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The Solar Ocean Energy Liaison

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Solar
OCEAN ENERGY
Liaison

INCORPORATING
The OTEC Liaison

VOLUME 6, NUMBER 10
October 1982

GEOTHERMAL-ENHANCED OTEC LOOKS PROMISING

The Applied Physics Laboratory of Johns Hopkins University, the Naval Civil Engineering Laboratory, and the Geothermal Utilization Division of the Naval Weapons Center have been jointly investigating the possible use of Geothermal-Enhanced OTEC (GEOTEC) power plants at several military stations and civil sites. The findings of this preliminary study were presented at the OTEC Session of the Oceans '82 Conference in Washington DC in September.

A GEOTEC plant would use geothermal water at 140° to 200° Centigrade for the heat source, and seawater for the heat sink in a closed-cycle OTEC-type plant. This combined system would enable sites which

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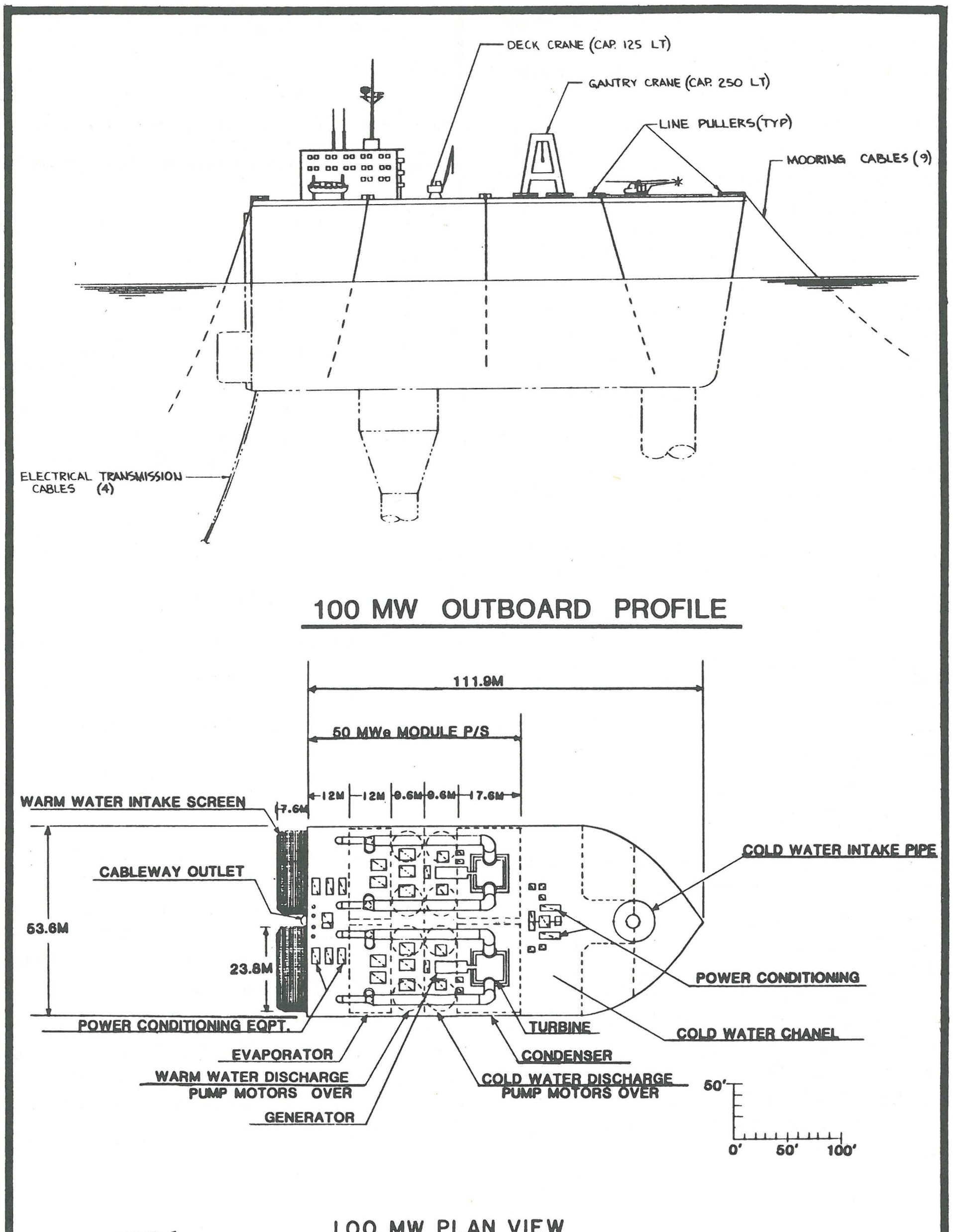

FIGURE 1

(Note: Recently, many alternative OTEC platform designs have emerged from the work being conducted by a number of researchers. The following is the first in a series of articles covering the current status of OTEC-platform R&D. This series will address a different platform concept in each article.)

GIBBS & COX LARGE-SCALE FLOATING PLATFORM

Using a fully integrated, total-system optimized design analysis, researchers at Gibbs & Cox have produced final conceptual designs for 100-megawatt and 400-megawatt floating OTEC platforms. The study was begun in February 1981, and the results were presented at the OTEC Workshop which followed Oceans '82 in Washington DC in September.

As baseline parameters, the study used design criteria based on the site conditions off Kahe Point, Oahu, Hawaii. This site was selected over a west-coast Florida site in a trade-off study which examined physical characteristics, cost factors, and economic/sociological concerns at each location.

Selection of the final 100- and 400-megawatt platform configurations was accomplished through a series of interrelated trade-off studies. The studies encompassed all major platform drivers, including power, seawater, position-control, and cold-water-pipe (CWP) systems. As portions of each study were completed, the pertinent data were made available to the platform-system study. Thus a totally integrated systems approach was used to evaluate and select the 100- and 400-megawatt platform configurations, resulting in an OTEC system which maximizes benefits from all subsystems (power, position-control, seawater, et cetera) while minimizing the drawbacks.

The power system was the primary driver for platform configuration. Using Westinghouse and Lockheed power-system designs, two groups of platform-configuration options were constructed (one for each plant size). Variables in the position-control system and CWP system were then fed into the analysis for final platform-design selection.

The 100-megawatt platform which was chosen is shown in Figure 1. The platform is divided fore and aft into two major sections. The forward section houses the CWP connection and cold-seawater distribution channels. The aft section houses the power-system components. Vertically, the platform consists of three levels not including

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OTEC
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SOLAR OCEAN ENERGY

(continued from Page 1)

possess neither a good "conventional" geothermal resource nor a good "conventional" OTEC resource to tap into a potential renewable energy source. Such hybrid GEOTEC® plants will be most efficient at locations where low sea-surface temperatures are available year-round, well outside the equatorial OTEC resource belt. There are many island and coastal areas where geothermal resources exist, especially along the edges of the Earth's major tectonic plates.

GEOTEC plants are particularly attractive for use at remote military stations and civil sites now dependent on imported oil for power.

Two design options have been examined for potential GEOTEC application: a single closed-cycle and a dual closed-cycle. The dual closed-cycle is more efficient but more complex than the single closed-cycle.

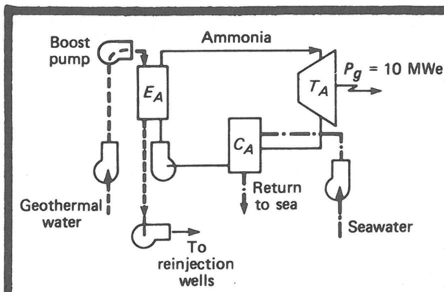
The plants are expected to be in the 10-to-40-megawatt range based on the size of demand in the potential sites; however if the geothermal resource permits larger plants, the surplus energy could be used to operate an energy-intensive product plant.

A single-cycle GEOTEC system operates on the same principles as a closed-cycle OTEC system (see Figure 1). Cost reductions will be realized through the smaller heat exchangers required, but additional costs will be incurred in the geofluid production and re-injection wells which are needed. These wells represent the most-costly item in the GEOTEC plant. Thus, by minimizing the geofluid-flow requirements, cost savings can be realized.

A dual-cycle GEOTEC plant would operate more efficiently than a single-cycle, and thus require a smaller geofluid flow. In a dual-cycle plant the heat source is used twice (in two separate loops) before re-injection (see Figure 2). By using a combination of working fluids such as water or isobutane in Loop A and ammonia in Loop B, and the geofluid discharged from Loop A in the Loop B evaporator, thermal efficiency is increased. A dual-cycle plant will require 20 to 45% less geofluid flow than a single cycle, and could thus reduce the number of geothermal wells required by up to 30%.

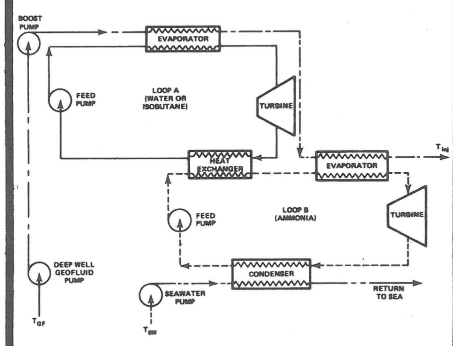
In the joint study being discussed, 11 potential GEOTEC sites at US military installations around the world were examined. Considering such factors as resource availability and quality, need, and political and economic factors, the Naval Air Station at Adak, Alaska in the Aleutian Island chain was selected as the best site for early GEOTEC application. The remote station is currently home to some 5,000 inhabitants and uses 9,000,000 gallons per year of JP-5 jet fuel for all electricity generation and space heating.

Preliminary cost estimates for GEOTEC plants at remote sites indicate that a plant with a geofluid temperature of 120°C will cost about twice as much as one with a 200°C resource. The cost of a 10-megawatt electric plant at Adak, with an anticipated 180°C geofluid resource, is tentatively estimated to be in the range of $2500 to $3000 per kilowatt. Further refinements of the cost estimate and more-detailed resource assessment are now under way.



Simplified diagram of GEOTEC binary cycle using ammonia as the working fluid.

FIGURE 1



Possible geothermal-enhanced OTEC dual binary cycle.

FIGURE 2

PUBLICATIONS AVAILABLE

The following publications are available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161:

Ocean Thermal Energy Conversion: A Review, by P.C. Yuen, Hawaii Natural Energy Institute, 178 pages, is available as DE82-901167 in microfiche only for $4 from NTIS.

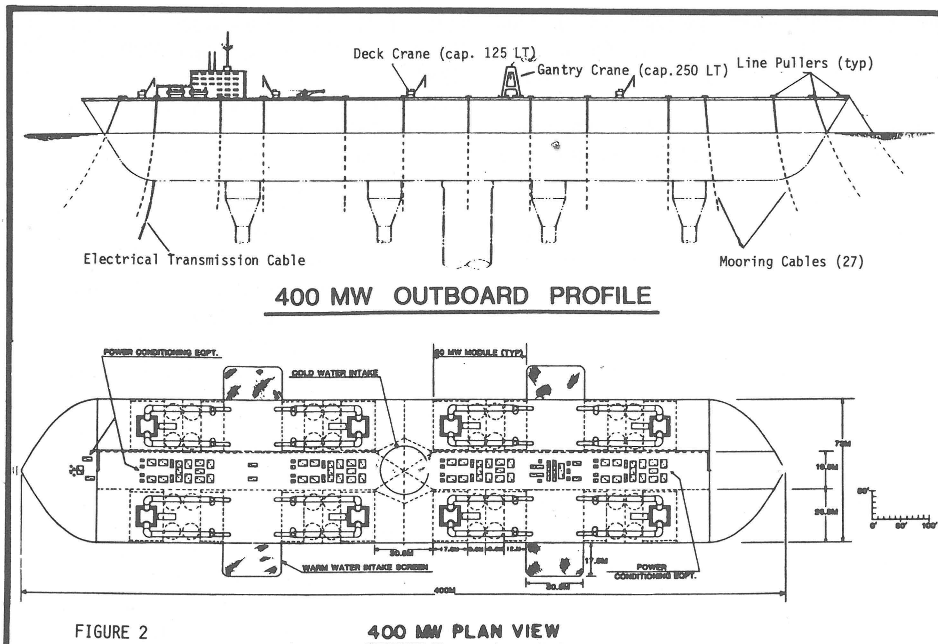


FIGURE 2

(continued from Page 1)

the deckhouse. The lower level contains the seawater system and the two evaporators and condensers. Situated above the heat-exchanger bays are the eight (two per heat exchanger) pump motors and auxiliary system equipment. The third level contains the two 50-megawatt turbine-generator sets with all associated power-conditioning equipment.

Figure 2 presents a diagram of the 400-megawatt platform. The platform is arranged in an axi-symmetric fashion with a total of eight 50-megawatt power modules (four on each side). The condensers of the four centrally-located power modules open directly to the midships cold-water-intake plenum. The four adjoining evaporators, along with the four extreme forward- and aft-located evaporators, take suction from four warm-water-intake plenums (one for each pair of evaporators). Cold water for the extreme fore and aft condensers is channeled to plenums by a centerline distribution channel. Vertically, the platform is arranged similarly to the 100-megawatt platform.

Both platforms were designed to American Bureau of Shipping standards for steel vessels where applicable. All steel plate is mild steel except in the area of the CWP connection, which is high-tensile steel. Two main longitudinal bulkheads and one centerline bulkhead are used to help resist primary longitudinal loads. Secondary loading was also considered for the ship side shell and bulkheads. An excess head of 20 feet over designed waterline was used to size the main framing system. A series of transverse bulkheads and deep webs provides separation of the power-system components and aids in carrying the secondary loads.

In the position-control-system analysis, a fixed-leg mooring system was selected over a dynamic position-control system. The latter option was viewed as less favorable due to higher parasitic losses (for thrusters), the requirement of auxiliary power-generating capacity (during OTEC-plant down periods), and the generally unreliable nature of dynamic positioning systems for permanent position-keeping.

Two types of fixed-leg mooring systems were considered: a modified conventional catenary mooring system and a detachable-turret mooring module. The turret-module concept uses a plug-like structure around which the platform is free to rotate. The mooring lines are attached to the plug, which also houses the CWP plenum and a slip-ring mechanism for power transmission to the electric riser cables. The turret system enables platform orientation to minimize environmental loading and allows for detachment from the mooring in the event of a severe storm. However the turret system represents a higher technical risk and impacts other OTEC subsystems. The modified conventional-spread mooring system was thus selected, despite the expected higher cost due to the increased number of anchor legs.

(Any readers who would like to submit information for inclusion in this series of articles on OTEC platforms should call or write Philip Haring at OE. This is an open-ended series covering technical and economic aspects, and will continue as long as information continues to come in.)

The CWP trade-off study consisted of a design analysis of 18 options considering system performance and integration with the platform design. Glass-reinforced plastic with a syntactic foam core was selected over concrete. Inside diameters of 71 and 80 feet (for 100-megawatt and 400-megawatt plants, respectively) were found to attain an optimum balance between reduced pipe-construction/deployment costs and degraded system performance.

These OTEC platforms represent a total-system-integration approach rather than a simple combining of individually-optimized subsystems. Factors considered in integrating these systems include subsystem performance, risk, and cost. Final cost estimates for the platforms are presented in Table 1. These cost and platform designs represent configurations favorably suited for the Hawaiian Kahe Point site, and are not necessarily optimized for other sites. They do, however, represent reasonable data points for large-scale platforms in general, and illustrate a reasonable economy of scale expected of platforms of increasing power output.

COST SUMMARY

Gibbs & Cox 100- and 400-megawatt Floating Platform
Reference Baseline

DESCRIPTION	COST ($ millions) 100-megawatt		400-megawatt	
PLATFORM SYSTEM				
Hull Structure	63.23		231.87	
Position Control	29.69		97.14	
Platform Support	27.01		31.91	
Outfit and Furnishings	13.96		47.58	
Seawater Systems	12.43		50.91	
Cold-water Pumps and Motors	13.20		52.80	
Warm-water Pumps and Motors	14.00		56.00	
Biofouling and Corrosion Control	3.29		19.83	
SUBTOTAL		176.81		588.04
COLD WATER PIPE SYSTEM				
Pipe System	26.70		64.10	
Screen	1.38		5.40	
Pipe/Hull Transition	1.49		2.23	
SUBTOTAL		29.57		71.73
POWER SYSTEM SUBTOTAL		173.20		692.70
ENERGY TRANSFER SUBTOTAL		21.26		50.50
10% MARGIN ON PLATFORM AND CWP SYSTEMS		20.64		65.98
TOTAL ACQUISITION COST		421.48		1,468.95
ADDITIONAL COSTS				
Acceptance Testing	10.25		15.00	
Deployment Services	59.80		130.12	
Facilities	9.69		26.78	
Engineering and Detail Design	21.70		24.25	
SUBTOTAL		101.44		196.15
TOTAL CONSTRUCTION/DEPLOYMENT COSTS		$522.92 Million		$1,665.17 Million
COST PER KILOWATT		$5,229.20/KW		$4,162.80/KW

TABLE 1

Sep 14: Concept Definition Investigation of a Shipboard Meteorological and Oceanographic Observing System: Contract N00019-82-C-0407 (RFP N00019-82-R-0051), for $149,871, awarded August 10th, 1982 to Lockheed Missiles and Space Company, Huntsville, Alabama. Naval Air Systems Command, Washington DC 20361.

● **Sep 14: Closed-Cycle Ocean Thermal Energy Conversion (OTEC) Pilot Plant:** Contract DE-AC-01-82-CE-30716.A002, issued under Solicitation DE-PN01-80-CS-80000 for $1,735,853, awarded to Ocean Thermal Corporation, New York, New York 10022. US Department of Energy, Office of Procurement Operations, Washington DC 20585.

Sep 14: Upper Ocean Dynamics: Contract N00014-79-C-0472 (no RFP), for $201,649, awarded August 3rd, 1982 to the University of California at San Diego, La Jolla, California 02093. Contract Negotiator D. Ward, 202-696-4508. Office of Naval Research, 800 North Quincy, Arlington, Virginia 22217.

Sep 16: Continuation of Living Marine Resources Study in the US South Atlantic Outer Continental Shelf: Negotiations are being conducted with the South Carolina Department of Wildlife and Marine Resources for a third year of biological sampling off the shores of South Carolina and Georgia. RFP AA851-RP2-42. US Department of the Interior, Bureau of Land Management, Branch of Contract Operations, Code 851, 18th and C Streets Northwest, Room 2447, Washington DC 20240.

Sep 17: Quantitative Analyses, Engineering Assessment, and Related Planning Documentation in Support of DOE Solar Energy Program Areas: Negotiations are being conducted with the Meridian Corporation, Falls Church, Virginia 22041, for Contract DE-AC-01-82-CE-30719. US Department of Energy, Attention Document Control Specialist, PO Box 2500, Washington DC 20013.

Sep 17: Argon-39 Measurements on Samples Extracted From Ocean Water: Contract DE-AC-02-81-ER-60009.A001, for $35,500, awarded to the University of Bern, CH-3012, Bern, Switzerland. US Department of Energy, Chicago Operations Office, 9800 South Cass Avenue, Argonne, Illinois 60439.

Sep 17: Solar Variability Observed Through Changes in Solar Figure and Mean Diameter: Contract DE-AC-02-80-ER-10753.A003, $98,541, awarded to the University of Arizona, Tucson, Arizona 85721. US Department of Energy, Chicago Operations Office, 9800 South Cass Avenue, Argonne, Illinois 60439.

Sep 17: Environmental Summary of the US Atlantic Continental Rise: Contract AA851-CT2-47 (RFP AA851-RP2-5), for $209,923, awarded July 26th, 1982, to Marine Geoscience Applications Incorporated, Box 656, Woods Hole, Massachusetts 02543. US Department of the Interior, Bureau of Land Management, 18th and C Streets Northwest, Washington DC 20240.

Sep 21: Analytical Support in Evaluating Energy, Economic, and Environmental Trade-offs: Contract 68-01-6614 (RFP WA-82-C233), for $826,677, awarded August 25th, 1982 to ICF Incorporated, 1850 K Street Northwest, Suite 950, Washington DC 20006. Environmental Protection Agency (PM-214-F), 401 M Street Southwest, Washington DC 20460.

Sep 21: Analysis of Potential Health and Econolocal Impacts of Emerging Energy Technologies: Contract DE-AC-01-82-ER-60066, for $225, 580, awarded to the National Academy of Sciences, Washington DC 20418. US Department of Energy, Office of Procurement Operations, Washington DC 20585.

Sep 21: Measurement of Total Organic Nitrogen and Phosphorus in Seawater: Contract NA-82-FA-C-00065, $29,962, awarded to the University of New Hampshire. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 14 Elm Street, Gloucester, Massachusetts 01930-3799.

Sep 24: Rankine Cycle Energy Recovery (RACER) System—Advanced Development: Expansion of current program for detail design, development, fabrication, and test of RACER Feedwater System Full-Scale Test Loop. Contract N00024-81-C-5340 with Solar Turbines Incorporated, 2200 Pacific Highway, PO Box 80966, San Diego, California 92138, will be modified to incorporate revised effort. For further information contact H. Jefferson, SEA 0253J, (303) 692-8306/7. Naval Sea System Command, Washington DC 20362.

Sep 24: Method for the In Situ Settling Velocity Determination of Particle Discharge During Deep Seabed Mining: Negotiations on a non-competitive basis are being planned with Ozfurgut Oceanographics PO Box 55373, Seattle, Washington 98155, Ref: NA-82-SAC-00755. US Department of Commerce, Office of Procurement Services, Contract Placement Division, Branch A, Room 6416, 14th Street and Constitution Avenue Northwest, Washington DC 20230. Attention Miriam Peace.

Sep 27: Study on the Failures and Degradation of Materials Used in Heat Exchangers and Condensers for Geothermal Service, and Conference on Material and Fluid Chemistry: DOE intends to conduct negotiations with the Radian Corporation in connection with a geothermal materials analysis study and a technology transfer conference on material and fluid chemistry. US Department of Energy, San Francisco Operations Office, 1333 Broadway, Oakland, California 94612.

Sep 27: Engineering Evaluations, Prototype Manufacturing, and Data: Reverse-Osmosis Water-Purification System: Contract DAAK70-81-D-0109-T00046, for $140,354, awarded September 13th, 1982 to the VSE Corporation, 2550 Huntington Avenue, Alexandria, Virginia. US Army Mobility Equipment Research and Development Command, Procurement and Production Directorate, Fort Belvoir, Virginia 22060.

● **Sep 29: Closed-Cycle Ocean Thermal Energy Conversion (OTEC) Pilot Plant:** Contract DE-AC-01-82-CS-80000.A001, for $1,828,422, awarded to the General Electric Company, Schenectady, New York 12345. US Department of Energy, Office of Procurement Operations, Washington DC 20585.