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London Report: Surf's End

In June 1974, the Central Policy Review Staff (CPRS), the "think tank" of Britain's Cabinet Office, published an odd report called *Energy Conservation*. Despite the eminence of its chairman, Lord Rothschild, and the reputed intellectual muscle of its participants, it was curiously incoherent - a grab bag of bits and pieces with little relation one to another. Undoubtedly the least appropriate, and most unexpected, part of the report was a section describing with considerable enthusiasm the virtues of a new technology for extracting useful energy from the motion of ocean waves. What this had to do with energy conservation in any narrow sense was unclear; but the CPRS was patently impressed by what it had learned, and correspondents fell over themselves to seek out the source of this unfamiliar notion.

By a stroke of excellent timing, almost simultaneously there appeared in *Nature* a letter which threw the requisite light on the matter. It was from Stephen Salter, a design engineer in the Department of Fluid Mechanics at the University of Edinburgh. The letter described the basis of a radically different form of power technology, one which can extract wave energy by means of devices which Salter, with a downbeat wryness - one of his most engaging characteristics - called "rocking ducks."

Salter has only recently transferred from the university's Department of Artificial Intelligence, where he had devoted much of his time to designing and building operating robots - self-propelled powered machines capable of responding to commands and carrying out manipulative tasks. In November 1973, he attended a landmark meeting on the topic "Energy in the 1980s" at the Royal Society in London. This meeting saw the first publication of *World Energy Strategies* by Amory Lovins, which has since become something of a classic and which, Salter says, convinced him to undertake a search for practical alternative technologies and led almost immediately to his plunge into work on wave power.

Methods of extracting useful energy from waves have cluttered patent offices in many countries for decades, and Salter insists that there is nothing particularly new in the concept. His innovation is in the hardware: the mechanical devices which convert the power of waves into a form of useful energy. Most of the earlier attempts at design have focused on the vertical motion associated with the passage of sea waves past a point. Salter, however, decided to consider the rotational motion of surface water under wave action. A given water molecule travels in a circle in the vertical plane: first, the molecule moves forward at the top of the circle, then downward; the next motion carries it in the opposite direction at the bottom of the circle; and finally, it moves upward and forward again with the next passing crest. Much of the energy of the advancing wave is delivered by the horizontal component of this circular movement. A circular cylinder floating in the water will have only brief rotational displacements back and forth about its axis; but if the cylinder's cross-section circumference is almond-shaped, with the longest radius pointing toward the advancing wave-fronts, the oscillatory rotation of the device is substantially increased. The seaward edge rears up smartly as an oncoming crest lifts it, then drops back into the following trough, swinging through an arc of 45 degrees or more - depending, of course, on the amplitude of the wave-train.

The above description of the system may be difficult to imagine, but a vision of Salter's pet ducks rocking happily in their fifteen-meter-long aquarium in Salter's cavernous laboratory at Edinburgh is unforgettable. The aquarium is a tank with transparent walls about a meter deep and a half meter thick, with a wave generator at one end. A futuristic bank of electronic instruments feeds the desired pattern of wave-train into the system, and the waves surge along within the walls of the tank. Various mechanical transducers and electrical instruments measure all the relevant characteristics of the passing waves. Then the waves encounter a duck mounted on a complex suspension which monitors all the forces exerted on it and by it. Salter and his colleagues are building up a bank of data on optimum ducks - surface shapes, internal mass distributions, and, particularly, reaction forces and moments associated with power take-off from the oscillatory rotation. They can already extract up to 85 percent of the energy from passing waves; it is an unambiguous and striking spectacle to see an irregular train of deep waves dashing themselves against Duck Number D0017, which absorbs most of the energy moving the waves, leaving only a slight ripple flowing onward.

The omens are propitious. During the early months of his work when Salter and his team were able to extract only 50 percent of the energy from their model waves, he wrote to the Department of Energy. Despite the fact that the department gets a steady stream of letters from enthusiasts, fanatics, and cranks, something prompted a civil servant to check into this latest claim. The fact that this claim came from the "Department of Artificial Intelligence" did not enhance its credibility; the first question asked by the civil servant on approaching the university was whether there was something as improbable as a "Department of Artificial Intelligence." All the early work had been done by Salter, and in the succeeding weeks his obvious hardheaded competence convinced a growing number of skeptics that there was, indeed, something exciting afoot. After the CPRS report and further official investigation, Salter was given a small grant to extend his efforts and to hire some assistance. Interest began to burgeon. The Central Electricity Generating Board began to acquaint itself with the

technology. One of the most interesting attributes of Salter's proposal was that energy recovered by the "rocking ducks" could be used to generate electricity, which could in turn be transmitted to shore for use in the regular public electricity supply system.

By late August 1976, the government was showing signs of conviction that the concept of energy extraction from waves could become a reality. Three other concepts for extraction of wave energy had by this time been "floated" (the metaphor is, for once, highly appropriate). Some four million pounds had been granted for further research on these three projects during the period 1976 to 1978. Salter's group won a renewed and increased grant for the purpose of building a new, large-scale testing tank in an unused lecture theater at the university, and for carrying out other tests in the country's largest marine testing facility. By this time Salter had all the necessary basic design for a full-scale offshore power-producing installation. It would consist of a large number of ducks, each perhaps ten meters in diameter and sixteen meters from end to end. All these ducks would be strung on a cable approximately a kilometer in length. The chain of ducks would float freely a few kilometers offshore; the location most favored would be beyond the Outer Hebrides. The irregularity of sea waves acting on such a long chain would produce a net random lateral motion; the chain would not have to be tethered or anchored in any way. Inside each duck, concentric with the backbone cable, would be some 48 differential hydraulic pumps, taking the oscillatory power from the outer envelope of the duck and converting it into high-pressure hydraulic power to turn sealed electrical generators. The power takeoff would be built from units already available off the shelf, and the entire system would be developed from modular packages. The ducks themselves could be constructed in shipyards - the work would certainly be welcome in Britain's shipyards at present.

Salter envisions another two years of development work, after which he is confident that full-scale ducks can be constructed for a prototype offshore installation, towed to an offshore site and subjected to the sort of intensive testing of which only the North Atlantic is capable. The costs that he calculates for the system already seem comparable to those of conventional nuclear electricity generation, and he feels that the economic prospects of the system are steadily improving. However, Salter warns that the system will involve other problems. Once power is collected from the offshore chain of ducks, getting it ashore will not be easy. Furthermore, transporting the power from the West Highlands to load centers will entail huge pylons through some of the most attractive countryside in Britain.

Nevertheless, Salter feels that such problems can be resolved. In addition, he anticipates that the system offers exciting prospects for export - for instance, there might be interest in a chain of Salter's ducks off the coast of California. Of course, as Salter points out, any such plan might meet with bitter opposition from one interested group in particular. If the rocking ducks convert 85 percent of the incoming wave energy to electricity - or hydrogen - what will become of surfing?