accomplishments:

- No significant improvements identified for the 40 MW_e plant.
- A first-generation, simplified analysis program was provided to DOE/HQ.

FY 1986 Milestones: None. (Project terminated in FY 85.)

Major Project Reports:

- Leidenfrost, W.; Liley, P. E.; McDonald, A. T.; Mudawwar, I.; Pearson, J. T. (May 1985). *Performance Assessment of OTEC Power Systems and Thermal Power Plants; Final Report.* Lafayette, IN: Purdue University; 2 vols.

ETEC

Title: Ocean Thermal Energy Conversion (OTEC) — Facilities

Contractor:
Marine Sciences Group
University of California
Berkeley, CA 94720

Directing Organization:
Energy Technology Engineering Center

Principal Investigator: P. Wilde
Telephone: (415) 642-6535

Project Monitor: A. Klein
Telephone: (818) 700-5513

Contract Number: RPF285560977

Current Contract Period From: 10/1/84
To: 12/31/85

Contract Funding:

Year	Amount	Source
FY 84	$136,000	ETEC

Research Area: Seacoast Test Facility Upgrade

Objectives: To assist ETEC in the design of selected features of the upgrade to Hawaii's Seacoast Test Facility at Keahole Point, Hawaii. Also, prepare and issue an environmental assessment of the impacts associated with construction.

Approach/Present Tasks:

- Develop the design criteria and conceptual approach for disposal of spent seawater.
- Research, assess, and issue an impact assessment of ETEC's design of the discharge upgrade.

Status/FY 1984 and FY 1985 Accomplishments:

- Scale model, dye studies performed to simulate discharge plumes and design requirements were recommended.
- Draft environmental assessment issued to DOE.

FY 1986 Milestones: None. (Project reassigned to SERI by DOE.)

Major Project Reports:

- Harms, V W.; Dengler, A. T., Jr. (September 1985). *Seawater-Discharge Analysis and Effluent-Plume Characteristics for the STF-Upgrade Project (Ke-ahole Point, Hawaii).* MSG-85-020. Berkeley, CA: University of California; 157 pp.
- Quinby-Hunt, M. S.; Sloan, D.; Dengler, A. P.; Wilde, P. (1985). *Environmental Assessment of Construction of Air Expanded Facility for the Seacoast Test Facility Stage-2 [Stage-2] at the Natural Energy Laboratory of Hawaii [NELH].* MSG-85-024. Berkeley, CA: University of California; 225 pp.

ETEC

Title: 40 MW_e Pilot Plant — Environmental Assessment

Contractor:
Marine Sciences Group
University of Calif. Berkeley
Department of Paleontology
Berkeley, CA 94720

Directing Organization:
Energy Technology Engineering Center

Principal Investigator: P. Wilde
Telephone: (415) 642-6535

Project Monitor: A. Klein
Telephone: (818) 700-5513

Contract Number: N378-001-ZKX

Current Contract Period From: 10/1/82
To: 5/30/85

Contract Funding:

Year	Amount	Source
FY 84	$317,000	ETEC
FY 85	$25,000	ETEC

Research Area: Oceanographic, Environmental, and Geotechnical Research

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Objectives: To assist Energy Technology Engineering Center (ETEC) to ensure that Ocean Thermal Corporation's (OTC) design is technically adequate from a marine sciences perspective and that an adequate environmental assessment of the proposed design and construction is made by OTC and others.

Approach/Present Tasks:

- Review documents selected by ETEC.
- Attend workshops and meetings to assure that technology transfer occurs.
- Prepare environmental assessment.

Status/FY 1984 and FY 1985 Accomplishments:

- Reviewed all pertinent documents from OTC and issued comments and recommendations to ETEC. Attended meetings and workshops.
- Issued environmental assessment.

FY 1986 Milestones: None. (Project terminated in 1985.)

Major Project Reports:

- Hunt, M. S. (May 1985). *Environmental Assessment, Ocean Thermal Energy Converson (OTEC) 40 MW Pilot Plant, Kahe Point, Oahu, Hawaii.* MSG-85-009. Berkeley, CA: University of California, 261 pp.

Title: Ocean Energy Program — Integration

Contractor:
Solar Energy Research Institute
Midwest Research Institute
1617 Cole Boulevard
Golden, CO 80401

Directing Organization:
Solar Energy Research Institute

Principal Investigator: K. Olsen
Telephone: (303) 231-1434

Project Monitor: K. Olsen
Telephone: (303) 231-1434

Contract Number: DE-AC02-83CH10093

Current Contract Period From: 10/1/84
To: 12/30/85

Research Area: Thermodynamic Research and Analysis

Contract Funding:

Year	Amount	Source
FY 84	$300,000	DOE
FY 85	$134,000	DOE

Objectives: To support the technical integration of the Department of Energy (DOE) Ocean Energy Technologies Program through management activities such as multi-year program planning, review and control activities, and integration of multi-laboratory systems analysis efforts.

Approach/Present Tasks:

- Participation in a multi-year program planning (MYPP) process.
- Development of an annual operating plan (AOP) will be performed under this task.
- Integration of the systems analysis efforts with the DOE multi-year program planning process.

Status/FY 1984 and FY 1985 Accomplishments:

- Integration of field input into the MYPP and the FY 1986 AOP was provided.
- A first-cut analysis of research priorities for open-cycle OTEC systems was produced.

FY 1986 Milestones: None.

Major Project Reports:

- *Federal Ocean Energy Technology Program Multi-Year Program Plan FY 85 - 89.* (December 1985). DOE/CH/10093-100. Available: NTIS. 37 pp.

SERI

Title: Non-Condensible Gas Sorption Kinetics

Contractor:
Solar Energy Research Institute
Midwest Research Institute
1617 Cole Boulevard
Golden, CO 80401

Principal Investigator: D. H. Johnson
Telephone: (303) 231-1752

Contract Number: DE-AC02-83CH10093

Current Contract Period From: 10/1/83
To: 12/1/85

Research Area: Thermodynamic Research and Analysis

Directing Organization:
Solar Energy Research Institute

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Funding:

Year	Amount	Source
FY 84	$150,000	DOE

Objectives: To determine requirements for processes to remove non-condensible gases at OTEC conditions and to identify and fabricate apparatus designed to accommodate heat and mass transfer testing.

Approach/Present Tasks:

- Analyze experimental gas sorption results obtained with seawater.
- Design experimental module for heat exchanger testing in seawater.

Status/FY 1984 and FY 1985 Accomplishments:

- Preliminary data on gas desorption in seawater have indicated that the bulk of the dissolved gases have evolved by the completion of the evaporation or condensation process.
- Conservative calculations have shown, for plant sizes greater than 1 MW, that even if all the dissolved gas in seawater comes out, the parasitic power load for the vacuum exhaust system is only about 10% of the gross power output of the open-cycle OTEC system.

FY 1986 Milestones:

- Complete a preliminary design of seawater test module for heat exchangers.
- Complete technical report on the design of an experimental system for OTEC heat and mass transfer research.

Major Project Reports:

- Penney, T. R.; Althof, J. A. (1985). "Measurements of Gas Sorption from Seawater and the Influence of Gas Release on Open-Cycle Ocean Thermal Energy Conversion (OC-OTEC) System Performance," *Intersol '85; Proceedings of the Ninth Biennial Congress of the International Solar Energy Society; Montreal, Canada; 23-29 June 1985*, Bilgen, E. and Hollands, K. G. T. eds. New York: Pergamon Press; pp. 1526-1530.
- Krock, H. J.; Zapka, M. "Gas Evolution in Open-Cycle OTEC." Presented at the 5th International Offshore Mechanics & Arctic Engineering Conference. Tokyo, Japan. April 1986.

Title: Open-Cycle OTEC Turbine Blade Study Report

Contractor:
Advance Ratio Design Co., Inc.
JEN Industrial Companies
2540 Green Street
Seltonville, PA 19013

Directing Organization:
Solar Energy Research Institute

Principal Investigators: K. McAffee
D. Thompson

Telephone: (215) 494-3200

Contract Number: XX-4-04088

Current Contract Period From: 2/1/84
To: 1/1/85

Research Area: Thermodynamic Research and Analysis

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Funding:

Year	Amount	Source
FY 84	$30,000	SERI

Objectives: To summarize progress made on composite blade technology as applicable to Ocean Thermal Energy Conversion (OTEC) conditions.

Approach/Present Tasks:

- Complete a report on the mechanical design and structural dynamic analysis of large open-cycle OTEC blades from an earlier study performed by Westinghouse for Solar Energy Research Institute (SERI).
- Investigate large composite blades by conducting a structural design study and considering candidate composite materials and manufacturing processes.

Status/FY 1984 and FY 1985 Accomplishments:

- Project completed January 1985.

FY 1986 Milestones: None.

Major Project Reports:

- Thompson, D. F. et al. (January 5). "Open-Cycle Turbine Rotor Structural Design Study." SERI. Golden, CO.

Title: Effects of Non-Condensible Gases on Heat Transfer

Contractor:
Solar Energy Research Institute
Midwest Research Institute
1617 Cole Boulevard
Golden, CO 80401

Directing Organization:
Solar Energy Research Institute

Pncipal Investigator: D. H. Johnson
Telephone: (303) 231-1752

Project Monitor: B. Shelpuk
Telephone: (303) 321-1759

Contract Number: DE-AC02-83CH0093

Current Contract Period From: 10/1/83
To: 12/1/85

Research Area: Thermodynamic Research and Analysis

Contract Funding:

Year	Amount	Source
FY 84	$319,000	DOE

Objectives: To develop analytical methods for design and performance predictions of heat exchange equipment operating with seawater and dissolved gases.

Approach/Present Tasks:

- Develop a mathematical model for heat and mass transfer in the presence of non-condensible gases based on the Colburn-Hougen analogy.
- Evaluate laboratory experiments on non-condensible effects in direct-contact condensation.

Status/FY 1984 and FY 1985 Accomplishments:

- Analyses were completed for the performance of jets and sprays in the presence of non-condensibles.

FY 1986 Milestones:

- Complete detailed experimental test plan for heat and mass transfer validation in seawater.
- Complete technical report on direct-contact heat and mass transfer processes.

Major Project Reports:

- Ghiaasiaan, S. M.; Wassel, A. T.; Lin, C. S. "Direct-Contact Condensation in the Presence of Non-condensibles." Presented at the 5th International Offshore Mechanics & Arctic Engineering Conference. Tokyo, Japan. April 1986.
- Bharathan, D.; Althof, J. A. *Experimental Study of Steam Condensation on Water in Countercurrent Flow in the Presence of Inert Gases*. 84-WA/Sol-25. New York: The American Society of Mechanical Engineers. 11 pp.

Title: Final Design and Construction of a Seawater Heat and Mass Transfer Experimental System

Contractor:
To be determined

Directing Organization:
Solar Energy Research Institute

Principal Investigator: To be determined
Telephone: N/A

Project Monitor: T. Penney
Telephone: (303) 231-1754

Contract Number: RFP RX-5-05107

Contract Funding:

Year	Amount	Source
FY 84	$320,000	DOE

Current Contract Period From: TBD
To: TBD

Research Area: Thermodynamic Research and Analysis

Objectives: To develop an experimental system for validation of open-cycle OTEC heat and mass transfer processes and coupling model.

Approach/Present Tasks:

- An existing conceptual design for a vacuum chamber apparatus and a supporting equipment module will be finalized and construction of the vacuum chamber completed.

Status/FY 1984 and FY 1985 Accomplishments:

- A procurement was initiated and solicited. The procurement was withdrawn until total costs for the experimental system could be accurately established.
- A procurement for overall system design was issued.

FY 1986 Milestones:

- Complete final design of a heat and mass transfer experimental system.
- Complete final test plan for the open-cycle experiment.

Major Project Reports: None to date.

SERI

Title: Study of Non-Condensible Gas Effects on Surface Condensers in Open-Cycle OTEC Systems

Contractor:
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

Directing Organization:
Solar Energy Research Institute

Principal Investigator: A. Thomas
Telephone: (312) 972-8071

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Number: DX-4-04116-1

Contract Funding:

Year	Amount	Source
FY 84	$160,000	SERI

Current Contract Period From: 6/1/84
To: 3/1/86

Research Area: Thermodynamic Research and Analysis

Objectives: To investigate the effects of non-condensible gases on surface condensers for open-cycle OTEC systems.

Approach/Present Tasks:

- Conduct a literature review and theoretical analysis of the performance of open-cycle OTEC surface condensers.

Status/FY 1984 and FY 1985 Accomplishments:

- A preliminary design of a surface condenser test unit and a draft test plan has been developed.

FY 1986 Milestones:

- Complete a technical report on performance analysis and test article design.

Major Project Reports:

- Panchal, C. B. "Experimental Study for the Open-Cycle Surface Condenser." SERI. Golden, CO. (In progress.)

Title: Design and Cost Studies of Critical Open-Cycle OTEC Components

Contractor:
University of Central Florida
Florida Solar Energy Center
300 State Road 401
Cape Canaveral, FL 32920

Principal Investigator: D. Block
Telephone: (305) 783-0300

Contract Number: XX-5-05001-1

Current Contract Period From: 2/1/85
To: 11/1/85

Research Area: Thermodynamic Research and Analysis

Directing Organization:
Solar Energy Research Institute

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Funding:

Year	Amount	Source
FY 84	$200,000*	SERI

Objectives: To continue thermoeconomic analyses of small-scale open-cycle OTEC plants for producing fresh water and electricity. To research advanced turbine designs and costs, and to investigate the possibility of using a deep well as an alternate source of cold seawater.

Approach/Present Tasks:

- Continue the thermoeconomic cycle analysis by investigating the off-design open-cycle OTEC plant performance and sensitivity of open-cycle OTEC plants to seasonal variations in the ocean thermal resource.
- Investigate the feasibility of deep wells for OTEC applications by investigation of possible locations and deep well options.
- Conduct a preliminary cost estimate for construction and operation of a research facility.

Status/FY 1984 and FY 1985 Accomplishments:

- The thermoeconomic analysis of small-scale open-cycle OTEC plants has been completed.
- Investigation of deep wells as a source of cold seawater has centered around several possible sites in Florida.
- Cost of drilling a new well and environmental issues may pose problems for locating a test facility at the proposed sites.

FY 1986 Milestones: None.

Major Project Reports:

- Valenzuela, J. et al. *Design and Cost Study of Critical OC-OTEC Plant Components.* (Draft)
- Higgins, J. C.; Block, D. L. (November 1985). *Deep Wells for OTEC Applications.* FSEC-CR-134-85. Cape Canaveral, FL: Florida Solar Energy Center. 80 pp.

*Using funding carried over from FY 1983.

SERI

Title: Open-Cycle Ocean Thermal Energy Conversion (OTEC) Experiments With Seawater

Contractor:
Hawaii Natural Energy Institute
University of Hawaii at Manoa
2540 Dole Street
Honolulu, HI 96822

Directing Organization:
Solar Energy Research Institute

Principal Investigator: J. Larsen-Basse
Telephone: (808) 948-6332

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Number: XX-4-0417-1

Current Contract Period From: 8/1/84
To: 1/1/86

Contract Funding:

Year	Amount	Source
FY 84	$258,500	SERI

Research Area: Thermodynamic Research and Analysis

Objectives: To continue experiments at the Natural Energy Laboratory of Hawaii (NELH) to investigate the following issues in open-cycle OTEC systems: Hydraulic scaling; effect of seawater versus fresh water on the performance and operation of open-cycle OTEC heat exchangers; performance of heat exchangers as a function of non-condensible gases, flow parameters, enhancement mechanisms, and temperature difference.

Approach/Present Tasks:

- Investigate instrumentation improvements, vacuum line control and analysis, evaporator and condenser tests, and noncondensible gases.

Status/FY 1984 and FY 1985 Accomplishments:

- Preliminary results have indicated that non-condensible gases are released significantly more easily in open-cycle OTEC experiments with seawater than in fresh water laboratory experiments.
- Difficulties in maintaining the vacuum in the experimental apparatus have delayed completion of meaningful evaporator/condenser tests.

FY 1986 Milestones:

- Complete final technical report.

Major Project Reports:

- Krock, H. J.; Zapka, M. J. "Open-Cycle OTEC Non-Condensible Gas Exchange Characteristics." Presented at the 5th International Offshore Mechanics & Arctic Engineering Conference. Tokyo, Japan. April 1986.
- Krock, H. J.; Zapka, M. J. "Non-Condensible Gas Exchange in the OC-OTEC Process —Experimental Seawater Results at NELH." Report 57. J.K.K. Look Laboratory, University of Hawaii. Honolulu, HI. August 1984.
- Krock, H. J. "Gas Analyses of Water Samples for OTEC Program." No. 15. Honolulu, Hawaii. University of Hawaii. Department of Ocean Engineering. 1981.
- Krock, H. J.; Zapka, M. J. (1985). "Open-Cycle OTEC Non-Condensible Gas Exchange Characteristics (abstract)." *Intersol 85: Biennial Congress of the International Solar Energy Society (ISES), June 23-29, 1985, Montreal, Quebec, Canada: Extended Abstracts*. Montreal, Canada: Solar Energy Society of Canada, Inc. p. 335.

Title: Heat and Mass Transfer Research

Contractor:
Solar Energy Research Institute
Midwest Research Institute
1617 Cole Boulevard
Golden, CO 80401

Principal Investigators: D. H. Johnson
J. P. Thornton
Telephone: (303) 231-1752/231-1269

Contract Number: DE-AC02-83C410093

Current Contract Period From: 10/1/83
To: 12/1/85

Research Area: Thermodynamic Research and Analysis

Directing Organization:
Solar Energy Research Institute

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Funding:

Year	Amount	Source
FY 84	$510,000	DOE
FY 85	$540,000	DOE

Objectives: To verify analytical methods with engineering data for the design and performance evaluation of high performance, reliable and cost-effective heat exchangers for use in an open-cycle ocean thermal energy conversion (OTEC) process.

Approach/Present Tasks:

- Development of advanced open-cycle experimental methodology and apparatus.
- Experimental testing and verification on direct-contact evaporation and condensation.

Status/FY 1984 and FY 1985 Accomplishments:

- Single spout evaporators and single stage direct-contact cocurrent and counter-current condenser geometries were experimentally tested and mathematical models of the process were formulated.

FY 1986 Milestones:

- Complete data report on open-cycle OTEC direct-contact condenser geometries.
- Complete analysis report on the experimental data versus theory for direct-contact condensers.

Major Project Reports:

- Bharathan, D.; Althof, J. A.; Parsons, B. *Direct Contact-Condensers for Open-Cycle OTEC Application Volume 1: Analytical Modelling Interim Report.* SERI/TR-252-2472. (Draft).
- Bharathan, D.; Althof, J. A. (1984). *Experimental Study of Steam Condensation on Water in Countercurrent Flow in the Presence of Inert Gases.* 84-WA/Sol-25. New York: The American Society of Mechanical Engineers; 11 pp. Available from: Engineering Societies Library, 345 East 47th Street, New York, New York 10017.

SERI

Title: Study of Non-Chemical Methods of Biofouling Control in OTEC Heat Exchangers

Contractor:
University of Hawaii at Manoa
Hawaii Natural Energy Institute
2540 Dole Street
Honolulu, HI 96822

Directing Organization:
Solar Energy Research Institute

Principal Investigators: P. Takahaski
A. Seki
Telephone: (808) 948-8366

Contract Number: XX-4-04095-1

Current Contract Period From: 8/1/84
To: 5/1/86

Research Area: Thermodynamic Research and Analysis

Project Monitor: M. Linskens
Telephone: (303) 321-1272

Contract Funding:

Year	Amount	Source
FY 84	$90,000	SERI
FY 85	$70,000	SERI

Objectives: To study the use of non-chemical methods of biofouling control in operating OTEC systems, particularly the use of ultraviolet (UV) and ultrasonic irradiation of the heat exchanger inlet water.

Approach/Present Tasks:

- Biofouling buildup is being measured as a function of the intensity, duration, and frequency of UV irradiation of the inlet water, and the intensity of ultrasonic irradiation of the inlet water to heat exchanger elements.

Status/FY 1984 and FY 1985 Accomplishments:

- A variety of tests has been completed with different intensities, duration, and frequencies. Data indicate that both UV and ultrasonic irradiance have only a slight effect on controlling the biofouling of OTEC heat exchangers.

FY 1986 Milestones:

- Complete final report.

Major Project Reports:

- Takahashi, P.K. "Study of the Non-Chemical Methods of Biofouling Control in OTEC Heat Exchangers." SERI/STR-252-2994. (Draft)

Title: Design of a Surface Condenser for Open-Cycle OTEC Systems

Contractor:
Argonne National Laboratory
9600 S. Cass Avenue
Argonne, IL 60439

Directing Organization:
Solar Energy Research Institute

Principal Investigator: C. Panchal
Telephone: (312) 972-8070

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Number: 85493

Current Contract Period From: 10/1/84
To: 9/1/86

Contract Funding:

Year	Amount	Source
FY 85	$160,000	SERI

Research Area: Thermodynamic Research and Analysis

Objectives: To analyze the effects of non-condensibles and to design and test a surface condenser with a low-pressure drop and no by-passing of the condensing surfaces or backmixing with the incoming vapor.

Approach/Present Tasks:

- Continue the theoretical analysis of heat and mass transfer in a surface condenser through the design, fabrication, instrumentation and experimental validation of the surface-condenser test unit.

Status/FY 1984 and FY 1985 Accomplishments:

- Calculations using the ANL-developed performance model have shown that, for better handling of non-condensibles, the condenser should consist of two stages; the main condenser and vent condenser.
- Analysis has shown that experimental validation is necessary to evaluate possible maldistribution of flow and the applicability of analytical methods to laminar flow for steam/gas mixture.

FY 1986 Milestones:

- Complete the design of the surface condenser and an initial test plan.

Major Project Reports:

- Panchal, C. B. (1984). "Heat Transfer with Phase Change in Plate-Fin Heat Exchangers." *AIChE Symposium Series No. 236, Volume 80, 1984.* N. F. Farukhi, editor. pp. 90-97. Presented at the 22nd ASME/AIChE National Heat Transfer Conference. Niagara Falls, NY. August 1984. The American Institute of Chemical Engineers.

Title: System Analysis for Open-Cycle OTEC

Contractor:
Solar Energy Research Institute
Midwest Research Institute
1617 Cole Boulevard
Golden, CO 80401

Directing Organization:
Solar Energy Research Institute

Principal Investigator: H. Link
Telephone: (303) 231-1069

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Number: DE-AC02-83CH10093

Current Contract Period From: 10/1/83
To: 1/9/85

Contract Funding:

Year	Amount	Source
FY 84	$180,000	DOE
FY 85	$145,000	DOE

Research Area: Thermodynamic Research and Analysis

Objectives: To evaluate the cost and performance of open-cycle OTEC by developing and using a numerical system analysis model which is consistent with other program analytical tools and which reflects the best data and algorithms currently available.

Approach/Present Tasks:

- Develop a consensus analytical process with other participating laboratories that leads to common system model structures, comparable component models, and consistent assumptions.
- Update component models as required to reflect new knowledge obtained from laboratory experiments and other research efforts.
- Use the system computer model to assist in the definition of research experiment test articles and operating ranges.

Status/FY 1984 and FY 1985 Accomplishments:

- Added cost algorithms to the open-cycle performance model and modified the resulting model to operate on ANL's Systems Analysis Language Translator (SALT) computer.
- Refined the open-cycle system model by adding a surface-condenser model, and by improving models of direct-contact condensation, passive seawater pre-deaerration, and overall plant cost and economics.
- Use the refined model to assist in the definition of direct-contact and surface-condenser experiments.
- Completed an improved system model which incorporated current experimental and cost data, and which could model off-design plant performance.

FY 1986 Milestones:

- Complete an improved system model that incorporates current experimental and cost data.

Major Project Reports:

- Parsons, B. K.; Bharathan, D.; Althof, J. A. (June 1984). *Open-Cycle OTEC Thermal-Hydraulic Systems Analysis and Parametric Studies*. SERI/TP-252-2330. 8 pp. Prepared for presentation at the Oceans '84 Conference, Washington, DC, September 10-12, 1984. Available NTIS: Order No. DE84013011.
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- Parsons, B. K.; Link, H. F. (September 1985). *System Studies of Open-Cycle OTEC Components*. SERI/TP-253-2794. 10 pp. Prepared for presentation at Oceans '85, San Diego, California, November 12-14, 1985. Available NTIS: Order No. DE85012176.

Title: Pneumatic Wave Energy Conversion System Test

Contractor:
Applied Physics Laboratory
The Johns Hopkins University
Johns Hopkins Road
Laurel, MD 20810

Directing Organization:
Solar Energy Research Institute

Principal Investigator: D. H. Johnson
Telephone: (303) 231-1752

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Number: DE-AC02-83CH10093

Current Contract Period From: 10/1/85
To: 9/1/86

Research Area: Experimental Verification and Testing

Contract Funding:

FY 85	$69,000	DOE

Objectives: To assess the potential of the McCormick Pneumatic Wave Energy Converter (PWEC) by testing the device on the Japanese barge *Kaimei* in the Sea of Japan.

Approach/Present Tasks:

- Continue the experimental testing and data reporting on the PWEC device.

Status FY 1984 and FY 1985 Accomplishments:

- The PWEC device was installed under a subcontract activity on the *Kaimei* and operational and performance data have been collected.

FY 1986 Milestones:

- Complete draft report on *Kaimei* test program data analysis.

Major Project Reports:

- *PWECS Operation and Maintenance Guide.* (August 1985). Plainfield, IL: CBI Industries, Inc.; 58 pp. plus figures and drawings.

SERI

Title: Operation and Maintenance of the Seacoast Test Facility for DOE OTEC Experiments

Contractor:
Research Corporation of the
University of Hawaii
402 Varsity Building
1110 University Avenue
Honolulu, HI 96826

Directing Organization:
Solar Energy Research Institute

Principal Investigator: T. Daniel
Telephone: (808) 329-7341

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Number: XX-4-4057-1
HX-5-5063-1

Current Contract Period From: 6/1/84
To: 9/1/86

Research Area: Experimental Verification and Testing

Contract Funding:

Year	Amount	Source
FY 84	$400,000	SERI
FY 85	$200,000	SERI
FY 85	$200,000	ANL

Objectives: To continue the operation of the Seacoast Test Facility (STF) of the Natural Energy Laboratory of Hawaii (NELH) for the purpose of conducting DOE ocean thermal energy experiments with seawater. (The second contract listed above is a continuation of the first contract.)

Approach/Present Tasks:

- Present tasks include provision and coordination of facilities, services, and operating personnel to meet the requirements of on-going and planned experiments at the Seacoast Test Facility, and coordination of site interface construction for future experiments.

Status/FY 1984 and FY 1985 Accomplishments:

- The STF continued to be operated for DOE OTEC experiments. Site construction for future experiments is progressing.

FY 1986 Milestones:

- Complete and deliver 1985 Natural Energy Laboratory of Hawaii (NELH) Annual Report.

Major Project Reports:

- *Hawaii Natural Energy Institute Annual Report, 1985.* (February 1986). HNEI-6901192. 75 pp. Available NTIS: Order No. DE86901192.

Title: Pneumatic Wave Energy Conversion System (PWECS) Installation and Testing

Contractor:
Applied Physics Laboratory
Johns Hopkins University
Johns Hopkins Road
Laurel, MD 20702

Directing Organization:
Solar Energy Research Institute

Principal Investigator: D. Richards
Telephone: (301) 953-5000

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Number: DX-5-05024

Current Contract Period From: 12/15/85
To: 11/18/86

Research Area: Experimental Verification and Testing

Contract Funding:

FY 85	$265,500	SERI

Objectives: To investigate the interactions between the ocean wave field, air chamber, and turbine power-train systems in an at-sea test of a prototype pneumatic wave energy conversion system (PWECS) utilizing the McCormick bi-directional pneumatic turbine design concept.

Approach/Present Tasks:

- An existing turbine prototype will be modified for installation on the *Kaimei* test barge, a test plan and schedule will be developed, and the prototype will be instrumented, installed, and the testing program executed.

Status/FY 1984 and FY 1985 Accomplishments:

- The prototype which was shipped to Japan and installed on the *Kaimei* barge was modified and tested using compressed air and shown to be functionally operational. An analysis of the compressed air testing results and documentation of the at-sea instrumentation has been completed.

FY 1986 Milestones:

- Complete the testing of the PWEC device.

Major Project Reports:

- Richards, D.; Weiskopf, F. B., Jr. McCormick Turbine-Pneumatic Wave Energy Conversion System (PWECS) Prototype Model Design and Performance Testing. (Draft).
- Richards, D.; Weiskopf, F. B.; Ritzcovan, P. J. (1984). *Pneumatic Wave Energy Conversion System Program Developments*. 84-WA/Sol-29. New York: The American Society of Mechanical Engineers; 8 pp. Available from: Engineering Societies Library, 345 East 47th Street, New York, New York 10017.
- Richards, D.; Seward, J. S.; Weiskopf, F. B., Jr.; Burcher, E. S. (1984). "Study of Utilization and Management of Power Generated by a Pneumatic Wave Energy Conversion System," *Alternative Energy Systems, Electrical Integration and Utilization; Proceedings of the Conference held at the Coventry (Lanchester) Polytechnic, Coventry, England, September 10-12, 1984*, West, M. et al., eds. Oxford, New York: Pergamon Press; pp. 191-204.
- *PWECS Operation and Maintenance Guide*. (August 1985). Plainfield, IL: CBI Industries, Inc.; 58 pp. plus figures and drawings.

Title: Definition and Evaluation of Innovative Concepts for Resource Extraction

Contractor:
Solar Energy Research Institute
Midwest Research Institute
1617 Cole Boulevard
Golden, CO 60439

Directing Organization:
Solar Energy Research Institute

Principal Investigator: H. Link
Telephone: (303) 231-1069

Project Monitor: B. Shelpuk
Telephone: (303) 231-1759

Contract Number: DE-AC02-83CH10093

Current Contract Period From: 5/1/84
To: 4/1/86

Contract Funding:

Year	Amount	Source
FY 85	$89,000	DOE

Research Area: Materials and Structural Research

Objectives: To identify and evaluate innovative approaches to deliver cold water to advanced ocean energy conversion plants and identify the research necessary to achieve the potential cost savings of these approachs.

Approach/Present Tasks:

- Perform a technical review of innovative concepts for the delivery of cold seawater.
- Develop one or more of the concepts to the point where an evaluation can be made as to its potential for significant cost reduction and the necessity for research breakthrough.

Status/FY 1984 and FY 1985 Accomplishments:

- A letter report was submitted to the Department of Energy (DOE) in which four concepts were identified as offering the potential to reduce costs of seawater piping systems.

FY 1986 Milestones:

- Complete preliminary evaluation of advanced concepts.

Major Project Reports: None to date.

Title: Evaluation of a Soft Cold-Water Pipe Concept for Land-Based OTEC Plants

Contractor:
Marine Development Associates
P.O. Box 3409
Saratoga, CA 95070-1409

Directing Organization
Solar Energy Research Institute

Principal Investigator: J. Wenzel
Telephone: (408) 741-1263

Project Monitor: H. Link
Telephone: (303) 231-1069

Contract Number: XX-5-05066-1

Current Contract Period From: 11/15/85
To: 5/15/86

Contract Funding:

Year	Amount	Source
FY 85	$130,000	DOE

Research Area: Materials and Structural Research

Objectives: To evaluate the viability of a soft cold-water pipe operation by performing a preliminary evaluation and by identifying major technical issues.

Approach/Present Tasks:

- Perform a preliminary specification of component costs including estimated material, fabrication, and deployment costs with the rationale for each.
- Perform a design analysis including deployment and in-place pipe loads, stress analysis, and required material strength properties.
- Perform configuration trade-off studies, develop deployment, maintenance, and repair scenarios, and complete a risk assessment study.
- Prepare a test plan that describes a method, a scaled-down pipe configuration, necessary measurements, and procedure for evaluation of results.

Status/FY 1984 and FY 1985 Accomplishments:

- Contract to be initiated in FY 1986.

FY 1986 Milestones:

- Complete preliminary and final analysis and deliver final report.

Major Project Reports: None to date.

SERI

Title: Geotechnical Properties and Measurements for Steep-Slope Areas With OTEC Development Potential

Contractor:
Naval Ocean Research and Development Activity
U.S. Department of the Navy
NSTL, Mississippi 39529

Principal Investigator: P. Valent
Telephone: (601) 485-4621

Contract Number: DX-5-05037-1

Current Contract Period From: 4/1/85
To: 6/1/86

Research Area: Oceanographic, Environmental, and Geotechnical Research

Directing Organization:
Solar Energy Research Institute

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Funding:

Year	Amount	Source
FY 84	$65,000	SERI

Objectives: To assess the technology capability for making geotechnical measurements and, in cooperation with other program participants, develop an understanding of the seafloor in steep-slope areas.

Approach/Present Tasks:

- Technology assessment of geotechnical surveying capabilities for continental slope areas.
- Technology development plan definition.
- Generic characterization of steep-slope sub-bottom properties.

Status FY 1984 and FY 1985 Accomplishments:

- Archived oceanographic data was researched and released to other program participants investigating steep-slope seabeds.

FY 1986 Milestones:

- Complete final report.

Major Project Reports:

- Valent, P.; Riggins, M. "Technology Development Plan: Geotechnical Survey Systems for OTEC Cold-Water Pipes." (In progress.)

Title: Steep-Slope Seabed Assessment

Contractor:
University of California at Berkeley
Marine Sciences Group
Berkeley, CA 94720

Principal Investigator: P. Wilde
Telephone: (415) 642-6535

Contract Number: XX-5-05000-1

Current Contract Period From: 1/1/85
To: 4/1/86

Research Area: Oceanographic, Environmental, and Geotechnical Research

Directing Organization:
Solar Energy Research Institute

Project Monitor: M. Linskens
Telephone: (303) 231-1272

Contract Funding:

Year	Amount	Source
FY 84	$258,000	SERI
FY 85	$132,000	SERI

Objectives: To investigate the geologic, geophysical, and geotechnical properties of the seafloor at steep-slope areas. To identify procedures for design and construction of ocean-energy related structures and their foundations; and to investigate the interrelationships of the ocean and ocean energy plants by studying oceanographic and environmental phenomena.

Approach/Present Tasks:

- Generic steep-slope assessment and identification of marine sediment types.
- Evaluation of side-scan mosaic systems.
- Model tests of the effects of steep-slope processes on ocean energy structures.
- Physical modeling of coastal zone effects of large volume OTEC water flows.
- Coastal zone impacts of OTEC construction/installation/operation.
- Biochemical simulations to assess biological and chemical impacts of OTEC plant operations.

Status/FY 1984 and 1985 Accomplishments:

- Physical modeling of the steep-slopes around Keahole Point, Hawaii were completed.

FY 1986 Milestones:

- Complete final technical reports.

Major Project Reports:

- Dengler, A. T., Jr. (March 1986). *Application of Avalanche Numeric Models to Turbidity Currents on Steep-Slopes; Steep-Slope Numeric Models; Year One Report.* MSG-86-001. Berkeley, CA: University of California; 38 pp.
- Harms, V. W.; Dengler, A. T., Jr. (September 1985). *Seawater-Discharge Analysis and Effluent-Plume Characteristics for the STF-Upgrade Project (Ke-ahole Point, Hawaii).* MSG-85-020. Berkeley, CA: University of California; 157 pp.
- Heuchling, P. (1985). *Lift-Off Phenomena: Three Dimensional Turbulent Density Currents on a Steep Slope in a Linearly Stratified Environment.* MSG-85-028. Berkeley, CA: University of California; 52 pp.
- Liang, H. B. (1985). *Three-Dimensional Density Current Study; Cold Effluent Discharge Hydraulics, an Application to Hawaii OTEC Pilot Plant Project at Kahe Point, Oahu.* MSG-85-027. Berkeley, CA: University of California; 163 pp.
- Schwab, W. C.; Chase, T. E.; Normark, W. R.; Wilde, P.; Seekins, B. A. (1986). *Generic Assessment of Steep-Slope Seabed Environments: Identification of Sediment Cover and Evaluation of Seabed Sonar Systems for OTEC Site Mapping.* MSG-86-004. Berkeley, CA: University of California; 75 pp.

SERI

Title: Study of Non-Chemical Methods of Biofouling Control in OTEC Heat Exchangers

Contractor:
Naval Ocean Research and
Development Activity
U.S. Department of the Navy
NSTL, Mississippi 39529

Directing Organization:
Solar Energy Research Institute

Principal Investigator: P. Valent
Telephone: (601) 485-4621

Project Monitor: M. Linskens
Telephone: (303) 321-1272

Contract Number: DX-5-05037-1

Contract Funding:

Year	Amount	Source
FY 84	$65 000	SERI

Current Contract Period From: 4/1/85
To: 1/1/86

Research Area: Oceanographic, Environmental, and Geotechnical Research

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Objectives: To assess the technology capability for making geotechnical measurements and, in cooperation with other program participants, to develop an understanding of the seafloor in steep-slope areas.

Approach/Present Tasks:

- This effort comprises three tasks: (1) technology assessment of geotechnical surveying capabilities for continental slope areas, (2) technology development plan definition, and (3) generic characterization of steep-slope, sub-bottom properties.

Status/FY 1984 and FY 1985 Accomplishments:

- Archived oceanographic data was researched and released to other program participants investigating steep-slope seabeds.

FY 1986 Milestones: None.

Major Project Reports: None.

Appendix A

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Appendix B

Acronyms and Abbreviations

ANL	Argonne National Laboratory
AOP	Annual Operating Plan
CWP	cold-water pipe
DOE	Department of Energy
DOE/HQ	Department of Energy Headquarters
ETEC	Energy Technology Engineering Center
GW	gigawatt
HOST	Hawaiian Ocean Science and Technology
kW	kilowatt
mm	millimeter
MW	megawatt
MW_e	megawatt electric
MYPP	multiyear program plan
NELH	Natural Energy Laboratory of Hawaii
NOAA	National Oceanic and Atmospheric Administration
OET	Ocean Energy Technology
OTC	Ocean Thermal Corporation
OTEC	Ocean Thermal Energy Conversion
PC	personal computer
PL	Public Law
POCE	proof of concept experiment
ppb	parts per billion
PWEC	pneumatic wave energy converter
R&D	research and development
SALT	Systems Analysis Language Translator
SERI	Solar Energy Research Institute
STF	Seacoast Test Facility
TBD	to be determined
UV	ultraviolet
WBS	work breakdown structure

Appendix C
Index of Contractors

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