OCEAN ENGINEERING

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The United States is losing a space race. We are losing to Russia, to Japan, even to Peru. The race is to occupy, control, and exploit the vast resources of "inner space" represented by the oceans. We have hardly begun to develop the technological base which will be necessary to meet this challenge although the need is now generally recognized and activity is vigorous. One vitally important element in this effort will be the development of educational programs which combine not only the best marine science but the best modern engineering science to educate men with the capacity to cope with the strange new world of the sea.

A PhD program in Applied Marine Sciences has been initiated at the University of California at San Diego by Scripps Institute of Oceanography and the Aerospace and Mechanical Engineering Sciences Department in response to the growing demand for individuals with such training and research experience.

THE RESOURCES OF THE SEAS

Athough 70% of the surface of the earth is covered by oceans containing most of its animal and plant life, man extracts relatively little knowedge and material of value from water areas compared to land areas. Less is known of the geography of the deep ocean than is known of the back surface of the moon. Only about 1% of man's food is extracted from the 400 billion tons of organic matter produced in the oceans every year, yet men go hungry. Some 25% of the earth's oil lies underwater, yet recently the value of sand and gravel mined near the shore was greater than the value of the oil pumped from underwater. Billions of dollars are lost each year in ruined crops, lost construction time and damaged property because of our inability to accurately predict, let alone control weather conditions dominated by oceanic transport phenomena. In spite of these facts, our total national oceanographic program just ten years ago was less than $10 million annually. This amount has since risen dramatically: President Johnson proposes $462 million for the next fiscal year.

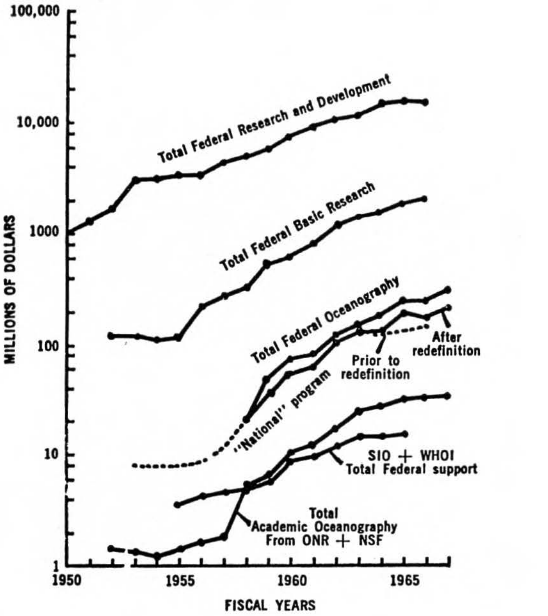

Fig. 1. Growth of Federal support for marine science and technology.

A significant fraction of the ocean bottom is not in deep water. An area about the size of Africa is in water less than 200 meters deep forming the so-called continental shelves. An intenational Convention on the Continental Shelves in Geneva reached an agreement in 1964 giving sovereign jurisdiction to the natural resources of the sea bed and subsoil of this land adjacent to coastal nations. In this way, the United States acquired 850,000 square miles of adjacent sea bottom or an increase in our territory of 25%. Clearly it is this land which can be expected to yield the first economic benefits.

THE NATIONAL OCEANOGRAPHIC PROGRAM

Appreciation of these vast resources has been awakening. From 1958 to 1965 Federal support to oceanography increased 11 fold as shown in Fig. 1 taken from the Panel on Oceanography of the President's Science Advisory Committee report[1] "Effective use of the Sea". This Panel recommended giving further expansion of the national oceanography program highest priority. They recommended a general increase of the nondefense component of the program from the 1966 level of $120 million to $210 million by fiscal year 1971 and an increase in basic research and education support from $15 million to at least $25 million in the same period.

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An important step forward in assuring a coordinated long-range national program for the effective use of the sea was the enactment of the Marine Resources and Engineering Development Act of 1966[1]. The Act established a Cabinet level National Council on Marine Resources and Engineering Development, headed by the Vice President, and a Commission on Marine Science. The Act also established as national policy "the advancement of education and training in marine science". Such legislation was motivated by the widespread impression that the nation's marine interests were not being adequately pursued because of organizational fragmentation of Federal responsibility for oceanography and due to lack of a sufficiently high level advocate for ocean science and technology in the administration.[1]

For whatever reasons, the United States is slipping behind in important areas of marine technology. Between 1954 and 1964 our annual fish catch actually decreased slightly from 6.13 to 5.82 billions pounds, while Peru's catch increased by nearly a factor of 50 to put her in first place with 20.2 billion pounds. Four other countries besides Peru lead us in this area. Lagging technology and obsolete equipment are certainly contributing factors. Our average medium-sized trawler in the Atlantic is 24 years old. Many segments of our maritime industry are struggling to stay alive. Japan leads the world in the development of "aquaculture" while this field is practically nonexistant in the United States, even though it has been estimated[2] that areas suitable for oyster production in the United States could produce more than the total fish catch of the world using modern methods of aquaculture developed in Japan. Three years after the loss of the submarine Thresher we still would probably not be abe to recover the Scorpion along most of its route across the Atlantic, even if we could find it. *All of these examples illustrate our past neglect of ocean engineering.*

Estimates of future world population growth indicate that conventional methods of food production will be hard pressed to meet either caloric needs or the critical problem of animal protein deficiency. Chronic protein deficiency is the leading cause of death for children between weaning and five years of age in all countries of the equatorial zone, accounting for as high as 50% of such deaths[1] as well as blighted health at all ages. Marine protein concentrate extracted from various species of hake can provide adequate protein to supplement one child's diet at a cost of only $2.00 per year using presently available technology. The "food-from-the-sea" program has been given the highest priority by the Marine Science Council.[3]

EDUCATION IN OCEAN ENGINEERING

The incredible efficiency developed by our agriculture is recognized as a key factor which permitted the economic success of this country. Many attribute this rapid development of agriculture to the stimulus provided by the Land Grant College system and the associated State Agricultural Experiment Stations which followed. When President Lincoln signed the Land-Grant Act in 1862 hardly a college in the country was equipped for laboratory teaching or research. The familiar pattern today of teaching and graduate research was an idea vigorously debated during the formative years of the land grant college system. In fact, a previous version of the Land Grant Act had been vetoed 4 years earlier by President Buchanan. The Land Grant Colleges brought major changes in the philosophy of higher education. Instead of teaching a narrow curriculum of philosophy, theology, dead languages and mathematics, the function of a university was expanded to include both the seeking and dissemination of new knowledge as well as teaching of the old. Since the inception of the Land Grant Colleges, the efficiency of the farmer has increased over 700%. Today, research-based increases in agricultural efficiency are estimated to save this country over $7 billion each year.[2]

In contrast to the seven fold productivity increase of the farmer, the productivity of U. S. fisherman has increased only 33% in the same period according to Senator Claiborne Pell,[2] author of the National Sea-Grant Colege and Program Act. The Sea-Grant College concept was inspired by the success of Land Grant Colleges, and was first suggested by Dean Athelstan Spilhaus of the University of Minnesota.

Dean Spilhaus envisions more than simply increased support to research and teaching in ocean engineering in the Sea Grant Colleges. He sees the same sort of educational extension work applied in marine technology as was developed in American agriculture: "county agents in hip boots" are even a part of his prescription for the propagation of new discoveries in ocean technology.

In 1963-64 the total U. S. oceanographic science staff was about 3000 including 500-600 PhD's. The growth in the numbers of students and degrees in oceanography or marine science is shown in Fig. 2. At present there are some 1000 students enrolled in over 50 marine science curriculums.[3] It has been increasingly apparent, however, that much less effort and support has been expended in training ocean engineers. Only 17 curricula in ocean engineering or technology were listed by the Interagency Committee on Oceanography in 1967-68[4] It is this situation which the Sea Grant College Act is intended to alleviate by its particular emphasis on ocean exploitation and applied research.

APPLIED MARINE SCIENCES AT UCSD

At La Jolla, the development of ocean engineering has been rather opposite to that expected by the Sea Grant College Act, although the end result may be similar. Instead of starting oceanic studies in an existing university, an existing center of marine science has started a new university. As described by Professor William Nierenberg, director of Scripps Institution on Oceanography in his testimony at the Sea Grant Colleges Hearings in 1966[2]:

> "For the past 10 years the oceanographers at Scripps have carried on continuous study and discussion of the best way to contribute further to the advance of ocean-related sciences. The first result and the principal one was the establishment of a new campus of the University of California at San Diego. It was agreed that a school of oceanography could not flourish unless it were closely associated with a university that had first-rate departments in the basic sciences and engineering. A school of marine science that is isolated from a first-rate campus is a poor concept in this day and age . . . the area of formal education in applied ocean science, sometime called ocean engineering . . . we hope to establish on a broad an surer basis in cooperation with our department of engineering, headed by Professor S. Penner."

The first college of the new San Diego campus is named for one of these oceanographers: Roger Revelle, former director of Scripps and a leader of the successful effort to establish a branch of the University of California at San Diego.

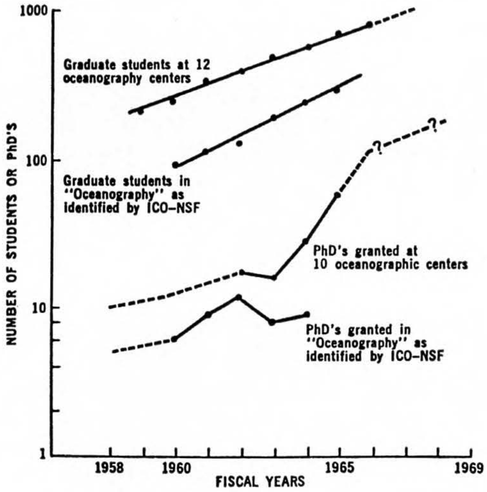

Fig. 2. Growth of students and degrees in oceanography.

At present the joint Applied Marine Sciences curriculum between the Aerospace and Mechanical Engineering Science Department and the Department of Oceanography is operating on an ad hoc basis, with perhaps half a dozen PhD candidates taking courses in both departments although considerable expansion is expected in the near future. Ten faculty members in AMES have expressed interest in the program, with backgrounds covering engineering physics and geophysics, mechanical, electrical, chemical, aeronautical and bioengineering, applied mathematics and mechanics, system dynamics and control, pathology and physiology. Among the thirty typical thesis topics which were suggested are:

Laboratory studies of wind generated waves
Turbulent transport phenomena at the air-sea interface and in stratified media
Noise models for analyses of undersea communication and detection, application of Kalman filtering and Folker-Planck-Kolmogoroff equations
Determination of wave heights by satellite
Structure of waterspouts, maelstroms and tsunamis

Because of the unusual breadth required of an applied marine scientist, it was agreed that the course material requirements for participation in the program should be substantially higher than the curricular requirements of either department for its candidates, totalling at least the material in 20 quarter courses and commonly more. Although there is clearly a need for individuals trained at all levels in ocean technology, it was concluded that only a PhD program would be consistent with the function of the University and the high level of competence in both fields of modern engineering science and oceanography which will be required of those individuals who can supply leadership in expanding application of marine science.

Recent developments have been the expansion of the interdepartmental ocean technology program to include the Medical School and Applied Electrophysics Department, the estabishment of a curricular group by Professor Warren S. Wooster, Chairman of the Scripps Graduate Department, to design the curriculum and initiate new courses which may be appropriate, and the selection of the University of California at San Diego for a Sea Grant College program.

SUMMARY

Greater efforts are needed in the development of applied marine science if the United States is to take full advantage of the potentially valuable resources of the oceans. Education will play a vital role in establishing the technological base, and the federal government has moved to assist the development of ocean engineering, especially through the Sea Grant College Act. The University of California at San Diego is developing a PhD program in Applied Marine Sciences in response to the awakening national awareness of the need to harvest the wealth as well as the knowedge of the sea.

ACKNOWLEDGMENT

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1968 Award Lecture

FLOW and TRANSFER at FLUID INTERFACES*

Part III - Convective Diffusion

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LET US CONSIDER steady, two-dimensional cases of the three classes of basic flow represented in Figures 2 and 6. These are parallel flow, in which surface dilation is absent; nearly parallel flow, in which there is mild surface dilation of "rejuvenation"; and irrotational stagnation flow, in which there is strong surface dilation and concomitantly the effect of convection normal to the interface completely overshadows that of convection parallel to the interface. The appropriately specialized versions of the convective diffusion equation are tabluated in Figure 11. Note that in the first two categories diffusion parallel to the interface can be neglected in comparison with convection in that direction. The boundary conditions in every case are a uniform and constant equilibrium concentration at the fluid interface and an unchanging concentration at great depths.

The leading convective diffusion solution for parallel flow is that of Leveque (1928), rederived by Elser (1949) and Kramers and Kreyger (1956); approximate solutions for some other instances of parallel flow have been computed by Beek and Bakker (1967) and Byers and King (1967). Perhaps the most useful exact solution will be that obtained recently by my coworker Majoch and described in Figure 12; although the

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*Based on the main part of the 1968 Annual Lecture to the Chemical Engineering Division, ASEE at the University of California at Los Angeles June 18, 1968, sponsored by the 3M Company.