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Volume 3, Number 6 (June 1979)

The Solar Ocean Energy Liaison

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Solar OCEAN ENERGY Liaison

INCORPORATING
The OTEC Liaison

VOLUME 3, NUMBER 6
June 1979

OCEAN WATER WILL POWER ELECTRICAL-GENERATING PLATFORM COMMISSIONED IN HAWAIIAN CEREMONY

Test Platform Will Operate 24 Hours a Day

The world's first at-sea power plant that will use sea water as "fuel" to generate electricity was commissioned in Honolulu May 29th in a formal Hawaiian ceremony.

The 50-kilowatt floating power plant, called Mini-OTEC (Ocean Thermal Energy Conversion), will use the ocean's warm surface water and cold subsurface water to vaporize and condense ammonia in a closed system which, functioning as a heat engine, will power a turbine generator.

Mini-OTEC was funded by the State of Hawaii, the Lockheed Missiles and Space Company, and the Dillingham Corporation. Lockheed performed the conceptual and system designs of the power plant.

Mini-OTEC began operation in June and will demonstrate that usable levels of electric power can be developed directly from natural heat stored in the vast ocean reservoir—thus pointing the way to commercial application.

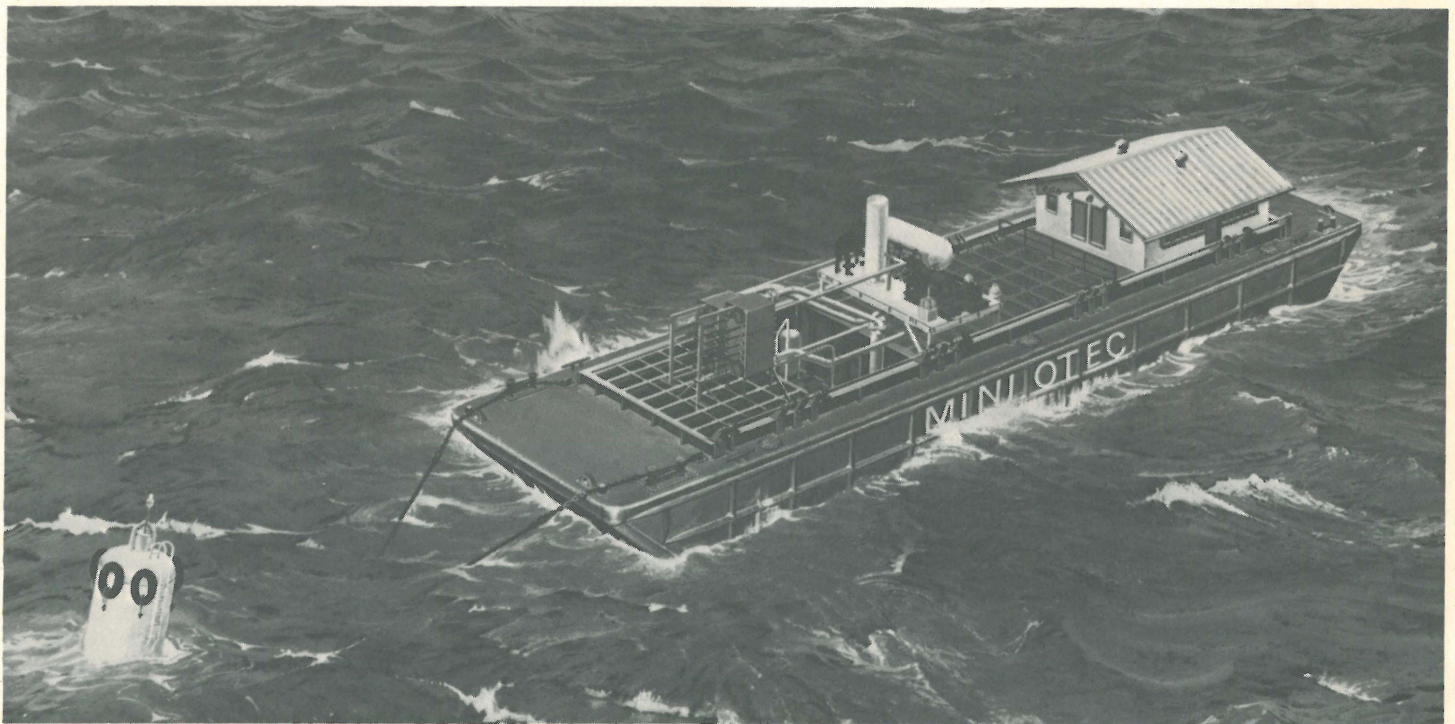
The ocean power plant is mounted on a modified Navy barge to be anchored about a mile and a half (2.4 kilometers) off Keahole Point on the west coast of the Island

of Hawaii. The barge will carry all of the power-plant apparatus. A cold-water pipe that will descend to about 2,170 feet (663 meters) to tap the cool water essential to the OTEC power cycle will be suspended from a buoy floating adjacent to the plant.

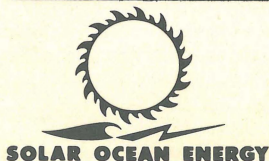
The Mini-OTEC project will generate about 50 kilowatts—15 of which will be fed into test loads aboard the barge. The other 35 kilowatts will power pumps, lights, test instruments, and other plant machinery.

Work on the Mini-OTEC project began last September with the announcement by

(continued on Page 4)



This painting shows the Mini-OTEC power plant as it appears at its operational site off the Kona Coast of the Island of Hawaii. Mini-OTEC was commissioned May 29th in a Honolulu ceremony. The 50-kilowatt demonstration plant began operation in June in 3500 feet of water. Mini-OTEC was funded by the State of Hawaii, Lockheed Missiles and Space Company of Sunnyvale California, and the Dillingham Corporation of Honolulu, with Alfa-Laval of Sweden contributing the two titanium heat exchangers. Other firms involved in the project include the Rotoflow Corporation of Los Angeles, which supplied the turbine-generator; the Worthington Pump Company of Philadelphia, which provided the sea-water pumps; Phillips Driscopipe Incorporated of Dallas, which supplied the cold-water pipe; and the B. F. Goodrich Rubber Company of Akron, which provided the flexible cross-over hose to connect the cold-water pipe to the barge platform. The test platform is expected to remain in operation 24 hours a day at its Keahole Point site.



IN THIS ISSUE: *Mini-OTEC, world's first OTEC demonstration producing net power: Page 1..... New developments on OTEC work in Japan: Page 6..... Eurocean's OTEC program: Page 3..... Other Ocean Energy projects: Waves: Pages 7, 8..... Tidal: Page 10..... Current: Pages 10, 11..... Biomass: Page 12*

Solar
OCEAN ENERGY
Liaison

INCORPORATING
The OTEC Liaison

AN INTERNATIONAL NEWSLETTER
ENGAGED AS LIAISON FOR ALL
FORMS OF SOLAR ENERGY FROM
THE SEA, INCLUDING:

OTEC
(OCEAN THERMAL
ENERGY CONVERSION)
WAVE - TIDAL - CURRENT
OFFSHORE WIND - BIOMASS
SALINITY GRADIENTS

VOLUME 3, NUMBER 6
June 1979

EDITOR/PUBLISHER
Richard Arlen Meyer

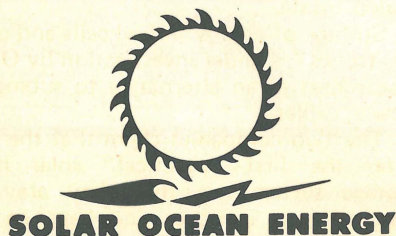
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Mildred Ward

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Letter From The Publisher

After more than a year's consideration, we have decided to change the name of our publication from *The OTEC Liaison* to *Solar OCEAN ENERGY Liaison* with this issue, which will be distributed gratis at the Sixth Annual OTEC Conference in Washington DC June 19th through 22nd.

Among the various forms of energy from the sea under investigation throughout the world, Ocean Thermal Energy Conversion (OTEC) is by far the single most important option based on the number of countries involved and the depth of involvement in funding, research, and history.

Solar OCEAN ENERGY Liaison will, therefore, continue to focus predominantly on OTEC. But other forms of ocean energy, particularly wave, current, and tidal, are receiving increased attention. While these other ocean energy forms have been mentioned in past issues of TOL, they will receive amplified coverage in the future.

Two other major reasons for the name change are (1) the difficulty lay persons have with the acronym "OTEC", even *after* it is spelled out, and (2) the fact that since ocean energy is obviously one of the solar-energy options with the greatest potential, we felt the word "solar" should be a permanent part of our name.

While the US Department of Energy rightly includes its Ocean Systems Branch in its Solar Division, other agencies still somehow separate solar energy from energy from the sea. An example is the June 11th article in *Time* titled "Energy: Fuels of the Future".

But, with the current energy situation having a vast effect not only on Americans' driving habits, but even more on worldwide economic issues, increasing attention is being given to the future of solar energy.

Organizations such as The Solar Coalition, the Solar Lobby, and the Solar Energy Industries Association are making themselves heard not only by the general public, but in governmental circles as well. With anti-nuclear protests increasing throughout the world, solar energy is finally beginning to receive the attention it deserves.

Solar OCEAN ENERGY Liaison intends to provide the same service in the future that *The OTEC Liaison* has in the past: to act as *liaison* and provide a forum for the international ocean energy community. We invite your participation.

Sincerely yours,

Richard Arlen Meyer

WHAT AN OPPORTUNITY!

As a special inducement to build the subscriber base to *Solar OCEAN ENERGY Liaison*, a *very* substantial discount price for *new subscriptions only* will be available to those attending the Sixth Annual OTEC Conference, to be held at the Shoreham American Hotel in Washington DC June 19th through 22nd.

Solar OCEAN ENERGY Liaison (SOEL) has an exhibit booth (Number 15) at the Conference under its former name, *The OTEC Liaison*. Visitors to the booth will see the *special reduced subscription price* displayed.

This offer is being extended to *new subscribers only*, and will expire at the end of the Conference.

This is an excellent opportunity to receive a year's subscription to SOEL at a very substantial saving.

OTEC BIOFOULING ARTICLE IN NEW MTS JOURNAL

An article titled "The Microfouling Problem and the Future of the OTEC Program", by Dr. William A. Corpe of Columbia University, appears in the current issue of the *Marine Technology Society Journal*.

TIME ARTICLE INCLUDES BRIEF MENTION OF OTEC/OCEAN ENERGY

In a copyrighted article in the June 11th issue of *Time* entitled "Energy: Fuels of the Future", various alternatives to coal, oil, and nuclear energy are briefly summarized, with estimates of their present status and potential.

Included in the article are paragraphs devoted to such alternative energy sources as shale, tar sands, geothermal energy, and coal gasification. "Solar" and "The Sea" are treated separately, and even wind power is treated separately rather than being included under "solar energy", as this editor feels it should be.

Under "The Sea", current, wave, tidal power, and Ocean Thermal Energy Conversion (OTEC) are mentioned. Direct quotes from the article cannot be published here, since permission to do so could not be secured in time for this issue. However we expect to reprint portions of the article in an early issue of *Solar OCEAN ENERGY Liaison*.

EUROCEAN'S OTEC PROJECT

Five-Year Plan Involves \$50 Million

(Editor's note: The information below is excerpted from a paper to be presented at the Sixth OTEC Conference. A pre-print of this paper was received by this publication in early May, but has not been quoted until now at the request of its author, B. Lachman, the Director General of Eurocean, to coincide with its distribution at the conference.)

While Eurocean is an association of European industrial companies—25 firms from nine countries, including France—the French decided last fall to pursue an independent OTEC program. That program was outlined in detail in the December 1978 issue of *The OTEC Liaison*.

Eurocean has proposed a 10 MWe floating closed-cycle pilot plant. The proposed program runs over a period of five years and involves about 50 million US dollars "requiring government funding". Another group within the Eurocean organization has begun an aquaculture feasibility study involving the combination of artificial upwelling with a small land-based OTEC plant and a desalination plant.

Funding Differs From US

Lachman's paper points out that while funds for such projects are available in the US in governmental programs, funding for this type and size of development work does not exist in Europe, "but can be established on an ad-hoc basis". In a survey of alternative sources of funds for this project—national institutions, international institutions, regional private organizations, national development banks, and foundations—governmental funding was found to be most appropriate, and is now being sought.

OTEC-10 MWe Pilot Plant

The Eurocean OTEC group was reorganized in Brussels in February 1979, and now includes the following member companies: Alfa-Laval of Sweden, the Banque Europeenne de Credit of Belgium, the Hollandsche Beton Group of the Netherlands, the Johnson Group of Sweden, Kockums of Sweden, Micoperi of Italy, Tecnomare of Italy, and Vattenbyggnadsbyran of Sweden.

A decision was reached earlier this year to prepare a proposal for a floating OTEC 10MWe closed-cycle pilot plant to accompany applications for funds to the Dutch, Italian, and Swedish Governments. This proposal was completed in April. The purposes of building a pilot plant of this size are: (1) to test the OTEC systems with full-size modules and sufficiently large components; (2) to verify the cost estimates for the commercial plant and thereby either reduce or eliminate the "safety" margins in the present prelim-

inary cost estimates; (3) to verify the possibilities of less-expensive technical solutions in the future, such as less costly materials; and (4) to facilitate future marketing.

Aiming at Commercial Operation

Thus the immediate objectives are to detail planning of the technical development of OTEC systems, and to obtain funds for this work. Technical development work aiming at commercial operations is now being continued by some of the member companies.

At this point it appears that Eurocean's current OTEC work and future operations depend on funding. As Lachman's paper states: "Accordingly, we have started the laborious process of obtaining such funding."

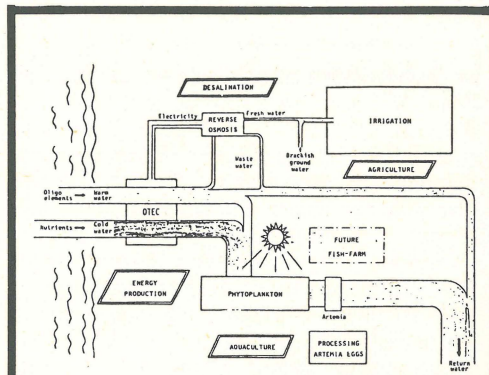


Figure 6: Plant Block Diagram

COMBINED AQUACULTURE, OTEC AND DESALINATION PROJECT

Another Eurocean project is related to the OTEC project, but, from a development point of view, is an aquaculture project. A decision has been made by eight member companies, some of which are participating in the OTEC project, to perform a six-month feasibility study on a combined aquaculture/OTEC/desalination project aiming at a commercial aquaculture and desalination operation with a small-scale OTEC plant. Figure 6 shows a preliminary block diagram for this combined system, and Figure 7 shows a possible first step in the development of an aquaculture pilot plant.

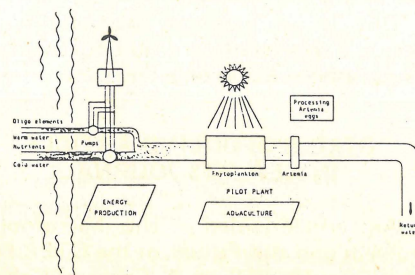


Figure 7: Possible First Stage

US AND FRANCE MAY CO-OPERATE ON OTEC RESEARCH

At a meeting held in Washington DC May 7th through 9th, officials from the United States and France met for the sixth time to discuss collaboration on oceanographic programs. Included in the discussions were initial explorations of future co-operation on both OTEC and biomass research.

Gerald Piketty, Director General of France's National Center for the Exploration of the Oceans (CNEXO), said that while ten programs in other scientific and technical areas have been agreed on, OTEC has not yet been definitely included, but is being considered.

CHINA IS WATCHING OTEC

In addition to representatives from the People's Republic of China attending OTEC conferences, correspondence devoted to OTEC and desalination is being pursued by Dr. Bryn Beorse of the University of California and the Director of the PRC's Shandong College of Oceanology.

SOLAR EXPORT SEMINAR SET

A one-day seminar to inform the solar industry on solar export opportunities will be held June 22nd in Denver, Colorado under the sponsorship of the Solar Energy Research Institute of Golden, Colorado.

US, CHINA REACH ACCORD ON OCEAN AGREEMENTS

On May 8th, US Commerce Secretary Juanita M. Kreps announced in Beijing (Peiping), People's Republic of China, that a historic agreement had been signed calling for close collaboration between oceanographers of the US and China for the first time.

NEW THERMAL BATTERY ANNOUNCED FOR STORING SOLAR ENERGY

The Dow Chemical Company of Midland, Michigan and Pipe Systems Incorporated of St. Louis have announced a new thermal battery for the economical storage of heat from solar energy. The device is a six-foot rod, three and a half inches in diameter, that is basically a high-density polyethylene container with calcium chloride hexahydrate permanently sealed inside.

Storage of energy in fuel cells and other "batteries" is under investigation by OTEC researchers as an alternative to submarine power cables.

The two companies claim that the rods offer the first "practical" solar heat-storage systems, in that they are economical and compact and have an expected life of 20 to 40 years.

MINI-OTEC PROGRAM OBJECTIVES

DEVELOP AN OPERATING OTEC SYSTEM

EXPAND PUBLIC AWARENESS OF OTEC POTENTIAL

USE OPERATING SYSTEM AS "RISK-REDUCTION" TESTBED FOR OTEC-1 AND BEYOND

GAIN "REAL WORLD" OPERATING EXPERIENCE OF AN OTEC SYSTEM

PROVIDE A SUBSYSTEM, COMPONENT, AND TECHNOLOGY TEST FACILITY

NEW POWER OUTPUT WILL PROVE VIABILITY OF OTEC

ADDITIONAL PARTICIPANTS BEING SOLICITED TO EXPAND TECHNICAL DATA BASE

OCEAN WATER WILL POWER ELECTRICAL-GENERATING PLATFORM COMMISSIONED IN HAWAIIAN CEREMONY

(continued from Page 1)

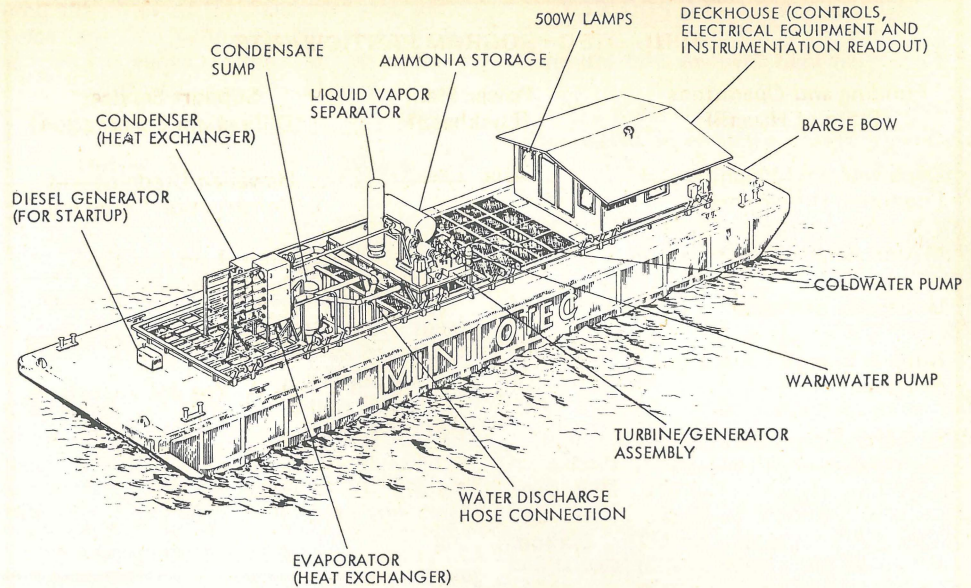
Hawaii Governor George R. Ariyoshi that the State would participate in and help fund the unique energy demonstration.

Ariyoshi called it "another historic step toward Hawaii's long-term goal to become energy self-sufficient... a small step technologically, but critical to the anticipated success of giant generating plants of the future."

Lockheed Mini-OTEC Program Manager Delbert N. Burwell says the demonstration plant, which will operate around the clock during its test period of six months, "is an important step toward finding supplemental sources of benign, non-polluting energy."

Mini-OTEC operations will be under the direction of Hank White, Operations Manager of the Hawaii Natural Energy Laboratory, a state agency. White and Joseph F. Rynewicz of Lockheed originally proposed Mini-OTEC as a demonstration system. "The potential of this project for providing electrical power from a renewable fuel source cannot be over-emphasized," said White. "Mini-OTEC will demonstrate the technical feasibility of tapping ocean thermal resources, and could play an important role in the energy economy of tropical islands in the foreseeable future."

Among those who witnessed the May 29th ceremony were members of the Hawaiian Congressional delegation and officials of the Hawaii State Government, the Lockheed Missiles and Space Company of Sunnyvale, California; the Dillingham Corporation of Honolulu; and Alfa-Laval



of Sweden. Speakers included US Senator Spark M. Matsunaga (D-Hawaii), Governor Ariyoshi, and Dr. John Craven, State Marine Affairs Co-ordinator. Hideto Kono, Director of the Hawaii Department of Planning and Economic Development, was master of ceremonies.

Among others attending the ceremony was Lockheed Corporation Vice-President H. Potter Kerfoot, General Manager of the Advanced Systems Division at Lockheed Missiles and Space Company. Kerfoot noted that Mini-OTEC is the culmination of nearly five years' work, beginning when Lockheed won one of two parallel contracts from the National Science Foundation to study the engineering and economics of the OTEC concept.

Functional responsibility for the Mini-OTEC project is as follows: Lockheed designed and built the power plant, heart of the system; Dillingham modified and outfitted the loaned barge, assembled the system, and transported the cold-water pipe and barge to the operations site; and the State of Hawaii directed and supported operation of the system through the Natural Energy Laboratory of Hawaii and the State Department of Planning and Economic Development. The State also funded the 2,170-foot polyethylene cold-water pipe and the modification of the barge which is being used as the plant machinery platform.

A major contributor to the project was
(continued on Page 8)

MINI-OTEC FACTS

Barge

(converted US Navy craft)
Length: 120 feet (37 m.)
Beam: 34 feet (10 m.)
Deck to Keel: 12 feet (3.7 m.)
Displacement: 268 long tons (272.29 metric tons)

Cold-Water Pipe

Material: polyethylene
Length: 2,170 feet (663 m.)
Diameter: 24 inches (0.6 m.)
Water Flow: 2,700 to 3,300 gallons/minute (102,600 L. to 125,400 L.)
Water Temperature: constant 41 degrees F. (5 degrees C.)

Warm Water

Flow: 2,700 to 3,300 gallons/minute (102,600 L. to 125,400 L.)
Temperature: 75 to 80 degrees F. (24 to 27 degrees C.)

Ammonia

Storage Capacity: 879 gallons/115 feet³ (33,060 L./3.2 m³.)
Flow: 5.1 lb./sec. (60 gallons/minute for liquid) (2.5 Kg./sec.)

Electricity

(continuous operation) **Test Platform Will Operate 24 Hours a Day**
Generate: 50 kw
Net: 15 kw

MINI-OTEC PROGRAM PARTICIPANTS

Funding and Operations (State of Hawaii)	Power Plant (Lockheed)	Support Services (Dillingham Corporation)
Department of Planning and Economic Development	Alfa-Laval	Hawaiian Dredging and Construction Company
Marine Affairs Co-ordinator	Rotoflow	Dillingham Maritime Pacific Division
University of Hawaii		Makai Ocean Engineering
Natural Energy Laboratory of Hawaii		A. A. Yee and Associates
Research Corporation of the University of Hawaii		Parsons, Hawaii
		Dames and Moore
		Phillips Driscopipe
		Worthington Pump

TECHNICAL DETAILS AND SPECIFICATIONS OF THE MINI-OTEC PROGRAM

The information below is excerpted from a paper authored by F. McHale of the Dillingham Corporation which was presented at the 11th Annual Offshore Technology Conference (OTC) held in Houston April 30th through May 3rd. The paper is entitled "Construction and Deployment of an Operational OTEC Plant at Kona, Hawaii".

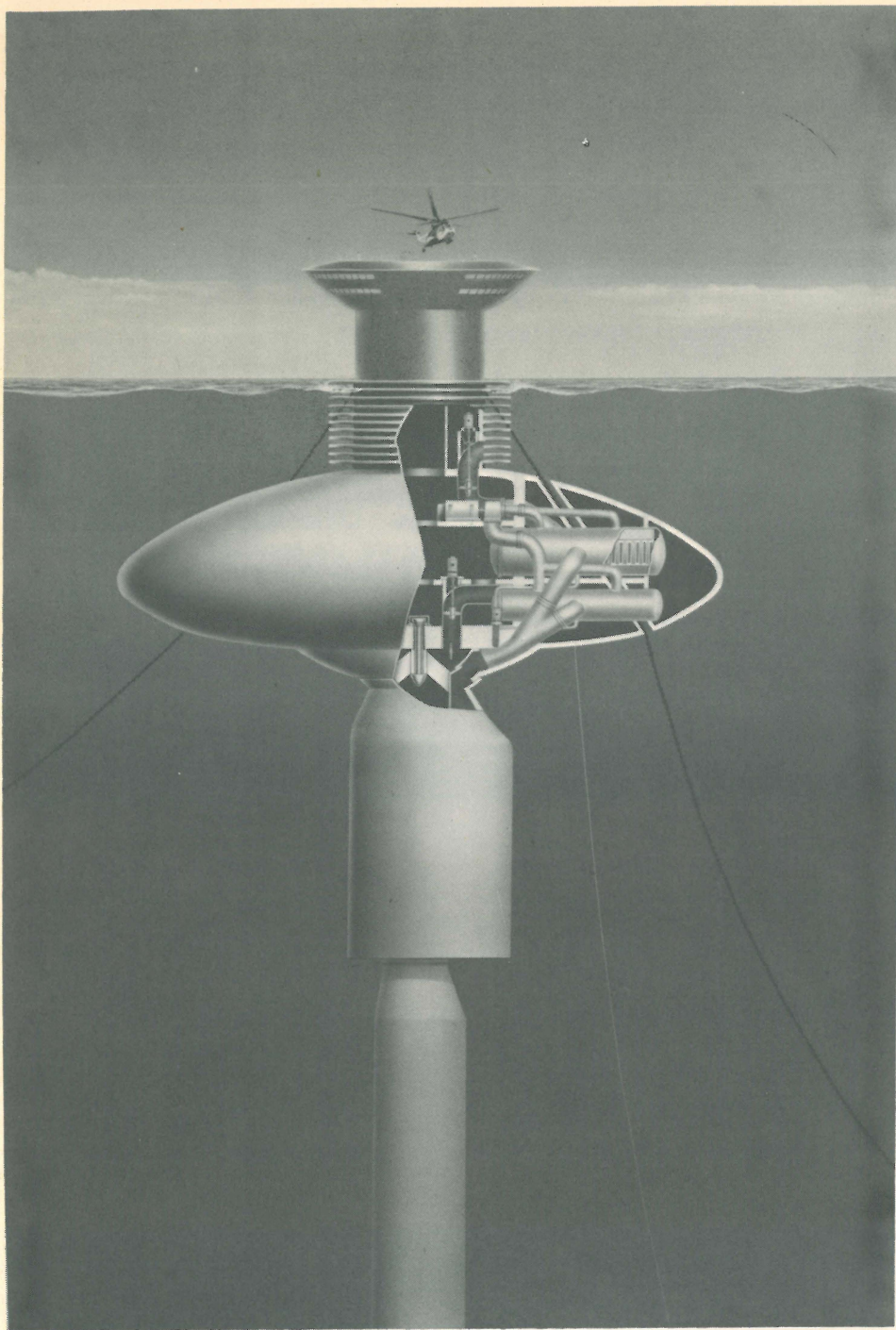
OTEC Platform

The US Navy YGN-70 is a non-self-propelled open-hopper dump scow. It was selected because of the relative ease of adapting the barge to accept the cold water, warm water, and effluent piping systems, and because of its low rental cost. The YGN-70 is a 120-by-33-foot rake-ended barge without skags, equipped with

(continued on Page 9)



This photo, received by Solar OCEAN ENERGY Liaison just prior to press time, shows the ready-to-go, ready-to-tow Mini-OTEC facility. The completely outfitted pilot plant was photographed immediately prior to the commissioning ceremony in Honolulu, from which it was towed to its on-site location off the "Big Island" of Hawaii, at Keahole Point. Mini-OTEC was connected to the already deployed cold-water pipe the week of June 10th, and is expected to be operable just before or during the Sixth OTEC Conference.



An artist's conception of the revised design of a proposed Japanese 100 MWe commercial-scale OTEC plant, intended to reduce the effects of ocean forces.

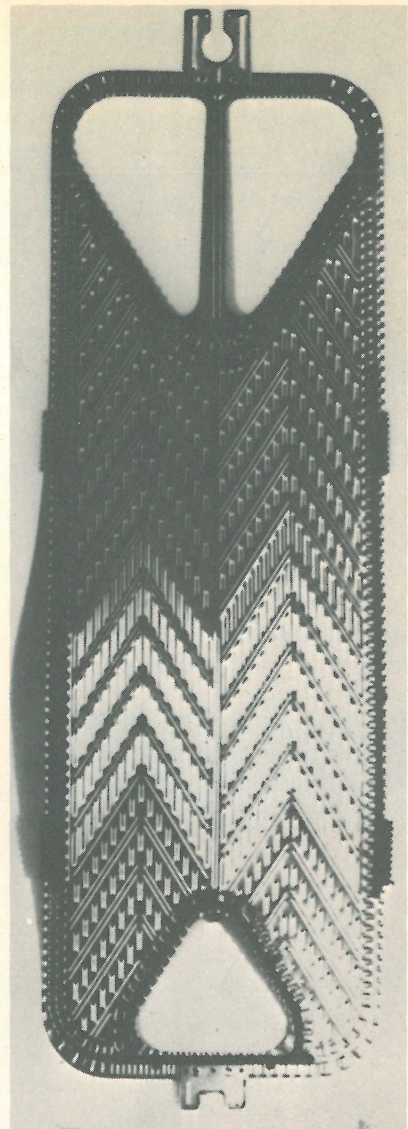
AN UPDATED REPORT ON OTEC DEVELOPMENT IN JAPAN

Extensive coverage of Japan's work on OTEC has been reviewed in earlier issues of *The OTEC Liaison* (see the January, March and September 1978 issues), as that country's progress in the field is second in the world only to that of the US. Additionally, Dr. Abraham Lavi, formerly of the US Department of Energy's Ocean Systems Branch and now back at Carnegie-Mellon University, visited Japan in September 1978, and offered his assessment of that country's progress in our September 1978 issue.

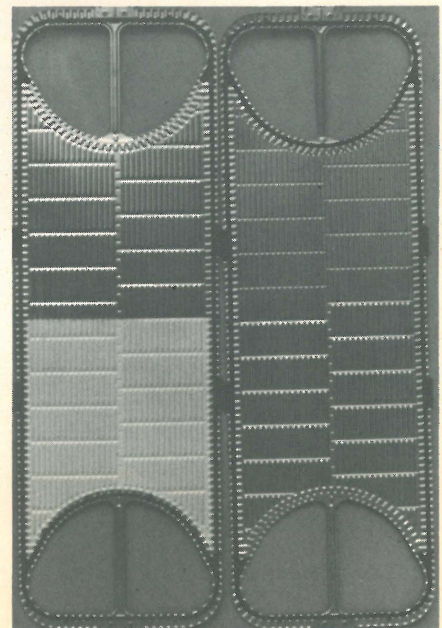
While the Japanese work in biofouling

and corrosion, cold-water-pipe research, and submarine cables still appears to lag behind that of the US, their detailed work in heat exchangers continues to be impressive.

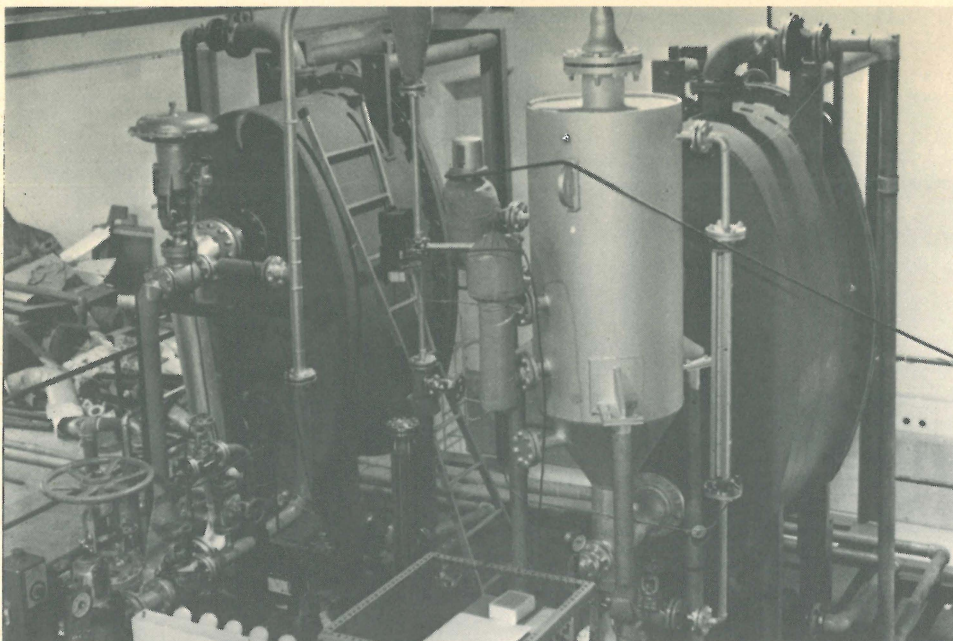
Principal research and development on OTEC continues in Japan at the Electro-technical Laboratory (ETL) in Tokyo, Saga University, Tokyo University, and the Toden Sekkei Company. ETL is a division of the Ministry of International Trade and Industry (MITI), with overall co-ordination of all OTEC work performed by the OTEC Committee of the Japan Heat Management Association, established in 1974. Some corrosion testing has taken place at the Government Industrial Research Institute of Chugoku.



Titanium heat-transfer plates for the condenser.



Titanium heat-transfer plates for the evaporator.



A photo of the 100-kilowatt OTEC plant being tested at Japan's Saga University.

Many large firms of international scope are also participating, including divisions of Mitsubishi Heavy Industry Ltd., Shibaura Electric Company, Ishikawajima-Harima Heavy Industries (the builders of the largest floating factory ever built—the wood-pulp processing plant built in Japan and floated to Brazil), Kawasaki Heavy Industries Ltd., and Hitachi Ships Ltd., among others.

Since the last report in this publication a number of additional developments have taken place and are briefly reviewed below.

(1) Design of a 100 MWe OTEC power plant has been carried out in consideration of the site characteristics of the best two of the five originally considered, one at Osumi and the other at Toyama.

(2) The structural design of a submerged 100 MWe power plant has been revised due to reduction of the effects of external ocean forces. An artist's conception of the revised design accompanies this story.

(3) A test facility for testing single-tube heat exchangers for both ammonia and Freon 22 has been constructed at ETL.

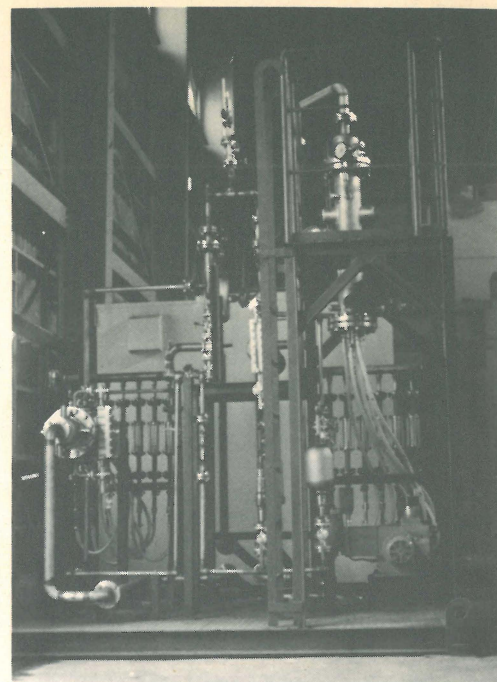
This is the first time heat-exchanger performance using ammonia as a working fluid has been investigated in Japan. (See photograph in this issue.)

(4) Cold-water-pipe simulation testing is under way at Tokai University in cooperation with the Shimizu Construction Company.

(5) Plate-type heat-exchanger research is in progress at Saga University in conjunction with the Hisaka Works Company Ltd. Their fifth such test facility, named "Shiranui 5", is a 100-kilowatt unit, and is illustrated in this issue, as are photos of the heat-transfer plates used in the heat exchangers.

Increased scientific and technical cooperation between the United States and Japan has been agreed on by both governments. (See story in this issue.)

Five technical papers on Japan's OTEC work will be presented at the Sixth OTEC Conference in Washington DC June 19th through 23rd. Following more thorough interpretation of these papers, a detailed treatment of Japanese OTEC research will appear in an early issue of *Solar OCEAN ENERGY Liaison*.



Single-tube heat-exchanger test facility at the Electrotechnical Institute in Tokyo.

US AND JAPAN SIGN ENERGY R&D CO-OPERATIVE AGREEMENT

In early May the Governments of the United States and Japan signed an agreement on co-operation in research and development in energy and related fields.

JAPAN TO TEST NEW SYSTEM OF WAVE ENERGY CONVERSION TO ELECTRICITY

The following article on the current status of research and development of wave energy in Japan appeared in the monthly newsletter of the Centre National Pour l'Exploitation des Oceans, Paris, and has been translated by TOL from the French.

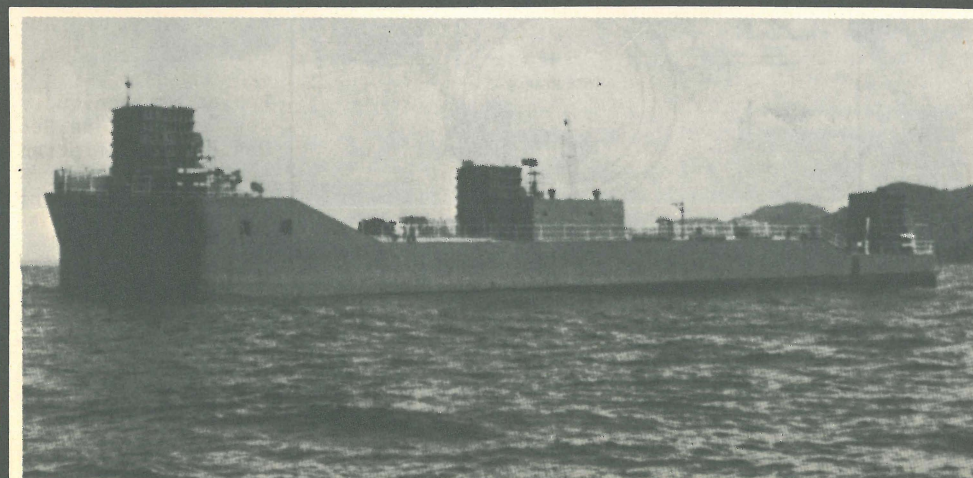
The Japan Marine Science and Technology Center began the study of electricity production from wave energy on a grand scale in 1974.

However wave energy had already been utilized in Japan for several years to supply several hundred luminous buoys with electricity.

Two years of dock tests retained the system of an oscillating water column that was introduced by Yoshio Masuda as the most proficient system of converting wave energy into electricity, construction facility, and watering.

In March 1976 the Japan Marine Science and Technology Center built a barge named *Kaimei*—80 meters long, 12 meters wide, and 500 tons in weight—for the purpose of testing some pneumatic swell converters.

The first sea tests of *Kaimei*, equipped with three pneumatic converters of 125 kilowatts, took place in 1978. These tests will continue in 1979 with the addition of seven more converters.



(continued from Page 4)

Alfa-Laval of Sweden, acting through the Energy Systems Division of Alfa-Laval Thermal Incorporated of South Deerfield, Massachusetts. Alfa-Laval furnished two titanium heat exchangers, major components of the Mini-OTEC power plant.

Other firms involved in the Mini-OTEC project are the Rotoflow Corporation of Los Angeles, which supplied the turbine-generator; the Worthington Pump Company of Philadelphia, which provided the sea-water pumps; Phillips Driscopipe Incorporated of Dallas, which supplied the cold-water pipe; and the B. F. Goodrich Rubber Company of Akron, Ohio, which provided the 175-foot (55-meter), 18-inch (45-centimeter) flexible cross-over hose to connect the cold-water pipe and the barge.

Mini-OTEC, a small-scale version of proposed sea-based generating plants, will gather extensive data that will be applied to current engineering studies of much larger commercial OTEC systems. When scaled up, a 200-megawatt commercial plant could provide for the electrical needs of a city of 200,000 persons.

Ocean Thermal Energy Conversion uses the warm surface waters of the ocean as a heat source and the cold water from the depths as a heat sink. Warm surface water is pumped through a large heat exchanger, where it vaporizes a fluid such as ammonia that has a low boiling point. As does steam in conventional power plants, this gaseous, pressurized ammonia drives turbine generators.

As it leaves the turbines, the ammonia moves through a second heat exchanger, where it is condensed to liquid by the cold ocean water pumped from several thousand feet below the platform. In this closed cycle, the ammonia is used continuously.

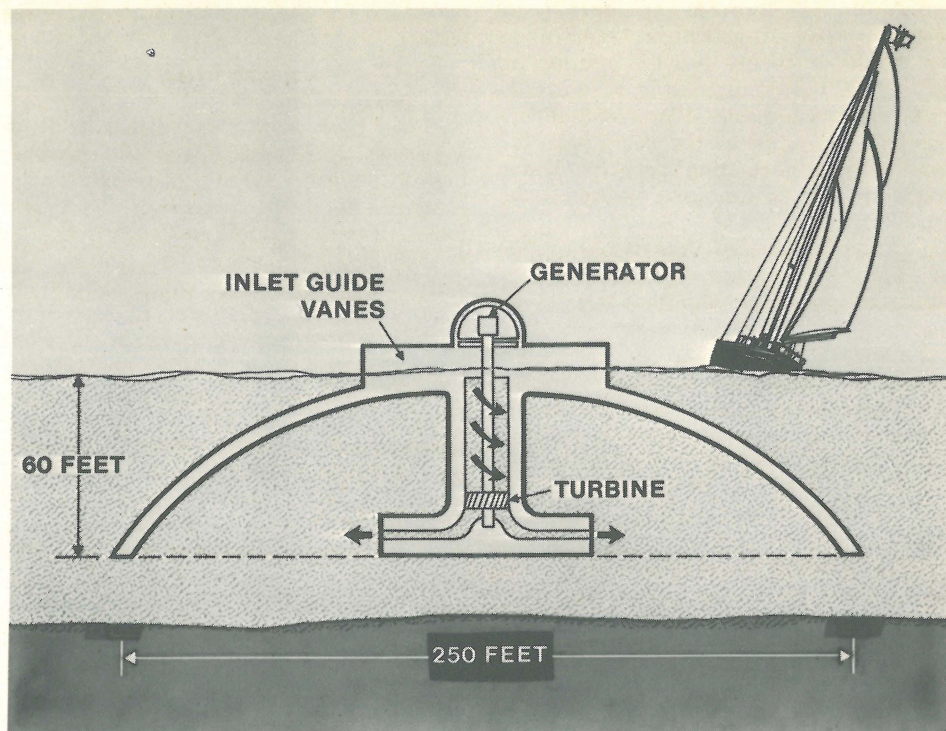
NEW SERI BOND STUDY

SUGGESTS OTEC AND OTHER SOLAR COMMERCIAL FINANCING OPTIONS

A draft study commissioned by the Law Program, Market Development Branch of the Solar Energy Research Institute (SERI) which may be of interest to OTEC planners has just been released.

The study, concerned solely with the legal aspects of tax-exempt bonds, focuses largely on Industrial Development Bonds (IDB), which are tax-exempt and marketable at lower interest rates for projects qualifying for special-activities or small-issue exemptions. OTEC is specifically discussed in the study. Details are available from George Morgan at (303) 231-1269.

LOCKHEED PATENTS "DAM-ATOLL", NEW DEVICE TO HARNESS UNLIMITED ENERGY OF OCEAN WAVES



Cutaway drawing shows Lockheed's Dam-Atoll, newly-patented wave-energy device. Waves arrive at ten-second intervals and are directed into the perimeter of the vertical chamber at the top. The energy is continuously drawn by the turbine wheel at the base of the core. This wheel with its associated shaft is the only moving part of the entire system.

BACKGROUND INFORMATION ON LOCKHEED DAM-ATOLL INVENTION

Culminating an intensive six-year study, two scientist from Lockheed-California's Rye Canyon research facility have been issued a patent by the United States Patent and Trademark Office for developing a revolutionary new device to harness the massive energy of ocean waves, a feat which has eluded mankind since the dawn of civilization.

Research scientists Leslie S. Wirt and Duane L. Morrow have named their ocean-wave energy-extraction device Dam-Atoll.

The Dam-Atoll unit is a dome-shaped artificial atoll 250 feet (75 meters) in diameter that operates when it is completely submerged beneath the neutral level of the sea. Made of concrete, it also bears some resemblance to the convex side of a hydro-electric dam. Hence the name Dam-Atoll.

The two conspicuous features of the now-patented Dam-Atoll are its novelty and simplicity. The novelty is notable in that man has always dreamed of controlling the power of the sea, but this is the first time the dream has been brought into waking reality. The simplicity is that of only one moving part and no intermediate energy conversions.

Leslie Wirt, the son of an automotive-engineering pioneer, likens the physical machinations of the invention to what happens in nature.

"Ancient Polynesian navigators noticed that when waves approached small Pacific volcanic islands called atolls, they didn't just go by them," says Wirt. "The waves wrapped around them. Atolls captured the waves from all sides and brought them into the center in spiral paths.

"What we have done is to build an artificial little island, or atoll, whose shape has been mathematically refined to do the most perfect job of causing the waves to spiral into the center."

Wirt goes on to explain that the water near the center of the unit is shallow. As breakers form, the water enters the central core and creates a large vortex or whirlpool which acts as a giant flywheel. The breakers, massive pulses of kinetic energy, arrive about every 10 seconds and are directed into the perimeter of a vertical chamber at the top. The energy is drawn continuously by a turbine wheel. This wheel with its associated vertical shaft is the only moving part of the system.

40 Megawatts Per Kilometer

The amount of power contained in waves is usually more than 40 megawatts per kilometer of beach. In a typical California community, each house uses at most 2.5 kilowatts of current. Therefore 40 megawatts would provide 16,000 homes with more than enough power to meet all needs.

To take this a step farther, based on an

average of 2.5 people living in each home, 40 megawatts of power would serve 40,000 individuals. According to Wirt, Lockheed's Dam-Atoll will provide an output in the one-to-two-megawatt range per unit. This would in theory provide a string of 500 to 1,000 units situated in ocean areas where there is typically a large amount of wave activity—such as the Pacific Northwest—with a generating capacity comparable to that of the great Hoover Dam.

Applications of Dam-Atoll

Wirt and Morrow, who have been close associates for the last 20 years, said that as the idea was originally conceived, the primary use appeared to be electrical-power generation. But it has since been discovered that there are many other potential applications. What has evolved is apparently the key to beneficial exploitation of the oceans—without burning precious oil.

"Now there is no reason," says Wirt, "to burn our fossil-fuel reserves in order to obtain the riches of the sea."

Fresh Water

The scientists said one of the primary functions of Dam-Atoll will be to provide fresh water for drinking and irrigation. This will benefit many of the Third World powers. There are already a number of practical commercially-built systems for extracting fresh water from the sea, but these devices are powered by steadily-diminishing petroleum resources. According to Wirt and Morrow, wave energy can easily and inexpensively be used instead.

"The Dam-Atoll unit can replace the diesel pumps," says Morrow. "Our wave-energy conversion unit will drive the pumps necessary for the desalinization of the sea water."

Calming Effect

Since Dam-Atoll removes energy from the waves, leaving placid waters in its wake, there is a wide range of possibilities for the creation of artificial harbors. This will facilitate the unloading of dangerous cargo a considerable distance off shore. The width of smooth water will be about the same size as the diameter of each unit.

Wirt and Morrow envision a staggered array of Dam-Atoll units to produce the calm seas necessary for an artificial harbor. Liquid natural gas and oil from super-tankers could be unloaded in the sheltered area of open sea and brought to shore in pipelines, thus averting accidents which might foul an entire coastline. And properly placed, the scientists say, a series of Dam-Atoll units could absorb the energy from destructive coastline waves and protect beaches and property from costly erosion.

Oil Scavenging

Another extraordinary characteristic of Dam-Atoll is that it can scavenge for oil slicks and seepage. In an ordinary type of wave situation, the Dam-Atoll unit ingests about 120 cubic yards (100 cubic meters) of sea water every second. This water is drawn predominantly from the surface of the ocean. If the water contains a film of oil, the oil too is swallowed. As the Dam-Atoll gradually but inescapably collects oil

(continued from Page 5)

five dumping pockets or hoppers. The barge has a depth of twelve feet and an unloaded draft of three feet. The working draft for the Mini-OTEC project is expected to be four feet.

Cold-Water Pipe

The 24-inch polyethylene pipeline which is to serve as a combined cold-water pipe and mooring line will be fused into its final 2,000-foot length on the shore of Kawaihae Harbor, about 20 miles from the deployment site. Using the pipe manufacturer's machinery, pipe joints will be trimmed, squared, and then heated to fusion temperature prior to being hydraulically pushed together to make the joint. As pipe joints are added to the pipeline, the forward end of the pipeline will be pushed over the breakwater to float in the protected harbor waters at Kawaihae.

When filled with air, the polyethylene pipeline floats with the major portion of its body out of the water. The polyethylene has a density of about 0.95, and when the pipe is flooded the pipeline floats with just the upper surface visible above the sea. In the empty configuration the pipeline is influenced by the winds, while in the flooded configuration the pipeline movements are primarily influenced by ocean currents. This means that both wind and current must be monitored at the deployment site.

The use of thru-bolted connections in the polyethylene is felt to be unsuitable, and an arrangement using external bolted clamps and an internal compression sleeve was used. This provides the required tension connection in the mooring. All steel items used in the mooring were treated by galvanizing or epoxy protective coatings.

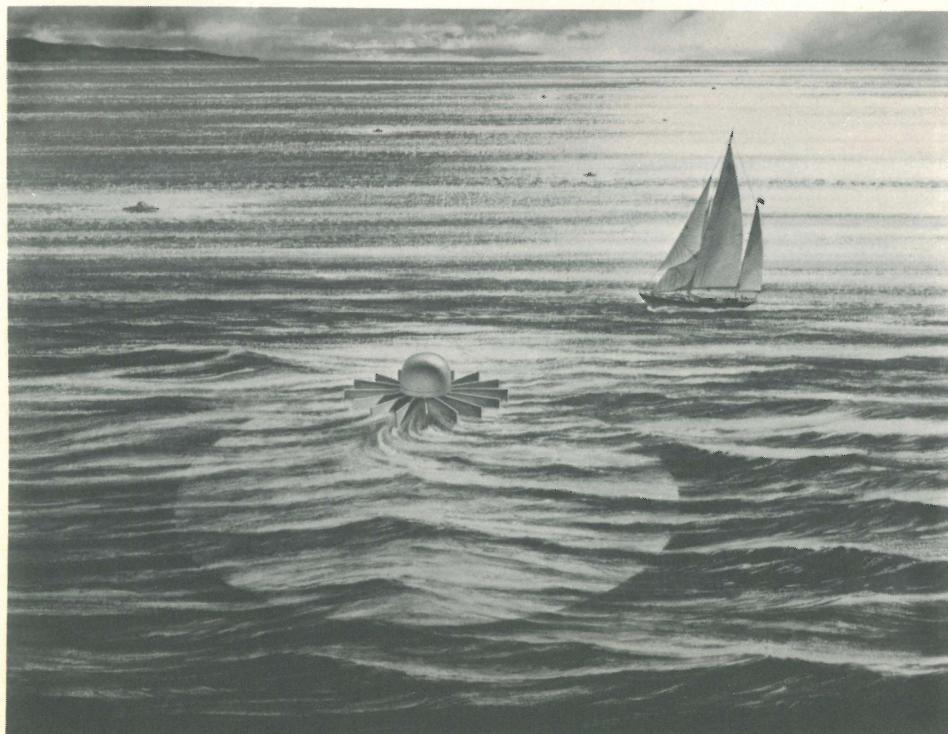
Heat Exchangers

Two plate-type titanium heat exchangers, contributed by Alfa-Laval of Sweden, will be installed. The capacities of the heat exchangers, one for the warm surface water and one for the cold deep water, can be increased simply by adding additional plates. Titanium is being used because it is believed to be the best metal currently available to resist salt-water corrosion.



SERI REORGANIZATION ANNOUNCED

Effective May 15th, a new organizational structure has been established at the US Department of Energy's Solar Research Institute (SERI). Dr. Paul Rappaport, formerly Director of the Institute, remains at the head of SERI, but with a new title: Executive Director. Additionally, three new groups have been established: Technology Development, Technology Dissemination and Administration, and a new Co-ordinating Board.



Artist's rendering of Lockheed's Dam-Atoll wave-energy extraction device illustrating how a series of the units would look in the sea

(continued from Page 9)

from spills and natural seepage, it will be possible to remove the trapped oil for practical, positive use.

"If these units are used to create the sheltered water for an off-shore loading facility," says Wirt, "all of the units protecting the ships against storm waves will be operating day and night to scavenge the slightest leakage or spill. Any coast using the Dam-Atoll for generation of electrical power would be spontaneously protected in the case of accidental spillage."

Both scientists agree that there is really no difference between harvesting wave energy and solar energy. "It is a way of harnessing solar energy," says Morrow, "because ultimately all of our power reserves come from the sun. When solar energy strikes our atmosphere, it creates the temperature differences that power the winds. And the wind is the force which powers the waves in the ocean. As a result, wave power is solar power about twice removed."

The Dam-Atoll project has been demonstrated to a number of ecology-minded individuals at the University of California at Berkeley and the Scripps Institute in San Diego, and experts at these institutions can foresee no negative environmental impact of Dam-Atoll, according to Lockheed officials.



TIDAL POWER

BAY OF FUNDY TIDAL PROJECT BREATHES NEW LIFE

Tidal power is currently being generated in both Russia and France. The latter's Rance station has been in operation for over twenty years, but only recently, with the explosion of oil prices, has it begun to approach economic competitiveness.

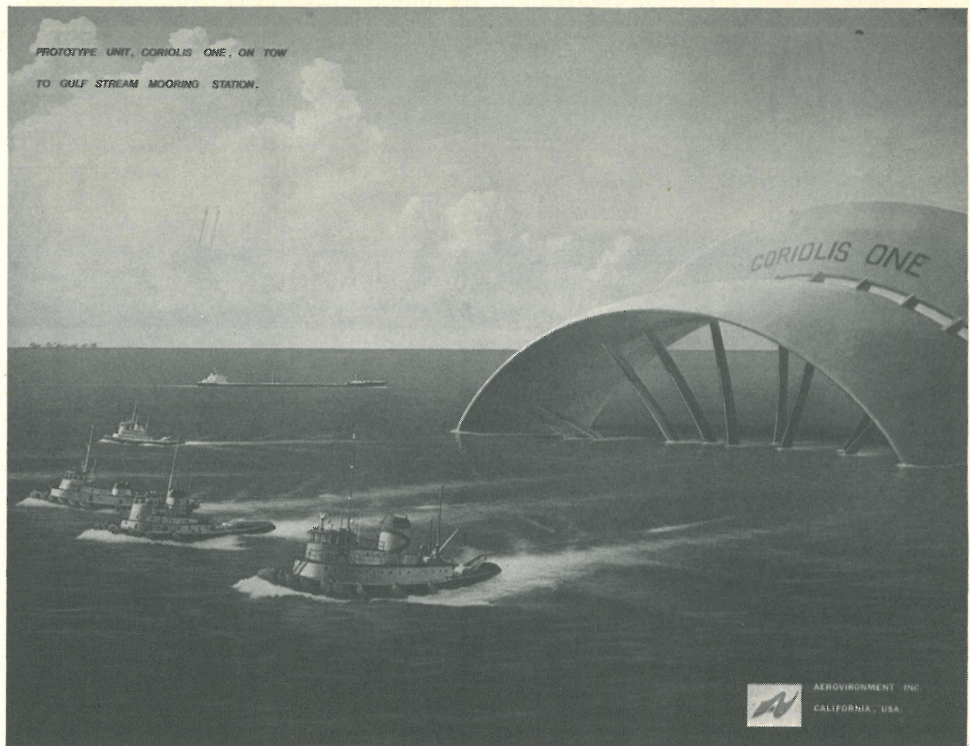
But the highest tides in the world, off the Bay of Fundy in Nova Scotia, have long been considered a source of abundant renewable energy, and recent developments have brought this project closer to realization.

The Bay of Fundy project is waiting for the Maritime Energy Commission (MEC) to get into business, says Dr. Les Kilpatrick, head of the Nova Scotia Power Commission. The Federal Government has been unenthusiastic about Fundy, and says in effect that it will not proceed further until MEC is formed.

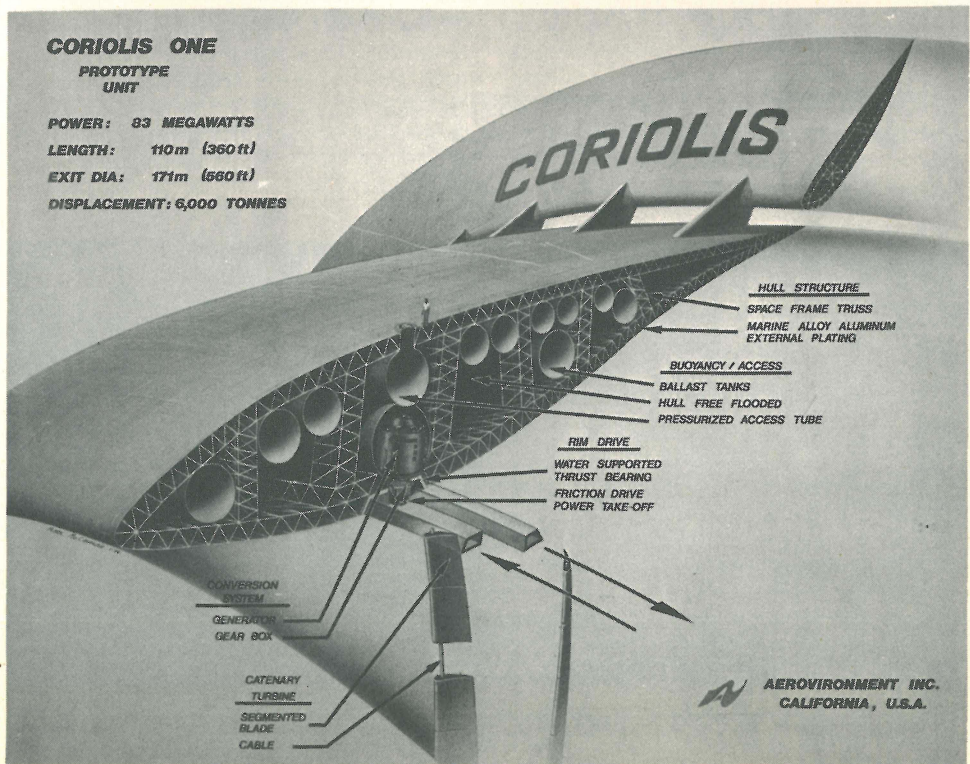
Preliminary studies have concluded that the project is feasible and that the go-ahead should be given for a pre-construction design and investigation. This step could take up to three years and would cost more than \$30 million, with total costs estimated at as high as \$3 billion.

OCEAN CURRENT ENERGY

US DEPARTMENT OF ENERGY AWARDS \$230,000 CONTRACT TO AEROVIRONMENT FOR OCEAN CURRENT TURBINE



The illustration above shows an artist's rendition of the "Coriolis" ocean turbine system in tow to its Gulf Stream mooring site, and provides an indication of the immense size of such a structure. Below is a cut-away sketch of the unit's power-generating plant.



**US DEPARTMENT OF ENERGY
AWARDS \$230,000 CONTRACT
TO AEROVIRONMENT FOR
OCEAN CURRENT TURBINE**

As reported in the January 1979 issue of *The OTEC Liaison* and also covered by a major article in the May issue of *OMNI*.

The Department of Energy has awarded a \$230,000 contract to AeroVironment Incorporated of Pasadena, California to continue development of a new way to harness ocean energy. If the next development and test phases confirm economic and engineering estimates, a major commercial exploitation effort can follow, involving shipbuilders and the manufacturers of large generators.

As now planned, each of the marine turbine systems—called "Coriolis"—will be over 500 feet in diameter and will be rated for 75,000 kilowatts delivered on-shore. It is estimated that each unit will have the potential to produce power at total costs in the range of new nuclear or coal-powered plants, with neither pollution nor radioactive waste. The energy produced by one proposed array of about 250 turbines would fill a large fraction of Florida's power needs and save 130 million

barrels of imported oil annually.

AeroVironment, the prime contractor in the current project, has conducted environmental and hydrodynamic studies of the turbines since early 1977. AeroVironment is a consulting and manufacturing company in the fields of energy and the environment whose president, Dr. Paul MacCready, gained international attention last year when he won the Kremer Prize for man-powered flight. The 96-foot wingspan, 70-pound winning aircraft is now on permanent display at the Smithsonian Institution. Dr. Peter Lissaman, the aircraft's co-designer and AeroVironment vice-president, will direct the Department of Energy project.

The basic concept, design, and key patents for the ocean turbine are the work of David F. Thompson, aeronautical engineer, and William J. Mouton, Jr., a civil engineer and Tulane professor of architecture, and the designer of a number of large buildings and innovative off-shore structures. Hydro-Energy Associates of Pennsauken, New Jersey, has supported four years of design work and model tests carried out by Mouton, Thompson, and IM Development Incorporated of Darby, Pennsylvania.

The program is targeted toward the installation in the Florida Current of an

array of large ocean turbines, each rated at 83 megawatts and about 560 feet (171 meters) in diameter. The system utilizes proven technology and state-of-the-art marine engineering, with deployment and mooring techniques similar to those currently employed on large off-shore drilling rigs. The development issues that remain untried involve the integration of the technical components into this unique new energy system. Calculations, considering the cost of building, mooring, and power transmission to the mainland, give a plant cost of \$1,050 per kilowatt, with power delivered at about 4¢ per kilowatt hour. This power cost is lower than that estimated for new power plants using nuclear energy, coal, or oil.

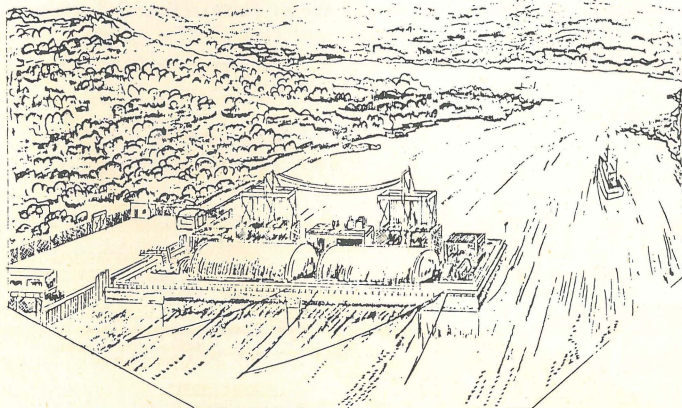
The objective of the current Department of Energy project is to analyze and measure the dynamic response and moored stability of the system through the use of water tests and computer calculations.

In future stages of the program, efforts will be made to attract support from large commercial organizations.

Supporters of the program see it as a large-scale yet straightforward approach to clean energy production from a continuously renewable source.

OCEAN CURRENT ENERGY

"AQUA-POWER BARGE" UTILIZES CURRENTS IN OCEANS, RIVERS AND STREAMS TO PRODUCE TURBINE-POWERED ENERGY



▲ Fluid Energy Systems' "Aqua-Power Barge" as it would appear situated in a river with sufficient current to produce power (three to seven knots).

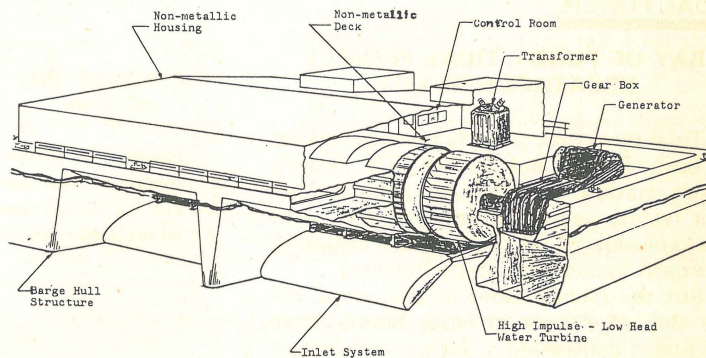
After dedicating over two years to research, analysis, engineering, and design, Fluid Energy Systems Incorporated of Santa Monica, California has received a \$46,000 grant from the US Department of Energy to construct an operating test-scale model of its Aqua-Power Barge.

By using water turbines, generators, electrical equipment, and an energy storage system, the barge should be able to provide low-cost electrical energy.

The major energy requirement for the barge is the presence of moving water, which may be oceans, (tidal or littoral currents), rivers, or streams. Calculations indi-

cate that the scale-model Aqua-Power Barge, 45 feet long by 18 feet wide, when moored in a water current of six knots, would provide approximately 50 kilowatts of installed power. In a littoral current, Tom Miller of Fluid Energy Systems estimates that 438,000 kilowatt hours of electrical energy could be provided each year.

One possible demonstration site is below the Golden Gate Bridge in San Francisco, where the waters have constant currents of three to seven knots and tidal currents of up to eight knots. "The barge could provide the bridge with all the elec-



CONCEPTUAL BASELINE - POWER BARGE

tricity it needs," says Miller.

Miller estimates the cost of a barge at \$1600 per kilowatt installed. A five-megawatt barge, costing \$8 million, could save 36,000 barrels of oil a year if it utilizes ocean tides, or 72,000 barrels a year in a run-of-river installation, Miller says.

On June 4th, Miller told *Solar OCEAN ENERGY Liaison* that Fluid Energy Systems hopes to start actual model testing late this month, and "to have some positive results by the end of July 1979". As data become available, they will be published in this newsletter.

**SEAWEED/KELP FARMS AS ENERGY SOURCE
IN ADVANCED STAGE OF DEVELOPMENT**

While the use of biomass from wood by-products, refuse, and even animal waste as an energy source is receiving increasing attention in an energy-concerned world, the prospects of biomass from the ocean are not widely known. However both private and corporate researchers have been pursuing this alternative energy source with increasing vigor in the last few days.

The giant kelp, or *Macrocystis pyrifera*, is the fastest-growing plant in the world. A single kelp plant can grow as much as two feet a day and reach a height of 200 feet in less than five months. When properly processed, kelp yields methane gas, liquid fuel, plastics, and many other products that we now obtain from petroleum.

Howard Wilcox, a civilian scientist at the Naval Undersea Center in San Diego, California, believes there is tremendous potential in kelp as an alternative energy source, with the possibility of a 100,000-acre kelp farm providing enough energy for a city of 50,000.

Wilcox should know. He has worked for years with Kelco, a San Diego firm which all but monopolizes the kelp industry in the United States. Kelp and its by-products are used extensively in the food, paint, and cosmetic industries, primarily as an emulsifier. Kelco, with its more than 800 employees, seems to find never-ending outlets for its products. The firm has also worked with Dr. Wheeler J. North of the California Institute of Technology, an expert in this field.

Kelco owns leases on 70 square miles of kelp forests off the southern coast of California, and has specially-designed vessels for harvesting. (See the photo accompanying this article.) Through the years the firm has learned to cultivate its crops more efficiently and more economically,



A kelp-harvesting boat.

as would any land-based farm organization.

Wilcox foresees vast floating fields of kelp anchored to rectangular grids to provide a continuous supply of the raw product which produces not only the expensive and profitable chemical agents currently in vogue, but badly needed energy as well.

Organizations such as the Department of Energy, the American Gas Association, and General Electric are already heavily committed to a pilot project now under way off the coast of California. Wilcox predicts that the first of a series of large "plantations" for the large-scale farming of kelp will be in place by the early 1990s.

**US GOVERNMENT
PROCUREMENT INVITATIONS
AND CONTRACT AWARDS**

Listed below are procurement invitations and contract awards related to OTEC in particular and ocean resources in general culled from the *Commerce Business Daily*. This is not to be construed, however, as a complete list.

June 4: Research on Severe Vortical Storms: Negotiations are to be conducted with TRW Inc., Defense and Space Systems Group, One Space Park, Redondo Beach CA 90278.

June 4: Study of the Ocean Fine Structure: Contract NAS6-2993, 1 May 79 (NASA Headquarters Applications Notice AN:OSTA-78-A dated 19 Apr 78), for \$52,331, awarded to the Johns Hopkins University, Charles and 34th Sts., Baltimore MD 21218. NASA, Wallops Flight Center, Wallops Island VA 23337.

June 4: Transcription of Three Mile Island Tapes: Contract NRC-10-79-400, fixed price requirements, for \$77,538, awarded to Neal R. Gross and Co., Inc., Washington DC 20005. US Nuclear Regulatory Commission, Washington DC 20555.

June 5: Selection of Pertinent Reports or Articles of Relevancy and Significance in the Subject Area of Water Pollution Effects on Aquatic Organisms and Preparation of Index-Abstract Worksheet: The Department of the Interior is negotiating with Environmental Information Services Inc., Mercer Island, Washington. RFCA 9613. US Department of the Interior, Office of Water Research and Technology, Contract and Grants Management Center, 18th and C Sts. NW, Room 4359, Washington DC 20240.

**OTEC MAINTENANCE CONTRACT
OPEN UNTIL JUNE 18TH**

The OTEC maintenance contract will be open to qualified bidders till June 18th. Contact Irwin Scott, Department of Commerce, at (202) 377-5053.

DOE'S DALE MYERS RESIGNS

Effective June 1st, Under Secretary of Energy Dale D. Myers resigned from his position, which he held since the formation of the Department of Energy in 1977.

Since the position is subject to Presidential appointment, Myers' successor must be nominated by the President and confirmed by the Senate.

**ENVIRONMENTAL ISSUE
PLANNED**

Due to increasing dialogue regarding the environmental aspects of OTEC—particularly the conjectural possibility of carbon-dioxide release—*Solar OCEAN ENERGY Liaison* will devote the major part of a forthcoming issue to that subject in late summer or early fall. Contributions are encouraged.

TRW'S EARNINGS UP

TRW Incorporated, a major OTEC contractor for the US Department of Energy, reported that its first-quarter 1979 earnings rose 22% on higher sales.

**NEW REPORT SEES FUTURE
US ENERGY INDEPENDENCE**

A study released in early June by a Washington-based research organization, Resources for the Future, indicates that by stepped-up research into solar and other types of alternative energy, the US could reach a "high degree of energy self-sufficiency" by the year 2000. The report was financed through a special grant from the Andrew M. Mellon Foundation.

(Editor's note: Now if only the US Administration will *listen* to such advice. This is only one of many such studies that have come to the same conclusion.)

WHAT AN OPPORTUNITY!

As a special inducement to build the subscriber base to *Solar OCEAN ENERGY Liaison*, a very substantial discount price for *new subscriptions only* will be available to those attending the Sixth Annual OTEC Conference, to be held at the Shoreham American Hotel in Washington DC June 19th through 22nd.

Solar OCEAN ENERGY Liaison (SOEL) has an exhibit booth (Number 15) at the Conference under its former name, *The OTEC Liaison*. Visitors to the booth will see the *special reduced subscription price* displayed.

This offer is being extended to *new subscribers only*, and will expire at the end of the Conference.

This is an excellent opportunity to receive a year's subscription to SOEL at a very substantial saving.