mentalist. What the myriads of tables in this version of the Good Book provide is information on the trade-off between speed, distance, and recovery times. The tables provide remarkably accurate predictions of performance. Consequently, the absence of much in the way of a theoretical underpinning is the more surprising. Fortunately, at least one stellar miler and cross-country runner (C. R. Taylor) appears to be devoting professional attention to these matters, even though he adopts an unorthodox style [see C. R. Taylor and V. J. Rowntree, "Running on two or on four legs: Which consumes more energy?" (12 Jan. 1973, p. 186)].

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Reference

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Power, Fresh Water, and Food from the Sea

Othmer and Roels (12 Oct. 1973, p. 121) suggest a system by which the oceans would be used to provide electric power, desalinized water, and nutrients for mariculture. Power would be generated by operating a heat engine between the warm surface waters and the cold bottom waters of the ocean. The Othmer and Roels scheme makes use of steam, produced by flash vaporization of the warm surface waters, as the working fluid.

A major problem with this approach is that the low vapor pressure (25 to 30 mm-Hg) of steam at the water temperatures available at the ocean surface (25° to 30°C) necessitates the use of very large turbines. For a power plant producing 1 gigawatt (1 million kilowatts) of electrical power (the typical size of a modern plant) the total area of the nozzle throat at the inlet to the turbine must be of the order of 10^4 square meters. For a conventional power plant, the comparable area is about four orders of magnitude smaller.

Such low-pressure turbines of the size necessary for a 1-gigawatt plant have never been constructed. The use of many moderate-sized turbines would be prohibitively expensive. Although a smaller plant, such as the 7180-kilowatt (net) plant suggested by Othmer and Roels would require a smaller turbine, the turbine size would still be out of proportion to the plant capacity, and the quantity of power produced would be uninteresting by today's standards. Ting (*1*) has estimated that the turbine inlet pipe for such a plant would exceed 13 meters in diameter.

The problem of turbine size is considerably alleviated if a separate working fluid is employed in a closed cycle. Lavi and Zener (*2*) suggest ammonia, and Anderson and Anderson (*3*) suggest propane. A more suitable pressure profile in the available temperature range can thus be realized, permitting a reduction in the turbine size by two to three orders of magnitude. For large-scale power production from sea thermal gradients, it would appear that schemes employing a separate working fluid are the more realistic.

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1. H. Ting, *Combustion* **42**, 16 (1970).
2. A. Lavi and C. Zener, *IEEE Spectrum* **10**, 22 (October 1973); see also C. Zener, *Phys. Today* **26**, 48 (January 1973).
3. J. Anderson and J. Anderson, Jr., *Mech. Eng.* **88**, 41 (April 1966).

A suspension bridge may be the best structure for crossing a particular stream; the advantages of a trestle bridge indicate it should be used over another. Then there are oranges which are squeezed, and prunes which are dried. Ammonia is a good thermodynamic fluid, propane another, each for particular conditions; and water has outstanding advantages for the system described in our article.

Whether bridges, fruits, or volatile liquids, individual methods are best for particular situations. A plant using water can be safe on shore rather than anchored far off at sea, where one part would be swept with the hurricanes that occur so often in tropic seas, a second part would be hundreds of meters below the surface, and a third part would be between these two. Cables on the ocean floor a kilometer below the surface would have to carry the *single* product, electric power, many kilometers to shore. Situations may exist where this is the only possible design, and we have no quarrel with it. We can only envy the brilliant imagination which created the idea, and wish its realization the good luck it will need.

The use of water as the working fluid can produce more power—by one-sixth to one-fourth—because there is no loss of a precious temperature drop in exchanging heat to and from a second fluid. Since no transfer of heat to another fluid is required, there would be no expensive heat transfer surfaces and no substantial reduction in efficiency thereby. Also there would be no losses of a volatile and somewhat hazardous fluid, propane or ammonia.

A shore-based plant using water as the working fluid would make fresh water as well as power. For several of the locations where the engineering and economics of such a plant have been studied, the sales value of the distilled and desalinated water produced in condensing the steam, which would have released its energy, is at least several times the value of the power produced using water or *any* thermodynamic fluid. Conventional power costs from a shore-based plant using fossil fuel are the common yardstick.

Desalinated water also has become expensive because of its energy requirements; often the profit earned by the two products instead of one is important. (Our study was never intended as an exercise in pure thermodynamics, but was a privately financed feasibility engineering study for a profit-making commercial venture.) By locating the plant using water as the fluid on shore, what is by far the most valuable asset of the deep sea water—its nutrients—can be utilized for mariculture; its freedom from pollution, noxious organisms, predators, and parasites would encourage growth of valuable fish for food. The upwelling of deep water would certainly provide a bounty to marine life around a power plant using propane as the working fluid in the open seas; but there is no way to cash in on this value any more than there is a way to make and sell distilled water using a fluid other than water. The plant we described may show more profit (by an order of magnitude) from mariculture than from power, regardless of which fluid is used; and that also will help pay the major cost of the pipes and pumps for bringing up the deep water and for their operation.

Davitian and McLean build up a gigantic, gigawatt straw man of the system using the water cycle. They then topple him over with some simple calculations which we never had the temerity to make; such a fantastic monster—over two orders of magnitude greater than our largest program—is not necessary to show a handsome profit for our three products compared to their one, which is the least valuable.

We never aspired to gigawatts, but we did show how, with a relatively small power plant and without extrapolation of engineering feasibility, one may come up annually, and very profitably, with gigaliters of fresh water and giga clams and oysters.

No one now argues with the idea of a suspension bridge across the Hudson River (and we will let some one else extrapolate to one across the English Channel; that is small compared to the magnitude of the extrapolation of our design by Davitian and McLean); but trestle bridges also have their place crossing creeks; and juice from oranges is good, while some specify dried prunes.

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Post-Project Research Grants

Even with superior grantmanship, many investigators receive notifications from Washington, D.C., to the effect that there are no research funds available with which to implement their approved meritorious investigations. Nonetheless, some of these researchers are undoubtedly continuing their scholarly pursuits on a less elaborate scale. One wonders if some granting agency —private, state, or federal—might establish a new form of research grant award that could be competed for *after* completion of an investigation.

The investigator would submit a letter of intent to a granting agency, be it a philanthropic, industrial, or governmental organization. The intended area of investigation would be specified and the minimal personal research expenses anticipated for the ensuing year. The investigator's scientific zeal for his area of scholarly pursuit must be such that the projected costs would be covered, without assured reimbursement, from the researcher's own pocket. The investigator would be required to prepare a report of his research acceptable for publication by a highly regarded journal within his special field of competence. Finally, when all is said and done, the investigator would submit to the potential granting institution copies of the accepted manuscript or reprints of the published results, together with evidence of relevant out-of-pocket expenses incurred. In other words, competition for the proposed partial or total research grant award would follow only *after* successful accomplishment of the project. There may be few takers, but it would be a sure bet—for science and for the potential granting agency: no results, no awards.

Such an innovation in research grant support cannot and should not take the place of present systems, for such post-project proposals probably would require a more substantial salary than that usually available to young investigators still on the initial steps of the academic ladder. On the other hand, among devoted established investigators there undoubtedly must be those who as yet are not prepared to throw in the towel in the face of approved but unfunded research grant applications. Dedicated scientists may be prepared to prune their operational costs and be willing to serve as their own temporary technicians or part-time secretaries in order to invest in the "academic bank." Such an attitude would especially be encouraged if the investigator were given half a chance that the investment in science could result in at least a partial (refund) award. In the final analysis the total expenditures (from whatever source) would no doubt tend to be less. And yet the creative individual's "most wanted" area of research could well offer the most exciting promise of a return in the fields of human health, education, and welfare.

A research grant award of the kind proposed would serve as an antidote to the current vogue of federally conceived, mission-oriented contract research and return more emphasis to individual creativity and resourcefulness. What is best for the fulfillment of the individual scientist is probably also best for science in the long run.

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