Current Issue Outline 79-3

Ocean Thermal Energy Conversion (OTEC)

Washington, D.C.
September 1979

U.S. DEPARTMENT OF COMMERCE
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OCEAN THERMAL ENERGY CONVERSION (OTEC)

Issue Definition

As continued reliance on imported oil places an increasing burden on the American economy, and as fossil fuels worldwide are being depleted, our interest is turning to renewable energy resources such as synthetic fuels, solar power, and energy derived from the oceans.

Ocean Thermal Energy Conversion (OTEC) uses the temperature difference between the warm surface layer of seawater--a collector of solar heat--and the colder subsurface layers to power a turbine and generate electricity, which is either transmitted to onshore power grids by underwater cable or used at sea to process energy-intensive products.

Although estimates of the potential output of OTEC plants vary, engineers have suggested that the process could be commercially operational in the mid-1980s, generating the equivalent of 3 quadrillion Btu (quads) by the year 2000, sufficient to meet a major share of U.S. energy demand.

The technology for OTEC is available, subject to testing and modification, and a small-scale prototype plant launched in May 1979 is currently undergoing a 6-month testing program.

Current issues relate to (1) system design and construction, (2) environmental effects, and (3) costs.

Background

The use of ocean temperature differences as a source of power was suggested in 1881 by the French physicist Jacques d'Arsonval. An open-cycle OTEC plant, using low-pressure steam as the working fluid, was built and operated by Georges Claude in 1929 in Cuba, but the output was limited. A French government-sponsored plant was proposed for the Ivory Coast of Africa during the 1950s; however, the structure never became operational.

In 1966 the construction of a 100-megawatt closed-cycle OTEC power generation plant, using the vapor of a working fluid was proposed. U.S. funding for OTEC research and development programs began in 1972, and several systems have been designed and studied through the funds of the Energy Research and Development Administration (now the Department of Energy), the National Science Foundation, and the Maritime Administration.

OTEC Systems Design and Construction Issues

The basic closed-cycle OTEC process is as follows. Warm water from the ocean surface, the temperature of which is maintained by the continual absorption of heat from the Sun, is pumped over coils that contain a fluid such as ammonia, propane, or Freon. The warm water heats and vaporizes the working fluid. The vapor turns a turbine, which drives an electric generator, and is then condensed by coils cooled by deep cold ocean water and recirculated. The process is much like the action in the condensing system of a conventional powerplant.

Several designs have been proposed for OTEC facilities. In general, they share the following characteristics: a platform or hull floating at the ocean's surface; large evaporator, turbogenerator, and condenser subsystems; ammonia as the preferred working fluid; and a large-diameter cold-water pipe, 2,000 to 3,000 feet long.

Designs for the platform include a barge plant and a spar-shaped plant. Various materials are being tested for the power system's heat exchanger components to ensure compatibility with the working fluid, cost-effectiveness, durability, and ease of maintenance.

The most crucial parts of the OTEC system are the cold-water pipe and the heat exchangers. The cold-water must be able to withstand stresses not only from the platform motions but also from wave motions and ocean currents during hurricanes. Materials under consideration for this structure include steel, concrete, fiber-reinforced plastic, and rubber. The over half-mile-long pipe must be deployed into a vertical position safely and endure the elements for 30 years.

The low-temperature difference heat exchangers must be capable of performing efficiently for 30 years also. A major problem is the biofouling and corrosion of the heat exchangers, as well as of other major components of the OTEC system. A slime layer develops on most surfaces exposed to seawater. In an OTEC plant, a buildup of marine microorganisms on the surface of the heat exchangers will reduce their efficiency. Various mechanical methods (e.g., brushes) and chemical methods (e.g., chlorine) for preventing or restricting biofouling are being tested.

Additional design and construction issues include the following:

1. The method of attaching the cold-water pipe to the platform to ensure that the joint will withstand the stresses under which it must function.

2. Assembly of the OTEC plant in shipyard facilities or in deep water, recognizing that heavy construction offshore presents additional difficulties, expenses, and risks.

3. The performance of long-distance underwater electrical cables that do not have large power losses and can survive the ocean environment.

OTEC Environmental Issues

The OTEC powerplant research and development programs have raised environmental issues of a biological, chemical, meteorological and oceanographic nature.

An underlying issue is the proposed location of the OTEC plants. Siting requirements prescribe a minimum temperature differential between surface and subsurface waters of at least 40°F for 5 continuous months. To achieve minimum energy loss through the electric cables, a location within 200 nautical miles of land is required. This narrows the geographical region to the tropical oceans between latitudes 35°N and 35°S.

Potential test sites are near Keahole Point, Hawaii and Punta Tuna, Puerto Rico, and in the Gulf of Mexico off New Orleans. Scientists estimate that solar energy stored in these waters is very great, and the relatively stable temperature differentials should permit year-round operation of OTEC plants and the transmission of electric power to onshore utility grids.

One criticism of OTEC proposals, raised in the U.S. House of Representatives, is that the immediate beneficiaries of this electricity would be the Gulf coast and southeastern States, Hawaii, Puerto Rico, and the Virgin Islands. It has been suggested that the limited regional application of the process in the near term may preclude a major commitment of Federal funds to the construction and commercial operation of OTEC powerplants.

Legal aspects of siting are being investigated and will involve local, State, Federal, and international questions of authority and regulation.

Specific issues relating to the effects of construction and operation of OTEC plants on the marine environment are:

1. Leaching of trace metals from heat exchangers, condensers, and the platform surfaces, such as copper from antifouling paints, which may adversely affect the marine environment.

2. The effect of chlorine or other chemicals used in biofouling control on other marine life.

3. The effects of nutrient redistribution resulting from the intake, discharge, and mixing of layers of seawater.

4. The effects of marine organism impingement on the intake screens and fish entrainment in the warm-water system or other parts of the plant.

5. The effects of accidental release of the working fluid.

6. The possibility that in the long run the operation of an OTEC plant will change the temperature in the surface waters.

The environmental impact of OTEC is being assessed, and regulatory and monitoring systems will need to be formulated. An allied issue, worker safety, will also require the establishment of appropriate procedures.

OTEC Cost Issues

Cost estimates for OTEC power vary greatly at this time; there is not yet operational experience on which to draw. In addition to consideration of expenditures for research and development; capital equipment; construction, operation, and maintenance; and regulatory measures; the following issues are noteworthy.

1. The fuel cost for an OTEC plant is zero. The fuel is a renewable solar energy.

2. The electricity used by the pumps and other onboard equipment is estimated at 30 to 35 percent, leaving a 65 to 70 percent net power efficiency.

3. OTEC power costs are expected to be comparable to coal-fired, oil-fired, and nuclear plants, or at least not so great as to preclude development; fuel costs for conventional and nuclear powerplants are expected to increase, whereas the fuel costs for OTEC plants will not.

In addition to the generation of commercial electricity without the consumption of fossil fuels, other applications of OTEC technology should be considered in evaluating the economic issues.

Floating OTEC plant-ships have been proposed for the industrial production of fertilizers. The Applied Physics Laboratory of Johns Hopkins University has designed a plant-ship for the production of ammonia; the electricity generated by the OTEC process is used to produce hydrogen, which is combined with nitrogen made from the air by liquefaction. Ammonia currently requires natural gas for its production. Other applications of the OTEC concept include water desalination and aquaculture, which makes use of the artificially induced upwelling of deep seawater nutrients.

Current Developments

Objectives established by the Department of Energy include the deployment of successively larger OTEC power plant prototypes beginning in 1980 with a 1-megawatt capacity (OTEC-1) to study the operation of the subsystems and the impact of biofouling. The target date of 1984 has been set for a 10- to 100-megawatt commercial demonstration plant (OTEC-10/100). The U.S. Congress is currently considering the level of funding for OTEC for FY 1980; the Department of Energy request is $33.8 million.

In Europe, a 10-megawatt closed-cycle pilot plant is being planned by Eurocean (25 companies from nine countries), as well as a combined aquaculture/desalination/OTEC plant. The French government agency CNEXO is making a feasibility study for a plant of 1- to 10-megawatt capacity.

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Because of the nature of current research and development efforts, much of the literature on OTEC is in the form of symposium or workshop proceedings and technical reports. These sources provide state-of-the art assessments and discuss specific design and application problems. Conference proceedings are listed as a whole; individual papers composing these volumes are not listed, because all are relevant to OTEC issues, unless otherwise noted.

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