Readers of *The OTEC Liaison* may have found surprising the inclusion (in TOL’s February issue) of a contract award described as *Research Into Direct Application of Hydrothermal Energy in North Dakota* in a publication on OTEC. However a study by three California engineers suggests that stored heat in dammed reservoirs offers over four times as much usable energy as is available from the hydroelectric turbines at dam sites.

The authors of a paper published in the January 12th issue of *Science*, entitled *Thermoclines: A Solar Thermal Energy Resource for Enhanced Hydroelectric Power Production*, suggest that the cold and water behind a dam be run through the Rankine cycle engines now being developed for OTEC plants or improved Nitinol heat engines before passing to the hydraulic turbine. Thus warm and cold water could be blended while passing through the latter so the output water temperature desired for downstream use could be regulated.

The engineers are J. L. McNichols and W. S. Ginell of the McDonnell Douglas Astronautics Company in Huntington Beach California, and J. S. Cory of Cory Laboratories in Escondido. In making their estimate of stored solar energy, they have taken account of both its theoretical potential and the probable lower energy output from any practical generating system. An article on this potential energy source appeared in *The Christian Science Monitor* January 18th, and is partially excerpted here.

(continued on Page 2)
(continued from Page 1)

The Science paper points out that the 15-degrees-Centigrade temperature difference actually represents an amount of potential energy equivalent to that of a gravitational "head" or dam height of 21,000 feet. However the amount of energy that could actually be converted to electricity would be equivalent to that of a "head" of only about 500 feet. This is still impressive compared with the 130-foot average effective "head" of United States hydroelectric dams.

The thermal energy available also would vary with the season, ranging from a few degrees or less in winter to as high as 20 degrees in summer. Although the energy supply would be variable, it would still be substantial for long periods. Data from three Western reservoirs - Lake Mead, Lake Shasta, and Clair Engle Lake - show that the temperature difference exceeds 15 degrees for three months and 10 degrees for five to six months (equivalent to a useful "head" of about 230 feet).

Utilizing Low Temperature Differentials

Obviously, the thrust of OTEC planners is the development of heat exchangers using far greater delta-Ts. In a letter to TOL from McNichols of McDonnell Douglas, he enclosed a paper presented last year (at the Interdisciplinary Conference on Environmental Systems in San Diego July 10th through 13th) dealing with a solid-state working medium-heat engine that would solve this dilemma. The paper, authored by McNichols, W. S. Ginell of McDonnell Douglas, and J. S. Cory of Cory Laboratories, is titled Low-Grade Thermal-Energy-Conversion Joule Effect Heat Engine. Pointing out the "great potential for OTEC and other low-grade thermal-energy applications", McNichols lists the principal advantages of Nitinol heat engines as follows:

(1) The working medium, Nitinol, was developed by the Navy as a corrosion-resistant material for ocean engineering applications. Thus the material can be exposed directly to sea water, and the need for closed systems and seals (and therefore costs) should be reduced drastically.

(2) The heat-transfer coefficient between liquid (say sea water) and a solid material (such as Nitinol) is more than three orders of magnitude greater than the heat-transfer coefficient from liquid (sea water) to solid (heat exchanger) to vapor (working media in a liquid-vapor phase engine such as the present OTEC Rankine designs). This should result in drastic reduction or even elimination of the requirements for heat exchangers, which is one of the dominating cost items in present OTEC cost estimates.

(3) The solid-medium working material combined with reduction in heat exchangers should result in much greater conversion-system power density.

The principal disadvantage of the solid-state Nitinol heat engine is the present primitive state of development. Although a number of small (0.5-1 watt) model engines have been built and perform well, no larger prototype engines have yet been completed. Here at McDonnell Douglas Astronautics Company we are currently in the design and construction stage of a 750-watt (one-horsepower) engine which should be operational by late 1979. This development program is being sponsored by the Department of Energy.

Rapidly Developing Nitinol Engine Technology

The San Diego paper is fascinating reading, and is available from the American Society of Mechanical Engineers in New York City. Nitinol engine studies are quite new, the first publicized working engine having been built by R. Banks in only 1973. Summarizing that paper is beyond the scope of this publication. Briefly, however, these heat engines use Joule-effect solid-state working materials which, when heated, contract with substantially greater force than is required to stretch them at lower temperatures, and the force difference is translated into work. The paper describes the energy sources, types of engines that have been built and studied, and potential Joule-engine applications. (See schematics of Nitinol engines elsewhere in this issue.)
would operate at an appreciably higher annual average electricity delivery by cable. However, some of the characteristics will reduce the costs of the OTEC plants near the equator. Cruising plants would be by relatively small and slow ocean current systems, which is expensive (approximately $80/ton) and in our view, unrealistic. If OTEC ammonia production is implemented, the ammonia should be transported in large dedicated tankers operated between the Atlantic site and New Orleans. For this method of shipment the cost estimated by APL, based on a projected dedicated OTEC ammonia carrier owned by Sun Shipbuilding & Dry Dock Co. (Ref. 1), is $11/ton (updated to 1978 dollars).}
Tropical Grazing near equator gives avg. operation difference

- Net power increases 30% (see Ref. 373, p. 6 of ref. article)
- Reduce platform-CWP cost to $150 (High) to $100 (Low)
- Increase annual power output by 12 to 19%

No shutdowns required due to significant wave activity in Gulf of Mexico, except due to hurricanes or frequent large storms. Shutdowns due to waves greater than 10 ft occur only 0.3% of time.

Use of shell-less aluminum heat exchanger designed for 20 yr life.

Tropical grazing instead of moored operation

128 ft (40 m) = 28 = 120 or 20% fewer in per due to AT

Lockheed’s 1976 report p. 1.2-10 shows Total per yrs. = $1250/kW

Ti XX = $137

Hence Ti XX = 67% of total per yrs cost

Assume R = factor of Table 6 = 0.67 ($50 to $500) = $570 to $910/kW

Table 1. Revision to Author’s OTEC Baseline Plant Cost (1976 Dollars) For Operation Near Equator

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (12 shell-less X)</td>
<td>$350</td>
<td>$150</td>
</tr>
<tr>
<td>Platform</td>
<td>$160</td>
<td>$100</td>
</tr>
<tr>
<td>CWP</td>
<td>$180</td>
<td>$100</td>
</tr>
<tr>
<td>Roofing</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Propulsion</td>
<td>$150</td>
<td>$80</td>
</tr>
<tr>
<td>Others</td>
<td>$150</td>
<td>$80</td>
</tr>
<tr>
<td>Cable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>$1370</td>
<td>$628</td>
</tr>
</tbody>
</table>

Pulley Power Cost, $/kW

- Fixed charge with Title XX funding = 10% and capacity factor = 0.95
  - 23 | 15.9
- 0.6% charge (from Table 4 note)
  - 4 | -
- (from Ref. 2)
  - - | -
| Total | 27.3 | 17.9 |

Table 2. Ammonia Production Cost from Grazing Plant-Ship: Tropical Siting AT = 4°F DOE Baseline Plant: (1976 Dollars)

- Capital cost of ammonia production plant
  - Electrolysis plant | $110 |
  - Ammonia synthesis, storage and transfer | $90 |
  - Heat engine for waste heat recovery | $10 |
  - Electrical | $220 |
  - Additional O & M charge (10% of fixed charge) | $9.9 |
  - Total O & M cost for ammonia production $/kW | High: 30.3 | Low: 17.9 |

A 325 MW (average annual output) power plant produces 1132 tons (1000 metric tons) of ammonia per day; (1 short ton requires 7078 kWh)

Cost (price) of ammonia cowash plant-ship (per short ton) to obtain authors’ stated return on capital

- $247 | $159
- Shipping cost - Atlantic I Site to New Orleans, 75,000 ton tanker
  - $11 | $11
- Delivered cost (price) in 1976 dollars per ton
  - $258 | $170
- Delivered cost (price) in 1976 dollars (reduced for 7% annual inflation)
  - $225 | $148
- Delivered cost (price) in 1973 dollars
  - $211 | $138

1. An icon at C.R. Burt Report, Detailed Design, Costs are increased 26% to convert to 1976 dollars.
2. The authors use the term "cost" in the economic sense to indicate the cost recovery or price needed to provide the stated return on capital.
3. Ibid. The high shipping costs used by DOE were based on large shipment from the first OTEC plant-ship. Data for estimating cost of tanker shipment were provided by Sea Shipping & Dry Dock Co.
4. Note that the costs (prices) are similar to the price range in Fig. 4, E.J., "Investment in Commercial Development of Ocean Thermal Energy Conversion (OTEC) Plant-Ships," 12/77 Table 3-11, p. 3-11 to recover plant investment in less than 7 years.

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and Atmospheric Administration, Offshore Technology, Giannotti and Buck, Value Engineering, the Applied Physics Laboratory of Johns Hopkins University, Gibbs and Cox, the State of Hawaii, the Puerto Rico Resources Authority, Aluminum Associates, Innovations Associates, and Worthington Pump.

Further information regarding exhibit space is available from E. J. Francis, Applied Physics Laboratory, Johns Hopkins University, Johns Hopkins Road, Laurel, Maryland 20810, (301) 953–7100, Extension 537. For general information and pre-registration, contact Dr. Gordon L. Dugger at the same address or call (301) 953–7400.

UNESCO BOOK ON "HARVESTING OCEAN ENERGY" NEARING COMPLETION

In a mid-March note from Dr. Gerald Wick of the Institute of Marine Resources of the University of California at San Diego, he reports that the first draft of the book Harvesting Ocean Energy, to be published by UNESCO, will be completed in June. Wick is the co-ordinating editor for the book, which will deal with all forms of ocean energy. The publication date is uncertain, but it is expected to be either late 1979 or early 1980.

AN OTEC POWER PLANT TO CARRY IN THE TRUNK OF YOUR CAR?

Many readers of this publication have had the opportunity during the last several years to view the film produced by Lockheed for the purpose of educating the public on the potential and workings of proposed Solar Ocean Energy/OTEC plants. These moviegoers will probably remember the speaker (an actor playing the part of d’Arsonval, who conceived the OTEC concept almost a hundred years ago) standing near a model of one proposed design—a miniature power plant about three feet high.

According to Fred Naef of Lockheed, it turns out that on more than one occasion a naive film viewer believed that the OTEC power plants being planned would be the size of the model in the film—yes, about three feet tall!

No doubt these individuals were looking forward to the day when they, as campers or small-boat men, could pop an OTEC into the nearest sun-heated pond, uncoil a garden-hose-size cold-water pipe, and plug in an extension cord to power their camping and boating equipment.

With miniaturization improving daily, this innovation may be worthwhile for some entrepreneur to pursue... as long as he gets proper clearances from all the relevant government regulatory agencies, of course.

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NOAA AWARDS OTEC CONTRACT TO LOCKHEED

March 23rd, 1979: A $233,450 contract to develop a method for anchoring ocean-based thermal-energy (OTEC) power plants has been awarded to Lockheed Missiles and Space Company, Incorporated of Sunnyvale, California by the National Oceanic and Atmospheric Administration (NOAA).

Officials of NOAA’s Office of Ocean Engineering said that the OTEC system requires an effective method of holding the floating power plants in position so that the electrical cables carrying power ashore will not disconnect.

Under the contract awarded by the Commerce Department agency, Lockheed will develop preliminary designs for each of two modular experimental platforms at a Puerto Rico site. In addition, the Lockheed effort will examine the feasibility of using similar designs for larger commercial OTEC power plants of up to 400 megawatts capacity.

NOAA is managing the contract in support of a Department of Energy program intended to perfect the OTEC plans.

OTEC PLANT/UTILITY TIE-IN CONTRACTS UNDER NEGOTIATION WITH DOE

The Department of Energy is negotiating contracts with two electric utilities to study how they could introduce OTEC power plants into their existing electrical systems and operate these plants successfully. Utility interconnection studies are part of an effort to prove the commercial applications of the technology. Puerto Rico is considered an early market for OTEC plants.

The Florida Power Corporation and the Puerto Rico Water Resources Authority will be conducting one-year studies which will include an analysis of the potential reliability and impacts of OTEC systems on their power supplies during the 1990s. Florida Power and Puerto Rico Water were among several utilities responding to a request for proposals issued by DOE’s Chicago Operations Office.

ENVIRONMENTAL EDUCATION MAGAZINE STRESSES SOLAR ENERGY AND OTEC

The March issue of Current Energy and Ecology, a publication dedicated to environmental education and read by both teachers and students at the primary and high-school levels, is primarily devoted to its lead article: “Solar Energy: On the Horizon?”

The issue deals with the various solar options, including Solar Ocean Energy/OTEC.

CALL FOR PAPERS EXTENDED FOR OCTOBER MTS OCEAN ENERGY CONFERENCE IN NEW ORLEANS

The Marine Technology Society (MTS)-sponsored Ocean Energy Conference and Exposition to be held at the Hyatt Regency Hotel in New Orleans October 10th through 12th has just extended its call for papers to April 1st. With the OTEC Session chaired by Dr. Ed Snyder III of TRW, the Conference will include an extensive exhibit of marine products and services, and over 2,000 people are expected.

Additional information can be obtained from Marine Technology ‘79, MTS, Suite 412, 1730 M Street NW, Washington DC 20036.

As announced earlier (see the December issue of TOLL), this will be the first time since 1974 that MTS and the Institute of Electrical and Electronic Engineers (IEEE) will hold separate meetings. The San Diego sections of MTS and IEEE will hold their Oceans ‘79 meeting in San Diego September 17th through 19th. Details are available from Oceans ‘79, 3065 Rosecrans Place, San Diego CA 92110, (714) 224–3928. The San Diego meeting’s theme is “The Technical Challenge of our Space”.

SOVIETS OPEN SOLAR INSTITUTE

The USSR’s first scientific–research institute of solar energy opened January 4th under the auspices of Turkmenia’s Academy of Science. Turkmenia, the largest of the USSR’s Central Asian republics, currently has a solar distillation plant producing 20 tons of drinking water daily.

STUDDS REPLACES BREAUX ON OCEANOGRAPHY COMMITTEE

Long a friend of OTEC, Representative John Breaux (D–LA) will become chairman of the Subcommittee on Fisheries, Wildlife Conservation, and the Environment of the House Merchant Marine and Fisheries Committee, and Representative Gerry Studds (D–MA) will replace him as chairman of the Subcommittee on Oceanography.

INTERNATIONAL PUMP SHOW

OTEC planners may wish to attend the International Pump Show (“World of Pumps”), to be held April 10th through 12th in New Orleans. This annual industrial exposition is international in scope, with pumps of every size and description on display from all over the industrialized world. With factory men on hand to discuss applications and help solve technical problems, this show could be useful in the planning and design of future OTEC power plants. For details contact World of Pumps, 622 6th Avenue West, Seattle WA 98119, (206) 284–6176.
US GOVERNMENT
PROCUREMENT INVITATIONS
AND CONTRACT AWARDS

Listed below are procurement invita-
tions 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.

Mar 5: Solar System Engineering and
Management Support for the Office of
Solar Applications and Commercialization:
The purpose and objective of this effort is
to provide technical and management support
to the Office of Solar Applications and Commercialization in accelerat-
ing the widespread application of solar
technologies in the marketplace. A cost-
plus-fixed-fee (CPFF) contract for one
year, with two one-year firm options, is
templated. An estimated 116,000 di-
rect productive man hours (DPMH) will be
required in the performance of the required
services for the basic statement of work of
one year, with 116,000 direct productive
man hours (DPMH) for each of the two
one-year firm options. Firms desiring a
copy of RFP DE-RP01-79CS30047 must submit their request in writing. The
RFP will be issued o/a 19 Mar 79. Firms are
specifically advised that telephonic re-
quests for this RFP will not be honored.
Offerors will be required to make a Disclo-
sure Statement Regarding Organizational Conflicts of Interest and to accept the Or-
ganizational Conflicts of Interests Clause
contained in ERDA PR Subpart 9-1.54.
US Department of Energy, Office of Pro-
curement Operations, Attn: Document
Control Specialist, 400 First Street NW
(MS 400 RB), Washington DC 20545.

Mar 5: Mechanisms for the Effects of
Variable Solar Activity on the Weather:
Contract ER-78-S-02-4634.A001, for
$57,200, awarded to the Aspen Institute
for Humane Studies, New York NY
10022.

Mar 13: Study for International Solar
Energy Commercialization: Contract DEAC01-79-CS-30028 (sole source), for
$96,386, awarded to Systems Consultants
Inc., 1054 31st St. NW, Washington DC
20007.

Mar 23: Administrative, Information,
and Special Studies Support Services for
Energy Technology: Negotiations are being
conducted with Orkan Corporation, Silver
Spring MD 20910, for Contract DE-AC-
01-79-ET-6006. Contract Specialist is
Dianne Scalzo.

Mar 23: Response of a Semi-Con-
strained Float for Ocean Wave Energy
Recovery: Negotiations are being con-
ducted with Slotta Engineering Associates
Inc., Corvallis OR 97330, for Contract
DE-AP-01-79-ET-21019. See Note 46.
Bruce Bakaysa. Department of Energy,
Office of Procurement Operations, Wash-
ington DC 20545.

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WORLD'S FIRST OFFSHORE
POWER STATION TO BE BUILT

No, it will not be an OTEC power plant.
But it has significance in that it supports
the contention that power generation is
feasible and practical offshore.

Unlike the offshore power-plant proj-
ects that were recently scuttled in the US,
the West German firm Kraftwerk Union
AG, a unit of Siemens AG, has received
a letter of intent from Nordwestdeutsche
Kraftwerke AG for the purchase of gas and
steam generators to be installed in the
world's first offshore power station, to be
anchored in the North Sea.

Fueled directly from an undersea gas field,
the station will transmit power to
shore for Northwestern Germany. Two
128,000-kilowatt gas-turbine generators
and a steam-driven generator with a ca-
pacity of about 120,000 kilowatts will be
fueled by undersea gas in the southern part
of the North Sea. The three generators
alone would cost about $30 million, with
the entire station costing around $300
million.

Although unrelated, the announcement
came on the heels of Kraftwerk's dismiss-
ing 120 of the 2200 workers at its West
Berlin power-plant—equipment factory due
to lag in construction of nuclear plants.
The firm said German court decisions and
protests from citizens' groups have blocked
$4.04 billion in nuclear contracts.

This story is repeated here as firm argu-
ment to counter the pronouncements of
some nay-sayers who contend that OTEC-
powered offshore plants are either infeas-
able or impractical due to their offshore
sittings.