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termine the suitability of that site for nuclear waste disposal.

Finally, there is the possibility that the waste capsules can be initially prevented from melting their way to the bottom of the ice by a suitably constructed, non-mechanical heat removal system with a design life of some hundreds of years. This system would dissipate the heat given off during the years when the capsules are most intensely radioactive, cooling them and maintaining their retrievability against the event of the development of a better waste-disposal plan.

J. CURTIS SIREN

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THE AUTHORS COMMENT: We appreciate the interest shown by the authors of the above letters and welcome this chance to amplify our thoughts with respect to the dispersibility of deeply buried wastes and the suitability of the Antarctic ice cap for waste disposal.

In response to the argument by A. T. Young, we believe that it is misleading to compare the defined inhalation and ingestion hazards of accumulated wastes with the volumes of air and water that exist in the biosphere because of the impracticality of dispersing globally significant quantities and concentrations of deeply buried wastes. An event (such as meteoric impact or volcanic eruption) that has potential for ejecting large quantities of deeply buried solids into the atmosphere also would be characterized by (1) mixing of the wastes with other materials in the formation (such that the toxicity of the airborne particles would be determined more by their natural physical and chemical properties than by their waste content), and (2) rapid sedimentation of most of the ejected solids in the immediate vicinity. Events potentially leading to dispersion in water would be characterized by extremely long time frames and would tend to leave practically all of the waste materials in local solid deposits because of (1) the limited solubility of the waste materials in competition with other materials, (2) the removal of dissolved species by ion exchange and (3) the removal of suspended species by filtration and sedimentation. It should also be noted that there are many types of naturally occurring materials in the earth's crust that could theoretically foul our biosphere if it were not for such physical chemical effects that effectively limit their dispersibility and provide for self-purification of the atmosphere and oceans.

In response to the comments by J. Curtis Siren, we believe that the relevant issue concerning the stability of the Antarctic ice cap is not its longevity as a geologic feature but the residence time of a particular water molecule in the ice. It is well established that Antarctica has been mantled by a continental glacier for a period of the order of 10^7 years. However, regardless of how stable the glacier may be, the ice within it is quite dynamic; it accumulates in the central portions, is transported by plastic deformation, and is both obliterated and discharged as icebergs around the edges. The length of time required for this cycling is quite variable in different parts of the glacier and, in general, is not accurately known. Even in a region of relatively stable ice it would be necessary to establish that stability would not be disturbed in the future, for example by climate-induced migration of the centers of ice accumulation.

There are several other similar objections to the use of the Antarctic ice cap for radioactive waste disposal but they all reduce to essentially one point: knowledge of the behavior, mechanics and dynamics of continental glaciers, and the effects that outside influences have upon them, is so incomplete that we feel they presently cannot be taken seriously as future repository sites.

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Realistic costs for hydrogen

Clarence Zener's article on solar sea power (January, page 48) considered various aspects of an ocean thermal-gradient electric power plant that would produce hydrogen.

We have considered the economics of selling this hydrogen to continental users as an intermediate for chemical products or as a fuel for clean electric power plants. The conclusions are that such hydrogen would cost from five to ten times what hydrogen from other sources of power plant fuel is likely to cost.

Zener states that the ocean-plant capital costs could be as low as those of land-based combustion power plant. If we take this at an optimistic value of about \$200 per kW including the cost of the electrolyzing equipment, then the electric power output from his plant would cost about 4 mills per kWh (14% fixed charge rate and 0.8 operating factor). Assuming 67% efficiency for conversion to hydrogen by electrolysis, which is appropriate for current industrial practice, the hydrogen price is about 4 mills per kWh

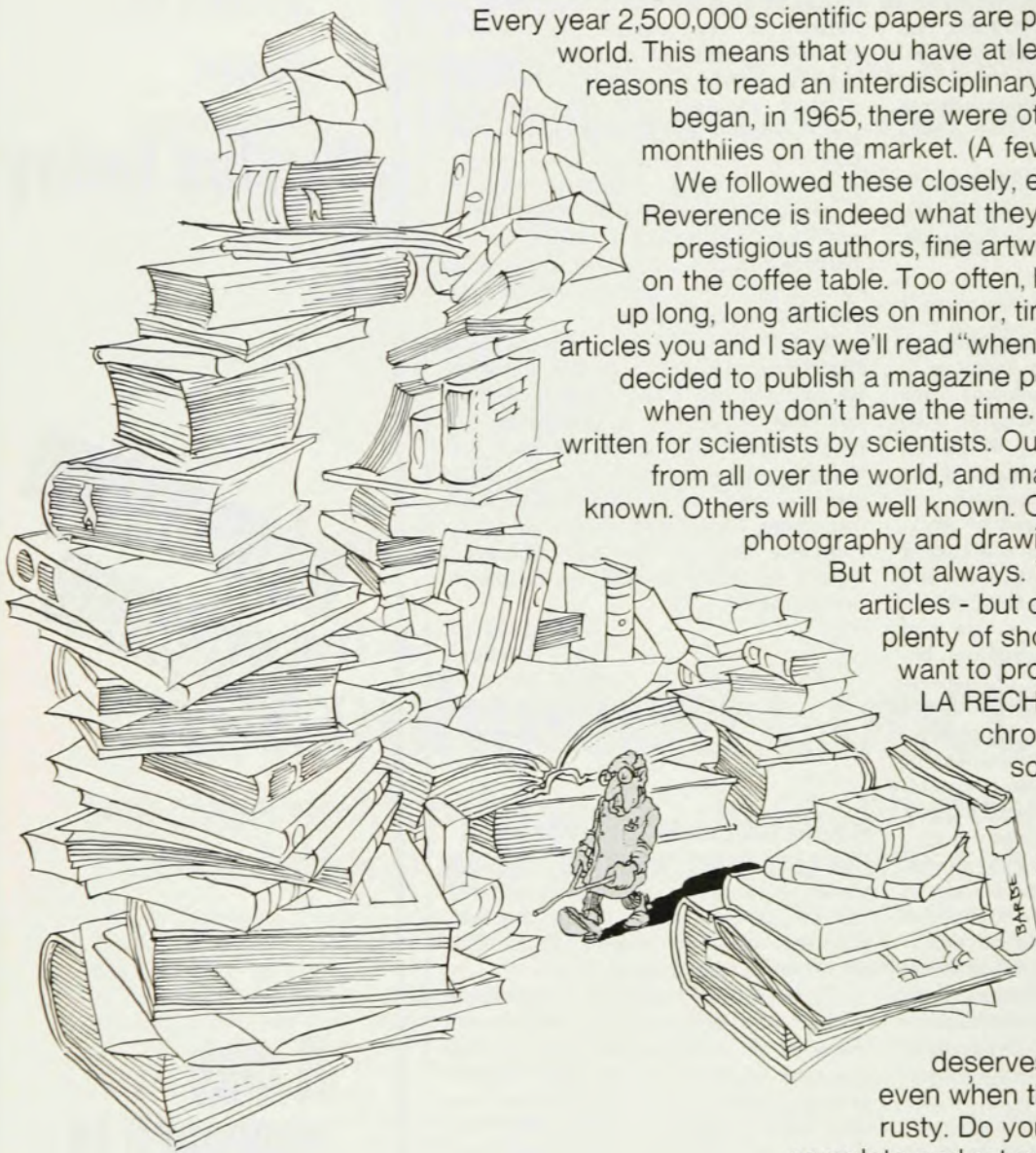
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times 300 kWh per million Btu divided by 0.67, or about \$1.80 per million Btu. This is three to five times the present cost of fossil fuels.

Similar cost disadvantages militate against the use of electrolytic hydrogen as an intermediate in energy systems whatever negligible-fuel-cost power source (ocean, solar, nuclear, hydroelectric, and so on) is used in the first step.

There are four considerations that we believe would raise the cost of Zener's ocean-produced hydrogen even higher:

- ▶ The fraction of ocean plant output necessary for pumping the heating and cooling water.
- ▶ The complications of operations and maintenance arising from a submerged operating mode.
- ▶ The scaling of heat exchanger unit costs (\$ per kW) inversely with the thermal efficiency.
- ▶ The cost for cryogenic or submerged transport of the hydrogen to shore.

These comments should not be construed as a criticism of the sea-power concept, but only as a plea to be realistic about the economic aspects. To be competitive in the near future in the hydrogen and fuel market, such a plant would have to be built at a capital cost of about \$40 per kW.

MICHAEL A. WAHLIG

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BLAKE MYERS

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THE AUTHOR COMMENTS: Wahlig and Myers are quite correct in emphasizing the near-future noncompetitiveness of hydrogen from solar sea power plants. Thus they compare an estimated cost of \$1.80 per million Btu for such hydrogen with present fuel costs of \$0.36 to \$0.60 per million Btu.

Those of us who are working on solar sea power are under no illusion as to the near-future competitiveness of electrolytic hydrogen from solar sea power plants. We do believe, however, that the near future as presently visualized may change rapidly and drastically. As straws in the wind, it is pertinent to observe:

▶ US companies¹ have signed an agreement with the Soviet Minister of Foreign Trade to build a 2000-mile gas pipeline in the Arctic Circle from Eastern Siberia to Vladivostok, to liquify the gas there and ship it to the US. Estimated cost of gas is \$1.50 per million Btu.

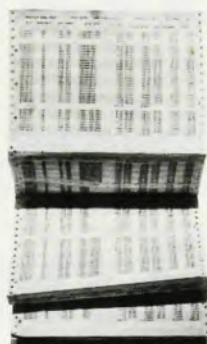
▶ The American Petroleum Institute² has estimated that offshore drilling platforms cost \$2 million for 150-feet

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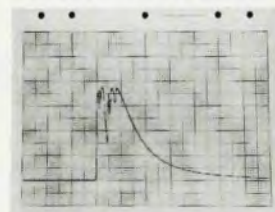


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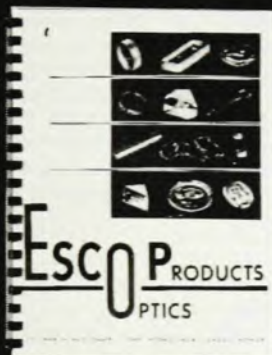
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depth, \$6 million for 400-foot depth, \$32 million for 800-foot depth. In spite of these escalations in costs, with increasing depth, the Interior Department last month invited bids for offshore tracks beyond the 200-meter depth.

► This country has no strategy for preventing a skyrocketing in the cost of oil from the Middle East. In fact, James Akins³ of the State Department states that \$7.00 a barrel (\$1.20 per million Btu) for Middle East oil may seem a conservative figure by 1980.

References

1. Wall Street Journal, 11 June 1973.
2. "One Answer to the Energy Crisis," American Petroleum Institute (1972); page 20.
3. James E. Akins, "The Oil Crisis: This Time the Wolf is Here," Foreign Affairs, April 1973; page 462.

CLARENCE ZENER
Carnegie-Mellon University

Plea for old Journals

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One of these problems is the almost total absence of good libraries in most secondary schools and in many universities. This and the serious difficulties of obtaining any form of hard currency explain why the vast majority of physics teachers in these countries do not even know that magazines such as *The Physics Teacher*, *PHYSICS TODAY* and *Physics Education* exist. Reading them would undoubtedly be of great help in their teaching and one of the few ways of keeping abreast with the latest developments in physics and in physics teaching.

Many physicists and teachers in developed countries subscribe to these magazines and usually forget about them after a first quick reading, if they keep them at all. In any case, there are normally nearby libraries where they can consult them afterwards if they wish. These possibilities are not open to many physics teachers in developing countries.

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