Eighth Symposium

NAVAL HYDRODYNAMICS

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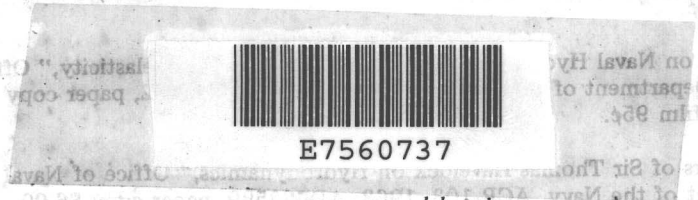

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Editors

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PREVIOUS BOOKS IN THE NAVAL HYDRODYNAMICS SERIES

"First Symposium on Naval Hydrodynamics," National Academy of Sciences—National Research Council, Publication 515, 1957, Washington, D.C.; PB133732, paper copy $6.00, 35-mm microfilm 95¢.

"Second Symposium on Naval Hydrodynamics: Hydrodynamic Noise and Cavity Flow," Office of Naval Research, Department of the Navy, ACR-38, 1958; PB157668, paper copy $10.00, 35-mm microfilm 95¢.

"Third Symposium on Naval Hydrodynamics: High-Performance Ships," Office of Naval Research, Department of the Navy, ACR-65, 1960; AD430729, paper copy $6.00, 35-mm microfilm 95¢.

"Fourth Symposium on Naval Hydrodynamics: Propulsion and Hydroelasticity," Office of Naval Research, Department of the Navy, ACR-92, 1962; AD447732, paper copy $9.00, 35-mm microfilm 95¢.

"The Collected Papers of Sir Thomas Havelock on Hydrodynamics," Office of Naval Research, Department of the Navy, ACR-103, 1963; AD623589, paper copy $6.00, microfiche 95¢.

"Fifth Symposium on Naval Hydrodynamics: Ship Motions and Drag Reduction,' Office of Naval Research, Department of the Navy, ACR-112, 1964; AD640539, paper copy $15.00, microfiche 95¢.

"Sixth Symposium on Naval Hydrodynamics: Physics of Fluids, Maneuverability and Ocean Platforms, Ocean Waves, and Ship-Generated Waves and Wave Resistance," Office of Naval Research, Department of the Navy, ACR-136, 1966; AD676079, paper copy $6.00, microfiche 95¢.

"Seventh Symposium on Naval Hydrodynamics: Unsteady Propeller Forces, Fundamental Hydrodynamics, Unconventional Propulsion," Office of Naval Research, Department of the Navy, DR-148, 1968; AD721180; Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Clothbound, 1690 pages, illustrated (Catalog No. D 210.15:DR-148; Stock No. 0851-0049); $13.00.

NOTE: The above books, except for the last, are available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151. The catalog number and the price for paper copy and for microform copy are shown for each book.

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PREFACE

Continuing in an uninterrupted manner since 1956, the biennial symposia on naval hydrodynamics convened for its Eighth Symposium, August 24-28, 1970 at Pasadena, California. This conference was jointly sponsored by the Office of Naval Research, the Naval Undersea Research and Development Center, and the California Institute of Technology.

The technical program in this series is traditionally structured about a limited number of topics of current interest in naval hydrodynamics. In the case of the Eighth Symposium, "Hydrodynamics in the Ocean Environment" was selected as the focal theme not only because of the present widespread research interest and activity in this subject but also in recognition of 1970 as the inaugural year of the "International Decade of Ocean Exploration." This motif for the Eighth Symposium was also aptly reflected in the banquet address to the participants by Rear Admiral O.D. Waters, USN, then Oceanographer of the Navy.

The organization and management of a meeting of this magnitude requires the attention and energy of a large number of people over a long period of time. To Dr. Harold Brown, President of the California Institute of Technology, to Captain Charles Bishop, Commander, Naval Undersea Research and Development Center, and to all the various members of their organizations who contributed in many different ways to the success of the Eighth Symposium, the Office of Naval Research is deeply indebted, and to them we extend our heartfelt gratitude and appreciation for a job well done. It is particularly appropriate, however, to acknowledge the specific roles of Professor Milton S. Plesset and Professor T.Y. Wu of the California Institute of Technology and Dr. J. Hoyt of the Naval Undersea Research and Development Center who as a group carried the lion's share of the responsibility for the detailed planning and day-to-day management of the Eighth Symposium. We take special pleasure in acknowledging the invaluable assistance of Mrs. Barbara Hawk, secretary to Professor Plesset, who in a most gracious and efficient manner carried out a multitude of important tasks in support of the Symposium. In addition, Mrs. Hawk, together with Mrs. Alrae Tingley, were responsible for the preparation of the typescript which was used in the publication of these proceedings. Mr. Stanley Doroff of the Office of Naval Research played his usual critical role, participating actively in every aspect of the planning and execution of the arrangements for the Eighth Symposium.

RALPH D. COOPER
Director,
Fluid Dynamics Program
Office of Naval Research

ADDRESS OF WELCOME

Rear Admiral C. O. Holmquist
Chief of Naval Research and Assistant Oceanographer for Ocean Science

I am pleased to welcome you to the Eighth International Symposium in Naval Hydrodynamics. This is a symposium sponsored every other year by the Office of Naval Research, with the objective of bringing together the leading investigators in the field of hydrodynamics research throughout the world.

ONR has held many international meetings during the nearly quarter-century of its existence. This is in line with its charter issued by Congress, which includes the responsibility to disseminate information on world-wide trends in research and development. It is for this reason, for example, that we have a branch office in London.

This series of meetings, however, has a unique characteristic. Every other meeting is held outside the United States. Two years ago we met in Rome, and two years from now we plan to hold this symposium in another country. This stimulates attendance by non-U.S. participants.

This year we welcome to the United States a number of distinguished researchers in the field of hydrodynamics. As you have noted in your program, you will hear papers read by scientists from institutions as far away as Australia. The information made available through this international meeting will not only provide the U.S. Navy with new ideas for significantly improving its ship designs but also a pool of knowledge that will stimulate international cooperation in science. The Navy has already received important benefits from an exchange of research data with other countries.

In regard to this symposium, ONR owes a great deal both to the Naval Undersea Research and Development Center and the California Institute of Technology, who have joined together to serve as hosts. We appreciate very much their efforts in arranging this meeting and providing the excellent facilities.

I might add as a personal note that I am delighted to have this opportunity to return to the Cal Tech campus, where I studied for my doctorate in the early 1950's. Since my field is aeronautics, I

cannot pose as an expert in hydrodynamics, although I am sure you recognize that the two fields have similar and related problems. In fact, in ONR we label our program Fluid Dynamics, with part of this program dealing with hydrodynamics and part with aerodynamics.

Aside from serving as co-hosts, both Cal Tech and NURDC have made major contributions to the work in hydrodynamics, some under ONR sponsorship. For some time Cal Tech has been studying a problem of critical concern to the Navy. This is the damage caused to propellers and other vital components by cavitation. Theoretical and experimental investigations on basic problems in fluid mechanics conducted here are assisting naval engineers in solving cavitation damage problems. At the same time, this work is adding to our knowledge of the phenomenon known as supercavitation, which has led to the development of supercavitating propellers and hydrofoils resulting in increased speed of specialized naval vehicles.

A major program at NURDC sponsorship promises not only to reduce drastically drag resistance during turbulent flow but also to reduce the flow noise which frequently interferes with sonar operations. I am referring to the use of polymer additives which when injected into the boundary layer of water promises to give naval vehicles the capability of burst speed.

At present NURDC is engaged in achieving a complete understanding of the mechanism of the drag and noise reduction properties of dilute solutions of polymer additives. This will give us a firm technical basis for predicting what extent we can achieve drag reduction and flow-noise suppression on Navy vehicles.

Research in hydrodynamics is carried out under contract to ONR at a variety of academic and at industrial organizations and at naval laboratories and field stations. Typical of the universities participating in the program are Stevens Institute, the Massachusetts Institute of Technology, Stanford, University of California, Harvard, Florida State, and Michigan in addition to Cal Tech. Industrial organizations include Hydronautics, Inc., and LTV Research Center and the Ampex Corp. Our in-house work in addition to NURDC is performed at the Naval Ship Research and Development Center, the Naval Research Laboratory, the Naval Ordnance Laboratory and the Naval Postgraduate School in Monterey, California.

Each of these three elements -- the university, industry and the Navy laboratory -- have a unique contribution not only to the Navy's fluid dynamics program but to Navy research and development in general. Universities provide us with the more fundamental data on which all good technology is based. Industry has special know-how in producing test beds and experimental hardward needed to prove our theories. The Navy laboratory provides in one location theoretical scientists working with naval engineers and naval officers

who have an intimate understanding of the Navy's operational problems.

As an example of what this combination can produce, we have developed computer programs to predict the coupled motions of heave and pitch for surface ships operating in a seaway. The input information that is used consists of ship geometry, forward speed, and a stochastic description of the sea state. Another computer program simulates the launch perturbations of a torpedo leaving a moving submarine. This provides a relatively inexpensive method for determining the operational limitations during launch, an insight into how launch problems can be solved, and tool for the design of future submarine weapon systems.

The research process is continuous and complex, and it is rarely, if ever possible, to label a new discovery as the product of one individual or even one institution. Research has to be cooperative, and we can achieve the most by cooperating on an international scale. As this meeting indicates, ONR and the Navy subscribes to that objective. I am sure that all of us are faced with the problem of producing the maximum amount of significant research results with a minimum of funds and manpower, so that we should all benefit from a mutual sharing of our knowledge.

ADDRESS AT THE SYMPOSIUM BANQUET

Rear Admiral O. D. Waters, Jr.
Oceanographer of the Navy

Mr. Chairman, distinguished foreign guests, geniuses in residence, Ladies and Gentlemen:

It is both an honor and a pleasure to be given an opportunity to speak here tonight to the delegates to the 8th Symposium on Naval Hydrodynamics.

It is obviously an honor for a mere sailor to be invited to talk to so erudite an audience and under such distinguished sponsorship as the California Institute of Technology, the Office of Naval Research and the Naval Undersea Research and Development Center.

It is a particular pleasure since it is not often the wheel of fortune stops right on your number and you get invited to speak just fifty miles from the birthplace of a brand new grandchild.

I believe it's customary about here for a visiting speaker to tell a condescending joke about California smog but since most of you read the newspapers you know that we on the East Coast are now living in a glass house where that subject is concerned. After all, when it gets to the point where you can no longer see the National Capital from the top of the Washington Monument you can't pass it off any longer as a morning haze.

In any case I arrived here by way of Alaska where most of the country's current supply of fresh air seems to be stockpiled so my lungs are back in pretty good condition.

This subject of smog and pollution in general reminds me that an acquaintance recently told me of an opinion poll he claimed had been taken among American Indians. Only 12% of them, he said, felt we should get out of Vietnam, but 88% thought we should get out of North America.

I originally intended to say a few kind words about the sponsors of this annual event but changed my mind. Anything about the valuable work that has been done in oceanography and many related fields by the Office of Naval Research and the Naval Undersea Research and

Development Center (our chief semanticist had us remove the nasty word warfare from their title) would come under the heading of bragging about a relative. And after bringing myself up-to-date on the history of the California Institute of Technology I felt there was just nothing I could say. Even an amateur of science who walks across a campus where such men as Millikan and Michaelson once tarried to think, feels as an art lover must feel when he walks on a stone bridge across the Arno where Leonardo once set his mighty sandal. The debt the nation and the Navy owe this Institute is beyond all calculation.

The point was adroitly made, I thought in a booklet about Cal Tech that Dr. Plesset was kind enough to send me. The booklet contained a picture of a man on a bicycle as an illustration of the Institutes recreational opportunities. The man on the bicycle who was unidentified in the caption, was Einstein.

Dr. Plesset also provided me with a program of Symposium events and I ran through it looking for a possible clue as to what I should choose as a topic. Several arresting items caught my eye. Listed was a paper on "The Second-Order Theory for Nonsinusoidal Oscillations of a Cylinder in a Free Surface." Another was on "Three Dimensional Instabilities and Vortices between two Rotating Spheres," and another on "Interaction between Gravity Waves and Finite Turbulent Flow Fields."

Well, I know when I'm out of my league so I decided to just make a few First Order remarks on the mission of Navy Oceanography and how it is organized.

First a definition. Hydrodynamics is not generally considered to be oceanography but then neither specifically is anything else. Oceanography as we use it is just an omnibus word for any scientific or engineering discipline as it applies to the oceans.

It is nothing new. In the American Navy it goes back at least to our pre-civil war patron saint, Lieutenant Matthew Fontaine Maury, who used his knowledge of winds and currents to help the clipper ships set their famous world speed records. In Great Britain it goes back to the famous voyage of the HMS CHALLENGER. Benjamin Franklin took a lively interest in it and so did Aristotle.

But modern oceanography in the Navy dates from the christening of the NAUTILUS and the nuclear missile submarines that followed it. Warfare had suddenly become truly three-dimensional. The new mission of Navy oceanography was to see to it that the Fleet was given the information it had to have to insure its ability to operate efficiently in this new and deadly area of underseas warfare.

Before I tell you how we went about this let me say a few

words about the broader aspects of oceanography. In the Navy we consider it as our field of special competence and we are entrusted with close to half the Federal budget -- or about 210 million dollars in this current year of fiscal austerity.

Work in the entire field however is carried on at three levels.

First there is the National effort. This involves industries like the oil business -- 15% of our oil already comes from underwater -- and the fishing industry where our annual catch can be greatly increased with a better understanding of the ocean currents and temperatures, which influence the distribution of fish -- and the growing aquatic recreation field where beach erosion, the character of marine life, the most efficient design of boat hulls and other oceanographic factors are most important.

The next area is the Federal effort. There are close to thirty major Federal agencies concerned with oceanography to some degree. The Department of the Interior in fisheries. The Food and Drug Administration in medicine from the sea. And the Coast Guard with a variety of oceanographic interests -- to mention just a few. This Federal effort is now being examined from an organizational standpoint. The President has recommended and the Congress is considering a broad new plan to streamline this effort under unified executive direction.

This brings me to the third area of oceanography, the military aspects, for which the Navy, quite logically, is the Defense Department agent.

Our job of controlling the seas for defense requires that Navy have the broadest program in scope in the Federal Government.

To avoid duplication of effort and give us a clear-cut chain of command we put all of our efforts under the technical direction of the Oceanographer of the Navy.

For organizational efficiency the program was set up in four divisions. These divisions are Ocean Engineering and Development, Ocean Science; Operations, and Environmental Prediction Services.

Our newest and fastest developing area is Ocean Engineering and Development. Seven major efforts are included here: undersea search and location; submarine rescue and escape; salvage and recovery; diving; instruments for survey and environmental prediction; and underwater construction. We have allocated 57 million dollars for these programs this year.

Our first rescue vessel, the DSRV-I, which can be equipped also for survey work was launched recently at San Diego. Our first nuclear deep submersible, the NR-I, has already completed its

early tests, and is currently undergoing some changes including improvements to its main propulsion system. The DSRV-II will be ready soon for launching. Our goal with these vehicles and their attendant systems is a capability of rescuing personnel down to submarine crush depth. They will be made available on request to other governments and some are already making the necessary modifications required for utilizing their services.

Our first nuclear propelled deep sea vehicle the NR-I, has done some bathymetric work during her sea trials and is undergoing continuing tests to determine the limits of her capabilities.

We are working on a Large Object Salvage System (LOSS). The goal is to develop a capability of bringing up a submarine intact down to a depth of 850 feet.

An extension of the engineering effort is our Deep Ocean Technology or DOT program designed to anticipate the multiplying requirements of the pioneering technology.

For instance we are well past the blue print stage on our proposed Deep Submergence Search Vehicle (DSSV) designed to operate to a depth of 20,000 feet -- a depth that accounts for 98% of the ocean floor.

An immediate concern is with new power packs. The old style batteries just can't give us either the speed, power or endurance now required. We need electrical systems that will operate in salt water and we are working on thermochemical power sources. We are currently sponsoring a design competititon between two firms in this area. It is a long range item that already shows promise.

Our new machines with all of the improvements we are achieving are no better than the skills of the men who operate them. To make the point by hyperbole, if I had only a dollar to spend I would spend 95 cents on training and equipping men and 5 cents on the hardware. So the whole engineering effort is concerned with extensive bio-medical work, particularly in relation to deep saturation diving.

We are already working deeper than 600 feet in the open sea and 1,000 feet experimentally. We are hoping to go to 2,000 feet, perhaps 3,000 feet before we are through.

This means we need more and more bio-medical data for equipment design and for shaping the selection, training, operational use and health care of our aquanauts and undersea vehicle pilots.

We are taking the field of underwater medicine from its rather narrow corner as an occupational sub-specialty, for its scope transcends its size in at least three important ways. First, it has forced us to study the effects of pressure on living systems,

a study neglected in biology as compared with other fields of science and one which promises to advance the understanding of normal processes. Second, it is an important confluence of the rapidly mixing disciplines of biology and engineering. And finally, it is the keystone to safe and effective utilization of a growing number of underwater systems.

Our second field, first really in long-range importance, is science.

The primary objective is to provide the basic knowledge needed in all our programs. About 75% of this effort is directed toward anti-submarine warfare particularly in studies of the behavior of sound underwater, as sound is our only practical method of detecting a potential underwater enemy. Much of this work is done under contract with academic and non-profit institutions such as Cal Tech where we can pick the brains of hundreds of the nations top scientists. Engineering, of course, comes in here to provide and equip the platforms that our research scientists need to work from -- ships, deep submersibles, flip type vessels that can stand on their head, surface and subsurface buoys, airplanes, satellites, even a floating ice island.

Next our Operations effort. It functions in direct support of the Fleet. In addition to much else, including various world-wide surveys, it carries out duties imposed on us long ago by law to prepare and disseminate charts and publications necessary for navigational safety both for Navy ships and for the Merchant Marine.

In support of this program is our Environmental Prediction section which operates as an undersea weather bureau to forecast those changes within the waters of the ocean that affect our operations. In this field we work very closely with the Fleet Numerical Weather Center.

Despite our concentration on our primary defense mission, the Navy program is necessarily a broad one -- the broadest in the Federal program -- for the seas are our domain -- and we must know and understand everything we can about them -- the animal life that abounds in them, the nature of the ocean waters, their circulation, the character of the bottom, and much else.

Thus many of the things we must learn and study are of interest to others, in the government, including foreign governments, in the academic world, in industry. I am proud to report that the Navy takes part in many cooperative programs in such fields as fisheries, oil and minerals from the sea, wave predictions, and others. We strongly support this phase of our program because as taxpayers it gives us a feeling of accomplishment to see federal tax dollars doing double duty. I will give just two examples.

A friendly neighbor, Iceland, asked for help when they realized that herring, which make up 90% of their export products, were going to be difficult to find this last season. The herring migrate from Norway and stop off at the East Coast of Iceland when they reach the cold edge of the Greenland current. When this current meanders or changes its location, as these ocean currents are likely to do, it may divert the fish away from their normal grounds near Iceland, as happened recently. We diverted an ice patrol plane with a heat measuring sensor long enough to find the cold wall of the current. And sure enough there were the herring. We are planning now to help Iceland develop its own capability for this kind of work.

We are also providing technical help in harbor improvement programs for several South American countries, and we are running annual courses on oceanography and hydrography for foreign students.

We opened our files on ice reconnaissance and trained some people and also provided an on-board oceanographer to the owners of the great new tanker the MANHATTAN, which has recently successfully navigated the Northwest Passage. Free passage of this once impassable channel should prove to be an invaluable national asset both from an industrial and a strategic viewpoint.

Recognition of the importance of oceanography and hydrography to present day and future naval operations, coupled with a concern for the availability of technically competent naval officers within these areas, has caused us to establish a new Special Duty Officer category. It will consist of approximately 140 officers of ranks Ensign through Captain. Promotion opportunities are equal to that of an Unrestricted Line Officer.

Inputs to the specialty at the Ensign level will come from the Naval Officer Candidate School at Newport, R. I., and the Naval Reserve Officer Training Corps Contract Units. Applicants must have a degree in oceanography, or in another field of earth science, physical science, marine science or engineering (with emphasis on survey engineering for hydrography or ocean engineering for oceanography); must have completed mathematics through calculus plus one year of college physics and chemistry; and should have a B average or better in mathematics, physical science and engineering courses. Graduates of the U. S. Naval Academy and the Naval Reserve Officer Training Corps Units (regular students) may apply after approximately three years active duty.

The first three years of commissioned service will consist of a tour of sea duty on an oceanographic or hydrographic survey vessel and a shore duty tour at a naval facility involving application of oceanographic information to naval operations. Subsequent tours may include management of research and development projects, oceanographic forecasting, mapping, charting and geodesy, instructor

duty, and administration of various areas of the Navy's Oceanographic program.

Turning to the Federal scene, the big push now would seem to be with the war on pollution and, certainly we need to fight it. Oceanography of course is involved here, particularly in the coastal zones, estuaries and lakes.

Thousands of words are being written on the pollution of our environment and the new "in" word is ecology. My daughter heard it and read it so often she decided to look it up. The dictionary told her it meant "the relationship between living organisms and their environment." "Here," she said, "I was wondering what it was and I've been right in the middle of it all the time."

Our new consciousness of our total ecology and the drive against pollution are going to lead to some complex conflicts -- such as between the off-shore oil interests and the conservationists -- the real estate developers and the fishing industry. When you drain a salt marsh, for instance, you interfere with the food chain that supports the fish we need for human food. Involved also is the huge and growing water recreation industry.

In solving our problems we have to be sure not to throw out the baby with the polluted bath water.

Has oceanography got an assured future? Yes of course. We are going to have to turn more and more to the inexhaustible seas for the food and the minerals we will need for the worlds exploding population.

But I don't see that future going up in a near vertical line as it did, for instance, in the space business. In the first place there are none of those big hunks of development money lying around these days.

But I do see it going up steadily in a much more gently rising curve.

But go up it will and as it goes we will need more and more sophisticated equipment and techniques to gather and evaluate information and ever smarter and better educated men to program and run them.

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