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September 1969

DEPARTMENT OF THE NAVY
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WASHINGTON, D. C. 20390

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planning, design, construction, operations, and certification of Ocean Engineering Systems and Deep Ocean Simulation Facilities. 3) Define existing problems and to collect all necessary facts which may be instrumental in solving these problems. This report contains a summary of ocean engineering topics discussed during the conference with emphasis on problem areas.

FOREWORD

The First Ocean Engineering Conference sponsored by the Naval Facilities Engineering Command, was held September 23-25, 1969, in Washington, D.C. to accomplish the following objectives:

- Disseminate information associated with ocean engineering to NAVFAC's engineering field divisions.
- Exchange ideas related to planning, design, construction, operations, and certification of Ocean Engineering Systems and Deep Ocean Simulation Facilities.
- Define existing problems and to collect all necessary facts which may be instrumental in solving these problems.

This report contains a summary of ocean engineering topics discussed during the conference with emphasis on problem areas.

A list of the organizations which participated in the conference is attached as Appendix B.

Michael Yachnis
Chairman

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KEYNOTE ADDRESS

by RAdm. W.M. Enger*

"Gentlemen, I have heard it said that a conference is a gathering of important people who say they can do nothing but allegedly decide that nothing can be done. I don't agree with that. I think this is a conference of great importance to us, and it really is a distinct pleasure and indeed I consider it a great honor to be here this morning to extend our welcome to this--our First Ocean Engineering Conference. It's a pleasure because all of us in the Naval Facilities Engineering Command concerned with Ocean Engineering matters have long looked forward to the opportunity that a conference such as this provides to further develop our understanding and expertise in this important and rapidly growing field of engineering.

The exchange of information and ideas which will take place during the next three days is certain to add to our knowledge of recent developments in Oceanography and Ocean Engineering. Of equal importance, it will give us a better insight into the problems and challenges that await us in the months ahead. It is a honor to open this conference, because we are favored by the attendance and participation of a host of distinguished oceanographers and ocean engineers, not only from our own Command, but from other Commands of the Navy and from industry and the academic world as well. It is not often that one can gather such an array of top talent in one room to address themselves to a common goal. My greatest regret is that my schedule does not permit attendance

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*Commander, Naval Facilities Engineering Command, Washington, D.C. 20390.

to all the sessions included on the agenda. I have a deep and continuing personal, as well as an official interest in the matters you will discuss here and would benefit greatly if I could participate. The fact that my time is pre-empted by other matters does not diminish my interest in what goes on here. I consider the ocean environment to be one of the great engineering challenges of the future and particularly so to the Naval Facilities Engineering Command. Although this Command looks forward with great enthusiasm to our future in this relatively new field, we do look back with equal degree of pride on our accomplishments of the past. We have, of course, had an association with structures near and in the water for nearly our entire history. However, we take particular pride in the accomplishments of the recent past. We initiated a program of Ocean Engineering nearly ten years ago and since that time have steadily acquired a growing expertise by participation in a large variety of ocean engineering or ocean engineering related products. But we are not satisfied. We know that true progress is made by constantly seeking to improve upon that which has been done before.

We view this Conference as a powerful tool in our determined effort to so improve. We intend to make beneficial use of the composite knowledge of many years of ocean engineering experience that is represented by the participants in the Conference. Gentlemen, you all have my sincere thanks for the contributions I know you will all make to the purpose of this Conference, and you certainly have my best wishes for an interesting and rewarding Conference. Thank you."

OCEAN ENGINEERING TOPICS AND OCEAN ENGINEERING POLICIES

by Capt. W.A. Walls*

"After the beginning that Admiral Enger has given us, I think anything I have to say about the policies will be anticlimactical, because he has set the tone of the Conference. I would like to note that I second the welcome that he has expressed and I would briefly like to talk about the policies which we have in ocean engineering.

Basically, our policies are the same as we have in any other field of engineering. I think there is one distinct difference, however, as a matter of degree relative to ocean engineering, and this has to do with the policy of continuing education and the advancement of engineering knowledge. Certainly this Conference that we are beginning this morning will second and support strongly this policy of continuing education and the advancement of engineering knowledge. I know there are tremendous challenges and problems in ocean engineering that will be discussed during the next three days. I note that the scope of the agenda is quite broad: starting with a Forecast of Ocean Engineering Trends followed by discussions on Deep Ocean Engineering Problems, Design Criteria, Construction Practices, Deep Ocean Simulation Devices and Materials of Construction. Each of these and the exchange of data and the open forum that is presented here during this Conference will contribute to our need and for our improvement of our education and knowledge of Ocean Engineering.

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There is one policy that I would like to mention in addition to the one I just talked about, and this has to do with some of our efforts here in certification. As Admiral Enger pointed out, we have had a decade of progress in ocean engineering beginning with the efforts of NCEL, the Naval Civil Engineering Laboratory in 1959, in Research and Development for site selection, survey, design and construction techniques, foundations, soils information, etc. A most significant milestone during this past decade has been the establishment of a technical council on ocean engineering by the American Society of Civil Engineers. This council was established by the request of the Naval Facilities Engineering Command. Most recently, we have become involved in the certification procedures and processes for manned ocean simulation facilities.

This leads me to stating that I would first like to thank those particularly of NAVSHIPS PMS-381 who have pioneered in this field and whose efforts have greatly helped us both in our own certification procedures and in providing us information on which we have based our procedures. I would like to take the opportunity to thank PMS-381 and also to thank those people of the Experimental Diving Unit (EDU) who have some certification work underway by contract. I think that our joint efforts with PMS-381 and EDU imply that we support strongly the need for common terminology in this area of certification--pressure vessels or simulation facilities--that will be used for ocean engineering. I realize that these procedures will vary according to the facility being certified and also they will vary according to the contractual procedures that each command uses to accomplish or to obtain the facility in consideration. However, I do thank EDU and PMS-381 for their help to date.

I would like to compliment finally, Dr. Mike Yachnis who put together this Conference and obtained the cooperation and the assistance of so many people from outside NAVFAC to sit on the panels and to contribute their knowledge to the progress of this Conference and hope that you do have a fruitful Conference. Unlike Admiral Enger, I have the time and am prepared and desire to see and to hear many of the Conference items."

A FORECAST OF OCEAN ENGINEERING TRENDS

by Capt. J.F. Dobson*

To effectively predict future trends, it is useful to examine history looking at similar periods. Three dates are important as references: 1492, 1807 Fulton's steamboat, 1955 commissioning of the Nautilus. Before 1492 man knew very little about the ocean. Between 1492 and 1807 all oceans of the world were explored and elements of sea power and sea law were established. From 1807 to 1955 the world's navies changed from sail to steam, coastal surveys were conducted, submarine and aircraft were added to the fleets, and man began to realize the potential of the oceans. Since 1955 a nuclear submarine fleet armed with nuclear missiles has been developed; ocean submersibles have been developed; and saturation diving has been developed. Additionally, there has been a change in the outlook of ocean engineering primarily because of the discovery of oil, gas, and resources along the continental shelf.

Looking to the future, Undersecretary of the Navy, C.F. Baird predicts that in 500 years man will be living in and exploiting the ocean completely, and that in 150 years the populations of the North Atlantic will have moved out to the continental shelf. In predicting advances in the next 15 years, progress in the national, Navy, industry/general areas are considered. Nationally, a prediction can be made by looking at the goals of the proposed National Oceanographic and Atmospheric Agency (NOAA) which include: test facilities and ranges, continental shelf laboratories, a lake restoration project, pilot buoy network, 20,000 foot

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exploration submersibles, and a continental shelf nuclear plant. In the Navy area, the development of the soviet submarines puts the ASW challenge as top priority. It is important to determine the effects of environmental factors on sound propagation; i.e.; temperature, chemical structure of the water mass, reverberations from the bottom, and natural sounds of the sea in order that the performance of sonar systems in all areas of the world can be predicted. Underwater fuel stations and logistics modules, floating support platforms for troops and equipment, and undersea dry docks are probable developments. In the industry/general area, man may be able to swim freely up to 12,000 foot depths by means of "fluid breathing," development and construction of subbottom stations will be realized; excavation of subbottom oil storage caverns will be developed; man will be better able to predict and to possibly control weather; the extraction of off-shore oil and gas could double, shipping could increase by a factor of four by the year 2,000; the expansion at sea/shore recreation facilities will be realized; water pollution of bays and estuaries could be controlled; and cooperative exploration of the sea could lead to better international relations.

The ingredients for successful explorations are men, capital, talent, and good education. The U.S. ranks high in all of these areas. Furthermore, the U.S. is the first nation in history to adopt a policy to study and to use the seas for the benefit of all men.

It is urged that the national oceanographic investments be based on prospects for payoff. And, it is hoped that the ocean engineering program in the next 15 years will not be an exploding one, but that it will be a program of methodical undertaking directed primarily toward technology and preparation of actual occupancy of the ocean.

DEEP OCEAN ENGINEERING PROGRAMS

Moderator: Capt. W.M. Nicholson

Capt. J.W. Boller
LCdr. N.T. Monney
Cdr. W.J. Eager
C.R. Odden
Cdr. R.P. Cope
T.P. Fleming
W.D. Bass
P. Cave
R.A. Breckenridge

INTRODUCTION TO U.S. NAVY'S DEEP OCEAN ENGINEERING PROGRAM

by Capt. J.W. Boller*

"Ocean Engineering is not an end in itself but a means to an end. It is a supporting element in the whole Navy program.

In the budget area, the money problem is not solely with RDT&E funds. The more severe problem arises in getting money for construction, maintenance, and procurement to the fleets. Now that we are in a tight money situation, we should use a "plucking" process rather than a "pruning" process with our established projects. In this way, the important projects will be accomplished in full rather than all the projects getting half-way done."

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*Head, Ocean Engineering and Development Branch of the Oceanographer of the Navy, Washington, D.C.

U.S. NAVY'S DEEP OCEAN ENGINEERING PROGRAM

by LCdr. Neil T. Monney*

The traditional missions of the Navy are antisubmarine warfare, strategic deterrence, mine warfare, surveillance, and strike warfare. A new dimension in these missions is rapidly growing in importance--the deep ocean. The goal of the Navy Ocean Engineering Program is a full utilization of the ocean environment in support of Navy objectives.

RAdm. T.D. Davies has a unique management position which allows him to interact in three directions. He is Chief of Naval Development, Deputy Chief of Naval Material for Development, and also, Assistant Oceanographer for Ocean Engineering. This provides effective coordination between CNM, the Asst. Secretary of the Navy for R&D, and the Oceanographer of the Navy.

Ocean engineering capabilities are being developed in seven major areas:

- Search and location
- Diving
- Rescue
- Salvage and recovery
- Surveying
- Environmental prediction
- Underwater construction

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*Technical Assistant for Deep Ocean Technology and Instrumentation, (Code 0327E), Headquarters, Naval Material Command, Washington, D.C.

The specific project underway to develop a submarine rescue capability is the Deep Submergence Rescue Vehicle (DSRV). A systems approach to the problem of submarine rescue is being employed. In case of an emergency, the DSRV can be flown either in a 3-C 141 aircraft or in a C-5A aircraft to any port in the world, and from there, transported either by submarine or by surface vessel to a disabled submarine. The DSRV had to be designed with weight and space considerations as principal constraints.

Other areas of work include the Deep Submergence Search Vehicle (DSSV) for which a preliminary design contract was awarded this spring. It is being designed to provide a sophisticated search capability at a depth of 20,000 feet. Another project of major interest is the unmanned vehicle CURV III, which will both conduct recovery operations and perform simple tasks to depths as great as 7,000 feet.

NAVOCEANO is improving its surveying techniques and environmental prediction techniques. The environmental techniques fall into two areas: the ocean, and the atmosphere above the ocean. Meteorologic data is primarily the responsibility of NAVAIR, and therefore, ocean engineering capabilities in this area are limited to buoys and satellites. All work done in buoy development is coordinated with the U.S. Coast Guard.

To advance the capabilities in ocean engineering, it is essential that a broad-base of technology be developed. Unfortunately, fund limitations are currently restricting development of this technology base. Management must define the critical deficiencies and relative priorities and then use the available money in the best manner possible. Areas in which critical deficiencies now restrict operations include power, materials technology, auxiliary equipment, biomedicine, diver systems, and environmental support. For example, under materials technology, problems involve strength-to-weight ratio, corrosion resistance, and fabrication techniques and testing.

In the early stages of developing systems hardware for ocean engineering, it became apparent that a large gap existed between exploratory development and actual hardware production. As a result, the Deep Ocean Technology (DOT) Program was initiated in 1968 to provide an advanced technology base. Two focal projects were established to guide this development--a deep submersible vehicle and a manned underwater installation. The intent was to develop the capability to construct the focal projects, but not to actually construct them.

Our ocean engineering developments are aimed directly at supporting national defense requirements as well as other benefits, such as in the areas of law, ocean services, resources, and sciences.

Site Selection

Geo-political and man-made considerations together with natural characteristics must be reviewed to determine site selection. The following questions should be asked: How close are adequate port facilities? What navigational aids are available? What is the surface traffic in area? Are there any submarine lanes or explosive ordinances or other dangerous refuge in the area? Furthermore, there is a need to know the wind conditions; whether the site is protected by a land mass; the direction of the prevailing winds; the time between storms that might hamper operations; whether or not heavy fog occurs in areas; and also, the range of temperature.

From a physical oceanography viewpoint, it would be important to know the sea state, the currents (both on the surface and at depths), whether any sea ice occurs in the area, the visibility in water, and the corrosion potential of the water.

From a biological viewpoint, an awareness of dangerous marine life and the fouling potential of the area would be carefully considered.

Geological and sediment consideration are: slope of the site and potential of slope failure, probability of seismic activity, major faults existing in area, what foundation preparations will be required and also, the susceptibility of the site to turbidity. Each one of the above considerations could be the most important depending on the mission involved.

There are three general missions of the program: (1) an in-shore facility supported from shore by an umbilical; (2) a near-shore facility without direct shore support, and (3) an off-shore isolated facility. For example, the first two categories could be an underwater laboratory and the last mission could be a large acoustic array. The most important facets for an in-shore mission would be visibility and working conditions, while for an acoustic array the most important area of the site to be considered would be ambient noise, suitability of the reflectivity of bottom sediments, suitability of existing topography for transmission, etc.

A background study would be required to define the necessary parameters and then to collect the existing oceanographic, meteorological and geological data for the geographical area of interest. On the basis of this material, a wide area survey would be planned. Various sites would be reviewed according to priority and acceptability of different parameters expected at each site. During preliminary reconnaissance, subbottom profiling would be used, together with magnetic survey to distinguish any major fault zone area. Local areas should be identified during the wide area survey, which have a high probability of acceptance within the parameters that have been outlined. Specific sediment, current, and water tests should then be made at those sites.

The next step to be taken would be an in-depth verification survey at one or more of the most promising sites. If the mission and site required special foundation considerations, a deep coring investigation would be made. Instrumentation is not now available for determining many of the site characteristics. A deep coring device and instruments that are capable of being left at the site in order to gather long-term on-site data is a major requirement. Another problem is getting an undisturbed sediment sample at a defined location, therefore, a better profiling system and a system of benchmarks is needed. Turbidity may be a problem during excavation and dredging operations. Determination of a need for soil-mass stabilization is another problem. A major consideration would be the design of the foundation used for the installation.

Problem Areas

- Money - The difficulty is obtaining money for construction, maintenance, and procurement to the fleets.

- <u>Repetitive and/or Overlapping Efforts</u> - Caution needs to be exercised in defining assigned functions to the various organizations. Definite rates need to be established and outlined specifically. NAVFAC, for instance, has been assigned the responsibility for floating cranes, fleet moorings, fixed surface and sub-surface ocean structures, tools and techniques, and equipment for underwater construction. This is a broad area, and one which can be built up substantially.

NAVFAC ROLE IN OCEAN ENGINEERING

Cdr. W.J. Eager*

By CNM charter, the Naval Facilities Engineering Command has the Navy responsibility for engineering, construction, maintenance, and repair of undersea facilities. In carrying out these responsibilities, NAVFAC must take positive action toward reducing the current extremely high cost of ocean facilities construction. The development of a series of standard modular components and interfacing components for undersea facilities is an essential element toward this end. A second essential element is the development of efficient environmental survey and work systems specifically designed for underwater construction operations.

These work systems must be properly interfaced with the facilities components and with the construction specialist who uses them. The third element which is required for cost effective undersea construction operations is a program to select and to train undersea construction and maintenance personnel as specialists in the several skill areas, and to continuously utilize these highly skilled specialists in their respective areas. A fourth element is to stimulate undersea construction contractors to greater "cost effectiveness" competition by utilizing fixed price contracts and through furnishing carefully engineered drawings and specifications, specialized work systems and, where appropriate, standard facilities components as government furnished equipment.

In addition to training for wartime related missions, military construction forces must be utilized to "work measure" undersea

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construction operations as a basis for scheduling and cost estimating and for improving the design of undersea facilities, work systems, and methods. Employment of these forces offers the additional value of training and experience for personnel who will subsequently manage contracts in this new and unique field of undersea construction.

One exception must be made to the NAVFAC responsibilities described above under work systems. Equipments to support the life, safety, and comfort of the construction or maintenance specialist when performing as a diver is the responsibility of NAVSHIPSYSCOM as are techniques associated with diving safety. Unique requirements imposed by construction operations will be furnished by NAVFAC to NAVSHIPSYSCOM for development of specialized diving equipment for construction divers.

To accelerate the NAVFAC capability to meet Navy undersea facility requirements, the Ocean Engineering Program Office has been organized at NAVFAC. This office is responsible for identifying Navy undersea facilities requirements and for coordinating the efforts of the several functional organization elements of NAVFAC in satisfying these requirements within scheduling and funding constraints.

The NAVFAC/NCF program, at its present state of development, consists of an extensive RDT&E effort under the Deep Ocean Technology Program. The program also includes the development of engineering and construction capabilities through the use of Naval Construction Forces and contractors on several focal projects. The construction of undersea facilities for Project TEKTITE I is an excellent example in this area. Specialized Seabee Underwater Construction Teams are being formed, equipped, and trained at the Construction Battalion Centers as a key element in underwater construction capability.

ROLE OF THE ENGINEERING FIELD DIVISION AND NAVAL CONSTRUCTION FORCES IN OCEAN ENGINEERING

by C.R. Odden*

The role of the Engineering Field Division and Naval Construction Forces in ocean engineering and seafloor construction is to become a vital link between headquarters and the activity requiring work to be accomplished in or on the sea. This link includes integration of the NCF (Seabees) into project work where appropriate.

NAVFAC, through Code PC-2, is directing its major ocean engineering effort into developing the capability for larger and more complex projects by participating and by performing work with ongoing projects. This capability is being strengthened continuously by efforts of our RDT&E program.

The development is basically being focused into two directions. The first, which is with the EFD, is providing ocean construction support to the Navy. MCON projects involving ocean simulation chambers, laboratories, piers, harbors, and undersea surveillance systems are being accomplished. Some EFD's are providing construction support to laboratories with RDT&E projects. In addition, work involving maintenance of ocean engineering facilities has been significantly increasing.

The second direction involves the Seabees. The Seabees have a tremendous potential for supporting worldwide ocean construction projects. Equipment on hand, combined with the emergency Underwater Construction

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Team (UCT), provides a construction potential second to none. In particular, the Seabees will have an early capability for cable laying, large object emplantment/recovery, construction blasting, and providing back-up support for deployed scientific expeditions.

One of the areas emerging as a strong potential for ocean or ocean-related projects is the Naval Laboratory. A good example of this work is EastDiv's support of the Underwater Sound Laboratory's construction efforts at Seneca Lake, New York. EastDiv is performing project management and engineering work on several related projects. These areas include a deep water mooring system, underwater cable laying, master planning, and providing cranes (through MidWest). These tasks are for a large floating systems measurement platform to be moored in the center of the lake for obtaining acoustic data of sonar transducers.

On all ocean engineering/construction projects, NAVFAC will maintain a capability to provide consulting services and engineering work, which will continue until a depth of experience is developed at the EFD level.

Many ocean construction projects funded by sources other than MCON are now being contracted out directly by various Naval facilities. Some of these projects should and can be more effectively performed by the EFD. Unfortunately, this situation has been provoked by the lack of communications between the laboratories and the EFD's. To solve this problem, an all-out effort must be made to develop a working relationship with individual project officers in charge of these special projects. One recommendation is that a NAVFAC ocean engineer be made available to assist in evaluating new work.

NAVFAC ROLE IN UNDERSEA NUCLEAR POWER

by Cdr. Ronald P. Cope*

The purpose of this briefing was to familiarize those present with the current scope of operations of NAVFAC's Nuclear Shore Power Program and especially those facets related directly to deep ocean engineering.

The first portion of the presentation was utilized to review OPNAV Instructions:

- 11310.1 - Nuclear Shore Power Reactors
- 11310.2 - Radioisotope Energy Applications
- 3040.5 - Nuclear Reactor and Radiological Accidents Associated with Naval Nuclear Reactors; Procedures and Notification Requirements for

These instructions are the basis of NAVFAC responsibility for all Navy nuclear programs other than those related to the Naval Propulsive Reactor Program. In addition the major tasks performed were enumerated as follows:

- Develop non-propulsive nuclear reactor power applications for Navy utilization.

- Develop radioisotope power applications for Navy utilization.

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*Director, Nuclear Power Division, (Code 042), Naval Facilities Engineering Command, Washington, D.C. 20390.

- Provide technical assistance for nuclear accident emergencies.

- Control and monitor radiological safety for non-propulsive nuclear reactor power systems and radioisotope power devices utilized by the Navy.

- Review safety implications of Navy-utilized nuclear devices in aerospace.

The remainder of this first portion of the presentation was utilized in reviewing the organization and resources of NAVFAC's Nuclear Power Division, Code 042, and the Naval Nuclear Power Unit at Fort Belvoir, Virginia.

The second portion of the presentation served to familiarize conferees with those programs related to Deep Ocean Engineering, specifically:

- Technical Development Plan Y41-02 for Portable Nuclear Electric Power Plants
- Radioisotope Power Devices
- Nuclear Reactors
- Radiological Safety

Each of the above programs was discussed separately with slides being presented showing actual applications and operating facilities. The importance of TDP Y41-02 leading to the coordinated (USN and USAEC) development of a 2 kw to 10 kw (electric) radioisotope power device and a 150 kw to 500 kw (electric) nuclear reactor system specifically intended for deep ocean application was emphasized.

The final segment of this presentation pointed to the support and possible future participation of Engineering Field Divisions in Code 042 programs. With NAVFAC playing a key role in undersea facilities, the Engineering Field Divisions are in a strong position to take the lead in geographical areas to foster and manage construction and operations support of the deep ocean facilities of tomorrow.

UNDERSEA NUCLEAR POWER

by T.P. Fleming*

This discussion concerns itself with the small power levels, from one-watt to several hundred watts, produced by radioisotopes and thermoelectric power conversion systems. Isotope units, for producing electrical energy, have been successfully utilized for applications in the ocean, for remote locations on land, and for outer space. The large advancements made in the development, design, and production of isotope units in the past few years can be imputed to their applications in the space program. Although the advancements in the technology have been significant, there are many problem areas yet to be resolved.

One of the most critical problems affecting the design of isotope units is weight. Present units in the one-watt range weigh approximately 800 pounds. A new Atomic Energy Commission terrestrial development unit will have an output of 60 watts and weigh approximately 1,000 pounds. For deep ocean applications, efforts have been concentrated on a 25-watt unit designed for a 20,000-foot operating depth; each unit weighs 4,200 pounds. The weight of this unit can be reduced to approximately 1,400 pounds for terrestrial use or ocean depths less than 1,000 feet.

The isotope units are economically advantageous for applications requiring small, highly reliable power for long duration (one to five years).

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Another problem area associated with radioisotope units is the limitations on the amount of electrical energy produced at present. There are no units to produce electrical energy in the kw range. However, with the cooperation of the Atomic Energy Commission, the Navy is developing a radioisotope unit which will have a power output in the two- to ten-kw range.

THE SEABEES ROLE IN OCEAN ENGINEERING

by W.D. Bass*

Purpose

- To provide information on status of Seabees
- To stimulate thoughts about the future

Background

- Shallow water divers in battalions involved in underwater exploration, inspection, and reconnaissance; preparation for pile driving, maintenance and repair of bottom-laid lines; clearing bridge wreckage; salvaging pontoons and cranes; placement of explosive charges, etc.
- Most underwater construction projects require team effort.

Programming for Two UCTs in FY72 (as Fleet Units)

- Organization (2 officers, 21 Group VIII)
- 150-foot capability
- Organic saturation diving systems
- Trained to perform underwater site survey/selection/preparation, structure assembly/construction/installation, and public works operation and maintenance.
- Self-sustaining for diving mission only.

Implementing Actions

- CNO Notice 5450 resulted from fleet request for expanded ocean engineering capability.

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*Concepts and Requirements Branch, (Code 0621A), Naval Facilities Engineering Command, Washington, D.C. 20390.

- TEKTITE opportunity afforded
- Personnel training milestones
- Four billets each for 1st and 2nd class divers at NCEL; to be expanded to one officer and 20 enlisted men.
- Small diver team at Davisville helps supports ammi-lift dock and dredge training program.
- SSEO diver-construction curricula development.
- Six Seabee divers in 1st class school.
- Underwater construction blasting training underway.
- Special NECs established for divers in construction rates.

Immediate Goals

- Establish capability to produce rapid ports.
- To provide oceanographic construction-diver support.

Rapid Port

- Configuration and components will require UCT services.

Oceanographic Support

- Suggest Seabee UCT maintenance of bottom-fixed installations after construction.

Non-Military Ocean Engineering Program Support

- Help establish seafloor real estate rights acting as land survey specialist.
- In-situ subsoil exploration; soil and rock testing.

Seabee Team Support

- Areas now beckon for civic action--aid in dredging, pier/wharf construction, removal of obstacles to navigation, etc.

Navy Tactical, Logistic, and Strategic Support (most important)

- Priority effort needed in supporting ASW program.
- Certain ASW concepts require use of bottom-fixed installation--lack of underwater construction capability may be influencing this.

Summary

- Broad spectrum of Seabee utilization indicated.
- Experienced UCT may be both indispensible and cost effective.

Problem Areas

- Lack of firm Fleet Operational Requirements (at present).
- Lack of existing CEC Officer Ocean Engineering expertise.
- Lack of underwater construction training facilities.
- Lack of funding.

DEEP OCEAN ENGINEERING

by Patrick Cave*
and
R.A. Breckenridge**

The objective of the Deep Ocean Engineering R&D Program is to provide the Navy with the capability to design, construct, emplant and recover, maintain and operate fixed ocean floor structures and equipment. The program was originated in 1959 at a funding level of $100,000. This program has steadily increased and in FY70 there is a planned expenditure of $3,550,000. Funding for this effort is obtained from the Exploratory and Advanced Development areas.

For planning purposes the Exploratory Development Program is divided into seven technical areas: (1) Site Selection and Survey; (2) Bottom Soil Properties and Foundations; (3) Construction Systems; (4) Anchors and Moorings; (5) Engineering Mechanics and Design; (6) Power Sources; and (7) Support Systems. Work has not been undertaken in the site selection and survey area due to limitation of funds; however, it is hoped that it can begin in the very near future.

The principal areas to be investigated in FY70 are as follows: In-situ soil investigations--the development and evaluation of in-situ testing equipment to measure engineering properties of marine sediments in water depths of 6,000 feet. Devices that are being developed and evaluated are vane shear, cone penetrometer, and plate bearing. Diver

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tools and techniques--the development and evaluation of diver's tools and construction techniques. Underwater power tools such as drills, chipping hammers, and torque wrenches are being developed and evaluated. Three power systems under development for these tools are pneumatic, oil hydraulic, and salt water hydraulic. In the diver's construction techniques area we are developing methods and techniques for handling and assembling components underwater.

The construction assist vehicle will be used for transporting divers, tools, and tool power supplies. The vehicle is designed to operate in water depths to 120 feet. Construction is scheduled for completion in early 1970.

NEMO is an acrylic capsule, providing one or two scientific observers with a shirt sleeve environment and panoramic visibility for stationary undersea observations at water depths to 1,000 feet. The NEMO will be winched up and down from an anchor placed on the seafloor. It is presently under construction by Southwest Research Institute and is scheduled for delivery to NCEL in December 1969.

Investigations are underway to develop an improved anchor for deep ocean applications. Direct rapid embedment without dragging and a high resistance to uplift loads are major qualities sought for such an anchor. Anchors that are embedded by an explosive charge and by vibratory methods appear to possess these desired qualities. With 50,000 pounds of holding power, anchors utilizing both of these methods have been built and will undergo evaluation during FY70.

In FY70, the program to provide reliable engineering data for pressure-resistant conical acrylic windows located in either submerged hydrospace structures, or land-based pressure vessels will be completed. This program has consisted of testing a number of windows under short-term and long-term hydrostatic loading and long-term cyclic loading.

The Deep Ocean Technology Program was initiated in FY68. The overall project direction and executive management of this program is retained by the Chief of Naval Material. The overall objective of the Deep Ocean Technology Program is to generate, expand, and exploit, as rapidly and economically as possible, the base of deep ocean technological knowledge. NAVFAC has been assigned the principal development activity for the following subsystems: (1) site selection subsystem; (2) site operations system; (3) foundations, anchors, and moorings; (4) construction system; (5) energy power; (6) structural subsystems; (7) construction support system; and (8) seafloor construction experiments. The FY70 highlights include the following:

- A deep ocean corer will be developed that will be capable of taking a minimum disturbed 50-foot core sample in water depths down to 6,000 feet.

- Initiate the development of a full-scale automated earth-moving subsystem for site preparation in any bottom except hard rock. The equipment will be capable of profiling a bottom surface to a predetermined engineering plan including cutting, trenching, and shallow hole drilling.

- Initiate the development of a system for drilling into the seafloor. The ultimate goal is to be able to drill into competent rock, install a pressure-resistant access hatch, dewater and excavate the subbottom. Technical problems that will be investigated in FY70 are methods to improve pumping of slurries, and for disintegrating hard rock.

- Complete the development of experimental "wet" and "dry" electric connectors. These connectors are for use down to 6,000 feet and will transmit 4,160/50-amp, 3-phase power.

- Continue the development of design guidelines for concrete structures for man-rated undersea installations. Both laboratory and in-situ experiments on spheres and cylinders will be conducted. The goal is to be able to design a concrete structure 50-feet in diameter for a 3,000-foot depth.

- Conduct an in-situ experiment that represents various technological phases of ocean engineering. The objective of this experiment is to demonstrate the capability for constructing manned bottom installations. SEACON I, as the experiment is called, will be at a depth of 600 feet. Plans and funding support requirements have been written for 24 experiments. The major experiment will be the construction of and the emplacement of a 10-foot diameter, 20-foot long concrete habitat.

There has been a deferment of $625,000 in the Deep Ocean Technology Program. These deferred funds are being taken from the SEACON project, and in the event the FY70 funds are reduced, the project will be cancelled.

DESIGN CRITERIA - STRUCTURES

Moderator: Dr. M. Yachnis

C.J. Kray
W.J. Tudor
Dr. J.D. Stachiw
T.H. Hayes
J. Angelo
W.E. Watkins

DESIGN PARAMETERS

by C.J. Kray*

In the design of waterfront structures, the Civil Engineer is confronted with the effects of wave action, tides, currents, temperature, and earthquake forces, as well as dead and live loads, earth and ice pressures, and buoyancy. The waves generation in seas, the advance of the wave forms (swells) toward the shores where they become the surf or breakers were discussed along with the wave action on the waterfront structures and their components, depending upon the condition and action of waves whether they are non-breaking, just breaking, or broken. Also mentioned were the tides--a periodical rising and falling of ocean level with varying range; the currents--a mostly horizontal periodic movement of water with various speeds, direction and duration, tidal, non-tidal, and combination flow; the temperature effects and earthquake loads on structures.

Present analytical knowledge is inadequate to evaluate effects of new structures on ocean environment, erosion, and depositions. To augment our judgment, models will be used with the simulation of natural processes such as littoral drift and tidal effects, wave and current action.

The above may consistute the problem area and especially behavior of the ocean waves and evaluation of the wave forces exerted on the structures and their components. The determination by measurements of the orbital velocities and acceleration of water particles would be helpful. Another problem area could be determination of wave forces on moored ships, buoys, and anchorages.

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DESIGN PARAMETERS

by W.J. Tudor*

The sea can be either friendly or hostile. It is calm and beautiful one day, furious and terrifying the next day. On days that are calm enough to make surveys and to do construction work, one must not forget that before long, unleashed violence will follow. The ability to modify this environment, and the ability to work in this environment is ocean engineering.

On the basis of surface circulation, the world ocean can be divided into seven oceans; namely, Arctic Ocean, Antarctic Ocean, North and South Pacific Oceans, North and South Atlantic Oceans, and the Indian Ocean. The water types of each of these oceans can be classified on the basis of the graphical temperature-salinity relationship.

The preliminary design of various shells of double curvature (spheres, multi-spheres, prolate spheroids, ellipsoids, toroids, paraboloids, etc.) used in pressure vessels for hydrospace systems is relatively simple The shell stresses can be determined from simple membrane formulas once the pressure (depth) is known. A complete analysis of the bending stresses as well as the membrane stresses is more complex and can only be discussed in general terms.

In order to deterimine the wave forces on an offshore structure in an irregular seaway, the following data is needed:

- The height characteristics of the components waves of different frequencies that occur in the sea. Bretschneider's spectrum

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with auxiliary relationship between wind speed, wave height, and period is fully satisfactory for engineering applications.

- The unit response of the structure for each of the component waves of different frequency: that is, determine the maximum force (plus or minus) per foot of wave height for a sufficient number of regular waves of selected frequencies corresponding to the sea spectrum. The ordinate of the unit response is then force/foot of height.

Then, by multiplying the spectral height by the square of the unit response (at the same frequency), the result is ordinates of force^2-secs. Furthermore, by plotting these for the full range of frequencies involved, the desirable force spectrum is obtained. Then by proceeding to get the area under this new spectrum curve, and by applying the Rayleigh constants, we get the 1/3 highest force, the 1/10th highest force, etc.

Problem Areas

The constructor and planner must cope with certain forces that affect the world-ocean contents as a whole. The biggest problem is the determination of the environment and calculations of the dynamic factors and their effect on construction-type operations. Among these are meteorological aspects, such as wind, atmospheric temperature and moisture, and precipitation and pressure; also, such forces as general climate, ocean currents, ocean thermodynamics, waves, tides, tidal currents, and sea-level fluctuations.

OCEAN FLOOR CONCRETE HABITATS

by Dr. J.D. Stachiw*

Concrete is not really suited for construction of temporary ocean floor habitats because its weight and bulk make it difficult to transport. The material is, however, ideally suited for the construction of permanent one-atmosphere or subfloor habitats.

Why is concrete ideally suited for such application?

- It is relatively easy to design a concrete pressure resistant enclosure, as the use of thick walls eliminates the danger of buckling, and thus the need for any internal or external stiffeners.

- No local thickening of the wall is required around penetrations (such as portholes and hatches), since the thickness of the walls is always adequate for incorporating ring-type steel reinforcement flange.

- It is very economical to make the pressure hull negatively buoyant by increasing the wall thickness of the hull, thus further increasing the safety factor of the hull.

- Casting of thick hulls with a single or double curvature is economical, can be performed to close tolerances, and does not generate residual stresses in the hull.

- The material itself is non-strategic, non-corrodible, inexpensive, and whose mechanical properties are well known.

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- The fabrication of concrete structures provides employment to many low-skill workers that are unacceptable to the aerospace industry.

What is known about building concrete habitats? If the capability to design and fabricate habitats is judged on the basis of average working stress level in the hull when the habitat is at operational depths, then the following capability levels exist.

- Low ($s < 1000$ psi) - Any competent structural engineer can design the habitat and a contractor can build it today.

- Medium (1000 psi $< s <$ 3000 psi) - NCEL has conducted a considerable amount of research in this area. Small test structures have been built and evaluated. By FY72, information will be available on which to base design of structures. Close supervision of the contractor will be required and some new construction techniques will be utilized, to insure that the concrete has the desired properties.

- High ($3000 < s < 6000$ psi) - NCEL is currently doing research in this area but the information will not be available until after FY75, on which to base safe designs. Some training of contractor personnel will have to take place and very close supervision of construction will be performed by Navy concrete construction experts.

- Exotic ($6000 < s < 9000$ psi) - NCEL is initiating research in this area. The current approach is to utilize acrylic impregnated concrete which yields compressive strengths of up to 20,000 psi. It is doubtful whether sufficient data will be available to design and build such structures prior to FY80 unless the funding for concrete increases by an order of magnitude.

When the various stress levels are converted into operational depths for ocean floor habitats, it appears to be within the state of current engineering knowledge to design positively buoyant pressure hulls for the 0 to 600-foot depth range and negatively buoyant hulls for 0 to 2,000-foot depth range. These hulls, subsequently, can be built on land using conventional concrete fabrication techniques, towed to location, and lowered into final position. The economics achieved by using concrete instead of steel for such depths is in the range of 90 to 95 percent.

Currently, the only reliable method of building concrete habitats is by casting them monolithically, or segmentally, on land and then towing them to location. Since divers can perform construction tasks underwater in the 0 to 600-foot depth range, the habitats can be assembled on the ocean floor from precast, sealed-off structural modules. To date, no technique or equipment has been developed that would permit assembly of habitats on the seafloor from precast modules without the aid of divers. Such a capability will not be developed prior to FY80 unless the available funding is increased by at least one order of magnitude.

At the present time, no capability exists or is foreseen for the near future, to cast concrete habitats in place. There is neither the knowledge of concrete setting times and strengths, nor the knowledge of casting techniques. NCEL has initiated a low-level research effort to determine the mechanical properties of concrete cast undersea, but, at least for the near future, no prospects exist for developing the undersea concrete casting techniques. If a major effort is initiated in this area, the capability may be developed to perform in-situ casting by FY75 for the 0 to 600-foot depth range, and FY80 for the 0 to 2,000-foot depth range.

POWER SUPPLY, DISTRIBUTION, AND UNDERWATER LIGHTING

by Terry H. Hayes*

The two factors which most affect the transmission of light in sea water are attenuation and scattering. The least attenuation occurs in the blue-green region at 5,100 angstroms.

Scattering of light is engendered by the illumination of suspended particles in the water. The observed effect, known as backscatter, is analogous to attempting to see through a dense fog. The problems associated with backscatter can be reduced by locating the light source from the observer and by using a multiple of medium intensity lamps rather than a single high intensity lamp.

The visibility range is a function of both turbidity and attenuation. In clear water (no turbidity), all natural light is attenuated at a depth of 100 feet. As the attenuation coefficient increases, the visibility range sharply increases.

As a result of total darkness at depths below 100 feet, artificial light sources must be employed. Although many light sources have been developed for underwater applications, only three have been used to any extent. These are: the quartz iodide light source, the mercury vapor light source, and the recently developed thallium iodide light source.

Each light source has unique characteristics which optimizes it for specific applications. All three light sources are used for general illumination. Quartz iodide is used primarily with color photography,

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while mercury vapor and thallium iodide are used for black-and-white photography and underwater television.

Power Sources

There are three means of supplying power to facilities located in the deep ocean--shore-based, surface-tendered, and in-situ.

Shore-based power is power which has been generated on land and transmitted to a load module by way of submarine power cables. Surface-tendered power is power generated on a buoy, ship, or some other platform floating on the surface of the ocean and transmitted down to a load module by way of cables. In-situ power is power generated on the ocean bottom.

In selecting a method for supplying power to a load module in the deep ocean, certain factors must be considered; i.e., the environment, depth and distance, duration, power level, power profile, power characteristics, voltage and current, reliability, maintainability, and cost.

When cabling power to a load module in the deep ocean, the cost of the cable itself represents the most significant dollar amount. The only way the cost of the cable can be reduced is by reducing the size of the cable. However, it is mandatory that the cable be sized to carry the necessary amperage and that the required voltage regulation be maintained. This can be accomplished by two methods: transmitting DC power and by increasing the transmission voltage.

When transmitting power from a surface-tendered platform, the costs of supporting the cable must be added to the cost of the system.

There are two methods of supporting a cable: by increasing its strength, and by attaching buoyancy materials to the cable to reduce its weight. However, adding buoyancy through the cable's length is not practical because it would produce a very large cable that would be hard to handle. Two types of buoys have been investigated for providing the required buoyancy: (1) hollow buoyancy spheres, and (2) homogeneous buoyancy material.

Two basic configurations have been considered for the cable suspension system: (1) a taut line configuration, and (2) a normal catenary configuration. Of the two systems, the taut line configuration tends to be more efficient in terms of overall suspension cost.

The most significant problem relating to transmitting electrical power to a load module in the deep ocean is the unavailability of suitable connectors because of mechanical problems, electrical problems, and pressure problems.

Possible sources for in-situ power plants are: batteries, fuel cells, and nuclear power.

UNDERSEA NUCLEAR POWER

by J. Angelo*

There are three distinct reasons why nuclear power is considered to be a strong contender as a primary source of power for deep ocean installations.

- Nuclear reactors are non-air breathers. Nuclear reactors, like fuel cells and batteries, can be easily sealed from the environment. Diesel units, on the other hand, require 12 to 14 pounds of air per pound of fuel for operation. Until some practical and economical way can be developed to supply air to a diesel unit on the ocean bottom and, at the same time, discharge the exhaust gases, the application of diesel units as a primary source of power for deep ocean installations is eliminated.

- The fuel utilized in nuclear reactors is a concentrated energy source. Nuclear fuel can produce electrical energy in the order of 10-kw hours per cubic foot of fuel volume. Diesel fuel produces electrical energy in the order of 10^3-kw hours per cubic foot of fuel.

- The process of producing heat energy is very simple.

There are both limitations and disadvantages as to why nuclear power is not used as the primary source of power in the deep ocean.

- The primary disadvantage is cost. The cost of nuclear power may be two or three times the cost of conventional power.

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- Reactors involve the handling and management of radioactive products and radiation levels around the reactor in the ocean. However, methods used for radiation shielding and handling of radioactive products developed in the commercial and military reactors can be utilized for deep ocean reactors.

Problem Areas

- To simplify the reactor for safety to permit unattended operations.

- To develop simpler and more reliable power conversion equipment to permit sustained operation on the ocean floor.

EQUIPMENT IN THE OCEAN ENVIRONMENT

by W.E. Watkins*

For many years NAVFAC has developed criteria for the design of shore-support facilities for the Navy establishment. Much of this criteria becomes obsolete when designs for the ocean environment are contemplated. New atmospheres have been developed to allow man to work at great depths. These new atmospheres affect the properties of materials that have been used over previous years in conventional construction. For example, heat transfer in helium atmospheres is greatly increased over that for air. This phenomenon, plus the resultant compression of unicellular insulation caused by the high pressures at ocean depths, greatly reduces the effects of the insulation.

Due to the increased heat transfer in helium atmospheres, established levels of temperature and humidity for physical comfort will have to be shoved aside and new criteria be developed.

These are only two examples of the effects the ocean environment is having on our existing criteria. New guidelines will have to be established and engineers will have to be reeducated, if we are to have both reliability and safety in our designs.

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CONSTRUCTION OF OCEAN ENGINEERING SYSTEMS

Moderator: D.C. Pauli

Newell T. Stiles

SUBSURFACE PROFILING INSTRUMENTS

by Newell T. Stiles*

Subsurface profiling instruments operate similar to the conventional echo sounder. The instrument consists of a sound source and a hydrophone receiver which are normally towed through the water. The instrument generates an acoustic pulse that is transmitted to and into the seafloor and records arrival times of the return echo. Echoes returned from acoustic discontinuities--almost always manifestations of sediment interfaces--are synthesized by the recording unit so that the end product is a real-time, continuous profile of the water column, bottom, and subbottom.

Seismic reflection techniques have been used for many years on land as a reconnaissance tool for determining the structural configuration within the crust of the earth. In recent years, marine scientists have extended this technology for use in the deep sea. Geophysical studies yielding deep subsurface penetration up to many hundreds of feet have been accomplished. These high-penetration profilers use low-frequency acoustic sources in the range of 20 to several hundred Hertz. Sound sources may be pneumatic, gas exploder, electrical discharge, or displacement type. The main liability of these systems is that they often lack the fine-grain resolution needed for many problems. To increase resolution quality, depth of penetration must be sacrificed.

Studies requiring high resolution of subbottom structures use sound sources in the kilo-Hertz range. The sources are either sparker,

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piezoelectric, or displacement. High-resolution, high-frequency, shallow penetration systems offer much promise for engineering investigations in the coastal environment. The systems are adaptable to small boat use and have proved their usefulness for such engineering problems as location of construction materials, location of spoil, estimating excavation costs, foundation studies, and location of pipelines and tunnels. Commercial fishing vessels use these techniques for locating fish. Recent estuarine studies have shown that the salt-water/fresh-water interface could be defined by acoustic means, thus offering a possible tool for water pollution investigations. Subsurface profiling has proved to be helpful in mine-warfare planning by defining areas of mine burial and mine impact penetration.

There are several limitations of subsurface profiling devices. A sacrifice must be made for either resolution or penetration. Moreover, "ground truth" data is a must. Establishing that a particular reflecting horizon exists may be simple, establishing what it is, still requires following the reflecting layer to a known point of origin, such as outcropping bedrock, or direct sampling. Also, an impedance contrast must exist. For example, coral heads overlain by calcareous muds would probably not be visible, whereas if overlain by terrigenous muds the probability is that the coral head would reflect the pulsed signal.

DEEP OCEAN SIMULATION FACILITIES

Moderator: W.J. Bobisch

K.H. Keller
Dr. J.D. Stachiw
J.W. McNeely, Jr.

DESIGN OF DEEP OCEAN SIMULATION FACILITIES

by Karl H. Keller*

Mr. Keller presented slides covering 39 high-pressure tanks that are available for static pressure, pressure cyclic, and temperature cyclic testing. He indicated that 22 more tanks would be added to this number by the move of the Naval Applied Science Laboratory equipment to Annapolis.

Significant among these tanks is the 10-foot inside diameter, 27-foot long, 12,000 psi static, 4,000 psi cyclic pressure "A" tank now installed at NAVSHIPRANDLAB, Annapolis. Pictures were shown of the testing of the Deep Submergence Rescue Vehicle Capsule No. 2 at the Sun Shipbuilding and Drydock Company, prior to transporting the "A" tank to Annapolis.

Also described was the 4-foot inside diameter, 10-foot long, "B" tank whose capability is also 12,000 psi static pressure, 4,000 psi cyclic pressure, to be delivered prior to the end of 1969. Both the "A" and "B" tanks have temperature cycling capability.

The 30,000 psi static pressure, 10,000 psi cyclic pressure (MILCON 1970) tank was illustrated in its relation to the tank complex. This tank has progressed through the Production Cost Estimate phase at NAVFAC, Chesapeake Division.

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The Deep Ocean Technology Program, now in its third year at NAVSHIPRANDLAB, Annapolis, was described in relationship to the high pressure testing program, and the type of tanks and fixtures used.

Pictures were shown of the eight AC and DC, 7-½ hp and 15 hp motors tested under pressure, describing their modes of failure and the corrective actions. Types of encapsulated and pressure compensated inverters and converters were shown, as well as planetary and friction drive speed reducers. DC motor commutation was discussed and the solution to this problem was given.

Materials research was outlined of the compatibility of elastomers, plastics, and metals with high pressure oils up to 20,000 psi; also, the fluids research on 11 candidate oils at high pressure, on lubricating, pressure compensating, and dielectric oils was outlined.

Tests on relays, switches, and other circuit interruption devices at high pressure were explained, including investigations on carbon "clinkers" between contact points for the various candidate oils. A research mechanical switch and a breakthrough on a 4-ampere and a 100-ampere solid state switch with a capability of 13,000 psi were shown.

The successful development of a 3,000 psi ceramic piston, ceramic cylinder wobble plate pump was traced, resulting in findings for the next step of a 9,000 psi pump for the Deep Submergence Search Vehicle.

Problem Areas

- Develop new oils to meet the desired oil parameters for high pressure.

- Develop seals to prevent salt water invasion of compensating oils and lub oils.

- Determine and validate theory of externally pressurized pipe and tubing in sizes up to 2 inches diameter.

- Develop AC and DC submersible motors in the 30 to 50 hp power range.

- Continue development of closed cycle thermochemical engine; 5 to 10 hp range.

- Continue development of high pressure switching devices.

- Initiate effort on traction oils for traction drives.

- Initiate program on high pressure testing of electronic components.

CONCRETE INTERNAL PRESSURE VESSELS

by Dr. J.D. Stachiw*

Several concrete internal pressure vessels of very large dimensions have been built abroad for nuclear power plants. The internal dimensions are on the order of 100 feet, while the working pressures are less than 1,000 psi. In the United States, there is only one pressure vessel under construction--by the Gulf Atomic, Inc., in Colorado. Similarly, the working pressure is also under 1,000 psi. Exploratory investigations indicate that vessels with an internal pressure capability of up to 3,000 psi can be built within the scope of the existing technology. However, with additional R&D in this area, the internal pressure vessel capability can probably be raised to 4,000 psi. The large concrete pressure vessel construction technique will lend itself especially well to the construction of pressure vessels for testing of complete operational submersibles.

It is noteworthy that concrete serves in internal pressure vessels only as a matrix for pretensioned steel cables which carry all the tensile stresses generated by internal pressure. But, because of the availability of this very inexpensive matrix, it is possible to utilize already available steel cables with very high tensile strengths and place them where they are most needed in the structure. Because of the high strength of cable steel and the selective placement of cables, considerably less steel can be used than in steel vessels. Furthermore, the cost of steel in commercially mass produced cables is an order of magnitude less

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than of steel in a custom forged, or welded pressure vessel. As a result, sizable economics can be achieved by using prestressed concrete for construction of very large internal pressure vessels.

The prestressed concrete vessels offer not only large savings in construction costs, but also more safety in case of over-pressurization. When over-pressurization occurs, the cables over extend and cracks appear in the concrete through which water may escape without any generation of fragments. Once the pressure is relieved, the cables retract, thus closing the cracks in the concrete and leaving the vessel undamaged for further service.

Deep Ocean Simulation Facilities

The current state of deep ocean simulation facilities is characterized by the following criteria:

- The lack of sufficiently large pressure vessels to accommodate ocean engineering hardware in the field, or on the drafting board.

- The reluctance of facility operators to permit implosion testing, or testing of soils in their vessels.

- The inadequate financial support of test facilities to allow for continuous maintenance.

- The inadequate staffing of test facilities in terms of numbers and available ratings for personnel.

- The absence of a uniform design code with adequate safety margin.

- The lack of appreciation on the part of management for safety hazards to which operators are routinely exposed without hazard pay.

It appears that similar operational funds should be made available for deep ocean simulation facilities, as are available for the ships of the Navy, without recourse to the very fragmented project type funding. It is estimated that the yearly level of such operational funds should be on the order of 25 percent of original plant value. Only by assuring continuous operational funding can the facilities be well-maintained and be successful in developing and retaining a cadre of highly qualified operators.

DEVELOPMENT OF PLANS AND SPECIFICATIONS FOR AN OCEAN SIMULATION FACILITY

by John W. McNeely, Jr.*

Introduction

Contracts have been awarded by SOEASTDIVNAVFAC for two of three increments of construction that will provide an Ocean Simulation Facility (OSF) at the Naval Ship Researchand Development Laboratory, Panama City, Florida. The first contract, awarded in June 1969 to Dyson and Company of Pensacola, Florida, will provide a 22,450-sq. ft. laboratory building, supporting utilities, a testing tank, and chamber foundations. The second contract, awarded in August 1969 to Hahn & Clay, Inc., of Houston, Texas, will furnish a 450-ton FY80 steel chamber complex. The third increment of construction, currently in the planning and design stage, will provide the necessary systems for life support, accommodations for chamber occupants, instrumentation, and systems for control and monitoring of chamber functions.

When completed, the OSF will be the largest man-rated pressure facility of its type, and the first that will permit testing and evaluation of man and equipment together in controlled simulated underwater habitat and hydrospace environments to pressures of 1,000 psig (2,250-ft. depth).

Facility Description

Each upper chamber of the chamber complex, will be provided with separate life support atmospheric conditioning and gas pressure systems which may be operated either manually, semi-automatically,

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or automatically by a programmed computer. Controlled mixes of compressed helium, oxygen, nitrogen, and/or compressed air will be utilized for pressurizing all chambers. Economical operation of the facility will be feasible with the helium reclaim system. Numerous view ports will be provided in each chamber to permit diverse observations and testing arrangements. A data acquisition system, including a computer, data logger, and telewriter, will be provided for monitoring and controlling chamber pressure and environmental conditions.

The wet chambers will be provided with fresh water and salt water supply systems, and subsystems that will permit control of temperature, turbidity, and salinity of the water. Pressurizing the wet chamber will be accomplished with the gas systems that are provided for the center and trunk chambers.

For a complete technical description of the project, reference should be made to the "Preliminary Engineering Study" and Program Cost Estimates that have been prepared for the project under NAVFAC Contract NBy-88722, and plans and specifications prepared for NAVFAC Construction Contracts N62467-69-C-0070, -0071, and -0072.

Procurement Procedures

The OSF is being sponsored under the MILCON Program for Facilities in lieu of the normal MILCON Program for R&D through which facilities of this type are usually procured. Accordingly, contract plans and specifications for this project have been developed for specific designs and specifications to permit "lump sum" bidding and awarding of contracts to the lowest bidders. This procedure also insures that a complete and useable facility will be provided within the authorized program construction funds, and permits a detailed evaluation of the designs and specifications from a safety standpoint prior to award of contracts.

Plans and Specifications

Development of plans and specifications for the OSF has been found to be a unique and difficult assignment, particularly with respect to the technology involved and scope of design considerations required. Many available codes, specifications, and guidelines have been researched and utilized, wherever feasible, in order to establish realistic requirements within the limits of current technology and accepted procedures. Materials and equipment have been selected not only for their performance characteristics in normal environments, but also for their stability and reliability in hyperbaric helium and oxygen enriched environments. In many instances it has been necessary to determine the availability of special materials and equipment which were necessary to meet design criteria, and to base designs and specifications on proprietary items that were found acceptable. Research and study of new developments in underwater technology and operating techniques have been necessary for prosecution of the design work. Consultations with many experts engaged in research and development work in allied technologies and underwater programs have been of great value in planning and design of the facility. Throughout all planning and design work, primary consideration has been given to insuring the adequacy of the facility from a safety standpoint. These and other considerations which have been given to the development of plans and specifications for the OSF will serve to insure that a safe and adequate facility will be provided.

Contract plans and specifications, as well as the "Preliminary Engineering Study" and Preliminary Cost Estimates, have been prepared by Sanders and Thomas of Pottstown, Pennsylvania, with technical and contract administrative guidance provided by NSRDL/PC and SOEAST-DIVNAVFAC.

Certification Requirements

In addition to procurement plans and specifications, it is a project requirement that necessary documents be prepared by SOEASTDIV that will permit an independent reviewing authority to survey all aspects of design and construction, and to certify that the facility is materially adequate from a safety standpoint. The purpose of this requirement is sufficiently stated in the following NAVFAC definition of "certification":

> "Certification insures an independent technical review has been made to insure the material adequacy of the facility to perform its intended function with safety to personnel - and in event of an emergency of any kind return individuals from any point in a simulated dive condition to ambient conditions - all within parameters set by the operators."

Inasmuch as certification criteria for hyperbaric facilities is currently being developed by NAVFAC--in accordance with the certification responsibilities assigned by NAVMAT--guidance provided by NAVSHIPS 0900-28-2010 has been utilized for preparation of designs and establishing construction contract requirements for the OSF. It is anticipated that criteria for hyperbaric chambers will be similar to NAVSHIPS criteria which requires the following categories of information be submitted for certification purposes:

- Design analysis and calculations
- Summary description of facilities
- Fabrication and construction procedures
- Quality assurance procedures
- Operations and maintenance procedures
- Scope of certification
- Operations analysis
- Material justification
- Test procedures
- Others as required

Included in the A/E and construction contracts are requirements for providing specific information and data that are necessary to develop the formal certification documents. During construction of the chamber facilities, design and construction data will be correlated and additional information developed as required for certification. After completion of construction and review of certification documents by the certification board, an on-site detailed survey of the "as-built" chamber facility and the certification documents will be performed. If the survey demonstrates that the facility will safely perform in accordance with the parameters documented, a Certificate of Certification will be issued by the Certification Authority for a specific period of time. At the end of the initial certification period the facility and its documents will require "re-certification" for an additional period.

The above procedures and requirements for certification may vary in detail as the work progresses, but will still follow the precepts outlined.

Conclusion

Problems which have been confronted in the development of plans and specifications are those which might be expected for a R&D type facility that is:

- The first of its type to be provided under NAVFAC procurement procedures.

- The first to be certified for material adequacy.

- The first to be designed and constructed to permit man and machines to be tested together in simulated hydrospace and habitats to 1,000 psig.

General problems which have been encountered throughout the work are those related to:

- Establishing realistic design and construction schedules.

- Maintaining schedules.

- Acquiring information and reference documents.

- Developing expertise in the disciplines of underwater technology.

- Limiting "off-the-shelf" equipments.

- "State-of-the-art" in design of man-rated hyperbaric chambers.

However, the special relationship that has been generated by the active participation of NSRDL/PC, A/E, and SOEASTDIVNAV in all phases of design and development of contract documents has made it possible to solve the problems which have been encountered.

All who have participated in planning and design work have considered the problems encountered a special challenge, and a welcome opportunity to contribute to the advancement of underwater engineering and technology.

MATERIALS OF CONSTRUCTION

Moderator: E.A. Lange

I.V. Bloom
Dr. P.P. Puzak
Dr. B.F. Brown

NON-METALLIC MATERIALS - PLASTICS

by I.V. Bloom*

Most questions concerning plastics in ocean engineering applications are involved with fiberglass reinforced plastics. This is probably because these materials appear particularly suited for deep submergence work due to their high strength-to-weight ratios. The problems are usually concerned with the availability of physical property data for reinforced plastic laminate structures fabricated by specific companies. Unfortunately, no such specific information is available in any handbook.

It may not be realized, but fiberglass reinforced plastics are not like the specific materials with which we are normally familiar: instead, they are composite structures whose properties depend on a number of variables including the basic materials used in the fabrication, the form of the reinforcement, and the processing method used. Therefore, any precise laminate properties available are valid only for a specific product, tested under specific loading conditions. This means that physical property information, except for general information which is readily available but not very useful, should be obtained from the plastic laminate manufacturer. But if the manufacturer does not have the data (and he probably won't if such rare information as fatigue loading, for example, is required), then the user should be prepared to determine the properties himself, or to make some good guesses.

Assistance, of course, can be obtained from Plastics Engineers who are highly knowledgeable in the field of reinforced plastics, and who

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can make pretty good guesses. But these are, after all, only guesses. This may not be good enough where reliability or safety may be involved. Therefore, if reinforced plastics are considered for use in this work to any great extent, particularly in applications that are critical then consideration should also be given to sponsoring more research and test work on the particular reinforced plastics to be used in order to obtain the data that is needed.

DEVELOPMENT OF HIGH-STRENGTH STEELS FOR OCEAN ENGINEERING APPLICATIONS

by Dr. P.P. Puzak*

The case histories and features of several pressure vessels which have failed catastrophically in service or in hydrotest were reviewed. It was noted that all of the illustrated failures involved Code-approved materials and fabrication practices. It was shown that these and other structural steel service failures are controlled by the dynamic properties of the material, not by the static properties normally measured with conventional laboratory tests. These structural steel service failures could have been prevented if the material selection procedures had been based on reliable test methods that defined something critical in the dynamic fracture performance of the material involved.

Information for material selection and design guidance for conventional structural steels used in pressure vessels construction was presented in terms of the Fracture Analysis Diagram (FAD) method for fracture-safe design. The FAD provides a practical procedure for the synthesis of fracture mechanics and transition temperature concepts. One important feature of the FAD is its definition of the effects of increased temperature above the NDT (nil-ductility-transition) on flaw size-stress relationships. The FAD analysis is indexed to the NDT temperature determined by the NRL drop-weight test (ASTM-E-208) which is a practical test of utmost simplicity. Several case histories for the fracture-safe design of pressure vessels were reviewed to illustrate use

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of the procedures for selection of materials based on NDT, the FAD, and the service requirements.

New interpretive approaches, using the Dynamic Tear (DT) test and the Ratio Analysis Diagram (RAD), to investigate the fracture characteristics of the high-strength steels were explained. The influence of heat treatments and processing variables on the fracture toughness-yield strength relations for the steels of Navy interest was described. Steels in the yield strength range from 180 to 210 ksi are at the mid-point of the "strength transition," which starts from a potentially high level of fracture resistance and drops to a low level of fracture resistance. The dramatic falloff in fracture toughness is also evidenced by the fracture appearance in the 1-inch DT specimens which changes from large, plastic enclave type fracture for an optimized 180 ksi yield strength steel to a mixed-mode type fracture for an optimized 210 ksi yield strength steel. Chemical composition has a direct effect on yield strength, but other factors, mainly purity of the metal, control fracture resistance. All air-melted materials above 180 ksi yield strength are brittle (plane strain properties) in sections exceeding 1-inch thickness. Vacuum melting significantly improves fracture resistance, and the order for increasing effectiveness is single vacuum-arc remelting, vacuum-induction melting, and double vacuum melting. By optimizing metal processing procedures, materials up to 180 ksi yield strength can resist fracture initiation at all elastic stress levels in thick sections as long as hardenability limits are not exceeded, whereas optimized material at 210 ksi yield strength is on the borderline of plane strain fracture even in sections that are less than 2-inches thick and have no toughness gradient through the thickness. This analysis is the only comprehensive characterization of the mechanical properties of premium high-strength steels of interest for critical ocean engineering applications.

The special problems to be encountered in thick-walled pressure vessels fabricated with the higher yield strength, heat treatable, quenched and tempered (Q&T) alloy steels were described. The effects of mechanical constraint and metallurgical variables on fracture toughness properties due to increasing section thickness were discussed. To illustrate potential problem areas in Q&T alloy steel vessels, the results of NRL investigations of the thick-walled NSRDL-Annapolis Chamber B pressure vessel were described. Sample material from six of the eight shear block seat areas cut out from around the periphery of this vessel provided data for the analysis. These six cutouts made it possible to determine the characteristics of the material around the periphery of the main body forging at the wedge lock closure location, and generally, it was found that the O.D. surface material exhibited excellent fracture toughness. However, the level of toughness which was very high at the surface dropped precipitously for several successive specimens taken at greater distances from the O.D. surface, a large central core region. This core, which comprised nearly 80 percent of the section, was shown to be highly brittle at 30°F. In addition, mechanical properties were not uniform around the periphery of the cylinder wall; significantly higher yield strength values and considerably lower toughness levels than those in the remainder of the vessel were found in a 4-foot segment. This variability in strength and toughness properties could only have resulted from inadequate heat-treating facilities and practices by the forging producer. On the basis of the above analysis, the main body forging of Chamber B was rejected by the Navy because of the non-uniform circumferential properties.

Procedures for reprocessing the forging to make it acceptable were described. Retempering experiments were conducted by NSRDL-Annapolis to provide information for reheat treating the forged, and then the hemi-head and weld metal were removed and the body forging was retempered. Strength and toughness properties obtained on trepanned cores removed from unstressed areas demonstrated that uniformity has been achieved. The pressure-temperature characteristics of Chamber B in its present condition are considered to be identical to those of Chamber A. NAVFACENGCOM designers and purchasers of new high pressure facilities were advised to include a requirement for a fracture resistivity analysis in the specifications of new construction to preclude a repetition of expensive salvage operations.

CORROSION AND ITS PREVENTION

by Dr. B.F. Brown*

Structures of a wide variety of (a) configurations, (b) intended service lives, and (c) availabilities for inspection and maintenance are either being deployed or being planned for deployment in the sea. Some of these structures carry isotope-powered thermoelectric generators. They are scheduled to be moored in the open sea, and if the power plant should either be breached or be cast adrift and fetch upon the wrong shore, the consequences would be far more serious than the loss of the dollar value of the material.

One of the characteristics of the corrosion of some of our better structural alloys for marine service is that the reaction incidence is highly random, therefore, the kinetics at one site may vary greatly from the kinetics at an adjoining site. Our marine corrosion technology needs four categories of contributions for newer marine structures which are either highly sensitive or highly expensive.

The first need is to develop some better way to quantify localized attack: The rate of weight loss and the rate of surface recession are far too crude for collecting the main body of extreme-value statistical data. One possibility of a new approach is the isolation of anodes from cathodes followed by the measurement of corrosion current flowing between anode and cathode by a zero-resistance method. Such a method will take considerable time to perfect and validate, but it is needed to modernize

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assessment methods. A second need is an improved concept of extreme-value statistics as applied to localized corrosion attack. A third area of needed contribution is the technology of the cathodic protection of non-ferrous alloys, particularly the aluminum and copper-base alloys. Cathodic protection technology was developed almost exclusively for steels (especially pipelines and ships), and it needs orderly extension into the non-ferrous field. Fourth, a small effort is needed to continue to develop a theory of corrosion phenomena and corrosion-control mechanisms. This structure of theory is required to provide a framework upon which to organize what would otherwise be a hopeless jumble of corrosion facts.

It is not in the cards for the research community to produce a corrosion-free alloy. Consequently, all metallic structures installed in the sea must be regarded as temporary. There can be, however, a wide range of service lives depending upon how well the designer, the fabricator, and the maintenance man utilizes existing corrosion technology. Avoiding costly mistakes from failure to make proper use of available corrosion and corrosion control data requires mangement action at the headquarters level. Members of the corrosion research community cannot obviate such mistakes by any amount of research, but they would willingly serve as advisers on hardware projects where their special backgrounds would be advantageous.

SOILS, FOUNDATIONS, ANCHORING, AND MOORING

Moderator: P. Brown

P. Brown
H.L. Gill
D.H. Potter

BOTTOM SOILS AND FOUNDATIONS

by Philip P. Brown*

The subject of soil mechanics as applied to the ocean has been a matter of concern to NAVFAC for at least ten years, beginning with the testing and analysis of some of the earliest deep ocean cores taken by the Naval Oceanographic Office.

Recently, we have been attempting to take a more comprehensive look at soil mechanics and foundation engineering as related to the ocean bottom.

One way to do this is to look at how we do things on land and consider what our present capability is for accomplishing the same in the ocean.

APPRAISING THE SITE AND SOIL CONDITIONS IN THE GROSS SENSE

	TERRESTRIAL	SEAFLOOR
Topography	Available Maps Airphotos Visual Examination	Refinement of Sonic Techniques
Land Form Identification	Area Knowledge Airphoto Interpretation Visual Examination	Insufficient Techniques Insufficient Techniques (Geol.) Knowledge
Subsurface Stratification	Geol. Interpretation Geophys. Measurement Visual Surface Indications	Promise in Geophysical Methods

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	TERRESTRIAL	SEAFLOOR
Subsurface Composition	Existing Borings Existing Excavations Area Experience Land Form Indications	No Experience or Existing Information

DETAILED OR MICRO INVESTIGATIONS

	TERRESTRIAL	SEAFLOOR
Site Exploration	Borings Sampling Tests In-Situ Tests	Depth Limitations Positioning Dis- turbance Problems
Foundation Design	Based on----- Analysis of Meas. Prop. Modified by Engineering Judge Rules of Thumb Economic Considerations	Probably - Much weaker range of soil strengths Judgment & Empiricism may be misleading
Assignment of Safety Factors	By Experience	Deformation/Strength Relationships are different-- Land F.S....not applicable Needs development Potential great
Earth Pressures	Strength Theory......? Empiricism	Land Experience May not be applicable

APPRAISING THE SITE STABILITY

	TERRESTRIAL	SEAFLOOR
Earthquake Potential	Accelerations zoned--modified by Local Geology	Limited Experience for zoning-- but potentially very active

	TERRESTRIAL	SEAFLOOR
Shear Slide Potential (Soil & Rock)	Ancient Slides Area Soil & Geol. Experience -- estimates of soil strengths	No Background experience-- Little Basis for strength estimates
Potential Flow Slides	Based on Density Gradation Sensitivity Indicators	Mechanisms Not completely understood Observations lacking
Creep	Surface evidence Survey Measurements	Not developed Not developed
Scour Potential	Current Measurements Empirical Relations	Similar techniques possible
Turbidity Flows	Not Applicable	Probability may be predictable

CONSTRUCTION AND OPERATIONAL ASPECTS FOR WHICH TECHNOLOGY MUST BE DEVELOPED

Foundation Construction
Driving

Drilling
Excavating
Grading
Tunnelling
Anchoring

Requires: Equipment

Technology

As well as Soils & Rock Technology

Bottom Preparation
Area Stabilization
Reduction of Turbidity
Predicting Trafficability

Operational Problems
Predicting Bottom Penetration
Predicting Breakout Forces

In summary, we are extremely handicapped in soil mechanics in the ocean area. Our measuring tools are limited--depth wise, area wise, and quality wise; we have no guiding, previous construction experience; we have no area experience; we will be dealing with weak soils which would be avoided on land construction either by moving the site, excavating the material or penetrating it to better materials; and finally, we will undoubtedly have more massive stability problems to face.

NCEL RESEARCH ON BOTTOM SOILS AND FOUNDATIONS

by H.L. Gill*

The significant problem areas related to seafloor soil mechanics and foundation engineering were outlined in the opening remarks by Mr. Brown. During this introduction some of the efforts underway at NCEL to overcome some of the handicaps mentioned by Mr. Brown were illustrated briefly. Slides of various items of soil sampling and testing equipment being used and developed were presented and examples of typical data being obtained were shown.

At present, there does not exist a soil sampler capable of obtaining undisturbed seafloor sediment samples to reasonable sediment depths in other than relatively shallow water. Each of the types of samplers now being used violates one or more of the criteria for undisturbed soil sampling; the most frequently violated criteria are those associated with the thickness of the sampler walls and the length-to-diameter ratio of the sampler. Gravity-type cores, such as the Ewing corer, have been used prevalently.

Examples of laboratory soil tests being performed on seafloor sediments, in addition to the standard classification tests, are the laboratory vane tests and tests to detect the carbonate-organic carbon content of the sediments. The results of a majority of the laboratory strength tests being performed are affected adversely by the inferior quality of the samples being used.

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At present the best quality information on the engineering properties of seafloor sediments for the design of seafloor foundations is being obtained by in-situ testing devices. A vane shear device has been developed in order to obtain measurements of the undrained shear strength of cohesive seafloor sediments in their natural, undisturbed state. The device is capable of operating in 6,000 feet of water, and measurements can be obtained to a sediment depth of 10 feet. The vane shear attachment of the device can be removed and replaced by a static cone penetrometer. The device is accommodated by the Deep Ocean Test Instrument Placement and Observation System (DOTIPOS); therefore, a TV monitor is available to provide visual observations of the tests on the seafloor.

Some seafloor soil deposits have been found to have exceptionally low shear strengths within the top 10 feet of the deposit. For example, in-situ strength tests at one site revealed an undrained shear strength of only 0.5 psi at a depth of 5 feet into the sediment. The strength increased gradually with depth, beginning at a value of essentially zero at the water-sediment interface. Both vane shear and cone penetration tests are usually performed at each site, and it has been found that of the two, the cone penetration tests usually provide the more consistent data.

Other in-situ tests are performed at seafloor sites with two plate loading devices which have been developed. One of these, the Plate Bearing Device, performs short-term plate loading tests to measure the bearing capacity of undisturbed seafloor deposits. It can accommodate a plate as large as 18 inches in diameter, and it has been tested on the seafloor at a water depth of 6,000 feet. Loads and corresponding displacements are measured and transmitted to the surface acoustically.

Whereas the displacements measured by the plate bearing device result principally from shearing distortions of the soil, the displacements measured by the other plate loading device result principally from elastic strains and consolidation of the soil. This latter device is a Long-Term Ocean Bottom Settlement Test for Engineering Research (LOBSTER) and one adaptation of this system is a 4-foot diameter concrete block with an instrumentation package attached to measure displacement and tilt of the foundation as a function of time. The foundation applies 100 psf to the soil. It can be left with its instrumentation functioning for as long as 400 days, and upon acoustic command from the surface, the instrumentation system can be floated to the surface with digital tape containing the test data. This system is designed for operation at water depths up to 6,000 feet.

A potentially critical problem during undersea operations is turbidity resulting from sediment disturbance by divers, equipment, and submersibles operating in the area. Turbidity at a site can reduce the visibility to a point where normally routine functions are impossible. For example, during penetrometer tests with a submersible at a water depth of 1,300 feet, fish disturbed the sediments to the extent that the previously clear water became so cloudy that the penetrometer could not be found even though the submersible was never more than 6 feet from the device. A chemical overlay system is being developed to alleviate such problems. A chemical has been developed that can be placed in a thin film on the seafloor to form a tough, but flexible, impermeable barrier over the sediments. The material bonds to itself, so it can be dispensed in strips without having to overlap an undesirable amount. A system is being developed to enable the material to be dispensed by a submersible.

Problem Areas

- Techniques for obtaining undisturbed seafloor soil samples.

- In-situ tests of sediment shear strength and compressibility to sediment depths greater than 10 feet.

- Turbidity suppressment.

- Development of equipment and procedures for installing seafloor foundations.

- Breakout and penetration.

- Sediment environmental characteristics such as turbidity currents, scour and fill, earthquake effects, slope stability, and trafficability.

ANCHORING AND MOORING

by D.H. Potter*

NAVFAC's responsibility under NAVMAT and the DOT program is for the planning, design, construction, and maintenance of fixed structures in the ocean, including development of foundations, anchors, and moorings.

The particular mission determines the degree of fixity required and, as a result, defines the appropriate type of mooring.

Problems encountered in mooring design can be put into two broad categories: (1) universal problems, and (2) particular anchorage problems.

Types of anchors presently being used include the dead-weight anchor, drag-type anchor, and piles. The STATO anchor is a recent development drag-type anchor capable of greater holding power/weight than other drag-type anchors.

Advanced-type anchors under development include free-fall embedment anchors, explosive embedment anchors, including the PADLOCK type, vibratory anchors, jetted-in anchors, and hydrostatic anchors.

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Most of the mooring failures to date have been due to mooring line failures, either the line itself or its fittings.

Characteristics desired for a mooring line are high tensile strength, lightweight, non-brittleness (capable of repeated bending), abrasion and crush resistant, kink resistant, torque balanced, corrosion resistant, easy to handle and to splice, and low in cost. The two main types of rope used are metallic wire rope and synthetic rope--each has some of these qualities, but not all.

Anchorage systems which have been used are (1) single and double buoy taut line systems, and (2) slack-line systems for small installations and multi-leg systems for larger installations.

Various problem areas include the following requirements:

- Anchors
  - More versatile
  - Easier placement methods
  - More holding capability
- Mooring Lines
  - A line with more desirable characteristics
  - Corrosion protection methods improved through better materials and better protective systems
- Anchorage Systems
  - Long lasting systems development for large installations in the deep ocean
  - Easier, faster, less expensive emplacement methods

A general problem area is a better understanding of NAVFAC's role in the ocean and its role with respect to NAVSHIPS, the Coast Guard, etc.

DIVING AND DIVING EQUIPMENT

Moderator: LCdr. R.D. Smart

LCdr. J. Osborn
LCdr. R.D. Smart

DIVING EQUIPMENT

by LCdr. J. Osborn*

The presentation was given to provide a quick look at available diving systems and equipment either presently available or being developed.

Diving Equipment

To date, the group of diving equipment on hand has been developed on a "case requirement" basis, some 100 to 150 years ago.

Equipment is used to protect the diver and to assist him in completing his job efficiently. Some of the parameters that put constraints on a diver and for which equipment is being developed to counteract these restraints are as follows:

- Visibility problems - visibility of 200 feet plus in some areas; zero visibility in other places (Anacostia River).

- Temperature problems - water temperatures can range from in the 90^{o}F to 28-29^{o}F in Antarctica.

- Type of work - from hard, "mulehauling" work to observation.

- Type bottom - hard, sandy to loose unconsolidated clay.

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*Deep Submergence Systems Project, (Code 301), San Diego, California.

- Mobility of diver - hardhat--relatively no mobility but good working power. SCUBA - good mobility but little heavy working capability.

- Communications - diver-to-diver, diver-to-surface, and surface-to-diver.

A simple explanation can be given for the difference between saturation and nonsaturation diving: decompression is needed to rid body of gas absorbed in the bloodstream due to high pressures (Dalton's Law). The amount of gas absorbed ultimately stabilizes after about twenty-four hours at a given depth, and the body is said to be saturated. If asked how long does it take to decompress a saturated diver, it depends on depth. As depth increases, the time needed for decompression increases. A rule of thumb is one day per 100 feet of depth. Therefore, saturation diving should only be used for long dives at deep depths.

Lt. Commander Osborn then gave a slide presentation of the present types of gear which included:

- Typical "hardhat" - available to Salvage Navy, the Seabees, and the Construction Battalions. It is the oldest piece of gear in the Navy and the most reliable if you are not in a hurry to go anywhere.

- Typical SCUBA open circuit diving rig with bottles on back.

- Umbilical supplied rig with gas supplied from surface. One problem with this gear is the tendency to become easily entangled in the lines if not paying very close attention.

- The Wiswell suit with thermal protection provided by an umbilical supplied warm water bath. Temperature can be controlled topside or by the diver. This is a good way to keep warm provided a constant flow of warm water is maintained.

- The MK VIII mixed gas rig. This is a semi-closed, saturation diving unit. The semi-closed unit conserves gas being used by dumping into hydrospace only a small amount of the exhaled gas. The rest is "scrubbed" of CO_2 and recycled.

- Kirby-Morgan helmet - provides communication to some extent.

Nonsaturation diving usually uses hard hat, open circuit, or some semi-closed rig such as the MK VI or MK VIII. Fewer support personnel needed for nonsaturation diving.

Saturation diving requires at least 50 percent of the personnel on the surface providing support.

- MK IX - a lightweight umbilically supplied rig.

- MK I diving system is primarily a nonsaturation system. It is operational.

The MK II diving system is presently undergoing test and evaluation and is not yet fully operational. Main components are the Personnel Transfer Capsule (PTC) and the Deck Decompression Chamber (DDC). The PTC acts as an elevator to transport divers between the surface and the ocean bottom. The DDC has total life support capability and is "home" for divers when not working in the water. It will support four men in a saturated mode for an indefinite period of time. There are two units now in the system.

Slides depicting the SEALAB III diving set-up were shown and also a tool test stand developed for SEALAB III to test tools and diver work ability.

Problem Areas

- Communications when the diver is breathing a helium/ oxygen mixture.

- Thermal protection to the diver.

- Equipment design to maximize efficiency of diver in the water.

- Containing helium in high pressure envelopes (up to 1,000 psig) where there are many hull penetrations and hatches.

- Certification of shore-based hyperbaric facilities where diving equipment and systems are tested or developed.

RELIABILITY AND SAFETY OF DEEP OCEAN ENGINEERING SYSTEMS AND RELATED EQUIPMENT

by LCdr. R.D. Smart*

This discussion was related to reliability and safety of vehicles and facilities in the ocean environment. The points to be stressed are why safety and reliability are problems in the ocean environments and the procedures that PM-11 employs in handling the particular problems.

Reliability and safety are not peculiar to the ocean engineering environment. Every piece of equipment and every system employed, in or out of the ocean, is designed, built, and operated with safe and reliable goals in mind. The problem lies in the fact that the engineer's concepts of safety and reliability have been associated with, and directly related to, the safety and reliability required in a dry environment. The concept of designing for the ocean environment poses new problem for designers, builders, and users of vehicles and facilities. Some of the more important factors are high pressure, current, humidity control, low temperatures, construction, and operation problems encountered by divers, inadequate test facilities, unproven methods, unproven techniques, and unproven materials. These uncertainties place stringent demands on reliability and safety.

To obtain reliability, one must think and apply safety and reliability into every step of the project, starting with the concept.

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During the design stage, the best method of control is the failure mode analysis. One must assume that every component of a system can have a failure. He must analyze this failure and any cascading secondary failures. He must determine what effects these will have and design the system accordingly.

When building a system or an equipment, several tests must be made, i.e., the components, the subsystems, and the interfaces. Where possible, a prototype should be built and tested to failure. If making a production run, a sample should be tested to assure good quality control, production control, and material traceability to prove that the sample is a good example of what is being produced. If only a single component is being built, a test must be carefully made to assure that a later test failure will not occur at a much lesser stress level.

Testing is a major problem. There is no facility in the United States, and perhaps no place in the world where a true environment test of manned deep ocean equipment can be given. Pressure tests with air, water, or helium can be given. But, presently, there is no facility where one can test manned equipment under pressure, in a cold environment, in sea water. However, one is now being built at NSRDL/PC. This facility will simulate nearly every condition that will be experienced in the deep ocean. To use the chamber will cost approximately $5,000 per day. Moreover, for those tests requiring a helium environment, these costs will be additional since helium is very expensive. It is becomes necessary to cycle large volumes of compressed helium, the cost becomes uneconomical. Systems for reclaiming helium have been developed, but [illegible] show that the [illegible] helium in the reclaim system is more costly than new helium.

In many cases, testing of materials and components will cost no more than the manufacturer's cost. Every test will require documentation, because without documentation, safety and reliability criteria are worthless. Indeed, documentation is expensive.

The next important step to ensure safety and reliability is the establishment of correct procedures--operation, maintenance, and emergency. Because these procedures have not been proven for new systems, they require verification. Consequently, this effort adds to the cost.

Even the best system in the world will have a zero reliability factor, if it is not properly maintained. Once a facility has been built, the responsibility for it does not end. At present, most facilities have a one-way trip to the bottom. However, as the systems become more complex, maintenance will become mandatory. Systems cannot be simply written off. Maintenance requires people, facilities, tools, and techniques, and as a result--great expense.

The capstone for the whole design, construction, and even to some extent, maintenance process is certification. Certification is sometimes considered a nuisance. However, it is the best checklist available today to ensure that a system is safe and reliable. Certification is the milestone where difficulties are most likely to be encountered. As stated by Captain Nicholson, one of the greatest certification problems is that facilities are designed to become operational several years in the future. During the design phase, certification documents will be written based on that particular design. As work and time progresses from design through construction, certification criteria will have to be changed. The final criteria after construction, at the time of certification will not be the same criteria that applied at the time of design. Nevertheless, revised documents and tests will have to be produced to state with certainty that the facility is adequate at the time of certification.

The road to reliability and safety is a long winding road with many pitfalls. PM-11 has traveled that road many times and is attempting to pass the knowledge acquired on to others so that they will benefit from our experiences.

SEALAB Project

The problems associated with building a habitat (SEALAB) for use in 600 feet of water are the same as on land except for the following criteria:

- Must be designed for 300 psi.
- Must be designed for 100% humidity.
- Must be designed for a salt spray environment.
- Must be able to maintain temperature within $\pm$ 1°F.
- Must be able to maintain breathing gases and to measure them down to fractions of 1%.
- Must be able to measure trace contaminants down to parts per million.
- Must design all the control and measurement systems to operate in a high pressure, helium, salt water, wet environment.

Problem Areas

The problem with helium leakage on SEALAB III was in the hull penetrations. The design of the hull stuffing tubes was based on a long history of use under similar, but not as severe, conditions. When built and tested under laboratory conditions, these stuffing tubes worked well. But afterwards, examination of the stuffing tubes used in the SEALAB habitat indicated that inadequate quality control procedures were used during construction. Fauity construction resulted in assemblies that were able to withstand 15 psi differential pressure tests but could not withstand the absolute pressure of 250 psi and temperature of 45°F that was present at the actual site. Due to the lack of a test facility, preliminary testing of the habitat and installed stuffing tubes were impossible. This points out the need for adequate test facilities to conduct deep ocean equipment tests under closely monitored conditions.

Diving Operations

In the opening remarks, the TEKTITE I operation was mentioned, in which NAVFAC was involved, together with the associated relatively primitive construction. It was then brought out that, in the foreseeable future, there will be requirements for more complex construction and maintenance capability by NAVFAC. The need for underwater vehicles and for underwater construction divers was stressed. There is a "grey area" where the problem is whether or not to use a vehicle with manipulator or a diver.

There is a need for man-on-the-scene in foreseeable operations--someone who can see, feel, and make on-site judgments on how to solve problems.

NAVSHIPS is developing advanced diving systems and bounce diving techniques that will take the diver to an 850-foot depth. PM11 is working on saturated diving systems that will allow divers to work in depths to 1,000 feet for weeks or months. NAVFAC is looking to Supervisor of Diving and PM11 to develop the diving systems to put the man on the bottom. NAVFAC feels they will be a major user of these systems in the future.

CLOSING REMARKS

W.J. Bobisch

CLOSING REMARKS

by W.J. Bobisch*

General

"I want to make a few comments concerning organization. NAVFAC has established a center of Ocean Engineering expertise at CHESDIV to centralize the engineering required for the design and highly technical aspects of construction of manned hyperbaric chambers. They are in the process of hiring personnel for this effort. We don't have a complete modus operandi yet. This is not to say that other people are not doing a great job. They are. John McNeely is doing a tremendous job in SEDIV. So is EASTDIV in New London. But the question is - can we afford the luxury of having expertise in many areas? We don't think we do. This is our thinking at the present time.

Here at NAVFAC HQ, we have a Project Management Office, PC-2 that you have heard mentioned a few times. This office is concerned with program management and are out scrambling for business and bringing it in.

In 04, the Engineering Division, we are developing engineering expertise which will be slanted primarily toward certification. We have our Deep Water Consultant, Dr. Yachnis, who has developed this fine conference.

*Chief Engineer, (Code 04B), Naval Facilities Engineering Command, Washington, D.C. 20390.

Conference, General

This has been an extremely stimulating conference. Everyone has been free with comments. Dr. Yachnis hoped to generate this and I am pleased to see that's the way it went.

There has been an impressive flood of knowledge demonstrated here. It resides in many people who have a desire to share their knowledge with the rest of us.

This conference has purposely outlined problems. It was not devoted to problem solving.

Conference, Highlights

- Stop daydreaming. Daydreams are fast becoming a life of reality--where you have got to do something.

- Think about safety early.

- The reliability of bottom surveys are questionable.

- We talked about available underwater nuclear power. I am pleased also to hear about a closed cycle diesel engine.

- NAVFAC, NCEL have stimulating programs.

- Concrete has a role for habitats on the bottom of the ocean.

- Dynamic forces of structures must be considered.

- Subsurface profiling; ocean survey techniques are advancing.

- We had a rundown on structures of various kinds for Deep Ocean Simulation. Included was someone saying, 'some old submarines have been tested'. Someone else said, 'if you do it my way, you don't need it'. He's right as far as material is concerned, but other items are required: viz., penetrations, etc. Other facets should be given thought to. This requires a total systems approach. It's not only the material. Someone else pointed out--you're certified for material, but quality of operator competence needs to be assured. This ran through the whole conference.

- NAVSHIPS explained how they've certified, and are certifying non-combatant submersibles.

- NAVFAC is developing certification techniques for man rated hyperbaric chambers.

- There are owner operator problems.

- Materials of construction were discussed.

- We received a good appreciation of fracture mechanics from Dr. Puzak's discussion.

- Soil mechanics and foundations need consideration.

- Deep water moorings have advanced but require more development.

- Diver equipment is being developed.

I feel there is a great deal underway in many areas and we can see operations that are going to involve NAVFAC as well as other people. It will mean more EFD's will be involved as time goes on. Cdr. Cope mentioned to me that an EFD in PACDIV was almost called upon to assist Headquarters in a Sea-Spider emplantment. We had a temporary abort there because of the sea state. We came back to Hawaii and needed some work done on some of the material that made up the nuclear power. We could have elected to ask PACDIV for assistance. However, we went to ONR at that particular time, and they did the job. That's why I said before: We in the working level are seeing to it that what needs to be done, is done. I'm very pleased to see the cooperation we have at the working level. That's not to say we don't have it higher up, we do. A lot of things need defining, though.

We had an interest demonstrated here from our head house:

- Admiral Enger
- Admiral Bartlett
- Captain Walton
- Captain Walls - who came in on a number of discussions, particularly the certification aspects.

I would like to congratulate the members of the conference committee for their well-done job. The interest of young people in Ocean Engineering is gratifying. It holds promise to the individual and to the organization they represent. I thank all participants for joining with us in this conference and the graciousness of the men who made presentations, and gave so freely of their knowledge."

APPENDIX A

CONFERENCE COMMITTEE AND AGENDA

OCEAN ENGINEERING CONFERENCE COMMITTEE

Dr. M. Yachnis	NAVFAC 04B4	Chairman
D. Potter	NAVFAC 04126E	Parking and Publications
E. Watkins	NAVFAC 04123F	Hotel Reservations
T. Hayes	NAVFAC 04124	Communications and Transportation
D. Olson	NAVFAC PC-2	Projection Equipment
D. Nelson	NAVFAC PC-2	Coordinator
D. Lussier	NAVFAC 04132A	Luncheon
L. Lussier	NAVFAC 04125	Luncheon

NAVAL FACILITIES ENGINEERING COMMAND

OCEAN ENGINEERING CONFERENCE

1969

AGENDA (Revised 5 September 1969)

Tuesday, 23 September
Morning - Room 2D-31

0815-0900	Registration	Corridor outside Room 2D-31
0900-0915	Announcements and Introductions	Dr. M. Yachnis, Consultant, Deep Water Structures, NAVFAC
0915-0925	Introduction of RAdm. W.M. Enger	Capt. W.A. Walls, CEC, USN Asst. Commander for Engineering & Design, NAVFAC
0925-1000	Welcome	RAdm. W.M. Enger, CEC, USN, Commander, NAVFAC
1000-1015	"Ocean Engineering Policies"	Capt. W.A. Walls
1015-1030	Coffee Break	
1030-1045	Conference Objectives	Dr. M. Yachnis
1045-1115	"A Forecast of Ocean Engineering Trends"	Capt. J.F. Dobson, CEC, USN, Assistant Commander for Research & Development, NAVFAC
1115-1145	Group Photo - Front Entrance of Building	
1145-1345	Conference Luncheon - Evans Farm Inn	

<u>Afternoon</u> - Room 2D-31

<u>Moderator:</u> Capt. W.M. Nicholson, DSSP (PM11-00)

		PANEL
	Group Discussion on "Deep Ocean Engineering Programs"	
1345-1430	U.S. Navy's Deep Ocean Engineering Program	Capt. J.W. Boller, NAVMAT LCdr. N.T. Monney, NAVMAT
1430-1500	NAVFAC Role in Ocean Engineering	Cdr. W.J. Eager, CEC, USN NAVFAC; C.R. Odden, NAVFAC
1500-1515	NAVFAC Role in Under-Sea Nuclear Power	Cdr. R.P. Cope, CEC, USN NAVFAC; T.P. Fleming, NAVFAC
1515-1530	Seabees Role in Ocean Engineering	W.D. Bass, NAVFAC
1530-1545	NAVFAC R&D Programs	P. Cave, NAVFAC
1545-1600	NCEL R&D Programs	R.A. Breckenridge, NCEL

Topics Suggested By: NAVMAT, Eastern Div - NAVFAC
Southwest Div - NAVFAC
Northeast Div - NAVFAC

Wednesday, 24 September
<u>Morning</u> - Room 2D-31

Group Discussion on "Design Criteria - Structures"

<u>Moderator:</u> Dr. M. Yachnis

0815-0900 Design Parameters

a. Waves
b. Tides
c. Currents
d. Pressure
e. Temperature
f. Seismic Loading

PANEL

C.J. Kray, NAVFAC
W.J. Tudor, NAVFAC

0900-0945	Design of Structures a. SEALAB b. TEKTITE c. Concrete Structures d. Penetrations	 Dr. J.D. Stachiw, NCEL D. Potter, NAVFAC
0945-1000	Coffee Break	
1000-1100	e. Power Supply, Distribution and Underwater Lighting f. Undersea Nuclear Power	T.H. Hayes, NAVFAC Cdr. R.P. Cope, NAVFAC J. Angelo, NAVFAC
1100-1200	Reliability and Safety of Deep Ocean Engineering Systems and Related Equipment	LCdr. R.D. Smart, DSSP W.E. Watkins, NAVFAC
1200-1300	Lunch	

Afternoon - Room 2D-31

Group Discussion of "Construction of Ocean Engineering Systems"

Moderator: D.C. Pauli, ONR — PANEL

1300-1400	Site Selection a. Subsurface Profiling Instruments b. Ocean Survey Techniques c. Site Selection and Development	 Newell T. Stiles
1400-1600	Construction Operations a. Installation of Habitats b. Ocean Manipulative Operations c. Diver Construction	PANEL J.J. Hromadik, NCEL Cdr. W.J. Eager

Topics Suggested by: Chief of Naval Research
Chesapeake Division - NAVFAC
Code 06 - NAVFAC
NCEL

Thursday, 25 September
Morning - Room 2D-31

Group Discussion on "Deep Ocean Simulation Facilities"

Moderator: W.J. Bobisch, NAVFAC

		PANEL
0845-0945	Design of Deep Ocean Simulation Facilities	K.H. Keller, NSRDL/A Dr. J.D. Stachiw, NCEL G. Anadale, CHESDIV-NAVFAC
0945-1000	Coffee Break	
1000-1030	Specifications for Chambers Life Support Systems, Materials and Workmanship	Dr. M. Yachnis J. McNeely, SOEASTDIV-NAVFAC D.J. Lussier, NAVFAC
1030-1115	Certification Procedures and Requirements	J.H. Purcell, NSHP - PMS-381 C.W. Stephens, NSHP - PMS-381
1115-1200	Present and Future Requirements for Submersible Support and Construction Materials	R.E. Miner, SOWESTDIV - NAVFAC
1200-1300	Lunch	

Topics Suggested by: Southwest Division - NAVFAC
Southeast Division - NAVFAC
Chesapeake Division - NAVFAC
NCEL

Afternoon - Room 2D-31

Materials of Construction

Moderator: E.A. Lange, NRL

		PANEL
1300-1400	a. Metallic and Non-Metallic Materials	I. Bloom, NAVFAC
	b. Development of High Strength Materials	Dr. P.P. Puzak, NRL

	c. Fouling, Corrosion, and their Prevention	Dr. B.F. Brown, NRL
	<u>Moderator:</u> P. Brown, NAVFAC	
1400-1500	Soils, Foundations, Anchoring, and Mooring	H.L. Gill, NCEL D. Potter, NAVFAC
	<u>Moderator:</u> LCdr. R.D. Smart	
1500-1530	Diving and Diving Equipment	Cdr. W.I. Milwee, SUPDIV (00CD) LCdr. J. Osborn, CEC, USN, DSSP LCdr. R.D. Smart
	Topics Suggested by:	Northeast Division - NAVFAC Chesapeake Division - NAVFAC Pacific Division - NAVFAC Northwest Division - NAVFAC Code 06 - NAVFAC Code 03 - NAVFAC NCEL
530-1600	Closing Remarks: W.J. Bobisch	

APPENDIX B

LIST OF PARTICIPANTS

NAVAL FACILITIES ENGINEERING COMMAND
OCEAN ENGINEERING CONFERENCE - 1969

REGISTERED ATTENDEES

Name	Activity	Code	Address	Tel. No.
W.E. Harrison	Armco	---	Washington, D.C.	113-3533
J.H. Pitcher	Armco Steel	---	Middletown, Ohio	425-2942
B. Wooden	Booz, Allen Applied Res.	---	Bethesda, Md.	656-2200
A.J. Coyle	Battelle Memorial Inst.	---	Columbus, Ohio	299-3151
Erasmo A. Martinez-Bracero	Carib Div.	045	Puerto Rico	722-0080
B. Ciurlionis	CBC SSEO	15332	Port Hueneme	982-5490
LCdr. T.C. Tucker	CECOS	099	Port Hueneme	
G. Anadale	Ches Div	048	Washington, D.C.	OX3-3317
K. Hankerson, Jr.	Ches Div	03	Washington, D.C.	113-3533
A.L. Sutherland	Ches Div	048	Washington, D.C.	OX3-3317
LCDR J.H. Osborn	DSSP	301	San Diego	225-3515
LCDR R.D. Smart	DSSP	PM11-211	Washington, D.C.	295-1594
A. Cianfrani	East Cen Div	042	Philadelphia	755-3960
Ltjg R.H. Parrish	East Div	09B1	New York	264-7326
D. Milano	East Div	045	New York	264-7330
D. Carreau	Gen Dynamics		Groton, Conn.	446-6056
E.C. Trageser	Gen Dynamics		Rochester, N.Y.	342-000
V.B. Tenney	Gen Electric		Philadelphia	962-2709
E.P. Rausa	HNTB		Washington, D.C.	548-6126
T.P. McAndrews	Lant Div	048	Norfolk, Va.	444-7631

T. Steidel	Midwest Div 04		Great Lakes	688-6800
R.C. Lewis	NADC	AEST	Johnsville	441-2422
Ens. J.G. Shannon	NADC	---	Johnsville	
H. Spivack	NADC	AEST	Johnsville	441-2422
W.D. Bass	NAVFAC	0621A	Washington, D.C.	OX5-6432
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W.J. Bobisch	NAVFAC	04B	Washington, D.C.	OX5-2019
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P.P. Brown	NAVFAC	04B2	Washington, D.C.	OX7-5983
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Cdr. B. Carioti	NAVFAC	041	Washington, D.C.	OX5-2019
Pat Cave	NAVFAC	0321C	Washington, D.C.	OX7-1298
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EOC T.J. DePaolis	NAVFAC	06121D	Washington, D.C.	OX5-3296
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L. Lussier	NAVFAC	04125	Washington, D.C.	OX7-7239
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C.R. Odden	NAVFAC	PC-2	Washington, D.C.	OX7-7782
D.L. Olson	NAVFAC	PC-2	Washington, D.C.	OX7-7388
D. Potter	NAVFAC	04126E	Washington, D.C.	OX7-7890
S.W. Shepherd	NAVFAC	0653	Washington, D.C.	OX5-2370
F.L. Slagle	NAVFAC	04121	Washington, D.C.	OX5-5939
B. Storer	NAVFAC	L03B	NCEL	982-4649
G. Travaglino	NAVFAC	042	Washington, D.C.	664-6316

Capt. W.A. Walls	NAVFAC	04	Washington, D.C.	OX7-7274
C. Williams	NAVFAC	0421	Washington, D.C.	OX5-5089
Dr. M. Yachnis	NAVFAC	04B4	Washington, D.C.	OX5-5895
Capt J.W. Boller	NAVMAT	MAT 327	Washington, D.C.	OX7-1300
N.T. Monney	NAVMAT	MAT 327	Washington, D.C.	OX7-1300
H.C. Beck	NAVOCEANO	02E	Suitland, Md.	763-1554
N. Stiles	NAVOCEANO	7250	Washington, D.C.	767-2842
R.A. Breckenridge	NCEL	L40P	Port Hueneme	982-5054
H.L. Gill	NCEL	L42	Port Hueneme	982-5376
M.C. Hironaka	NCEL	L41	Port Hueneme	982-5054
J.J. Hromadik	NCEL	L43	Port Hueneme	982-5423
J.D. Stachiw	NCEL	L44	Port Hueneme	982-5792
G.M. Gans, Jr.	NNPU	01C	Fort Belvoir	192-6316
L.N. Rosenberg	NOL	652	San Diego	583-6571
W.R. Sowell	North Am. Rockwell	---	Long Beach	590-1411
F. Vail	North W Div	043	Seattle	AT3-5200
Dr. B.F. Brown	NRL	---	Washington, D.C.	
E.A. Lange	NRL	6318	Washington, D.C.	767-2947
P.P. Puzak	NRL	6381	Washington, D.C.	767-3571
M. Shimkus	NRL	2312	Washington, D.C.	767-2215
R.B. Allnutt	NSRDC	706	Carderock	158X706
K. Hishida	NSRDC	706	Carderock	158X706
H.E. Prucha	NSRDC	780	Carderock	158X706
K.H. Keller	NSRDL/A	A-108	Annapolis	268-7711
E.M. Petrisko	NSRDL/A	A-108	Annapolis	268-7711
W.T. Jenkins	NSRDL/PC	710	Panama City	234-2281
N.F. Schuh	NSRDL/PC	753	Panama City	234-2281
R.R. Mossbacher	NSRDL/PC	71050	Panama City	431-3820

H.E. Wheeler	NURDC	65201	San Diego, Calif.	222-6311
W.C. McKay	Ocean Sc. & Engr.	---	Washington, D.C.	657-4222
Paul Proctor	Ocean Sys.	---	Reston, Va.	471-1310
Lt.j.g. H.A. Cole	ONR	485	Washington, D.C.	767-2848
D.C. Pauli	ONR	485	Washington, D.C.	197-2848
LCdr. W.H. Kay	PAC DIV	09A1	Pearl Harbor	3-4100
H.W. Boehly	RSC Ind.	---	Washington, D.C.	659-1867
H. Perfetto	RSC Ind.	---	Washington, D.C	659-1867
S.E. Terrill, Jr.	RSC Ind.	---	Washington, D.C.	659-1867
E.J. Wheeler, Jr.	RSC Ind.	---	Washington, D.C.	659-1867
H.A. Maier	Sanders & Thomas	---	Pottstown, Pa.	326-4600
J.G. Ritchie	Sanders & Thomas	---	Washington, D.C.	293-1373
J.W. McNeely	SE DIV	042	Charleston, S.C.	743-2676
R. Miner	SW DIV	043	San Diego, Calif.	235-3793
Ed Briggs	Southwest Res. Inst.	---	San Antonio, Tex.	044-2000
D.H. Rowland	U.S. Coast Guard	M-2/ USP	Washington, D.C.	964-5760
H.T. Suzuki	U.S. Coast Guard	M-2/ USP	Washington, D.C.	964-5760
Dr. F.E. Camfield	Univ. of Delaware	---	Newark	738-2449
Dr.E. Chesson, Jr.	Univ. of Delaware	---	Newark	738-2449
T.G. Lantzas	Westing-house	---	Washington, D.C.	628-8843

APPENDIX C

DECADE OF NAVFAC'S PROGRESS

Dr. M. Yachnis

A DECADE

OF

NAVAL FACILITIES ENGINEERING COMMAND

PROGRESS

IN

OCEAN ENGINEERING

1959 - 1969

by

M. Yachnis D. Sc.

Naval Facilities Engineering Command

PREFACE

During his welcome address to the participants of the "First Naval Facilities Engineering Command Ocean Engineering Conference" RADM W. M. Enger, Commander, NAVFAC, pointed out that he considers the ocean environment to be one of the great engineering challenges of the future, particularly so for NAVFAC which has had an association with structures near or in the water for nearly its entire history.

During the same conference CAPT W. A. Walls, Assistant Commander for Engineering and Design, NAVFAC, emphasized the importance of the policy of continuing education and the advancement of engineering knowledge which are unique characteristics in the new area of ocean engineering. He acknowledged the tremendous challenges and problems in ocean engineering and pointed out our efforts in material certification of shore based manned hyperbaric and deep ocean simulation pressure chamber complexes.

The purpose of this paper is to document the progress made by the NAVFAC family in the area of ocean engineering during the decade of 1959-1969. The projects listed are characteristic samples of essential projects executed during the above period.

I. HISTORICAL BACKGROUND

A. Justification of NAVFAC's Involvement in Ocean Engineering

In recent years emphasis was placed on ocean engineering because of new developments in naval warfare. For more than a hundred years, NAVFAC has been responsible for planning, designing, constructing, and maintaining the U. S. Navy's shore facilities. Through these years, NAVFAC has been recognized Navy-wide by its successful performance in war and peace, as the sole technical leader in the above areas. Consequently, NAVFAC has accumulated a tremendous amount of technical information and experience related to structures near and in the water, namely, piers, wharves, drydocks, cargo handling facilities. This information and experience have been incorporated in NAVFAC's Design Manuals, Definitives and Standard Drawings which are nationally recognized by both government and private industry. In the international level, very often foreign countries request and receive from NAVFAC design and construction assistance for structures in the water. It was, therefore, logical to extend NAVFAC's responsibilities to fixed hydrospace systems and deep ocean simulation facilities.

B. NAVFAC Initiates a Deep Ocean Engineering Program

In 1959, NAVFAC initiated an extensive deep ocean engineering research and development program to be executed by the Naval Civil Engineering Laboratory at Port Hueneme, California, which included site selection and survey, bottom soil properties and foundations, design and construction methods, construction materials and equipment, anchors and moorings, power sources, and support systems. This program was primarily oriented towards constructing methods and systems in the deep ocean. Its final objective was to utilize the experience gained during the construction phase of the program in the development of an in-house design capability for various hydrospace systems.

Since 1959, CEC officers and civilian scientists and engineers, in NAVFAC and NCEL, have been deeply involved in the solution of ocean engineering problems in shallow and in deep water.

II. RESPONSIBILITIES

A. NAVMAT Assigns Ocean Engineering Responsibilities to NAVFAC:

By Organizational Manual - NAVMAT Notice 5460 of 3 May 1966 - NAVFAC was assigned the responsibility for fixed surface and sub-surface ocean structures. The new dimension of "Deep Ocean Civil Engineering Systems" was added to NAVFAC's mission. By OPNAVNOTE 5450 of 21 November 1967, CNO informed naval command elements of the responsibilities and capabilities of the Naval Construction Forces in support of Navy's deep ocean engineering program. It further advised of the responsibilities of COMNAVFACENGCOM to plan for and develop the resource capabilities and material support of fixed surface and sub-surface ocean structures for the Operating Forces of the Navy and Marine Corps and associated activities.

B. NAVFAC Role in the Deep Ocean Technology (DOT) Project:

NAVFAC has been assigned a significant role in the Deep Ocean Technology (DOT) Project, Technical Development Plan 46-36X. The principal objective of DOT is to develop a broad technological base through DOT focal projects - a manned seafloor installation and a deep submersible vehicle - which are designed as test beds for guiding development. Under

Technical Development Y41-02, NAVFAC has been assigned total Navy responsibility for the development of nuclear power systems in the range of 2-10KW(e) and 100-KE(e) for ocean engineering applications.

III. ACCOMPLISHMENTS

A. Projects Executed by NAVFAC

1. Generation of an "ASCE Technical Council on Ocean Engineering

In September 1966, NAVFAC initiated a petition to ASCE to form a Council of Ocean Civil Engineering. Considerable reluctance existed on the part of ASCE initially to sponsor the council. Early in 1967 a "Technical Council on Ocean Engineering" was organized. This council and its five committees include the best talent on Ocean Engineering in the country today. The interest of the Civil Engineer in this new and challenging area was such that the first ASCE conference on "Civil Engineering in the Oceans" held in San Francisco, in September 6-8, 1967, was planned for 150 attendees, but over 300 attended.

2. Project Tekite I.

A multi-agency project for four scientists to occupy a research station for 60 days at a depth of approximately 50 feet in Greater Lameshur Bay, offshore of St. John's Island, Virgin Islands. General Electric Co., Missile and Space Division, Valley Forge, Pa., built the undersea research Station which consists of two vertical structures [illegible] feet in diameter by 18 feet high connected by a four foot diameter [illegible]. The station is connected to shore with lines for power, air, [illegible] Navy, NASA, and Interior Department sponsored the [illegible] and NAVFAC engineers demonstrated their capability to design ocean engineering systems and perform underwater construction. In addition, NAVFAC assisted Project Management Ships (PMS 381) in the safety review of this project (see Fig. 1).

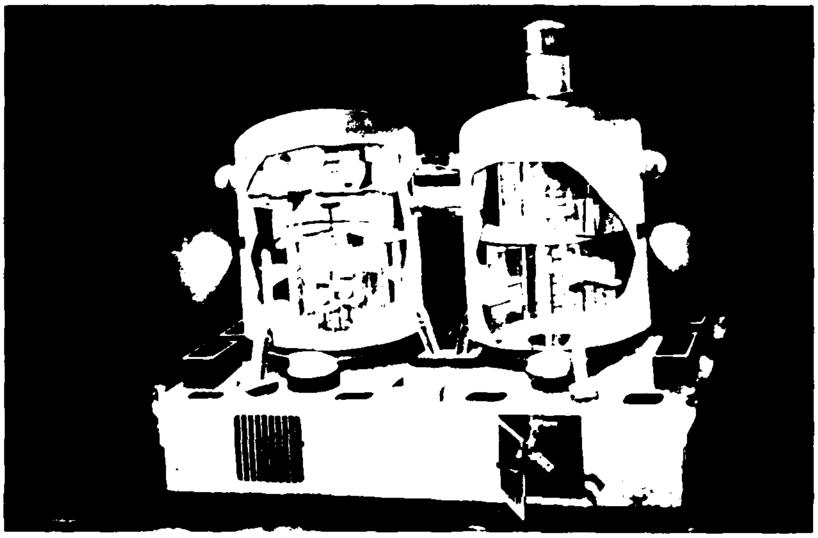

Fig. 1. Tektite Habitat

3. Project on Interfacial Waves

The existence of interfacial waves in the oceans is a fact rather than an exception; however, very little is known about their theoretical aspects, their generation, and their interaction with currents, other interfacial waves, surface waves, waves generated by earthquake disturbances on the ocean bottom, and other associated ocean disturbances.

For this reason NAVFAC initiated a study of interfacial waves in order to obtain a better understanding of the phenomenon and generate sound criteria for the design of ocean engineering systems (see Fig. 2).

4. Deep Ocean Simulation Facilities

NAVFAC in coordination with its Engineering Field Divisions - Chesapeake Division, Southeast Division, and Eastern Division - have been involved in engineering investigation, consultation, testing, and design of pressure vessels; namely:

a. Deep Ocean Simulation Facility, P-280, NCEL

b. Pressure Vessel Complexes, U. S. Naval School, Deep Sea Divers and Salvage, Washington, D. C.

c. Pressure Vessel Complexes, Experimental Diving Units, Washington, D. C.

d. Deep Submergence Test Vessels, Naval Ship Research and Development Laboratory - NSRDL - Annapolis, Maryland

e. Deep Ocean Engineering Pressure Building, Chambers, NSRDL - Panama City, Florida

f. 1,000 p.s.i. pressure chambers, U. S. Naval Submarine Base, New London, Connecticut

g. Britisn Escape Training Facility, Building 70, U. S. Naval Submarine Base, New London, Connecticut

h. Pressure Vessel Complex, U. S. Navy Oceanographic Office, Washington, D. C.

i. Hyperbaric Chambers, Naval National Medical Center, Bethesda, Maryland.

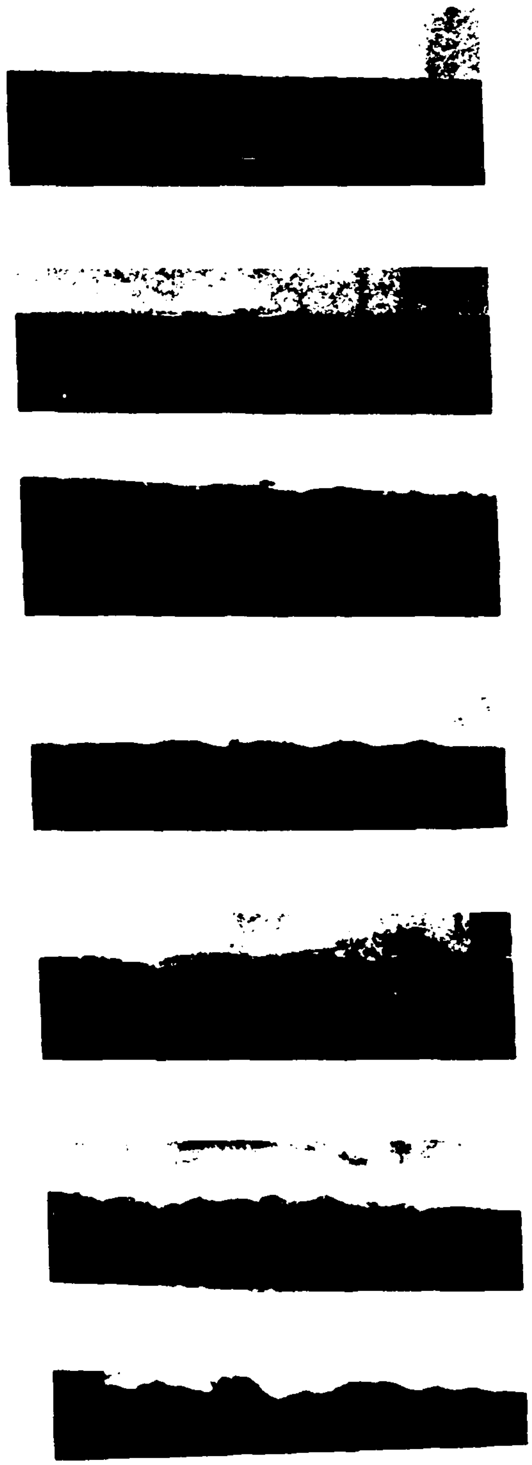

Fig. 2. Generation of Interfacial Waves

Some of the main parameters of the pressure facilities are shown on Table 1.

5. In March, 1969, the Chief of Naval Material assigned NAVFAC the responsibility for material certification of shore based manned hyperbaric and deep ocean simulation pressure chamber complexes. This included all decompression/recompression chambers diving pressure tanks and any pressure vessels used for testing equipment which are part of a shore facility. The certification process of the pressure chambers at Panama City, Florida, (Fig. 3a and 3b) and the U. S. Naval Submarine Base, New London, Connecticut (Fig. 4) is in progress.

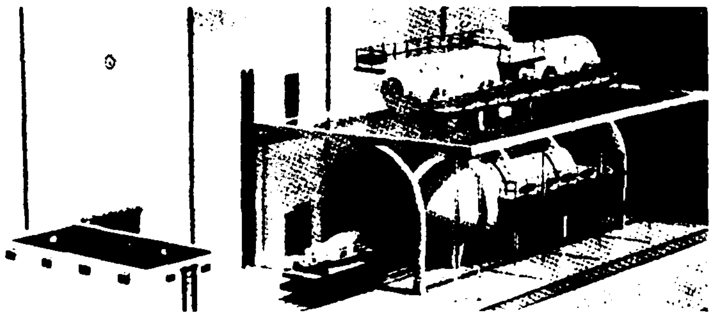

Fig. 3a. Pressure Chambers, Panama City, Florida

TABLE I

OCEAN SIMULATION FACILITIES

Facility	Configuration	Inside Dia. (ft)	Max. Inside Length (ft)	Max. Sta. Pressure (Int) p.s.i.	Cyclic Capability (Cycles)	Fluid	Remarks
[illegible]	Cylindrical "	10.0 4.00	25.00 25.00	13,200 13,200		S.W., Air	
Deep Sea Divers Wash., D.C.	Cylindrical " "	9.63 9.63 6.29	11.79 10.75 14.15	150 150 150	---- ---- ----	F.W., Air F.W., Air F.W., Air	Two Complexes Wet Chamber, Vert, Fixed Igloo Dec. Chamber Hor., Fixed
CDC, Wash., D.C.			SAME AS DEEP SEA DIVERS				
NSRDL - Annapolis, Md.	Cylindrical	10.00	27.00	12,000	$2x10^6$ at 4,000 p.s.i.	S.W., Air	
NSRDL - Panama City, Florida	Cylindrical "	15.00 8.00	45.00 63.00	1,000 1,000	2,500 at 1,000 p.s.i.	S.W., Air	Medical locks 100,000 cycles at 1,000 p.s.i. (See Figs. 3a & 3b)
U.S.N.S.B. New London	Cylindrical " "	8.50 7.00 7.00	17.04 15.00 9.00	1,000 1,000 1,000	10,000 10,000 10,000	S.W., Air S.W., Air S.W., Air	Diving Chamber, Vert, Fixed Research Chamber, Hor. Fixed Outer Chamber, Hor., Fixed (See Fig. 4)
British Escape, New London	Cylindrical	5.33	6.16	66 (External)	12,500	S.W.	
U.S. Navy Ocean. Office	Cylindrical	2.00	12.00	20,000	unknown	S.W., Air	
NMRI, Bethesda	Cylindrical	6.50	20.00	445	----	S.W., F.W. Gases	
University of Pennsylvania	Cylindrical " " " " "	10.0 10.0 8.0 6.0 6.0 8.0	8.00 16.00 11.00 8.00 4.00 12.00	75 75 800 800 800 800	----		Max. altitude 150,000 ft. All other chambers hor. except: Wet Chamber Vert. (See Fig. 5)
State University of N.Y. at Buffalo	Cylindrical Spherical	7.0 7.0	15.00 ---	2,550 2,550	-----	S.W., F.W. Gases	Sphere affixed to acylindrical wet pot (See Fig. 6)

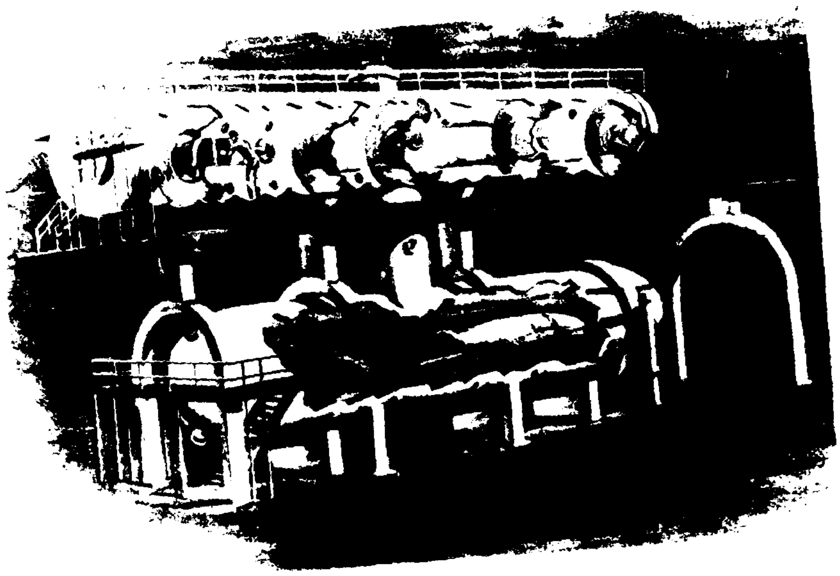

Fig. 3b. Interior of Pressure Chambers, Panama City, Florida

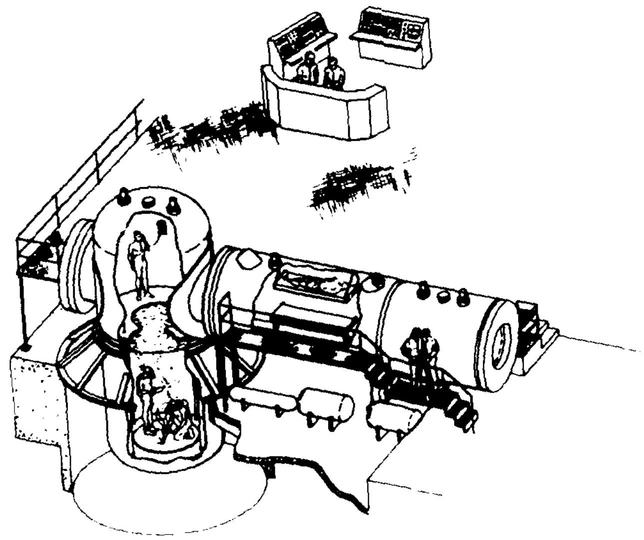

Fig. 4. Pressure Chambers, New London, Connecticut

The Project Manager, Deep Submergence Systems Project (PM 11) requested that NAVFAC determine the material safety of the University of Pennsylvania Hypo-Hyperbaric Facility (see Fig. 5). Similar requests are underway with regard to certification of the hyperbaric facilities at State University of New York at Buffalo (see Fig. 6), Duke University, the escape tunnel at the Experimental Diving Unit, in the Washington Navy Yard, and the Divers Decompression Chamber at the Naval Underwater Warfare Center, San Diego, California. The Naval Air Development Center, Johnsville, Pennsylvania requested that NAVFAC proceed with certification of a fiber glass Underwater Observation Tower (see Fig. 7).

Requests for certification of existing and new pressure chamber complexes are expected to be numerous.

6. Pressure Chamber Design Manual

The Engineering and Design group of NAVFAC initiated action with its ultimate goal to generate a "Pressure Chamber Design Manual" which will include selected parts of the ASME Boiler and Pressure Vessel Code plus new design considerations applicable to the size of vessels being constructed or planned to be constructed in the future.

7. Material Certification of Hyperbaric Facilities Manual

NAVFAC has entered into a contract with Battelle Memorial Institute for the purpose of expanding the coverage of the Diver Decompression Chamber (DDC) Material Certification Manual [1], being prepared for Experimental Diving Unit (EDU), to include certification requirements for the "wet pot" portions of a pressure chamber complex. In

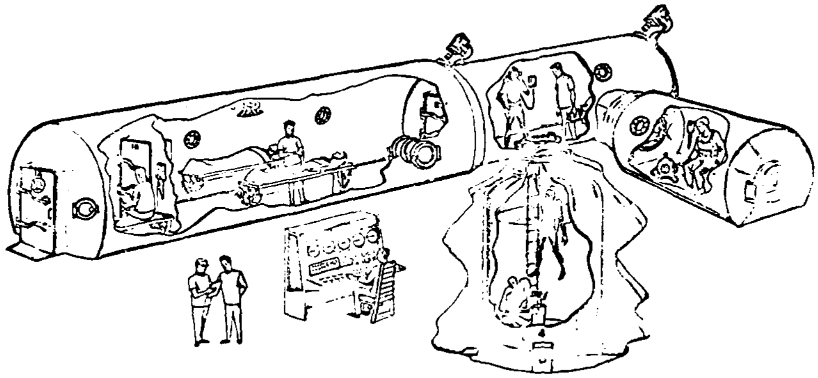

Fig. 5. University of Pennsylvania Hyperbaric Chamber Complex

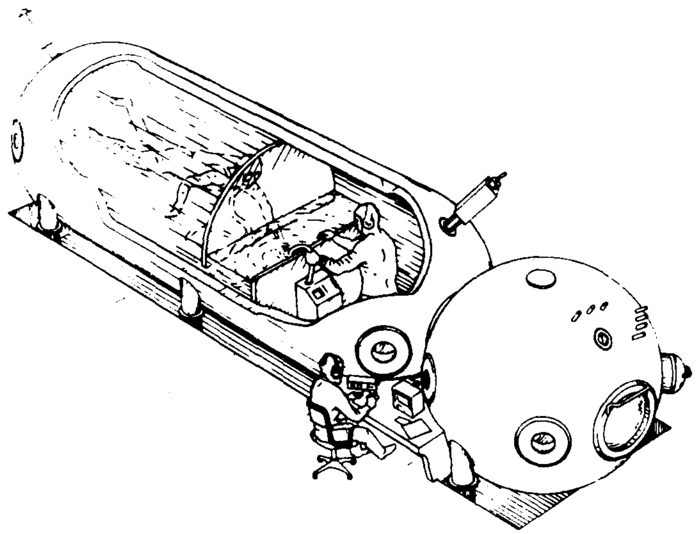

Fig. 6. State University of New York at Buffalo Pressure Chamber Complex

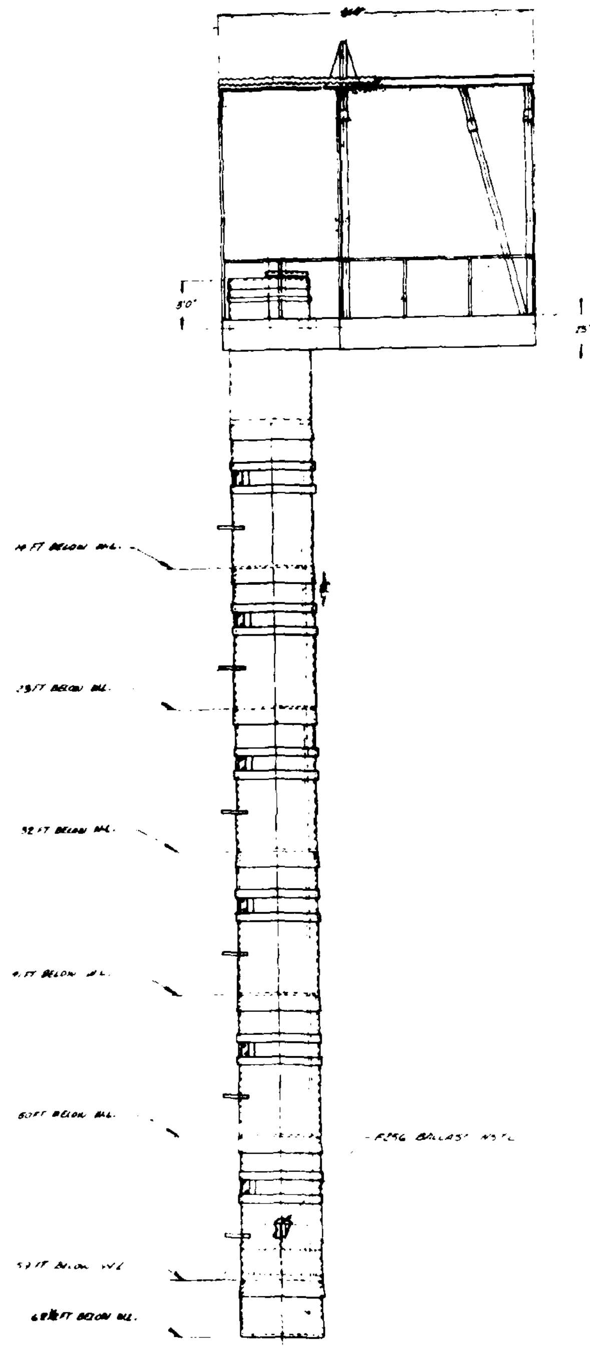

Fig. 7. Glass Underwater Observation Tower

addition, action has been initiated so that a common certification manual be generated which can be used by NAVSHIPS PMS-381, EDU, SUPDIV, and NAVFAC.

8. Engineering and Design Consultation for Ocean Engineering Systems

a. Underwater observation tower and float assembly at the Naval Air Development Center, Johnsville, Pennsylvania. This unique structure is cylindrical in configuration and has an inside diameter of 60 inches and a length of 63 feet.

b. Off-Shore Platform for the U. S. Coast Guard.

c. British Escape Training Facility, Naval Submarine Base, New London, Connecticut.

9. Implementation of Study Topic 68-I, NAVFAC/Naval Construction Forces Role in Ocean Engineering [2].

a. Establishment of an Ocean Engineering Program Office (PC-2). Its mission is to organize, manage and coordinate, both internally and with other Navy Commands, Bureau and Offices all aspects of NAVFAC's Ocean Engineering Program responsibilities.

b. Establishment at Chesapeake Division a field center of ocean engineering expertise.

c. Establishment of a three week Ocean Engineering course at CECOS.

d. Formation of an underwater construction team.

e. Development of selected advanced ocean engineering concepts to be presented to OPNAV.

f. Establishment in Code 04 of a Management Structure for the Deep Ocean Technology Program and an Ad Hoc Interim Ocean Engineering Task Force.

10. Under-Sea Nuclear Power Generation

Numerous Radioisotope Thermoelectric Generators, recommended by NAVFAC's Nuclear Division, have been successfully used in Navy projects. The safety analysis of these RTG's is reviewed by NAVFAC's Radiological Safety Committee.

B. Projects Sponsored by NAVFAC and Executed by NCEL [3].

1. Diver Construction

(a) Diver's Tools including power systems

(b) Diver-Constructor (DIVERCON 1): A diver-constructed underwater repair and storage facility with self-supported weight-handling system. Successful tests in shallow water were conducted in 1968.

(c) Development of a construction assistance vehicle

(d) Engineering Manual for Underwater Construction

2. Sea-Floor Soils

(a) Plate bearing device to 6,000 feet to test ocean floor sediments

(b) Deep Ocean Test Instrumentation Placement and Observation System (DOTIPOS)

(c) Research on bottom stabilization overlay

(d) Development of a corer utilizing a bottom - sitting platform that will take samples from sediments strata 50 feet thick in water depths to 6,000 feet.

(e) Bottom Breakout Forces

(f) Soil Testing in Pressure Vessels

(g) In-situ vane shear and cone penetrometer

3. Undersea Site and Material Studies

(a) Sea - Floor Construction Experiment (SEACON) which involves sea-floor engineering and construction techniques.

(b) Six submersible Test Units (STU) have been emplaced on the sea-bottom and recovered successfully as part of the material evaluation program.

(c) Undersea Coatings

(d) Seals and Gaskets

(e) Concrete studies

(f) Fouling investigations

4. Undersea Equipment and Systems

(a) Earthmoving and drilling on the ocean floor

(b) Load handling

(c) Anchors and moorings

(d) Power transmission

(e) Radioisotope Power Sources

5. Ocean Structures

(a) Development of Manned Underwater Station for depths down to 6,000 feet. Study by Westinghouse, General Dynamics, and South West Research Co.

(b) Navy Experimental Manned Observatory (NEMO). This is a 66 inch diameter spherical acrylic hull with a rated operational depth of 600 feet.

6. Ocean Simulation Laboratory Studies

(a) Viewing Ports

(b) Underwater Lights

(c) Acrylic Plastic Hulls

7. Reports

Numerous Technical Reports, Technical Notes, and Miscellaneous Publications.

CONCLUSION

NAVFAC's basic philosophy is that true progress is only made by constantly seeking to improve.

NAVFAC's family has the composite knowledge of many years of ocean engineering experience which if properly utilized can improve the nation's Technical competence - through:

1. Improving the way that knowledge is disseminated to government agencies, industry, and academic institutions.

2. Improving the planning, design, construction, operation and certification of ocean engineering systems and deep ocean simulation facilities.

3. Making a systems analysis of existing problems and collecting all technical information required for the solution of these problems.

REFERENCES

[1] Battelle Memorial Institute, Columbus Laboratories, 505 King Avenue, Columbus, Ohio, General Requirements for Material Certification of Hyperbaric Facilities (Preliminary Edition), January, 1970

[2] Department of the Navy, Naval Facilities Engineering Command, Washington, D.C., Summary of the Report on Study Topic 68-1; Plan for Definition of NAVFAC/NCF Role in Ocean Engineering, September, 1968

[3] NCEL, Ocean Engineering Program, March 1966 - March 1967, March 1967 - March 1968 and March 1968 - March 1969