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ENVIRONMENTAL, MONITORING AT KAHE POINT, OAHU, HAWAII FOR OTEC PILOT PLANT DEVELOPMENT

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August 1982

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ENVIRONMENTAL MONITORING AT KAHE POINT, OAHU, HAWAII

FOR OTEC PILOT PLANT DEVELOPMENT

A.T. Dengler, V. Harms, E.O. Hartwig,
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Washington, D.C. 20585

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INTRODUCTION

The Ocean Thermal Energy Conversion (OTEC) program of the Department of Energy has entered the first design phase for construction of a pilot plant. Contracts for two pilot plant configurations, both at Kahe Point, Oahu, Hawaii, are being supported. The Marine Sciences Group has developed a set of Environmental Technical Requirements designed so that environmental concerns will be adequately addressed. These concerns include factors which could hinder normal operations of the pilot plant as well as issues involved in permitting and licensing.

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ABSTRACT

Two 40 MWe Ocean Thermal Energy Conversion (OTEC) Pilot Plant programs are in the initial phase of development near Kahe Point, Oahu, Hawaii. The two options being examined are: (1) a shelf-seated artificial island, connected via a causeway to Oahu, using stainless steel heat exchangers, with the thermal resource enhanced by effluent from a near-by power plant, ammonia working fluid and biocide (chlorine) cleaning; and (2) a shelf mount tower 1 mile off shore using submerged aluminum heat exchangers, R-22 working fluid, and slurry cleaning with biocide (chlorine) backup.

The Marine Sciences Group has the responsibility for Environmental Technical Requirements including:

- siting criteria; environmental design and operational criteria;
- thermal resource evaluation and variability;
- physical, chemical and biological data requirements; and
- regulatory requirements.

Due to siting, design and operational differences the proposed two pilot plant options have individual environmental monitoring criteria and requirements. Due to the close spatial proximity of the proposed pilot plants they also have required environmental data which are common to both.

This paper presents a set of objectives which, if met, would satisfy the Environmental Technical Requirements. Tasks which would meet these objectives are then outlined for each configuration.

PILOT PLANT CONFIGURATIONS

The nearshore configuration consists of a very shallow water (8 meters) shelf sited plant (i.e., land-based) seated on a manmade island with a dolos breakwater 200 meters off Kahe Point, Oahu, Hawaii. The warm water resource is augmented by a connection to the cooling water output of the Hawaii Electric Company (HECO) 600 megawatt fossil fuel power plant at Kahe Point. The OTEC plant's net output is 40 megawatts, and the full cooling water output of the HECO plant is required to obtain this power output. The cold water pipe, is a 10 meter diameter concrete bottom laid pipe, with joints and seals to account for contours. It traverses at least 5,700 meters to a water depth of 800 meters. The pipe will be slip formed on the beach and deployed with the aid of buoyancy tanks. The heat exchangers are of stainless steel, horizontal shell/tube construction, with biocide (chlorine) cleaning. The working fluid is probably ammonia. The discharge is uncertain, but probably mixed and at 65 meters water depth.

The offshore configuration consists of a shelf mounted tower 1.5 kilometers offshore at Kahe Point, Oahu, Hawaii. The tower is 100-120 meters tall, constructed of steel, and seated on a pile foundation. The cold water pipe is approximately 10 meters in diameter and 3000 meters long extending to a water depth of approximately 800 meters. The heat exchangers are of aluminum, flat plate construction with sand or other slurry cleaning and biocide (chlorine) backup. The working fluid is probably R22 (Freon). The discharges are separate; warm at 110 meters and cold at 50 meters depth.

ENVIRONMENTAL TECHNICAL REQUIREMENTS CONCEPTUAL DESIGN

1. Provide at the start of Phase I an initial design and operational criteria including the thermal resource and survivability based on available data.
2. Prepare a site and design specific Environmental Assessment (EA).


4. Identify major environmental issues/problems.

5. Plan and initiate data acquisition program for environmental monitoring studies.

6. Plan future detailed design and operational criteria studies.

SITING CRITERIA—ENVIRONMENTAL DESIGN AND OPERATIONAL CRITERIA

Data needs in this section are primarily directed toward the establishment of the OTEC plant design and operational criteria at the OTEC pilot plant, the shore-based construction, and deployment sites. The results are used by the design engineer/naval architect in the development of all related OTEC ocean systems.

The OTEC pilot plant is designed to survive the 100 year storm/hurricane and associated wind, waves and current velocities. Also the OTEC pilot plant is designed to operate onsite with the CWP connected in sea conditions up to and including 5 m significant wave heights and 15 m/sec winds. The 5 m wave height is taken as the upper limit for normal operation. [However, should there be a very significant overall system cost benefit derived from a lower wave height of perhaps 3-4 m while still maintaining a maximum number of annual days operation, then DOE may elect to accept the lower wave height as a design requirement.]

A. Meteorological Data

1. General description of the major climatic systems and of the local climatic conditions

2. Normal climatology and variability (by months)

3. Extreme meteorological events

B. Oceanographic Data

1. General description of the major oceanographic systems and of the regional oceanographic features in terms of ocean currents and water masses

2. Normal marine climatology and variability by months

3. Extreme oceanographic events

C. Other Design Data

1. Earthquake and tsunami frequency and intensity

2. General oceanographic conditions at site and along pipe and cableways

D. Shorebased Facility

Comparable design/operational criteria must also be developed for coastal installations and construction areas. Considerable information developed for the OTEC site may be applicable to the coastal locations or can be modified for the new depths, etc.

THERMAL RESOURCE—EVALUATION AND VARIABILITY

The thermal resource is the single most important aspect of the environmental data needs. The instantaneous temperature profile is easily measured. However, the temperature value and the heat content at any depth are variable in time particularly in the upper layers (warm water resource). As an annual cycle exists, this represents a minimum period of data measurement. Because the environmental conditions at the site can vary significantly year to year, several years of measured data are necessary. Longer variations (over several decades) are estimated from shipboard and other observations of the sea surface temperatures. More frequent variations occur in response to cold fronts, tropical storms and meandering eddies. Hence, these processes are understood and quantified with a more frequent measurement program such as with satellite surface temperature maps and in-situ confirmation.

OTEC plants will also induce both small scale (near field) and large scale (far field) changes in the seawater temperatures depending on their size, number and operating duration. The potential problems range from local recirculation of the effluent to major erosion of the thermal resource in semi-enclosed waters.

DOE has or is presently developing several numerical and physical models. These studies and the serial measurement program represent DOE's approach to the problems involving the thermal resource and its variability and alteration by OTEC plants, and not preclude the use of other comparable techniques, models, etc.

The data and studies will show whether the thermal difference is sufficient to provide the stated power availability. Also, whether the daily averaged surface current exceeds 0.13 m/sec to insure transport of the OTEC pilot plant effluent. The upper limit (Vm) can be stated with supporting rationale. Determination of Vm includes consideration of Section I.
A. General Area Resource Description
(historical only)
1. Mean distribution and monthly variability
2. Mean ocean current distribution and variability

B. Site Specific Thermal Resource Description
(Measured field data at the site-Phase I)
1. Mean distribution and monthly variability of the resource.
2. Mean ocean current distribution and variability

C. Natural Variability of the Thermal Resource
Researchers have shown that significant long and short term temperature variations occur resulting from major long period atmospheric and oceanic conditions and from short period storms, eddies, etc., which will influence OTEC operations and siting criteria. These are evaluated
1. Long-term sea surface temperature changes
2. Short-term sea surface temperature changes such as cold fronts, hurricanes, eddies, upwelling, etc.

D. OTEC Induced Variability of Thermal Resource and Related Plume Dispersion
The OTEC pilot plant will redistribute the ambient warm and cold seawater. The OTEC pilot plant entrains large volumes of warm surface water and cold deep water, discharging it at a third depth of intermediate temperature. To avoid thermal drawdown and recirculation three design concerns to be discussed are: 1) intake/discharge location (depth, distance offshore, etc.); 2) intake/discharge configuration; and 3) scalability (added capacity, plant spacing, etc.). DOE studies can be consulted for application to the OTEC pilot plant, although other methods may also be acceptable. Site and regional measurements of the current velocity, tides and the water masses (Temperature and Salinity) are needed for input data. These areas of interest are evaluated for the following:
1. Near and intermediate fields
2. Far field
3. Field measurements

BIOLOGICAL AND CHEMICAL ENVIRONMENTAL DATA

Biological and chemical environmental data are needed to insure the proper engineering design for thermal efficiency, survivability and licensing of the OTEC plant. The programs to acquire these data are outlined below.

A. Pre-Operational Data Base

1. To obtain this chemical and biological data base all applicable historical information are analyzed and entered into a common data base.
2. Gaps in the data are identified. Gaps are situations where data are lacking but required for design, survivability and impact assessments. These gaps are substantial at this site, therefore immediate attention is given to completing the analysis of existing data in parallel with collecting and analysing missing data (see Appendix B). An approved collection strategy to fill data gaps should be used.
3. In order to perform a satisfactory environmental assessment as required by the Pilot Plant EA (DOE/EA-O147) several potential control areas are identified and studied. Data collected in these studies will help fill in the data gaps.
4. The contractor's data is collected, analysed and reported in an approved standard manner. An approved quality assurance plan is also used. This insures effective use of past work, rapid integration of proposed work and efficient design of future collection programs.

B. Pre-Operational Design Assessment for Permits
The predicted ranges of impacts for contractor proposed OTEC designs are assessed using a common design assessment algorithm. Data for this assessment comes from the common data base (e.g., current field, density, nutrients, etc.) and contractor supplied design specifications (e.g., depth of intakes and discharges, mixing, discharge velocities, etc.). This provides near real-time permit assessment for the contractor and DOE. Third party verification such as for the offshore Platform Verification Program operated by the U.S. Geological Survey can be used to protect any proprietary information. In the event that contractor results are inconsistent with other analyses the contractor provides input data and output results to the third party for verification.

C. Environmental Monitoring Program
The contractor provides space for and begins to design a laboratory into the OTEC facility for physical, chemical, biological and engineering oceanographic research. This facility performs two functions:
1) Pre-Operational
   - Perform required physical, chemical, biological and engineering research.

2) Operational
   - Continue to perform required physical, chemical, biological and engineering research.
   - Monitoring of the OTEC plant's operations and impact.

D. Special Studies

The list of studies will change with each design phase based upon knowledge acquired previously. These studies are designed to provide data for: 1) thermal resource; 2) survivability assessment; and 3) licensing. Applicable historical data is analyzed for each study. For each study the site requirement for the data is given, i.e., general: data from exact site not required; and site specific: data is from exact location of proposed OTEC site.

1. Micro-fouling (site specific)

Begin study to determine micro-fouling rate and control strategy for contractors specific designs for warm water intake and evaporator. This is a library study and results in a referenced detailed experimental study plan and report.

2. Toxicity (general)

Assess toxicity of working fluid(s) and biocide(s) for specific designs. This is a library and computer study and results in a referenced detailed experimental study plan and report. The use of the common design assessment algorithm (see B above) will facilitate this task.

3. Macro-fouling (site specific)

Begin study to determine fouling community, macro-fouling rate and control strategy. This is a library study and results in a referenced detailed experimental study plan and report.

4. Cold Water Entrainment (site specific)

Determine source (i.e., depths, from which area, etc.) of cold water. Knowing this, propose a study plan to assess impact on the cold water (deep-water) community. This is a library and computer study and results in a referenced detailed experimental study plan and report. The use of the common design assessment algorithm (see B above) will facilitate this task.

5. Fisheries Impact (site specific)

Begin studies to assess impact of OTEC plant operations on Oahu fisheries. Fisheries studies include not only commercial species (e.g., skipjack tuna) but also representative local bottom-dwelling and nektonic species. Studies concentrate on larval and juvenile life stages with attention paid to depth, longshore and offshore distributions and variability.

Strong consideration can be given to incorporating an effective fish diversion system into the design to reduce fish entrainment.

Historical data on natural mortality rates is gathered as these rates must be ascertained beginning in Phase II. Assessment of fisheries impacts will be facilitated through the use of the common design assessment algorithm (see B above). This results in a referenced detailed experimental study plan and report.

6. Coral Reef Impact (general)

Assess impact of discharge water on coral reef community. This is a library and computer study and results in a referenced detailed experimental study plan and report. The common design assessment algorithm (see B above) will facilitate this task with respect to nutrient and turbidity levels with distance from the discharge.

REGULATORY REQUIREMENTS

The contractor will comply with all federal, state and local laws and regulations. The most encompassing of these is the EIS potentially required by DOE and the EPA under the NEPA. The accepted Final EIS supports the application for the issuance of the NPDES permit by EPA. During Phase I, the contractor shall prepare a site specific environmental assessment (EA) in compliance with NEPA and as required by the Pilot Plant EA.

A. Environmental Impact Statement

The contractor will initiate collection of any data necessary for preparation of a final EIS and acquisition of the NPDES permit.

B. Other Regulatory Agencies

The contractor will obtain the required permits from any federal, state or local regulatory agencies having jurisdiction in the development time frame of the OTEC pilot plant (i.e., cable routes, shore site construction areas, assembly site, etc.). The Government will assist the contractor in permit application activity.

OBJECTIVES AND TASKS, COMPARISON

In Table 1 the environmental monitoring tasks for the two pilot plant configurations are compared for each objective derived from the Environmental Technical Requirements.

Acknowledgement

This work was supported by the U.S. Department of Energy under contract DE-AC03-76SF00098.
<table>
<thead>
<tr>
<th>TASK nearshore site</th>
<th>TASK offshore site</th>
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</thead>
<tbody>
<tr>
<td><strong>OBJECTIVE</strong></td>
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</tr>
<tr>
<td><strong>1 Currents and Density Monitoring</strong></td>
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</tr>
<tr>
<td>Place current meters with conductivity and temperature sensors to give wide coverage of area for tidal and longshore components through several seasons.</td>
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<tr>
<td><strong>2 Design Evaluation</strong></td>
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</tr>
<tr>
<td>Model the design configuration. Proprietary models must be verified through agreed on third party. Permit modeling may be done by State of Hawaii.</td>
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<td><strong>3 Design Assessment for Permits</strong></td>
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</tr>
<tr>
<td>Through use of existing model(s), assess range of predicted impacts given each design configuration. Reassess as data becomes available. Modify model as required. Contractors supply configuration, non-proprietary data and other design input variables.</td>
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</tr>
<tr>
<td><strong>4 Optimal Location of Discharge</strong></td>
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</tr>
<tr>
<td>Assess re-entrainment and environmental problems. Best if discharge pipe moved to shelf break.</td>
<td>Analyze plume characteristics of having separate cold and warm water discharges. Present arrangement will potentially cause a shallow water plume of unknown and varying mixture.</td>
</tr>
<tr>
<td><strong>5 Micro-biofouling</strong></td>
<td><strong>5 Micro-biofouling</strong></td>
</tr>
<tr>
<td>Establish site specific study to ascertain micro-biofouling rate and control strategy.</td>
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</tr>
<tr>
<td><strong>6 Long- and On/Off-Shore Current and Density Coherence</strong></td>
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</tr>
<tr>
<td>Present plan to assess current and density coherence.</td>
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<tr>
<td><strong>7 Cold Water Source</strong></td>
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</tr>
<tr>
<td>Measure physical, chemical and biological variables of cold water source. Must know density structure and current regime to use in an entrainment model of cold water. Model output will guide locating of physical, chemical and biological sampling.</td>
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<tr>
<td><strong>8 General Bathymetric Survey for Siting</strong></td>
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</tr>
<tr>
<td>Perform a bathymetric survey of shelf. Slope survey already performed by USGS-LBL.</td>
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<tr>
<td>OBJECTIVE</td>
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9 **Bathymetric and Bottom Sampling Survey for Pipe and Plant Siting**

<table>
<thead>
<tr>
<th>Objective</th>
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<tbody>
<tr>
<td>Detailed routing survey for CWP/MWDP and OTEC plant site (slope, geology, geotechnical, biology, bottom currents, etc.).</td>
</tr>
<tr>
<td>Detailed routing survey for CWP and platform siting (slope, geology, geotechnical, biology, bottom currents, etc.).</td>
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10 **Tsunami Protection**

<table>
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<th>Objective</th>
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<tbody>
<tr>
<td>Determine if design capable of withstanding tsunami. Present alternative site if present one is not suitable.</td>
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<td></td>
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<tr>
<td>Place wave rider(s) to determine wave forces impinging on OTEC related structures.</td>
</tr>
<tr>
<td>Place wave rider(s) to determine wave forces impinging on structure, pipes and heat exchangers.</td>
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</tbody>
</table>

11 **Wave Forces**

<table>
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<th>Objective</th>
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<tbody>
<tr>
<td>Agree to use a standard data collection, analyses and interpretation scheme for all variables.</td>
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</table>

12 **Standard Sampling Techniques**

<table>
<thead>
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<tr>
<td>Establish contract for central lab(s) to analyze all physical, chemical and biological data. Analyses paid for by contractor requesting analyses.</td>
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13 **Central Physical, Chemical and Biological Laboratory**

<table>
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<th>Objective</th>
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<tbody>
<tr>
<td>Design a laboratory into the OTEC facility for physical, chemical, biological and engineering oceanographic research.</td>
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14 **Oceanographic and Engineering Research and Monitoring Laboratory**

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<th>Objective</th>
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<tr>
<td>From existing data (biological, chemical, physical) select several control areas for study. Collect and analyze samples from the several control areas to adequately assess them. Must include all depths of potential impact.</td>
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</table>

15 **Select Control Area**

<table>
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<tbody>
<tr>
<td>Present an acceptable plan to complete an environmental assessment per pilot plant EA (DOE/EA-0147). Plan must include a before vs. after impact assessment. This requires analysis of existing data to determine data gaps and quality of estimates (i.e., accuracy and precision) for such variables as nutrients, phytoplankton, zooplankton, meroplankton, ichthyoplankton, primary production, natural mortality rates, etc. Requires some field program.</td>
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<td>Table 1 (continued).</td>
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<tr>
<td><strong>OBJECTIVE</strong></td>
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<tr>
<td><strong>TASK nearshore site</strong></td>
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<tr>
<td>17 Data Base</td>
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<tr>
<td>18 Competing Uses</td>
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<tr>
<td>19 Dredge Spoils</td>
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<tr>
<td>20 Turbidity</td>
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<tr>
<td>21 Sediment Transport</td>
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<tr>
<td>22 Toxicity</td>
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<tr>
<td>23 Fish Diversion System</td>
</tr>
<tr>
<td>24 Macrofouling</td>
</tr>
<tr>
<td>25 Cruise Plans</td>
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</tbody>
</table>
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