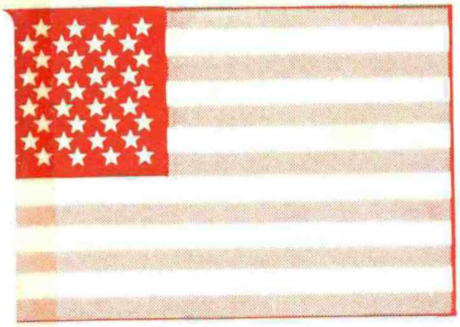

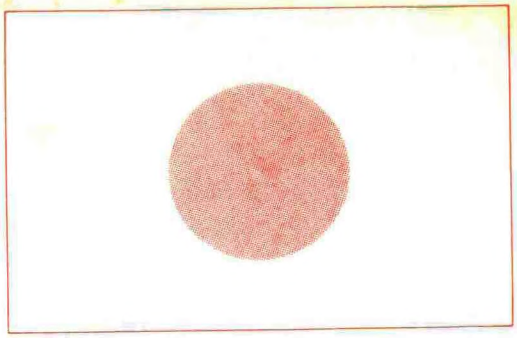

U.S.A.

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UJNR

U.S./Japan Cooperative Program in Natural Resources

日米天然資源協力プログラム

12TH MEETING U.S.-JAPAN MARINE FACILITIES PANEL

SEPTEMBER 1983

CONFERENCE RECORD

Twelveth Meeting of the

United States - Japan Cooperative Program in Natural Resources (UJNR) Panel on Marine Facilities

September 1983

March 1984

PREFACE

This document contains technical papers and special reports presented at the Twelveth Meeting of the Marine Facilities Panel of the United States-Japan Cooperative Program in Natural Resources (UJNR), held August 26-27, 1983 in San Francisco, California. Following the meeting, the Panel participated in a study tour of marine facilities from September 1-13, 1983. A final meeting was held September 9, 1983. A schedule of the entire program and a summary report of the meeting and study are provided herein.

The purpose of this document is to provide a permanent record, and to enable a wider dissemination of the technical information presented and exchanged at the meeting.

The United States-Japan Cooperative Program in Natural Resources was established in 1964 to facilitate cooperative efforts and technology exchange in the field of natural resources that would provide a better environment for present and future generations. Seven of the 17 UJNR panels deal with marine science and technology and are a part of the Marine Resources and Engineering Coordination Committee (MRECC) of UJNR.

Participating governmental agencies in Japan are: the Science and Technology Agency, Ministry of Foreign Affairs, Environmental Agency, Ministry of Agriculture, Forestry, and Fisheries, Ministry of International Trade and Industry, Ministry of Transport, Ministry of Construction, and Japan Marine Science and Technology Center.

Participation of governmental agencies in the United States include: the Department of Agriculture, Department of Commerce, Department of Energy, Department of Interior, Department of Transportation, Department of State, Department of Defense, and Environmental Protection Agency. The Marine Facilities Panel meeting enabled a valuable exchange of technical information between key representatives of the ocean community from Japan and the United States.

Special recognition is given to Dr. Morton Smutz who served as Editor of this document.

Mr. Vadus and
Dr. Nagasawa

OPENING REMARKS

Hitoshi Nagasawa
Chairman, Japan Panel

It is a great pleasure for me to give an opening address on the occasion of the 12th US-Japan Joint Meeting of Marine Facilities Panel on behalf of the Japanese Panel members and advisers.

I would like to express our appreciation to Chairman Mr. Vadus and all the other US Panel members for the effort and cooperation extended to us in planning and organizing an excellent technical program and study tour of marine facilities.

It is an honor and privilege to serve as Chairman of the Japan Panel and to coordinate activities with Chairman Mr. Vadus and his distinguished Panel. I shall do my best to meet the objectives of our cooperative program of the development and utilization of marine resources and ocean space, and build on the accomplishments of the past chairmen and members. I appreciate the cooperation and valuable technical contributions given by the members and advisers of Japanese panel. I would especially like to acknowledge the accomplishment made by our former Chairman, Mr. Muneharu Saeki.

At the 11th meeting in Tokyo in May 1982, there were 13 members and advisers from the US and 34 from Japan and a total of 57 papers and reports were exchanged and reported in conference proceedings in the Japanese and English languages. At this time, 16 participants from Japan are going to present 22 papers and reports on advanced marine facilities, ship technologies, undersea systems, and port and harbor facilities. I hope this meeting will provide a timely forum for the exchange of information useful for the experts engaged in the field of marine technology.

Through these meetings, I am quite confident that, in addition to the exchange of valuable technical papers or reports, our Panel has played an important role in the development of technology in marine facilities by fostering the close personal relationships among the members and advisers of both panels. I sincerely hope that both panels will find this 12th meeting and study tour mutually rewarding and successful.

Joseph R. Vadus
Chairman, United States Panel

Distinguished members and advisers of the UJNR Marine Facilities Panel and guests. On behalf of the U.S. Panel it is my pleasure to extend our warmest welcome and best wishes to Dr. Hitoshi Nagasawa, Chairman of the Japan Panel and to each of the members and advisers of the Japan Panel. It is good to be together again with so many friends, and to establish new friendships with those of you participating in a Marine Facilities Panel meeting for the first time.

UJNR was established by our two governments 19 years ago to facilitate cooperative efforts and exchange of technology in the field of natural resources. Our Marine Facilities Panel, one of seven dealing with marine science and technology, is now meeting for the 12th time. We are confident that this meeting and study tour will be one of the most productive in the series.

During the past year, we have broadened the membership of the U.S. Panel to include additional representatives from the U.S. Government and from the private sector. We are very pleased to include you in our UJNR association and we welcome you to this meeting.

Those of us who have had the opportunity to participate in one or more previous meetings of the two panels remember the accomplishments of our technology exchanges and study tours and the mutual benefits we have received from these associations. In particular, we remember the beauty of Japan and the warm hand of friendship extended to us and the hospitality of everyone.

I was pleased to note that the proceedings of our 11th meeting held in Tokyo last year were printed both in English and Japanese. In order to improve our technology exchange, we have prepared pre-prints of the U.S. and Japan papers to be presented at these technical sessions.

I would like to express our appreciation to Chairman Nagasawa and the Japan Panel for planning and organizing an excellent technical program in response to the U.S. request for technical information.

We are also seeking opportunities for more cooperative efforts between the two panels, especially in participation in joint projects. We would like members of both delegations to keep this in mind during the presentations. We will be able to discuss such matters more fully at our closing session in Washington, D.C.

We hope that your will find the technical program and study tour informative, interesting and mutually beneficial.

ITINERARY

Date	Local Time	Event
Aug 25	1300	Japan Panel arrives at San Francisco International Airport.
	1900-2100	NACOA-UJNR Reception, California Academy of Sciences.
Aug 26	0830-1700	Opening of 12th Joint Meeting at the San Francisco Hilton Hotel.
Aug 27	0830-1300	Meeting continued.
Aug 28	1400-2000	U.S. Reception hosted by Mr. James Wenzel Saratoga, CA.
Aug 29-31		OCEANS'83 Conference and Exhibits.
Sept 1	1000-1700	Bus to the California Maritime Academy. Visit to the Ship Glomar Explorer.
Sept 2	0815-1000	Bus to Richmond, CA. Visit Matson Lines Automatic Ro-Ro Containerization Facility.
	1030-1200	Visit Sperry Naval Integrated Storage, Tracking, and Retrieval System (NISTARS) (Automated Supply Facility in Port of Oakland).
	1330-1515	Bus tour of Port of Oakland.
	1530-1630	Briefing by Lockheed Ocean Systems Personnel.
Sept 3	0830	Depart San Francisco for J.F. Kennedy Airport, N.Y.
	1640	Arrive in New York. Bus to Garden City Hotel, Garden City, Long Island, N. Y.
Sept 4		Free Day
Sept 5		Free Day - U.S. Holiday (Labor Day)
Sept 6	0900-1300	Visit Sperry Corporation Facilities, Great Neck, Long Island, N.Y.
	1400-1600	Visit the Maritime Administration's Computer-Aided Operations Research Facility (CAORF), Kings Point, Long Island, N.Y.
	1600-1700	Visit Sperry Ship STAR, a seagoing marine test facility.

Sept 7	0830-1230	Bus to International Underwater Contractors, Inc., City Island, N. Y. Presentation on IUC capabilities and tour marine facilities.
	1330-1430	Bus to La Guardia Airport.
	1500-1600	Flight to Washington National Airport Taxis to Lombardy Towers Hotel, Washington, D.C.
Sept 8	0830-1200	Bus to Westinghouse Oceanic Division, Annapolis, Maryland. Presentations on Westinghouse marine activities and tour of facilities.
	1200-1300	Bus to Baltimore Harbor.
	1300-1400	Visit Aquarium.
	1400-1630	To Baltimore Port Authority conference room, World Trade Center. Presentation on Harbor Facilities. Tour of Baltimore Harbor.
	1630-1730	Return to Lombardy Towers Hotel.
	1830-2030	Reception at National Academy of Sciences, hosted by Japan Panel.
Sept 9	0900-1300	Final Meeting, National Academy of Sciences, 2101 Constitution Avenue, N. W. Washington, D. C.
	1400-1600	Special Session conducted by Dr. Noboru Hamada on "Sail Rigged Ships".
Sept 10	1100	Depart to Honolulu via Washington National Airport.
	1815	Arrive Honolulu airport.
Sept 11	0800-1700	Visit to Island of Hawaii including: Sea Coast Test Facility for OTEC research and development, geothermal wells, and the University of Hawaii.
Sept 12	0900-1200	Visit University of Hawaii. Presentations on High Technology Programs.
Sept 13	0900	Depart for Tokyo.

FINAL MEETING

The final meeting was held at the National Academy of Sciences Building, 2100 Constitution Avenue, Washington, D.C., on September 9, 1983, with Mr. Joseph R. Vadus presiding and Professor John Flipse, Chairman of the Marine Board, National Research Council, serving as host. Dr. Robert White, President of the National Academy of Engineering, sent a message of welcome but was not able to attend.

Mr. Vadus summarized activities of the 12th meeting and study tour and expressed the hope that all objectives were accomplished. Dr. Nagasawa thanked Mr. Vadus and other members of the U.S. Panel for their efforts in making the meetings and tour successful. A question and answer period followed between participants concerning various subjects discussed at the conference.

Mr. Vadus announced that the U.S. would again publish an English version of the Conference Record of the 12th meeting and would distribute these to members, advisers, and key individuals in the marine community.

Mr. Vadus commented on the difficulties encountered in arranging joint projects between two countries. Arrangements for scholar exchange and for diving technology training have been arranged. Cooperative research projects are much more difficult. A discussion followed on possible areas of cooperation. Professor Flipse pointed out the scientific success of deep-ocean drilling projects depend on engineering advances, and suggested that it would be timely for Japan industry to become involved.

Dr. Nagasawa asked for initial suggestions and requests for the 13th meeting in Japan. Mr. Vadus had earlier discussed the possibility of holding our meeting sometime between March and September 1985 to take advantage of the opportunity to attend Expo '85 in Tsukuba City. Dr. Nagasawa suggested Monday, March 25, as a tentative starting date in Tokyo. After a two-day technical meeting, four or five days would be spent visiting marine facilities in the Tokyo area followed by visits to facilities in Hokaido and in the northeast of Honshu before returning to Tokyo for the final meeting.

Mr. Vadus adjourned the meeting with thanks to all participants and announced a special presentation to be held that afternoon by Dr. Noboru Hamada on "Sail Rigged Ships."

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Mr. Robert Rupp	Sperry Corporation
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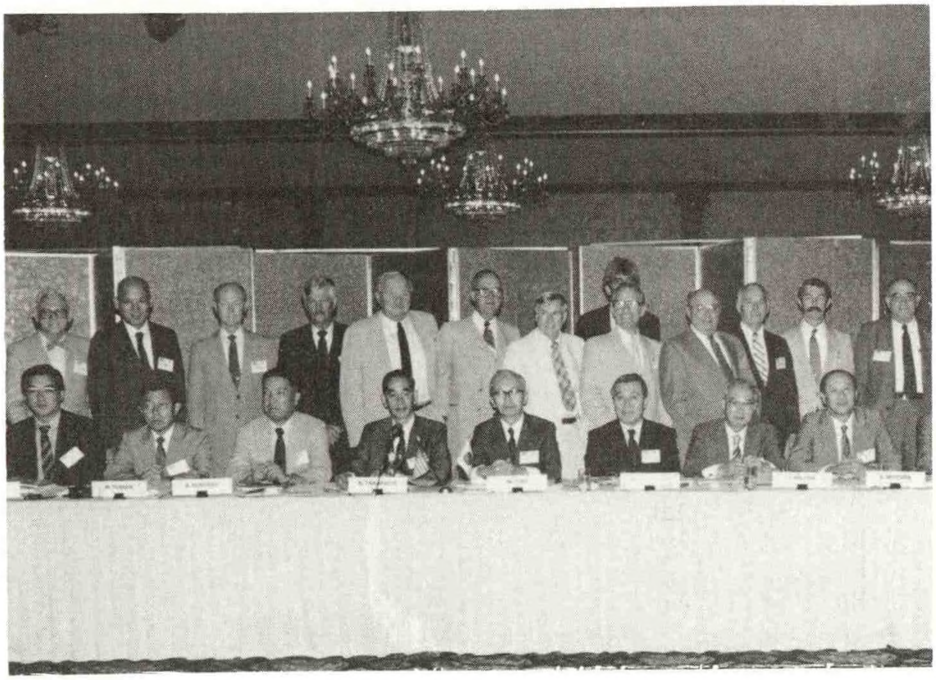
Dr. Luis Vega	EG&G

Meeting Room at San Francisco Hilton Hotel

CONFERENCE ATTENDEES AT SAN FRANCISCO HILTON



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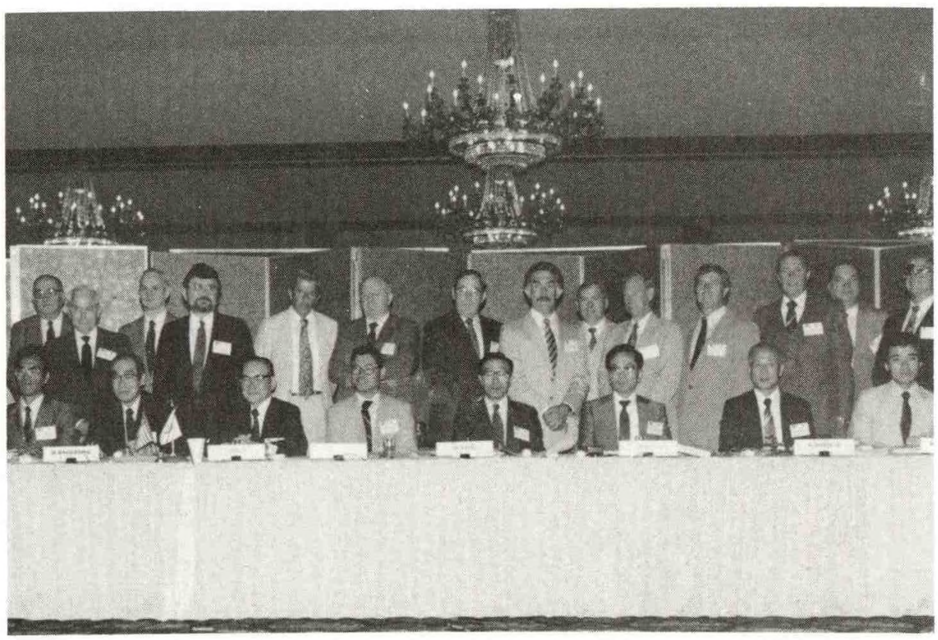

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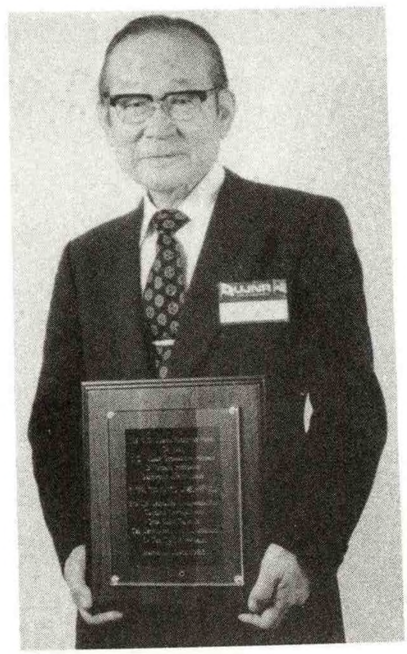


Mr Vadus presenting award to Mr. Tamio Ashino for his dedication, leadership, and valuable contributions over many years in the development and advancement of the UJNR Program.

SPECIAL PRESENTATION

Noboru Hamada
President
Japan Marine Machinery Development Association

THE WORLD'S FIRST MOTOR-SAILS TANKER "SHIN AITOKU MARU"

1. The circumstances of the birth of the motor tanker equipped with sail.

(1) At the beginning, I planned to save energy by equipping the conventional ship with sails but I got the approval of only three owners due to the first attempt. I began the investigation of the plan for the conventional ship "Aitoku Maru" according to the constructive proposal by President Fujiwara of Aitoku Co., Ltd.

(2) The owner who intended to furnish the conventional ship had a hard time making a decision because of an expenditure of about one hundred million yen for the development which would include hull reconstruction, docking time of one month, and the anxiety of the instability of the ship caused by tall sailing gear.

(3) The owner, being actively involved with advance technology, could endure the possible economical situation caused by insufficient energy savings produced by the use of sails, but from the technical standpoint the purpose of utilizing wind would fade away. Accordingly, we gave careful investigation and consideration to the carrying out of our plan.

(4) The owner wished at the beginning to adopt an automatic control system not only for the sails but also for the main engine in order to save manpower, but this system was excluded due to minimization of expenditures under the condition of indistinctness of sailing performance.

(5) The owner proposed the suspension of an offer of the conventional ship under an uncomfortable atmosphere caused by much anxiety over the economical problem and the safety of the ship equipped with sails. So I had to change my plan and investigate again using all possible means.

(6) To meet the owner's request, I got approval from the Japan Shipbuilding Industry Foundation to prolong our plan to create a two year project. On the other hand, I again asked the owner to furnish the conventional ship, stressing that when considering the rising cost of oil the sail-rigged ship (engine main with sail auxiliary) could prevail throughout the world's oceans.

(7) Meanwhile, the early spring in 1980 the owner proposed to make energy saving ship by improved navigational performance with utilize wind even if the effect of sail becomes small. And I could get the same opinion with the owner to build as a whole the high economical ship equipped with sail of fine type hull includes bow and stern form, propulsion system with suitable propeller, main engine and main shaft generator system, exhaust gas utilize system and adopts newly developed machinery which were developed by our association. Thus the project forwards on step to the realization of the ship equipped with sail.

(8) I have proposed the alteration of our plan again to the Japan Shipbuilding Industry Foundation and could get the great advance to the realization of the sail equipped commercial ship by the special consideration and assistance toward the tangible plan for the sailing tanker as future ship.

(9) First of all, I have investigated the safety of the sail equipped ship together with the owner and asked to the Ship Bureau, Ministry of Transport because we have not yet the Registration of J.G. for sail ship. Fortunately we could hold "the Committee of investigate the safety of sail equipped ship" under Chairman Dr. Motora, the professor of Tokyo University with a member from Ship Bureau, Ministry of Transport. And got the conclusion that the ship is not passenger ship but the safety is guaranteed according to "the coefficient 1 of safety factor C of passenger ship enter service to international navigation (This is not apply also to the ferry of coastwise service)", so that the ship was built as coastal service.

(10) The building of sail equipped tanker was decided on February 1980 between the owner and Japan Marine Machinery Development Association with extensive support. In September 1980, the world first sail equipped tanker "Shin Aitoku Maru" was launched with eight months only.

An information medium reported to foreign countries via satellite as well as domestic.

But there were some cold wind rather than favorable wind against "50% effective of energy saving".

2. The actual result of "Shin Aitoku Maru"

Sail equipped tanker "Shin Aitoku Maru" has continued the voyage during one and half year since September the year before last without any trouble. So that by inspection of two years after, the durability namely the least of maintenance fee will be confirmed.

When I have planned sail equipped commercial ship seven years ago, I could not get much support. And received many attentions that I should investigate meteorological condition first and favorable navigation route for sailing ship before commencement. In short, there are great many opposite opinions.

When I planned sail equipped ship, I started with the intention of contributing to curtail oil even the slightest amount.

But the actual result of sail equipped "Shin Aitoku Maru" has indicated unexpected excellent performance. The ship has an excellent stability at rough weather so that continued to operate up to now without took shelter which these small ships usually have to carry out. This means to execute an unexpected high ratio of operation not only achieved the result to save fuel cost of more than 50 percent.

From operating results rolling and pitching of "Shin Aitoku Maru" are very small and able to navigate against rough weather of 30 m/sec wind speed and 7 M wave height so that could operate without rest of a single day.

Moreover, the sailing gear of the lifting type hard sail could utilize the wind except from 40°forward that means utilize all of the wind from 360° direction. And this is verify by the fact of better stability of sailing ship when navigated in rough weather of 15 m/sec wind together with the same type sister ship "Aitoku Maru" which is scheduled to equip the sailing gear. As the conclusion, the sailing gear has achieved unforeseen important results of energy saving as well as the stability of the ship.

The principal operating results are the following:

(1) The Sea of Japan during winter season with snowing by 30 m/sec wind which until now such a small ship could not navigate, but "Shin Aitoku Maru" has entered to Niigata Port. It was on 6th January and the reason of excellent stability was not yet elucidated.

According to the captain of "Shin Aitoku Maru", he has received the information about 30 hours before that the unloading will be impossible until next 8 o'clock unless enter into the port till 16 o'clock on 14th January in rough weather of 20 m/sec wind. It has verified the excellent stability and regularity by enter into the port at 16 o'clock 45 minutes on 14th January before one hour and fifteen minutes front of the scheduled time and the ship got high reliability for regularity form shipper.

(2) Even the ship was engine main with sail auxiliary, the operating results without engine and sail only of 3.75 knots speed by 6 m/sec breeze from stern side, two hours more than 8 knots speed by 25 m/sec wind from stern side, and has better stability with comfortableness compare with using engine have been confirmed.

(3) I have received many inquiries about the effect of saving energy by sail and these sailing ships use estimated horsepower which read out from instrument in actual operation. But it was proved 40 - 50 horsepower smaller than actual power in case of 900 estimated horsepower according to the

calculation by computer which introduced in order to analyze low fuel consumption level of 130 g/psh of the ship.

It has confirmed by comparison of operating results during wintertime with the same type sister ship (not equipped sail now but will equip as soon as sail is completed) that the effect of saving energy by sail only is 30%.

(4) I got the report that at the sea trial of wave height 3 m, wind direction right 45°, wind speed 15m equipped only one sail gear unfurled on the forecastle of the ship the condition of left 10°, right 26°, period 7.9/s was changed at once to left 15° right 22° period 7.3/s by furled the sail and in case of unfurled, the rolling angle decreased more than 30%, period approach to 8/s with much comfortable condition.

(5) From one year actual operating results, the mean horsepower of this ship was 850 horsepower at 12 knots speed. In case of the same voyage with mean speed of conventional ship the horsepower is 650 horsepower. The mean horsepower was 11,000 and maximum was 1050 horsepower when came back quickly from Formosa at 14 knots speed.

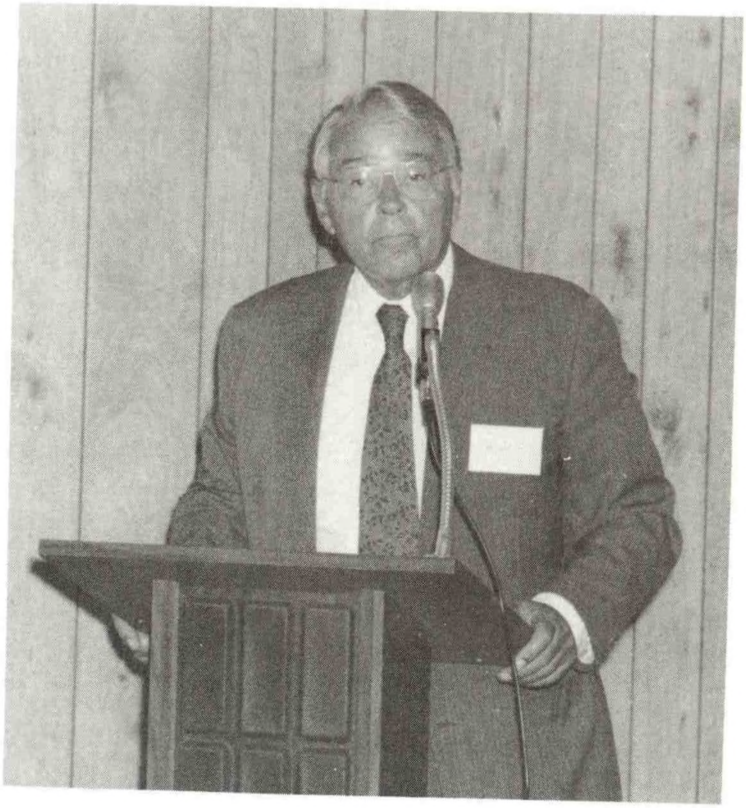
(6) According to the investigation at the dock just one year after, the surface smoothness of propeller was as same as launch time by mean of water grinding due to the idle rotation of propeller when cruising at more than 12 knots by sail only. Based upon this fact and the results from (5), the blade area of propeller was reduced to 20% lighten weight (from 265 kg to 217 kg) and the propeller of 1600 horsepower was replaced by 1200 horsepower propeller which is the limit of common use for the sail equipped ship, and also changed the smoothness of the blade to 6 (ordinary 12 to 15 at brand-new). This new propeller was fitted to the ship in January 1982 and could confirm about 7 percent less fuel consumption on the same voyage compare with the old one.

(7) Conventionally, the ship has oil purifier and prevent the sludge flows into the main engine. But this ship has homogenizer and can burn the sludge and water which will be about 900 liters by one year so that also can save the labor and expenditure.

(8) "Shin Aitoku Maru" has on board as much as 936 each of parts and machinery and all of these were controlled by computer as same as the warehouse on shore. In spite of small number of eight crews, the supply and exchange of these parts and machinery can carry out quite simply owing to the input of the software which able to supply these parts and machinery during several years. And by this we can confirm to keep in warehouse the minimum necessary amount of stock for the ship.

Usually, the reports after the delivery of the ship are limited only for accident or trouble. But I must appreciate much for the cooperation of the owner, captain and crews of the ship to collect the data which will be very useful for the next sail equipped ship. And moreover these are fulfilled by only eight crews without any additional investigator.

SPECIAL PRESENTATION



J. Paul Lyet
Former Chairman, Sperry Corporation
Chairman, President's Export Council

INTERNATIONAL TRADE AND TECHNOLOGY DEVELOPMENT

It's a great pleasure to be with you today. It gives me a chance to give you some views about two subjects that are very important to us..."international trade" and "technology." As Kurt Merl pointed out, the core of Sperry's business relationship with Japan is high technology. So, Japan's interests and views are always under consideration by Sperry. They are important to us. Today, high technology is becoming more of an issue between nations. And that leads me to discuss some things with you from my perspective as chairman of President Reagan's export council.

Today's issues in international technology can be illustrated best by a case study that's very close to Sperry. The first electronic computer was introduced to the public just 37 years ago. The inventors were faculty members of the Moore School of Electrical Engineering at the University of Pennsylvania, Dr. John Mauchly and Presper Eckert, who founded their own company. Later, their company joined Sperry and was the forerunner of our computer systems operations. Dr. Mauchly died but Presper Eckert is still with Sperry. That underlines the fact that the information processing revolution is very young. At the beginning, people, corporations and governments thought of the computer as a novelty with limited significance. It was created under military contracts for wartime purposes. Very few people saw its commercial potential. I can tell you from direct experience that Sperry and a few other companies invested tens of millions of dollars in computer technology for 15 years before any of us made any profit from it. Sometimes we were faulted for making "bad" investments. Today that perception has reversed. Information technology now has great economic and political importance. So much so, in fact, that channels of technology trade between nations are threatened. There's a fundamental convergence of interests in technology and trade. So, in my view the number one challenge facing the international economy today is the issue of keeping technology trade open and growing.

I believe two major trends will dominate U.S. and Japanese world trade for the rest of this century. These are:

- o The rapid evolution of the global economy
- o The much more rapid evolution of high technology.

The United States, Japan and other industrial nations can't escape growing interdependence, like it or not. I think Japan is much more alert to this than the United States. In the past we in the United States tended to think of ourselves, naively, as self-sufficient. To some extent we were. But, from now on all countries have to recognize that self-sufficiency is not compatible with a modern industrial state, no matter how much we admire the ideal. So, we all have to find ways to manage in a global economy. The best medium is open trade.

The United States is the largest international trader. And Japan is next largest. But, we in the United States have fallen into the economically dangerous position of importing more than we export. In 1982, our merchandise trade deficit was $42.5 billion. This year our merchandise trade deficit could reach $70 billion. In the past this deficit usually was offset by our exports of services and international financial transactions. But even there (balance on current account) we are now in deficit. It has become politically convenient to blame this on our foreign trading partners. Japan has drawn blame and so have European nations. Some blame is deserved. But most of the deficit is due to our own shortcomings.

The United States is addressing this in a positive way. We're seriously attempting to avoid protectionism by working to increase exports. Obviously, that's difficult with the dollar as strong as it is. But U.S. interest rates won't stay high forever, nor will the dollar stay high relative to the yen, the deutschmark, the pound and other major currencies. So, we are preparing for the change in the tide.

The dollar has been unduly high in relation to other currencies for many reasons.

- o Interest rates have been relatively high - reasons have been the Federal Reserve's monetary policy has been designed to dampen inflation and to endeavor to offset the failure of inflationary fiscal policy with its enormous deficits. As inflation has diminished, monetary policy has loosened and rates have eased, - but they are still too high and foreign money is still chasing the dollar. There has been an attempt at intervention, but it has not been and cannot be a solution.

- The dollar is a reserve currency and a safe haven currency and thus monetary flows have been distorted by heavy outflows from economically depressed countries in Europe and elsewhere.

- OPEC deals in dollars - Thus petro dollar demand has raised dollar values. Countries in many parts of the world, desperate for trade have lowered the value of their currencies - either by acts of omission or acts of commission -- restrictions on inward capital flows, interest rate ceilings.

Last fall President Reagan signed into law the Export Trading Company Act of 1982. And, I'm happy to note, that this was the number one item on the agenda of the President's export council. My colleagues and I worked very hard for it. The significance of this law can be measured against the fact that two-thirds of Japan's exports are through ETCS. So, we've learned an important lesson from you. I hope we can execute that approach as well as Japan.

The sector where the United States still has a major export advantage is in high technology..."information processing", "guidance and control systems", "aerospace", "communications", "polymers", "electro-optics", "biology", and so on. These are growth industries today. But their expansion is just beginning. Science-based enterprises grow at a much more rapid rate than do more fundamental industries, such as steel. They take much less from the society in terms of environmental and other concerns. They give much more, in terms of human progress. So, today, we see each of the industrialized nations acting in various ways to encourage domestic high technology development. The way they do that concerns all of us. When they do it openly and in a positive way, we all benefit. When they do it in ways that shut out others, that hurts all of us.

Technology trade is an umbrella phrase. It covers several related sectors. These include:

- technology sales - the sale of products embracing high technology;
- technology exchange, licenses, and know-how; and
- technology protectionism.

The "sale" of technology is the least troublesome. But in the United States it's becoming more so. There are two aspects to the issue. The first goes to the "strategic interests" concern. There's a view in some quarters that sale of high technology products to nations whose policies we oppose helps those nations, while the sale of grain or low technology products doesn't. That's a legitimate and widely held view. This is a very difficult and complicated problem:

- Our government controls the export of our high technology products - but there are often disagreements between the Commerce, State and Defense Departments.

- The rules are less stringent for shipment to our allies - but are complicated because we try to control the reshipments from our allies to others.

- o Our allies do not have the same degree of concern as we as to certain countries - or, more correctly, - they put trade before principle and we lose the business.

So, there is much debate on the subject and it has intensified because the export administration law is about to expire, and Congress must pass a new one.

The second aspect of this problem is competition. Many countries are competing for international high technology markets through subsidy or other arrangements. The United States has no adequate response. And, while the general agreement on tariffs and trade helps, it has no policing provisions. COCOM is supposed to result in a common approach on controlled items, but it is nothing more than a gentlemen's agreement.

Next we look at technology exchange. This is a very complicated issue. It means much more than the shipment of products from place to place. Rather, essentially, it's the transfer of knowledge from mind to mind. In fact, this U.S.-Japan facilities panel is an example of technology transfer at work. You exchange ideas more than anything else. That's valuable for the future of both countries. Unfortunately, high technology has growing national strategic implications, not only in Japan and the United States, but in every other major country as well. These go beyond purely military concerns into fundamental economics. The questions that each of our countries must ask are:

- o Where will we be 10 years or a 100 years from now?
- o Strong or weak?
- o A leader or a follower?

One thing we all know for sure is that high technology will be a big part of that future. So, the exchange of technology is not just important to individual nations, it's important to the world. But, like all other trade, it must be fair. In the long run I don't think there's any way to prevent the exchange of knowledge. But some nations think there is. So we see attempts to shut down certain channels of information. I don't pretend to have a solution to the contradiction between the need for each nation to maintain its military and economic security and the need for technology exchange. There are no absolutes. These conflicts have to be resolved case-by-case.

An issue related closely to this is the growing amount of control on the flow of information between nations. This is called transborder data flow. This trend is not only a growing impediment to technology transfer, it's also affecting day-to-day operations of international business. In fact, transborder data flow controls are one way some countries are force-feeding their domestic data processing industries---West Germany, Canada, France and Brazil are examples. This, too, is a complicated issue. But it boils down to a simple questions: Are we going to maintain an unimpeded flow of information, or is information going to be treated as a state secret?... Or as a commodity subject to taxes, controls, and censorship? We will probably always need and always have some "protectionism" to protect our core industries.

The free trade promise that "comparative advantage" should dictate sourcing through the unimpeded functioning of the market system is fine so long as it does not operate to leave nations at the mercy of foreign suppliers of products essential to security. This is a subject being debated all over the United States today as we seek to determine whether we should have a more structured industrial policy. This gets into productivity R&D, stockpiling, government subsidies for industry, tariffs, educational policies targeting and the like (the market system will prevail!).

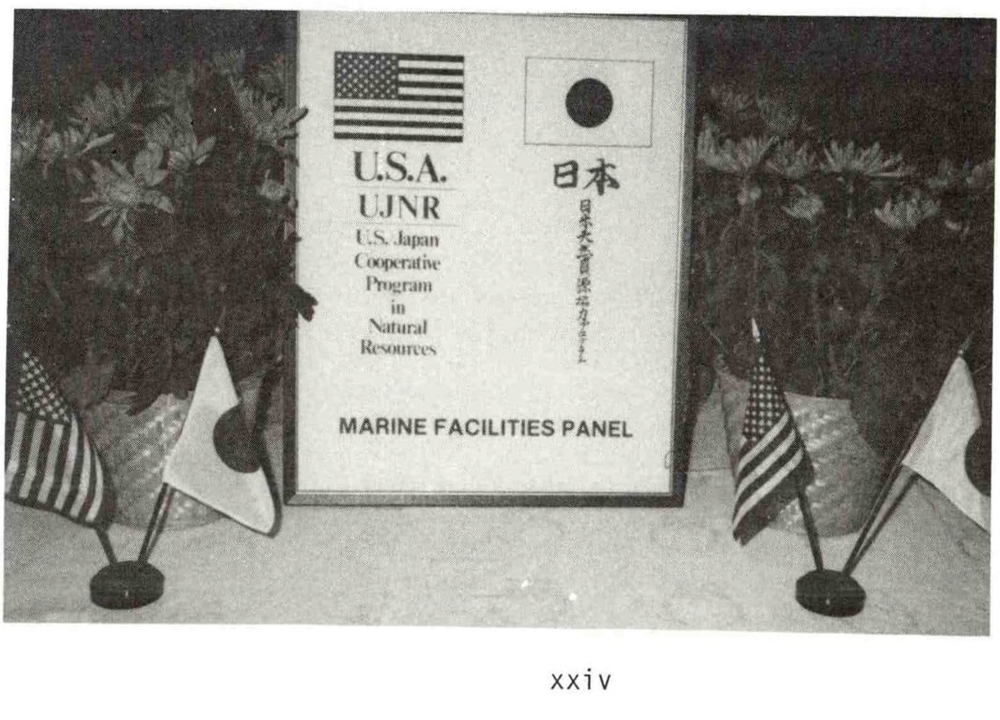
Licensing - The view still persists in the U.S. that we have more to lose than to gain. Anyone familiar with where many of the best ideas are coming from today in all fields knows we have much to gain.

I think our goal must be full and fair freedom of exchange. That brings me to the final issue of protectionism. Unfortunately, it is often the policy of nations, for domestic political reasons, to protect their industries from foreign competition. The GATT agreements over the years have been aimed at preventing that. Indeed, I think most nations recognize their obligations. But attempting to meet them is a slow and frustrating process. In technology we now see many nations protecting the development of domestic technology by preventing imports from abroad. I think they hurt themselves more than they protect. And, it's not just the industrial countries. Some of the so-called third world nations are attempting a quantum leap into high technology through protectionist modes. Brazil is just one example.

So, in brief, those are the principal issues that I see affecting the future of foreign trade in high technology:

- o The need to increase technology sales
- o The need to aid technology exchange on a fair basis
- o The need to limit technology protectionism.

Trade is much more than a way to exchange goods and services. It is the medium for the exchange of ideas and the development of progress. If trade benefits are to work on a global scale then we must make certain now that walls aren't built to prevent high technology trade between nations.



FIELD TOUR

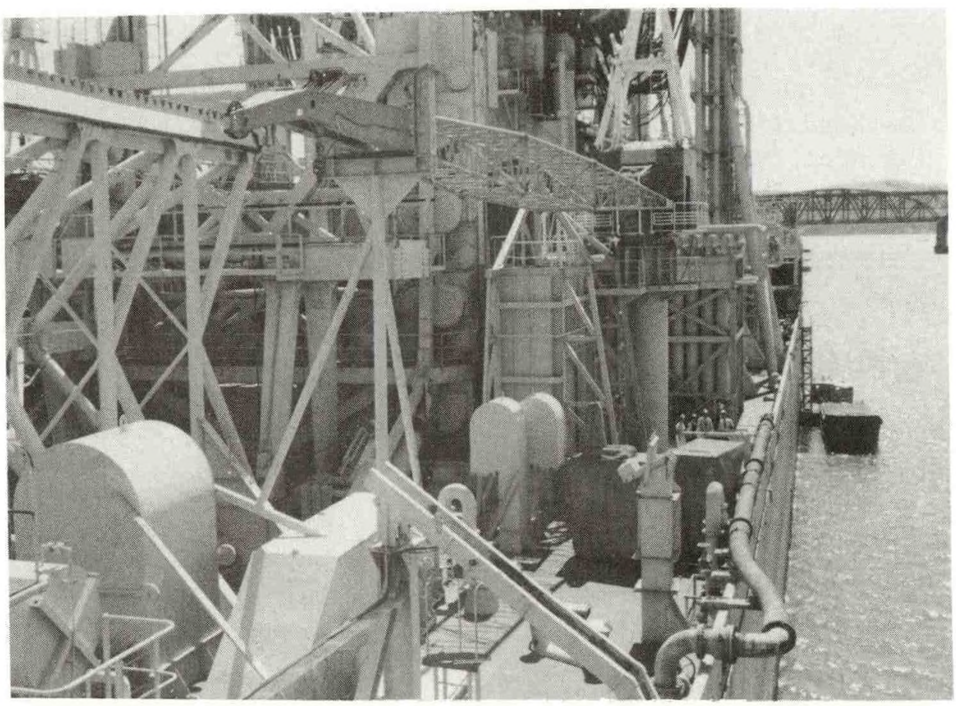
September 1 - 13, 1983

GLOMAR EXPLORER, San Francisco Bay (September 1, 1983)

The visit to the GLOMAR EXPLORER was arranged and conducted as a part of the OCEANS '83 Conference.

The GLOMAR EXPLORER was originally designed as a heavy-lift, deepsea vessel in the Pacific. The National Science Foundation let a contract to Lockheed, SEDCO, Earl & Wright, Western Gear Corporation, and Honeywell Marine Systems for preliminary design of the EXPLORER conversion to a drillship. Design work was completed in mid-1983.

The accompanying figure shows the converted configuration. The redesign calls for three new azimuthing thrusters (retractable) below the keel, relocation of deck cranes, provision of blowout preventer stacks, new derricks, automatic piperacker, and core elevator.



Port-Side View of Glomar Explorer

MATSON TERMINALS, INC., Port of Richmond, California (September 2, 1983)

Captain William Matson sailed his three-masted schooner from San Francisco, California to Hilo, Hawaii in 1882, thus initiating what has now become a major west coast marine corporation. In 1925, Matson Terminals was established as a wholly-owned subsidiary. The company is headquartered in San Francisco with terminals in Honolulu, Seattle, Port of Oakland, Port of Richmond, and Los Angeles.

In 1976, Matson Terminals began work with the City of Richmond, California, to develop the Port's first container-handling facility. Matson Terminals is now under contract to manage and operate the MATSYSTEM (Matson Automated Terminal System) at Terminal 3.

MATSYSTEM consists of a shoreside container crane on the wharf area, a container conveyor system, a yard gantry crane, and a "Transtainer" for properly loading and unloading containers on trucks. The system provides efficient container handling and precise positioning of containers both on and off ship.

Richmond Terminal of Matson Line

PORT OF OAKLAND, Oakland, California (September 2, 1983)

The Port of Oakland is the largest container port on the Pacific Coast. It receives and dispatches 80 percent of its 11 million tons of cargo each year in containers.

The Port of Oakland is located on the eastern side of San Francisco Bay. It has 19 miles of waterfront, 475 acres of container terminal facilities, and 28 berths. Seventeen of the berths can serve container, combination container/-break bulk, and roll-on/roll-off ships.

All of the marine terminal facilities are port-owned, although they are operated by private steamship or terminal companies under lease on tariff agreements. The Port is in the midst of a $92 million expansion program that will increase the port container yard capacity by approximately 40 percent.

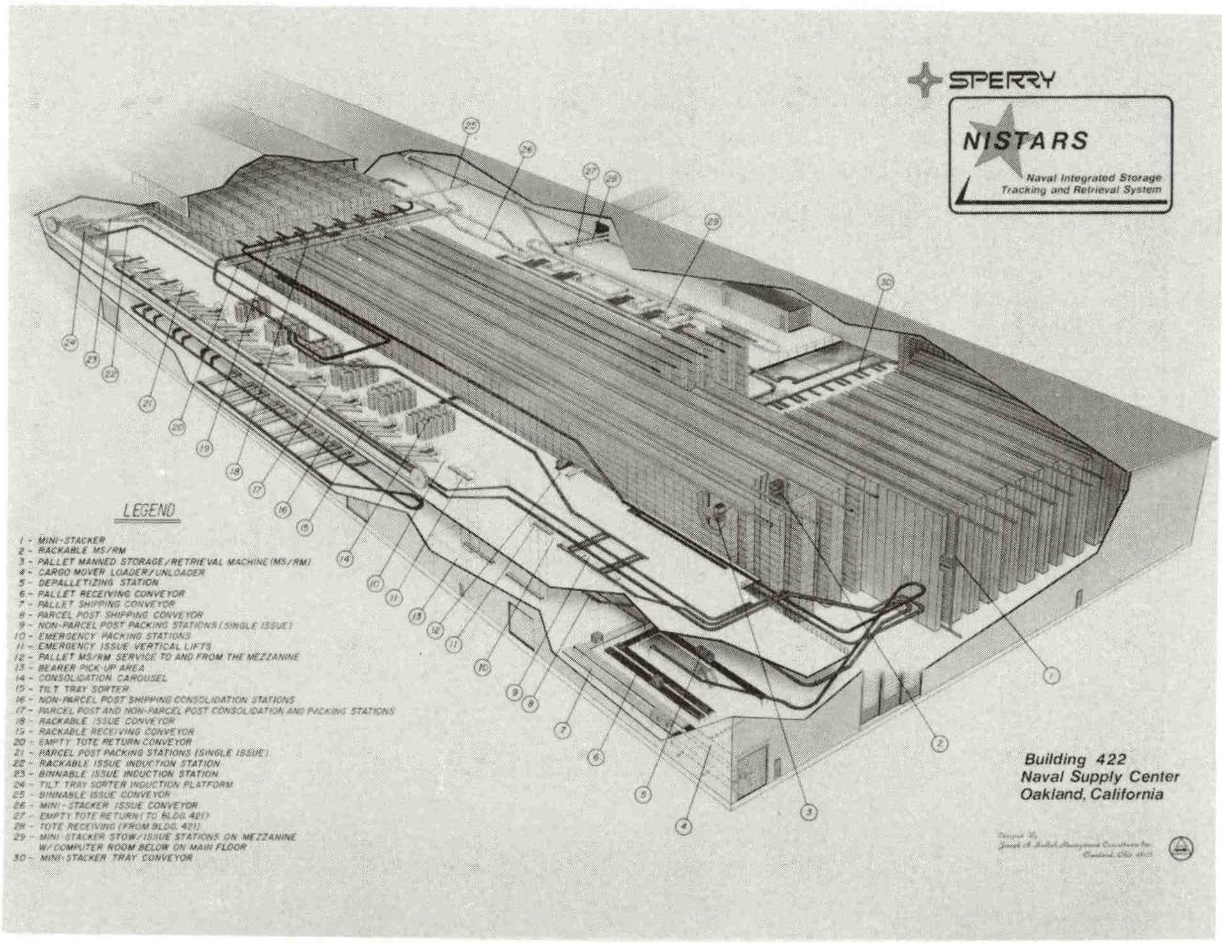
Aerial View of Port of Oakland

<u>SPERRY, NISTARS</u> (Naval Integrated Storage Tracking and Retrieval System), Oakland, California (September 2, 1983)

NISTARS is operated by the U.S. Navy in Oakland, California; San Diego, California; and Norfolk, Virginia. The facility at Oakland will serve as an operating system for further refinement of the systems at the other two Naval Supply Centers.

The purpose of NISTARS is to provide the Navy with a highly-efficient facility to control the inventory of parts and material. It has been designed to process 15,000 receipts and 75,000 issues per day. It will use computer control of 4,500,000 part numbers to be located in 10,800,000 unique locations.

The Oakland NISTAR facility was partially completed and undergoing tests at the time of the visit.



Sketch of NISTARS Warehouse

LOCKHEED OCEAN SYSTEMS, Sunnyvale, California, (Presentation at Oakland) (September 2, 1983)

Lockheed is one of the 65 largest companies in the U.S. with annual sales of more than $5 billion and 70,000 employees. Lockheed Ocean Systems is an advanced ocean-technology group of Lockheed Missiles and Space Company, Inc.

Lockheed Ocean Systems' marine activities include ongoing program activities in naval weapon systems, offshore oil services, ocean mining, ocean energy, ocean and environmental sciences, submarine and advanced ships, manned and unmanned submersibles, and basic marine technology.

The presentation highlighted the development, design, and testing of the DEEP OCEAN MINER with the capability to mine ocean-floor resources to depths of 20,000 feet.

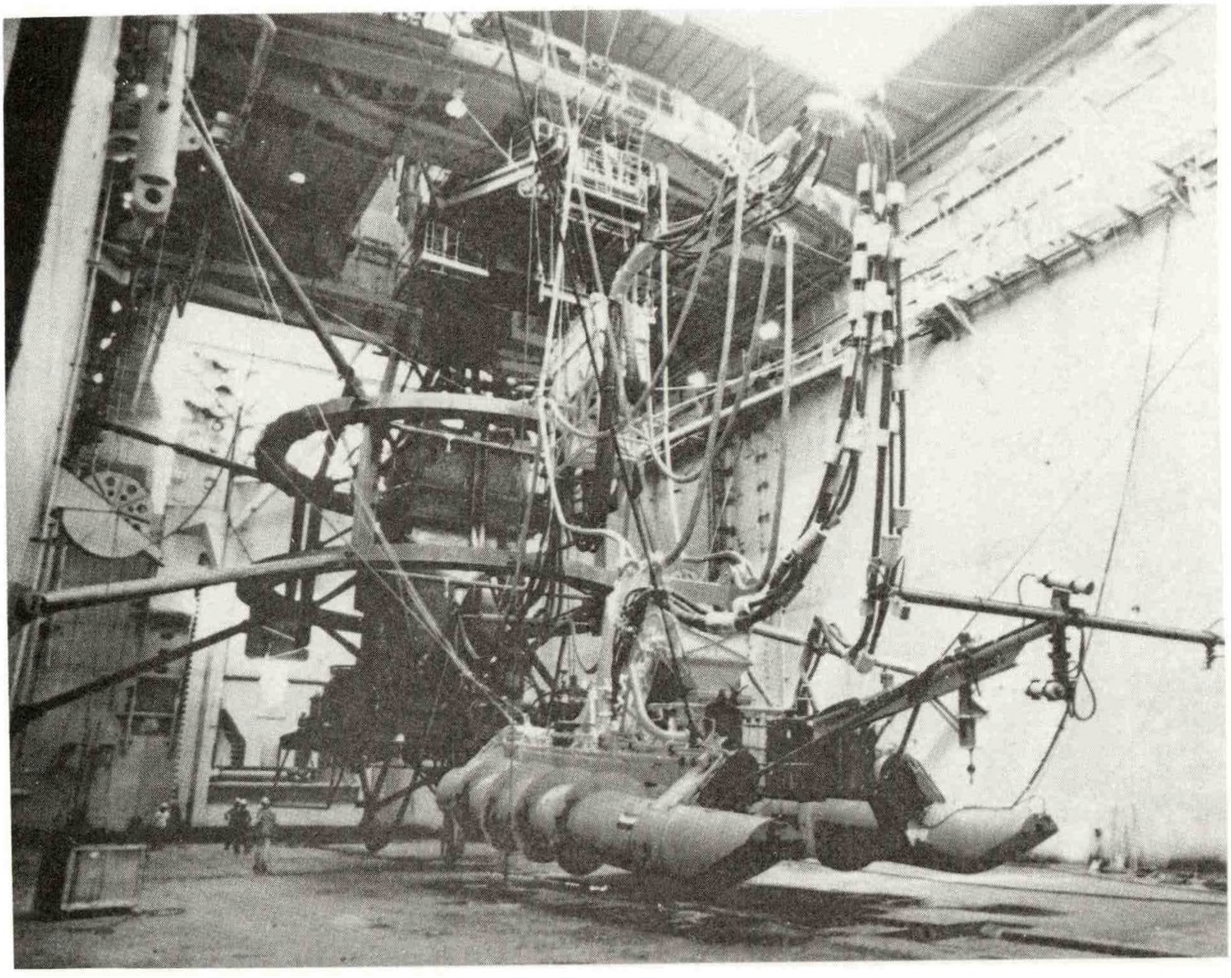


Photo of 1/10-Scale Model of Deep-Ocean Miner

COMPUTER-AIDED OPERATIONS RESEARCH FACILITY, King's Point, New York (September 6, 1983)

The Computer-Aided Operations Research Facility (CAORF) has been designed and constructed for the U.S. Maritime Administration as an advanced visual system simulating real-world situations under controlled conditions for both training marine personnel and for research. The computer-operated visual scene "puts man in the loop" to show his capabilities and limitations under stressful conditions such as congested traffic and poor visibility.

Among the many research areas conducted at the CAORF facility are collision analysis; ship control, navigation, and operational procedures; bridge system design; and analyses of harbor designs and restricted waterways. CAORF was of particular value in the highly important task of specifying the minimum safe operating conditions for bringing supertankers in and out of the harbor at Port Valdez, Alaska.

A modern bridge that looks and feels like a typical vessel puts the captain and pilot in a familiar setting with instrumentation that simulates actual shipboard facilities.

Field-Tour Group at CAORF;
Simulated View of Norfolk, Virginia Harbor in Background

SPERRY CORPORATION, Great Neck, New York (September 6, 1983)

Mr. J. Paul Lyet, former Chairman of Sperry Corporation and chairman of the President's Export Council, commented on the importance of international exchange and gave his full support to the activities of our panel.

Sperry Corporation now has approximately 75,000 employees, operates in 30 countries, with sales of $5 billion (information processing, machinery products, and defense and aerospace services). The Great Neck facility is primarily concerned with Electronic Systems Operations.

Briefings were presented on (1) Mobile Integrated Navigation, (2) Current and Future Marine Technology, (3) SRP 2000, autopilot, (4) Deep Sea Rescue Vehicle (DSRV), (5) Towed Unmanned Submersibles (TUMS), and (6) Basic Integrated Navigation, Instrumentation and Positioning/Control System (BINIPS).

A tour featured the most advanced marine navigation systems. Sperry's product line includes radars, collision avoidance systems, gyrocompasses, steering gear and alarms, ship stabilizers, speed logs, and autopilots.

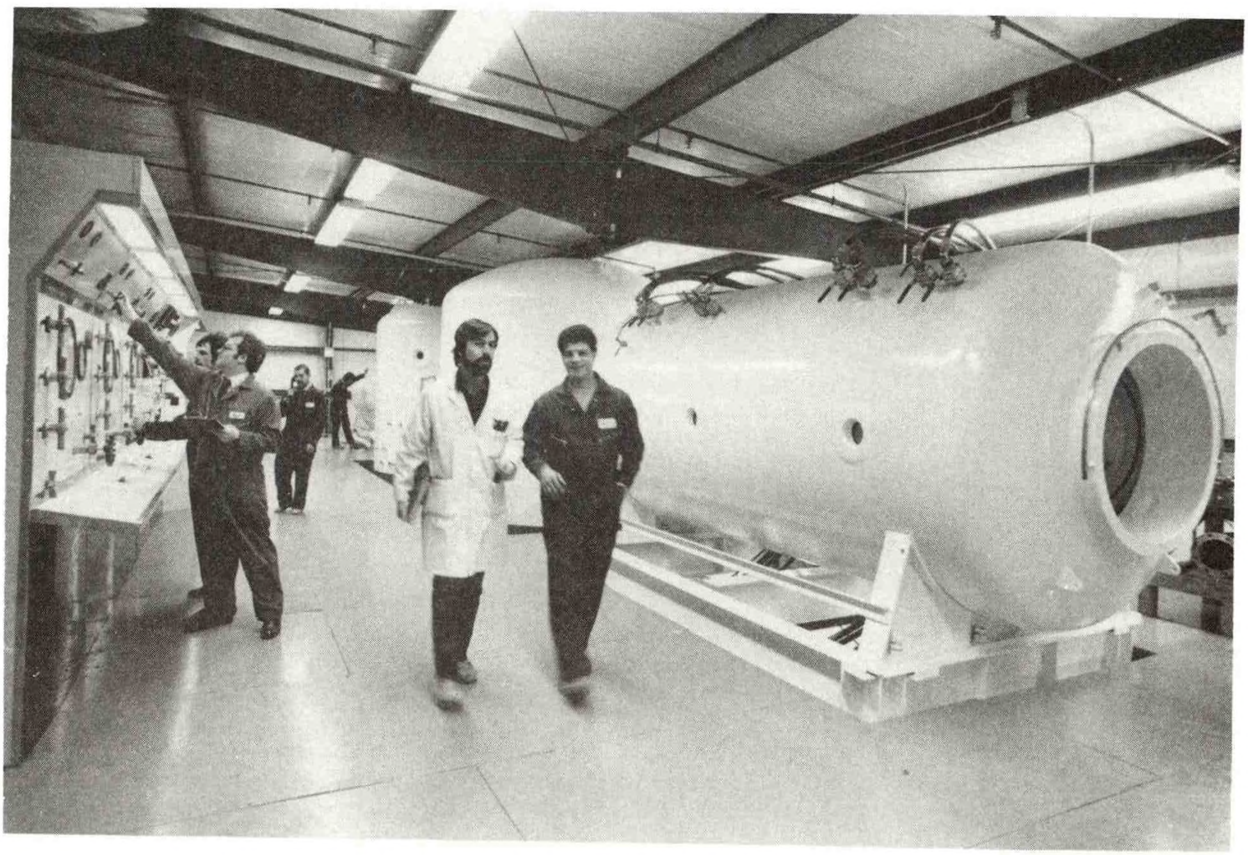
Field-Tour Group at Sperry

INTERNATIONAL UNDERWATER CONTRACTORS, INC., City Island, New York
(September 7, 1983)

The International Underwater Contractors, Inc. (IUC) Group of Companies provides highly diversified services involving use of manned and unmanned submersibles, marine survey, shallow and deep diving, construction diving, support services, salvage operations, and project management.

IUC personnel have designed, built, and used a series of progressively more advanced undersea vehicles. An example of an advanced design system currently available for use is the ROV MANTIS: a 2,300-foot remote-operated or manned vehicle outfitted with dual six-function seawater hydraulic manipulators, water jet system, dual TV cameras, Honeywell acoustic tracking beacon, 35-mm still camera, auto depth/heading/altitude control, cable cutter, and obstacle avoidance sonar.

A special feature of IUC in the North American Hyperbaric Center established in 1982 to provide state-of-art advanced diver training for commercial divers and to promote and investigate the medical specialty of Hyperbaric and Diving Medicine. Research, diver training, and health care, as well as Hyperbaric Oxygen Therapy on both an emergency and non-emergency basis, are provided. The Center houses a diving bell inside a wet chamber allowing student divers to experience deep-water working conditions and is an integral part of IUC's Professional Diving School of New York, Inc.



View of Hyperbaric Chamber at I.U.C.

WESTINGHOUSE CORPORATION, OCEANIC DIVISION, Annapolis, Maryland (September 8, 1983)

The Oceanic Division of the Westinghouse Electric Corporation employs about 1000 people and specializes in the development of ocean related electro-mechanical and acoustic systems for both commercial and defense systems.

The General Manager, Walt Dunkle, briefed the UJNR group on Westinghouse corporate structure and the Oceanic Division's position within the Company.

Rear Admiral Mike Rindskopf USN (Ret), presented an overview of the wide scope of Division activities, from deep towed sonar to acoustic flow meters for leak detection on the Trans-Alaska oil pipeline.

Specific mini presentations were made to highlight current advanced technology projects. These included:

- A lightweight mine neutralization vehicle
- The AN/AQS-14 helicopter towed mine hunting sonar
- Subsea electro-hydraulic control systems of oil wells
- Autonomous vehicle applications of bottom navigation and executive logic control systems based on artificial intelligence concepts

A tour of the Division's facilities was made with work place discussions in the transducer manufacturing facility and the acoustic test tank.

Field-Tour Group at Westinghouse

PORT OF BALTIMORE, Baltimore, Maryland (September 8, 1983)

The port of Baltimore is one of the largest container ports in the United States and handles more export general cargo than any other East Coast port. The port's normal cargo volume is in the range of 35 million to 40 million tons of foreign cargo annually, with about 6 million of those tons in the general cargo category. More than 60 percent of all general cargo is handled in containers.

The port of Baltimore is strategically located on the western shore of the Chesapeake Bay, some 200 miles closer to midwestern industrial areas than any other East Coast port. Its geographic location makes it a choice center of trade. The port has 45 miles of waterfront and close to 200 berths to accommodate all types of bulk cargo, conventional and container cargo, and roll on/roll off ships.

Marine terminals are owned by the Maryland Port Administration and private firms. The majority of the general cargo facilities are under public agency control, whereas virtually all the bulk facilities (oil, coal, grain and ore) are privately owned and operated. The port of Baltimore is in the midpoint of an expansion program which started in the mid-1960's and will continue through the year 2000 when container capacities will be doubled that which presently exists. By the year 2000 the port expects to double its volume of business.

Aerial View of Baltimore Harbor

UNIVERSITY OF HAWAII NATURAL ENERGY LABORATORY, Honolulu, Hawaii
(September 11, 1983)

The Natural Energy Laboratory is located a few miles south of the Kona Airport on the Island of Hawaii. The NEL was established in 1974 to exploit the Ocean Thermal Energy Conversion (OTEC) process using the close proximity of deep, cold water just offshore from the laboratory. The UJNR group was hosted by Dr. Tom Daniels, NEL Director, who explained the history and technical accomplishments of the OTEC program at the laboratory.

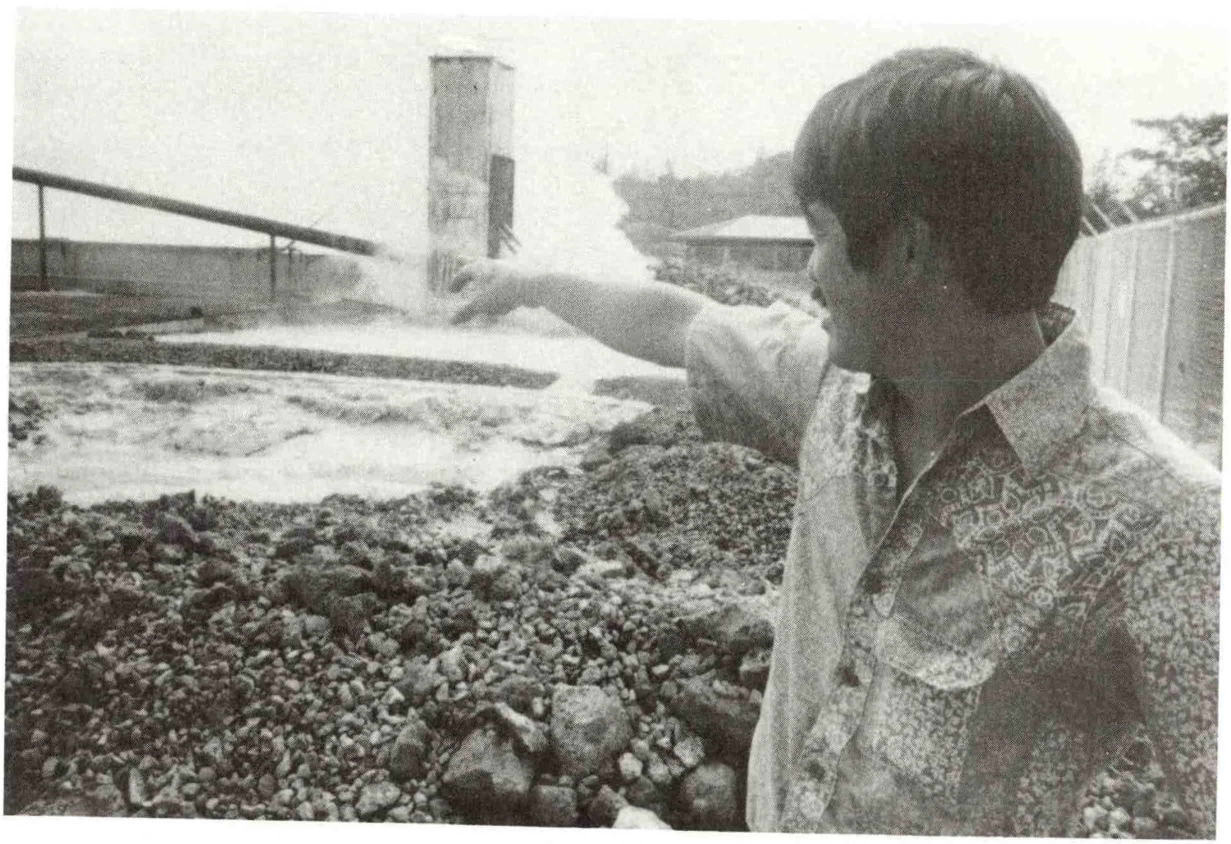
A tour of the NEL included the OTEC aquaculture experiments where the cold, nutrient-rich water has been used to grow trout, lobster, and abalone. As a result of this work, a full-scale commercial venture in abalone farming is scheduled to start in the near future.

Dr. John Craven Leads Field-Tour Group at University of Hawaii

GEOTHERMAL WELLS, Puna District, Hawaii (September 11, 1983)

The lower east rift zone of Kilauea Volcano in the Puna District of Hawaii is the site of the Hawaii Geothermal Project. The Hawaii Electric Light Company is presently operating a 3-megawatt pilot plant at the site. The Abbott well, which provides the steam for the pilot plant, was drilled in 1976 as part of a Federally-funded project. The project engineer at the site, Mr. Nakamura, provided an excellent tour of the facility. The pilot plant has been in operation since 1980 and presently provides about 2.8 megawatts to the Hawaii Electric Light grid for distribution. At least three other consortia are active in developing additional wells.

On their return trip to the airport, the group was driven past Kilauea Volcano, and stopped at Volcano House.



View of Hawaii Geothermal Energy Project Site

UNIVERSITY OF HAWAII AND HYPERBARIC FACILITY AT LOOK LABORATORY, Honolulu, Hawaii (September 12, 1983)

The first part of the morning was spent at the University of Hawaii Manoa Campus. The group received briefings on the Hawaii Undersea Research Laboratory (HURL) project from Dr. John Craven, and on the status of the Pacific International Center for high Technology Research (PICHTR) from Dean Paul Yuen, the Director of PICHTR. A visit was then paid to the laboratory of Dr. John Learned, who presented a brief on Project DUMAND (deep Undersea Muon and Nutrino Detection) and showed various pieces of hardware, including glass sphere-encased photo detectors and a model of the array.

The group then visited the Hyperbaric Facility at the Look Laboratory. The facility has been performing basic research in decompression sickness and physiology for several years, and officially opened as a treatment center in April 1983. An in-depth briefing was presented by Mr. Akinori Morita, a Japanese national graduate student at the University of Hawaii.

Mr. Tamio Ashino Demonstrating Control Skills at CAORF Facility

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Additional Papers
(not presented)

A REVIEW OF NOAA'S OCEAN PROGRAMS

JAMES W. WINCHESTER

THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA is an agency with a rich tradition of scientific service and a vast variety of ocean products. We possess a wide variety of research and development skills and tools. There are exciting new initiatives and plans to use our capabilities to serve our own nation and our colleagues throughout the world.

Thank you, Mr. Chairman. Ohaiyo gozaimasu, and good morning.

It is a great privilege and pleasure to welcome you here today, to review briefly for you the ocean programs of NOAA. Our agency, and its predecessors, have worked in the oceans since President Thomas Jefferson founded the Coast Survey in 1807. That was the first scientific agency of the United States government, and it is now a part of NOAA.

Our traditional ocean products include nautical charts of the United States and its territories and possessions, tide and current charts and tables, bathymetric maps, and associated publications of use to mariners and operators of small boats. We conduct applied research and development in cartography, instrumentation, and survey methods. We operate a fleet of ships for deep water oceanographic and fishery research, hydrographic surveys, circulatory studies, pollution monitoring, and coastal and estuarine research. We also operate a small number of aircraft for research and aeronautical charting.

Our scientists conduct research in the physical oceanographic and atmospheric sciences in all the oceans of the world. In addition to pursuing domestic research objectives, they have participated in the Global Atmospheric Research Program, they are members of the scientific committee of the International Whaling Commission, and they regularly work with their colleagues from universities and from other nations in a great many broad international environmental studies.

During the great U.S. conservation era of the late 19th century, a U.S. Fish Commission was established to investigate the disappearance of many fishery resources along our coasts. This eventually became the National Marine Fisheries Service, which is the part of NOAA that conducts biological research and works to preserve the health of our Nation's marine fisheries.

We are responsible for establishing the estuarine sanctuaries for conservation and research, and marine sanctuaries for a variety of purposes. The first marine sanctuary protests the site of the ship Monitor, the Civil War ironclad that ushered in a new era of naval architecture. While under tow, it sank in a storm off North Carolina, and is now the object of historical and archaeological research.

We monitor and conduct research on ocean dumping, and provide research support for activities looking toward the establishment of deep water ports.

We are a part of the national response effort for offshore and coastal spills of hazardous materials, providing scientific coordination to the Coast Guard. Our response teams have become well-known throughout the world, and have been invited by other nations to lend their expertise at spills abroad -- including the Amoco Cadiz wreck off France and the current well blowout in the Persian Gulf.

NOAA's undersea research program supports four regional underwater laboratory systems operated for us by universities -- one in the Virgin Islands, one in North Carolina, one in Hawaii, and one in Southern California. We are planning another in the colder waters of the north-eastern United States.

We also use a variety of submersibles in our research, including the deep-diving Alvin operated by Woods Hole Oceanographic Institution, and the Johnson Sea-Link vessels with diver lockout capability.

We operate the National Oceanographic Data Center, with historical information on the climate and environment of the world's oceans.

NOAA thus possesses a wide variety of research and development skills, and many tools

-- ranging from satellites to data buoys, from multidisciplinary laboratories to field stations as far away as Antarctica. We seek to blend these many capabilities into coherent, useful programs of service to our people and to our colleagues throughout the world.

I would like to tell you about some the initiatives NOAA is now undertaking in the oceans to achieve these objectives.

You may recall the Coastal Zone Color Scanner, an experimental instrument still operating on the old Nimbus 7 spacecraft. Its products clearly show areas of large phytoplankton bloom, sediment transport in estuaries, and details of oceanic circulation.

With infrared added, they show thermal upwelling and areas of thermal pollution, and become especially useful to fishermen and to persons charged with monitoring ocean pollution.

We would like to put a next-generation Ocean Color Instrument on our polar-orbiting satellites. The Improved TIROS-N spacecraft now available have room to accommodate it. We will use it operationally to provide the fishing industry and pollution monitors with near-real time information. The National Aeronautics and Space Administration agency will use it for additional experimentation.

In another area, we have recently begun what we call Project PORTS -- our acronym for Port Objectives for Real Time Systems. We are working with the marine transportation industry and our port and waterway authorities on this.

We are beginning with systems to provide real time tide and water level information to ships entering and leaving harbors. To these will be added data on currents, waves, and weather, and perhaps ice conditions in northern ports. We're also considering electronic display of digital nautical chart information.

We are looking forward to the day when a ship entering a harbor will display the appropriate nautical chart on a CRT screen on the bridge. Real-time information on the ship's exact position will also be displayed on the screen -- along with water depths, currents, winds, buoys and channel markers, and the positions, directions, and speeds of other water traffic.

The navigator will have a moving image of everything he needs for accurate and safe navigation under any conditions.

We have also taken a first-step toward a marked improvement in service to the general marine community. In October we will open, in Seattle, our first Ocean Services Center. This will be a one-stop facility for a full suite of NOAA products and services. Its customers will include commercial and sport fishermen, merchant marine captains, shippers, recreational boaters, and operators of offshore oil rigs.

People in the "value added" industries who use NOAA reports and data collections in the course of making their own marketable products will find help there -- as will, of course, the general public. A Japanese Ship captain in port will be able to drop by and pick up all NOAA products and services that he needs for his outgoing passage.

Both operational and retrospective information will be available -- marine weather warning and forecasts, nautical charts, fishery trade and marketing information, access to environmental data bases, and satellite data. An operational unit located at the center will provide 24-hour-a-day weather and oceanographic services over an area from the Oregon-California border to the U.S.-Canadian border, and out to about 300 miles offshore.

The center will be staffed by our weather and ocean service experts, and will have computer access to the National Meteorological Center and the Navy's Fleet Numerical Oceanography Center guidance portfolios.

Seattle was selected for the first such center because of the large number of NOAA units already there. We expect to see additional centers created during the next year.

In closing, I would like to touch briefly on a part of President Reagan's recent proposal to establish a Department of International Trade and Industry. If Congress approves the proposal, NOAA will become a separate agency.

The President's proposal thus will not only give U.S. trade policy a strong, focused organization, but will achieve for NOAA the independent role originally envisioned for it. The 1969 report Our Nation and the Sea, which led to the establishment of NOAA, recommended that it be a separate agency, "the principal instrumentality within the Federal Government for administration of the Nation's civil marine and atmospheric programs."

A major advantage of independent status will be to place NOAA on an equal footing with other scientific and technical agencies, such as the National Science Foundation and the National Aeronautics and Space Administration. In the White House and the Office of Management and Budget decision processes, NOAA's programs and budgets will be considered along with those of other scientific and natural resource agencies.

In addition, implementation of NOAA decisions on such important issues as fisheries, deep seabed hard minerals, and marine mammals will be speeded up. NOAA will also gain the freedom to bring issues directly to the White House when necessary.

The establishment of NOAA as an independent agency is tied to the approval of the new Department of International Trade and Industry, and recognizes that NOAA has both the operational scale and the program cohesiveness to be independent.

I will be most pleased to try to answer any questions you may have.

Thank you very much.

Collision Risk Assessment of LNG Tankers

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The ships of exclusive use for dangerous cargo such as LNG or LPG carriers are remarkably increased recently in Japan, and it is needed to study the safety assessment on the danger of collision on these ships especially navigating narrow channel or bay.

As the first time, the investigation on the safety of LNG tankers at collision was carried out by the Japan Association for preventing Marine Accidents, and the similar investigations was carried out recently especially aimed to establish the LNG power plant at the coast of Osaka bay.

At the early stage of these assessment, we studied the event flow of the disaster expansion as shown in Fig. 1.

In these investigations, the behavior of ship hull fracture at collision was studied both experimentally and theoretically. It is easily known that the most serious condition at collision is occured at a ship run against LNG tankers at right angles.

The theoretical analysis on ship fracture at collision was obtained using the theory studied by the committee of the Japan Shipbuilding Research Association (I was the chairman of the committee), and the results were compared with that obtained by the theory of Minorsky or Det Norske Veritas.

As the results of analysis, the critical speed which is defined as the speed of safety limit at collision is obtained with respect to the ship scale.

This critical speed is shown in Fig. 2 on 125,000m^3 LNG tankers.

It will be considered that if a ship run against LNG tankers at the speed above critical limit, LNG tanks are fractured and LNG flow out from the ship.

In the former investigation, the critical ship speed is obtained as 6 kt for a ship of 10,000 tons displacement, and 10 kt for a ship of 3,000 ton.

This critical ship speed shows rather low speed compared with that obtained by latter investigation. The reason is as follows that, in the calculation of absorbed energy of ship hull fracture at collision, the fracture of ship bow is not taken into account in the former investigation though this is taken into account in the latter investigation.

In the theory of recent investigation, bow construction is assumed as an ideal frame structure with effective width of plate, and the ultimate strength of the structure is calculated by F.E.M. analysis. The theoretical analysis on the fracture of side structures of LNG carrier is calculated by the method developed by the Shipbuilding Research Association in Japan.

Relations between fracture load and deformation of bow structure obtained by this theory are shown in Fig. 3 for container carrier and in Fig. 4 for oil tanker.

The comparison of fracture load and deformation curve on bow structure and side structure of ships is shown qualitatively in Fig. 5.

The maximum collapse load at ship collision will be estimated from this curve by a conception that the absorbed energy due to fracture of construction equals kinetic energy of ship motion at the collision.

On the safety assessment of Osaka bay, we had an observation on speeds of actual navigating ships in the bay, and it was found the maximum of the ship speed amount to 14 - 15 kt which exceed the critical ship speed at collision obtained by calculation.

From these results, it was considered that the safety assessment on the collision probability of the ships navigating exceed the critical speed is necessary. The probability calculation was carried out based on the accidental data of actual ship collisions in Japan and Osaka bay.

It was obtained by the calculation that the probability on tank fracture of LNG carriers at collision is approximately 4×10^{-6} per year. It is difficult to evaluate this value of probability, but there was the discussions in the committee to establish the LNG power plants that this value is sufficiently safety compared to the probability of fire or motoring accidents.

Ref.1 Research Committee Report on Safety of LNG, Osaka City, 1983, 5

Ref.2 Report of Study on Preventing the Accidents of Dangerous Cargo Carrier Ship, The Japan Association for Preventing Marine Accidents, 1974

Ref.3 On the Ultimate Strength of Bow Construction, T.Ohnishi, H.Kawakami, W.Yasukawa, H.Nagasawa, IWABSE "Ship Collision" 1983

Ref.4 A Study on the Collapse of Ship Structure in Collision with Bridge Piers, H.Nagasawa, K.Arita, M.Tani, S.Oka, Naval Architecture and Ocean Engineering Vol.19, 1981. The Society of Naval Architects of Japan

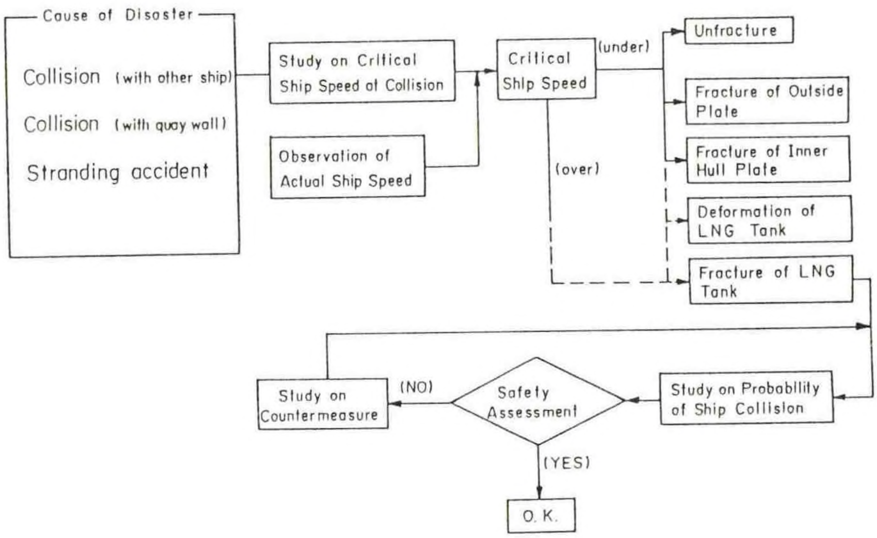

Fig. I. Flow of Study on Safety Assessment

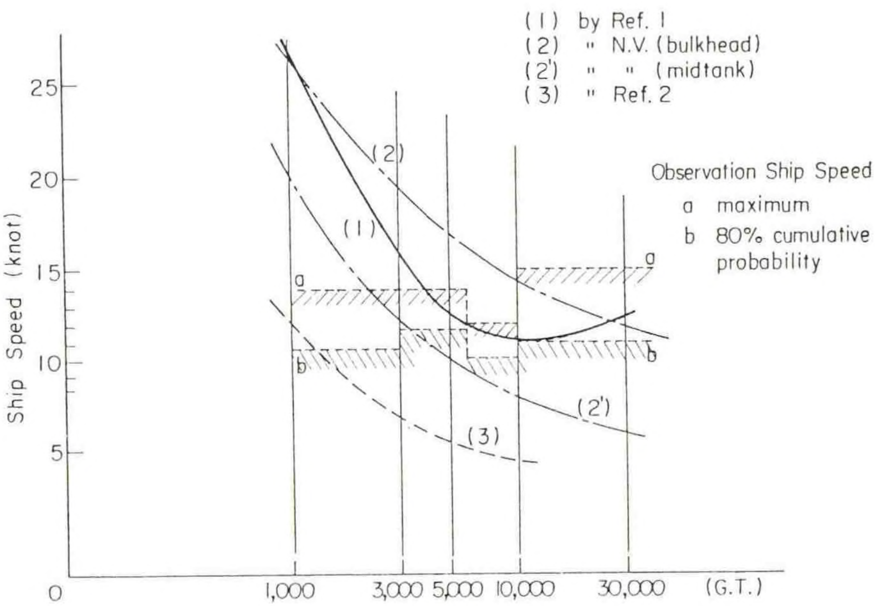

Fig 2 Critical Ship Speed at Collision and Observation Ship Speed

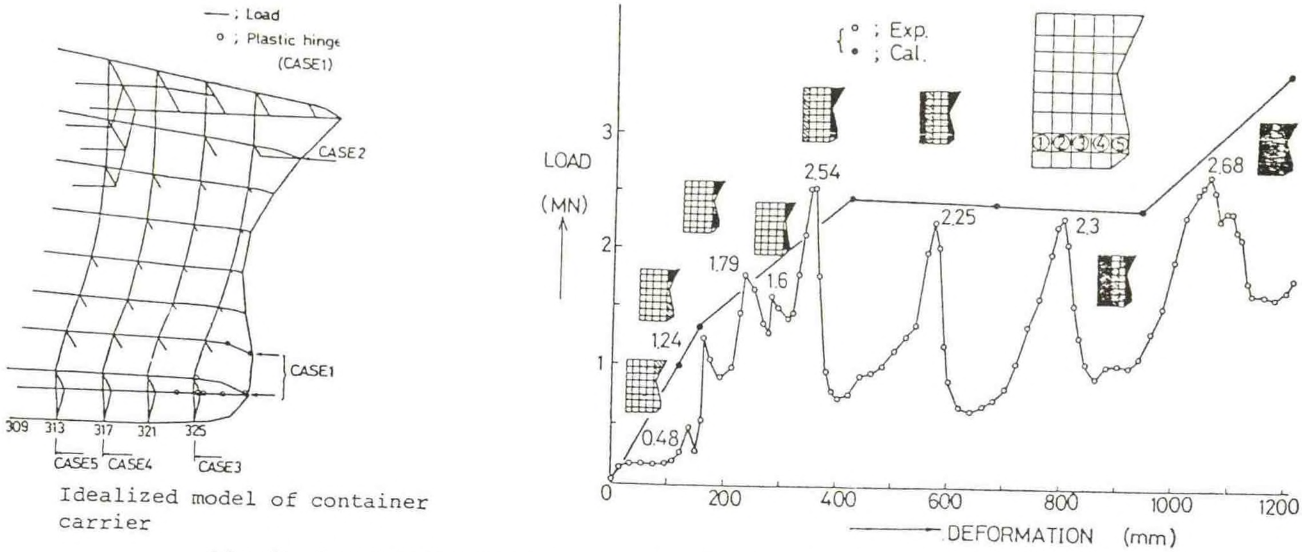

Fig.3 Load-deformation curve of container carrier model

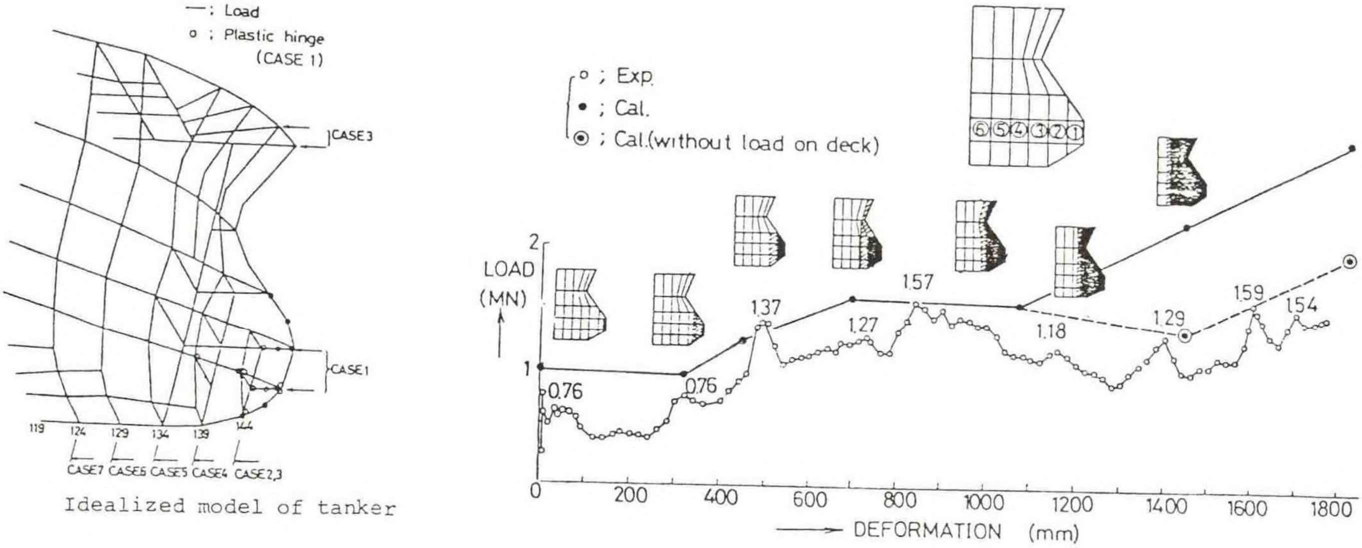

Fig.4 Load-deformation curve of tanker model

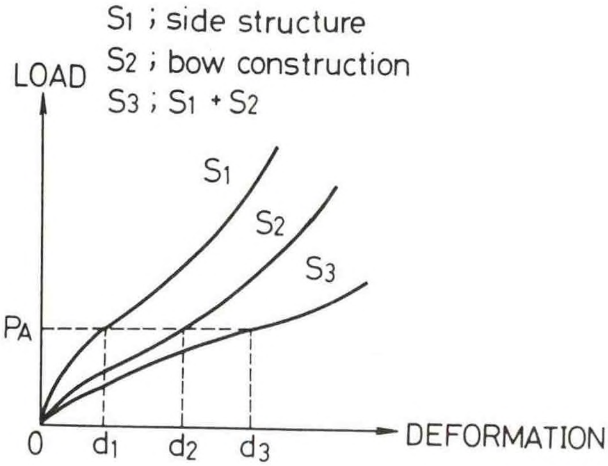

Fig.5 Load-deformation curve of bow and side structure

SHIPPING OPERATION OF THE FUTURE

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ABSTRACT

For Japan heavily relying her essential resources such as oil, iron ore and grains on the imports from overseas, it has been one of the critically important tasks to warrant Japan's economic security by ensuring a stable and efficient transport of goods to and from overseas trading partners. In this sense, it is considered to be a future task of crucial importance to encourage development of ships of high added values with their shipboard living and working environments upgraded through drastic sophistication of ship automation and labor-saving towards the oncoming 1990s made possible by R & D endeavors on building economical ships of high intelligence and high reliability.

Research and development for building ships of greater system intelligence and high reliability equipment and system

Basically, ship-related techniques can be divided into energy-saving techniques, automation and labor-saving techniques and techniques for the enhancement of safety and pollution prevention. On the energy-saving techniques, R & D activities have recently been vigorously thrusted forward in association with the increasing fuel prices, with considerable results, and further improvements in this area are likely to assume in the future. While on the other hand, on the automation and labor-saving techniques, a highly rationalized ship served by a complement of 18 crewmembers is going to be realized in the near future, but from a long range viewpoint, demand is considered to grow further for developing ships with still smaller complement through greater rationalization in shipboard systems with largely improved ship operating efficiency. However, realization of such a ship is by no means possible if effort would be made merely by extending the conventional techniques, and thus it is necessary to promote a systematic research and development to cope with such a demand standing on a long range viewpoint while ensuring to have leaps in upgrading the technology.

In conventional ships, almost all ship operating duties have, in principle, relied on crew's personal judgements and disposals. For this reason, much labor of the crew is shared by such shipboard services, and moreover, judgements on weather and sea conditions, also ship's conditions had to but rely on the experience and intuition of individuals involving selective actions not necessarily optimum. However, thanks to the successful results of studies on the effects of wind and waves on ship's motions and conditions, and to great development of high accuracy sensors and very large-scale integrated circuit (VLSI), the conditions of the ship herself and surrounding conditions can now be evaluated scientifically on board the ship, and further, the measured results and shore-based instructions are effectively utilized for optimum ship operation on account of the development in the area of the intelligence system. What is more, the development in the space techniques is bringing about the advanced art of sea and weather forecast and their correst observations, thereby the possibility of large-scale transfer of shipboard duties to the shore base is growing. On the foregoing grounds, it is important to develop an integrated ship-shore system and sophisticated ship operating automation system via maximum utilization of these techniques and means for realizing added promotion of system automation and labor-saving for materializing a drastic improvement in ship operating efficiency.

On the other hand, trouble-free operations of ships have conventionally been ensured solely by effecting constant maintenance work by a number of crewmembers. Along with the ever degrading fuel quality and sophistication in the energy-saving techniques, the shipboard maintenance work tends to become more and more complicated. To intensify ship operating automation and labor-saving under such circumstances, the maintenance-free features of the shipboard systems are most basic requirements, and for this reason, it is necessary to vigorously develop a plant of high reliability where the reliability of shipboard equipment and machinery including the main propulsion engine is enhanced to a great extent. Further, for enabling the crewmembers to enjoy comfortable sea life without feeling any drawbacks induced by such a reduced manning arrangement even in ships served with extremely small number of crewmembers, it is desirous to develop new crew accommodation and lifesaving systems. We should say that these studies and researches are particularly important from the viewpoint of ensuring to build ships of high added values, improvement of shipboard working environment and proper maintenance of the leadership long held by Japan in the area of technology.

(1) High reliability plant

(i) High reliability equipment

Realization of maintenance-free features through elucidation of detailed combustion process of fuel oil, development of hardware techniques and equipment by making best use of heat-resistant and corrosion-resistant materials with resultant upgrading of reliability of marine equipment and machinery to a great extent is envisioned.

The major tasks here as viewed from the standpoint of improving energy-saving results and measures against low grade fuel oil for upgrading overall reliability can be identified in how elaborately harmonize those mutually inconsistent technical requirements.

(ii) Failure prediction and diagnostic system

Significant upgrading in the reliability of marine machinery and equipment is envisioned by effecting R & D on the software techniques relating to maintainance feature capable of correctly predicting area and time of occurrence of failure for exact and immediate carrying out of maintenance work by monitoring and evaluating the operating condition of the shipboard machinery and equipment through scientific means replacing the conventional way of manual monitoring practice mainly relying on human intuition.

Development of an effective monitoring and evaluation system of the operating condition of marine machinery and equipment constitutes itself as a task here.

(2) Sophisticated system of automatic ship operation relying on an integrated ship-shore system and intelligence-intensive method

(i) Automatic optimum ship operation system

To enable ships to have most economical and safe operation with the functions of the integrated ship-shore information control and management system relying on sea and weather information data processing; evaluation of hull stress created by cargo load and external forces caused by wind and waves; and prediction of the resultant energy-saving effects; evaluation of operating conditions of machinery and equipment; and utilization of INMARSAT.

The targets here also include optimization of work load allottment for ships' crew and operating system.

(ii) Automatic entering/leaving port operation system

In conventional ships, on-deck work at entering/leaving port operation is carried out solely by crew hands. The intent of this project is to ensure maximum degree of automation in such on-deck work including in-harbor maneuvers and docking/undocking operations for the improved operational safety and labor-saving achievements.

On items relating to berthing operation and cargo operation which are considered difficult for large-scale automation for the time being, use of a system relying on shore support may be considered. However, effort will be made for minimizing the work load through the employment of some degree of automation and centralized control systems.

(3) New accommodation and lifesaving systems

(i) Comfortable living system

Improved stabilization in shipboard living is envisaged through the upgraded reliability in all aspects of living-related systems such as fresh and sanitary water supplies and discharges, heating, air-conditioning and ventilation which have conventionally been relying on crewmembers' labor. In the meantime, it is also aimed at establishing design techniques on comfortable shipboard living installations and constructions taking into consideration of measures for dealing with special mental care and human behaviors in times of emergency supposed to occur in association with the reduced manning arrangement of ships.

(ii) New lifesaving system

As the lifesaving system in ships of reduced complement, a lifeboat system capable of lowering and launching, floating off and releasing, and recovering safely and securely in full automatic mode of operation from and to a ship in motion and under heavy weather.

Effort will also be made for improving protection of life of seafarers in a marine casualty in cold waters by developing water-and cold-resistant lifevests.

MANAGING RISKS OF SHIP ACCIDENTS

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ABSTRACT

Risk analysis and risk management mean many things to different people. Insurance companies manage risks by spreading coverage of high value assets over many underwriters. Investors manage risk by holding several different assets in their portfolios. Managers of large research and development projects manage risk by careful technological forecasting and by frequent and detailed project reviews. Those responsibile for ship safety can manage risks by careful analysis of the specific hazards involved and by evaluating potential improvements in simulator studies.

RISK ANALYSIS

Insurance underwriters analyze life risks differently from ship risks. In life insurance, there are large numbers of insured persons in the fund pool. The risks are numerous and homogeneous. Statistical analysis is appropriate. Ship risks are individually much larger. They vary greatly by owner, trade, and class of vessel. Statistical analysis is inherently far less precise for ship accident risks than for life risks. It is important to use many forms of analysis to define the risks associated with specific ship operations. Understanding the nature of the risks is an important first step toward risk management.

In a 1978 study [1] of navigation to and from the Louisiana Offshore Oil Part (LOOP), we used several means to define the chances of spilling oil due to ship accidents. One method involved laying out the routes and studying the charts, coast pilots, sailing directions and weather patterns in the areas of concern. These areas were the Florida Straits, Gulf of Mexico and the Louisiana Coast. Personnel involved in the study rode a ship through these areas and discussed navigational hazards with the crew. They also visited an offshore port in Saudi Arabia to observe and discuss navigational approaches.

Another approach was to review records of all vessel accidents from 1969 through 1977 in the offshore Gulf of Mexico; the accidents were plotted and causal factors were tabulated. Most of those were other than tankers. A special analysis was made of tanker casualties, most of which occurred outside the Gulf of Mexico.

The final analytic method was development of "fault trees", logic diagrams of causal sequences known to result in ship accidents. After development, these logic trees were validated by assuring that each accident in a new sample could be analyzed using logic sequences in the tree. This indicated that no major accident risks had been left out.

All of the separate analyses were combined by the analysts into subjective hazard ratings for the different hazards that might cause a major accident. The most significant hazards were found to be the chances of a human factor problem in restricted waters and the possibility of damage due to severe hurricanes. More moderate hazards are the offshore oil rigs near the approaches to the oil port and floating derelicts or debris in the Gulf.

The statistical oil spill risk was also calculated. A negative binomial probability distribution was used for tanker oil spill accident frequency and the lognormal distribution was found to describe spill sizes given that a spill occurred. The total risk that a spill as large or larger than that from the TORREY CANYON (109,500 long tons) was found to be about 10% over a 30 year port life. Thus, the statistical analysis only showed us that a non-neglible risk existed. It did not help tell us how to manage that risk.

RISK MANAGEMENT

Knowing that the major problem would be human error in restricted waters, we next investigated ways to help avoid human error. A set of simulator experiments was conducted at the Ship Analytics, Inc. simulator in North Stonington, Connecticut. [2] The most restricted water area for LOOP traffic is the approach to LOOP itself due to periods of heavy winter fog, small fishing vessel traffic, oil rigs and the fact that the only anchorage at LOOP was inside a restricted zone where tanker masters were not allowed to proceed without a LOOP mooring master (similar to a pilot). Figure 1. shows the LOOP complex.

*This paper is the sole responsibility of the author. It does not necessarily reflect official U. S. Coast Guard policy.

Four problems were devised to present realistic, but difficult problems to tanker masters. The scenario designs were based on interviews with masters familiar with the area. After the simulations were created, they were checked by an expert tanker master for realism. Several minor revisions were made as a result.

An experimental design was devised to test various on-ship and off-ship navigation aids. Twelve teams of vessel masters and mates were test subjects. All were current professional large tanker officers. Four of these had received team training and voyage planning instruction at the simulator school in Southampton, England.

Various data were logged by computer during the simulations: vessel track and speed, closest distance to other ships and oil rigs, numbers of engine orders and rudder orders. Other information was taken by experiment monitors: number of fixes using radar, LORAN-C, fathometer or radio direction finder. Finally, other information was provided by the masters in debriefing sessions after the simulator runs.

Based on these experiments, specific recommendations were made regarding the mooring master pick up point, anchorages, charts, and aids to navigation.

Several principles of risk management were illustrated in this case.

First, multiple methods of risk analysis are needed to identify the actual hazards of a project as well as the numerical risk.

Second, one must recognize that the control of shipping risk is mostly in the bands of the bridge watch and conning officer. Safety improvements must be evaluated based on how they affect the conning officer's motivation and capability to handle the ship safely. Simply placing another gadget on the bridge or in the harbor may do nothing for safety.

Third, human beings are variable (among individuals and over time for the same individual). Thus, safety evaluations require statistical measurement.

Fourth, safety improvements seldom are effective independently. Aids to navigation and charts have related effects. Bridge equipment and training in the use of that equipment and its role in overall watchstanding procedures are all interrelated.

Fifth, although not illustrated in this study, safety does not remain constant after a one time decision to make certain improvements. Long term supervision and refresher training are also needed.

FUTURE DIRECTIONS

It is a mistake to collect data only on ship accidents, where people are in fear of the law. All countries should establish voluntary incident reporting systems guaranteeing legal immunity. Such a system exists for U. S. air traffic. Under that system, pilots are willing to discuss their problems and errors frankly. If ship safety researchers could have more reliable information on the human problems of ship traffic, we could do better risk analyses.

We should also have data and voice recorders on ships to record the steering and engine control sequences leading up to accidents and the communications involved.

The ship safety research community worldwide is conducting many independent lines of research. Much of this research is not widely read and there is no means to integrate it into a cohesive body of knowledge. Efforts should be made to coordinate related research results into principles of risk management by consensus where feasible or at least by majority and minority opinions. Topic areas might include: accident statistics, accident reports, scenario design, risk analysis methods, aids to navigation requirements, shipping channel dimension requirements, vessel speed control, vessel traffic monitoring systems, the pilot-master interface, mariner proficiency demonstrations, and navigation watch procedures.

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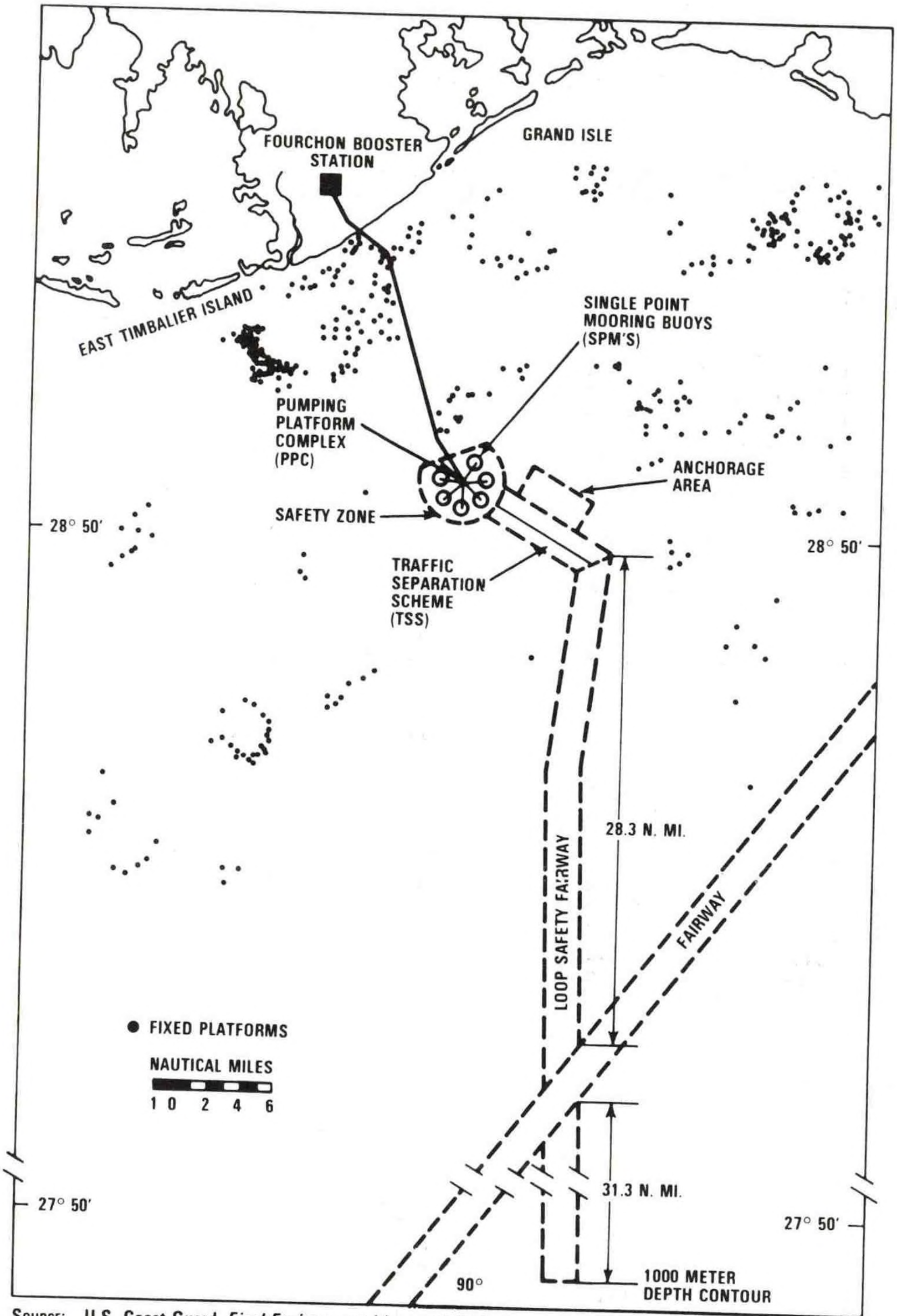

SOURCE: U.S. Coast Guard, *Final Environmental Impact/4(f) Statement, LOOP Deepwater Port License Application,* Vol. 1, Department of Transportation, 1976.

FIGURE I LOOP SAFETY ZONE, ANCHORAGE AREA AND TRAFFIC SEPARATION SCHEME

REMOTELY OPERATED VEHICLES AND ROBOTICS, MANIPULATORS

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ABSTRACT

10 ROVs have been constructed and 4 are under development in Japan. 7 of them belong to JAMSTEC. Some of those vehicles are utilizing or planning to use fiber optic tether cables with Kevlar strength member. They are MARCAS, Submarine Robot, HORNET-500, DOLPHIN-3K and two other unnamed vehicles.

As to robotics, JAMSTEC once constructed autonomous vehicles and planning to develop robot vehicle of high intelligence.

Two manned submersibles and three unmanned vehicles have manipulators, two of them are FFM.

INTRODUCTION

Since 1975, 10 tethered vehicles have been constructed in Japan. 9 of them are still operational. JAMSTEC owns 4 vehicles, they are Mosquito, JTV-1,2 and ROV-400. Except for ROV-400 which was built by Mitsui Shipbuilding Co., three vehicles were designed and constructed by JAMSTEC. Developers of other vehicles are JAMSTEC. Developers of other vehicles are ocean development company, underwater TV company, heavy industry and telephone and telegraph company.

The smallest can be carried by a man and the largest weighes about 3.5 tons. The purpose of this paper is to review ROVs in Japan. Additionally a brief look will be taken at robotics and manipulators.

ROVS OPERATIONAL

MURS-300

This vehicle was developed by Mitsui Ocean Development Co. (MODEC) in 1979.

Specifications are;

Operational depth	300 m
Weight in air	2600 kg
Size	270(L) x 210(W) x 185(H) (cm)
Speed	3 knots
Propulsion	7.5 HP x 4
Instrumentation	Color TV x 1, LLL b/w TV x 1, light 250 W x 4, 500 W x 2, CTFM Sonar, gyrocompass, depth sensor, alti--meter, manipulator (7 d.f.)
Remarks	The vehicle is not so active. The last dive was in the April of 1982.

ROV-400

This launcher type vehicle was built by Mutsui Shipbuilding Co. in 1980 and owned by JAMSTEC.

Operational depth	400 m
Weight in air	Vehicle 120 kg Launcher 270 kg
Size	Vehicle 74(L) x 76(W) x 150(H) (cm) Launcher 110(L) x 100(W) x 150(H)
Speed	1.5 knot
Propulsion	200 W DC x 4
Instrumentaion	Color TV with tilt mechanism x 1, light 500 W x 2, Magnetic compass, depth meter
Remarks	The vehicle is also not so active. The last dive was in the summer of 1982.

Mosquito

A simple open frame vehicle which was designed and built by JAMSTEC and HOKUSHIN electric Co. in 1980.

Operational depth	100 m
Weight in air	45 kg
Size	70(L) x 55(W) x 38(H)
Speed	1 knot
Propulsion	Two magnetic torque coupling thrusters provide forward/ reverse motions. Depth is controlled by up--down of the cable.
Instrumentation	b/w TV x 1, light x 1

JTV-1,2 and DLT-300-1,2

JTV-1 was designed and built by JAMSTEC. JTV-2 and DLT-300-1 are a commercial vehicle, constructed by Q.I. Co.,Tokyo under the permission of JAMSTEC. DLT-1 was delivered to a diving company in 1982. DLT-2 is under construction and to be delivered to the National Institute of Polar Research.

Operational depth	: 200m , 500 m(option)
Weight in air	: 43 kg(JTV-1), 48 kg(DLT-1,2)
Size	: 52(L) x 64(W) x 50(H) (cm)
Speed	: 2 knots
Propulsion	: Four 100 W DC magnetic torque coupling thrusters provide three dimensional motions.
Instrumentation	: CCD color,b/w TV, light 150 W x 2, magnetic compass, depth meter, still camera

MARCAS

The vehicle is designed and constructed by KDD Laboratory for inspection of submarine cables and soil property tests. The vehicle is completed in 1981. Unique characteristics of the vehicle are using fiber-optic tether cable.

Operational depth	: 200 m
Weight in air	: 570 kg
Size	: 120(L) x 180(W) x 110(H)
Speed	: 2 knots
Propulsion	: 3 HP AC motor x 4, Altitude from the sea bed is automatically maintained.
Instrumentation	: Color TV x 1,SIT b/w TV x 1,light 300 W x 2, AC and DC magnetic sensor, magnetic compass, pinger direction finder, metal detector, soil tester
Remarks	: The vehicle using a wavelength division multiplex optical fiber transmission and optical rotary joint for data transmission. The vehicle is mainly used in the Japan Sea and East China Sea.

OTHER VEHICLES

There is other two vehicles, one is a launcher type vehicle of Mitsubishi Heavy Industry and the other is a 300m vehicle of MODEC, both vehicles utilizing fiber-optic cables.

ROVS UNDER DEVELOPMENT

Three ROVs are under development in JAMSTEC. They are Submarine Robot, HORNET-500 and DOLPHIN-3K. All of them are planned to use optical fiber tether cable and wavelength division multiplex optical fiber transmission. The main features of them are shown in Fig.1.

Submarine Robot (BOX FISH)

A battery powered test vehicle for the future development of highly intelligent vehicle. The vehicle has two micro-computers and controlled by optical fiber cable transmission or preprogram. The vehicle shall be completed in the summer of 1983.

HORNET-500

The vehicle is larger and deeper version of JTV-1. The vehicle utilize fiber-optic and electrical cable of 7 mm diameter. The cable is composed of 2 power conductors, 2 glass fiber reinforce optical fibers and 3 tension members(glass fiber). The cable was developed under cooperation between JAMSTEC and Furukawa Electric Co. Ltd. The vehicle has one color TV(ENG) and one b/w after TV, one still camera and manipulator The vehicle shall be completed at September in 1983.

DOLPHIN-3K

JAMSTEC is now developing a larger ROV for deep sea survey. The vehicle,named DOLPHIN-3K, is capable to dive 3300 m of depth. The vehicle shall be completed at 1986. Specifications of the vehicle are:

Operational depth	: 3300 m
Weight in air	: 3.5 tons (approximate)
Size	: 300(L) x 200(W) x 190(H) (cm) (approximate)
Speed	: 3 knots
Propulsion	: 10 HP x 2 (f/r),7.5 HP x 2 (u/d),7.5 HP x2 (port/stbd)
Instrumentation	: Color TV (ENG) x 2, SIT b/w TV x 1, b/w stereoTV x 1, still camera, CTDV, obstacle avoidance sonar,direction finding sonar,

	altimeter, depth meter, current meter, manipulator, grabber/cutter.
Remarks	: The tether cable of the vehicle is under testing.

ROBOTICS,MANIPULATORS

Robot industry in Japan is highly advanced but very few of robot technology is applied in the sea. MITI has a plan of Working Robot at severe environments. Working Robot in the sea is one of the plan, but precise schedule are not known. JAMSTEC is planning to develope highly intelligent vehicle, but it takes rather long time to complete such a vehicle. Manipulators for underwater vehicles are shown in Fig.2. Automax Co.Ltd. is a main developer of manipulator.

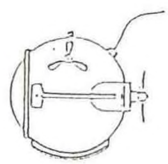
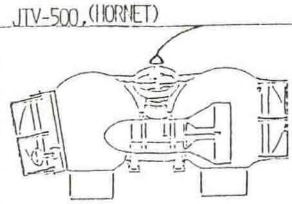
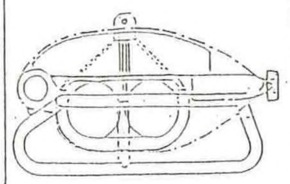
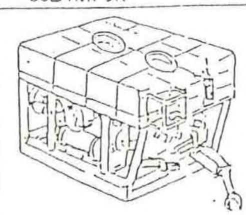
	JTV-1, (LADYBIRD)	JTV-500, (HORNET)	SUBMARINE ROBOT, (BOX FISH)	DOLPHIN-3K
				
DIM. WEIGHT	ø 430, 43 KG	1130L x 960W x 560H, 90 KG	1200L x 1200W x 600H, 120 KG	3000L x 2000W x 1900H, 3500 KG
DEPTH	200 M	500 M	500 M	3300 M
POWER S.	AC 100 V	AC 1100 V	BATTERY 24 V 40 AH	AC 2500 V
COMMUNICAT.	TWO-WAY ASYNCHRONOUS	MULTI-OPTICAL WAVE LENGTH	MULTI-OPTICAL WAVE LENGTH	MULTI-OPTICAL WAVE LENGTH
CABLE.	ø 16	ø 7 OPT.FIBER POWER CONDUCTOR	ø5 (ø 1) OPT.FIBER	ø 30 OPT,FIBER,POWER CONDUCTOR
INSTRUMENTATION	COLOR TV (CCD) x L LIGHT 150 W x 2 STILL CAMERA,STROBE DEPTH SENSOR COMPASS 4 x 70 W DC THRUSTERS (MAGNETIC TORQUE COUPLING)	COLOR TV (500 LINE) x 1 B/W TV x 1, LIGHT x 4 STILL CAMERA, STROBE DEPTH SENSOR RATE GYRO 2 x 200 W DC,2 x 120 W DC (MAGNETIC TORQUE COUPLING)	STEREO-COLOR TV x 1 LIGHT x 2 DEPTH SENSOR MAGNETIC COMPASS 2 x 110 W DC, 2 x 70 W DC (MAGNETIC TORQUE COUPLING)	COLOR TV, STEREO-TV,B/W TV LIGHT MORE THAN 6 STILL CAMERA,STROBE x 2 DEPTH SENSOR GYRO, RATE GYRO MANIPULATOR (7 D.F.) GRABBER/CUTTER (5 D.F.) 10 HP x 2 THRUSTERS 7.5 HP x 4 THRUSTERS

FIG.1 SPECIFICATIONS OF VEHICLES DEVELOPED IN JAMSTEC

Fig 2. Manipulators(Specification)

	Vehicle name	JAMSTEC	KAWASAKI	HAKUYO	SHINKAI 2000	MURS-100	MURS-300	DOLPHIN-3K
VEHICLE	Weight in Air	--	--	6.6	24	0.9	2.6	3.5
	Depth	--	--	300	2000	100	300	3300
	Payload	--	--		0.1			0.15
	Completed Year	1976	1980	1971	1981	1981	1975	To be completed in 1986
MANIPULATOR	Type	Hyd.	Hyd.	Hyd.	Hyd.	Hyd.	Hyd.	Hyd.
	D.F.	7	7	5	6	6	7	7
	Force feed back	7 (Force reflecting)	7 (Symmetrical)	--	--	3	--	4 (Symmetrical)
	Lift (kgf)	50	45	10	20	10	20	20
	Reach (m)	1.2	1.8	1.5	1.5	1.2	1.2	1.5
	Weight (kg)	110	200	100	147	55	88	88
	Shoulder Rotation		-80°~+20°	±30°	150°			
	LFT-RT	90°	-30°~+80°	90°	55°	150°	120°	0°~-90°
	FWD-SWD	90°				75°	120°	-30°~-90°
	Elbow Upper Arm Rotation	90°				180°	180°	-90°~-90°
	UP-DWN	120°	-5°~-125°	210°	105°		120°	0°~120°
	LFT-RT					165°		
	Wrist Rotation	180° Forearm	-90°~+90°	180°	±90°			
	LFT-RT		-60°~+60°		220°		120°	-60°~-60°
	UP-DWN	90°	-30°~+90°			120°	120°	-90°~30°
	Grasp Opening (mm)	100	0~150	100	150	130	100	150

TRAINING DIVE OF SHINKAI 2000

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ABSTRACT

Japanese 2000m deep submergence research vehicle "SHINKAI 2000", delivered to JAMSTEC on October 1981, has been placed at the training of the pilots after the delivery. And from June 1983, she has been placed for the mission divings. In this paper, the outlines of the training, newly developed observation and sampling apparatuses, and the results of the annual survey are presented.

SHINKAI 2000 has been developed for researches on geophysics, biologies, sea floor mineral resources, bio resources and inspections of artificial objects etc., and was delivered to JAMSTEC on October 1981.

Principal particulars of SHINKAI 2000 is as follows;

L(OA)	9.3m	Crew	1 Observer
B(MLD)	3.0m		2 Pilots
D(MLD)	2.9m		
Weight(in air)	23.3ton	Payload	100kg
Maximum Operating Depth			2,000m

1. TRAINING DIVE

In order to train the pilots of SHINKAI 2000, they were trained using both the operation simulator on land and SHINKAI 2000 herself at sea.

Training dive at sea was carried out from January 1982 to May 1983 as seen in Table 1.

The training on the launch and retrieval operation by support ship "NATSUSHIMA" was carried out using dummy model of SHINKAI 2000 before the training dive.

Total dives are 58 times and dive hours in total are 221 hours.

Through these dives, some mechanical troubles occurred but the training dives have been almost carried out following to the initial plan (see Photo 1).

1.1. EXAMPLE OF 2000M DIVE

In Fig.1, the typical dive profile to 2,000m deep is shown, which was executed on 25 March 1983 at KUMANONADA.

1.2. RESULT OF DIVE TRAINING

(1) The underwater acoustic navigation system worked so well that NATSUSHIMA could track the descending, ascending, cruising and bottomming

SHINKAI 2000 precisely.

(2) SHINKAI 2000 could find out and pick up the silent pinger that had lost at sea from the support ship through training dive, and showed good abilities for the survey of the lost objects. Moreover, she could carry out the operations at the area of cliff and slope.

(3) After about one year training, JAMSTEC team could succeed to dive to 2000m deep sea and got technics and procedures necessary for the deep diving including the launch and retrieval operation of SHINKAI 2000.

(4) Manipulator worked well however more improvement is required for the accurate handling of some of the observation and sampling apparatuses such as rock drill.

(5) SHINKAI 2000 has observed dislocation and many types of life through one year training dives. There are some kind of fishes (see Photo 2) which are found as the first time in Japan. Then the research dives beginning from Summer of 1983 are showing fruitful results.

2. NEWLY DEVELOPED RESEARCH AND OBSERVATION APPARATUSES

SHINKAI 2000 has one manipulator, sample tray, stereo camera, monochrome TV camera but these apparatuses are not sufficient for the underwater survey and research. So JAMSTEC has newly developed water sampler, sediment sampler etc., and tested fitting to SHINKAI 2000 at deep sea (see Photo 3).

(1) Water Sampler

Type I (for midwater)

Capacity	1 lit. x 9
Closing Media	Step Motor

Type II(for bottom)

Capacity	2 lit. x 3
Motor	AC100V/60Hz 15W
Pump	Max. 15 lit./min

(2) Sediment Sampler

Type A (Core Type)	50mmdiax200mm with core retainer
Type B (Grab Type)	Motor Drive

(3) Sub Bottom Profiler

Frequency		4.5 kHz
Acoustic Output Level		variable Max. 96 dB/1μbar
Beam Width	Transmitter	50°x75°
	Receiver	75°x75°

(4) Water Sensor

Depth, Dissolved Oxygen, PH
Acoustic Velocity

(5) 1 kW Light

Type	Halogen Lamp
No. of Light	3

(6) Rock Drill

Type	Electro Hydraulic Type
Core	20mmdiax460mmlong
No. of bit	6 exchangeable in underwater

3. EXPERIMENT OF RESCUE BUOY SYSTEM AT DEEP SEA

SHINKAI 2000 has a rescue buoy in order to cope with the emergency situation.

This rescue buoy system was experimented using a dummy sinker, and its performance was confirmed to be able to retrieve the submersible from 2000m deep sea easily (see Fig.2).

Safety is one of the most important features for the manned submersible, therefore, besides this rescue buoy system, JAMSTEC is now developing the unmanned submersible "DOLPHIN-3K" which can be applied to the rescue operation. The outline of this vehicle is shown in Dr. HATTORI's paper "Remotely Operated Vehicles and Robotics, Manipulators" at this UJNR-MFP Meeting.

4. ANNUAL SURVEY OF SHINKAI 2000

(1) SHINKAI 2000 was repaired at the annual survey under the Ship's Safety Law of Japan between October 1982 and January 1983. In this survey, pressure hull, hatch, view port, navigation and communication apparatuses, life support system, rescue and safety system etc. were fairly checked. They were in good conditions. All systems were again assembled and completely tested in the water and at sea. They showed good performances.

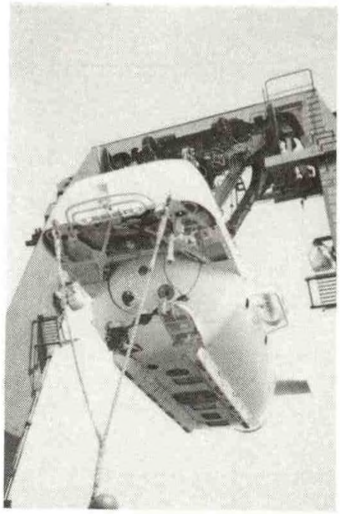
(2) Main batteries are so designed as to be exchanged at 75 cycles charge and discharge or one year whichever short. So JAMSTEC exchanged these batteries with new ones at the annual survey, which had been used about one year. However, for the longer use of these batteries, endurance limit will be tested and confirmed using actual one.

(3) Launch and Retrieval system of NATSUSHIMA is in very good condition. The breaking strength of lifting rope (85mmdia Tetlon Nylon Double Braided type) showed 83% value relative to the initial strength (165ton) after 40 cycles of launch and retrieval operations.

(4) In April 1983 after 2000m dive, SHINKAI 2000 was registered to NIPPON KAIJI KYOKAI (NK), Japanese classification society, as the first submersible for the society.

TABLE 1. TRAINING DIVE 1982/1983

VOYAGE	DATE	No. of DIVES	SEA	DEPTH(m)	NOTE
1983-I	1982.1.26-3.25	3	SAGAMI	4-20	TEST DIVE, TRAINING DIVE
II	1982.4. 6-4.27	10	SAGAMI	50-320	TRAINING DIVE
III	1982.5.21-6.25	16	SAGAMI	98-507	TRAINING DIVE
IV	1982.9.10-9.18	3	SAGAMI	820-830	TEST DIVE, TRAINING DIVE
	1983.1. 7-2.23	12	KII-SUIDO	245-1000	TEST DIVE, TRAINING DIVE TEST OF WATER SAMPLER AND CORE TYPE SEDIMENT SAMPLER
	1983.3. 4-3.25	8	SURUGA KUMANONADA	1370-2000	TRAINING DIVE
1983-I	1983.4.19-5.26	11	SURUGA	970-1570	TRAINING DIVE, TEST OF SUB-BOTTOM PROFILER AND GRAB TYPE SEDIMENT SAMPLER



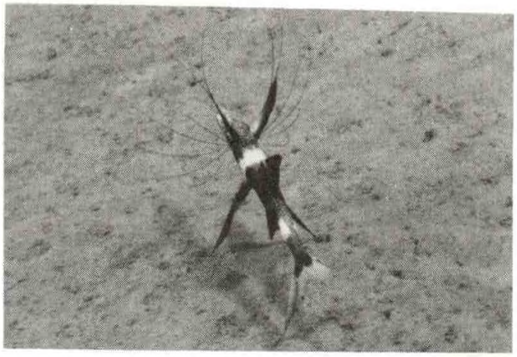


Photo 2. Tri-Pod Fish Photographed at the depth of 800m

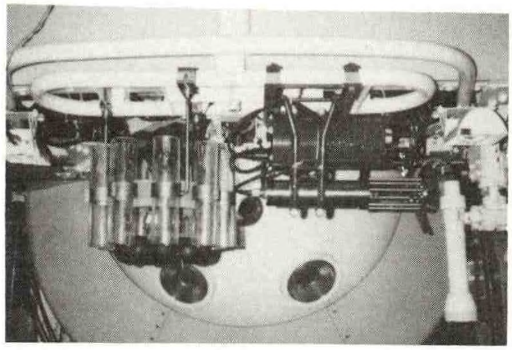


Photo 3-1 Water Sampler and Water Sensor

←Photo 1 SHINKAI 2000 and A-Frame Crane

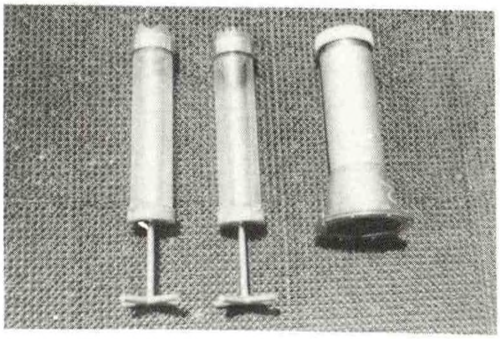


Photo 3-2 Core Type Sediment Sampler

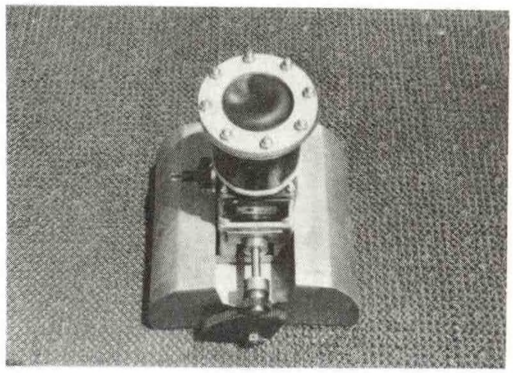
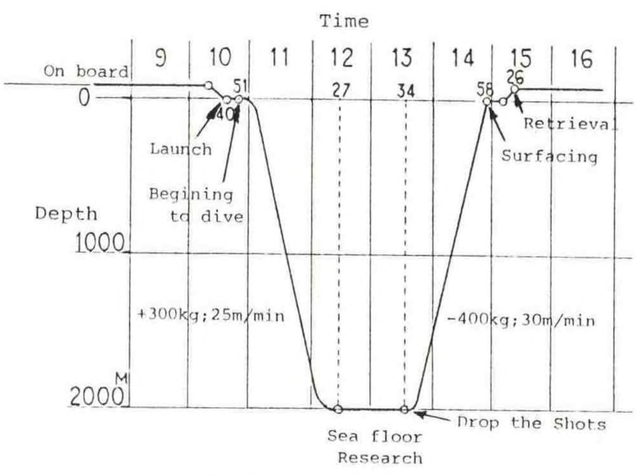


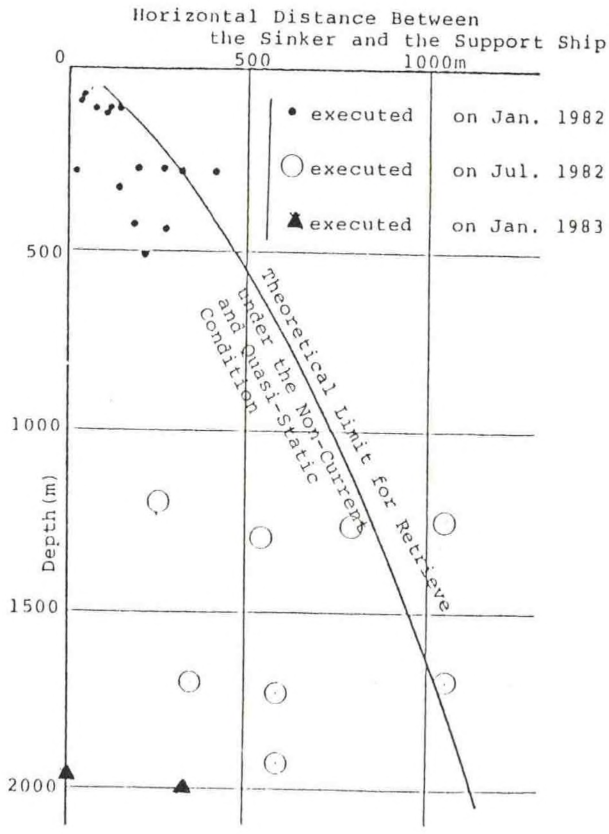
Photo 3-3 Grab Type Sediment Sampler

Fig. 1. Typical Dive Profile



Area; KUMANONADA 2,000m deep
Date; 25 March 1983
Sea State; 3
Crew; 2 Pilots and 1 Observer

Fig.2 Experimental Results of Rescue Buoy System at Sea



UNDERSEA VEHICLES - AN OVERVIEW

R. FRANK BUSBY

BUSBY ASSOCIATES, INC.

The undersea vehicle field continues strong. Specialization in vehicle types and capabilities has resulted in expanded task performance in all areas of oil exploitation, the chief factor in their development and growth. The future of "conventional" manned submersibles is uncertain, while the future of ROVs seems positive. Having demonstrated reliability, the manufacturers and operators of ROVs are currently engaged with increasing the data quality and work versatility of this class undersea vehicle.

The offshore oil and gas industry sparked a virtual revolution in the undersea vehicles community; particularly in the area of remotely operated vehicles (ROVs). Although the diver still remains the mainstay of the underwater service industry, every major company includes in its inventory a variety of vehicles, each one providing a specific capability unique to its design. These vehicles and capabilities include manned submersibles, ROVs and hybrid vehicles.

MANNED SUBMERSIBLES

Within this category are five vehicle types: 1) one-atmosphere, untethered swimming vehicles; 2) one-atmosphere, tethered vehicles; 3) observation/work bells; 4) lockout vehicles; and 5) atmospheric diving suits.

One-Atmosphere, Untethered Vehicles

This class of manned submersible constitutes the more or less "conventional" vehicle. They support the occupants at one-atmosphere pressure and are self-powered by batteries. Maneuverability is obtainable in the x, y and z axes by control of onboard thrusters. (Representative vehicle: ALVIN)

One-Atmosphere, Tethered Vehicles

Accommodates one person at atmospheric pressure, power supplied from the surface via an umbilical cable, maneuverability 3-dimensional by thrusters. Designed and used primarily for work on and about fixed structures. (Representative vehicle: MANTIS)

Lockout Vehicles

Submersible configured into two sections (generally interconnected), one section is at 1-atmosphere pressure and supports pilot and observer, the second section can be pressurized to ambient pressure and serves to lockout diver and to support diver/tender and supervisor. Vehicle is generally free-swimming, electrical power is generally supplied by onboard batteries, but can also be from a surface-connected umbilical. Maneuverability is obtainable in the x, y and z axes by control of onboard thrusters. Life support, diver heating, and breathing gasses carried onboard. (Representative vehicle: PC-1202)

Observation/Work Bells

Occupants at one-atmosphere pressure. Power derived from batteries or umbilical cable. Designed for finely-controlled maneuverability in the x-y axes around and within structures, limited self-maneuvering capability in the vertical (z) axis. Always operates with tether to the surface. (Representative vehicle: ARMS)

Atmospheric Diving Suits (ADS)

One person capacity. Occupant at one-atmosphere pressure. Powered by operator or through surface-connected umbilical and tethers. Two dimensional to three-dimensional maneuverability, anthropomorphic configuration. (Representative vehicle: WASP/JIM)

REMOTELY OPERATED VEHICLES

Four vehicle types fall into this category: 1) tethered, free-swimming vehicles; 2) bottom-crawling/structurally-reliant vehicles; 3) towed vehicles; and 4) autonomous vehicles.

Tethered, Free-Swimming Vehicles

Provides CCTV and is capable of maneuvering in three dimensions. Power is supplied from the surface via an umbilical cable. Designed primarily for mid-water operations. Dives positively bouyant and relies on verticle thrusters to remain submerged. Manipulative capability available. (Representative vehicle: RCV-225)

Towed Vehicles (Mid-Water)

Closed Circuit TV (slow scan). Propelled and powered by support ship via a surface connected umbilical cable. Power unlimited. Maneuverability in x and y axes controlled by tow ship direction, z axis controlled by winch on ship. Generally designed for 6000 in depth. (Representative vehicle: DEEP TOW)

Towed Vehicles (Bottom and Structurally Reliant)

CCTV generally available. Propulsion and power obtained from support ship. Vehicles are supported by a pipeline or structure on which the vehicle is towed from the surface. All vehicles in this category are used for pipeline or cable trenching. All of these vehicles are one of a kind and purpose-designed; consequently, there is no typical representative.

Bottom-Crawling Vehicles

CCTV generally supplied. All power and control is from a surface platform via an umbilical. Vehicles obtain propulsion from wheels or caterpillar-like tracks in contact with the bottom. The majority of these vehicles are large, massive affairs used for pipeline and cable trenching--or bottom excavation. There are no typical representatives.

Structurally-Reliant Vehicles

Vehicles in this category obtain their power from the surface and their propulsion from wheels, rollers or push/pull rams in contact with a pipeline, rails or a ship's hull. Most have CCTV, all are specifically designed to conduct a specific task, such as pipeline trenching, hull cleaning/ inspection or Subsea Production Systems Maintenance.

Autonomous Vehicles

Vehicles in this category are self-powered (batteries) and operate without an umbilical. Maneuverability is generally in 3-dimensions and data collected is stored aboard the vehicle. None transmit TV signals and all are essentially in the development stage. They may operate within a preprogrammed schedule or, in some instances, they receive course changes and commands from the surface via an accoustic link. No one vehicle is representative of this group.

HYBRID VEHICLES

These vehicles are combinations of the foregoing vehicles and the diver to provide a specific capability. Several such vehicles are in use in offshore oil today, and include the following:

Diver/ROV

Controlled by diver or remotely. Provides diver assistance in underwater inspection, maintenance or construction/repair. (Representative vehicle: DAVID)

Diver/ROV

Bottom-crawling pipe trencher controlled by diver. (Representative vehicle: Comex Services)

ROV/Submersible

Bottom-crawling pipe trencher controlled by crew in a one-atmosphere chamber. (Representative vehicle: Travocean Co.)

ROV/Submersible

Tethered, free-swimming vehicle controlled by crewman in a one-atmosphere chamber or remotely from the surface. (Representative vehicle: DUPLUS II)

GROWTH OF FIELD

There are a variety of factors which have encouraged sub-surface penetration of the ocean. Until the 1960's, the driving forces were food, gems, salvage, military advantage and recreation. For a brief period in the sixties science was a driving force. But nothing has had an effect equal to the present force of offshore oil and gas. Tables 1 and 2 speak eloquently for the influence of the offshore energy field which began in ernest to penetrate deeper, more hostile waters in the early seventies. Of particular interest is the growth in Tethered, Free-Swimming ROVs.

WORK ACCOMPLISHMENTS

In only a very few instances do specific types of vehicles conduct work which only they are exclusively capable of performing. At any given time the diver, the manned submersible and the ROV can be found conducting similar tasks. The deciding criteria in the offshore oil and gas industry is what can do the job successfully and at the least cost. A listing of the tasks performed by undersea vehicles for offshore oil/gas, other industrial interests and military activities is presented in Table 3.

TRENDS

The following observations are brief capsulizations of trends which have developed over the past several years in the undersea vehicle field. There is no intention to attempt to forecast what will be forthcoming. Such forecasts are not impossible, they are simply unrealistic without knowing what the price of a future barrel of oil will fetch.

General

The recent drop in oil prices has yet to make a visible impact on industrial undersea vehicle activities. ROVs, in particular, are currently used primarily in support of oil and gas production. This phase has not slackened. The greatest impact has been on the diver who has dominated the exploration and, particularly, the developmental phases of the offshore oil and gas industry.

The vehicle field is undergoing a significant transition. In the late 1950's and the 1960's, this was a fledgling industry where simply penetrating the ocean's depths was an achievement. Gone now are the frequent claims of "firsts" which dominated the early years. Now, both the participants and the vehicles have matured, and go about their business with little, if any, of the sixties' fanfare. The emphasis now is aimed at improving the quality and expanding the quantity of work the vehicles can accomplish. The feasibility of placing man or his surrogate beneath the surface has long since been demonstrated. Now the goal is to produce reliable vehicles equipped with reliable tools and support systems. We have, in one author's terms, "greened."

A great deal of effort is being placed on manipulative devices. Whereas most of today's manipulations are of the "rate-type", there is an increased trend toward spatially correspondent manipulations with proportionate speed. In this latter type the manipulative movement parallels the human arm and its speed is proportionate to the displacement of the operator's control. The most advanced of these manipulations include: tactile feedback; force feedback; and ambient noise monitoring.

Manned Submersibles

The industrial applications of manned submersibles has fallen off significantly. Of the 267 vehicles produced since 1960 (Table 1), only 142 of these have operated within the past three years or are in a condition where they could be readied for diving within 30 days. Of the 142 total vehicles, 38 are government funded and 7 more are under construction. There are only two manned submersibles presently under construction for an industrial customer. The greatest casualties have been in one-atmosphere untethered and lockout submersibles. As far as can be determined, all vehicles in the one-atmosphere, tethered, observer/work bell and ADS categories are operational. The reason for this fall off in activity seems to be the advent of the ROV and, possibly, the limitations of battery power. The future of the one-atmosphere, untethered vehicle and the lockout vehicle in industrial use is uncertain.

One aspect of manned vehicles which has shown increased activity is in the area of power. Projects are underway in England, France and Italy to equip submersibles with closed-cycle diesel or stirling engines.

Remotely Operated Vehicles

ROVs have taken center stage in the undersea vehicle area. Their phenomenal increase can be seen in Table 2. There is, as of now, no indication that the field is saturated. But the subject of oversaturation is (and has been since 1978) of great interest. One aspect of tethered, free-swimming ROVs that has made itself clear is a sorting out in the numbers of manufacturers of industrial vehicles. Of the 610 vehicles which have been built since 1960, approximately 450 have been produced by four companies, there have been 28 different manufacturers of tethered, free-swimming ROVs, since 1960.

Specialization in ROV design to perform a specific task is on the increase. Current efforts in this area have included anode replacement vehicles; deep drilling support vehicles; mine neutralization vehicles, pipeline inspection vehicles; diver assist vehicles; light, medium and heavy inspection/work vehicles and a wide array of bottom-crawling and structurally reliant vehicles designed to perform single-purpose tasks.

A greater attention is being paid to ROV umbilical cables; particularly in the area of fiber optics. The application of fiber optics in reducing umbilical diameter, increasing bandwidth and reducing electrical noise is a subject of current interest both in the industrial and military community.

Since television is one of the most critical capabilities of ROVs, it is not surprising that efforts are increasing to provide higher quality TV viewing. There are over 18 manufacturers of underwater TV cameras. The rate at which they announce the advent of a "new", "improved" or "innovative" TV camera is almost dizzying. Current interest seems to be centered at the CCD (Charged Coupled Device) camera which eliminates the imaging lines element and can be used for both color and black and white.

CAPSIZING OF MOORED SEMI-SUBMERSIBLE PLATFORM AND ITS SIMULATION

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ABSTRACT

This paper presents the some results of both theoretical and experimental studies on the capsizing of moored semi-submersible platform in waves. Especially, the author's attention is paid to analysis of the larger steady tilt of the platform under the excitation caused by the wave-induced vertical lift force on the lower hulls. The time histories of the platform motions predicted by the present method are compared with the experimental ones with good agreement.

1. INTRODUCTION

Over many years, semi-submersible platform have been believed to be most stable floating structure in waves and numbers of this type structure have been constructed for drilling oil in the open sea. However, because of short historical background of semi-submersible platform, it is considered that many unknowns concerning with the stability exists. Since the existing stability criteria of the most classification society for semi-submersible platform are based on free floating body like conventional ship, they are not considering current force, wave-induced steady forces, mooring forces which are important factor for the moored body. Some attempts to study on the stability of semi-submersible platform have been done since the ABS rule on the stability criterion came into force in 1973. Recently, Numata et al. [2] reported that the semi-submersible platforms having small metacentric height had a tendency to behave with a steady tilt in addition to the oscillatory motions in waves and this curious phenomena was considered in order to introduce the serious situation of the semi-submersible platform in waves. This problem indicates that the safety of semi-submersible platforms in waves is still a problem even though the stability requirement is satisfied with the rule.

Wide experimental approach was, therefore, subsequently performed at Hiratsuka Research Labolatory of Sumitomo Heavy Industries, LTD. to realize the capsizing phenomena of the moored semi-submersible platform in the wave tank. The details of this experimental approach was already presented at "Stability '82" in Tokyo in Oct. 1982, and this paper shows analitical studies of those experimental results with simulation.

2. SOME STUDIES ON STEADY TILT OF SEMI-SUBMERSIBLE PLATFORM

The intitial effort has been directed primarily toward experimentation to obtain a better understanding of mechanism of capsizing semi-submersible platform in waves. The model which represented a twin lower hull type platform with eight supporting columns was selected for the tank test and is illustrated in Fig. 1 while the principal particulars of the model is shown in Table 1. The model was moored by eight spread mooring chains at the center of model basin.

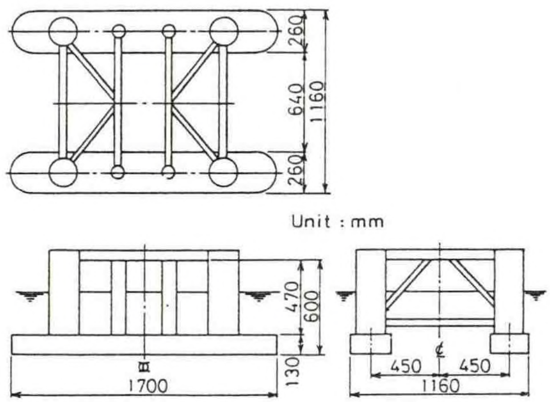

Fig. 1 1/60 Model of Semi-Submersible Platform

	1/60 MODEL	PROTOTYPE
LENGTH OF LOWER HULL(L)	1.7 M	102.0 M
BREADTH OVER LOWER HULLS(B)	1.16 M	69.6 M
DISTANCE BETWEEN LOWER HULLS	0.9 M	54.0 M
DRAFT(d)	0.4 M	24.0 M
DISPLACEMENT(Δ)	163.5 KG	36,200 TON
HEIGHT OF THE CG(KG)	0.3 M	18.0 M
METACENTRIC HEIGHTS		
(GM_T)	0.028 M	1.68 M
(GM_L)	0.044 M	2.64 M
LENGTH OF MOORING LINE	11.5 M	690.0 M
CHAIN WEIGHT PER LENGTH(IN WATER)	0.038 KG/M	136.8 KG/M
PRE-TENSION	0.45 KG	97.2 TON

Table 1 Principal Particulars of 1/60 Model of Semi-Submersible Platform

A lot of experimental works had been imposed for the analysis of the steady tilt of semi-submersible platform by

1) varying fairleader height
2) varying metacentric height
3) varying wave frequency

and so forth. Results obtained from the tank test have shown that the angle of the steady tilt was strongly influenced by the location of the fair-leader as well as the metacentric height(See Fig. 2). When the location of fairleader is higher than that of the center of gravity(CG), the platform has a tendency to tilt to the weather side direction. It is noteworthy that the angle of tilt increases drastically as the wave period decreases and in consequence wave-induced drift force becomes fairly large at such wave period.

To determine the mean tilt angle theoretically, the quasi-static analysis of the steady tilt was conducted. The equations of forces and moments acting on the platform are balanced in equilibrium position and are expressed by the following equations.

$$W + (T_w)_v + (T_L)_v = F$$

$$(T_w)_h - (T_L)_h = D$$

$$M_D + M_T = F \cdot GZ$$

where D : Drift Force
W : Displacement
F : Buoyancy
GZ : Lever Arm from CG
M_D, M_T : Overturning Moments due to Steady Force and Mooring Tension
T : Mooring Tension

suffix w : weather side
L : lee side
h : horizontal direction
v : vertical direction

Fig. 2 shows the comparison between the experimental data and the calculated results obtained by the previous equations for the steady tilts due to different fairleader height. It is seen that the estimated steady tilts are agreeable with experiment qualitatively but not quantitatively. This indicates that more larger heeling moment should be induced by other additional forces such as the steady lift force on the lower hulls. The effect of the steady lift forces on the lower hulls originally have been argued by Numata et al.[2] as the steady tilt phenomena of unmoored semi-submersible platform. It is extremely difficult to assess such complicated behavior of the moored semi-submersible platform in waves by means of the quasi-static solution. In such a case, non-linear analysis of time domain may be applicable to simulate the dynamic behaviors of the platform.

The steady tilt phenomena caused by the difference in vertical second order steady lift force on each lower hull becomes significant in the case of the listing semi-submersible platform having small GM. Especially, when the platform has larger angle

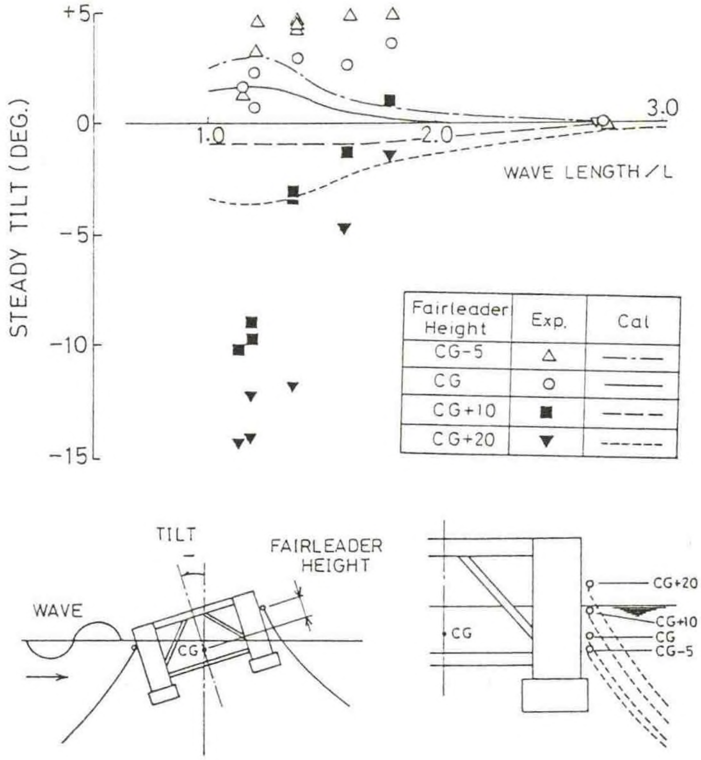

Fig. 2 Steady Tilt of Moored Semi-Submersible Platform in Beam Sea(H_w = 25 cm)

of tilt by mooring lines, the heeling moment due to the vertical lift force increases drastically and causes the serious situation of the platform. Photo. 1 shows some serious situation of the model which was considered as capsizing phenomena. This phenomena appears to occur in relatively short, steep regular waves(wave height = 25 cm or 15 m in full scale, wave period = 1.141 sec. or 8.8 sec. in full scale). It is interesting to note that the wave having 15 m in height and 8.8 sec. in period is no longer considered as the severest design sea state for existing platform in open sea.

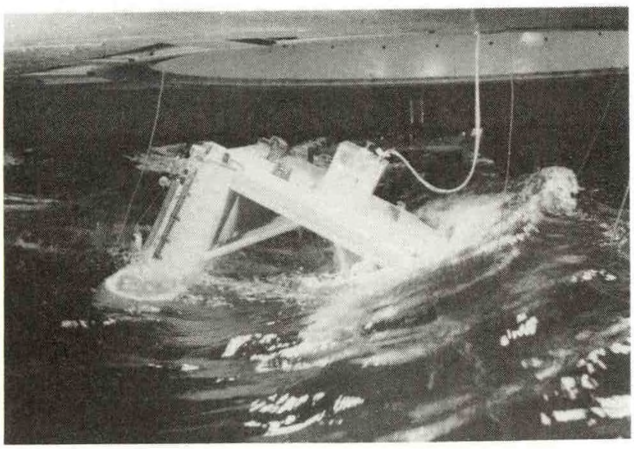

Photo. 1 Some Dangerous Behavior of Moored Semi-Submersible Platform in Waves

3. DYNAMIC BEHAVIOR OF THE MOORED PLATFORM BY TIME-DOMAIN SIMULATION

The simulation in time-domain is required to clarify the mechanism of the capsizing semi-submersible platform. The investigation presented here was undertaken in response to this need. The method was developed by using strip theory for computing hydrodynamic coefficients and wave excitations. The motions of platform were computed by solving coupled non-linear equations of motions for beam sea in time-domain.

The frame of reference for platform motions is a right-handed Cartesian coordinate system originating at the center of gravity of the platform(See Fig. 3). The equations of platform motions are as follows:

Sway (X)

$$(M + A_{11})\cdot\ddot{X} + A_{12}\cdot\ddot{Z} + A_{13}\cdot\ddot{\phi} + \rho/2\cdot C_{dx}\cdot A_x\cdot|\dot{X} - \tilde{z}\cdot\dot{\phi} - \dot{\xi}|\cdot(\dot{X} - \tilde{z}\cdot\dot{\phi} - \dot{\xi}) - \sum_j T_{xj} = F_1(t) + F_{d1}$$

Heave (Z)

$$(M + A_{22})\cdot\ddot{Z} + A_{21}\cdot\ddot{X} + A_{23}\cdot\ddot{\phi} + \rho/2\cdot C_{dz}\cdot A_z\cdot|\dot{Z} + \tilde{x}\cdot\dot{\phi} - \dot{\zeta}|\cdot(\dot{Z} + \tilde{x}\cdot\dot{\phi} - \dot{\zeta}) + C_{22}\cdot Z + C_{23}\cdot\phi - \sum_j T_{zj} = F_2(t) + F_{d2}$$

Roll (ϕ)

$$(I_\phi + A_{33})\cdot\ddot{\phi} + A_{31}\cdot\ddot{X} + A_{32}\cdot\ddot{Z} + \rho/2\cdot C_{dx}\cdot A_x\cdot|\dot{X} - \tilde{z}\cdot\dot{\phi} - \dot{\xi}|\cdot(\dot{X} - \tilde{z}\cdot\dot{\phi} - \dot{\xi})\cdot\tilde{z} + \rho/2\cdot C_{dz}\cdot A_z\cdot|\dot{Z} + \tilde{x}\cdot\dot{\phi} - \dot{\zeta}|\cdot(\dot{Z} + \tilde{x}\cdot\dot{\phi} - \dot{\zeta})\cdot\tilde{x} + C_{33}\cdot\phi + C_{32}\cdot Z - \sum_j(T_{xj}\tilde{z}_j - T_{zj}\tilde{x}_j) = F_3(t) + F_{d3}$$

where
- $\tilde{x}_{(j)}, \tilde{z}_{(j)}$: Lever from CG in x and z directions
- M, I_ϕ : Basic mass and moment of inertia in roll
- A_{ij}, C_{ij} : Added mass and restoring coefficient
- ρ : Density of water
- C_{dx}, C_{dz} : Viscous damping coefficients in x and z directions
- ξ, ζ : Displacements of wave particle in x and z directions
- A_x, A_z : Shaded area of lower hulls in x and z directions
- T_{xj}, T_{zj} : Mooring Tensions in x and z directions
- $F_i(t), F_{di}$: First and second order wave forces or moments

($\bar{x}, \bar{z}$) . . . Coordinate System for Wave

(x, z) . . . Coordinate System for Motions

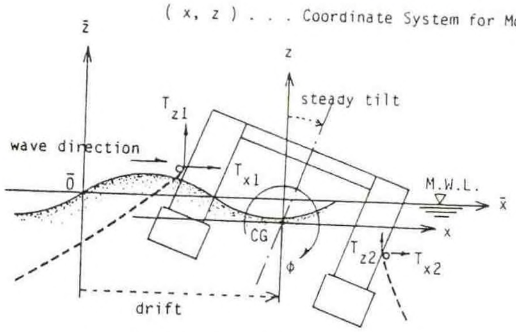

Fig. 3 Coordinate System of Simulation

Fig. 4 illustrates the sway and roll motions of the model in regular waves(wave height = 25 cm , wave period = 1.141 sec.) obtained from experiment and theoretical simulation. Since the fairleader is located at lower position from CG, the angle of steady tilt results as possitive direction(lee side direction). In the case of the higher fairleader height than CG, the model has a tendency to heel weather side down as is shown in Fig. 5. In Fig. 5, Roll(1) indicates the result of roll motion with the effect of steady lift force while Roll(2) is the case neglecting the steady lift force. Since the model had a tendency to incline in the direction of pitch at the 25 cm wave height in the tank test, the wave height was changed to 20 cm for these comparisons. Although the angle of steady tilt by simulation results as somewhat larger than that of experiment, Fig. 5 indicates that the influence of the second order wave force acting on the lower hulls in vertical direction (which is considered as small in magnitude) cannot be disregarded for the estimation of the tilt angle of moored semi-submersible platform in waves.

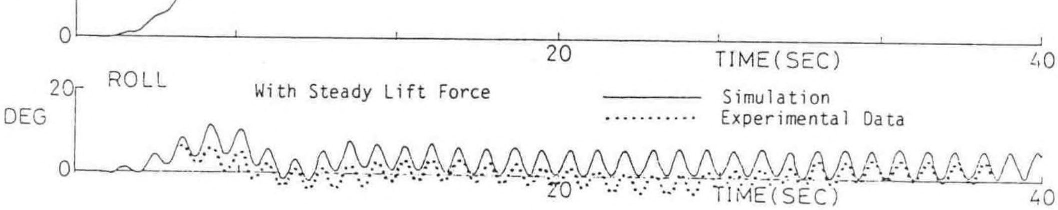

Fig. 4 Theoretical Results of Platform Motions in Beam Sea Obtained from Computer Simulation

(H_w = 25 cm, T_w = 1.141 sec. ; Fairleader = CG - 5)

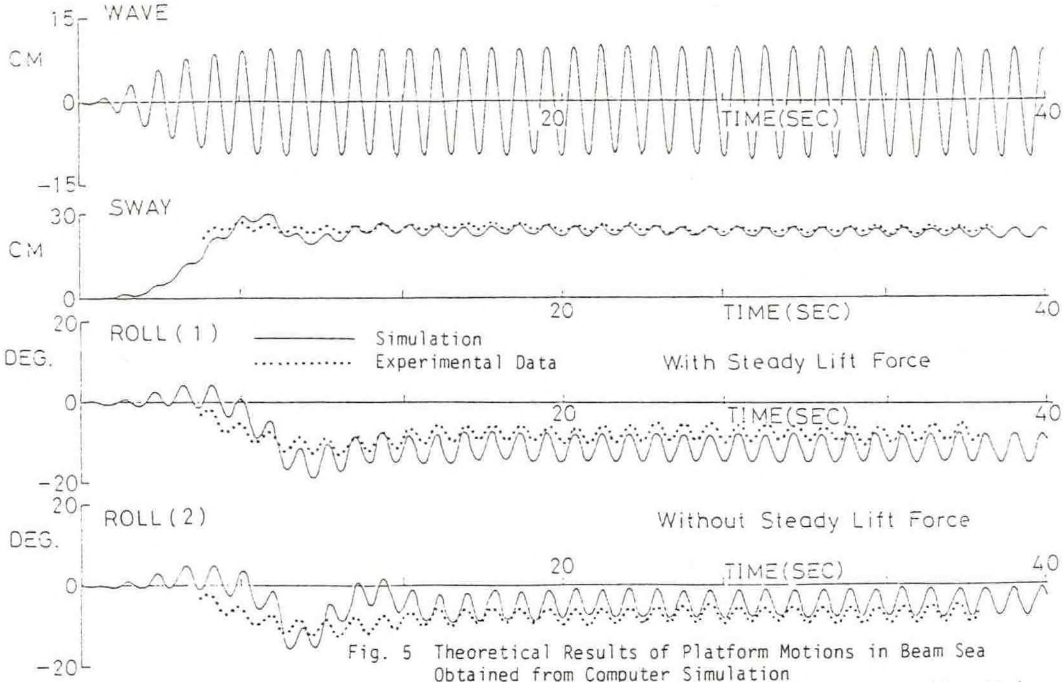

Fig. 5 Theoretical Results of Platform Motions in Beam Sea Obtained from Computer Simulation (H_w = 20 cm, T_w = 1.141 sec. ; Fairleader = CG + 20)

4. MECHANISM OF THE CAPSIZE OF MOORED SEMI-SUBMERSIBLE PLATFORM

In the previous sections, insights of the steady tilt phenomena by means of theoretical computations were forcussed. Furthermore, a possible dangerous behavior including capsize of moored semi-submersible platform is discussed here.

The mechanism of the larger tilt of the model in waves is somewhat complicated. First, the model starts to drift in the lee side direction due to wave-induced drift force. As the model shifts, the mooring lines located on the weather side of the model become taut until equilibrium of the net horizontal forces is achieved. In this case, it is obvious that the platform having small GM has a tendency to develop a constant heel. When the platform heels, the steady lift force acting on the lower hull close to the free surface increases drastically while decreasing the lift on the other hull causes larger heeling moment.

On the other hand, results obtained from the tank test have shown that the angle of the steady tilts was strongly influenced by the location of the fairleader. If the fairleader is located at higher position of the platform, the heeling angle becomes much larger. This indicates that the influence of the mooring line could no longer be disregarded for the safety of the semi-submersible platform. The larger angle of steady tilt allows waves to ride on the upper deck sometime, which may cause an additional inclination and/or capsize of the platform.

5. CONCLUDING REMARKS

Both theoretical and experimental works on the steady tilt of moored semi-submersible platform were conducted and some of the results are presented in this paper. From this study, it has been made clear that the additional overturning moment caused by the steady lift force on lower hulls cannot be neglect to predict the angle of tilt for the moored semi-submersible platform. Although the theoretical simulation is agreeable with experiment, further investigations are need to verify the full applicability of this simulation and to extend the capability to include the effect of the green-water on the upper deck which is considered as another important factor for capsizing phenomena.

ACKNOWLEDGMENTS

The authors deeply appreciate the valuable discussions by Professors M. Bessho of Defence Academy and S. Takezawa of Yokohama National University. Moreover, special thanks are due to Mr. S. Nagamatsu and the staffs of the Hiratsuka Research Laboratory of Sumitomo Heavy Industries,LTD.

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SHIP OPERATIONS RESEARCH AND DEVELOPMENT IN THE UNITED STATES

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ABSTRACT

"Ship Operations Research and Development" has been defined as "the systematic pursuit, and subsequent innovative practical application, of scientific knowledge and understanding in the effective use of resources (men, money, and material) in the efficient operation of ships and barges." This paper provides a brief overview of the joint industry-government sponsored ship operations research and development program coordinated and/or managed by the Maritime Administration, U.S. Department of Transportation. The Program is comprised of four major program areas, as follows:

I. Fleet Management Technology Program
II. Ship Performance and Safety Program
III. Cargo Systems Technology Program
IV. Ship Operations Simulation Program

"Ship Operations Research and Development," the subject of this paper, has been defined as "the systematic pursuit, and subsequent innovative practical application, of scientific knowledge and understanding in the effective use of resources (men, money, and material) in the efficient operation of ships and barges." Ship operations research and development, as thus defined, is conducted in the United States by individual companies, by the cooperative efforts of multiple companies and/or professional or trade associations, and by cooperative efforts of industry and the Government. Although precise numbers are not readily available, it is believed that the largest share of the ship operations research and development (R&D) conducted in the United States falls in the latter category; i.e., industry/Government sponsored R&D, with the Government represented by the Maritime Administration, U.S. Department of Transportation. This paper provides a brief overview of the Maritime Administration's ship operations R&D program as of mid-calendar year 1983 (Federal Government's fiscal year 1983).

The Ship Operations Research and Development Program sponsored by the Maritime Administration (MARAD) is comprised of four major program areas, as follows:

I. Fleet Management Technology Program
II. Ship Performance and Safety Program
III. Cargo Systems Technology Program
IV. Ship Operations Simulation Program

Each of these programs is discussed briefly in the text which follows:

I. Fleet Management Technology Program

A. Background

In the recent past, there have been enormous changes in the technology of ships, boats and cargo handling, in the pace of the actual movement of goods, and in the degree and nature of international competition. The philosophy and techniques of managing the business of U.S. international and domestic water transportation companies are in the process of adjusting to new requirements and challenges. In many cases, though, today's shipping technology is being employed with little more than yesterday's management capabilities. It seems obvious, therefore, that the basic nature of managing a ship operating company should respond to the demands brought about by modern shipping technology.

Effective and safe utilization of large capital intensive ships requires that modern management techniques be applied, in conjunction with advanced computer technology and sophisticated communications systems, to a broad range of functional requirements. Individual companies now use the advanced technologies of management science, operations research, information processing, computer technology, industrial engineering, and communications networks to varying degrees in order to enhance management capabilities at sea and ashore. However, it is believed major gains can be achieved if these technologies are further applied industry-wide to the broad range of planning, operational, and administrative functions performed by maritime companies.

For a number of years the use of management technology by the maritime industry has been fostered by MARAD through computer-based management and control systems that were designed as joint industry-government projects, on a cost-sharing basis. Over forty computer-based management capabilities have been developed to date.

Research projects of MARAD's Fleet Management R&D Program continue to utilize the cost-sharing concept and apply advanced management techniques to specific shipboard and shoreside procedures. The ultimate products of the Program are made available for use by all U.S. water transportation carriers.

B. Objectives

The objectives of the Fleet Management Technology R&D Program are to improve cargo productivity, corporate profitability, competitive position, and company performance within the U.S. water transportation community. To this end, MARAD's Office of Research and Development encourages companies to propose projects pertinent to specific functions that can be made more efficient by utilizing modern management technologies such as:

- o Management Science
- o Industrial Engineering
- o Operations Research
- o Information Processing
- o Computer Technology
- o Communications Networks

Research areas of interest to the Maritime Administration include the categories of: Corporate Planning, Cargo Services, Vessel Operations, and Performance Evaluation. Within these principal categories are general activities that, in turn, can be separated into a number of components that eventually become specific projects.

a. Corporate Planning

This category involves projects related to corporate decision making for service optimization and resource allocation. General activities include: Cargo Flow Demand Assessment, Transportation Network Analysis, Ship Allocation and Scheduling, Executive Decision Support, Terminal and Handling Requirements, Capital and Operational Budgeting.

b. Cargo Services

This category relates to operational procedures involving all aspects of cargo movement and shipper services. Examples of general activities are: Shipment Booking and Documentation, Equipment Tracking and Tracing, Marine Terminal Process Control, Cargo Load/Discharge Management, Corporate Revenue/Expense Monitoring, Office Data Communications.

c. Vessel Operations

This category involves all aspects of managing and planning commercial ship operations, from the perspective of the vessel as well as company management ashore. General activities are: Ship Technical Performance Monitoring, Computer-Aided Crew Training, Shipment and Voyage Analysis, Ship/Shore Data Communications.

d. Performance Evaluation

This category is concerned with procedures and techniques to measure performance, either for an individual company or segments of the U.S. fleet. The output of projects within this area provides methodology, standards, historical perspective, and analytical results. Examples of the type of activities are: Shipper/Consignee Service Review, Corporate Productivity Analysis, Trade Route Competitive Assessment, Corporate Financial Performance, Government Regulatory Impact.

II. Ship Performance and Safety Program

A. Background

U.S.-flag shipping has serious problems in its ability to compete with foreign ships. The gap in ship operation costs between U.S. ships and foreign competitors is growing larger every year. The high operating costs of U.S. shipping lie principally in the areas of manning costs, fuel costs, and overhead expenses. The technical content of the Ship Performance and Safety Program was developed with the aim of arresting and narrowing the operating cost gap by addressing the problems of:

- o Effective manning
- o Fuel efficiency
- o Power requirements and maintenance costs

The strategy of the Ship Performance and Safety Program is to identify and develop, in close cooperation with all segments of the U.S. maritime community, the conditions whereby the U.S. maritime industry can recruit, train, and retain skilled personnel who are able to exploit all possibilities within the present and future technical, economical, and social frameworks and thus strengthen the competitiveness of U.S.-flag shipping.

B. Objectives

The principal objective of the program is to reduce ship operating costs by appropriately utilizing advanced technology, capital investment, and human resources. This objective will be accomplished by challenging and exploiting the following:

1. U.S. seafaring personnel represent a valuable resource which can be employed more efficiently through new and improved organizational methods and more productively through the appropriate utilization of advanced technology.

2. Increased efficiency, productivity, and operational reliability can be realized by developing and implementing technological advances within the areas of ship design, maintenance, fuel efficiency, and computer systems.

The specific objectives of the Ship Performance and Safety Program focus on three major areas which strongly impact ship operating costs. These three mutually reinforcing program elements and the objectives of each are:

a. Effective Manning

Determine the most economic and safe minimum manning levels for ships by employing U.S. seafarers more efficiently through new and improved organizational methods and more productively through the appropriate utilization of advanced technology.

b. Fuel Efficiency

Reduce fuel costs by making more efficient use of fuel through development of a new technology that permits the accurate measurement of each factor of ship operation that causes fuel losses.

c. Power Requirements and Maintenance Costs

Reduce hull and propeller frictional losses and extend the periods between drydocking by development of new and improved maintenance management practices and new hull-coating materials.

III. Cargo Systems Technology Program

A. Background

The Maritime Administration's Cargo Systems Technology Program encompasses three principal activities which address the needs of the U.S. maritime community to increase cargo throughput and reduce operating costs. The three program areas are as follows:

1. Cooperative Cargo Systems Improvement
2. Dry Bulk Cargo Systems Improvement
3. Military Sealift Improvement

B. Objectives

1. Cooperative Cargo Systems Improvement

The objective of this program is to reduce cargo systems costs by bringing new technology applications to the maritime cargo handling industry. Cargo handling costs represent a significant percentage of total daily operating costs for U.S.-flag carriers. Eight U.S.-flag liner carriers cooperate in this program by sharing in the cost of projects, acting as project directors and by providing terminals, equipment, labor, and other services in support of the projects. The Naval Supply Systems Command has also provided funding for projects where they have a special interest, and the U.S. Department of Agriculture (Office of Transportation) has assisted in projects dealing with agricultural commodity cargo systems.

Productivity improvement is vital for the survival of the U.S.-flag maritime industry. The industry, plagued with problems of low profits, a traditionally conservative attitude, and a lack of technology-oriented personnel, has not taken advantage of technology advancements made in other industries which can be adapted to marine cargo handling. The Maritime Administration acts as a catalyst to bring industry together to identify common problems and bring about solutions which will benefit U.S.-flag carriers by reducing costs, improving productivity, and increasing the share of cargo carried on U.S.-flag ships.

2. Dry Bulk Cargo Systems Improvement

The objective of this program is to assist in the development of cargo systems which will allow U.S. carriers to compete with foreign carriers. A very small share of the United States' dry bulk trade is being carried on U.S.-flag ships. High transportation costs when compared to foreign carriers is the causal factor. Underlying factors are high shipbuilding costs, high vessel operating costs, poor fuel efficiency, high crew costs, and a lack of highly productive cargo handling systems.

There has been little or no incentive to induce private investment in U.S.-flag dry bulk ships except for government-impelled cargoes. This program seeks ways in which U.S. owners can be commercially profitable in the operation of U.S.-flag dry bulk vessels without government financial assistance by increasing the productivity of cargo systems and improving vessel utilization.

3. Military Sealift

The objective of this program is to develop, test and demonstrate, in cooperation with the Navy and U.S.-flag commercial carriers, materials handling systems which enhance the capabilities of the commercial merchant fleet to meet military sealift requirements.

IV. Ship Operations Simulation Program

A. Background

The Maritime Administration in 1972 initiated construction of a ship operations research laboratory in which the operating environment of a ship at sea is simulated on land. This facility, the Computer Aided Operations Research Facility, generally referred to as CAORF, is a sophisticated human factors laboratory which, through realistic simulation of the maritime environment, enables the researcher to examine the influence of the human element in ship operations. The simulated environment includes the visual out-of-a-window wheelhouse scene and a replica of the wheelhouse itself, including all of the customary navigation and communication equipment. This simulated environment enables the researcher to view the performance of a watch officer and/or bridge team in control of a vessel in a wide variety of operating scenarios including risk situations.

B. The objectives of MARAD's Ship Operations Simulation Program conducted at CAORF are as follows:

1. Reduce the frequency of collisions, rammings, and groundings.

2. Ensure that a pool of trained marine personnel exists.

3. Support the development of ports and new port operations.

4. Establish standards and criteria by which to measure improvements in performance.

The facility--which is unique worldwide--supports the efforts of the U.S. port authorities, ship operators, programs internal to the Maritime Administration and regulatory activities such as the Coast Guard and National Transportation Safety Board, the military (specifically the U.S. Army Corps of Engineers and the U.S. Navy) and the international community, including national governments and IMO.

In addition to performing work funded by industry and agencies other than the Maritime Administration, CAORF conducts MARAD's own research program which has been developed to affect the safety and productivity of the merchant marine. MARAD's program is a combination of basic and applied research directed at five major program areas:

1. Navigation and Vessel Control
2. Port and Waterway Design and Operations
3. Training and Certification
4. Vessel Maneuvering Characteristics
5. Technology Transfer and Industry Liaison

Dissemination of Results

Perhaps the single most important aspect of the MARAD R&D effort is the dissemination of research findings that will lead to eventual implementation. The ultimate aim is to share results of one company's work with all other companies in the water transportation industry. This requires designing and developing functional systems and procedures that are transferable to other companies with similar requirements. The traditional avenue to achieve this objective is through issuance of technical reports.

In addition to the publication of the required reports, the Maritime Administration seeks to translate research findings into action through annual conferences at which participants in the research program are invited to give presentations on the results of their completed projects or provide progress reports. The conferences serve a dual purpose: to provide a forum for knowledge sharing and interaction, and to aid the Maritime Administration and industry in formulating cooperative projects directed toward achieving the highest priority program goals.

Such conferences are organized and sponsored by the Maritime Administration at various locations and are open to industry and other government agencies. Presentations generally fall within four categories:

1. Results of completed and ongoing research projects sponsored under the MARAD R&D Program,

2. Results of other research in the same or closely related fields,

3. Operational experience of research projects that have been implemented,

4. Future research and development needs of maritime companies.

U.S. SHIPBUILDING RESEARCH IN THE 1980's

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ABSTRACT

Shipbuilding research in the U.S. has grown in scope and complexity during the 1970's. The National Shipbuilding Research Program is involved with wide ranging projects which address Advanced Manufacturing Technologies for research in the 1980's.

Background

The Maritime Administration has been sponsoring a cooperative shipbuilding research program since early in the 1970's. The National Shipbuilding Research Program (NSRP), as it has become known, has from its inception been a collaborative effort with the U.S. shipbuilding industry. The primary objectives sought to be achieved through the NSRP are cost reductions and accelerated deliveries. These objectives are consistent with the goal of maintaining an economically stable U.S. shipbuilding industry through increased productivity.

Over the past decade, the NSRP has built up a nationwide industry organization with over 400 participants with representation from all major U.S. shipyards. The program strategy has been to respond to the needs of the shipbuilders as they perceived them and carry these projects to successful implementation.

The NSRP conducts its planning and control functions through nine technical panels under the Ship Production Committee of the Society of Naval Architects and Marine Engineers. The panels, listed in Table 1, cover the major cost centers and technology areas of the production processes which make up ship construction. The projects, which are proposed and selected by the consensus of shipbuilding experts represented on the individual panels, are usually of a near-term nature, have wide application, and are cost-shared with the industry participant chosen to perform them.

TABLE 1

NSRP TECHNICAL PANELS

SP-1	Facilities
SP-2	Outfit and Production Aids
SP-4	Design/Production Integration
SP-6	Shipbuilding Standards
SP-7	Welding
SP-8	Industrial Engineering
SP-9	Education and Training
SP-10	Flexible Automation
SP-023-1	Surface Preparation and Coatings

Looking over the past decade of NSRP projects, several trends emerged. The early stages of the program focused on short-term projects and concentrated on hardware developments. These projects demonstrated to shipbuilders the effectiveness of cooperative research and that technology development and implementation can improve productivity.

The second five years have seen the number of research programs expand, industry participation grow and the scope of the program broaden. In addition to traditional technologies, programs in outfit planning and unit construction, standardization, industrial engineering, facilities engineering, design/production integration, educational development and flexible automation have been initiated. With this increase in scope, the range of participants has grown to encompass not just shipbuilders but design agents, equipment and material suppliers, and academia. Likewise, the focus of projects has broadened to include not just facilities and equipment development, but also organizational and management technologies to improve productivity. It is worth noting that a number of these projects have studied (and are studying) in detail the highly efficient construction methods and technologies utilized by Japanese and European shipbuilders and these are seeing wide application by U.S. shipyards.

The foregoing overview serves to provide a departure point for my main topic of U.S. Shipbuilding Research in the 1980's. This is because the emergent technologies, which are being dealt with in the 1980's by the NSRP, can be characterized as Advanced Manufacturing Technology. The degree of sophistication required to integrate, coordinate and plan for the application of these methods and hardware represents a "second generation" in ship production research. Therefore, it is apparent from the complexity of Advanced Manufacturing technologies that the current make up of the NSRP must include a diverse membership including designers and academia, not just production process experts. It must also include a wide range of subprograms featuring design production systems and approaches which impact multiple construction areas.

Advanced Manufacturing Technology

In order to discuss this topic it is necessary to define several key concepts which are at the heart of today's manufacturing research and development. The concept of Group Technology is defined in its broadest sense as "...the logical arrangement and sequences of all facets of company operations in order to bring the benefits of mass production to high variety, mixed quantity production."[1] The second concept is that of Social Technologies referring "...to innovative organizations of work and human resource management practices employed in experimental or quasi-experimental settings for the purpose of improving performance in the work place (quality, safety, efficiency)."[2] The third concept is the term Flexible Automation which is meant to encompass the technological areas relating: (a) the combined use of robots, numerically controlled machines (single and multipurpose), and conventional machines for use in the low volume shipbuilding environment; and (b) the integrating (including automation where necessary) of such "flexible" vs. fixed manufacturing techniques into an optimal facility for ship production.

Each of these concepts represents a systematic approach to solving productivity problems. In order, they address: organizational, sociological and mechanical manufacturing areas. Taken individually and reduced to their subprogram project level it is evident that these approaches are refining and applying existing technologies to conventional manufacturing processes. However, when taken in the aggregate and seen with their inherent overlaps, the focus is on shipbuilding as a macro-system. This macro-system, fitting under the umbrella term of Advanced Manufacturing Technology, includes technical systems of stunning complexity, highly sophisticated organizational methods, as well as the humanistic components of ship production.

The NSRP is pursuing projects and encouraging dialogue and experimentation in each of these three conceptual frameworks. The rest of this paper briefly describes completed and ongoing work which constitutes the thrust of research of the 1980's in U.S. shipbuilding. Where appropriate possible follow on projects or directions for out-year projects will be mentioned.

Organizational Approaches in Advanced Manufacturing Technology

As previously mentioned, the second phase (late 1970's) of NSRP activities included subprograms addressing outfitting. With the publication, in December of 1979, of the report entitled Outfit Planning[3], the different methods for organizing the installation of components, other than ship hull structure, were identified.

The inherent advantages to "zone outfitting" (i.e., interim-product oriented construction, based on segmented production process 'problem' classes, of everything within a limited three-dimentional space) concepts were contrasted with systems-by-systems approaches used in 'conventional' (component on-board installation after a portion of the ship is erected) and 'preoutfitting' (earlier outfitting of large structural sections prior to erection of a hull). These advantages are represented in Figure (1) below. The adoption of zone outfitting necessitates changes in organizational philosophy. This is evident in the design process where zone-by-zone methods must be incorporated with the overriding change being the requirement that design information must fully anticipate the needs of material procurement and production. In the production area zone outfitting, as practiced by Japanese shipyards, allows for a more uniform production flow and taking advantage of this requires modification in scheduling techniques.

This production related aspect of zone outfitting was separately explored by the NSRP with a report on Product Work Breakdown Structure[4] (PWBS). Group Technology methods for the application of mass production techniques to a variety of products in widely varying quantities form the underlying logic for the PWBS framework for classification based on manufacturing problems of purchased components, fabricated parts and subassemblies to achieve coordinated work flows.

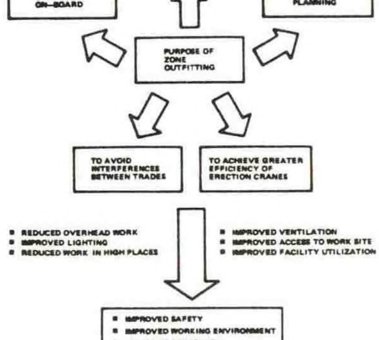

FIGURE 1 : Goals and benefits of zone outfitting

These two efforts have served to communicate productivity increasing organizational management technologies to U.S. shipbuilders and, through the industry organization of the NSRP, the importance of these concepts has been recognized. In particular, the need for full integration of the two functions of design and production is being addressed by a separate panel of industry experts. This panel has an ongoing project entitled "Group Technology Parts Classification and Coding System" which focuses on implementation and enhancement of the PWBS framework for U.S. shipyards. The study when completed in 1984 will include a classification and coding system usable by a broad spectrum of the industry and which is designed to be compatible with shipyard computer aided design and manufacturing (CAD/CAM) systems.

As mentioned earlier several U.S. shipyards have implemented parts of these technologies and have in place product work breakdown frameworks. The NSRP has encouraged these pilot program frameworks and during 1982 funded a project to study the adoption of "process lanes" by a U.S. shipyard. Organized process lanes (or production lines) are also based on Group Technology principles. As identified by Okayama and Chirillo in Product Work Breakdown Structure[5] (see Figure (2)), in Japan the process of ship construction utilized several designated material flow routes for the processing of all material. These process lanes provide for sequential manufacture of detailed parts and pieces, assembly of these components into progressively larger and more complex units and ultimately the construction of these units into the ship itself. Each process lane consists of a series of work stations with a permanent group of workers performing a specific function or process - these work stations are organized so that work in progress is moved in a lane from one station to the next. Part of the study of using this concept in a U.S. shipyard will focus on the effects and interfaces with design, production planning, CAD/CAM systems and material procurement. A comparison between existing production systems and the proposed system with economic analysis will also be an output of the study for completion in early 1984.

The two projects described are hardly exhaustive of the efforts by the NSRP to research and develop refined organizational technologies for U.S. shipyards. One direction will include a project exploring Computer Aided Process Planning in the shipyard environment. This project will be initiated by early 1984. Computer aided staging of resources and sequencing of fabrication steps is currently being utilized in the aerospace industry. The project will deal with possible shipbuilding applications, based on group technology principles, as well as industrial engineering techniques for operations sequencing with computer modelling methods. This represents a promising area which will result in decreased planning costs, reduced schedules, optimized process selection, increased flexibility, improved quality, and increased standardization.

Sociological Approaches to Advanced Manufacturing Technology

As identified in Figure (1) above, the adoption of zone outfitting methods not only results in higher productivity and better quality, but also improved worker safety and improves the working environment. The natural reflex is to postulate the existence of a positive relationship between the human side of work and productivity. As James C. Taylor suggested in a paper given in

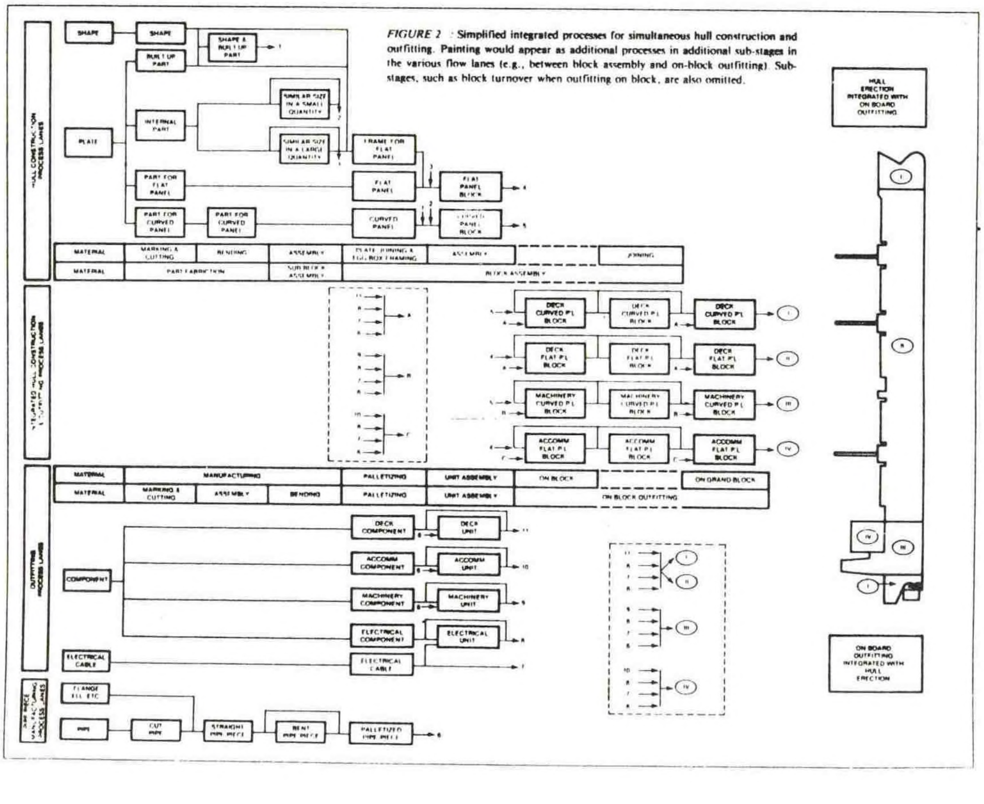

FIGURE 2 : Simplified integrated processes for simultaneous hull construction and outfitting. Painting would appear as additional processes in additional sub-stages in the various flow lanes (e.g., between block assembly and on-block outfitting). Sub-stages, such as block turnover when outfitting on block, are also omitted.

1975: "Work that is meaningfully arranged, both for the humans involved in its execution and for its technical requirements, typically results in a higher quality product and, not infrequently, in greater productivity as well."[6]

In general the NSRP, along with sister bodies such as the National Academy of Sciences Committee on Navy Shipbuilding Productivity, has recognized the potential for significant productivity gains for U.S. shipyards through work force innovation. To further this end the Education Panel of the NSRP has recently conducted a three-day workshop for an industry-wide, joint management/labor examination of human resource innovations. These innovative methods include the principle areas of: (a) worker participation (especially quality circles and quality of work life); (b) work redesign (e.g., autonomous work groups, multiskilled workers); and (c) behavior modification (e.g., performance engineering, performance management). This project drew upon the resources of shipyard (and other industry) management and labor leaders, academics and consultants involved with social research, and government labor officials. Part of the agenda dealing with worker participation pointed out the "Quality Circle" (QC) experiences of Norfolk Naval Shipyard which began their experiment in 1979 and Lockheed Marine Shipbuilding which started theirs in 1980. The QC concept includes, to varying degrees, the decentralization of management (especially relating to safety, quality, and efficiency), statistical methods, and behavioral science. In general, QC has been a widespread management practice with Japanese and European shipyards since the 1960's, however, in the U.S. shipyards it calls for innovation in the integration of a parallel management chain in the existing organizational framework. The system is especially beneficial in that it allows for flexibility of emphasis on safety, quality, or productivity enhancements to suit individual yard concerns. It is likely that studies on U.S. shipyard implementation of QC concepts will form part of the NSRP in upcoming years.

The workshop on Social Technologies also highlighted areas where the systems approach is being applied to workforce productivity problems. The application of the Performance Management theory (i.e., employee performance measurement, work performance feedback and worker improvement recognition (positive reinforcement)) in a systematic continuing program is a simple example of such an approach. More complex approaches include socio-technical system design which "...differs from other approaches to the problem of matching work to people by attending simultaneously to the technical and production requirements of the work and to the psychological and social aspects of individual and group requirements."[7] Such system modelling allows for integration of one or more of the previously mentioned social technology concepts such as quality circles, autonomous work groups and classical principles of scientific management.

This sophisticated technique is a likely direction which the NSRP will continue to study for shipyard workforce innovation in the 1980's.

<u>Mechanical Approaches to Advanced Manufacturing Technology</u>

Although U.S. shipbuilding research has, to a degree, been preoccupied with the opportunities for productivity gains which advanced organizational structures present, a traditional core program to develop improved elements in facilities, welding and surface preparation and coatings areas is, and has been, ongoing. Of particular interest is the NSRP Welding Panel studies involved with the application of robots to perform shipyard welding and material handling tasks.[8] One study utilizing a fixed-position, jointed-arm, pendant-taught, machine is currently being conducted by a U.S. shipyard, with a concurrent Navy project being conducted to develop a simplified teaching system and an acceptable visual tracking system for that robot.

The evaluation of the computer controlled pedestal mounted robot shown in Figure (3) to perform arc welding tasks in Todd shipyards has served as a test bed for state-of-the-art robotics as adopted to the shipyard. The basic design and analysis of an arc-welding robot work station and the test of welding performance were obvious technical questions to be solved and preliminary findings indicate that a programmable automated machine can be taught: to manipulate the tool attached to it, and to consistently, with accuracy, perform the task or process. More importantly, the project has served to bring out the developmental aspects to the cost-effective use of flexible automation. To highlight a few of these:

- o results confirm the importance of adequate workforce preparation which should include training prior to the introduction of the new technology;

CINCINNATI MILACRON

T-3 ROBOT

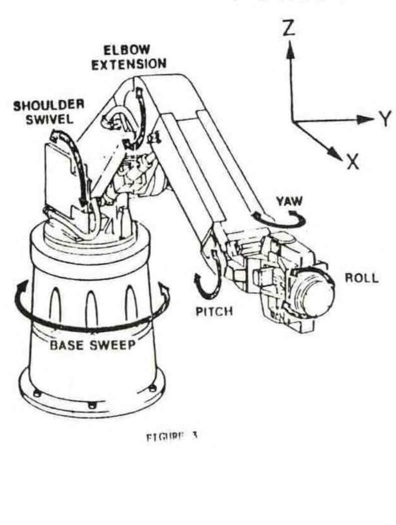

FIGURE 3

- o results indicate fit up and positioning are of critical importance and emphasize the need for artificial intelligence and sophisticated sensory devices yet to be developed;

- o the question of material handling and robot accessibility is a crucial factor in the productivity equation - one early conclusion was the need for a more sophisticated feeding and positioning device;

- o "Teach time" was confirmed as the most significant factor limiting the productivity of flexible automation machines in the small batch manufacturing environment; and

- o the necessary production planning which is required to optimize flexible automation, e.g., identification of acceptable candidate parts for welding on the robot; establishing minimum batch vs. teach time that is practical and economical to produce on the robot.

An additional result was the NSRP Welding Panel decision to evaluate a portable, wand-taught "apprentice" welding robot for a second type of application (see Figure (4)). This evaluation, begun last year, will include: the identification of areas such as various fabrication shops and on-board locations to apply this robot; the design of a portability vehicle for the system; determining optimum man/machine(s) loadings; further assessments of group technology as applied to candidate parts; and, the economic viability of the system as developed or modified.

To summarize, the advantages to the use of robots can include:

- o increased product quality
- o flexibility
- o reduced workforce injuries
- o precision
- o improved worker morale
- o reduced production costs
- o improved equipment utilization

THE APPRENTICE

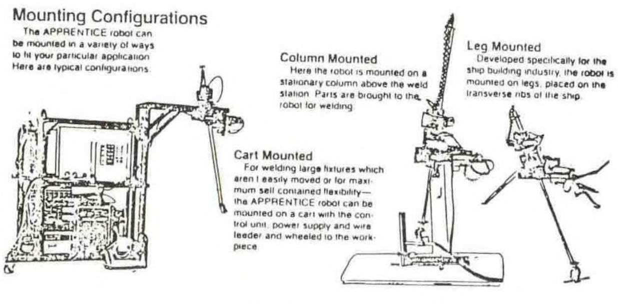

FIGURE 4

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- o reduced personnel training cost
- o round-the-clock output availability

However, the disadvantages of this technology may include:

- o capital costs
- o primitive sensory devices
- o organization management adjustments
- o space requirements
- o requirements for specialized work flow and parts orientation

With this in mind, the NSRP is committed to the application of this high-technology to the shipbuilding arena. It has recognized the existence of the separate subset of problems attendant with adopting and developing existing robotics technology. This current technology is rooted in high production, fixed position, assembly line, manufacturing industries in contrast to the low volume, variable size (from small to extremely large), and broad range of complexity of the subassemblies which make up ship manufacture. Therefore, a new panel to deal with this area of Flexible Automation was initiated by the NSRP. Amongst its first projects scheduled for award in the upcoming months, is a planning project for the introduction of flexible automation in U.S. shipyards to realize fully the advantages and minimize the disadvantages listed above. Specific application projects are also planned. It is also quite possible that the limitations of robotics in shipbuilding may become the impetus for new technology research and development in methods and process improvements such as innovations and new materials for welding, bonding or painting which allow maximal automated production as well as the greater sophistication required in sensing and teaching machinery peripheral to the robots themselves.

Conclusion

This paper has touched on a handful of projects out of a total NSRP program which at any given point in time may have 60 ongoing projects. However, these few projects serve to indicate the thrust of U.S. shipbuilding research in the 1980's and typify the complex systems which are now being tackled by this industry/government cooperative program in its second decade.

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Operational Experiences with the High-Speed SSC Passenger Ferry SEAGULL and New Concepts in the SSC

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ABSTRACT

A concept of the Semi-Submerged Catamaran (SSC) or Small-Waterplane-Area Twin-Hull (SWATH) appears to be one of the ideal approaches to a modest-sized ship with good seakeeping and ample deck space, as well as sustained speed in waves.

This paper describes operational experiences of the world's first high speed SSC ferry SEAGULL, the outline of a 2800 G/T SSC support ship which is scheduled to be delivered in 1985, and some new concepts for the SSC including small prototypes and experimental craft.

INTRODUCTION

As one of the ideal ship concepts to meet the design requirements for good seakeeping and spacious deck space within modest-size, the SSC has been developed mostly in Japan and the United States.

The SSC consists of a pair of submerged main hulls or lowerhulls, an above-water platform structure, and streamlined surface-piercing struts which connect lowerhulls to the upper structure. Because of this unique hull shape, the SSC is less susceptible to the wave forces in a seaway and has longer natural periods of motion than a conventional monohull ship. Furthermore, this type of ship can provide greater effective deck space and less speed loss in waves, in addition to good stability.

Mitsui Engineering & Shipbuilding Co., Ltd. (hereinafter called Mitsui) began development of the SSC in 1970 with high expectation for a wide field of applications in commercial use, while the U.S. Navy is aiming to use the SWATH ships for various military missions. There are now four SSCs being operated: the high-speed SSC ferry SEAGULL (Photo 1), the hydrographic survey vessels KOTOZAKI and OHTORI, and the workboat SSP KAIMALINO, as well as some small prototypes and experimental craft such as the 19.5 meter demonstrator SWATH boat SUAVE LINO. Portions of full-scale test results and operational experiences have been published to this date. (1), (2)

Photo 1 SEAGULL

Aiming for an offshore support base for a large scale of experiments at open sea, the Japan Marine Science and Technology Center (JAMSTEC) decided to construct a larger SSC-type underwater experimental work support ship.(3) This 2800 G/T support ship will be completed at the Chiba Works of Mitsui in 1984 and delivered in 1985.

OPERATIONAL EXPERIENCES OF THE SEAGULL

Japan consists of many islands and there are many ferry routes on which fairly high waves cause problems with regular service and ride comfort. One of the domestic shipping companies, which operates many ferries on the routes between our main island of Honshu and the seven remote islands near Tokyo, had been concerned about passenger complaints of poor ride quality and resultant seasickness.

In order to improve their ferry service with regard to passenger comfort, over the past ten years the company has considered enlarging the size of their ferries or adopting a relatively small-sized new type of ship capable of carrying a large number of passengers at high speed with good seakeeping characteristics.

They compared various ship types including hydrofoils, hovercraft, etc; however, they noticed some disadvantages such as limitation of the number of passengers, high initial cost, and high maintenance cost. Consequently, they found the SSC to be the most suitable ship to meet their demands relating to ship motion, speed in waves, and economy.

The basic design requirements for the SEAGULL were the capacity to carry 446 passengers at a service speed of 23 knots and the ability to run comfortably even in rough seas with a significant wave height of up to 3.5 meters.

Accordingly, the main particulars of the SEAGULL were decided as follows:

Length b.p.	31.5 m
Breadth, max.	17.1 m
Depth	5.845 m
Draft, full	3.15 m
Draft, max.	3.8 m
Displacement at full draft	343 tons
Main Engine	High speed diesel 4,050 PS X 2 sets
Speed max.	27.1 knots

The SEAGULL was put into commercial operation on the route between Tokyo and the remote islands of Oshima and Niijima, as shown in Fig. 1, in July 1981. Except for the summer season, July and August, she has been running twice daily round trips between Atami and Oshima island.

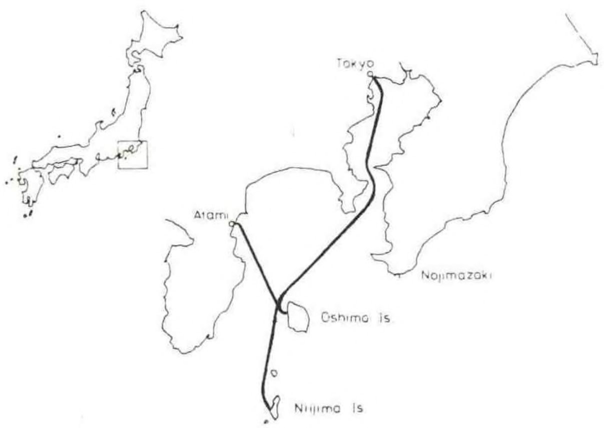

Fig. 1 Operational routes of SEAGULL

Passenger comfort in the SEAGULL has been optimal because of relatively minor motion and acceleraton. According to measured motion and acceleration during full-scale seakeeping tests, the significant value of pitch and roll motions were less than 1.5 degrees and the vertical acceleration was less than 0.1 G for all headings in sea state 4.

This fact was proven by a very low seasickness ratio among SEAGULL's passengers with less than 0.2 percent recorded from August 1981 to February 1982. Women, children and aged, who are liable to get seasickness easily, particularly enjoy this mode of sea travel. The children are also fascinated by the novelty. The SSC has changed the image of high speed passenger boats.

The accumulated operating distance was more than 20,000 n.m. from July to December 1981 and nearly 40,000 n.m. in 1982. The main engines were driven more than 4,500 hours as of February 1982. The Z-drive system which was newly developed by Mitsui provides high transmission efficiency as well as high reliability.

As shown in the following table of scheduled and suspended runs, a 94 percent ratio of total operation to scheduled service was recorded in 1982.

1982	Scheduled	Suspended due to wave conditions
January	124	0
February	112	0
March	124	6
April	120	6
May	124	0
June	120	12
July*	90	12
August*	88	8
September	120	18
October	124	7
November	120	4
December	12	0
Total	1,278	73

(Operational routes: Atami-Oshima island,
*: Tokyo-Oshima, Niijima islands)

As well as measuring wind velocity and direction, the significant wave heights and wave directions were observed on board SEAGULL during her operations. In the vicinity of the operational routes, strong south to west-southwest winds blow frequently from April to August while dominant wind directions from October to March are north to east-northeast. We have learned from the data that the SSC is only slightly influenced by the winds which generate wind waves. For example, there were many days with wind velocity of more than 10 m/s in May and October in 1982, but the SEAGULL was operated 100 percent and more than 94 percent respectively in those months, and very few passengers experienced seasickness.

During the month of September there were some strong typhoons which traced on the areas near Tokyo. This resulted in cancellation of all ferry services around Tokyo Bay and the remote islands for several days.

Furthermore, some runs were cancelled due to vulnerable port facilities on Oshima island facing the open sea, and due to the operator's in-house rule by which the ship is not operated in case that more than 3.5 meter waves will be prospected before leaving the mainland port. Therefore the operating rates in the summer season or the typhoon season were obliged to be decreased. Fig. 2 shows the distribution of the visual wave heights during 1982.

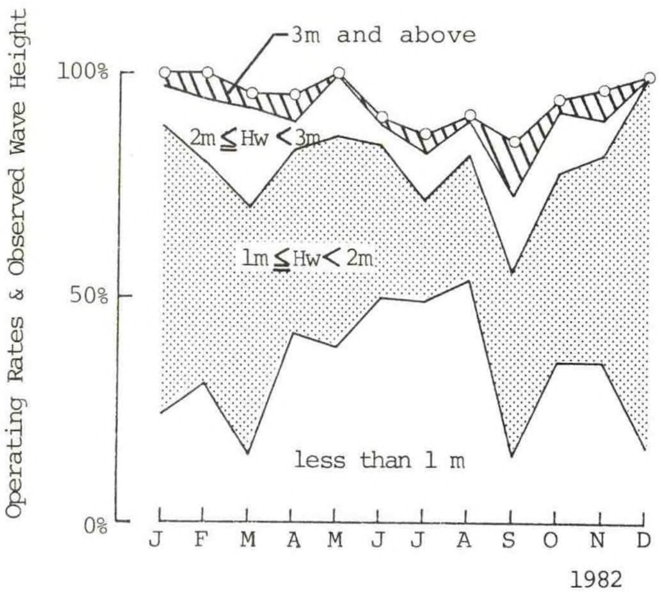

Fig. 2 Operating rates and observed waves heights during operation

The figure indicates the operators of the SEAGULL maintained their regular survices in high waves of more than 3 meters in significant value except for some extremely bad conditions, i.e., a combination of wind waves and large swells caused by a typhoon. The operator was concerned about the effects of wave impact on the underside of the upper structure; however, no excessive wave impact nor damage were reported.

The SSC has enjoyed a good reputation for ride comfort and this fact resulted in higher seat occupation ratios than those of conventional ships.

2800 G/T SSC SUPPORT SHIP

In the field of ocean development, as well as marine transporation, relatively small-sized stable ships are required in order to conduct a large scale of field experiments such as deep ocean floor survey etc. JAMSTEC planned to construct a support ship equipped with a submersible decompression chamber (SDC) and a deck decompression chamber (DDC), both of which are used for underwater experimental works, in addition to a dynamic positioning system (DPS) for station keeping.

After an extensive study of the basic features of the vessel, the SSC was selected because of its excellent stability at sea and spacious work deck with a center well which provides easy and safe handling of the SDC during hoisting and lowering from and to the water.

Artists impression is seen in Fig. 3 and principal particulars are shown as follows:

Length b.p.	53.0 m
Breadth, max.	28.0 m
Depth	10.6 m
Draft, max.	6.3 m
Gross tonnage	2,800 tons
Main propulsive motors	
Rated output	860 KW x 4 sets
Normal output	760 KW x 4 sets
Speed	abt. 12 knots

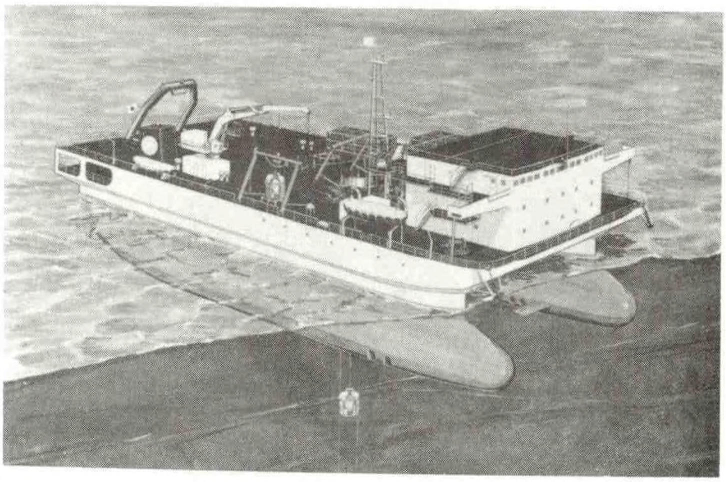

Fig. 3 Artists impression of the SSC support ship

The construction and operational experience with this large SSC as well as experience with the first Japanese-designed & built DPS will be very valuable for future designs of various ships of this type in the field of ocean development.

OTHER SSC DESIGNS

In addition to the SEAGULL, the 250 G/T, 25 meter hydrographic survey vessel KOTOZAKI has been operated in the Inland Sea of Japan by the Fourth District Port Construction Bureau, Ministry of Transport since March 1981. (Photo 2) Now this vessel is being utilized for bottom and water sampling works, as well as for meteorological and oceanographical observations. It is worth noting here that the captain said the tasks in rough seas, which they couldn't with conventional ships, could be achieved with this SSC-type survey vessel. The vessel is specially equipped with controllable-pitch propellers and fin stabilizers manually operated for smooth navigation in a wide range of speeds up to 20.5 knots.

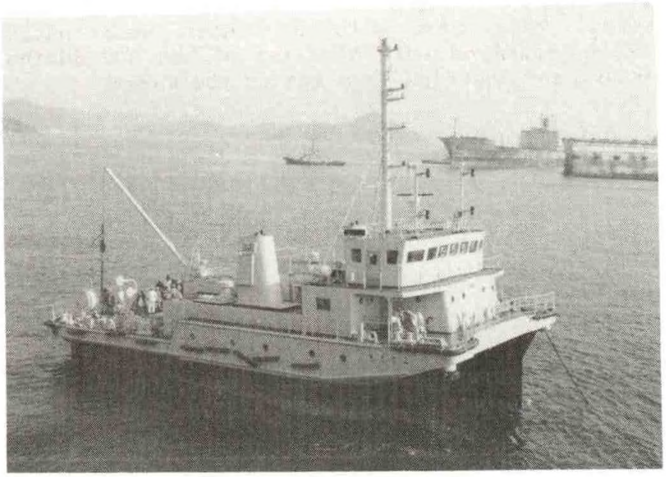

Photo 2 KOTOZAKI

Mitsui also built the 18 ton, 11 meter experimental SSC MARINE ACE in 1977, in order to experience design synthesis and establish design technology of the SSC prior to construction of the SEAGULL.

The experience gained from the MARINE ACE and the successful operation of the KOTOZAKI indicate the possibility and utility of the small prototype SSC in various fields. The inherent stability and safety as well as ample deck space of the SSC are very appealing to small boat design.

In order to confirm total performance and special problems on such a small boat design, several small SSC boats were built and tested. The most recent one was completed in 1982 under the sponsorship of the Japan Marine Machinery Development Association (JAMDA). (Photo 3)

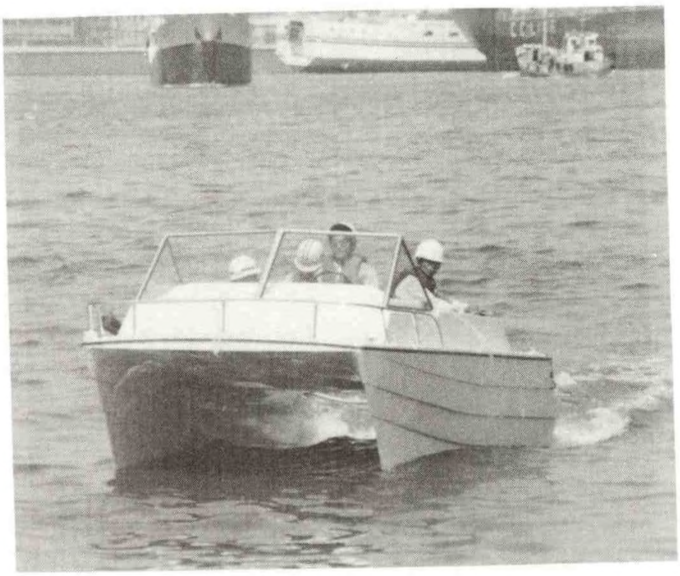

Photo 3 SSC Pleasure Boat

The main particulars of the prototype are as follows:

Length overall	4.97 m
Breadth, max.	2.60 m
Depth	1.54 m
Draft, full	abt. 0.83 m
Engine	Gasoline outboard egnine 25 PS X 2 sets
Complement	8 persons
Speed, at 70 percent load draft	abt. 17.5 knots

This SSC pleasure boat is equipped with a pair of movable forward fin stabilizers whose fin angle can be adjusted to change the ship's trim adequately under various load conditions on deck. Main portions of the hull are made of fiber-reinforced plastic (FRP) from the maintenance point of view.

Fig. 4 shows an illustration of a small SSC with a luxurious saloon as one of the future applications.

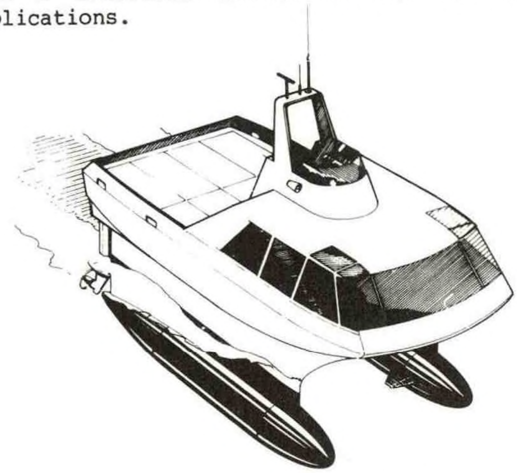

Fig. 4 SSC Saloon Cruiser

Development of the SSC has continued for more than 10 years. Three different types of the SSC, i.e., MARINE ACE, SEAGULL, and KOTOZAKI were built by Mitsui and a larger SSC support ship will be delivered in 1985. In addition, some small prototypes and experimental craft were built in order to expand the applicable area of the SSC and to further enhance the SSC performance. Evaluation of total performance including economy, of the SSC should be done through as many operational experiences as possible.

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SHIPBUILDING TECHNOLOGY INCLUDING ROBOTICS IN SHIP CONSTRUCTION

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ABSTRACT

The recent striking technological developments in the area of electronics, new materials and space techniques have caused great and accelerated technological innovations in a vast field of industries. It is anticipated that the shipbuilding industry would also make giant leaps in consequence of successful achievements of development of shipbuilding robots and others through positive utilization of these technological innovations.

The progress in mechanization and application of automation in the building process of ships is slower comparing with that of other industries, and thus the shipbuilding industry is yet remaining in the extremely labor-intensive type industry. The form of production to order, highly diversified shipbuilding specifications which differ from ship to ship to the requests of each shipowner, and large mass and heavy weight of each structural component and several other reasons are all considered responsible for such slow pace of mechanization and application of automation in this specific field of industries.

While on the one hand, the Japanese shipbuilding industry is recently being chased seriously by those developing shipbuilding countries with cheap labor cost serving in the background. Moreover, it is confronted with multiple other serious problems such as the advent of the era of old ages, ever refining industrial structure, and shortage in skilled labor force arising from the increasing number of white-color-oriented young people.

For this reason, it has rendered itself as an urgent problem for the Japanese shipbuilding industry to promote labor-savings in design and production processes for ensuring significant upgrading in the productivity and to restore the attractiveness as the working site through the reduction of dirty work, dangerous work and improvement of working environment in work items such as cutting, welding, painting, work at an elevated place and in confined compartments.

On the other hand, even in the industry of shipbuilding featured by its small lot production in large diversification, drastic systematization and greater application of automation techniques in all phases of design and production have been regarded as the important tasks along with the striking developments of microelectronics and sensor techniques evident in recent years and resultant sophistication in information processing techniques. In addition, development of new manufacturing processes is also promissing due to the development of new materials.

In recognition of the foregoing, it is considered extremely important for the sound development of the Japanese shipbuilding industry to promote R & D on shipbuilding robots and new manufacturing process whereby realize large magnitude of labor-saving and improvement in working environment, while ensuring significant upgrading in the reliability of manufacturing process and in product quality with eventual sophistication and modernization of the shipbuilding industry of this country.

(1) Shipbuilding robots

- o Automation in fabrication process
- o Automation in assembly process
- o Automation in welding process
- o Automation in surface cleaning, polishing and painting processes

Development of shipbuilding robots capable of meeting each phase of the diversified shipbuilding process requirements involving least process routines by promoting the sophistication of industrial robot techniques displaying an accelerated progress in recent years.

(2) Innovative manufacturing process

- New welding and bonding techniques
- Simplified electric cable processing techniques
- New type paints
- New type working system

To promote further rationalization of shipbuilding process by introducing innovative techniques for welding, electric cablelaying, painting, etc., with consequential increase in working speed and extension of the scope of advance outfitting work.

ENERGY CONSERVATION ON NAVAL SHIPS AND ELECTRIC PROPULSION

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ABSTRACT

Research and Development efforts in the areas of shipboard energy conservation and electric propulsion systems are described. Primary emphasis is on those which are underway at the David Taylor Naval Ship Research and Development Center (DTNSRDC). Significant accomplishments include biofouling protection systems to reduce hull drag, and steam-plant machinery modifications, both intended to meet 1985 Navy energy reduction goals. Major thrusts presently underway involve pursuit of longer range goals and include development of more efficient propulsion engines and heat recovery systems, as well as the design of more efficient hull forms and electrical distribution system components. A key program in this area is electric propulsion, with emphasis on superconductive machinery. A 300 kilowatt system was successfully developed and operated in a 20 meter testcraft. Finally, ongoing efforts to develop broad-range ship fuels, including those derived from synthetic sources such as oil shale and tar sands are presented.

INTRODUCTION

Although most of the free world is currently experiencing a period of adequate oil supplies, the U.S. Navy remains committed to improving the operating efficiencies of ships currently in the fleet, and to the design and construction of more efficient ships in the future. This was recently reinforced when the Chief of Naval Material established corporate goals for this year which included three specific items relating to energy considerations in ship operations: (1) The need for all commands to make conscious efforts toward energy conservation and improved energy management; (2) pursuit of improved mechanisms for translating energy conservation technologies to fleet use; and (3) efforts to overcome operating problems resulting from the trend to poorer quality mobility fuels. In actual practice the Navy has placed a high priority on energy conservation in both hull form and machinery system selection during on-going ship acquisition projects such as those associated with the new amphibious support ship, LSD 41, and the new destroyer, DDG 51.

Research and development efforts expressly intended to promote energy conservation or the use of alternate mobility fuels are supported by the Navy Energy R&D Program. Many other projects are not being developed with energy efficiency as their primary goal, but will ultimately make significant contributions toward the achievement of the Navy's energy consumption goals for new construction ships. With regard to achievement of goals to reduce the fuel consumption of existing ships, mainly conventionally steam-powered, the Energy R&D Program has developed and implemented many significant procedures as well as new equipment on a retrofit basis. Similarly, the Energy R&D Program has borne the responsibility for development and qualification of synthetically-derived mobility fuels from oil shale, and for attempts to broaden the spectrum of petroleum fuels available for use. For future ships, however, this program supports the full-range development of certain subsystems, but plays a more important role in complementing major directed projects such as reverse osmosis desalination and regenerated gas turbines.

In the following sections, brief descriptions will be provided of the thrusts and accomplishments associated with the three project areas addressed above, namely: (1) Existing Fleet Energy Conservations; (2) Future Fleet Energy Conservation; and (3) Ship Fuels. Additionally, as an addendum to the future fleet discussion, a description of the ongoing Electric Drive Project will be provided because of the importance of this technology to achievement of long-range energy goals.

EXISTING FLEET ENERGY CONSERVATION

Primary emphasis has been placed upon this program area during the first five to seven years of intensive energy R&D by the Navy. This was deemed appropriate because it is through these efforts, that is, those directed at ships presently in the fleet, that near term fuel efficiency improvements are most likely. Areas of investigation were subdivided into: (1) Systems analysis; (2) hull drag reduction; (3) combustion improvements; (4) auxiliary system modifications; and (5) performance monitoring. As mentioned above, specific projects in all of these areas have been supported totally be the Navy Energy R&D Program, and DTNSRDC has served as the Lead Laboratory.

The Systems Analysis task has formed the basis for identification of ways to reduce shipboard fuel consumption which are effective from the standpoint of both technical feasibility as well as cost. The methodology has involved thermodynamic analyses of the total plant for all alignment and operating conditions, sea trials to correlate actual to design conditions, ship impact assessments for proposed modifications, and life cycle cost analyses to determine payback as a function of retrofit cost, estimated savings, and remaining ship life averaged over the entire class. At the present time, these analyses have been performed for all combatant ship classes and are underway for auxiliary classes.

At the outset of the program, increases in hull drag because of the accumulation of biofouling on underwater hull surfaces was identified as the single largest factor contributing to increased fuel consumption. To offset this, a two-phase program was initiated. The first phase, establishment of a comprehensive hull cleaning program, was fully implemented in the fleet in 1979. Estimated fleet fuel savings resulting from this procedure are 8-10 percent. The second phase involves the development of improved antifouling hull coatings which will remain fouling-free for at least five years without cleaning. Initially, the use of commercial ablative-type coatings is likely to be authorized. However in the long term, the Center is looking toward the use of non-ablative polymer-type coatings which will permit the application of less paint with consequent savings in labor as well as material costs. These advanced coatings are based upon an Organometallic Polymer (OMP) concept which was conceived at the Center during the mid-1960's as part of an independent research program. In this concept, organotin is reacted with a polymer, as in commercial coatings, however, ablation is not utilized to maintain a biocide release rate. Therefore, fewer paint layers are required. Experimental application of two such coatings on two ships have been intact and fouling-free for in excess of four years. Successful implementation of these improved biofouling protection systems is expected to double the fuel savings experienced with hull cleaning.

The combustion improvements and auxiliary systems modifications presently underway are all outgrowths of the analyses of specific ship classes previously described. A Combustion Optimizer has been developed which senses oxygen in the stack gas and automatically regulates boiler excess air to the point of peak efficiency. This system is presently being upgraded to use several parameters (oxygen, carbon monoxide and opacity) as well as microprocessor controls to provide an automatic recalibration capability for Automatic Combustion Control (ACC) systems. A cold starting capability has been devised for main feed pump turbines to eliminate the need to idle a standby unit, a practice which consumes about 1250 pounds of steam per hour on a frigate-sized ship. An improved economizer has been qualified which more effectively utilizes the higher heat content of the distillate fuels which are presently in use.

The fifth area indicated above, Performance Monitoring, was established following sea trials on several classes of ships which demonstrated conclusively that significant efficiency improvements can be realized if ship operators have precise information concerning the impacts of various machinery alignments and operating procedures. Two systems are currently under development: A fully automated system which periodically scans the entire engineering plant, calculates efficiencies, and provides diagnostic and trending information; and a second system which is manual, that is, requires that data be read from ship's gauges and keyed into the computer. Although the first system provides maximum utility, it is likely that the latter will be implemented initially because it is less complex and more adaptable to a shipboard environment.

FUTURE FLEET ENERGY CONSERVATION

This program area, which is the most germane to the R&D mission of DTNSRDC, is also the one with the potential to provide the most significant energy impact to the Navy. This is due mainly to the fact that efforts, as far as new-construction ships are concerned, are not constrained by any pre-existing configuration and do not involve the premature disposal of an otherwise useful piece of equipment. It is, therefore, the area which will receive increasing emphasis in future years.

Projects in this area again fall into five major areas: (1) Energy Analyses; (2) Propulsion Systems; (3) Electrical Generation Systems; (4) Auxiliary Systems; and (5) Hydrodynamics. The first, Energy Analyses, involves energy distribution computation, ship impact assessments and life cycle cost estimates of proposed system arrangements for both ongoing ship acquisition projects as well as for anticipated future ship types. As in the existing fleet case, these form the basis for R&D decisions; however, for longer range applications; that is, 1990 and beyond.

Propulsion system improvements, understandably, offer the maximum potential for fuel savings since propulsion requirements account for approximately two thirds of total ship fuel consumption. Several major efforts are underway to improve the efficiencies of gas turbine engines during cruise conditions. The first involves development of a Rankine bottoming cycle for the LM-2500 engine. This concept which is termed "RACER" (RAnkine Cycle Energy Recovery) offers the possibility of a 15-20 percent improvement in cycle efficiency relative to simple cycle engines. Its development is underway with a projected fleet introduction date of 1986. The second involves the development of a regenerated cruise gas turbine; that is, one which recovers exhaust heat to preheat combustion air. Although this is a relatively new program, investigations by three manufacturers of engines in the range of 10,000 to 25,000 horsepower have shown cycle efficiency improvements of 20-26 percent relative to simple cycle engines. An attractive feature of this concept is that is has only one working fluid, air, which should greatly simplify manning and maintenance in any eventual application. Realization of this concept, however, is probably in the post-1990 time frame.

Exploitation of the full potential of new propulsion concepts involves the integration of these into an overall system which permits operation of prime movers at or near their maximum efficiency points during most of their mission profiles, and additionally makes optimum use of all sources of energy. One area which represents a principal thrust at DTNSRDC is intended to complement these goals. This is electric drive. This concept permits arrangement flexibility, variable reduction ratio and integration of propulsion and electrical generation systems. In the near term normally excited systems may be employed. However, in the longer range, superconductive systems will permit minimization of machinery size and weight with maximum utilization of technology. It is in this area that the Center is allocating the bulk of its resources.

The technologies of superconductive excitation, advanced current collection and direct conductor liquid cooling can be applied separately or in combination to provide motors and generators which are compact, efficient and highly controllable. In naval drive applications, significant ship size, cost and performance benefits will result from the improved machinery power density coupled with the arrangement and operating flexibility inherent in electric transmission. Ship design impact studies for a general-purpose gas turbine-powered destroyer show a 14 percent reduction in full load displacement, a 29 percent lower propulsion fuel requirement, and 9 percent lower ship builder contract costs for an advanced electric drive system, compared to an identical non-cross connected mechanical transmission system.

The technical approach to demonstrating the feasibility of building full-scale systems for operational evaluation has included the development of 300 kilowatt proof-of-principle electrical machines and experimental rigs to validate design concepts, and to provide data for the preliminary design of full-scale 22-37 megawatt systems. Current programs involve the construction of 2250 kilowatt model systems incorporating design parameters, materials, and fabrication and assembly approaches defined for the full-scale systems. The 300 kilowatt system work has progressed to a successful shipboard demonstration in the DTNSRDC 20 meter testcraft, Jupiter II, which took place in September 1980. This demonstration which involved a series of trial runs in the Chesapeake Bay off Annapolis marked the first time a superconductive system had been tested at sea, and represented the culmination of efforts to exploit this technology which were begun at the Center in the early 1970's.

In addition to being the first shipborne operation of a complete superconductive drive, there were several other technological achievements demonstrated during the 300 kilowatt system trials:

- The superconductive motor and turbine driven generator each retained their status as the highest torque and power density units of their type ever operated.
- The motor, which includes a single superconductive coil cooled with a closed cycle helium refrigerator, operated comfortably at a sustained torque level 50 percent greater than its design value.
- The generator magnet winding, the first superconductive opposed-field winding built in the USA, operated at a current density exceeding 25000 amperes per square centimeter (A/cm^2), the highest ever demonstrated in a superconductive machine.
- The liquid metal current collectors in the motor and generator operated at current densities exceeding 1000 A/cm^2, approximately 100 times greater than that of conventional brushes.
- The reversing switchgear, designed for 25000 amperes, is one tenth the size of conventional equipment, yet more efficient.

Shipboard test operations with the 300 kilowatt system are being followed by the 2250 kilowatt model system evaluation which is presently underway, together with demonstrations of supporting technologies in other key component areas which are not adequately modeled in the 2250 kilowatt systems.

The principal electric propulsion machinery technology areas which are being developed in support of the current program are: (1) Direct liquid-cooling of rotor, stator and field windings of motors and generators (deionized water or oil), (2) High performance sliding contacts for low-speed propulsion motors and high-speed generators (solid brushes and liquid metal current collectors) and associated ancillary systems, (3) Superconductive magnet systems and associated cryogenic helium refrigeration equipment, and (4) Advanced-design ancillary components for shipboard electric propulsion systems such as lightweight switchgear and liquid-cooled, co-axial; high current transmission lines.

Cryogenic helium refrigeration equipment development in support of superconductive motor and generator developments is concerned with the two major components of such systems, compressors and liquefiers. Alternative design concepts for each of these components are being developed in experimental prototype models. Unlike the scale-modelling effort in electrical machines, the helium refrigeration equipment is being developed at full-scale, i.e., the helium compressors and liquefiers under development are sized to provide cryogenic helium for the superconductive magnet in a full scale propulsion motor or generator.

Ships' Service electrical generation system developments span a full spectrum from retrofit to advanced systems. A program is underway to reduce the fuel consumption of the 501-K17 gas turbine (which is used for electrical power generation aboard the DD 963 and CG 47 classes) by 10 percent while increasing its power output by 50 percent. A mounting and enclosure system is being designed and built for diesel generators in the 1500-2500 kilowatt range which will reduce the system size and weight by 30 percent while meeting all ASW noise goals. For advanced system concepts, a battery energy storage system is being developed which will either eliminate the need for operation of redundant generator sets (off-line system) or will augument standard power sources during peak demand periods or periods of low propulsion power operation (on-line systems). Auxiliary systems are consistent with this philosophy and include items such as heat pumping heating, ventillation and air conditioning systems, high-efficiency lighting and electric motors, reverse osmosis desalination, and variable speed motor controllers for improved part-load efficiency.

Finally, in the area of hydrodynamics, efforts are directed at the development of improved hull and appendage configurations. Some of these, such as the use of propulsion pods or nacelles, are ideally suited to the electric drive concepts discussed previously. That is, they permit the complete removal of drive-train components from the ships' hulls. Other areas include use of contrarotating propellers, bearing-in-rudder-post designs as opposed to offset spade rudders, and the retrofit of bulbous bows on many auxiliary-class ships. The ultimate goal of this area of research is the development of a hull design methodology which will permit optimization of energy savings without sacrificing other critical parameters such as seakeeping and survivability.

SHIP FUELS

The final area is perhaps the most important from the standpoint of time criticality. The changing nature of crude sources and finished fuels have created an interesting and unpredictable situation. The military specification presently in use was prepared for straight-run fuels. However, with the abundance of heavy crudes presently on the market, the use of hydrocracking and other similar processes has produced fuels which have properties not generally predicted using current tests. One graphic example of this is storage stability. The U.S. Navy stores fuels, for emergency reserves, far longer than commercial counterparts. Tests, previously reliable, have shown some of these fuels to be acceptable, whereas in practice the fuels have failed and caused severe problems. Consequently, the near-term goal of the Mobility Fuels Program is to determine solutions to these types of problems. In the longer range, efforts are directed at expanding the Navy's capability to use broad-range fuels, although it is unlikely that these would transcend the distillate range. It's anticipated that these efforts will be completed in the 1985 time frame.

A second goal of this program is the qualification of fuels derived from synthetic sources. Of interest are primarily those derived from oil shale and tar sands. Consideration was given to alcohols and to hydrogen, but these were found to be unsuitable for shipboard use because of factors such as energy density and safety. Coal liquids are considered to be long-range alternatives.

The most significant experiment conducted to date has been the production of 73,000 barrels of crude at the Naval Oil Shale Reserves in Anvil Points, Colorado. This crude was refined by SOHIO into a full set of military fuels which were proven to be completely acceptable. With regard to ships, 17,000 barrels of Diesel Fuel Marine (DFM) were refined. Testing in boilers, diesels, gas turbines, and fuel handling systems proved that this fuel was as good or better than the conventional (referee) diesel fuel. The final test and demonstration was performed during June and July of 1983 when the USS SCOTT (DDG 995) was powered for approximately 150 hours on 172,000 gallons of shale-derived diesel fuel. This demonstration conclusively proved that acceptable military fuels can be refined from oil shale.

SUMMARY AND CONCLUSIONS

The efforts described in the preceding sections constitute a systematic approach to solving the U.S. Navy's energy problem through intensive and directed research and development programs. In the near term, machinery system and hull form modifications will provide the operating efficiency improvements necessary to achieve the Chief of Naval Operations (CNO) goals of a 10 percent reduction in fuel consumption by 1985, and a 20 percent reduction by 2000. In the longer range, implementation of radically different ship design innovations will facilitate the achievement of reductions.

The mobility fuels situation is similar to that of conservation in that near-term efforts are directed at improving current procedures, namely the military specification for fuel procurement; and the longer range goals involve development of new concepts, namely, new fuel sources and broader specifications. It's anticipated that the tasks underway will achieve the goal of development of a fuel specification by 1990, which is both source and process independent, and which will accommodate the orderly utilization of synthetic fuel from sources such as oil shale and tar sands.

ADVANCED DESIGN FOR SEMI-SUBMERSIBLE OFFSHORE PLANT SYSTEM FOR PROCESSING NATURAL GAS

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ABSTRACT

A semi-submersible offshore plant system for processing natural gas has been designed with the basic technology studies such as oscillation tests of a distillation column and a packed column for processing LNG, and tank and wind tunnel tests of floating LNG plant. Evaluated from the technical and economic points of view, the system is basically concluded as feasible.

INTRODUCTION

An offshore gas field newly discovered will sometimes have to be given up due to the economic and technical difficulty in laying pipelines traceable to adverse natural or rear conditions such as a long distance from the land, water depth and the scale of the gas field itself.

Design work on an offshore natural gas processing system is intended to effectively utilize such a small gas field (that does not allow development by pipelines for economic or technical reasons), or the gas accompanying oil.

This system is to treat natural gas chemically onboard a semi-submersible offshore plant and convert it into LNG, and then transport it to the users by tankers or barges instead of pipelines. When a gas field is dried up, the offshore plant can move to other easily. It benefits small gas fields scattered over many locations and suits Japan's natural conditions.

DESIGN CONDITION

Original gas in place: 15,000 MM m^3

Gas production rate : 3,600 M m^3/d

LNG processing rate : 2,400 t/d (756 M t/y)

LNG storage capacity : 28,800 t

Water depth : 300 m

Meteorological and sea conditions:

Condition	Wind velocity (m/s)	Wave		Tidal current (knot)
		H1/3(m)	T(s)	
Operation limit of the plant	20*	7	6∿20	3
One year's storm	36*	10	9∿20	3
100 years' storm	60**	18.5	11 ∿20	3

N.B. * : 10 minute average
**: max. instantaneous

OUTLINE OF LNG PLANT

LNG processing unit	:	1 set of 2,400 t/d capacity
Semi-submersible structure	:	mat type, 90m(L) x 90m(B) x 40m(H to main deck), draft (light 6.5m, full 25m), mat (90m x90m x 5m), LNG storage column (55mø x 32mH), outside column (58mø x 35mH), support columns (4 - 15mø x 35mH, 4 - 3mø x 35mH)
Mooring system of the structure	:	Ordinary anchor/chain type, chain 12 - 100mmø x 1,350m, anchor 12 - 60 tons (in water)

(Refer to Figs. 1 & 2.)

BASIC TECHNOLOGY STUDIES

During the design stage of the system, the necessary technology has been analyzed point by point and related experiments have been carried out. Major experiments which have been performed include:

(1) Oscillation test of a distillation column

Oscillating (rolling, swaying and/or heaving individually or simulataneously) a gas liquid contact tower with sieve trays with downcomers or dual flow trays without downcomers, phenomena such as tray pressure drop, weeping and entrainment were observed and the effects of oscillation on the mas transfer were measured. (Refer to Fig. 3.)

(2) Rolling test of a packed column mainly used as a absorber or a stripper, for two kinds of tower packings

The same observation and measurement as (1) were done.

(3) Tank and wind tunnel tests of LNG plant

(a) Current test of LNG plant and LNG tanker in calm water,
(b) Wind tunnel test of LNG plant,
(c) Motion test of LNG plant in waves,
(d) Relative motion test between LNG plant and LNG tanker in waves,
(e) Relative motion test between LNG plant and LNG tanker in current and waves, and
(f) Relative motion test between LNG plant and LNG tanker in wind and waves

were carried out. (Refer to Fig. 4.)

CONCLUSION

According to the technology studies and test results carried out, the performance of LNG plant during wind, waves and current will satisfy the operational requirement for the LNG processing unit, and then it is estimated to be operable almost throughout the year.

Estimation of the economy of the system was also done and the result shows that the system will be feasible.

As a conclusion, a large scale pilot plant test is recommended before constructing a actual plant.

ACKNOWLEDGEMENT

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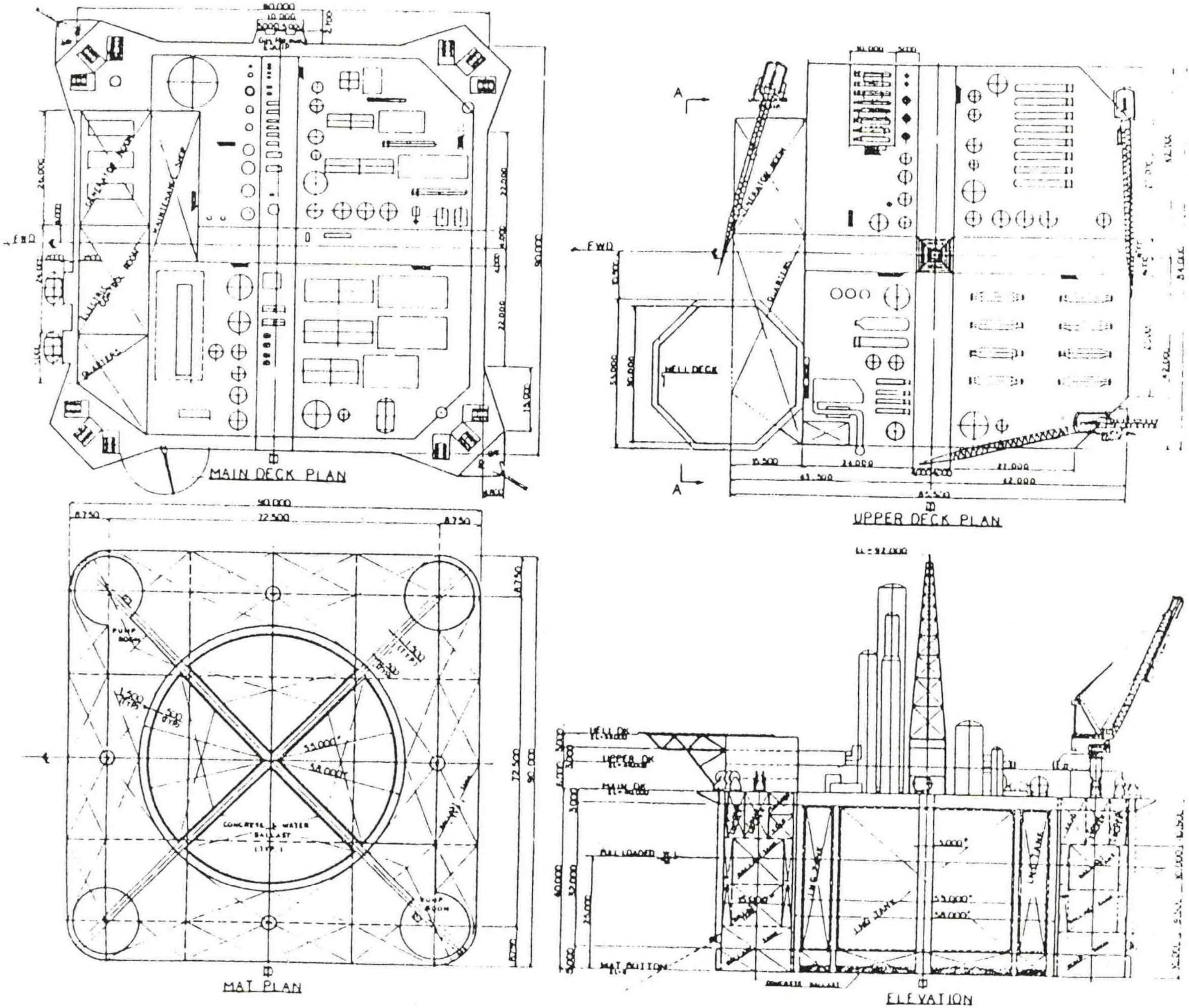

Particulars of LNG processing unit	
Gas production rate	3,600 M m³
LNG processing rate	2,400 t/d
LNG storage capacity	28,800 t

Particulars of semi-submersible structure			
L x B x H/d			$90^m \times 90^m \times 40^m / 25^m$
Displacement (at d = 25m)			110,000 t
Structure	Mat		$90^m \times 90^m \times 5^m$
	LNG storage column		$55^{md} \times 32^m H$
	Outside column		$58^{md} \times 35^m H$
	Support column		$4-15^{md} \times 35^m H$ $4-5^{md} \times 35^m H$
Tank capacity	LNG storage		$61,300^m (28,800^t)$
	Ballast	Mat	31,600 m^3
		Support column	22,900 m^3
		Outside column	19,300 m^3

Fig. 1 General arrangement of offshore LNG plant

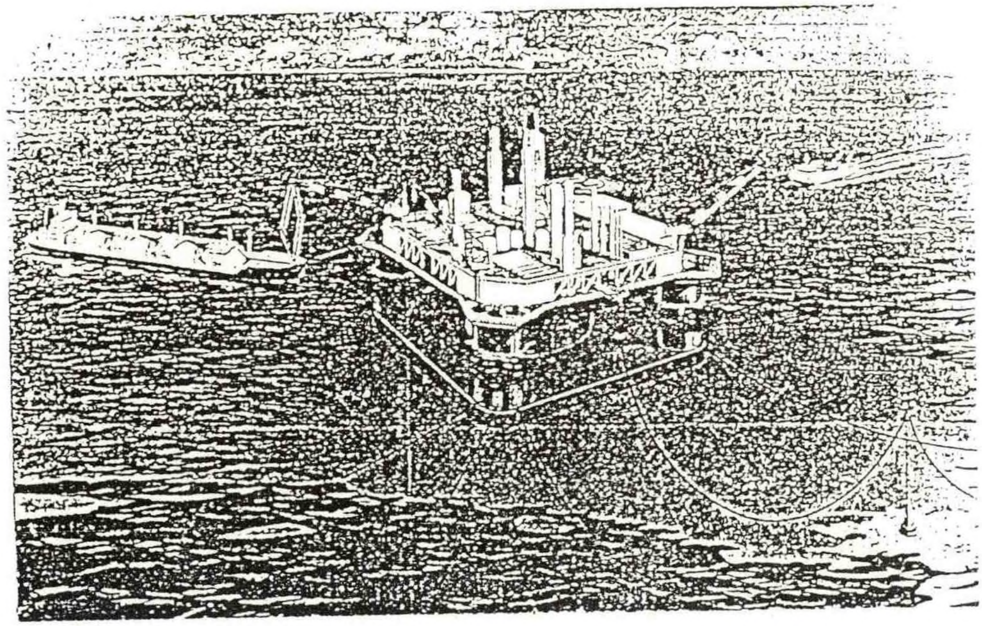

Fig. 2 Perspective of LNG plant system

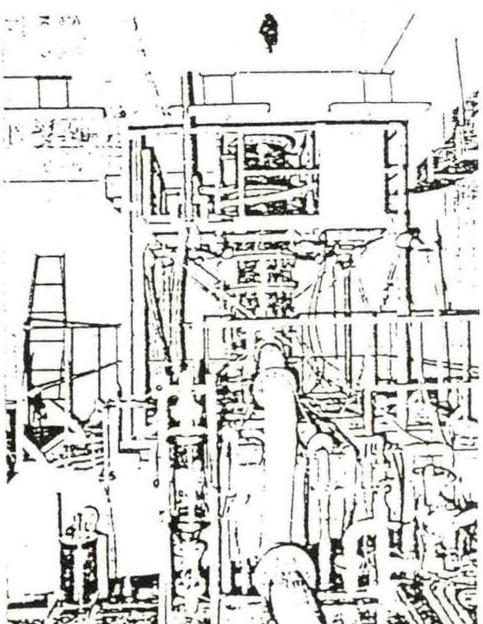

Fig. 3 Oscillation test of a distillation column

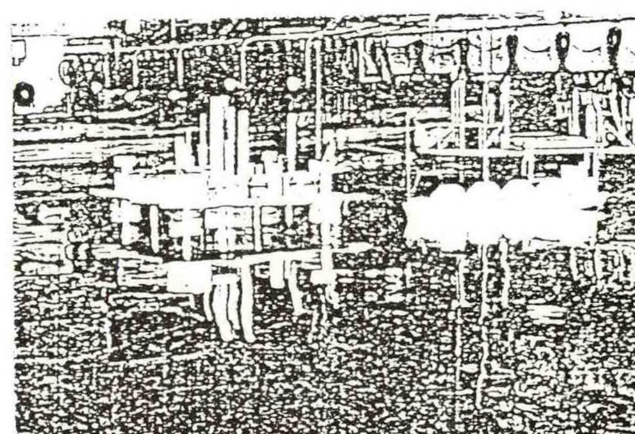

Fig. 4 Relative motion test between LNG plant and LNG tanker in wind and waves

ADVANCES IN U. S. COAST GUARD MARINE VEHICLES

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ABSTRACT:

The U. S. Coast Guard Advanced Marine Vehicles Research and Development Program is directed at the application of advanced marine vehicles to operational missions. Vehicles which are being considered can be categorized under five headings: fully-submerged hydrofoils, surface-piercing hydrofoils, hovercraft, planing craft, and small waterplane area twin hull (SWATH) craft. These craft surpass the mission effectiveness of conventional cutters in most operating areas due to superior speed or seakeeping capability. However, the benefits may be received at the expense of degraded fundamental mission tasks or capabilities, e.g., towing, boarding, or payload.

A primary objective of this research and development program is to quantify the cost-effectiveness trade-offs of using advanced marine vehicles to perform the Coast Guard's operational missions. The approach is to conduct operations analyses, along with literature reviews, and operational and technical evaluations.

INTRODUCTION:

The latest and most comprehensive U. S. Coast Guard research and development effort in advanced marine vehicles began in 1980. The program was instituted as a means of evaluating the utility of evolving advanced marine vehicle technology within the context of the Coast Guard's operational missions. Previous research work in this area addressed the potential fulfillment of missions or mission tasks with advanced craft which were selected from a very limited field of first-generation alternatives. In recent years, advanced marine vehicle technology has progressed through the conceptual phase to the development of second and third generation vehicles and subsystems whose design and engineering characteristics are both practical and viable. There can be no doubt that the advanced state of the technology at the present time is one of the most important strengths of the present program. The general categories of advanced marine vehicles which are represented by proven demonstrator craft in the size range of primary interest to the U. S. Coast Guard (100-1500 tons) are the following: fully-submerged hydrofoils, surface-piercing hydrofoils, hovercraft, planing craft, and small waterplane area twin hull (SWATH) craft. In all cases, these craft-types surpass the mission effectiveness of conventional cutters of the same general size in most operating areas due to superior speed capability (in calm water or in a seaway) or superior seakeeping capability. However, the benefits may be received at the expense of other fundamental mission tasks or capabilities, e.g., towing, boarding, range, and payload; and, as always, each improvement has a commensurate impact on life-cycle cost.

This research and development program is composed of two interactive project areas: one which addresses the operations research/operations analysis aspects and one which is designed to establish and maintain a relevant technical data base. In this way, the continuously updated operations research work can drive the technical portion of the program which, in turn, provides the input to the various operations research models. Either portion of the program can support long-term or short-term requirements of the operational Coast Guard.

BACKGROUND:

The most significant precursors of the present U. S. Coast Guard advanced marine vehicles research and development work were very limited evaluations of a British Hovercraft SK-5 air cushion vehicle for use as a search and rescue craft and broader evaluations of first generation fully-submerged hydrofoil craft for use as multi-mission patrol craft. An operational demonstration of the SK-5 craft was conducted in the late 1960's. This led to a series of short evaluations of the craft[2,3]. In all cases, the poor reliability of the propulsion and auxiliary equipment overshadowed the advantages of improved speed and the amphibious capability which were manifested during the operational evaluations and contributed to the deterioration of interest in the air cushion concept for fulfilling the Coast Guard's search and rescue mission requirements.

The speed of fully-submerged hydrofoil craft both in calm water and in a seaway has been perceived correctly as a real advantage in offshore patrolling. Three U.S. Navy experimental fully-submerged hydrofoils were evaluated by the Coast Guard in the offshore patrolling missions at different times from 1972-1978[1,4,7]. The most comprehensive of these operational evaluations was

Figure 1. USCGC FLAGSTAFF

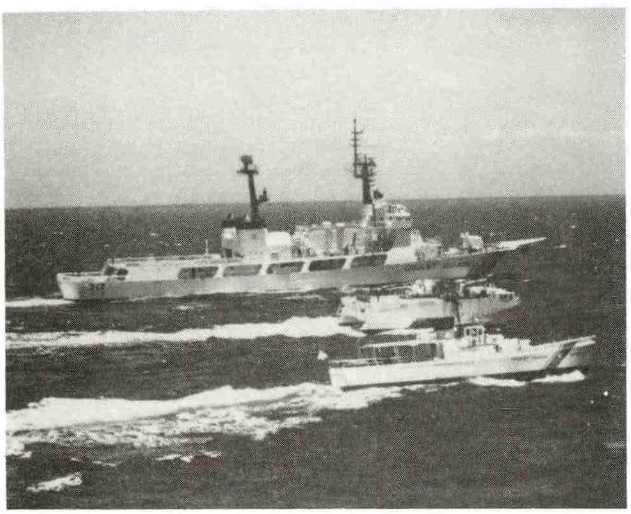


Figure 2. Side-by-side Trials

Figure 3. USCGC DORADO

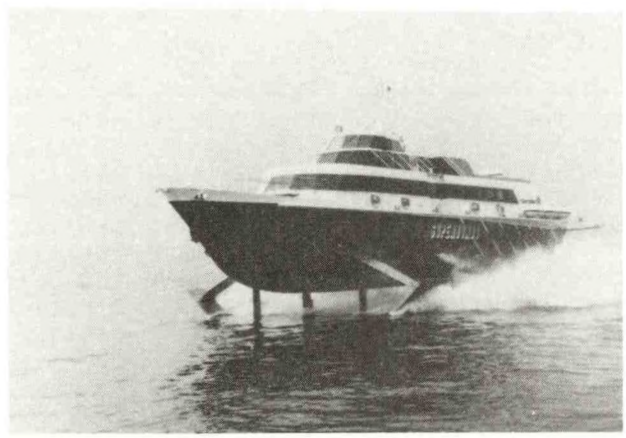


Figure 4. RHS-200

that of the FLAGSTAFF (Figure 1) which was a commissioned vessel of the U. S. Coast Guard from 1974 through 1975 and again from 1976 through 1978. In accordance with the Coast Guard's multimission attitude toward its cutters, the hydrofoils were evaluated as search and rescue and offshore patrol craft. Again, although the craft demonstrated their effectiveness in some mission areas, the evaluations were plagued by mechanical failures and maintenance problems. Nevertheless, the results were educational both for the Coast Guard and for the competing hydrofoil craft manufacturers.

A third effort which was extremely important for its technical value was the technical evaluation of the SSP KAIMALINO, a 220-ton SWATH ship which was constructed for the U. S. Navy by the U. S. Coast Guard Yard in Curtis Bay, Maryland. The side-by-side seakeeping tests, which were conducted in 1978 (Figure 2), demonstrated clearly the greatly improved seakeeping characteristics of the relatively small SWATH ship with respect to a 100 ton Coast Guard patrol boat and a 3000 ton high endurance cutter[6,8]. It is no doubt the primary reason that, among all of the advanced marine vehicle concepts, SWATH commands the largest degree of appreciation within the operational Coast Guard today.

RECENT WORK AND DEVELOPMENTS:

The field testing portion of the present program has yielded some very informative and demonstrative results. In particular, a technical and operational evaluation of a 140-ton surface effect ship manufactured by Bell-Halter (Figure 3) gave the Coast Guard its first look at a small surface effects ship which might fulfill some mission needs in the patrol boat size range[5]. The results of the evaluations gave new life to the surface effects concept for Coast Guard missions. Three such craft have been procured for use in patrolling the Southeast coast of the United States. A technical evaluation of a 40-ton SWATH ship demonstrated the viability of the SWATH concept in the smaller size range. Subsequently, a technical evaluation of a 120-ton surface-piercing hydrofoil craft manufactured by Rodriquez Cantiere Navale of Messina, Italy (Figure 4) demonstrated the capabilities of such craft when equipped with an active stabilization system.

Most recently, side-by-side trials of the SSP KAIMALINO and a 1000-ton ocean-going buoy tender were conducted near Oahu, Hawaii. The trials examined all facets of the buoy tending mission including transit and buoy servicing. Again, the SWATH ship demonstrated a much improved seakeeping capability in transit over the larger ship. Measured rolling motions showed that the buoy tender rolled twice as fast as the SWATH ship with maximum roll angles which were four times as great as those of the SWATH. This improved performance persisted through the zero speed servicing trials. Moreover, at zero speed the motions characteristics of the SWATH were observed to be independent of relative heading to the seaway, whereas the buoy tender had much more difficulty handling the buoy in a beam sea than in a head sea. These trials demonstrated once again the advantages of the SWATH concept, this time in a working mission. Since most working missions do not require high transit speeds, these advantages are not diluted by the large fuel penalty which must be assessed to higher speed SWATH ships.

The most significant difference between these evaluations and those discussed previously was the demonstrated improvement in reliability of the craft which were evaluated over that of the early generation air cushion vehicles and hydrofoils. For this reason above all others, the field testing portion of the work has been a great asset to the advanced marine vehicles research program.

CONCLUSIONS:

The U.S. Coast Guard's Advanced Marine Vehicles Research and Development program is very active, particularly in the area of full-scale ship trials. Since the emphasis of the program is on comparative naval architecture, side-by-side trials with operational craft are conducted whenever possible. So far, the results have been extremely useful in matching craft concepts to operational missions. The primary considerations in this regard are the speed required and the expected sea states. At this time, the performance and cost data which has been generated for patrol boats (100-300 tons) indicates the best general matching shown in Table 1. The results of future work will be used to refine this general matching scheme and to discriminate more clearly among the craft alternatives within the particular categories of speed/sea state.

Table 1

Speed \ Sea State	Low	High
Low	Conventional Monohull	SWATH
High	Surface Effects Ship Planing Craft Surface-Piercing Hydrofoils	Fully-Submerged Hydrofoils

REFERENCES:

1. Irvine, James F. and Donald T. Blake, "Operational Evaluation of the Hydrofoil Concept for U. S. Coast Guard Missions. Phase I. Report of Operations with the USCGC Flagstaff (WPBH-1)"

2. Lutton, Thomas C., "Air Cushion Vehicle Evaluation, San Francisco, California, Point Barrow, Alaska, 1 January 1971-31 August 1971"

3. Lutton, Thomas C., "Air Cushion Vehicle Evaluation, San Francisco, California, St. Ignace, Michigan, Milford Haven, Virginia, TRNAPO '72"

4. Mitchell, T. R. et. al., "Observations of the Performance of TUCUMCARI (PGH-2) in U.S. Coast Guard Mission Oriented Trials"

5. Spangler, Peter K., "Test and Evaluation of the Bell Halter 110-Foot Surface Effect Ship Demonstration Craft"

6. Wiker, Steven F. et. al., "A Vessel Class Comparison of Physiological, Affective State and Psychomotor Performance Changes in Men at Sea"

7. Williams, R. E. and P. L. Ehrman, "Operational Evaluation of the Hydrofoil Concept for U. S. Coast Guard Missions - Executive Summary"

8. Woolaver, Dennis A. and J. Brooks Peters, "Comparative Ship Performance Sea Trials for the U. S. Coast Guard Cutters MELLON and CAPE CORWIN and the U. S. Navy Small Waterplane Area Twin Hull Ship KAIMALINO"

NEWLY BUILT LARGE OIL SKIMMER

(NO. 3 TAKAHOKO MARU)

Ikuo Mutoh

Mitsui Ocean Development & Engineering Co., Ltd.

ABSTRACT

NO. 3 TAKAHOKO MARU was completed on 30th May, 1983 and delivered to Mutsu Ogawara Oil Storage Co., Ltd.(MOOS) which operates a national crude oil storage base including an offshore oil transshipment terminal with a single point mooring buoy, at Mutsu Ogawara, Aomori Prefecture.
She is one of the working boat fleet which consist of a tanker loading supporting vessel, an oil boom deploying vessel and an oil skimmer. She is one of the largest exclusive oil skimmer in the world as she was designed to keep her seaworthiness in the hostile open waters of Pacific Ocean.

INTRODUCTION

1. Main Features

1) She is a MODEC Inclined Plane Oil Skimmer(MIPOS) of which the forward part is catamaran hull and the aft part is mono hull and the oil main collecting system is built in the hull. Floating debris is collected by the net conveyor. Fig. 2 shows the principle of the oil and debris collecting system.

2) She can spray two kinds of oil dispersant and tow the oil spill absorbing material so as to prevent the expansion of oil spill.

3) She has a powerful fire fighting equipment including a foam fire extinguishing system against VLCC fires.

4) She has a good manoeuvrability and towing force as a result of two sets of steerable nozzle propeller.

5) She can work in the hostile condition of open seas due to the large skeg and bilge keels.

6) She is constructed in accordance with explosion proof standard of small tanker regulations, and has a gas detecting device and water curtain system.

7) She can haul up an end of a floating hose of the single point mooring buoy by a revolving deck crane through a ramp way at stern, for exchanging the oil with water in the hose.

8) She can handle the mooring ropes for the tanker and also guard the waters.

2. Principal Particulars

Length overall	: 44.70 m
Length b.p.	: 37.80 m
Breadth(moulded)	: 12.00 m
Depth(moulded)	: 4.50 m
Designed full load draft	: 3.40 m
Gross tonnage	: 483 tons
Speed(max.)	: 11.78 knots
Speed(service)	: 10.00 knots
Complement	: max. 20
Main engine	: 1,300 ps x 720 rpm x 2, 4 cycle diesel engine
Propeller	: Steerable nozzle propeller x 2

3. Special Equipment

(1) Oil Recovery System
(MODEC Inclined Plane Oil Skimmer)

When the vessel run ahead at a speed of 2 - 4 knots, floating oil spill will stream down along the inclined plane between the fore catamaran hull, and during passage through the bottom of the oil collecting well, the oil will rise up into the collecting tank. Thus once the oil is captured in the collecting tank, it will never flow out from the tank due to the buffle plates' effect.

Oil recovery capacity :
abt. 92.8 m^3/h (based upon experiments at 30 cm wave height, 10 m wave length, 6 mm of oil thickness, heavy oil)

Oil transfer capacity :
abt. 160 m^3/h

Oil storage capacity :
Main recovered oil storage tank ----- 90 m^3 x 2
Auxiliary oil storage tank ----- 60 m^3 x 2

Oil transfer pump :
Type: Mono axial, Mohno pump (Electro-hydraulic motor driven)
Capacity: abt. 80 m^3/h (variable)
Delivery head: abt. 40 m

Oil water separator :
Type: Gravity separation

(2) Debris Recovering System

Floating debris are recovered by a metal mesh conveyor made of stainless steel net and perforated debris holding plate, driven by a hydraulic motor. The conveyor is usually stored on the deck horizontaly and in case of the operation, it is lowered on the surface.

Recovering capacity :
20 kg/m^2 of floating debris density

Recovered debris are contained in the container bags made of canvas. The debris container bags are handled by a deck crane with 10 t-m capacity on forecastle.

(3) Oil Dispersion System

Two kinds of oil dispersant, emulsification and gelatinization are used. The emulsifying liquid mixed with sea water is dispersed from two fixed nozzles at a rate of 600 ℓ/min., by a general service and fire pump of 48 m^3/h x 50 m capacity. The gelatinizing liquid is dispersed by a portable nozzle at a rate of 40 ℓ/min. by a dispersing pump of 2.4 m^3/h x 5 kg/cm^2 capacity.

(4) Spilled-oil Absorbing and Recovery System

The vessel has the towing booms stretching out 2 m outboard, for spilled oil absorbing materials "Oil Sweeper". The absorbing materials, composed of 3 tandem units with 4 lines on each side can absorb 2.4 kℓ of oil in total. The absorbing materials are hauled up on the aft deck well by an aft deck crane and the absorbed oil is recovered by a squeezing machine. After squeezing, the absorbing material can be used again.

(5) High Viscosity Oil and Debris Recovery System

The vessel has a special recovery towing net "Sea Sweeper" for high viscosity oil and debris, which is towed by two vessels including this vessel. A collecting bag fitted at end of the towing net is separated after the operation, and the bag is lifted up by an aft deck crane on the deck well.

(6) Fire Fighting System

Fire pump : Diesel driven pump
Capacity: 720 m^3/h
Delivery head: abt. 130 m

Fire monitor :
1 set x 6,000 ℓ/min. on the mast
2 sets x 3,000 ℓ/min. on the wheel house top

Water curtain nozzle :
6 sets 125ℓ/min.

Foam fire extinguishing system :
Foam liquid capacity: 9 m^3

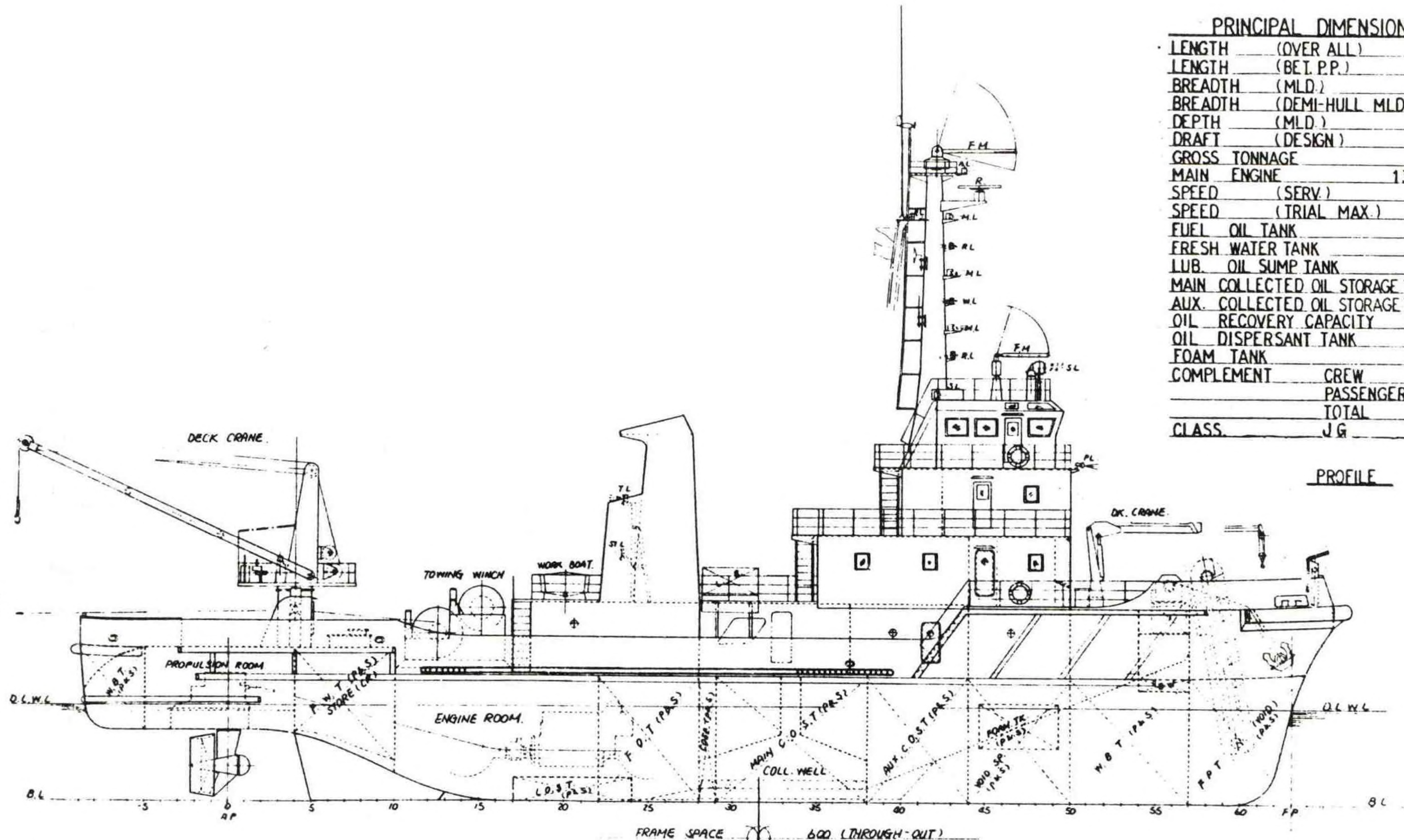
References:

1) I. Mutoh : "MODEC Oil Skimmer(MIPOS)" UJNR, MFP. 1975 (Fairbanks)

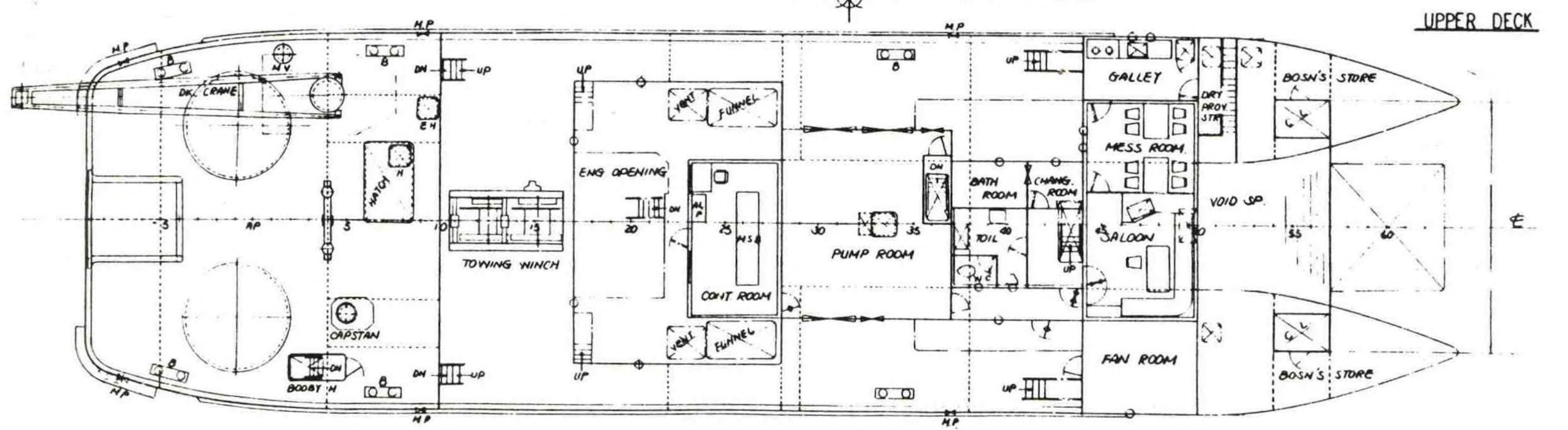
2) E. Tasaka, S. Motora : "The Development of Oil Fence (Booms) and Oil Skimmers" UJNR, MFP. 1979 (Tokyo)

PRINCIPAL DIMENSIONS

LENGTH	(OVER ALL)	ABT. $44^{M}70$
LENGTH	(BET. P.P.)	$37^{M}80$
BREADTH	(MLD.)	$12^{M}00$
BREADTH	(DEMI-HULL MLD.)	$4^{M}00$
DEPTH	(MLD.)	$4^{M}50$
DRAFT	(DESIGN)	$3^{M}40$
GROSS TONNAGE		ABT. 490^{TON}
MAIN ENGINE		1300^{PS} (MCR) × 2^{SET}
SPEED	(SERV.)	ABT. 10.0^{KT}
SPEED	(TRIAL MAX.)	ABT. 11.0^{KT}
FUEL OIL TANK		ABT. $40M^3$
FRESH WATER TANK		ABT. $40M^3$
LUB. OIL SUMP TANK		ABT. $5M^3$
MAIN COLLECTED OIL STORAGE TANK		ABT. $180M^3$
AUX. COLLECTED OIL STORAGE TANK		ABT. $120M^3$
OIL RECOVERY CAPACITY		ABT. $92.8M^3/H$
OIL DISPERSANT TANK		ABT. $1.5M^3$
FOAM TANK		ABT. $18M^3$
COMPLEMENT	CREW	8^{P}
	PASSENGER	12^{P}
	TOTAL	20^{P}
CLASS	JG	

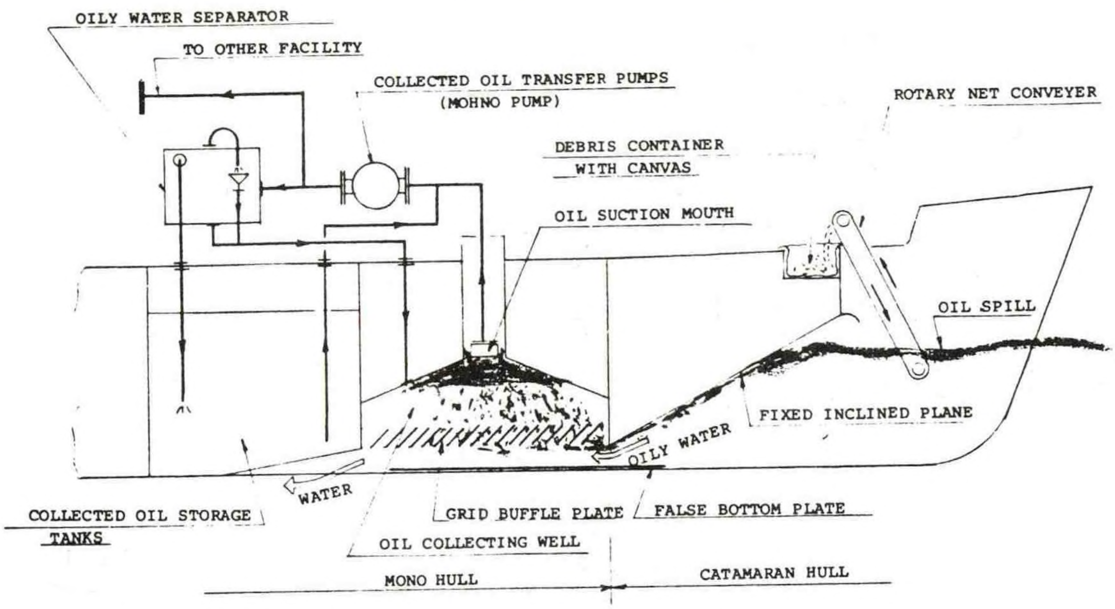


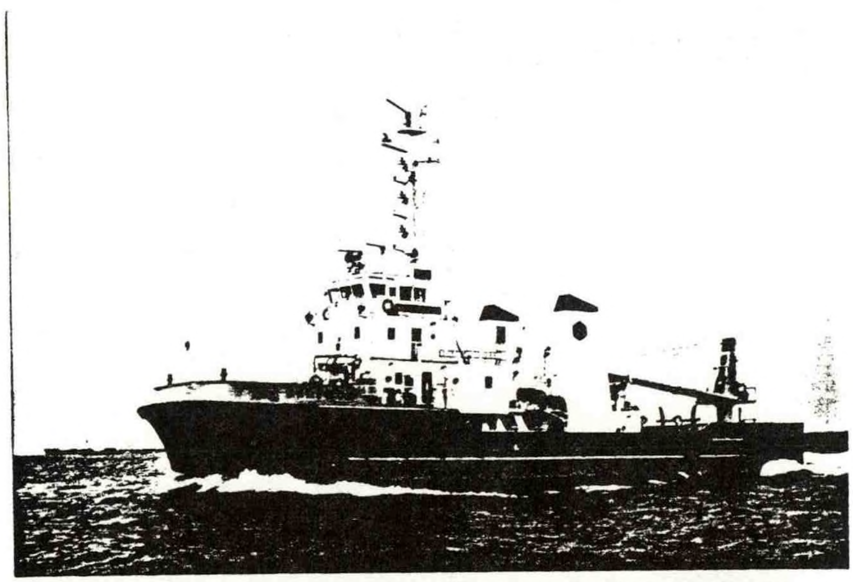
PROFILE

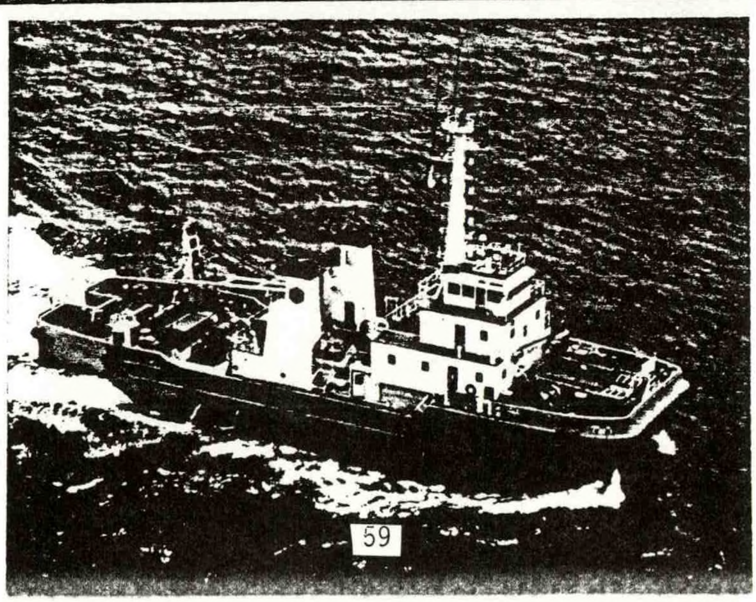


UPPER DECK

OIL AND DEBRIS COLLECTING SYSTEM OF MIPOS







DUAL SKIRT OIL BOOM "MOBAX"

Ikuo Mutoh

Mitsui Ocean Development & Engineering Co., Ltd.

ABSTRACT

The dual skirt oil boom which we developed was once introduced at UJNR's Marine Facility Panel in 1978. After that, we tested it in waves and currents using actual oil at Institute of Ocean Environmental Technology's test facilities which were built in 1978. By this test, we could confirm the performance and capability of the boom in waves and currents. It was named "MOBAX" and its two types, MOBAX - I and II, have been developed.

INTRODUCTION

1. In case of conventional oil boom with single skirt, it is reported that the retained oil would flow away from the skirt bottom if the current speed exceeds abt. 0.7-0.9 knot, as shown in Fig.1.

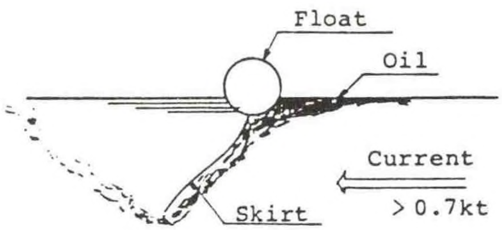


Fig.1. Conventional Oil Boom

However, MOBAX can retain the oil in higher currents up to abt. 1.4 knot, by virtue of its dual skirt and baffle plate system.

2. Principle of MOBAX

MOBAX is a dual skirt oil boom as shown in Fig.2 and 3. When the current speed is less than 0.6 knot, both skirts are upheld nearly vertical, and spilled oil is retained in front of the forward skirt as shown in Fig.2.

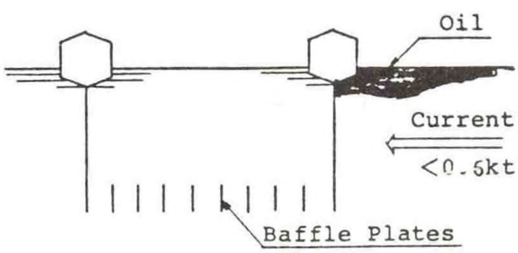


Fig.2. MOBAX in a low current

When the current speed exceeds 0.6 knot, the forward skirt gets to incline gradually and the stagnated oil in front of the forward skirt begins to flow down in droplets along the inclined skirt. The down-flowed oil droplets float up off the forward skirt bottom into the dual skirt space through baffle plates fitted at the bottom of the dual skirt. The oil once captured within the dual skirt space will not flow out owing to the effects of the baffle plates which reduce the eddy currents in the dual skirt space.

Fig.3. MOBAX in a high current

3. Principal Particulars of MOBAX

1) MOBAX - I

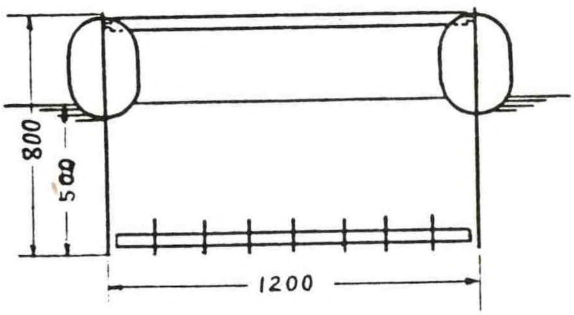


Fig.4. MOBAX - I

Total height : 800 mm
Freeboard : abt. 300 mm
Draft : abt. 500 mm
Weight : abt. 10 kg/m
Length of one unit : 20 m
Joint : Slide fastener (JIS)
Tensile strength : abt. 5000 kg

The skirt is conventional oil boom of which the float is made of polystyrene foam covered with polyethyrene and skirt is made of PVC coated fabrics.

The baffle plate is made of PVC coated fabrics and the connecting pipe of dual skirt and stiffeners are made of stainless steel.

2) MOBAX - II

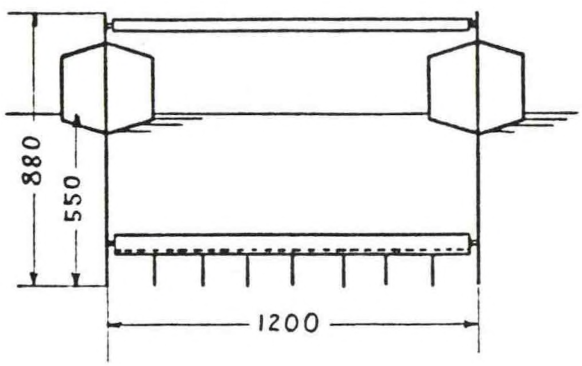


Fig.5. MOBAX - II

Total height : 880 mm
Freeboard : abt. 330 mm
Draft : abt. 550 mm
Weight : abt. 15 kg/m
Length of one unit : 20 m
Joint : Slide Fastener
Tensile strength : abt. 8,000 kg

All construction material is GRP except for the skirt which is made of nylon cloth coated with neoprene.

4. Performance of MOBAX

The full scale tests of MOBAX - I and II were carried out with oil at the tank test facilities of Institute of Ocean Environmental Technology at Tsukuba, in March, 1981.

1) MOBAX - II connected with the wing booms of conventional single skirt was tested with oil in a large square test basin being towed in various speed, as shown in Fig.6.

The length of MOBAX - II was 10 m and the length of wing booms was changed to 10 m and 20 m. The wave conditions were 30 cm in height, and 6 m and 10 m in length.

$$\frac{L}{10^m + 2\ell} = 0.6$$

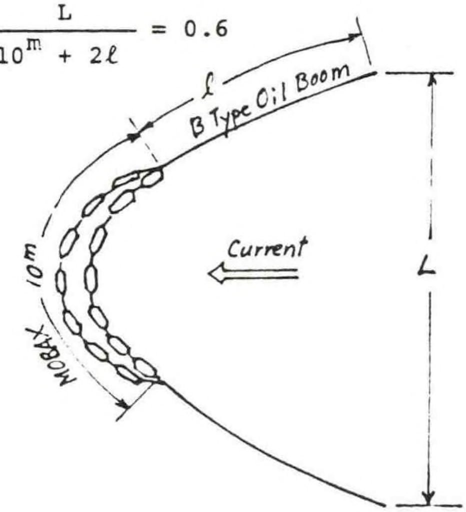


Fig.6. MOBAX Test

2) MOBAX - I and II were also tested with oil in a circulating water channel to confirm the oil collecting performance in waves and currents. The wave conditions then, were 60 cm in height and 10 m in length.

3) After the above tests, the performance of the MOBAX is clarified as follows;

(a) Wave conditions:
30 cm in height
10 m in length
Wing boom: 10 m in length

Up to abt. 0.9 knot current, the oil is retained in front of the forward skirt. When the current exceeds 0.9 knot, the oil starts floating upward into dual skirt space and when the current exceed 1.4 knots, a small volume of oil begins to leak backward.

(b) Wave conditions:
30 cm in height
6 m in length
Wing boom: 10 m in length

Nearly same as the above, but when the current exceeds 1.2 knot, a small volume of oil begins to leak backward.

(c) Wave conditions:
60 cm in height
10 m in length

Up to abt. 0.8 knot current, the oil is retained in front of the forward skirt. When the current exceeds 0.8 knot, the oil starts floating upward into dual skirt space and when the current exceeds 1.2 knot, a small part of oil begins to leak backward.

(d) The oil containment capacity of MOBAX is abt. 90 % of spilled oil under the condition of 30 cm wave height and 1.4 knot current speed.

5. Conclusion

As a result of the full scale tests in waves and currents, it was confirmed that MOBAX has a good retainability and containability of spilled oil in waves and currents. MOBAX can be used in waves and currents, not only for retaining oil but also for recovering spilled oil when fitted with a suitable suction mouth and hose in the dual skirt space. MOBAX is also designed to be foldable compactly for easy carrying and handling.

References:

1) I. Mutoh : "MODEC Oil Boom for High Current"
UJNR MFP 1978 (Annapolis)

2) E. Tasaka, S. Motora : "The Development of Oil Fences (Booms) and Oil Skimmers"
UJNR MFP 1979 (Tokyo)

THE SEAKNIFE

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ABSTRACT

The SeaKnife is a new revolutionary type of boat that can attain very high speed with exceptional stability and maneuverability. Results of some of the tests that have been conducted and plans for its future use are discussed.

INTRODUCTION

This paper will describe in a very brief way the evolution of a unique vessel called the SeaKnife. It is unique in its hull design and the performance which this design allows in heavy seas and its stability both at very high speeds and dead in the water.

DISCUSSION

The SeaKnife was originally built in 1971 by hydrodynamist Peter R. Payne of Annapolis, Maryland. The design was patented. During the seventies, the boat (a 21'version) was extensively tested in the United States, England and in Russia. Models were also tested widely in various tow tanks. In all cases the performance characteristics, such as stability, maneuverability, speed and ability to operate in heavy seas far exceeded expectation.

In 1980 SeaKnife Limited Partnership acquired an exclusive license to produce the vessel for all applications and sizes. This partnership was headed by Ron Cain of McLean, Virginia. Also in 1980 a 34' wood hull prototype was built and since that time has undergone extensive testing.

In the summer of 1982 demonstrations were run for high-ranking Navy, U.S. Coast Guard and Customs personnel, along with foreign military attaches and other representatives of foreign governments and commercial organizations. The demonstrations were received and declared unanimously as "fantastic."

In the spring of 1983 some limited tests were run by NavSeas and the U.S. Coast Guard at the NavSeas Combat Systems Engineering Station at Norfolk, Virginia, and reported on in NAVSEACOMBATSYSENGSTA Report No. 60-113. Due to a breakdown in certain of the test equipment, the tests were not as thorough as had been hoped. However, the report does state, "The SeaKnife maneuvers well and imparts the feeling that very tight turns can be made at very high speed. The boat did NOT exhibit ANY negative maneuvering characteristics," and "It was further noted that when the SeaKnife was dead in the water, like most craft, it eventually assumed a beam sea attitude. When in this position, there was practically no roll induced by the waves. The craft would heave slightly and pitch up by the stern as the wave passed, but no significant beam sea induced rollings were noticeable." These tests were run in 6-foot seas. Further data on these tests indicate the performance is far superior in all aspects and the ride was at least 2-1/2 times better than a longer hull deep-V 38' Scarab vessel being tested simultaneously.

Comments by four SEAL team officers who both rode in these tests and operated the SeaKnife are as follows:

1. Believes the SeaKnife has a real potential and would like to continue the tests.

2. The overall performance was outstanding and the maneuverability was exceptional.

3. Very stable at speed and dead in the water.

4. The advantages of the boat are its speed and maneuverability, its tight turning radius and low profile. You can lay the boat on its side and turn it 180° at full throttle without reducing power within two boat lengths.

A design has been prepared for a 83' patrol boat configuration with the following specifications:

SeaKnife Patrol Boat Configuration

LOA	83'
Length at waterline	64'
Beam	37.6'
Beam at bottom	22.6'
Depth to gunwale	10'
Maximum displacement with full load (with Harpoon missiles) (70.2 Lt)	157,148 lbs

Light ship displacement
(without mission items) (31.5 Lt) 70,475 lbs

Performance:
Range (SS-0) 1,706 n. miles
at maximum continuous power (4330 hp)
Range (SS-3) 1,323 n. miles
at maximum continuous power (4330 hp)
56,467 lbs fuel
20,000 lbs fuel option bladdertank 2,134 n. miles

Pursuit Power:
One 501-KF Allison (maximum available hp, 6000)

Port Power:
Two Garrett GT601
Using one GT601 at 8 knots (range is 3,800 n. miles)

Speed:

Full load	50 knots
Lt load at 80% of power	78 knots
Short time top speed with light load	100 knots

Plans are underway to build this patrol boat with private funding. It will probably be built in the United States but there have been discussions on building it overseas. Conversations with a major U.S. aluminum company are expected to yield an agreement to produce the boat in kit form. This would simplify its construction in countries lacking sophisticated shipbuilding facilities.

My position with SeaKnife is in marketing it overseas in all configurations: work boat, patrol boat, sport fishing or recreation vessel. Surveys have indicated a very extensive market, and we are currently having discussions with a number of prospective purchasers.

I have available some copies of the following reports which discuss various aspects about the SeaKnife:

"Explanation of the Super-critical Hull Design and the Performance of the SeaKnife," by Peter R. Payne;

"A New Approach to Fleet and Base Naval Protection," presented to the Falklands Conference by Ron Cain, September 3, 1982;

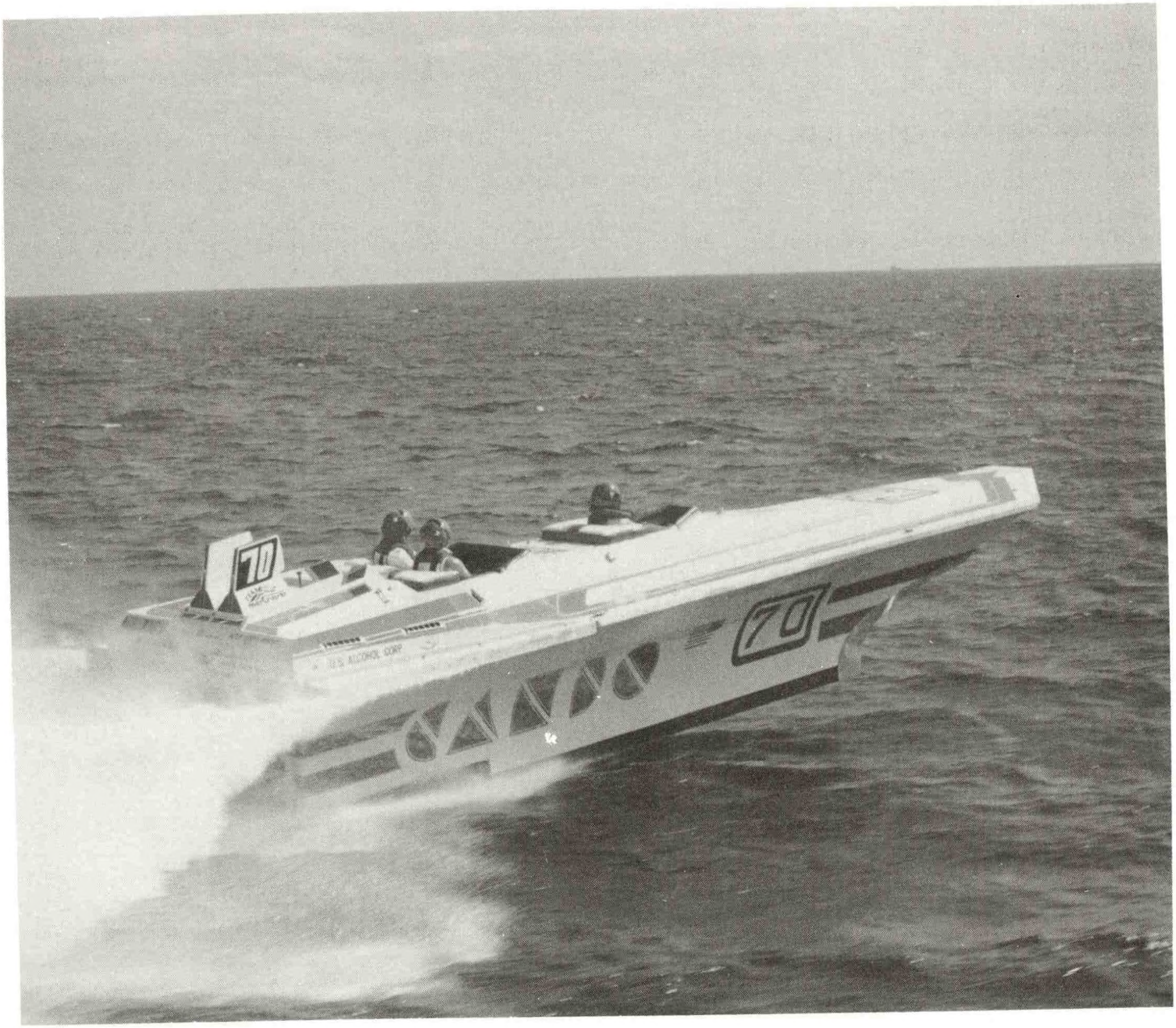
"Naval Design on the Knife's Edge," by David Harvey, Defense & Foreign Affairs, May 1982;

"Performance Test Results for a 34 Foot SeaKnife," by C. E. Shields, NAVSEACOMBATSYSENGSTA Report No. 60-113, June 1983.

SUMMARY

In summary, we believe the following characteristics make the SeaKnife a very attractive platform for almost any job: speed, maneuverability, stability at high speed and dead in the water, low profile and smooth ride.

I have a short film taken during certain of the demonstrations which will illustrate some of these characteristics.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OCEANOGRAPHIC RESEARCH VESSEL "TANSEI MARU"

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ABSTRACT

The TANSEI MARU (Fig. 1) which is the most modern oceanographic research vessel completed on October 15, 1982 at Shimonoseki Shipyard & Engine Works of Mitsubishi Heavy Industries, Ltd. to the order of Ocean Research Institute, University of Tokyo (The Ministry of Education) replaced the first TANSEI MARU completed in 1963. The vessel is designed for multi-purpose observations and research, i.e. basic research concerning the ocean bed, including physical, chemical, biological, geological, and meteorological, fishery research and other fields.

INTRODUCTION

She is a single decker with a long forecastle and a deck house and careful consideration has been given to the design of her hull forms and structural arrangements to ensure adequate propulsion performance during normal navigation, improved performance for slow speed navigation, and also prevention of vibration.

The vessel is designed so as to have high performance for seaworthiness which allows out sea conditions. It also has ample stability and reserve buoyancy so that it can accommodate any future increase or modification in observation device.

A complete system of hybrid navigation equipment is installed, and this is the first time for a vessel of this class. This equipment has also made it possible to significantly improve the accuracy of position measurement, which is particularly important for research vessels.

1. Leading Particulars

Classification	: JG, Fishing vessel
Overall length	: 51.00m
Length between perpendiculars	: 45.00m
Breadth (moulded)	: 9.20m
Depth (moulded)	: 4.20m
Designed full load draft (moulded)	: 3.70m
Gross tonnage	: 469.84 ton
Service speed	: 12 knot
Complement	: Total 38 (Crew 23, Scientist 11, Reserve Personnel 4)
Main engines	: 750PS x 720/237 rpm, two sets of diesel engines with a reduction gear. Two engines are coupled to one main shaft.
Electric generators and prime movers:	
(Main generators)	300kVA9240kW) AC 450v 60 Hz 2 sets
(Prime movers)	360PS x 1,200 rpm 2 sets
(Auxiliary generator)	300kVA(240kW) AC 450V 60 Hz 1 set
Propeller	: 2650mm x 4 blade c.p.p.x 1 set
Bow thruster	: 980mm x 4 blade c.p.p. x 1 set
(Electric motor)	160kW x 1,160rpm

Sewage and waste water treatment equipment:
Aerobict TF-40(with a capacity for 40 persons)

2. Arrangement of Equipment for Research and Observation

(1) Operation deck for observation

A wide operation deck (wooden deck) is prepared in the stern part to deal with increases in size or changes in the ovservation equipment, and the living quarters are positioned midship a little nearer to the bow.

A wide wooden deck is also constructed on the long forecastle deck forward of the living quarters, and a considerable amount of observation work can be carried out there.
To utilize the limited space on the vessel as effectively as possible, equipment on the operation deck has been positioned asymmetrically, that means the observation winches have been installed on the port side to secure a wide space on the starboard side facilitating observations.

(2) Observation winches

Four observation winches, including a large one which can lower or lift research and observation equipment to or from a depth of 7,000m, are installed in positions which has been decided through full consideration for operation efficiency. The possibility of mounting portable winches in future is also taken into account.

* No. 1 winch
  Electrohydraulically driven,
  3t x 43m/min, ø9.14mm x 7,000m
  This winch is used for the collection of samples of water or mud, living organism, etc. in deep sea areas using large equipment.

* No. 2 winch
  Electrohydraulically driven,
  1t x 76m/min, ø6.37mm x 4,000m
  This winch is used for lowering and lifting a conductivity temperature depth sensor using an armored coaxial cable.

* No. 3 winch
  Electrohydraulically driven,
  1t x 75m/min, ø4.76mm x 7,000m
  This winch is used for the collection of water or mud samples or living organisms, taking measurements, etc., using medium-sized equipment.

* No. 4 winch
  Electrically driven, 160Kg x 115m/min, ø3mm x 1,500m
  This winch is used for lowering and lifting various BT (Bathy Thermograph) and optical measuring devices, water and mud sample collection, collection of lviing organisms, etc., in shallow sea areas using small equipment.

(3) Observation support equipment

Installations include a fully hydraulic setting up type gantry (large A-shaped frame) at the stern, a large electrically driven davit on the starboard, a davit for a piston corer on the starboard aft, and other davits and booms, etc., are installed so that the handling of large equipment can be carried out efficiently to facilitate observation.
In addition, it is equipped with several hoists and telescopic (folding) type deck crane, and efficient heavy load handling and cargo work is possible using this equipment. A 6 meter working boat is also provided.

* Setting up type gantry (large A-shaped frame)
  Electrohydraulically driven, working load at the fully swung out position 5 ton, working load during setting up 1 ton.
  This gantry, since it is operated on a fixed stand, is used for No. 1 and No. 3 winches and for mooring and can be supported with a stopper at vertical or a half (45°) position to enable to perform observation work, such as drawing nets. This allows continuous operation.

* Starboard rotary davit
  Electrically driven, 1t x 0.3 rpm, maximum radius 2.1m.
  This davit is used in combination with No. 2 or No. 3 winch for swinging out equipment from the starboard bulwark opening to the outside of the board with the equipment suspended and then lowering and lifting it in this position.

* Davit for the piston corer
  Manual operation (swivelling), electrically driven hoist 0.9 t (hoisting).
  This davit is situated at the stern on the starboard side, and is equipped with an electrically driven hoist. It is mainly used for lowering and lifting a piston corer in the swung-out position.

* Telescopic (folding) type deck crane
  Electrically driven,
  650 kg x 4 m (2.6 tm)
  This crane is situated at the after part of the long forecastle deck port side and is used for cargo handling and heavy load transfer on the deck.

* Working boat
  L 6m x W 2m x D 0.9m, Complement 6 persons, made of al-alloy, 22 PS, Approx. 6 knot
  This boat is housed to the port side of the long fore-castle deck and is used for simple observation work in shallow sea or estuarine areas or as a communication boat.

* Line hauler
  Electrohydraulically driven, 150 kg x 268 m/min.

* Geomagnetic electro kinetograph (GEK) reel
  Manual operation for ø11m x 310m wire, equipped with two receptacles

* Front deck davit
  Manual operation, rated load 500 kg (for the No. 4 winch)

* Other special equipment
  Boom for drawing in nets, electrically driven hoist, detachable platform, frame bed for the piston corer, temporary frame bed for the winch, etc.

(4) Laboratory (Fig. 2)

The laboratory, which is adjacent to the stern operation deck, occupies about 53 m2 of the central part of the upper deck on the starboard side and consists of dry, semidry and wet areas to make it possible to carry out operations efficiently.

To provide a laboratory which is adaptable to research in various fields, no partitions between sections are provided, the arrangement of desks can be easily changed or they can be removed in its entirety, cables can be stretched temporarily, thus the laboratory can be used for multiple purposes.

* Dry laboratory (Approx. 21 m2)
  Anemoscope and anemometer, gyroscope, electromagnetic log, doppler speed log, wire feed length meters for the winches remote monitor for the hybrid navigation equipment, etc.

* Semidry laboratory (Approx. 20 m2)
  Aspectic and dark room (clean boosters, germicidal lamps), water temperature recording indicator, storage for chemicals, etc.

* Wet laboratory (Approx. 12 m2)
  Place for processing collected samples, frame bed for detachable water collector, tension meter, etc.

(5) Research Equipment in the Vessel

Instruments installed at the bottom of the vessel include the transmitter/receiver of a tidal current meter positioned the bottom of the stern, the transmitter/receiver of a PDR (precise depth recorder) housed in the dome projecting out at the forward bottom part of the vessel, a fish echo sounder at the bottom of the midship part of the vessel, a scanning sonar and an electromagnetic log which are installed one above the other at the after bottom part of the vessel.
These items of equipment are covered with streamlined domes or guide vanes to protect them from driftwood and to reduce the hydrodynamic resistance as much as possible. The various items of equipment are disposed in such a way as to prevent interference between them.

* PDR
  12 kHz, 8,000 m — 1 set
* Fish finder I
  28 kHz, 5,200 m — 1 set
* Fish finder II
  50 kHz, 1,850 m (200 kHz, 630 m) 1 set
* Scanning sonar
  75 kHz, 0-800 m — 1 set

* Marine meteorological observation equipment 1 set
* GEK (geomagnetic electro kinetograph) 1 set
* CTD (conductivity temperature depth recorder) 1 set
* Compressor for air guns
  Discharge pressure 120 kg/cm2
  Discharge rate 1.8 m3/min.
  1 unit

3. Machinery Part

The main engines, the reduction gears and the controllable pitch propeller can be controlled either from the engine control room or the wheel house.
Low load operation for long periods is anticipated during survey and observations with this vessel, and therefore a system was adopted which couples the two main engines provided with low load performance to one main shaft. A main engine driven generator is also installed to conserve energy.
The engines which drive the generators are equipped with a remote operating device and an automatic starting device operated from the engine control room.

These engines are also equipped with a data logger and a CRT for automatically monitoring various data including pressure, temperature, etc., recording this data and giving alarm signals. Moreover, for more comfortable research activities and life in the cabins, vibration proofing and noise isolating measures were incorporated and air conditioning equipment is provided for all the rooms.

4. Electric Part

In consideration of the particular requirements of this vessel for undertaking research, the electrical equipment is installed with the emphasis given to continuity of power supply, assurance of the power supply to cope with future developments and research, a communications system which can provide the convenient and reliable communications required for research and observation work, arrangements which allow efficient fitting-out work, adaptability to future increases in the amount of equipment, etc.

- * Static precision power equipment
  10 kVA, AC 100V, 3ϕ 60 Hz — 1 unit
- * Shore connection facility
  AC 440V, 60 Hz — 1 set
- * Transformers
  - General purpose 450/105V, 25kVA — 3 units
  - General purpose 450/225V, 15kVA — 3 units
- * Hybrid navigation equipment
  NNSS, Decca navigator, LORAN, Doppler speed log, central processing unit, fixed disc device, magnetic tape device, CRT display terminal, printer, X-Y plotter, CRT color plotter, controller, remote display, etc., are included in this equipment.
- * Reflection type magnetic compass — 1 set
- * Electrical control steering device — 1 set
- * Gyrocompass — 1 set
- * Radio direction finder — 2 sets
- * Doppler speed log — 1 set
- * Radar and collision warning equipment — 2 sets
- * Monitoring television system — 2 sets
- * Electromagnetic log — 1 set
- * Wireless installation
  - 500W, 125W and 75W (reserve) transmitters — 1 each
  - All-wave receiver, emergency automatic receiver — 2 each
  - All-wave reserve — 1 set
  - Tele-printer — 1 set
  - Facsimilě equipment — 2 sets
  - International VHF wireless telephone set — 1 set
  - Tele-talk equipment — 1 set
  - Ships telephone — 1 set
  - Portable radio equipment for life raft — 1 set
  - Automatic exchange telephone system — 1 set

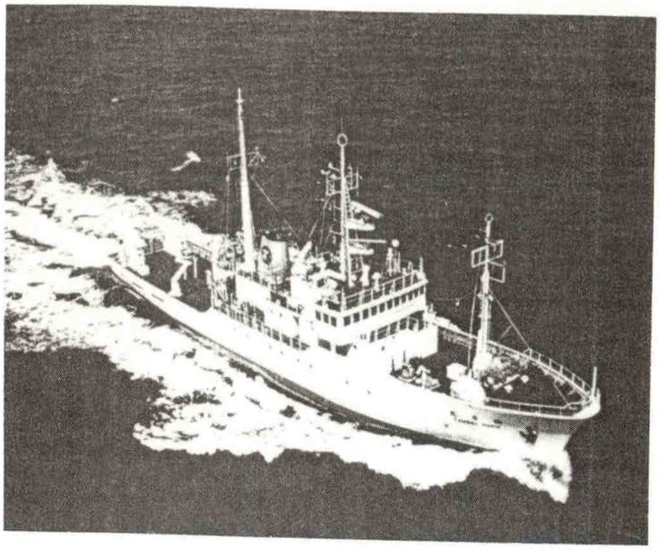

Fig. 1 TANSEI MARU on Cruise

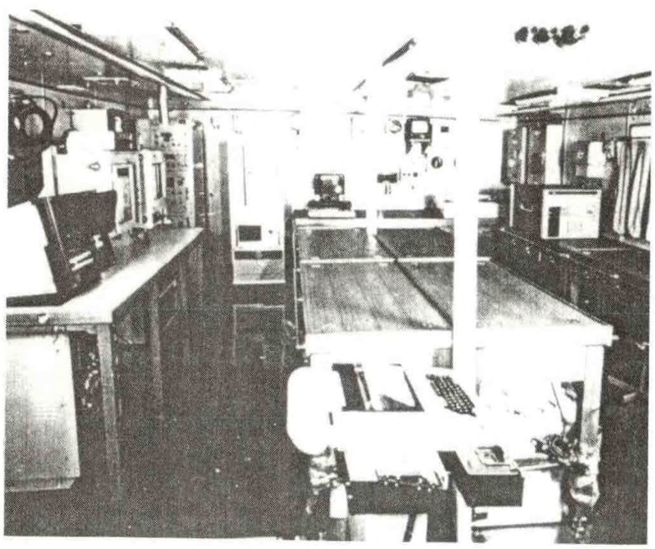

Fig. 2 Laboratory

AN UPDATE ON MARINE TRANSPORTATION IN THE UNITED STATES

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ABSTRACT

Despite increased activity and interest on the part of the Reagan Administration and Congress, the U.S. marine transportation industry continues to decline in almost all of the key indicators. The proposed actions announced over the past year have yet to take the form of actual changes in this industry. A recently completed study by the National Advisory Committee on Oceans and Atmosphere (NACOA) has outlined many of these problems and makes recommendations for their solution.

Introduction

In my presentation of this same topic last year, I addressed the current state of the U.S. flag Merchant Marine with special emphasis on the actions proposed by the then new Reagan Administration. I also commented on how these initiatives were received by the Congress, who would have to pass implementing legislation for most of them. Finally, I reviewed the positive actions that had been implemented by the Administration that affected the U.S. industrial sector.

For this year's update, I would like to present the findings and recommendations of a recently completed study on the U.S. maritime industry. The study was done by the National Advisory Committee on Oceans and Atmosphere (NACOA) and was entitled, Marine Transportation in the United States: Constraints and Opportunities. I had the honor to be chairman of the study during its 2-1/2-year duration.

Before reviewing the results of the study, I think it is useful to be aware of the basic, existing policy statement which is supposed to direct the U.S. maritime industry. This is the statement of intent embodied in the Merchant Marine Act of 1936, which is still a valid law of the United States of America:

> It is necessary for the national defense and the development of its foreign and domestic commerce that the United States shall have a merchant marine (a) sufficient to carry its domestic water-borne commerce and a substantial portion of the water-borne export and import foreign commerce of the United States and to provide shipping service essential for maintaining the flow of such domestic and foreign water-borne commerce at all times; (b) capable of serving as a naval and military auxiliary in times of war of national emergency; (c) owned and operated under the U.S. flag by citizens of the United States insofar as may be practicable; (d) composed of the best equipped, safest, and most suitable types of vessels, constructed in the United States and manned with a trained and efficient citizen personnel; and, (e) supplemented by efficient facilities for ship building and ship repair. It is hereby declared to be the policy of the United States to foster the development and encourage the maintenance of such a merchant marine.

Unfortunately, it is quite clear that we have not met the mandates of this law.

U.S. Marine Transportation: An Industry in Trouble

The National Advisory Committee on Oceans and Atmosphere (NACOA) was concerned about the deteriorating situation found in many parts of the U.S. marine transportation system. In brief, the following summarizes some of the major problems and existing conditions observed by the Committee:

o In 1950, the U.S. Merchant Marine ranked first in the world (by deadweight tonnage); by 1980, it ranked eighth, despite significant government subsidy programs designed to cover differential operating and construction costs between the U.S. Merchant Marine and its foreign competition.

o Although the United States is the major trading nation in the world, foreign-flag vessels carry more than 96 percent of its exports and imports (on a tonnage basis). In fact, foreign flag ships of only seven nations transport 75 percent of U.S. international water-borne commerce.

o The five major maritime shipping nations -- the Soviet Union, Greece, Japan, Norway, and the United Kingdom -- carry from 50 to 32 percent of their foreign trade in their own flag vessels. The United States carries only 4 percent.

o Employment in the U.S. maritime industry has dropped drastically in the past 10 years. Seagoing employment has plunged 65 percent from 1965 to the present. In the shipyards, employment of skilled workers devoted to merchant ship construction has dropped by 71 percent in only the past seven years. Most of this decrease in maritime employment is caused by the competitive disadvantage of U.S. ship operators and shipbuilders.

o U.S. military planners seriously doubt whether the nation has sufficient sealift capability (which must come largely from the commercial sector) to meet its military treaty commitments throughout the world.

o The 27 major U.S. shipyards that comprise the active industrial base of U.S. shipbuilding are in serious trouble. Unless the government takes immediate, vigorous offsetting actions, some yards will be forced to close in the next couple of years.

o The U.S. Navy's expanded shipbuilding program to construct 150 new vessels will assist the ailing industry, but 75 percent of the work (by dollar value) will go to just four yards, and only 15 of the 27 yards are now equipped to build military vessels (warships). The remaining 12 commercial yards predict that their order books will go to zero in the next 3 to 4 years, if current trends continue.

o Although the growth of world trade has leveled off owing to the poor state of the world economy and the present oil glut, it is clear that world trade will expand in the future. The diverse, but effective, assistance programs of foreign governments greatly aid foreign ship operators and their shipyards in competing with the United States. These direct and indirect government subsidies keep foreign-flag industries in "good track position" for the time when world trade will move into a more vigorous growth mode. The United States does not now have such effective programs.

o U.S. merchant marine and shipping laws, dating to the early part of this century, identify and attempt to remedy many of the problems facing the U.S. marine transportation system. Yet, these acts have not effectively maintained an American merchant marine capable of meeting our national security needs.

There are indications of improvement as a result of actions taken or being considered by Congress, the Reagan Administration, and industry. Some are:

o Reduction of the domestic regulatory framework that is unequally imposed on U.S. ship operators in competition with foreign-flag operators.

o Recognition and removal of subsidy programs that do not work and the consideration of new, more effective assistance programs.

o An increased Navy shipbuilding program that will provide work and upgrade part of the shipbuilding base.

o Increased military development and use of chartered commercial vessels for military sealift requirements. This also will stimulate new vessel construction and older vessel conversion for these charters.

o A move toward Congressional consideration of a national cargo reservation formula that will help the United States match the practices of many other foreign states that reserve percentages of their imports and exports for their flag vessels.

o A greatly improved relationship between maritime labor and industry to develop better work practices leading to cost savings, a better competitive position, and more growth (and thus more jobs) for the U.S. Merchant Marine.

o Special, limited incentives to assist the U.S.-flag operator in international trade to replace and upgrade his ship assets through foreign construction and acquisition.

National Security: The Basic Determinant

A basic question that requires policy reaffirmation at the highest levels is whether or not a U.S.-flag merchant marine is vital to America's national security interests. The term "national security" includes not only national defense but also control over a significant part of the transportation system that keeps our economy functioning.

From a pure "free-market economics" point of view, it might seem highly desirable to let foreign treasuries and companies subsidize both the carriage of U.S. maritime trade and the cost of vessels built overseas. These would then become subsidies to the U.S. economy.

However, the NACOA review points to the weaknesses of our current marine transportation system. The U.S. lacks control over a substantial portion of its maritime imports and exports. Military advisors warn of the inability of the U.S. merchant marine to meet treaty obligations and wartime needs. And as the shipbuilding base disappears so does emergency or wartime construction surge capability.

If national security is the key, then the time has come for the U.S. merchant marine to again emerge as a strong force in its trade. This implies regulatory structures and operating practices competitive with those of foreign-flag operators and their respective shipbuilding bases. The Merchant Marine Act of 1936, President Reagan's 1980 pre-election statements on our maritime industry, and many other Congressional and Presidential statements point to the national security importance of a viable U.S. merchant marine. But, in the case of the 1936 Act, these goals have not been achieved in nearly a half century of effort. Although some of the actions proposed by President Reagan are being implemented, it is perhaps too soon to tell how effectively the Administration's directions will be translated into actions benefitting the U.S. marine transportation system.

The NACOA Recommendations

The aim of NACOA's study was to assess the adequacy of U.S. marine transportation in terms of:

- o National security
- o World trade and its implications on marine transportation
- o U.S. domestic marine shipping trades
- o Ports, workers, and terminals
- o U.S. policies and regulations
- o Foreign government policies for marine transportation

In reaching its final conclusions, NACOA observed that:

(a) Congress and the Administration have affirmed for the past 60 years that a U.S.-flag marine transportation industry, with the supporting industrial base, is essential to our nation's national security in peace and in times of emergency.

(b) Legislation and federal government regulation, programs, and subsidy supports have not had the desired impact on the U.S. marine transportation industry.

It was the Committee's view that certain actions should be initiated or expedited if the U.S. merchant marine is to develop and fill the major security and economic role that agrees with proclaimed U.S. policy.

NACOA's recommendations, which derive from its broad overview of the major elements of this industry, are the following:

1. The Construction Differential Subsidy Program should be eliminated by Congress through amendments to the Merchant Marine Act of 1936.

2. The Maritime Administration should initiate discussions with the liner operators to encourage early termination of Operating Differential Subsidy contracts and eventual elimination of the program.

Simple removal of subsidy assistance without a simultaneous offset of new remedies and incentives could be a crippling blow to the industry. In NACOA's view, it is important that these subsidy reductions be phased out at a rate commensurate with the achievement of benefits from other actions. Because such remedies and incentives for industry promotion can only become effective over a period of time, coordination of the recommended reductions in subsidy with the following actions is essential:

(a) The Maritime Administration should promptly provide competitive incentives for U.S. shipyards to bridge the gap between termination of the Construction Differential Subsidy and other measures that would offer increased work for U.S. yards.

(b) Congress should enact legislation to: (i) authorize closed liner shipping conferences and empower these conferences to collectively set intermodal transportation rates; and, (ii) permit shippers who consign cargoes to establish "shippers councils" to negotiate collectively with the liner conferences.

(c) Given the recent involvement of the U.S. shipbuilding industry in the task of rebuilding our naval fleet and given the absence of Construction Differential Subsidy funds, the Maritime Administration should relax restrictions governing the current Operating Differential Subsidy (ODS) Program as follows: (i) U.S. shipowners should be permitted to qualify for ODS with respect to foreign-built vessels registered under the U.S.-flag provided they otherwise meet the criteria for qualifications; and, (ii) U.S. shipowners should not be disqualified from ODS, when they would otherwise qualify simply by reason of operating other vessels in foreign-flag shipping activities.

This does not contradict the recommendation to terminate the ODS program; it simply recognizes that, in the interim, some immediate adjustments need to be made to the ODS program to make it work more effectively while means are found to reduce and eventually terminate the program.

3. U.S. ship depreciation allowances and schedules should be made competitive with those provided by foreign governments for their merchant fleets.

4. Congress and the Administration (a) should support continuing Federal investment in major port developments in the interest of national security; and, (b) Congress should pass legislation that would greatly streamline the planning and permitting process for port improvement developments.

5. U.S. Coast Guard regulations relating to design and standards of construction of U.S.-flag vessels should be made consistent with the accepted standards established by the world's leading classification societies.

6. The Department of Defense (a) should be encouraged to continue to shift to the private sector the ownership of and/or the contract management for the major share of its noncombatant (sealift and service support) ship capacity; and, (b) should be urged to continue to offer charters of sufficiently long duration to encourage operators to build or buy vessels through utilizing their own investment funds.

7. The current review of regulations affecting the U.S. maritime industry by the Presidential Task Force on Regulatory Relief should be expedited.

8. Congress should take the lead in formulating national cargo policy within an expanded system of bilateral agreements.

9. The Department of State should expedite the development of an effective response to the Code of Liner Operations of the U.N. Conference on Trade and Development (UNCTAD).

10. The Title XI and Capital Construction Fund programs should be preserved by the Maritime Administration with their benefits remaining applicable solely to vessels of U.S. registry constructed in U.S. shipyards.

11. The Maritime Administration should increase the level of its support for research and development and coordinate its efforts with those of the industry.

NACOA recognized that some of the recommendations in this report imply costs to U.S. taxpayers. However, with the stated U.S. policy that a strong merchant fleet and shipbuilding industry are of high priority for national security, the costs for achieving a strong U.S. maritime industry should be considered along with those of the Department of Defense.

Events Since the NACOA Study was Completed

Since the NACOA report was submitted to the President and Congress in early 1983, there have been several new initiatives proposed by these two branches of government. As noted earlier in this paper, none of these has led to any major remedial actions yet, but some innovative ways of being explored to solve the major problems facing this industry:

o The development of a national cargo reservation policy to ensure a certain portion of U.S. exports and imports are shipped in U.S.-flag vessels is proposed by the "Competitive Shipping and Shipbuilding Act of 1983" (H.R. 1242) introduced by Congresswoman Lindy Boggs. A similar bill (S.1000) sponsored by Senator Paul Trible is before the Senate. This Act would reserve a maximum 20 percent of all U.S. bulk cargo shipments for U.S.-flag vessels over a 200-year period of increasing reservation. This would result in the construction of approximately 268 bulk carrier ships for the U.S. Merchant Marine. In terms of jobs, the program would create 18,000 shipyard and support industry jobs, as well as seagoing jobs for about 9,000 merchant seamen. The first hearings on this Bill were held in May. Therefore, it is too soon to know how successful this congressional initiative will be. It should be noted that nearly one fourth of the House has endorsed this proposed legislation. If it fails, it will still have served the purpose of opening up serious consideration of national cargo reservation policies at the highest levels of government.

o The "Maritime Redevelopment Bank Act of 1983" (H.R. 3399) was introduced in June by Congressman Mario Biaggi. This proposed act would create a government-backed financing authority to help support and ensure investment in ship construction through a "U.S. Maritime Redevelopment Bank." The Bank would have $2 billion in assets through a line of credit with the U.S. Treasury and would also have an additional $2 billion in loan insurance capability. It would work between shipbuilders, ship buyers, domestic and international financial markets, and could even take equity positions in ship assets.

o The "National Ocean Policy Commission Act of 1983" (H.R. 2853) was introduced in the House in May by Representative Walter Jones. Later in the month, a similar bill was introduced in the Senate by Senators Pell and Hollings. The proposed legislation would establish a 15-member, presidentially appointed National Ocean Policy Commission to consider and suggest a national ocean policy framework. Marine transportation is one of the stipulated areas to be studied.

While each of these initiatives will meet resistance from within Congress and from the Reagan Administration, they do show a new departure from the old remedies of times past. Then, the solution seemed to throw money at the problem in terms of more subsidy and ill-conceived protection measures for the U.S. marine transportation industry.

If a significant number of the initiatives already put in motion over the last 2-1/2 years by the Reagan Administration and Congress, and those outlined here are implemented, then the U.S. maritime industry may eventually find its way back to good health.

FUNDAMENTAL STUDY OF THE HUGE-SCALE FLOATING PLATFORM FOR USE OF SEA SPACE

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ABSTRACT

In this paper, the model experiment results on the behaviours of a huge scale floating platform in waves are presented. The platform consists of an array of floating bodies such as columns with lowerhulls supporting a wide upperstructure which will be used for various porposes either industrial or transportational.
The wave exciting forces and hydrodynamic forces associated with the motions of platform have been measured for several combinations of floating bodies so as to clarify the hydrodynamic interactions which affect on the behaviours of the platform.
The elastic responses and the distributions of the bending stresses of the upperstructure as well as the mooring forces acting its multi-anchoring system have also been investigated experimentally by the large scale models in waves.

After the feasibility study on the floating airport was carried out [1], fundamental investigations on the technical problems concerning with the huge scale floating platform are being continued which is considered to be realized for various purposes as industrial plants, storage of oil or gas, city or transportation center and so on, to extend the use of sea space beyond the coastal area.

A lot of technical problems are still remained to be solved in order to ensure the construction of a large platform in the severer environmental conditions. The common and fundamental techniques are summarized as follows:

1) Accurate understanding and exact description of environmental conditions including the prediction of the severest storm expected to encounter within the life of the structure,

2) Accurate estimation of external forces excited by wind, current and waves or of hydrodynamic forces associated with the motions of the structure,

3) Accurate calculation or simulation of motions excited by the external forces taking account of the elastic responses of the structure which could not be ignored for such large platform,

4) Optimal design of mooring system to achieve the equilibrium of tension forces acting on the mooring lines of the multi-anchoring system within the allowable mooring capacity,

5) Development of the anchoring system having a great capacity to resist the tension forces,

6) Development of several construction and installation techniques such as towing, assembling or connecting of elemental platforms which would be built in docks and towed to the sea area where the platform is installed.

At the Ship Research Institute, the research is being carried out along with the following procedures.

a) Preliminary Design of the Platforms

The floating platforms have been designed assuming several purposes as container yard, LNG storage tank, coal center. The image of such a platform is shown in Fig. 1, and the preliminary design of a container yard is in Fig. 2.

The floating bodies supporting the platform consist of various types corresponding to the loading capacities of the columns with a buoyant footing, the columns with a lowerhull or the barges which have been chosen as the fundamental shapes as shown in Fig. 3.

b) Investigation of External Forces Excited by Waves

As the first stage of study, the wave exciting forces acting on the individual or the assembly of the floating bodies have been measured by the models settled in waves. Some examples are shown in Fig.4 and Fig. 5. In the figures, the wave excited surge forces acting on the component platform of an array of columns with buoyant footing are presented and compared with the theoretical values calculated by using the exciting forces acting on the single body ignoring the mutual interactions between columns.

c) Investigation of Responses of the Platform in Waves

The motions of the platform in waves have been measured. An example is shown in Fig. 6 which represent the surging amplitudes in regular head wave. The calculation have been done excluding the mutual interactions between elemental bodies but the results show rather good agreement with the experiment in the significant wave period range.

Elastic responses,i.e. the deflections of the platform have been also measured by using accelerometers or photo-electric position sensors distributed on the platform. The influence of the rigidity of the upperstructure on the dynamic or quasi-static deflection or bending stress induced by the external forces has been investigated through model experiment as well as theoretical analysis.

An example of deflections of a platform is shown in Fig. 7 in the form of stereographic display.

d) Mooring Forces in the Environmental Conditions Combining Wind, Current and Wave

The platform models were moored in the basin and the tension forces acting on the multi-mooring lines have been obtained experimentally so as to grasp the non-uniformity of the induced tensions. The direction of the models against external forces has been chosen variously. An example of the distribution of mooring forces measured in oblique irregular waves combined with wind and current is shown in Fig. 8.

e) Connecting Forces When Assembling the Element of Platform

The connecting forces and moments acting on the joint jigs between unit platforms which are to be assembled into one huge-scale floating platform at sea have been investigated experimentally in regular waves, and the measured results are compared with the theoretical values. Fig. 9 shows the amplitudes of forces and moments acting on joint jigs between a L-shaped large structure and a unit platform under assembling as illustrated in the figure in head and beam seas. Of the experimental values, the white and black dots represent the forces and moments corresponding to the position of the unit platform behind or in front of the large structure against incoming waves, respectively. Theoretical results show good agreement with the experiment in spite of ignoring the hydrodynamic interations between floating bodies. [2]

The connecting processes just before the rigid connection were simulated on the models with the joint jigs which hold some clearance for each other, and the relative motions and impact forces which occur when the relative motion amplitude is limited by the clearance of the jigs were measured. [3]

f) Access Technology

As to one of the access technology to the platform, the behaviours of the moored ships have been measured together with the forces acting on the mooring lines or on the fenders by the model ship in waves. The effects of wave directions and wave periods are investigated in comparison with the conventional mooring systems as dolphin or pier.

The following problems are subjected to the future researches which will be continued till 1986.

1) More detailed investigation on the hydrodynamic interactions between various floating bodies to achieve an accurate estimation of structural responses as well as mooring forces of the platform. This should be pursured theoretically, refering the obtained experimental data.

2) Development of analysis method of dynamic responses of platform which is considered flexible, taking account of non-linear hydrodynamic forces.

3) Establishment of the design criteria which will be determined by the severest environmental condition. The impact forces induced by the breaking waves should be taken into account.

4) Researches on the estimation methods of the largest mooring forces which would be associated with slowly drifting motion of the platform under the combined effect of wind, current and waves.

5) At-sea mesurement of motions and mooring forces on the prototype platform to ascertain the design procedures developed by this research project. The prototype model test of a developed mechanical anchor will be also planned.

The most part of this project is being supported financially by the Science and Technology Agency.

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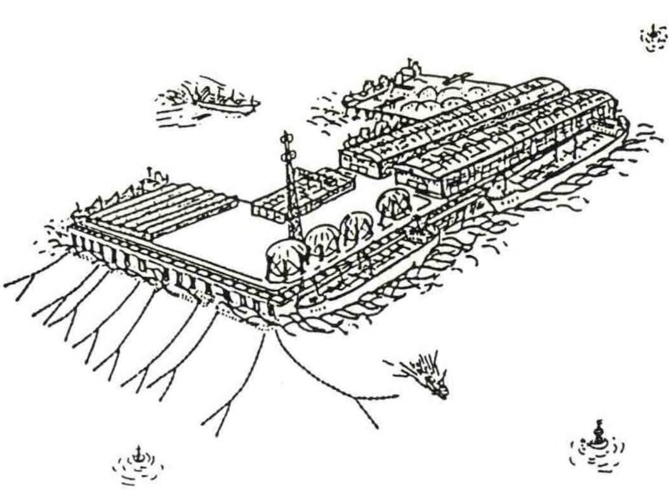


Fig.1 Artist Image of a Floating Platform

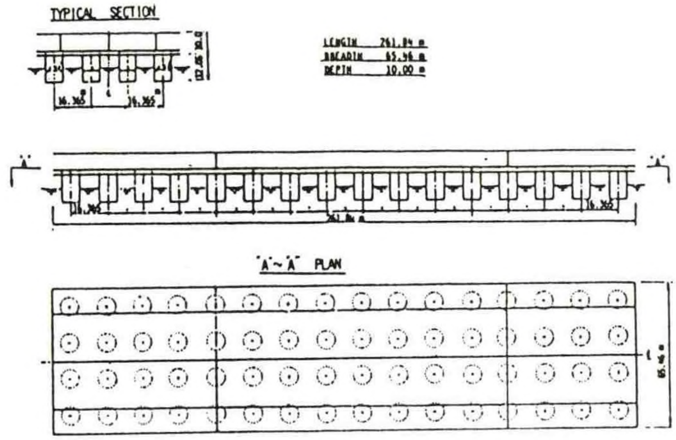
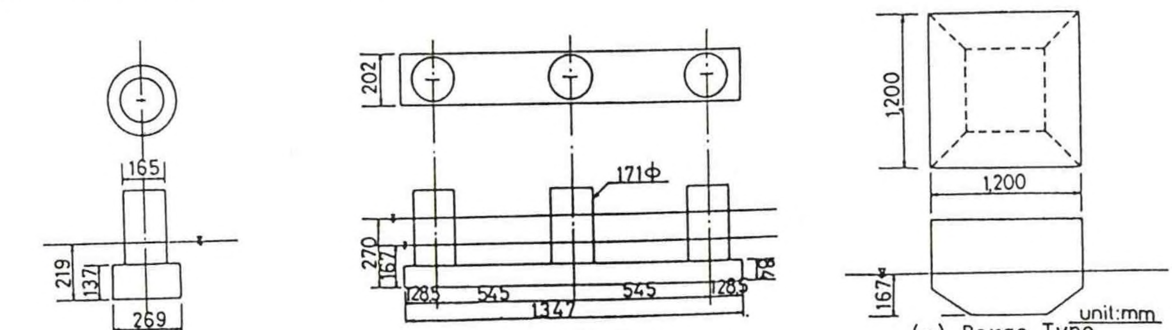


Fig.2 Platform for Container Yard (1 unit)



(a) Footing Type

(b) Lowerhull Type

(c) Barge Type

Fig.3 Floating Bodies Supporting a Platform

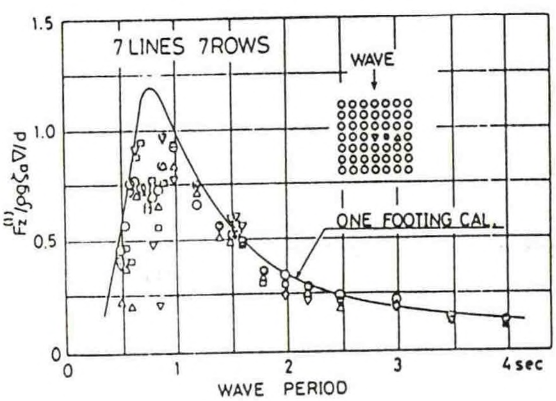


Fig.4 Wave Excited Surging Forces

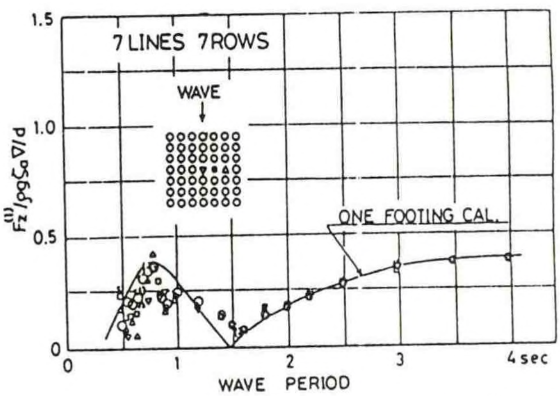
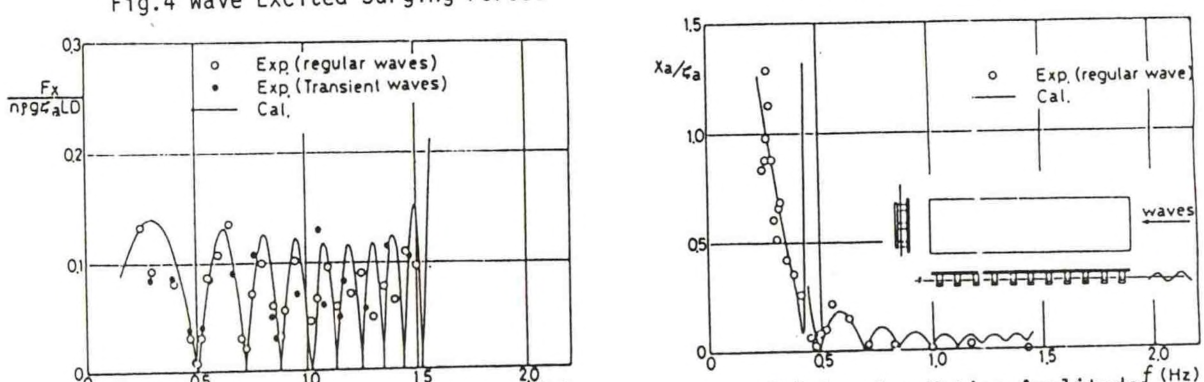


Fig.5 Wave Excited Heaving Forces



(a) Surging Force

(b) Surging Motion Amplitude

Fig.6 Wave Excited Force & Amplitude of Surging Motion

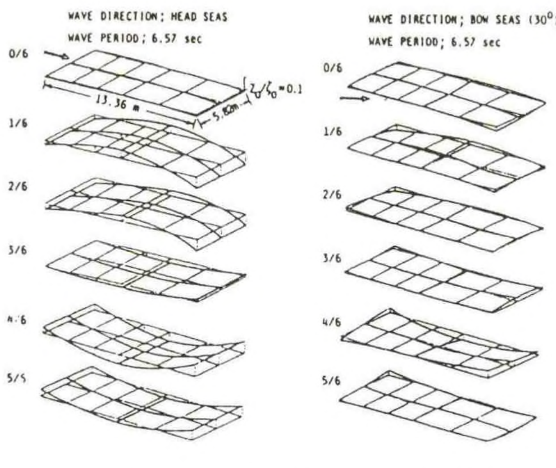
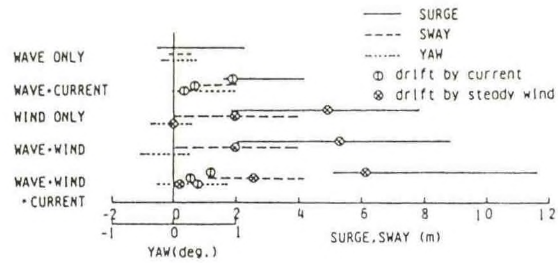
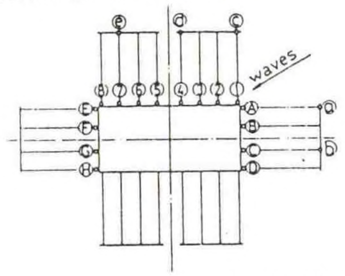


Fig.7 Deflection of a Platform





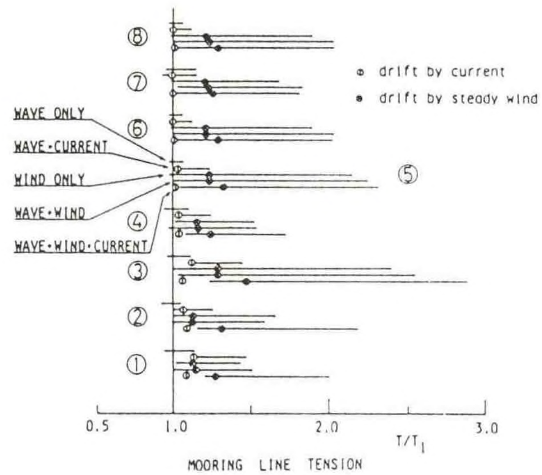
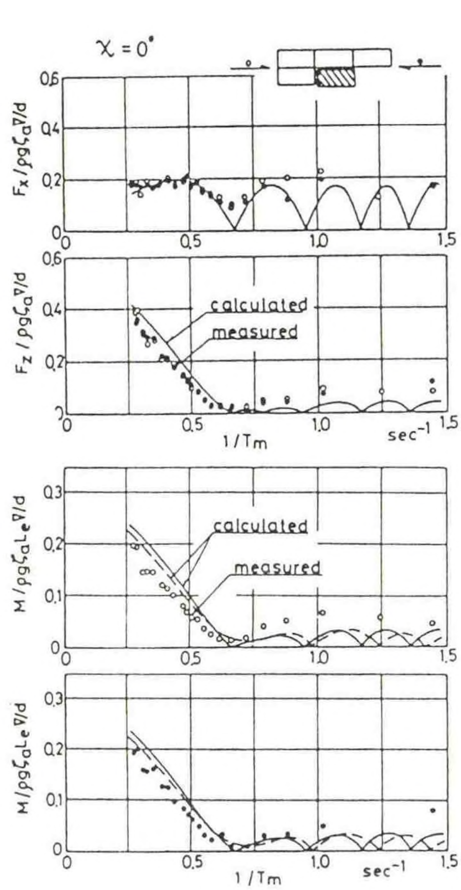
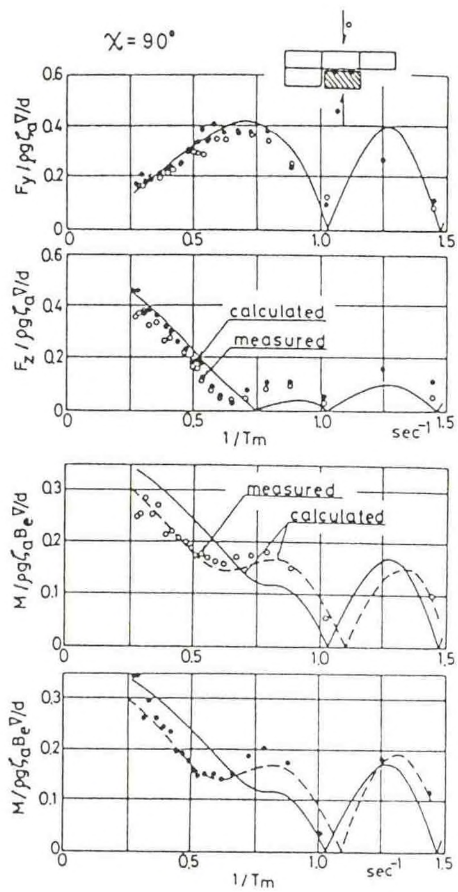


Fig.8 Distribution of Mooring Forces



(a) Head Seas



(b) Beam Seas

Fig.9 Connecting Forces and Moments

ICE ENGINEERING IN JAPAN

Hitoshi Nagasawa and Hiromitsu Kitagawa

Ship Research Institute

ABSTRACT

There is an eager demand for the energy source and resources developments, and ice engineering has gained attention to support the Arctic marine transportation R&D programme. The historical background and present states of ice engineering and the related problems in Japan are tersely described.

INTRODUCTION

The structure of energy supply in Japan has been quite fragile because of the lack of indigenous energy resources. It is then necessary for Japan to continue to promote the alternative energy policies steadily from the economic perspective as well as the security, planning, overall and international co-operation perspectives. Simultaneously, much effort should have been made to seek for new suppliers of conventional energy resources such as oil and liquefied natural gas.

It was in 1968 that Alaska was fully expected to be an oil producer with the discovery of the Prudhoe Bay field. This presented an innovative opportunity to begin to transform some of the potential of the Arctic region into reality. Arctic energy resources involve many stages and types of activities, ranging from resources exploitation to well balanced technological development in storage, transportation and supporting system, and co-ordination between the various technical planning fields should be envisaged.

Because the Arctic oil and gas will become necessary for the North American consumers and also earnestly hoped to be transported to Japan, some research programmes on the Arctic marine transportation have been conducted in Japan since 1974.

HISTORICAL BACKGROUND

In some districts of Japan they have been frequently suffered from heavy snowing in winter. However, there has been something of the artistic interest in snow, particularly in snow crystals, in Japan. They seem to have felt much more interest in snow than in ice. Ice has commonly been regarded as cold, unfamiliar and prosaic.

T. Doi, the lord of a feudal clan, published 183 figures of snow crystals in 1840, and this was contemporaneous with the publication of the results of observations on snow crystals in the Arctic by W. Scoresby, English whale fisher. Since then, the figures of snow crystals have commonly loved and used in the pattern of kimono.

Prof. Nakaya probably followed tradition, and made a study of snow crystals. He built a small low temperature laboratory in 1935 at Hokkaido University. The first artificial snow crystal was grown by him in a cold room of this laboratory in 1936, and this success led to his extensive investigations on the artificial production of various snow crystals which bore rich fruit in after life as the famous Nakaya diagram. Various pioneer works on icing, frost heaving, thunderstorm electricity, formation of discoidal ice from water, etc. were performed in this small laboratory. Prof. Nakaya laid the fundations of the science of snow and ice in Japan.

The Institute of Low Temperature Science was established in Hokkaido University in 1941 and has succeeded to Prof. Nakaya's scientific fortune. This Institute has been a significant and stimulating research center of snow and ice, in particular, in the field of fundamental physics of snow and ice.

The scientific and technological studies of snow and glaciological problems have also been pursued in some of the universities in the northern district of Japan and private works, such as electric power companies.

Popular attention has been attracted to the Antarctic. In 1912, sublieutenant N. Shirase commanded expedition to the Antarctic and discovered Kainan Bay, which was named after his schooner, Kainan-maru. To participate in the scientific research programme of the International Geophysical Year in 1957-1958, the first Japanese Antarctic Research Expedition was dispatched to the Antarctic in 1956. The Antarctic research ship with ice-breaking capability, the Soya, which was converted from a cargo ship and ice strengthened, threaded her way through rather the heavy ice of Lützow-Holm Bay, and in January 1957 the expedition established Showa Station at 69 00'S and 39 35'E on East Ongul Island in Lützow-Holm Bay.

Unfortunately, Showa Station was temporarily closed between 1962 and 1965. Superannuated ship, the Soya, supplied a main reason for this discontinuance. A new icebreaker Fuji was therefore planned and built in 1965, and an inland station Mizuho was established in 1970. The National Institute of Polar Research, which is a reorganization of the Polar Research Center, has been the research center of the Antarctic research programme.

In the 1970s the energy situation has focused attention on the Arctic as a major source of oil and gas. The remarkable success in the exploitation of the Arctic oil in Alaska has aroused a growing interest in ice engineering, in particular, in commercial ice-going ships, and the research on ice has become more intensive and more closely linked with industrial demands. An important development in ice engineering in Japan was set in motion in 1977 when the Government granted permission to establish an ice model basin at the Ship Research Institute, Ministry of Transport, and the facility has been in service since 1981. The recent energy situation and industrial demands exerted new pressures to expand and co-ordinate scientific and technological activities in the Arctic marine transportation R&D programme.

BASIC RESEARCH ON SNOW AND ICE

Intensive studies on snow and ice physics have been pursued at universities, colleges, non-profit institutes and industries. The Japanese Society of Snow and Ice has taken the initiative in stimulating the researches. The National Committee on Snow and Ice, which is one of the specialized committees of the Science Council of Japan, has studied and reviewed the policies and essential programmes for the related researches.

Glaciological and meteorological studies in Alaska, Greenland, the Arctic and the Antarctic have been carried on since 1957 mainly at the Institute of Low Temperature Science with the international co-operation. Scientific researches in the Antarctic have been pursued with the co-operation of all interests involved and also with the international co-operation. The National Institute of Polar Research has played a major role in them.

Mechanical properties of sea ice has been studied at the Institute of Low Temperature Science, particularly by Prof. Tabata and his colleague.

ICE-OCEAN-ATMOSPHERE SYSTEM

Meteorological and oceanographical studies have been made at the Meteorological Agency, universities and non-profit institutes.

In the Sea of Okhotsk ice floes are generally observed in winter. Environmental studies have been pursued mainly at the Institute of Low Temperature Science, the Meteorological Agency and the Maritime Safety Agency.

REMOTE SENSING AND ICE RECONNAISSANCE

Remote sensing techniques are studied in general at the Radio Research Laboratories, the Meteorological Research Institute, universities and private works.

LANDSAT data have been analyzed at the Institute of Low Temperature Science, universities and governmental organizations. Impulse radar system, microwave radar system, remote sensing techniques by SLAR and SAR, and HF radar system have been studied for observations and forecasts of sea ice. Recently, the Society of Remote Sensing Technology of Japan has been established and the Society is expected to play a considerable part in the research and development of remote sensing techniques in Japan.

Ice reconnaissance has regularly been made in winter through the Maritime Safety Agency in co-operation with the District Meteorological Observations and the Institute of Low Temperature Science in the Sea of Okhotsk.

RESEARCH AND DEVELOPMENT OF ARCTIC VESSELS

Research project on the Arctic marine transportation has been conducted at the Ship Research Institute since 1974. The first ice model basin in Japan was constructed in 1981 and has been in service. Extensive model experiments on arctic tankers and polar LNG carriers have been carried out at the Ship Research Institute in co-operation with the Shipbuilding Research Association of Japan under the policy guidance of the Ship Bureau, Ministry of Transport. The systematic series tests in ice are carried out with particular interest in effects of parallel body length, length-breadth ratio, shape of midship section, bow shape, frame lines and block coefficient on performance in ice and propeller protection from ice. Preliminary study on ice load on hull surface of ships is also made. Feasibility study of arctic tankers was carried out with a co-operation between the governmental organizations and industries.

In 1982, the second ice model basin in Japan was constructed at the Tsu Research Laboratory of Nippon Kokan Co., Ltd., and this was the first commercial ice model basin in Japan. The basin is 20 m long, 6 m wide and 1.8 m deep and has been used for experimental investigations on ships as well as various types of marine structures which will operate in ice-covered waters. Model ice is created from carbamide-water solution of appropriate concentration.

There are still a number of technical problems left in the practical design of arctic tankers and polar LNG carriers. The accurate prediction of power, ship speed and behaviour of ships in ice-covered waters is of the utmost importance to shipbuilders and seamen. However, no analytical method can give a satisfactory description of the icebreaking. Full scale measurements are undoubtedly indispensable in ice problems, though they cannot be easily made. Much individual and collective efforts will have to be directed to analytical approaches by making the best possible use of ice model basins and theories. Energetic and international co-operation should be given in attaining the object.

ICEBREAKERS IN JAPAN

Several icebreakers have been constructed in Japan. The first one was the Odomari, navy ship of Japan, which was built in the 1920s, and had a displacement of 2,200 t. Unfortunately there was no data on her icebreaking capability.

The second icebreaker was the Soya, which was originally built in 1938 as an ice-strengthened cargo vessel and converted into an icebreaker for the Antarctic research programme. The Soya had been in service and transported personnel and supplies to Showa Station in the Antarctic until she was replaced by the Fuji in 1965. After the retirement from the Antarctic service, the vessel had operated in the Sea of Okhotsk as an icebreaking patrol ship of the Maritime Safety Agency and was replaced again by the new Soya in 1978 and got finally an honourable retirement.

The Fuji, the third icebreaker, was delivered to the Japanese Defence Agency in 1965. Since then the vessel had performed the hard mission to supply necessary goods and materials as well as personnel to the Antarctic every year. The Fuji is a sophisticated icebreaker equipped with several cargo gears, facilities for two cargo helicopters and some spacious holds. The hull form is of con-

Table 1 Main Particulars of Icebreakers in Japan

	SOYA	FUJI	SOYA, NEW	SHIRASE
LENGTH, overall, m	83.66	100.0	98.60	134.0
BREADTH, max., m	15.80	22.0	15.60	28.0
DEPTH, moulded, m	9.30	11.8	8.00	14.5
DRAFT, designed, m	5.52	8.1	5.22	9.2
DISPLACEMENT, designed, tonne	4,614	5,250	3,803	11,600
SPEED, max., knots	12	17	21	19
SHAFT HORSEPOWER, PS	4,800	12,000	15,600	30,000
PROPULSION SYSTEM	D	D-E	D	D-E
PROPELLER	2 FPP	2 FPP	2 CPP	3 FPP
ICEBREAKING CAPABILITY, m (ice thickness, at 3 knots)	0.8	1.0	1.0	1.5

D; geared diesel, D-E; diesel-electric, FPP; fixed pitch propeller

CPP; controllable pitch propeller

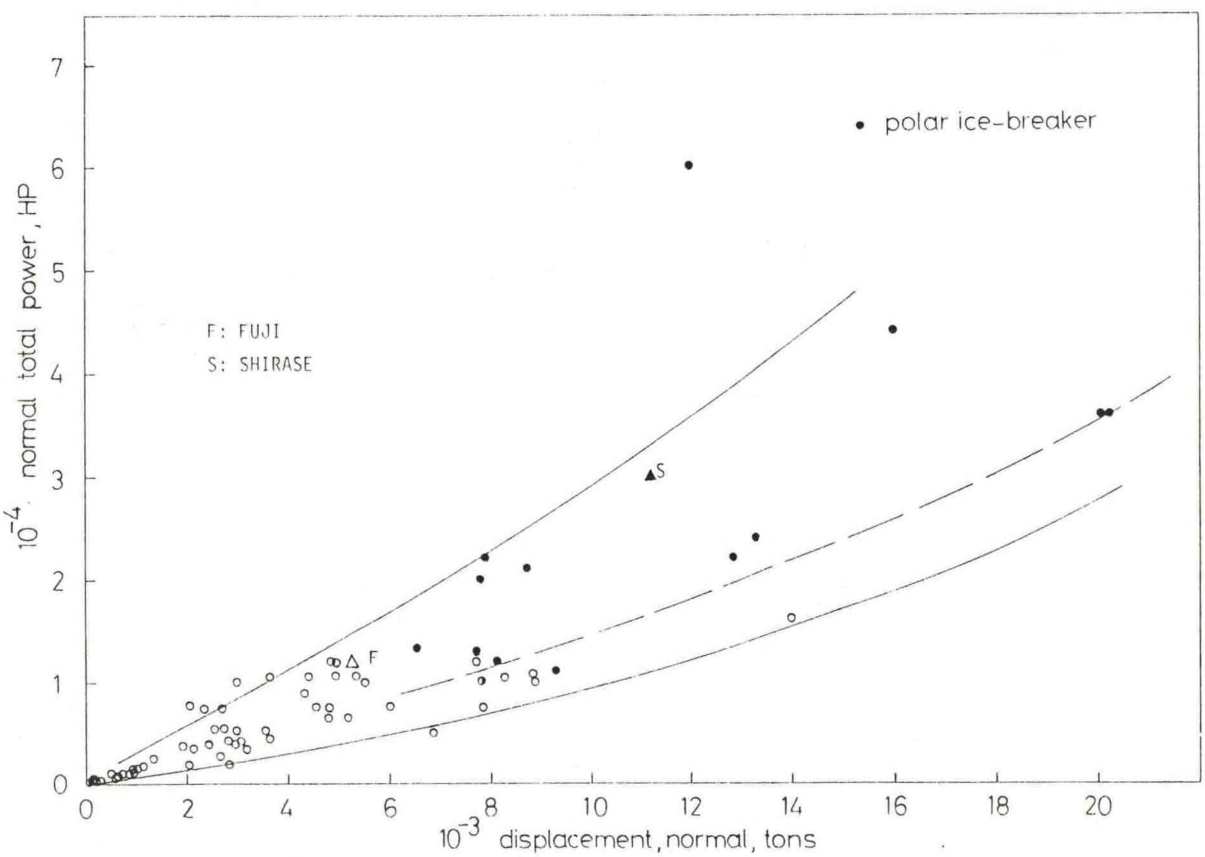


Fig. 1 Shaft Horsepower and Displacement of Icebreakers

ventional icebreaker type. She has diesel-electric propulsion systems, two propellers and one rudder. The propellers are of four-bladed built-up type and made of specially cast stainless steel. The Fuji will be released from the Antarctic mission and relieved by the Shirase, new Antarctic research ship, in 1983.

In 1978, an icebreaking patrol ship, the new Soya, was built and delivered to the Maritime Safety Agency of Japan. Operational areas of the Soya are in the Sea of Okhotsk, the Japan Sea and the Pacific Ocean. The primary mission of the ship is to provide patrol, search and rescue support to shipping, including the towing of vessels disabled in ice, in all designated operational areas. The secondary mission is to conduct ice reconnaissance and reporting, including the carrying-out-of investigatory probes in northern waters and conducting limited oceanographic and meteorological programmes.

The Shirase, new Antarctic research ship, was constructed in 1982. The carrying capacity of the vessel is about 1,000 t, which is twice as much as that of the Fuji. The displacement is twice and shaft horsepower is 2.5 times as large as that of the Fuji. The vessel is of all welded steel construction with a cruiser stern and a modern icebreaking bow contour of the latest design. Her icebreaking capability was confirmed by model testings in ice for the first time in Japan. Her construction and materials are almost the same as those of the Fuji, which has not had any damage in the hull for fifteen years. Icebreaker hull forms are inherently easy rollers and not the most comfortable of vessels in which to travel. To ameliorate this condition, the Shirase is equipped with a roll stabilization system of the flume type. Heeling and trimming tanks are also included. Main propulsion plant is of diesel-electric type for tripple screw installation. The propellers are of four-bladed, built-up type and are made of specially cast stainless steel. Low friction coating is applied (INERTA 160).

Main particulars of the icebreakers of Japan are shown in Table 1 and some trend of icebreakers in power and displacement is indicated in Fig. 1.

FULL SCALE EXPERIMENTS IN ICE-COVERED WATERS

Full scale experiments are indispensable in ice engineering problems. Full scale measurements with an icebreaking patrol ship of the Maritime Safety Agency, the Soya, were performed in ice for the first time in Japan in the Sea of Okhotsk in February, 1983. The primary objective of the experiments is to examine fundamental icebreaking performance and ship-model correlation in ice. Physical and mechanical properties of sea ice in which the vessel was operating were also measured. Thrust, torque and number of revolutions of propellers, ship motions, vertical and horizontal accelerations, vibrations of shafts and strain of shell plates and frames of hull were measured in pack ice. Turning trials in ice were performed with the effectual assistance of her helicopter

Corresponding model testings in level ice were carried out in the ice model basin at the Ship Research Institute. This full scale testing programme was planned and conducted at the Ship Research Institute in co-operation with the Ship Bureau, the Maritime Safety Agency and the Meteorological Research Institute. Further full scale measurements will hopefully be made in the near future.

Another full scale measurements are planned and expected to be carried out in the Antarctic area with the Shirase during her ordinary operation in ice-covered waters in 1983/1984.

ARCTIC OFFSHORE TECHNOLOGY

Basic studies on ice forces exerted on structures in ice are made at the Ship Research Institute and industries in model scale. Large scale model experiments of ice forces on cones and cylinders have been conducted by shipbuilding industries in a natural sea-water lake in Hokkaido.

A measuring tower of cone-shaped structure has been set up for ice load measurements off Monbetsu in Hokkaido by Mitsui Shipbuilding Co., Ltd. The company has developed so-called Archimedean-screw ships, which have excellent capabilities in operating in ice-covered waters as icebreaking supporting ships.

Caissons and some types of offshore structures for the arctic region were constructed by shipbuilding industries.

OIL IN ICE-COVERED WATERS

Preliminary study on oil spill recovery devices operating in the arctic environment and below freezing temperature has been made at the Institute of Ocean Environmental Technology and some organizations.

CONCLUDING REMARKS

The northern countries have long been conducting trials and researches on ice engineering problems and are substantially advanced through rich and varied experiences, in comparison with Japan.

However, it can be expected that the well advanced shipbuilding technology in Japan will fully be utilized for developing ice-going commercial vessels, and that a concerted effort of the governmental organizations and individual private works will surely bring good results and lead to rapid progress in ice engineering in Japan.

Safety requirements of the vessels and structures to be in operation in ice-covered waters will emphasize the necessity of international co-operation.

ARTIFICIAL ISLANDS FOR ARCTIC OFFSHORE EXPLORATORY DRILLING AND PRODUCTION ISLANDS

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Professor of Civil Engineering
University of California, Berkeley

INTRODUCTION

The Arctic Ocean has been identified as having major potential for offshore petroleum reserves. Active exploration has been underway from almost a decade in the Canadian Beaufort Sea and is now being carried out in the Alaskan Beaufort. To support exploratory drilling operations now, and production facilities in the near future, a variety of structures capable of resisting the forces and effects of Arctic sea ice have been developed. These range from sand and gravel islands in water depths up to 20 meters to caisson-retained islands, and steel and concrete caisson-type structures for deeper water. In the near future, fixed platforms will be required to perhaps 100 m. water depth.

Since the design and construction of many of these structures have been adequately covered in previous articles in the technical literature, this paper will direct its attention to several specific aspects that are currently attracting detailed engineering consideration. These include ice forces, weak soil strata below the seafloor, dynamic interaction of ice structure, and foundation, design for local high concentrated loads, deployment through shallow waters having significant ice fragments, provision of full contact between base and seafloor and material properties suited to the special Arctic conditions.

Innovative and daring structures are appearing in the Arctic and more are on the drawing boards. Their success will depend on thorough engineering and proper Arctic-oriented construction.

Basic Design Requirements

The structure must provide the requisite platform area and weight capacity to support the drilling and production facilities required. At the present stage, transport by pipeline is the most likely scenario: hence storage, other than surge storage, is not a requirement.

Adequate space and weight capacity must be available for consumables, because of the difficulty or even impracticability of resupply to islands located in dynamic ice zones, especially during break-up in early summer.

The operating and storage levels must be protected from the intense cold, ranging to -50°C, the wind, and during the summer open water season, the spray from the frequent intense storms.

Sea ice, of course, dominates the design criteria. The structure must resist the pressures imposed by the slowly moving winter ice conditions and the impacts from ice floes in the open water (summer) season. Both ice regimes may impose high concentrated local loads of the order of 1,000 tons per square meter as well as global loads that may reach 1,000 to 1,500 tons per meter width.

These loads must then be transferred through the structure to the base and thence into the seafloor soils.

The Arctic seafloor soils generally consist of silty clays and clayey silts, usually overconsolidated, underlain by sands. Saline permafrost exists at varying depths beneath the seafloor.

Because of the fragile ecology of the Arctic, constant attention must be devoted to ensuring against pollution and activities which will cause excessive disruption to the fish, whales and other wildlife.

It is under the above conditions and requirements that Arctic offshore structures must be constructed, working in the short open water season, even then subject to storms and ice invasion.

Areas of Special Attention

A number of areas are currently being addressed in detail by various companies, consultants and industry-wide groups, assisted in may cases by governmental and university research projects. Some of these are discussed in more detail below.

Ice-Structure Interaction

The sea ice features of the Arctic are many and varied, ranging from sheet ice to unconsolidated pressure ridges to multi-year consolidated floes and ridges. This is especially true in the highly dynamic shear zone (Stahmuhki zone) between the perennial polar pack and the fast ice that forms in the seasonally open water annulus near shore. Unfortunately, this coincides with the area of must current interest for exploration and production.

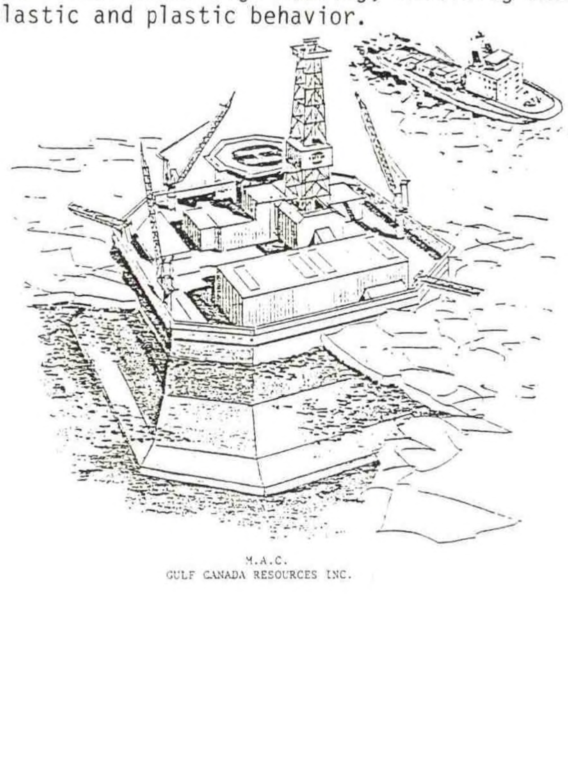
The ice exerts its force on structures in a variety of modes, depending on the structure's configuration and the ice features involved, with failures by crushing, flexure, buckling, and shear. The overall force is limited by the driving force of the ice sheet behind the largest feature that can lodge against the structure without failing.

Current practice is to address global forces on the structure as being linearly proportional to the width of the structure; however, this is only valid within a limited range. It ignores the observed fact that larger contact areas fail at lower unit forces, due to heterogeneity, whereas on smaller exposed faces, e.g., the leg of a monopod or jackup, the unit force is increased due to confinement and homogeneity.

The ice feature will fail at the lower limit of the multi-modal system, that is, under a combination of failure modes that requires the least energy.

The impact of an isolated multi-year floe is one parameter controlling the design; it's apparent crushing strength is increased due to high strain rate. At higher velocities, a brittle mode of failure due to propagation of radial and circumferential cracks may occur.

The kinetic energy of such an ice floe must be absorbed by failure of the ice (usually in crushing), and strains in shear and bearing in the foundation soil as the structure is displaced and tilted. These soil strains are highly non-linear under high loading, involving both elastic and plastic behavior.



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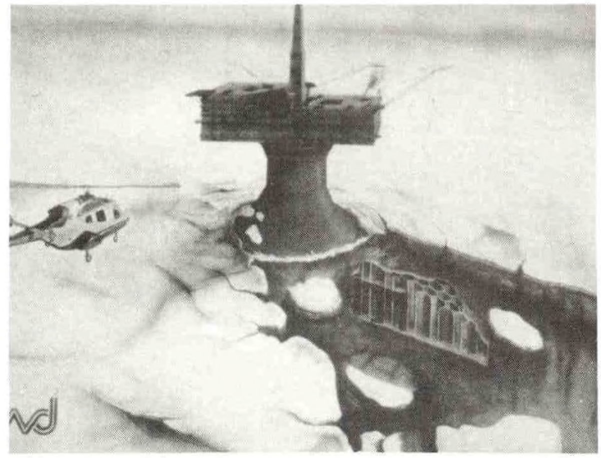
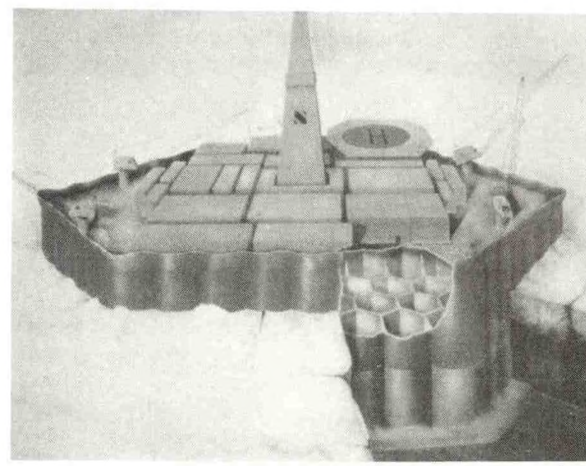


Brian Watt Associates
Arctic Cone Exploration Structure (A.C.E.S.)



Brian Watt Associates
Arctic Exploration Structure (BWACS)

It is important to investigate the dynamic response of the entire system rather than to treat the structure and its foundation as rigid. Computer programs have been developed at the University of California (Berkeley) and in industry, to describe the interactive dynamic behavior.

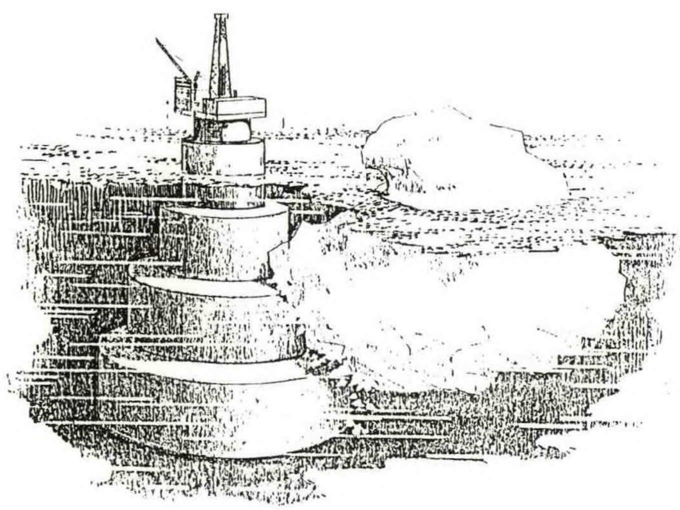
There is considerable evidence developing that the actual (observed) forces of impact by a floe against a semi-rigid body are less than those calculated by conventional momentum exchange theory. Possible explanations may include a reduction in crushing strength of the leading edge of the ice due to temperature and salinity gradients and hydrodynamic attenuation of pressure in the last meter or so prior to contact.

Winter ice phenomena become a second parameter, with values often equal or exceeding those of the summer ice floe impact. The scenario may be that of a ridge embedded at the leading edge of a floe, the entire floe being driven by the ice sheet. The strain rates in winter are lower, but the contact is more complete and uniform. The colder, hence stronger, ice can exert high forces on the structure.

While there is beginning to evolve a general concensus as to the winter and summer ice forces to use in the design of exploratory structures, the design feature for a long-term production structure is still subject to considerable debate.

What are the character, size and velocity of the largest features to be experienced on such a structure with an acceptable probability of occurrence?

A phenomenon that may have to be considered for production structures are the ice islands or at least, ice island fragments. These are fresh water glacial ice, tabular bergs, which are spewed out irregularly by the Ward Hunt glacier on Ellesmere Island, to be caught up in the polar pack. They are not only large in size but are uniformly deep, hence comprise very large masses.



STEPPED PYRAMID
BEN C. GERWICK, INC.

Fortunately these are readily identified by side-looking radar from aircraft (or eventually satellite) and thus, while similar in rarity and extreme force to major earthquakes, unlike them, will give ample warning of their imminence.

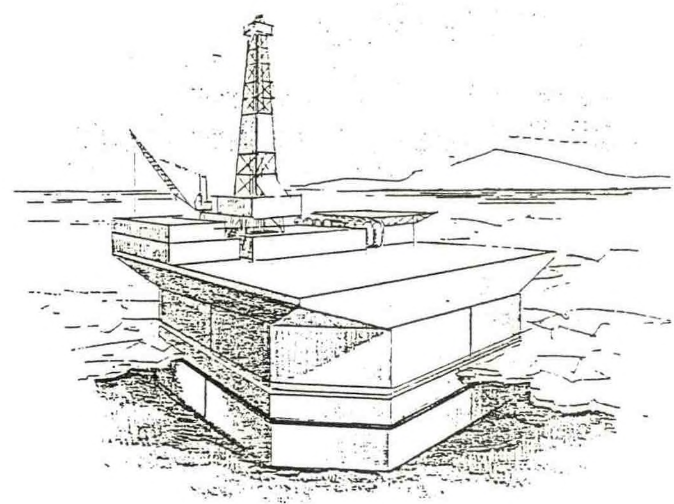
Local ice forces are limited only by the crushing strength of ice. It is these which determine, to a large extent, the design of the peripheral wall. The crushing strength is increased by a factor of 3 or more, as compared to the uniaxial unconfined strength, due to confinement, often referred to as "indentation factor". The effective strength is also a function of temperature, salinity, crystal orientation, and strain rate. It is accepted that these high local unit forces will occur only over limited areas: they will decrease significantly as the contact area increases.

The ice forces, both the local forces referred to above, and the more generally distributed global forces, just be transmitted through the structure in compression and shear, and eventually into the base of the structure. A suggested philosophy of structural design is to design within elastic limits for all frequently-anticipated forces and combinations of forces.

For the rare events, especially a concentrated local force of impact, inelastic behavior can be accepted, with permanent cracking of the ice wall, stretching of the wall's flexural steel beyond yield, and even local crushing, where it is confined by reinforcement.

A ductile failure of the wall is desired, that is a failure in flexure, without brittle crushing or punching shear. These undesirable failure modes can be prevented in concrete structures by three-dimensional confinement and by provision of a sufficient quantity of well-anchored stirrups.

For steel structures, ice-breaker vessel experience has shown that rarely do the hull plates fail: they yield in ductile fashion. Rather it is the scantlings and frames behind the wall that buckle. Some steel designs provide for plastic deformation of the scantlings in order to provide ductility.



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An evolving structural concept is the hybrid design, in which concrete and steel plates are used in composite action: the steel plates providing the tension steel and confinement. Obviously, the steel and concrete must be well-tied together if composite action under dynamic impact is to be assured.

Foundation Soils

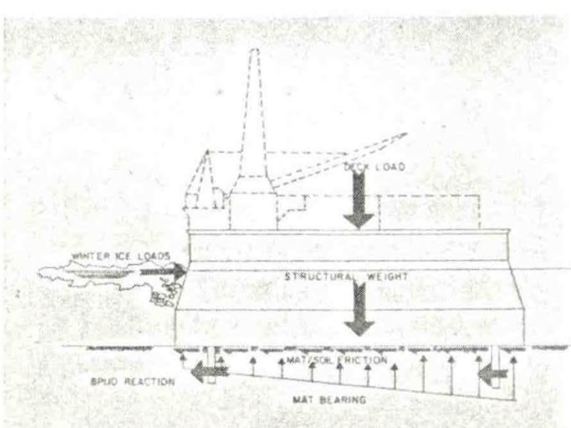
The generalized profile for the Beaufort Sea is that of silty clays and clayey silts, overlying a dense sand stratum. The depth of the silt-clay overburden varies rather widely, but 5 to 25 meters will cover most locations. This overburden is overconsolidated to a greater or lesser degree, believed due to freeze-thaw action while exposed during glacial epochs when the sea level was lower.

The sands are usually ice bonded (permafrost), although near the upper portions of the stratum, this tends to be discontinuous, due to salinity and gradual thawing over geological times.

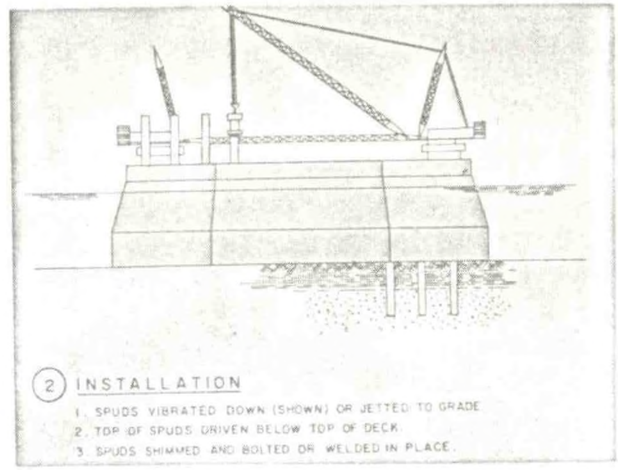
Between the silt-clay and the sand there is frequently encountered a thin (one meter) stratum of very weak clayey-silt. The origin of this stratum is controversial, some ascribing it to organic deposits whereas an explanation preferred by this author is that of clathrate (methane hydrate) decomposition as the perma-frost has thawed, with the gas released being trapped in the impermeable silty-clay, and hence increasing its internal pore pressure to such an extent as to largely offset the effect of depth of overburden and water.

In any event, this weak zone has apparently led to slope failures, even in areas of very gradual slope (1° to 2°) and poses a problem of shear transfer into the more competent soils below.

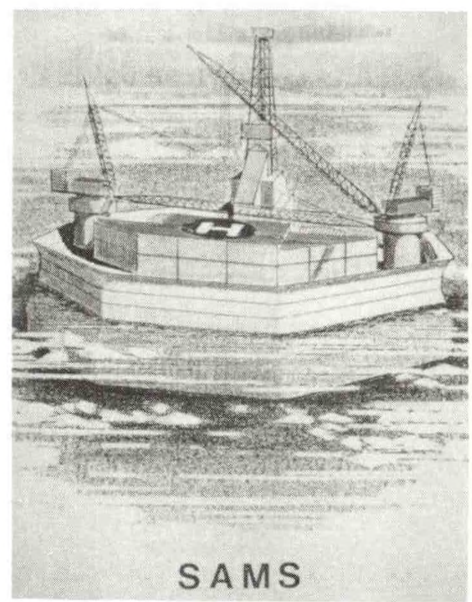
The proposed solutions vary with depth of location and structure requirements. They include dredging and refill with granular material, as has been carried out for Tarsiut and other structures in the Canadian Beaufort Sea, and the use of large diameter steel spuds or dowels, designed to transfer the shear loads from the structure into the competent sands below. Proposals have been made on the concepts of drainage (of gas and water) combined with controlled surcharge, and freezing.



SAMS



SAMS Installation



SOHIO Arctic Mobile Drilling System

Structure - Soil Contact

A relatively uniform contact between the base of the structure and the seafloor is desirable in order to provide for shear transfer at the interface as well as bearing. Yet the typical Arctic seafloor, at least to depths of 50 meters, is extensively gouged by the keels of ice ridges. This plowing action not only develops trenches 1 to 3 (maximum 5 to 7) meters deep but forces up low ridges on each side. The trenches later fill with soft unconsolidated sediments.

While an optimal location will, of course, be adopted for each specific structure, it will still have to accommodate bottom irregularities. These can result in high local forces acting on the base slab.

Attempts have been made to level the contact area by first placing an underwater sand embankment, then levelling its surface. In the open sea, however, it has not proven practicable to level it to the requisite tolerances. Further sand irregularities can develop higher pressures against the base slab than clay: the latter will fail in shear under the high bearing.

The solution so far adopted has been to slurry-in sand under the base, using the methods developed in Denmark and The Netherlands for underbase fill beneath subaqueous tunnels (tubes).

For permanent structures, special grouts can be used, following the practice for the North Sea concrete platforms, and previously used in offshore terminal construction in Australia.

Another solution, adaptable to exploratory structures on relatively uniform seabeds, is to use deep skirts, preferably tapered or stepped, so as to transfer bearing and shear loads into the soil below the depth of scour.

Pile and Spud Installation

Piles and spuds, generally large-diameter, heavy-walled steel tubulars, have been proposed as means of transferring shear and also bearing and uplift, so as to resist overturning.

The installation of these may be rendered unusually difficult, due to the need to penetrate overconsolidated silts, which are very dense and tend to plug the pile tip. At deeper penetrations, fully or partially ice-bonded sands will be encountered.

Experience in both of these materials elsewhere (Cook Inlet and Prudhoe Bay) has shown that high pressure jets are very effective in breaking up the overconsolidated silts and permafrost.

Driving with a large impact hammer, while jetting, would undoubtedly prove most efficacious; however, there may be imposed severe restrictions on underwater noise during the fall migration of the bowhead whale. Thus vibratory hammers or jacking systems may be indicated.

Means of underwater noise attenuation, such as air bubbling, may also be employed.

Shallow-Water Deployment

The presence of the perennial polar ice pack off Point Barrow, Alaska, severely restricts the open water area, and hence the available water depth for deployment of floating structures. Similarly, due to the very gradual slope of Beaufort Sea shores, there are many locations which limit the draft during deployment.

It seems relatively certain the structures and transport barges will encounter some floating ice, hence they must be ice-strengthened near the touring waterline. Use of pusher tugs may be preferable to towing on a towline.

Skirts projecting beneath the base will further reduce the underkeel clearance.

Various concepts are in design to overcome this problem of draft, recognizing that it occurs for only a few hundred kilometers and in waters that are generally calm, due to the limited fetch imposed by the ice. These include:

- Use of an air-cushion within the skirts to partially overcome their added draft. Air cushions have been successfully employed on a number of North Sea caissons in order to reduce their draft during initial float out.

- Provision of temporary buoyancy in the form of attached steel tanks. Often these can also serve the added purpose of controlling buoyancy and stability during set-down at the installation site.

- Splitting the structure horizontally, so that each half can be towed around separately, then joined after arrival or at the installation site.

- A similar approach is to reduce the overall height of structure (and hence its draft) by placing an underwater embankment of sand and gravel on which to found the structure.

- The structure can be made lighter in weight, by the use of steel internals in some locations, in lieu of concrete, or by the use of structural lightweight concrete. Recent developments in high-strength lightweight aggregates and in making strong and durable lightweight concrete have made this option especially attractive.

Durability

The Arctic environment is an extremely harsh one, with extreme low temperatures reaching to -50°C, ice abrasion, and cold saline water with high oxygen content. The loadings from ice not only include impact loads, but cyclic crushing, leading to stress peaks at a frequency of 1 to 2 Hz. Thus fatigue may also be a potential problem.

Steels must be selected that will not lead to brittle fracture at the low temperatures. The welding materials and procedures must be selected so as to preserve this ductility.

Exposed steel surfaces are subjected to a combination of corrosion and abrasion. While corrosion rates are moderate, due to the low temperature, the ice wipes away the corrosion products, exposing fresh surfaces. A loss rate of 0.2 to 0.3 mm. per year is not uncommon.

Concrete is exposed to freeze-thaw attack. Although the number of cycles is not large, intensity is severe. Near the water line, the concrete may become partially saturated. This is also the zone with the greatest number of cycles, due to the thawing action of waves in the fall, just before final freeze-up. The use of air-entrainment, plus pozzolans in the mix, can provide the necessary degree of protection.

Ice abrasion also acts on concrete, eroding the sand-cement matrix. Current attention is being directed to increasing the strength of this matrix by the use of finely-ground pozzolans such as condensed silica fumes.

In order to enable the use of structural lightweight concrete, a number of current research projects have been directed towards ensuring the freeze-thaw and abrasion resistance of the resultant structure and exposed surfaces. Detailing of the steel reinforcement is also of importance, in order to minimize cracking, and to ensure that any cracking which does ensue does not stretch the reinforcement above yield; i.e., the cracks will always be under a closing force. This prevents progressive ice wedging from widening the crack.

Consideration is being given to using epoxy coated reinforcement on the steel closest to the exposed face, in order to prevent corrosion occurring after the cover has been reduced by abrasion.

The very low external temperatures, combined with warm internal spaces due to operations and produced oil, lead to significant thermal strains. Similarly, experience shows that the radiant heat of the sun acting on cold faces can produce important thermal strains.

Typical concrete walls are thick, leading to severe gradient through the walls, with the potential for surface cracking to develop. Satisfactory preventive means include pre-stressing, the prevention of initial micro-cracking during construction due to heat of hydration and shrinkage, the the provision of face reinforcement.

Finally, the frictional resistance between the ice and the exposed face of the structure has an important effect on the global forces and mode of failure of the ice. Low friction coatings have been developed for the steel hulls of ice-breakers. While similar coatings can be applied to concrete, research is till underway to ensure that such coatings will not trap water vapor behind them, leading to freezing rupture of the concrete skin behind the coating. This has occurred in conventional concretes; however, it may be that the dense concretes now being produced and the use of lightweight coarse aggregate to reduce microcracking may render the concrete sufficiently impervious to water vapor transmission.

Standards and Practices

A number of professional and technical societies have addressed the special problems involved in work in the Arctic. They have produced recommendations for design and construction which are of great value, although still subject to revision as more experience is obtained.

These organizations include the American Petroleum Institute, American Concrete Institute, Federation Internationale de la Precontrainte, and the bi-annual conference "Ports and Ocean Engineering under Arctic Conditions (POAC)".

Industry-government and joint industry associations have sponsored extensive research on the Arctic, developing means for effectively meeting the demands of the environment. These include the Arctic Petroleum Operators Association (APOA) of Canada and the Alaska Oil and Gas Association (AOGA). The Canadian Government and the U.S. National Bureau of Standards have also addressed these issues in a number of reports.

Finally, there has been intensive research in several Universities and by consulting firms, primarily sponsored by industry.

Thus there is an extensive body of knowledge existant and developing which will enable the unprecedented problems of the Arctic offshore environment to be met with structures which are safe and efficient. Continuation of this development is essential if we are to meet the increasing challenges as operations move further offshore, into deeper waters and more severe ice regimes.

Undersea Foundations Work on Honshu-Shikoku Bridge

Honshu-Shikoku Bridge Authority

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The construction of Honshu and Shikoku connecting bridge (Kojima-Sakaide route) was started in 1978, and will be completed in 1988. Honshu (main islands of Japan) and Shikoku island will be connected by roads and railways after this route is completed.

This route pass through five small islands between Honshu and Shikoku as shown in Fig. 1, and six new bridges will be built between these five islands. The total distance of the route is about 10 km.

The longest bridge in this route is called Bisanseto bridge and it across the Bisanseto channel of 3 km wide. There are two sea lanes of south and north in this channel, and more than thousand ships pass these sea lanes in a day.

Two suspension bridges having central span of 1100 m and 990 m will be built across these two sea lanes. Six piers of these bridges are built in the sea, and the anchorage pier in south end is the biggest one. The dimensions of this pier is 75 m in length, 59 m in breadth and 50 m in depth under water plane, and the volume is 220,000 m^3.

This is the biggest structure as the underwater pier in the world. These underwater piers of the bridges are built on hardrock in sea bottom to support the huge load from the suspension bridges. The rock consists of granite, and it is needed to remove the surface of 5 - 15 m because of weathering and to expose hard surface which is taken as basic bottom plane of piers.

The depth of the deepest basic bottom plane of piers is 50 m under water plane.

The construction work of underwater pier was started by excavating sea bottom, and the crushing rock by underwater blasting was carried out to excavate the rock surface efficiently and surely.

After drilling to the surface of bedrock by the drilling machine installed on the SEP (Self Elevating Platform), explosive in cartridge was charged on the bottom of drilling hole through the casing tube.

Though the maximum tide current at pier site amount to 4.5 knot, the drilling work was continued day and night not affecting the tide current, because these drilling and medicine manufacturing works were carried out on the SEP.

The platform of SEP is supported by four pillars while at work, and easily moved to another place by floating the platform.

Many holes of 10 cm diameter and 2 m space were drilled in lengthwise and transversely, and explosive of 20 - 30 kg was charged in each hole.

The initiation is carried out when the total of these explosive amount to about 1,000 kg. On the initiation in deep sea or high tide current, wireless initiation system by ultrasonic type or electromagnetic induction type was used.

The rocks loosened by blasting were dredged by grab dredger. On the surface of excavated bedrock, there were undulations of about 50 cm. Finally the surface of bedrock was shaved by 2.5 m diameter rotating boring machine mounted on the SEP.

After all surface of the bedrock was finished, the surface which come to the basic plane of the bottom of pier was almost completly flat within 10 cm undulations.

The inspection of the surface was carried out by the divers of technical experts to judge that the bedrock could support the huge load due to the suspension bridge.

The special diving system was applied on diving 50 m depth, and helium-oxygen was used instead of air for breathing gas.

The diving excort ship SEATOPIA developed by Japan Marine Science and Technology

Center was effectively used in these diving works.

On the other hand, basic structure of the bridge pier was fabricated as the huge steel caisson in shipyard, and transported to the pier site by tug boats. 12 tug boats of 40,000 horse power in total were used in the transportation. The maximum size of these steel caissons is 75 m in length, 59 m in breadth and 55 m in height, and the total weight of steel is 16,000 tons.

These caissons have buoyancy compartments between out and inner side plates, and are possible to float in sea with 10 m draft.

At the pier seite, these steel caissons are moored by eight mooring ropes of 76 mm diameter to eight concrete anchors of 900 ton previously set arround the pier, and keep the position against tide current.

The position of these caissons are adjusted exactly to that of pier foundations by the control of winch.

The position of the caisson is surveied from survey tower, but these information was input to a miniature computer installed on the caisson through telemeter and indicated on a cathode-ray tube display.

Thus the operater of winch on the caisson can learn the position of caisson.

The caissons sink by pouring water into the buoyancy divisions of it, and stop at 1 m above the bottom of sea, and after then they are slowly founded on the bottom of sea by 3,000 ton floating clane adjusting the depth and inclination of the caissons.

The allowance of setting the caisson was expected to be within ±50 cm in position, and the results in actual construction attained within this allowance. At the best case, this allowance attained within 4 cm.

After setting on the bottom of sea, concrete was placed in the steel caisson. This work was carried out in water and the prepacked concrete method was used.

The process of construction method is as following that, coarse aggregate is firstly placed directly in the caisson and mortar composed of cement, flyash, water, sand and admixture, is pumped in through previously placed pipes to fill the voids.

Coarse aggregate graded in size between 8 cm and 15 cm is transported on sea by pusher burges, and throw into the caisson by unloader barges having capacity of 1000 m^3/hr.

For mixing and pouring of mortar, mortar plant barge having capacity of mortar pouring 240 m^3/hr which developed by Honshu Shikoku Bridge Authority was used.

This work was carried out 72 hours continuously to pouring mortar into one compartment of the caisson.

After the concrete in placed in the caisson, the construction of anchorage piers is completed.

Now the construction of six anchorage piers in Bisanseto bridge is continued successfully. They were already found, and five caissons were already finished the prepact concrete works.

Fig.1 The Kojima-Sakaide Route of the Honshu-Shikoku Bridges

RECENT MARINE BOARD ACTIVITIES

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ABSTRACT

The U.S. Navy proposes to order 133 new ships from U.S. commercial shipyards between 1983 and 1986. The Navy has instituted a shipbuilding technology program to foster the development and implementation of shipbuilding technology and thereby increase productivity. A committee of the Marine Board identified and appraised ways to improve the productivity of commercial building of Navy ships as discussed herein.

INTRODUCTION AND OBJECTIVES

The Marine Board is responsible for marine engineering and transportation matters within the Commission on Engineering and Technology Systems (CETS) of the National Research Council (NRC). It acts within its particular area of responsibility to bring about participation of the national community of engineers, scientists and other professionals in the activities of the National Academy of Sciences and the National Academy of Engineering.

Since the 1982 meeting of the UJNR Marine Facilities Panel in Japan, the Marine Board studied a wide range of maritime issues including Ocean Resources and Marine Transportation Development; Coastal, Port and Harbor, and Inland Waterway Use; Support of Ocean Science and Engineering Research; and National and International Cooperation and Information Exchange. Twelve major reports were issued reflecting the broad extent of the Marine Board interests with one of the studies described below.

PRODUCTIVITY IMPROVEMENTS IN U.S. NAVAL SHIPBUILDING

To enhance national security, the U.S. Navy is interested in improving the capability of the U.S. shipbuilding industry, including shipbuilding companies, their suppliers, and ship design agents, to build naval ships. The Navy is seeking to improve the quality of ship construction, to decrease ship construction time, and to increase productivity through the advancement of planning and production technologies. This report is the first of a multi-year effort and is therefore introductory in nature. Its objectives are limited: to describe the status of shipbuilding productivity in the U.S., to acknowledge and describe the substantial industrial activity that is directed towards productivity improvement, and to identify and appraise a number of issues for subsequent technical assessment.

The Basics of Productivity

The history of shipbuilding clearly demonstrates that the productivity of shipbuilding is greatly affected by the status of certain fundamental aspects of industry. The purpose of this report is less to measure and evaluate productivity than to recommend how it may be improved. Toward this objective, the committee's analysis indicates that shipbuilding productivity is enhanced and improved when certain conditions are present and positive:

- Ships are built in volume and on long-term contractual commitments.
- Designs are standardized and explicitly directed toward ease of manufacturing.
- Shipbuilders individually and as an industry invest in and employ technologies and facilities which improve productivity and constantly seek to improve their equipment and production processes via innovation and application of human and financial resources.
- Management systems and personnel do an aggressive and effective job in production planning, contracts, information systems, and project management, taking advantage of continuing developments in management science and techniques.
- Managers place consistent and substantial emphasis on the development of superior human resources, focusing on effective communications, employee training and development, and participative organizations, all with genuine concern for the welfare of employees.

Another fundamental requiring attention is the documentation of the productivity of the U.S. shipbuilding industry in constructing naval ships. The committee recommends that the Navy conduct studies to analyze and evaluate the productivity of the U.S. shipbuilding industry in constructing naval vessels so that efforts to improve productivity can be focused on problems and opportunities. It is also necessary to consider the productivity of shipbuilding supplier industries because procuring, assembling, and installing supplier-built systems represents the largest single cost area in naval shipbuilding.

Productivity-related research and development is central to the advancement of shipbuilding technologies. Productivity-related research and development exists in shipyards today largely as the result of the National Shipbuilding Research Program, which is funded by the Maritime Administration (MarAd) and the Navy.

Shipbuilding Productivity Issues

With the understanding that productivity improvements in naval shipbuilding will not be forthcoming through the development and application of technologies unless and until the fundamentals of industrial health are attended to, the committee identified areas where substantial productivity improvement appears to be possible.

Shipbuilding Industry and Supplier Productivity

To effect substantial improvement in naval shipbuilding productivity, it will be necessary to investigate problems and opportunities in the supplier industries as well as shipyards. The suppliers and the shipyards also need to be assessed as a system, since the interface between them complicates production planning and the quality of supplied materials affects the quality of the product and the necessity of rework.

Industrial Factors

Intergration of Design and Production The degree of integration of the engineering phases of ship production -- ship design, production planning, early material ordering, and production engineering and employee training -- is a major determinant of production efficiency. These engineering phases are segregated in U.S. shipbuilding to a greater degree than in some other countries. Further, such separation of engineering phases does not occur in many other American industries. Assessments are needed of how the lack of integration affects productivity, the extent to which it is difficult to introduce productivity innovation and how more complete integration of the engineering phases of ship production can be achieved.

Work Flow in Shipyards The scheduling and flow of materials and work in shipyards bear on productivity. The extent to which improvements in facility layouts, production processes, and materials handling can improve the efficiency of materials and work flow needs to be assessed in each shipyard. Opportunities for improvements need to be identified and pursued.

Modern Production Control Techniques The potential fo product-oriented work breakdown structures to produce significant productivity gains in Navy shipbuilding needs to be determined. Impediments to the introduction of product-oriented work breakdown structures need to be identified.

Management System Modernization and Computerization The extent to which significant Navy shipbuilding productivity improvements can be made through shipyard management system modernization and computerization needs to be determined. Specific actions to this end need to be identified.

Computer-Aided Design and Manufacture (CAD/CAM) The use of computers in ship design and manufacture has the potential to improve productivity significantly. However, the successful integration of computers into and between shipyards, the design agent, and the Navy requires organizational and procedural changes. Ways to harness the potential of computers in shipyards need to be outlined and pursued.

Human Resources Issues

Quality of Engineering and Management Personnel The implementation of new technologies and productivity innovations in shipbuilding will require basic strengthening in engineering and management functions and personnel. Needing identification are the means to attract engineeing and management personnel to the field, to improve the adaptability of existing personnel to new technologies and innovations, and to train them.

Labor-Management Relations Improvements in labor-management relations are needed to pave the way for the implementation of new technologies and productivity innovations in shipbuilding.

Training and Retention of Skilled Labor As shipyard production processes become more sophisticated, it will be necessary to attract, train, and retain skilled shipyard workers. Problems and opportunities in skilled worker training and retention need to be identified and developed.

Participatory Management/Organization of Work The potential for productivity improvement through reorganizing shipbuilding work to better utilize human resources needs to be established. The nature and extent of alternative approaches and their potential contribution and applicability to Navy shipbuilding need to be explored.

Institutional Factors

Capital Formation The importance of financial stability to capital formation and productivity innovation needs to be established, as does the extent to which the Navy can or should assist U.S. shipbuilders and their suppliers in developing a healthy financial climate suitable for productivity innovations. Aspects of this include the degree to which the government can share financial risks of production technology advancement, whether the shipbuilding workload can be stabilized over the long term, the financing of capital improvements, and whether U.S.

shipbuilders are competitive in warship production.

Contracts The effects of the scope and duration of ship procurement contracts on shipbuilding need to be assessed. In addition, opportunities need to be investigated for reducing the complexity of Navy contracts and speeding up decision making.

Materials and Equipment Standards Areas in critical need of standardization (defined as the use of standards) need to be identified. The body of existing starndards needs to be distilled into a usable base of information, to facilitate their implementation (for without use, standards themselves are of no consequence). The extent to which commercial marine standards meet military requirements, the potential benefits to the Navy from supporting the development and application of commercial marine standards, the needs and implications of updating, deleting, and supplementing military standards, and the additional areas in which the development of material and equipment standards would contribute to productivity improvement all need to be assessed.

Quality Assurance Means to achieve and improve the ability to meet Navy shipbuilding quality standards in the initial installation of material, equipment, and systems need to be identified and evaluated.

Employee Safety and Health Means to improve the safety of Navy shipbuilding need to be identified and evaluated as well as the benefits of comprehensive safety and health programs. Yards and vendors need to be encouraged to provide such programs. Yards and vendors need to be encouraged to provide such programs. The Navy needs to be aware of potential health and safety exposures.

Effects of Federal Laws and Regulations The impact of government laws and regulations on shipbuilders needs to be better understood, since the cost of regulatory compliance is added to the cost of building ships.

CONCLUSIONS AND RECOMMENDATIONS

Support the National Shipbuilding Research Program

The National Shipbuilding Research Program has resulted in productivity-related research and development in the shipyards and a growing awareness on the part of management of the value of such activities. Benefits result from the process of technical interaction of shipbuilder representatives in the program as much as from the substance of the activities undertaken. The process results in direct benefits in terms of productivity advances to the Navy.

With U.S. Navy shipbuilding currently accounting for the majority of the total ship construction activity in the United States, continued U.S. Navy and Maritime Administration support of the National Shipbuilding Research Program is justified, important, and vital. The support of the program should continue to be shared by those who benefit from it.

> Recommendation: The Navy and the Maritime Administration should continue to participate in and support the National Shipbuilding Research Program.

Analyze and Evaluate the Productivity of the U.S. Shipbuilding Industry in Constructing Naval Vessels

The productivity of the U.S. shipbuilding industry in building commercial vessels has been analyzed and evaluated, and has been established as approximately half that of the leading foreign competitors. In contrast, the productivity of the U.S. shipbuilding industry in building naval vessels has not been well documented; it needs to be analyzed and evaluated so that efforts to improve productivity can be focused on specific problems and opportunities.

> Recommendation: The Navy should conduct studies to analyze and evaluate the productivity of the U.S. shipbuilding industry in building naval vessels and determine the relative productivity of U.S. and foreign naval shipbuilding as an aid in focusing its programs on specific problems and opportunities.

Foster Rapid Development and Application of CAD/CAM for Naval Shipbuilding

CAD/CAM technologies offer an opportunity to improve productivity not only by reducing the direct labor contribution to a number of technical tasks, but also by making possible and stimulating the coordination of engineering phases and management functions. Furthermore, shipyards that have applied CAM to their operations have realized reductions in fitting and welding costs. The Navy, as the major shipbuilding customer in the United States, is in an outstanding position to resolve CAD/CAM legal issues and to cause or foster its rapid application in shipbuilding, in conjunction with the shipbuilding industry.

> Recommendation: The Navy should sponsor the development of an integrated product definition data base for establishing its shipbuilding requirements and communicating among the shipbuilding industry. The Navy should encourage its use and the development of complementary, compatible data bases by ship designers, shipbuilders, and vendors.

> Recommendation: The Navy should participate in and support the development and application of graphic exchange specifications applicable to shipbuilding. Together with the shipbuilding industry, it should cause a shipbuilding interest group to be established within the IGES program.

Recommendation: The Navy should sponsor a continuing forum in conjunction with the broader CAD/CAM industry to allow shipbuilding and design agent CAD/CAM managers to plan jointly for the Navy development and use of computer technology.

Encourage Development and Use of Standards

Increased development and use of standards represents a significant opportunity for productivity improvement in Navy shipbuilding. With increased support in terms of committed technical talent and also financial resources, the benefits of standardization can be realized.

Recommendation: The Navy should accelerate and increase its support of the Mil Specs improvement program to eliminate the lag between the state of military standards and the state of technology so that standards can be used effectively in the accelerated naval shipbuilding program. This should include minimizing the number of Mil Specs where commercial standards will suffice.

Recommendation: The Navy should accelerate and increase its financial support of and technical participation in the industrial standards activities conducted under the auspices of the Society of Naval Architects and Marine Engineers' Ship Production Committee and the American Society for Testing and Materials in order to be as effective as possible in the current accelerated Navy shipbuilding program.

Recommendation: Both the Navy and the ASTM standards program procedures should be reviewed and revised to shorten the period needed to update their standards.

Improve Human Resources

The cultivation of human resources is essential to the productivity of organizations. It begins with management commitment and includes human relations, labor relations, personnel functions (i.e., recruitment, selection, training, and retention), and industrial engineering.

Perhaps the most essential human resources challenge in shipbuilding is to improve the physical and organizational conditions of shipbuilding work by altering the relationship between employees and management and the relationship between employees and tasks. In particular, participatory management and small group/multiskill worker organizational innovations which focus on effectiveness, performance, quality, and safety, have significant potential for improving the productivity of the commercial construction of U.S. Navy ships. An outstanding innovation is the training of workers for multiple skills, and then the organizing of work tasks to take advantage of the flexibility of the multi-skilled worker. The logic for the emphasis on human resources is that weakness in this area--for example, manpower shortages--may, in fact be occasioned by physical and organizational deficiencies, such as failure to provide satisfying and challenging jobs.

Increased attention to the physical and organizational conditions of shipbuilding work can strengthen an already sound human resources situation, but in cannot substitute or correct for basic deficiencies. Shipbuilding in particular is prey to unstable work load and consequent high personnel turnover as the result of variables outside industrial control, including the economic climate, government procurement policies, and national industrial policy.

Investment in human resources is not easily justified in an environment of high personnel turnover. Yet, such an approach is self-fulfilling in the sense that minimal human resource investment will lead to greater voluntary turnover. Since the immediate and mid-term survival of the U.S. shipbuilding industry hinges very largely on Navy construction, the Navy needs to give careful consideration to contracting so that a number of shipyards are able to sustain stable employment. In any other environment it is unlikely that management and the work force will commit themselves to improving human resources in general and, in particular, to experimenting with participatory management/organizational development programs.

Recommendation: The Navy should encourage experiments with worker participation and organizational change by considering requests from industry (labor and management) to share in the costs of experimental programs; and, by means of a continuing periodic forum, foster the transfer of information between companies and unions involved in or considering social technology projects. The forum would allow both the Navy and commercial yards to share their growing experience with productivity-related social technologies.

GOVERNMENT-INDUSTRY RELATIONSHIPS IN ADVANCED PROGRAM PLANNING AND DEVELOPMENT

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ABSTRACT

For successful promotion of R & D on shipbuilding technology with substantial results assured, it is particularly important that an overall and efficient R & D project is materialized under proper allottments of duties shared by the Governmental, industrial and academic circles guided by an integrated national R & D plan, realized through the interdesciplinary collaboration in an organic manner with financial aids given by the positive utilization of the funds raised by private and other non-governmental organizations.

Since the important tasks of technical developments not only involve high-graded technical requirements but also they spread over a vast field of diversified sectors such as electronics, new materials and space techniques, it is necessary to actively promote highly interdisciplinary mode of R & D among different academic circles and different industrial circles while ensuring a well concerted cooperation in an organic manner for achieving, with substantial results, the technological sophistication meeting the changing industrial structure, advent of the era of old ages, and changing business environment caused by the rising tide of the developing shipbuilding countries and others.

For substantiating the foregoing proposals, an integrated plan for the efficient promotion of R & D should be established on the basis of the following concepts.

1. Policy-making on an integrated R & D plan

(1) The Government of Japan must draw an integrated R & D plan for promoting the research and development project with a vast coverage smoothly and effectively.

(2) In planning R & D projects, targets of the R & D should be set as specific as possible from task to task, and at the same time, the specific R & D items necessary for achieving the objectives of the R & D projects should be clearly defined as annual projects classified by responsible body of R & D and by progressive stage of R and D.

Also, the period of various R & D projects should tentatively be set at or about 5 years though some of them may require longer periods during which viability of each R & D item should be appraised by conducting fact-proving experiments as much as possible.

(3) On the tasks for adapting the Japanese shipbuilding industry to the 21st Century, it is considered difficult to set down any clear-cut R & D projects at the moment, and hence assessments on technical problem areas and possibility of solutions, investigations of the size of social needs in the future or basic research and studies should be made.

2. Establishment of R & D organization and system

(1) For promoting the R & D projects on the important tasks for R & D, an extreme concentration of expertise in a wide perspective and research and study abilities is necessary, and in this context, it is considered particularly important to assign the role to play in promoting the R & D projects to private enterprises of our country who are greatly accumulating technological force especially in recent years so that their technological development potential and vitality can be utilized to the fullest possible extent, and at

the same time it is desirous to positively make use of the private R & D organizations and systems serving as a common area of forum for developing their joint researches and studies as much as possible.

(2) Under the R & D organization and system herein given, the Government of Japan should ensure overall promotion of the projects by conducting evaluation of the status of development at each stage and review of the R & D projects on each item of such projects in accordance with the integrated plan of R & D projects, and further, on items relating to the techniques for the safety of ships and reliability, or those requiring proper adjustments and coordination to and with the social systems and organizations because of their public nature where satisfactory progress of R & D by the forementioned organizations and systems of the private enterprise is unable to be anticipated, it is expected that such specific R & D items will be better undertaken by the national research and development organizations.

(3) Since the R & D projects stated herein will require a huge amount of money for an extended period of time, the Government must take special consideration for the proper allottment of such fund so that it is properly distributed according to the order of importance, but at the same time, positive use of money raised by those private financial bodies should also be considered.

ADVANCES ON MEASURING CURRENT

JAPAN MARINE MACHINERY DEVELOPMENT ASSCCIATION
FURUNO ELECTRIC CO., LTD.

Abstract

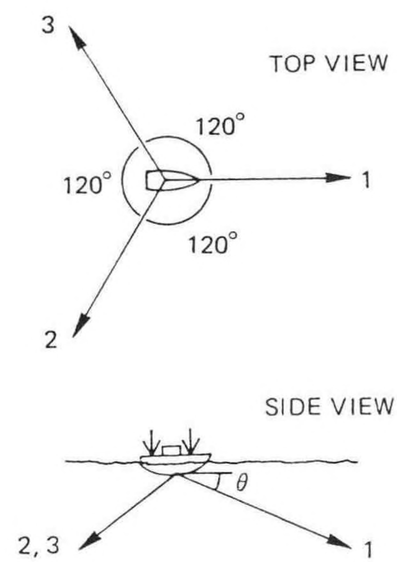
Doppler sonars are recognized as an accurate speed sensor for any type of vessels. When ship's speeds relative to ocean floor and watermass are measured at the same time, a speed of a tidal current can be derived from the difference between these two speeds. The Doppler sonar current indicator provides accurate data on ocean currents at three selected depths as well as ship's speed. These measurements can be automatically done without anchoring.

Introduction -- Development of the Doppler Sonar Current Indicator

Current speed and direction at a selected depth is obtained by calculating the difference between the ship speeds mentioned above and measured against the selected depth. If the ground tracking speed is used as reference, the current speed and direction calculated should also be against the ground. Using this principle, JAPAN MARINE MACHINERY DEVELOPMENT ASSOCIATION and FURUNO ELECTRIC CO., LTD. developed the Doppler Soner Current Indicator, model CI-20 in 1979.

The CI-20 is capable of measuring currents at three depth layers simultaneously. Maximum depths for measurement of ship's ground tracking speed and current depends on the ground and sea conditions; typically to 450 meters for ship's ground speed and 70 meters for current speed.

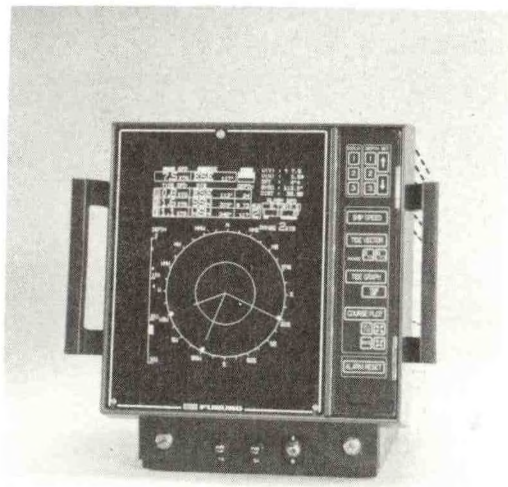
Acoustical pulses are emitted in narrow beams in 3 directions separated 120 degrees from each other and tilted by a certain angle, and this configuration eliminates the effect of heaving. The ship's speed data can be used for Satellite Navigator, true motion radar and scanning sonar and dramatically increases the accuracy of these equipments. The indicated tidal direction can be stabilized by interfacing ship's gyro through gyro converter.



The CI-20 has made it possible to measure the current while the ship is cruising. Over 400 sets of CI-20 have been installed on survey vessels and fishing boats. The majority of users are purse seiners because of dynamic measuring capability of ocean current data.

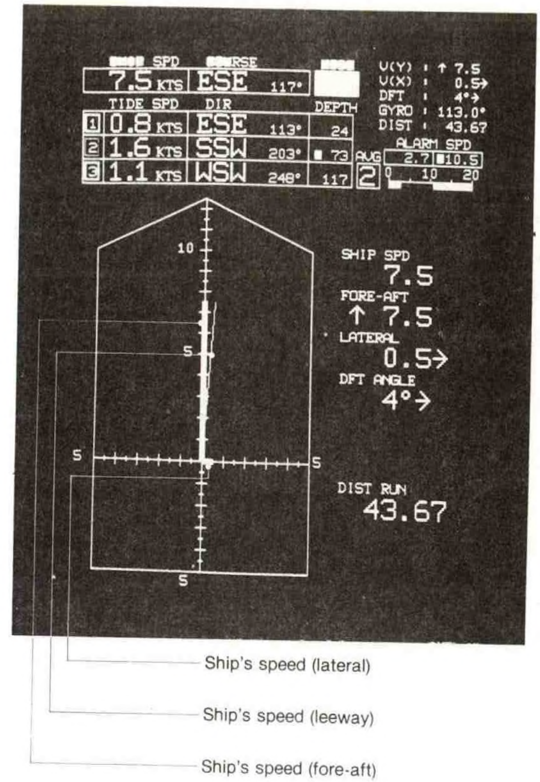
Further Development -- Multi-function Current Indicator CI-30

In order to present the current information more effectively, totally new display device has been developed. This is model CI-30 and has a 14" hi-resolution color CRT instead of the numerical display of the CI-20. Internal memory is increased to store the data for 6 hours. All data is displayed on the color screen.

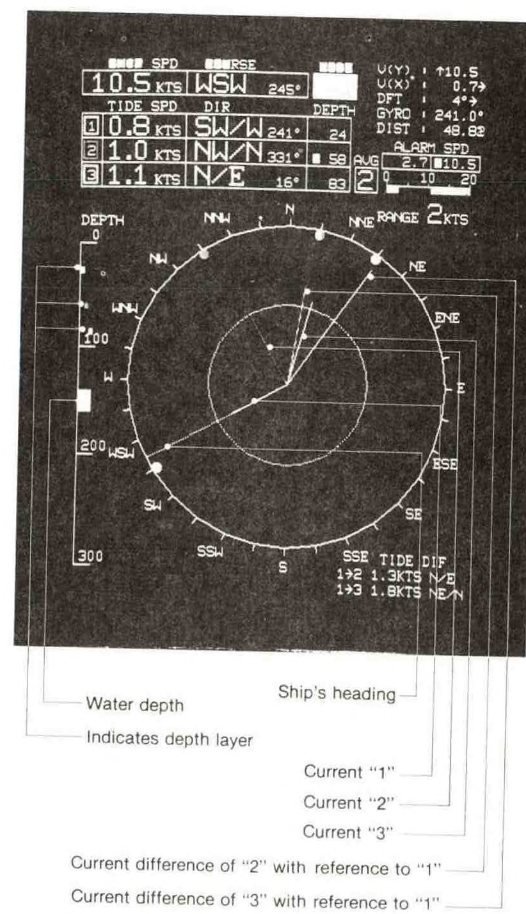


Following are brief explanations of the display modes. The screen provides choices of information: (1) Vector display of ship's speed in fore-aft (yellow), lateral (yellow) snd leeway (green) directions; (2) Vector display of current speed and direction of each of three layers. A different color is specified for each layer (yellow, purple and blue); (3) Current and water depth history for 6 hours (plotted every 2 minutes) and 30 minutes (plotted every 15 seconds); and (4) Course plotting with depth and current data drawn at a selected interval in vector on the courseline. In all display modes, the upper section of the screen displays the tabulated data on ship's speed and course, tidal speed/direction at 3 different depths, and alarm set speeds.

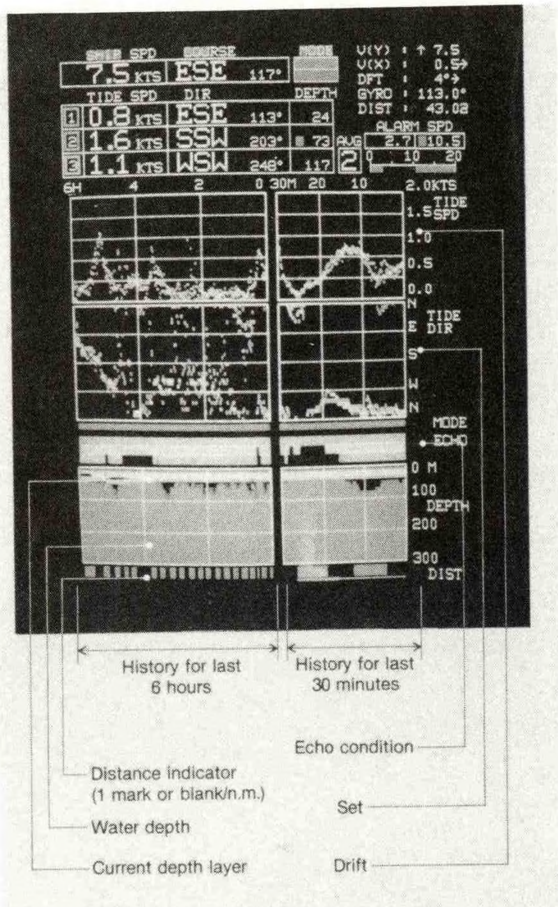
(1) Ship's Speed



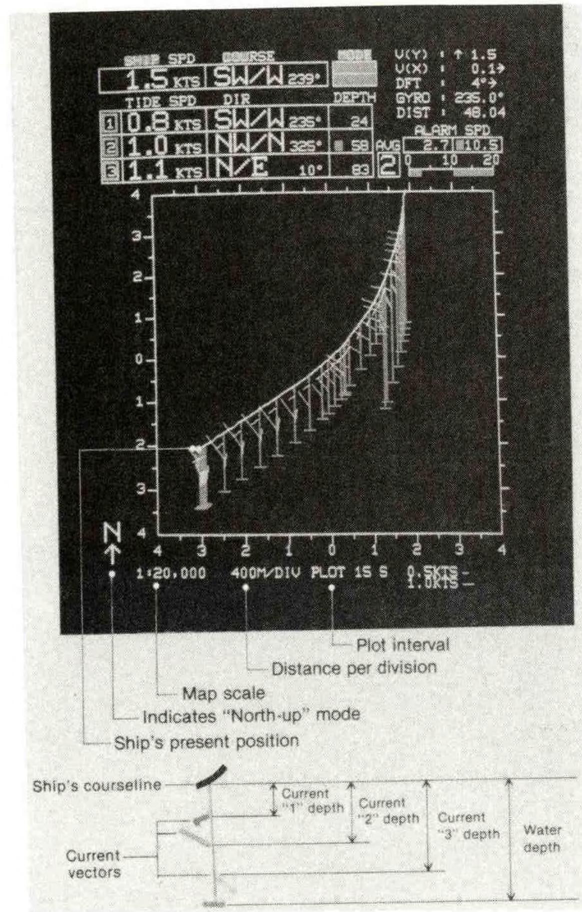
(2) Current Speed



(3) Current and Depth History



(4) Course Plot



JACK-UP DRILLING PLATFORM IN 500-600FT WATERS

SHIBATA, Kiyoshi

ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.

ABSTRACT

The concept design of the very unique jack-up rig has been developed by IHI.
The new type rig can work at the sea in 600' deep by the way of two stage legs.
This papers show the report to introduce the outline of the new jack-up rig.

INTRODUCTION

Today, the search for petroleum is becoming increasingly intense in offshore areas where the water depths are beyond the capability of the present jack-up drill rigs which are limited to about 300 to 400 ft.

In the process of developing conventional jack-up drill rigs toward the rigs capable of operation in deeper water, three hurdles will be expected in technical field.

The first hurdle is an instability in transportation, the second one is a vast amount of bending moment acting on legs when they are standing on the sea floor in survival sea condition, and the last one is a problem of supporting marine conductor pipes.

The unique jack-up drill rig invented by George G. Sharp, Inc., New York, seems to be able to clear the above three hurdles.

IHI, Ishikawajima-Harima Heavy Industries Co., Ltd., are developing, under the license agreement with G.G. Sharp Inc., modifications and improvements to the said original design that may make it more competitive with other types of deep water drill rigs.

The basic feature of platforms having jacking systems in two stages will be able to serve for the stable jack-up platforms capable in operation in deeper waters, for example, for oil production platforms in marginal oil field, drill rigs for production wells, work-over rigs for oil production platforms, and self-elevating platforms for offshore constructions, etc.

OUTLINE

The unit is capable of achieving dependable performance in 500 ft. of water in the Gulf of Mexico during the hurricane season and in 550 to 600 ft. of water at other times. Certain design modification will permit platform placement in 600 ft. of water in the Gulf of Mexico during the hurricane seasons. The unit consists of an upper and lower platform, each with four legs.

The basic feature of the unit is that the jacking of the drilling platform is done in two stages, so that the legs in each stage average about 350 ft. in length which is within the state of the art for towing with all legs in the full up position.

The upper platform, which provides most of the buoyancy when at sea, and which is raised out of the water on location, resembles a conventional jack-up platform.

The heart of this unique drilling platform is the lower platform, which is a pipe truss of open lattice work upon which the upper platform rests when floating, and which is located roughly at mid-water depth when on location.

The upper legs, upon which the upper platform can be jacked up and down, are rigidly connected to the lower platform.

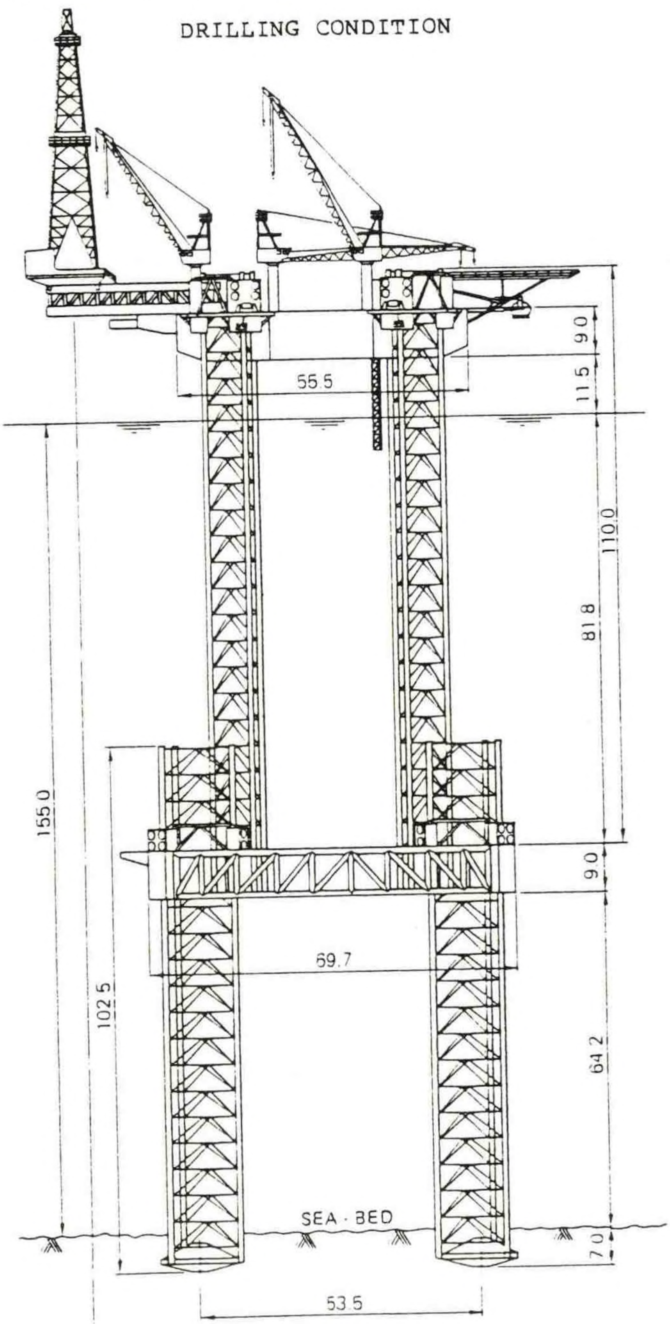
The lower legs are arranged for jacking through wells in the lower platform corners. These legs are adjustable after they have made contact with the sea floor.

The unit is designed to be self-drydocking, that is, it will be possible to raise the upper and lower platforms and upper legs above the water all at one time and to raise individually one lower leg at a time above the surface for inspection and maintenance.

In deeper waters, the conventional drilling platforms must increase in size and scantlings in order to withstand storm loadings and to have enough floating stability, which results in substantial cost increase.

The two stages jack-up platform concept makes it possible to design the platform with lighter steel weight than the conventional type for the same depth of water, thus competing economically with semi-submersibles.

DRILLING CONDITION



PRINCIPAL PARTICULARS

PLATFORM

Upper platform	
Length	182' (55.5m)
Length (overall)	abt.277' (84.5m)
Breadth	180' (55.0m)
Depth	29.5' (9.0m)
Lower platform	
Length	229' (69.7m)
Breadth	254' (77.4m)
Depth	29.5' (9.0m)

LEG

Structural type	Triangular truss of pipe
Length and number	
Upper legs	361' (110.0m) x4
Lower legs	336' (102.5m) x4

CAN

Diameter	47.6' (14.5m)
Height	18.4' (5.6m)

CANTILEVER 108' long x 51' wide x 20' high

JACKING SYSTEM

Upper jack	Electric rack & pinion type
Lower jack	Hydraulic rack & pinion type

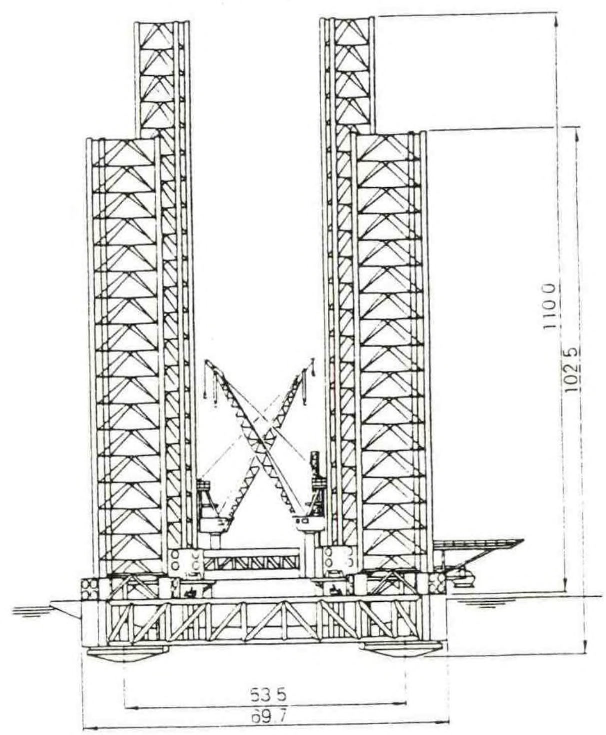
OPERATION

Well center aft of stern	max. 50'
Draft (towing)	abt. 14.8' (4.5m)
Total variable load	2,000 MT
Crew quarters	Up to 90 men

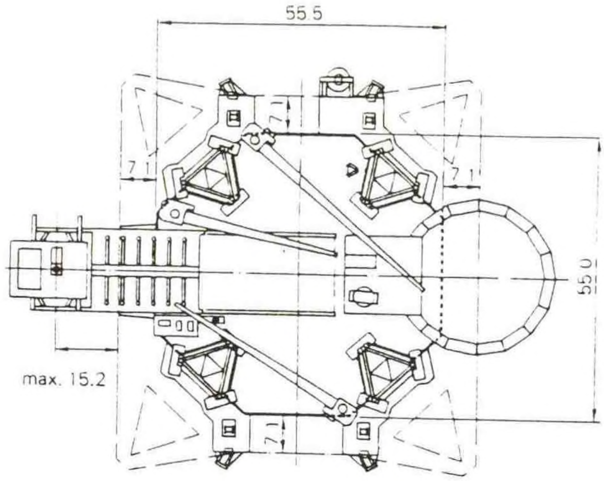
Operating condition with 23' bottom penetration and 37.7' air gap;

water depth	wave height	wind velocity
600' (optional)	50'	115 mph
550'	54'	115 mph
508'	61'	115 mph

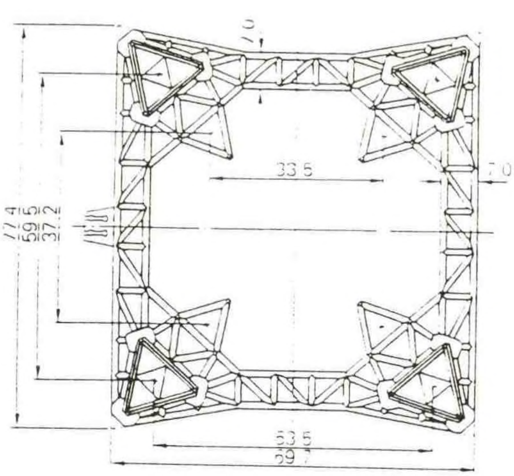
AFLOAT CONDITION



UPPER PLATFORM



LOWER PLATFORM



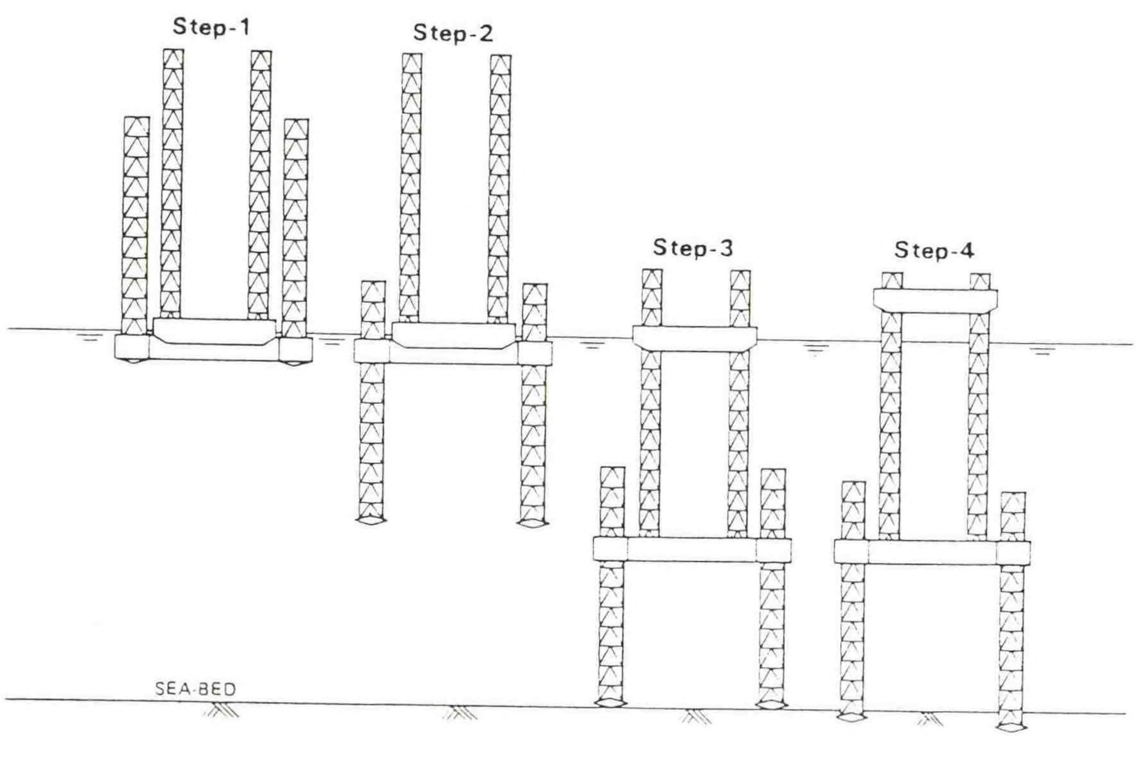
OPERATIONAL SEQUENCE

Step-1 The unit will arrive at the site and be positioned with anchors.

Step-2 The lower legs will be lowered by rack & pinion jacks, which are designed to operate under water and located on the lower platform.

Step-3 The conventional rack & pinion jacks mounted on the upper platform will lower the assembly, consisting of the lower platform and upper and lower legs, onto sea bottom.

Step-4 The lower legs are preloaded as they touch bottom, after which the upper platform is elevated to attain the optimum air gap above the water.



DESALINATION PLANT BARGE

Masanobu Terada

Hitachi Zosen Corporation
6-14, Edobori 1-chome, Nishi-ku, Osaka, 550 JAPAN

ABSTRUCT

The concept of process plant barge is a relatively new technology, the development of which is made by blending of land-based engineering technology and offshore technology.

The concept appears to have excellent technical and commercial advantages and has a wide range of applications.

This paper represents the case of desalination plant barge.

INTRODUCTION

Hitachi Zosen Corporation delivered two desalination plant barges to Saudi Arabia, one at Jubail area in the Arabian Gulf and another at Yanbu area in the Red Sea as a full turn key basis.

Followings are outline of the desalination plant barge.

Barge Section

Length of barge	:	70.0 m
Breadth	:	40.0 m
Depth	:	12.5 m
Grounded draft		
(at lowest tide)	:	3.0 m
(at highest tide)	:	5.1 m

Plant Section

Sea water evaporator : Multi-Stage flash type x 2 trains
Capacity, 410 m^3/h per train

Brine heater : Horiz. shell and tube x 2 sets

Sea water intake pump : Vert. elect. mixed flow type x 3 sets

Brine recycle pump : Horiz. elect. centri. type x 4 sets

Product water pump : Horiz. elect. centri. type x 2 sets

Utility Section

Boiler : 2 drum water tube type x 2 sets

Main generator : 2,100 kW x 4 sets

Some of improved technology applied for the above desalination plant barge are introduced as below-mentioned.

LAYOUT PLAN OF DESALINATION PLANT BARGE

In order to materialize the economical desalination plant barge, layout plan of equipment on the barge is very important to minimize the barge size.

In case of land-based plant, the equipment is usually arranged on the plane area to utilize the wide space, while in case of barge mounted plant, they should be arranged in the three-dimentional space.

The desalination plant barge applies the layout plan as shown in the Fig. 1.

SEA WATER INTAKE SYSTEM

The desalination plant barge is installed at open sea of Jubail area.

Sea water is directly sucked from open sea through the intake pool constructed as a part of barge.

The sea water flow pattern in the intake pool is so complicated that some countermeasurements were investigated to avoid air turbulence to the intake pump.

The model test was carried out to investigate this problem and to decide the reasonable sea water depth at lowest tide.

As a result of model test incorporating some countermeasurements, the minimum water depth without air turbulence was found as 2.2 m and the designed water depth was settled as 3.0 m with margin.

Floating sands movement was also checked, using the above model and confirmed the floating sands are not harmful to the sea water intake pump.

STRUCTURE OF BARGE BED

The barge is designed to ground on the prepared barge bed by ballast water.

The structure of bed and surface preparation was carefully checked.

The structure of barge bed is shown in Fig. 2.

Unevenness of bed surface was measured and the area of touch between barge bottom and bed surface was checked.

The Fig. 3 shows condition of 50% surface touch. Based upon this figure, partial stress of barge bottom plate was calculated and confirmed to be within reasonable stress level.

SHORT DELIVERY

Short delivery is one of advantages of plant barge concept.

Time table of actual construction is presented.

Only sixteen months was requested to complete the plant.

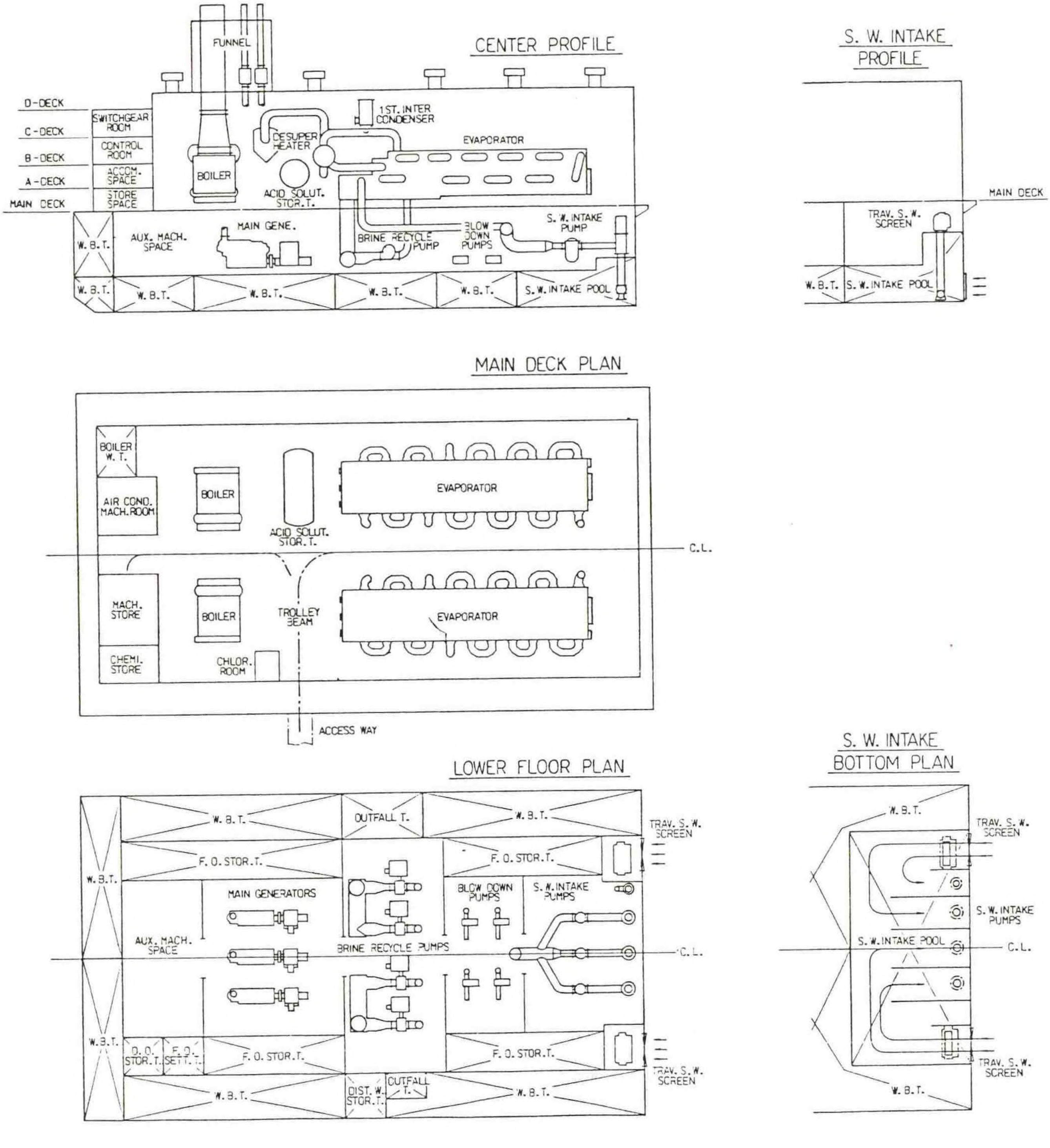


FIG.1 LAYOUT PLAN

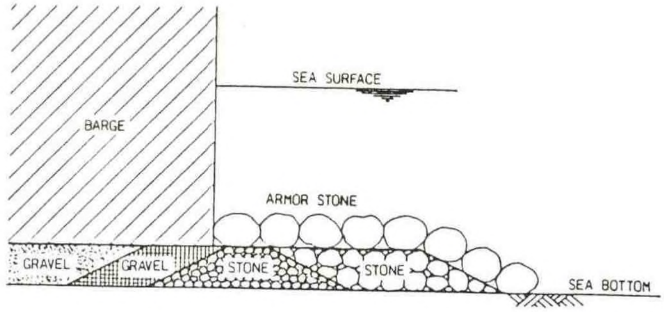


FIG.2 STRUCTURE OF BARGE BED

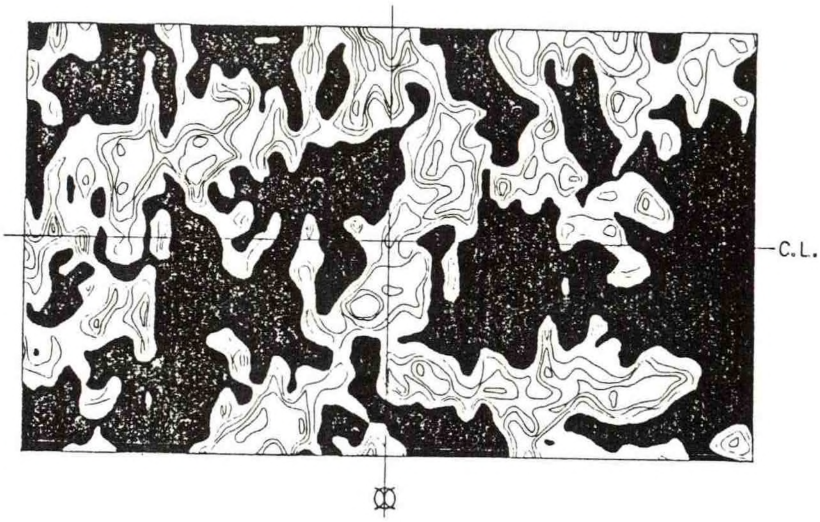
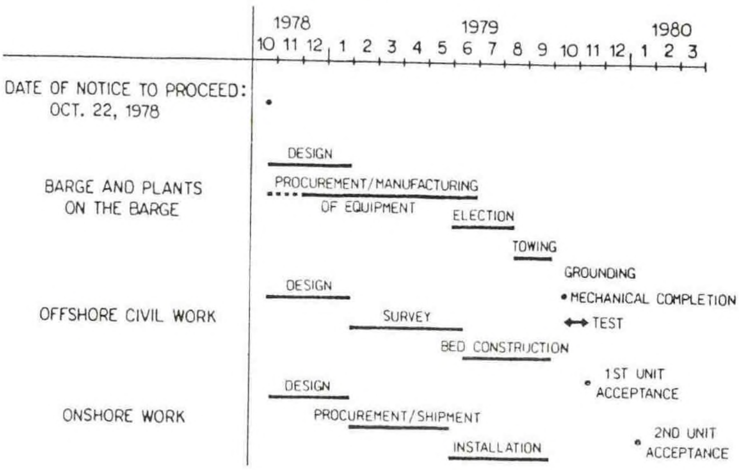


FIG.3 50% TOUCH AREA BETWEEN BARGE BOTTOM PLATE AND BARGE BED SURFACE

TIME SCHEDULE



MANGANESE NODULE MINING SYSTEM

National Research & Development Program
(Large-Scale Project) Office
Agency of Industrial Science & Technology
Ministry of International Trade & Industry, Japan

Since manganese nodules were first discovered in the deep ocean floor during the great oceanographic expedition by the HMS Challenger from 1872 to 1876, many geoscientists have been studying these deep ocean concretions. Manganese nodules are golf-ball to fist-sized, dark brown to black-colored concretions which are found over most of the ocean floor, especially in depths of 4,000 to 6,000 m. Most of their shapes are potato-like spheres, but they range from disks to irregular lumps. Manganese nodules are manganese-iron oxides which contain some valuable minerals such as copper, nickel, cobalt and manganese. Because of their richness in these four strategic metals, the great economic and industrial issues have arisen since the 1960s.

Manganese nodules are considered to be an important future source of minerals which are crucial to Japanese industrial and national security interests. In other words, recavering manganese nodules from the deep ocean floor will ensure a stable supply of four strategic metals as "guasi-domestic" sources for Japan.

From a technological viewpoint there are three aspects to the deep ocean manganese nodule mining:

1) the exploration system to find an economic deposit;
2) the mining system to collect the nodules efficiently on the deep ocean floor, to lift the nodules efficiently from the ocean floor to the mining ship, and to control the equipment which is used in the system; and
3) the processing system to extract the useful metals from the nodules.

Among them the exploration activities in Japan have been conducted since 1975 using the exploration system on board the "Hakurei-Maru" and the "Hakurei-Maru #2." The system for extracting the metals from the nodules, or processing, has been also studied in Japan; therefore the mining system has been forcused to be developed as a new mining technology for Japan.

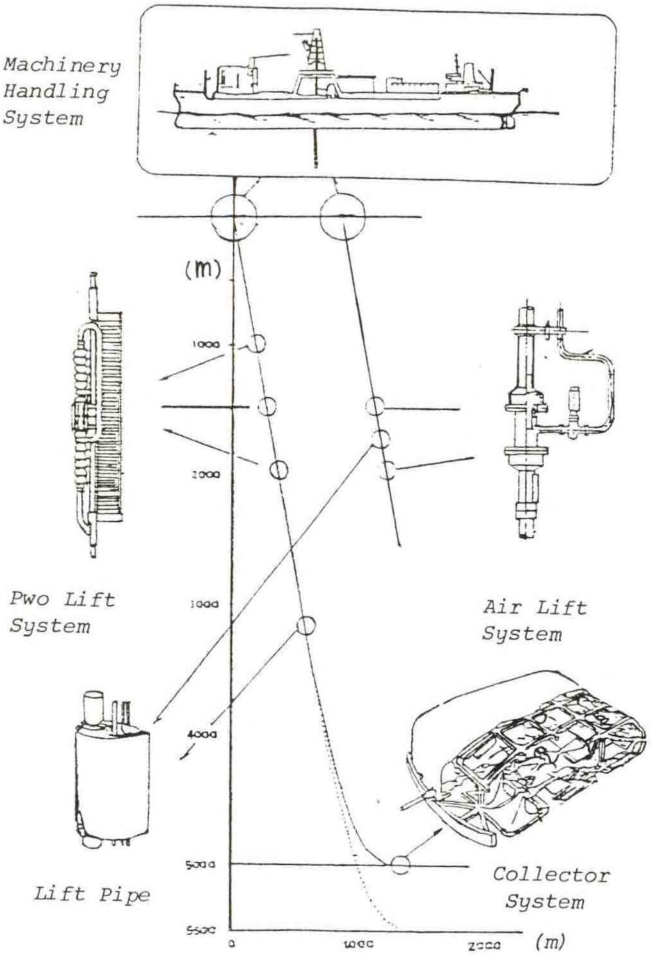
In addition, according to the new Law of the Sea Treaty adopted at the United Nations Conference on the Law of the Sea on April 30, 1982, those who would develop deep ocean manganese nodules would have to possess their own mining technology and would be required to transfer it to The Entarprise.

Under such circumstances, Japan started the Large-Scale Project named the Research and Development Project of Manganese Nodule Mining System in FY 1981. The mining system being researched and developed in the Project is a hydraulic mining system in which manganese nodules are collected by a towed vehicle on the ocean floor and are transported in a slurry of seawater and nodules through the lift system onto the mining ship.

The hydraulic mining system consists of four sub-systems to be researched and developed in the Project:

1) the collector system which is towed along the ocean floow at depths of 4,000 to 6,000 m by the mining ship, collects the nodules, eliminates unnecessary objects, and supplies desirable size and delivery rate to the lift system;
2) the lift system which transports a slurry of the nodules and the seawater using either a pump system or an air lift system from the collector system to the mining ship through a long pipe string which also tows the collector system along the ocean floor;
3) the machinery handling system which is mounted on a mining ship in order to hang, lower, and raise such underwater equipment as the collector and lift systems; and
4) the measurement and control system which measures, supervises, and controls operations of each sub-systems in order to conduct the mining operation safely and efficiently.

The Project has been conducting the development studies in each sub-system; furthermore inter-sub-system coordination and commercial feasibility have been also confirmed. At the last stage of the Project the pilot scale mining test is scheduled in the Pacific Ocean.



A Figure of Manganese Nodule Mining System

UNDERSEA TECHNOLOGY PROJECTS
AT THE NAVAL OCEAN SYSTEMS CENTER

James M. Patton, CAPT., USN
Commander, U.S. Naval Ocean Systems Center

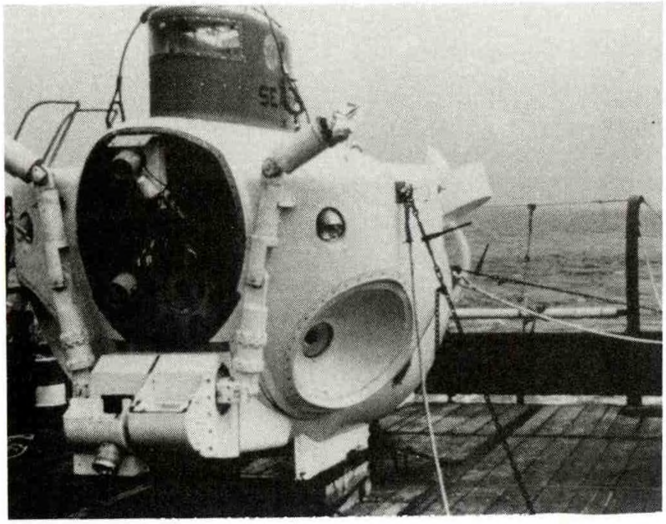
Naval Ocean Systems Center
San Diego, California

ABSTRACT

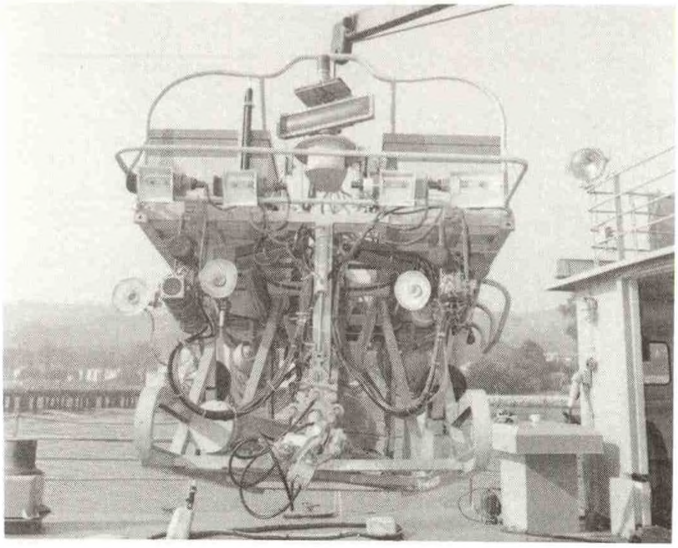
NOSC's mission is to be the principal Navy RDT&E center for command control, communications, ocean surveillance, surface and air launched undersea weapons systems, submarine arctic warfare, and supporting technologies. Ocean technology provides broad-base support to the NOSC missions as well as many other undersea programs.

Successful projection of the Nation's policy at sea requires that the classic missions of the Navy be prosecuted by resources with continually improving capabilities. In addition to the fighting ships and aircraft of the Fleet, knowledge of the oceans and the capabilities to work deep in the ocean are very important. The undersea requirements of mine and countermine warfare, undersea surveillance, lost devices and ship losses require means to accurately locate, inspect, classify, install, maintain, recover, and/or neutralize items within the sea. Five generic missions are identified that require research and development for undersea systems. These are SEARCH AND RECOVERY, SALVAGE AND RESCUE, SURVEY AND INSPECTION, NEUTRALIZATION, and DEPLOYMENT OF SENSORS. These, in turn, require application of new technology to sensors, navigation, communications, tools, energy storage, and the vehicles to support them. The Navy has developed and is operating a series of manned undersea vehicles from the original TRIESTE, to the deep submergence rescue vehicles, AVALON and MYSTIC, the TURTLE, and SEA CLIFF, and provides support to the ALVIN for university research. Next came the cable-controlled undersea vehicles of the CURV family for undersea work, the SNOOPY family for undersea inspection, and the RUWS for deep undersea technology demonstration. Advanced technology is now being applied to untethered, free swimming undersea vehicles. While certain relatively shallow operations (to 6,000-10,000 ft.) can be efficiently accomplished by tethered vehicles with their unlimited power availability and immediate teleoperator monitor and control, untethered vehicles offer the advantages of a smaller support ship since cable handling and storage is not required, and freedom of the support ship from rigid station keeping. The untethered vehicle does not require excessive thrust to tow a cable or hold it against currents, is not constrained in depth due to cable configuration, or suffer entanglement with undersea obstacles. It can run long distances from one area to another, and turn and repeat maneuvers, without concern for surface support. The primary goal of the undersea technology program at the Naval Ocean Systems Center is to apply

DEEP SUBMERGENCE RESCUE VEHICLE



DEEP SUBMERGENCE VEHICLE "SEA CLIFF"

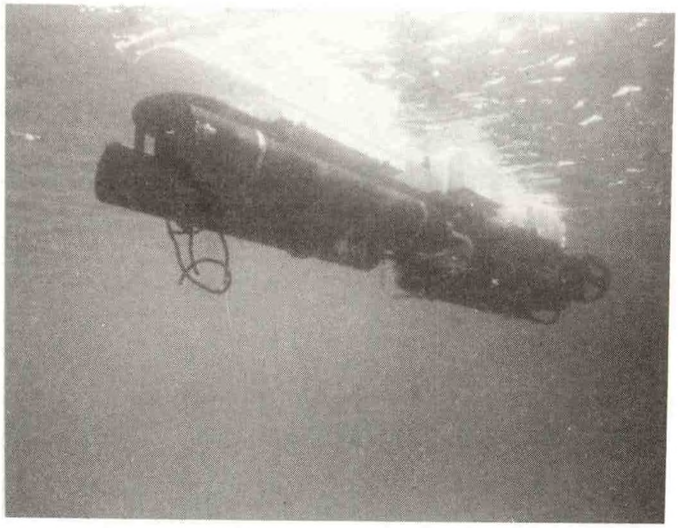


CABLE-CONTROLLED UNDERWATER
RESCUE VEHICLE, "CURV III"

new technological advances in microprocessors, control theory, energy storage, optical, magnetic and acoustic sensors, data links, voice actuated and supervisory controlled manipulators and tools into a system that, when given the decision and control logic of artificial intelligence, can perform a multitude of undersea tasks.

Personnel at the Naval Ocean Systems Center have developed a test bed autonomous vehicle on which new technological items may be tested and validated in full scale undersea operations. This autonomous vehicle supports both Navy requirements and those of the United States Geological Survey (USGS) offshore tower and pipeline inspection needs. The following film gives an introductory explanation of the

ELECTRIC "SNOOPY"



NOSC FREE-SWIMMING VEHICLE

vehicle concepts, shows it in operation, and demonstrates some of its applications.

NOTE! This seven minute sound film includes the following information.

The free-swimming vehicle is a robotic test-bed submersible developed to demonstrate improved vehicle system technology. This submersible, which is 9 feet long, about 20 inches high, and 20 inches wide, has a modular construction which allows expansion to accommodate additional payloads and new sensor systems as the technology for those systems advances to the point at which fabrication and testing become feasible. The vehicle is designed to follow a set of predetermined program tracks, such as a parallel-path search or a figure-8 demonstration run. In this mode of operation, the vehicle is programmed via a computer console and an umbilical cable, which is disconnected after the initial preprogramming phase. The vehicle is then allowed to follow this course until its mission is complete. If an emergency arises, there are automatic procedures that allow the vehicle to turn on an emergency beacon. This action shuts off all thrusters, and the vehicle is recovered at the surface. After initial tests with this mode of operation, other methods of vehicle command control and communication will be demonstrated. In particular, an acoustic control link and an acoustic slow-scan television link are planned. The end result will be a system which is not limited by cable drag and cable-handling problems and one which should perform rudimentary tasks without direct operator control.

FABRICATION AND LOAD OUT OF A HUGE JACKET

Akihiko Sempaku
Assistant Project Manager, North Rankin Project Team

Nippon Kokan K.K.

ABSTRACT

The North Rankin "A" Jacket was constructed at Tsu Works between April 1980 and April 1982 for use in the development of a natural gas field in the north-western part of Australia. With a height of about 147m, bottom dimension of about 67m x 83m, and 22,000t in weight, this barge-launching type jacket is ranked fourth largest in the world. In its construction, various new technologies were fully exploited, such as a large block construction method including panel roll-up with a floating crane (the first such process ever used in the world), dimensional control with an electronic tachymeter, loading out of a barge float type from a quay with big tidal changes, welding procedure requiring high quality (including COD test), etc..

1. INTRODUCTION

In 1947, the first full-scale offshore drilling operation was undertaken in the Gulf of Mexico. At first, the drilling for offshore oil and natural gas was confined to shallow water regions of only a few meters in depth. However, as the price of crude oil rose to inflationary levels coupled with rapid advances in drilling technology, offshore drilling activities slowly began to move into deeper water regions. Furthermore, drilling for oil and natural gas in regions where such operations were hithert believed to be inconceivable, such as the North Sea oil fields, became a reality. In the northwest region of Australia, three offshore natural gas fields, North Rankin, Goodwyn and Angel, in a region 130m in depth and 130km in distance off the shores of Dampier, were discovered between 1971 and 1972. Development of this vast source of natural gas has begun with the aim of starting delivery of gas of Western Australia in 1984 and exportation of LNG to Japan in 1988. Our company, Nippon Kokan K.K., became a major contributor to this development project when we accepted an order from the Australian development consortium, Woodside Offshore Petroleum Pty., Ltd., to build one of the world's largest class jackets for the development of the North Rankin natural gas field, which lays at depths of 3,000 to 4,000 meters below seafloor. The construction work, completed in April of 1982 at NKK's Tsu Works, involved numerous modern technical methods of construction including the world's first panel roll-up opration using floating cranes. dimensional control with the aid of electronic tachymeters, welding methods conforming to strict quality standards and a jacket load out operation using a special barge capable of adjusting its displacement to large variations in tidal condition at the quay. The main characteristics of these technical methods employed in the construction of the North Rankin "A" Jacket will be introduced.

Fig. 1 Location of North Rankin "A" Jacket Installation Site

2. SUMMARY OF CONSTRUCTION WORK

2.1 Basic Description of the Work

The following is a basic description of the work involved in the construction of the North Rankin "A" Jacket.

(1) Outline drawing: Conceptual drawing of the North Rankin "A" Platform is shown in Figure 2.
(2) Contractor : Woodside Offshore Petroleum Pty., Ltd. (abbr. WOP), Australia
(3) Designer : Earl & Wright Consulting Engineers (USA)
(4) Scope of work: Material procurement, fabrication, load out, up to and including tie-down opration
(5) Work period : Contract award - 4.16.1980
Delivery date - 4.01.1982
(6) Configuration: 8 leg barge launch type
(7) Water depth : 124.5 m
(8) Dimensions : Top section - 38.4 x 60.4 m
Bottom section - 67.4 x 82.9 m
Overall height - 146.5 m
(9) Weight: Weight at the time of load out

Jacket structure	- 15,000t approx.	
Floatation tanks	- 2,000t	"
Carried piles	- 3,000t	"
Piping & others	- 2,000t	"
Total	- 22,000t approx.	

(10) Dimension and thickness of principal members
Inner leg : 1600mmø
85mm max. plate thickness
Outer leg : 1500mmø, 3000mmø, 4500mmø
65mm max. plate thickness
Brace : 600 - 1300mmø
700mm max. plate thickness
F. Tank : 4000mmø, 5000mmø
15 - 20mm plate thickness
(11) Number of conductor guides: 34
(12) Material : BS4360 50D modified
(13) Outfitting: (a) Riser pipe
(b) Grouting line
(c) Piping used for upending

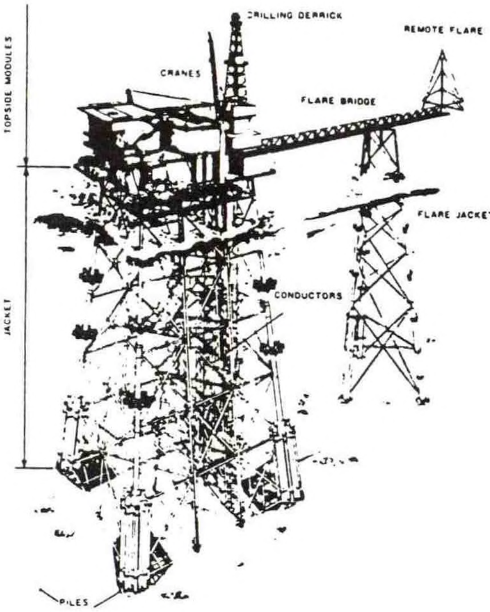


Fig. 2 Overall View of North Rankin "A" Platform

2.2 Special Characteristic of the Jacket Structure

Special characteristics of the jacket structure are given below.

(1) Cluster

Eight piles are positioned around each of the four outer legs of the jacket. Thus, pile sleeves are fixed to the lowest part of these legs in order to connect the piles to the legs, thereby forming what are known as "clusters".

(2) Floatation tank

In order to obtain the necessary buoyancy during launching, detachable floatation tanks are attached to both sides of the jacket.

(3) Carried piles

To simplify the piling operation, eight piles, two on each of the four outer legs of the jacket, are installed at the construction yard.

(4) Deck truss

The deck truss and the jacket are of uniform construction. This design allows direct installation of the upper deck module onto the top of the jacket.

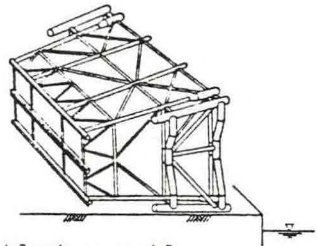
(5) Riser pipes

A pipeline will be laid on the seafloor for bringing the gas to on shore. In order to connect this pipeline to the upper deck module, three riser pipes are installed on the jacket.

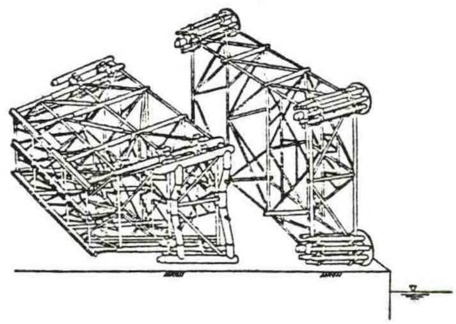
2.3 Method of Construction

Basically, the jacket was divided into three blocks along the length of the structure as shown in Figure 3.

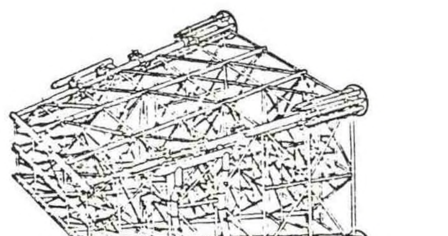
Each member was assembled on ground in extermely large sub-blocks (weighing in the neighborhood of 1000t) and subsequently put into place using a 3000t floating crane barge. For this purpose, the No.1 block was built close to the quay and then "skidded" inland to allow for assembly of the No.2 block near the quay. In this way, a "skid back" construction method was implemented. The floating crane was used twelve times to lift panels built of legs and braces into place and also to lift the floatation tanks into an upright position and to lift the clusters into place. As a result, a lot of high altitude work could be avoided, and use of large land cranes could be conserved. The sequence of jacket assembly is depicted in Figure 3.



(1) No.1 block assembly



(2) Skidding and No.2 block assembly



(3) No.3 block assembly

Fig. 3 Jacket Assembly Sequence

3. LOAD OUT

3.1 Summary

After completion of the jacket fabrication, it was loaded out onto the launching barge.H-109(owned by HEEREMA Co., Holland) on 14th April, 1982.

The method of load out employed is generally called the "floating type" method. In this method. the verical motion of the launching barge induced by variations in the added weight of the jacket and the level of the tide, and all other changes in configuration experienced during the transfer of the jacket from land to barge are fully compensated for by ballasting adjustments made on the barge. In other words, the barge is constantly maintained parallel to the water surface and at the same level as the land surface.

The load out of a jacket weighing in excess of 20,000t using the floating type method had been accomplished in only one previous case by McDermott Co., USA. However, this method of load out has never been implemented before in a region such as that surrounding Tsu Works, where tidal variations may cause differences in water depths of up to 2.4m. Therefore, completeness in planning and coordination had to be insured well in advance of the actual loading operation through meticulous engineering calculations and the development of suitable control systems.

3.2 Sensitivity Study

A three-dimensional computer model analysis was conducted in order to estimate the changes in configuration and the stress response conditions of the jacket during load out. Based on this analysis, the jacket/barge configuration and the maximum allowable difference in ballast conditions at each point in the load out sequence were determined and established as the control standard used during the actual operation.

3.3 General Load Out Procedure

Figure 4 shows the general load out procedure.

3.3.1 General procedure for skidding

Two units of skidding jacks installed on the launching barge H-109 were used for pulling the jacket onto the barge. These jacks were of a diesel oil hydraulic gripping type with a maximum specified horizontal force of 2000t/unit and an average displacement speed on 4 min/m. In order to minimize yawing and sideways motion of the jacket, a part of the uniform control mechanism was altered such that the two jack units were made to operate identically and simultaneously by operation of just one of the units.

For the purpose of decreasing friction during sliding, teflon was coated on the top surface of the skidrail on both the land and the barge and in addition, grease was spread beneath the wooden sliding surface supporting the jacket on the skidrail.

A special grease was used to keep the friction coefficient between jacket and skidrail below 0.15. The horizontal reaction force resulting from skidding was transferred to the quay through the temporary fender affixed to the end of the barge. This fender acted as a structural pin connection for both edges of the barge, permitting the use of the barge under the influence of various external forces.

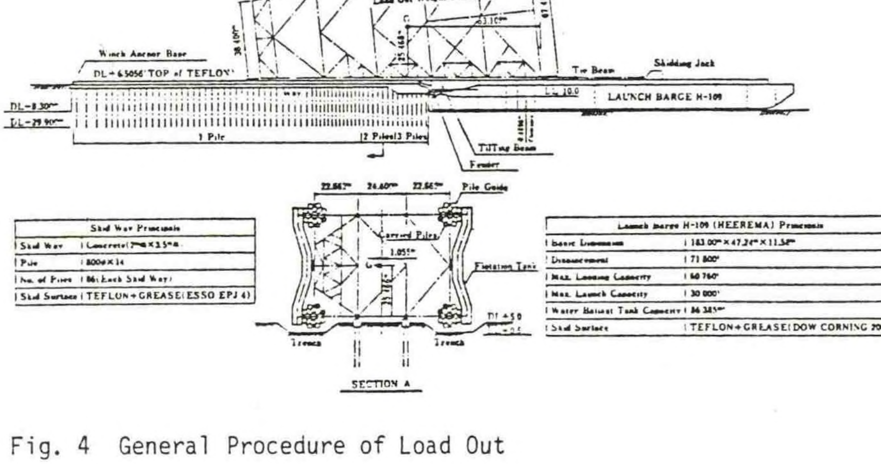


Fig. 4 General Procedure of Load Out

3.3.2 General procedure for ballasting

The arrangement of ballast tanks is shown in Figure 5. These tanks were categorized and used according to specific ballasting functions as explained below. Furthermore, a total of 87 water pump units were fitted to each of the tanks for ballasting work ($4m^3$/min/unit). Each pump was made to be operated by a centralized remote control unit which was temporarily installed on the central control panel aboard the barge. Although the H-109 barge was equipped with a $2000m^3$/h capacity diesel ballast pump, it was deemed insufficient for the present work and was delegated for use as a backup system in case of power failures or other such problems.

(1) Adjustment to added weight

In response to increases in added weight due to the gradual loading of the jacket onto the barge, ballast adjustment was made by pumping out excess ballast water such that the barge maintained constant displacement. For this purpose, 24 water pump units were installed and put to use within the 15 tanks as shown in Figure 5.

(2) Adjustment to trim

In the adjustment to added weight described previously, the center of gravity of the added weight of the jacket and the corresponding outflow of ballast water could not be maintained at the same point along the barge and hence, inevitably, this difference resulted in a trim moment. To combat this problem, and thus keep the barge at a horizontal position at all times, a total of 12 pump units were installed within the 4 tanks indicated in Figure 5, such that during each step in the load out procedure the necessary ballasting work was carried out.

(3) Adjustment to heel

In order to counteract heel moment arising from variations in the position of the jacket's center of gravity, a total of 3 water pump units were fitted to the 2 tanks shown in Figure 5 and thus the necessary ballast work was carried out.

(4) Adjustment to tide level

Again, for the purpose of maintaining the barge at constant level with respect to the quayside, ballasting and deballasting was also required to compensate for both the increase and decrease in buoyancy due to variations of tide level. For this work, a total of 48 pumps were installed within the 6 tanks shown in Figure 5 and thus the barge could be maintained at a preset level even under a maximum tide level difference of 2.4m and a maximum tide level variation of ±53cm/h.

J: Tanks for jacket weight compensation
H: Tanks for heel adjustment
W: Tanks for tide adjustment o: ballast pump
T: Tanks for trim adjustment •: deballast pump

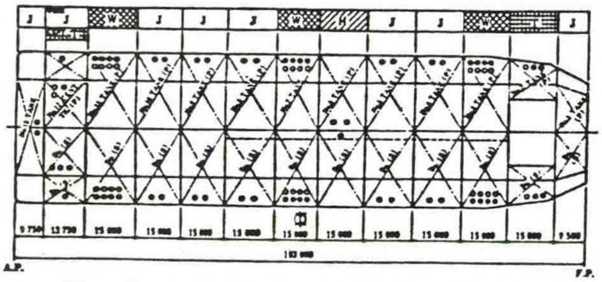


Fig. 5 Arrangement of Ballast Tank

3.4 Ballast Control Work

3.4.1 Jacket/barge level control

Deviations from the preset level of the barge resulting from the weight of the jacket, differences in mooring conditions, differences in volume of ballast water etc. were estimated. For this purpose, the following two conditions were monitored during load out.

(1) Difference in level between the edge of the quay and the barge

A standard level was used to monitor the difference in level between the edge of the quay and the barge at all times, and to establish whether the difference fell within the allowable limit predetermined by analysis.

(2) Changes in the general configuration of the jacket and barge

Changes in the general configuration of the jacket and barge at a total of 24 points along the jacket and the barge, corresponding to node points where the jacket weight added onto the barge undergoes a large and sudden change during loading, were measured and continuously monitored to determine whether these changes deviated widely from theoretical estimations. For this purpose, a "jacket/barge configuration variation monitoring system", consisting of a graphic display system on top of a measurement data processing system, capable of simultaneously determining the ballasting adjustment required to correct deviations in the jacket/barge configuration, was developed and put to full use.

3.4.2 Ballast control for tide variations

As a result of tidal observations through the years, the tide level near Tsu was found to vary in the range of 10-20 cm from the values given in the tide charts issued by the Government's Weather Bureau. Furthermore, the existence, at the same time, of another oscillation with a period of 10 minutes and a wave amplitude of 5 cm has been confirmed. In response to those tide variations which cannot be forecasted, a "tide level adjustment ballast control system" was developed and utilized. This system enables the forecasting of tidal variations expected during the following 20 minutes interval based on tide data acquired during the past two hours period. At the same time, the system provides the output necessary for suitable operation of the pumps. With this system, a forecasting accuracy of ±1 cm for tide levels encountered during the subsequent 20 minutes time interval is possible, and thus deviations in ballast adjustments to tide levels could be kept to a minimum.

4. CONCLUSION

Thus the North Rankin "A" Jacket has gone through the aforementioned stages of development, and on April 26th, 1982 it was towed out to sea by two ocen-going tugboats. On May 22nd, after a 6,000 km voyage, the jacket arrived at Dampier. And, on June 6th, it was successfully set on the seafloor. In having been able to exploit some of the most recent technical know-how, our company feels that the successful completion of the construction of one of the world's largest class offshore drilling platforms is of special significance. We intend to make full use of the knowledge gained from this valuable experience by focusing our efforts towards the realization of even larger scale offshore structures.

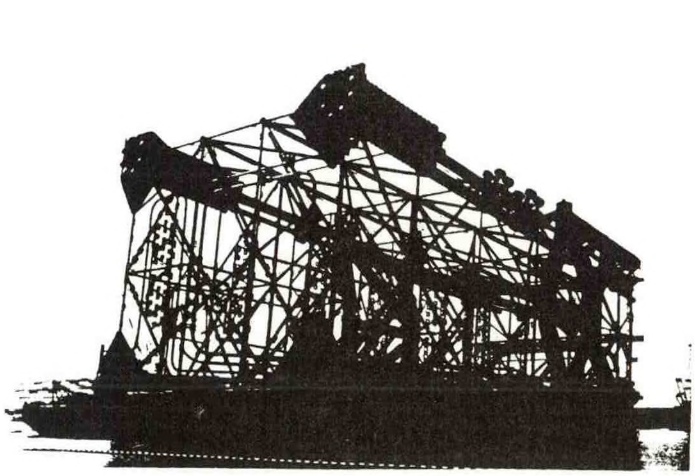


Photo: The Jacket on Barge

TELEOPERATOR TECHNOLOGY DEVELOPMENT

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ABSTRACT

This paper briefly describes the Naval Ocean Systems Center's newly initiated program in teleoperator technology. The goal of this program is to develop the technology base required to build teleoperator work systems (remotely operated vehicles), that will be able to perform man-like work and inspection in areas too hazardous for human habitation. Our approach concentrates on the development of a generic anthropomorphic system that will allow a remote operator to utilize the vast assortment of tools, vehicles and systems that currently exist for human use. Sensory information from the remote site is presented to the operator in a way that enhances natural interpretation and provides a sense of "remote presence." Experience to date indicates that this sense of remote presence vastly reduces the time and effort required for a remote operator to perform complex manipulative tasks.

Introduction

The Naval Ocean Systems Center (NOSC) and its predecessors have a long history of development and operation of remotely operated vehicles (ROV's). The earliest versions of these undersea work vehicles were relatively simple, utilizing a TV camera and lights, and a simple grabber that provided a capability for grasping small objects and recovering practice torpedoes. As ocean engineering technology has evolved over the past several decades, ROV's have become more sophisticated and reliable, incorporating precision navigation, sonar and specialized tools and manipulators. In addition they have proven their value in gathering scientific and engineering data. These systems have progressed to the point where they are employed worldwide by the off-shore oil industry and salvage companies.

Generally speaking, ROV's perform very well when they are utilized to accomplish tasks for which they were specifically designed. Conversely, experience has shown that difficulties often occur when unanticipated situations are encountered, even though only minimal manipulative performance is required. On the other hand, many of the tasks that are difficult or impossible to accomplish with current ROV's can be accomplished quickly by a diver if depth and other safety considerations permit.

In an attempt to capitalize on the remarkable adaptive and dexterous skills of man, the NOSC Hawaii Laboratory has initiated research and development work on teleoperator devices that will permit human-like work capability in hazardous environments. Teleoperators, as described in this paper, represent a special class of ROV's. They are devices that are man-like or anthropomorphic in general size and form (they could, however, be made either larger or smaller), and rely on replicating human motor skills and sensory capabilities in a manner that is natural and as realistic as possible.

These teleoperator systems will have subsystems and components to provide mobility, sensing (sight, sound, feel, direction, etc.) and manipulation, and will be remotely controlled in real time by a human operator. Such a system will permit the operator's extension of the sensory-motor functions and problem solving skills to a remote or hazardous site as though the operator were actually there; a concept referred to as remote presence. In actuality, the word teleoperator has become almost synonomous with ROV's in contemporary meaning. The work described here might better be described as the development of remote presence systems technology. Our use of the word teleopertor is intended to retain the essence of the definition offered by Johnson and Corliss in their original technology survey (1).

In any event, teleoperation as we are concerned with it here involves the human being as an essential part of the control system. The human operator provides the real-time manipulation of controls and the correct interpretation of displays and other information received from the remotely deployed unit. It is on this basis that we distinguish teleoperation from the closely related field of robotics. Robots, unlike teleoperators, are designed to be virtually independent once they are programmed and set into operation. The component parts , i.e. computers, sensors, displays, controls, and actuators, are used in both types of systems, but the teleoperator system is distinguished by the fact that it adds enormous adaptive skills and cognitive capabilities by maintaining man in the control loop.

The key to success in this teleoperator development, however, depends in large measure on the successful development of new man-machine interface hardware that enhances the sense of remote presence. Ultimately, the ideal display will be transparent in the sense that the the operator will not be aware that he is interacting with a machine but will feel that he is actually at the remote site. We believe that maximizing the man-machine interface transparency is crucial in allowing the operator to use his natural perceptual motor and cognitive skills to maximum advantage.

Teleoperator System Description

The basic functions of a teleoperator system are similar to those of other ROV's and are represented in the simplified block diagram of Figure 1. The major difference between our program to develop systems that achieve a high degree of remote presence and more conventional ROV's is in the area of the man-machine interface. In that portion of Figure 1, noted as the operator station, we show separate functions of control and display with each having an interface boundary with the human operator. It seems likely, however, as we continue to push the development of transparent man-machine interface hardware that the display and control functions will merge together in such a manner that the operator will literally "wear" a sensory feedback and control uniform as opposed to sitting in front of a display console containing control knobs, buttons and display screens.

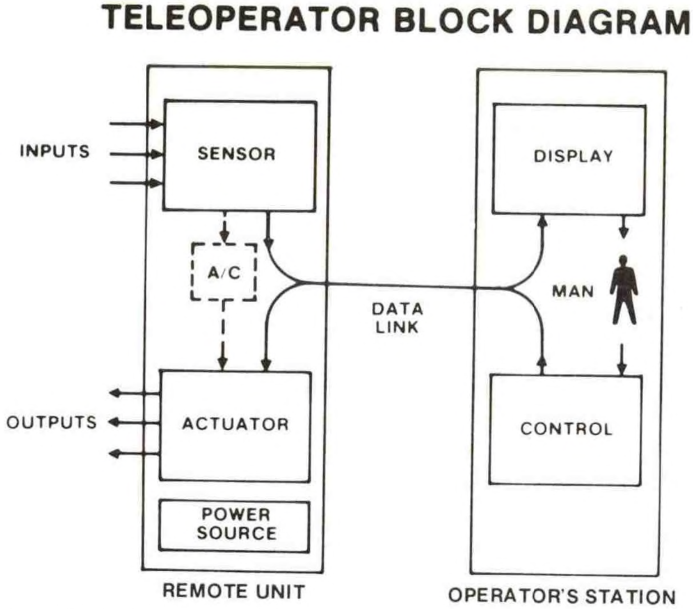

Figure 1. Teleoperator Block Diagram Indicating major functional subsystems.

Although the basic definition of teleoperator systems highlights the importance of the human operator, there are functions that may be best accomplished with some degree of automation or even artificial intelligence in future systems. The A/C block in Figure 1 represents such autonomous control. As an example, teleoperator system status could be monitored and the operator alerted only if a malfunction has, or is likely to occur, much like the sensation of pain alerts the human biosystem.

Considerable development has occurred over the last few years in each of the functional areas shown in Figure 1. For example, in our past ocean engineering research work at NOSC, we developed advanced TV cameras and displays. We demonstrated the advantages of stereoscopic TV imagery over conventional TV systems, especially under real world conditions of poor visibility (2,3,4). These tests and demonstrations were performed with a single relatively unsophisticated direct coupled manipulator. Earlier research (5) has shown that binaural hearing is extremely important in enabling man to detect, localize and recognize sound in the environment and to aid in directing visual acquisition of the source. Other work at the Naval Explosive Ordnance Disposal Technology Center (NEODTC) supported the development of a pair of prototype anthropomorphic manipulators. These arms together with their exoskeleton controllers represent a high degree of sophistication in manipulator technology.

Based on our knowledge and experience of this earlier work and development, we felt that much of the technology to support anthropomorphic teleoperator work systems was in existance, but what was lacking was the developmental effort to combine and integrate the components into an experimental prototype system. Our most recent efforts have moved in this direction in order to gain experience and identify the technology areas requiring further development. This prototype teleoperator system, shown in Figure 2, consists of a head, arms and torso and the man-machine interface head-coupled display controller which provides a one-to-one match between the operator's visual-motor space and that of the remote system. This allows the operator's head, arm and torso motions to be coupled to the remote system in real time. The degree of remote presence achieved in this experimental prototype system has been remarkable, even though there are many obvious improvements to be made.

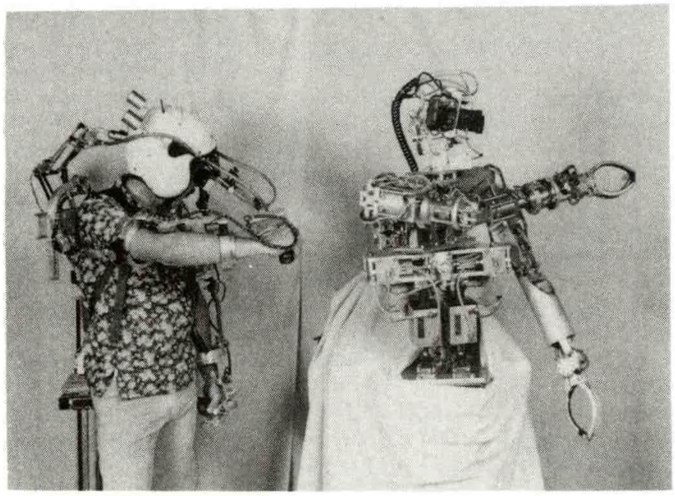

Figure 2. This photograph shows the operator with helmet mounted stereo TV display, exoskeleton manipulator and torso control units. The slight mismatch of corresponding positions between the remote unit and operator is easily adjusted with trim control.

Figure 3 shows a closeup of the remote system. The sensors on the head consist of two black and white TV cameras mounted at an interocular distance of 2.5 in. and two miniature microphones located in artificial pinnas that simulate remote "ears". The head has 3 degrees of freedom with 180 degrees of pan, 45 degrees of roll and over 180 degrees of tilt. The arms, which were developed over ten years ago for another program, have 7 degrees of freedom plus end effector open/close.

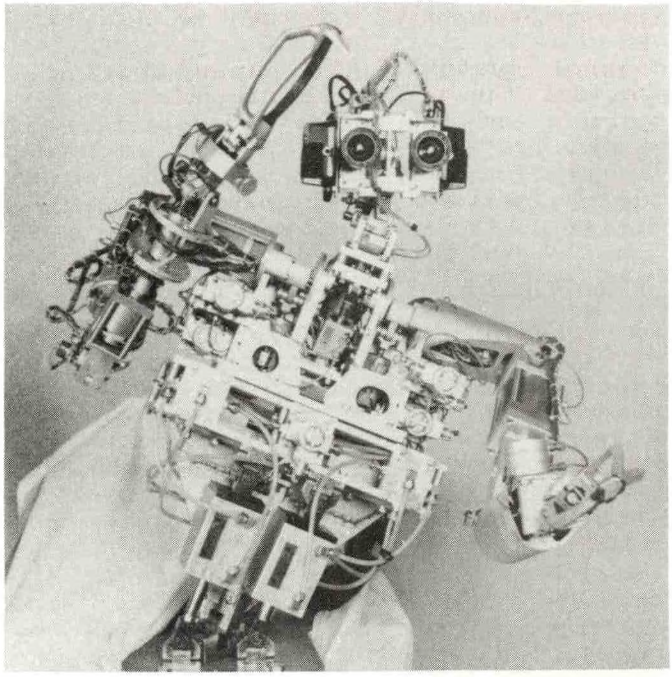

Figure 3. Close-up view of remote teleoperator unit showing the two TV cameras (stereo eyes), binaural hearing sensors and several of the servo valves and hydraulic actuators.

The system torso, or "waist", has 3 degrees of freedom, allowing pan, tilt and roll motions. All of the controlling actuators are hydraulic, running at a pressure of 500 psi.

The manipulators, mentioned previously, were modified slightly and incorporated in our prototype unit. These two manipulators are controlled with exoskeleton controllers which allow the operator to control the motions of both arms in a very natural way. The direct coupling between the operator's head and torso motions with that of the remote system provides the operator with the visual motion and parallax cues that establish a very natural and realistic visual presentation. Very recent work in our laboatory has shown that these head motion cues aid operator performance in depth perception tasks.(6)

The binaural hearing subsystem provides the capability to quickly localize sound in three-dimensional space and greatly adds to the sense of remote presence. These features, combined with the one-to-one visual motor space correspondence, allow the operator to perform some relatively complex motions and manipulative tasks in an easy and natural way, thus a definite sense of "remote presence" is obtained and effectively utilized.

The data link for the present system is a full duplex optical fiber 3km in length. Data from the remote unit is transmitted at a wave length of 1.3 microns and control signals to the remote unit are transmitted at 0.85 microns. Actuator power for this experimental prototype is supplied by an external electro-hydraulic unit.

Future Efforts

Preliminary research experience to date with our experimental prototype teleoperator has reinforced the belief that the concept of a high fidelity, remote-presence system offers a tremendous advantage for the performance of complex tasks.(7) Future work will emphasize the development of a more sophisticated arm/hand subsystem, including force feedback and, if possible, a degree of tactile capability in the fingers, much like the human hand.

Other high priority tasks will include the development of a more comfortable and transparent display/control interface unit. Color stereo vision will be incorporated and experiments with kinesthetics, or body coupling, will be undertaken so that motions of the remote unit are sensed and displayed to the operator.

Conclusion

In conclusion, the goals we have established to guide our research and development of teleoperator systems concentrate on the development and utilization of the sense of remote presence for the human operator. We hope to do this with the highest fidility possible, which implies a man/machine interface that is so comfortable and "transparent" that the operator literally is at the remote location; i.e., the operator will have achieved remote presence through extending his complete sensory/motor-skill capability to a remote location.

The program of research and development that will be required to implement these concepts is varied and extensive. It will include surveys of existing technologies, design and engineering development of the components of generic teleoperators, integration of components into working systems, test and evaluation in specific work environments, as well as basic research in perception. Additionaly, human factor studies of the array of special problems involved in the complex man-machine interaction will be conducted (8). We also plan to continue to introduce artificial intelligence (AI) developments into our teleoperator systems to the extent (and when) they become available. In this manner we will be taking steps toward integrating a symbiotic relationship between human and computer control. We believe the payoff will be considerable if we are ultimatly successful in the development of a complete technology base for teleoperator and robotic systems.

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Advanced Design and Prototype Experiments of Subsea Oil Production System

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Abstract

In view of rapid increase of needs to develop subsea oil resource in deeper sea over 300m, Ministry of International Trade and Industry has been promoting a seven-year project on "Subsea Oil Production System" which deals with fundamental and elementary technology for producing oil in deep sea where a fixed platform system is not practical.

An extensive experiments at sea using prototype well head system, pipeline system, manifold system and riser system which have been constructed as a part of this project will be conducted in the fall of this year.

Introduction

Development of offshore oil resources has become more and more important in recent years, and also new oil resources tend to be found in deeper sea area as seen in Fig. 1. In Fig. 1 deepest oil field now being under production is 312 m and deepest oil field being at test drilling is 1499 m.

Therefore it will be necessary to be prepared for production technology for deeper water than 300 m at such depth fixed platform type production systems seem to be almost unpractical due to enormus quantity of steel needed and long period of time required for platform construction.

It will be necessary for Japan which is sorely deficient in oil resources to be prepared for deep water oil production in the year ahead.

In this view, The Agency of Industrial Science and Technology (Ministry of International Trade and Industry) instituted a seven-year research project starting in 1978 with a budge of roughly ¥15 billion in order to develop a "Subsea Oil Production System".

This project aims to develop fundamental and elementary technology for deep subsea oil production system together with investigation into total system, and will end up with an integrated experiments at sea. Practical work has been conducted as a contract basis by the Technology Research Association of Subsea Production System which is a joint venture of private companies dealing with oil production and offshore engineering.

1. Outline of the research and development

1.1 aims and target

Principal target of this project is as follows:

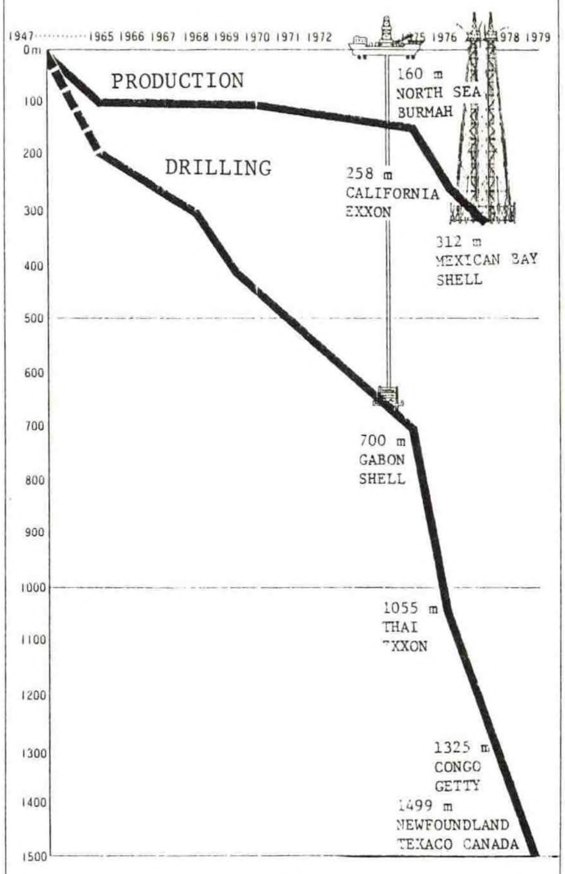


Fig. 1

1) Water depth: over 300 m
2) Subsea installation, operation and maintenance are to be done without aid of divers and guide lines.
   well head system and flow lines are to be buried under sea floor.
3) Harmonization with fishing and environmental safety has to be secured.

A conceptual drawing of total system thus planned is shown in Fig. 2.

As seen in Fig. 2 the system consists of 1) the well head system, 2) the pipeline system which connects each well head to the manifold center, 3) the manifold system which gathers oil and gas and controls flow rate from each well head, and also controls valves and switches channels to which maintenance tool is pured down, 4) riser and oil storage system

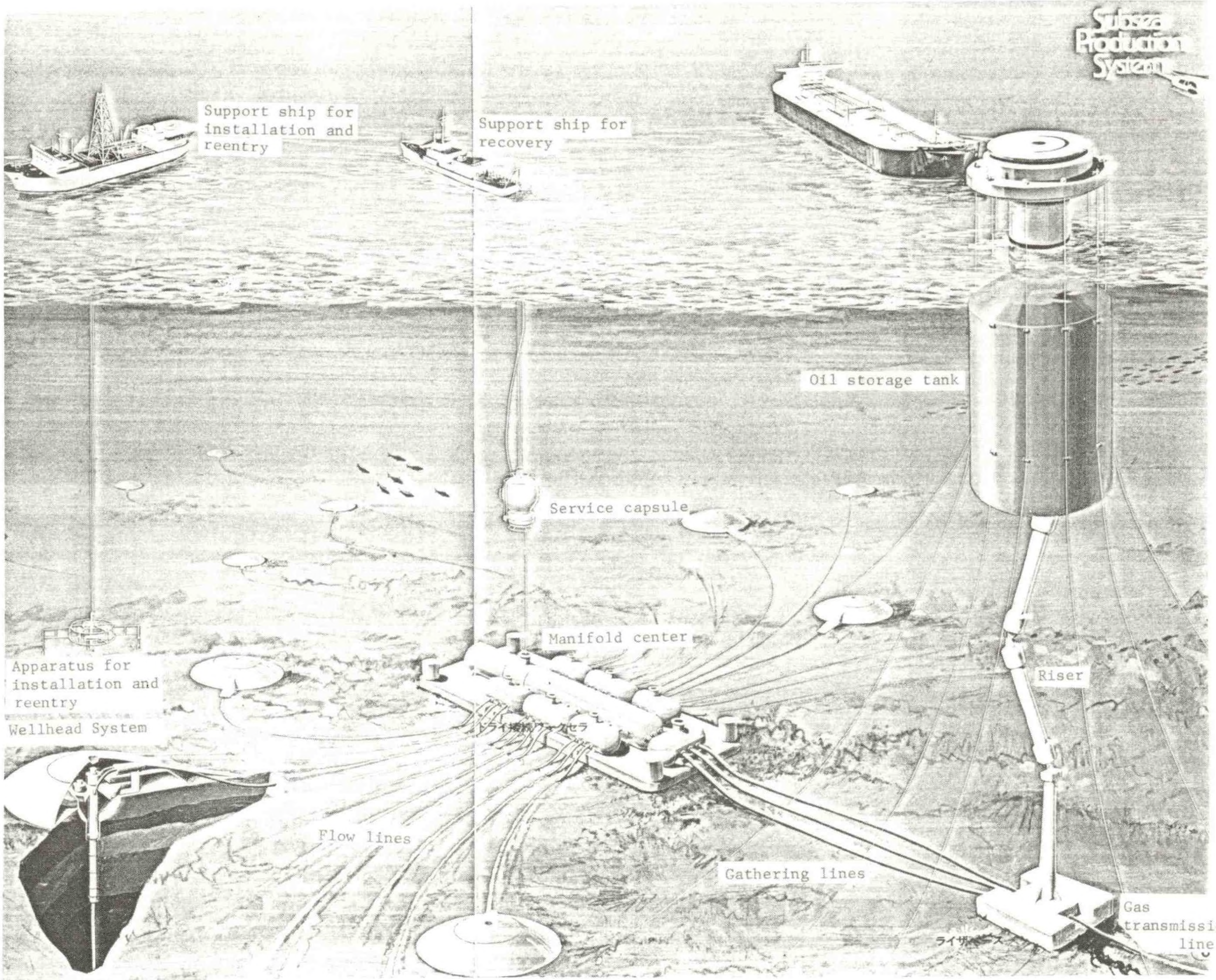

Subsea Production System
Support ship for installation and reentry
Support ship for recovery
Oil storage tank
Service capsule
Manifold center
Riser
Apparatus for installation and reentry
Wellhead System
Flow lines
Gathering lines
Gas transmission line

Fig. 2

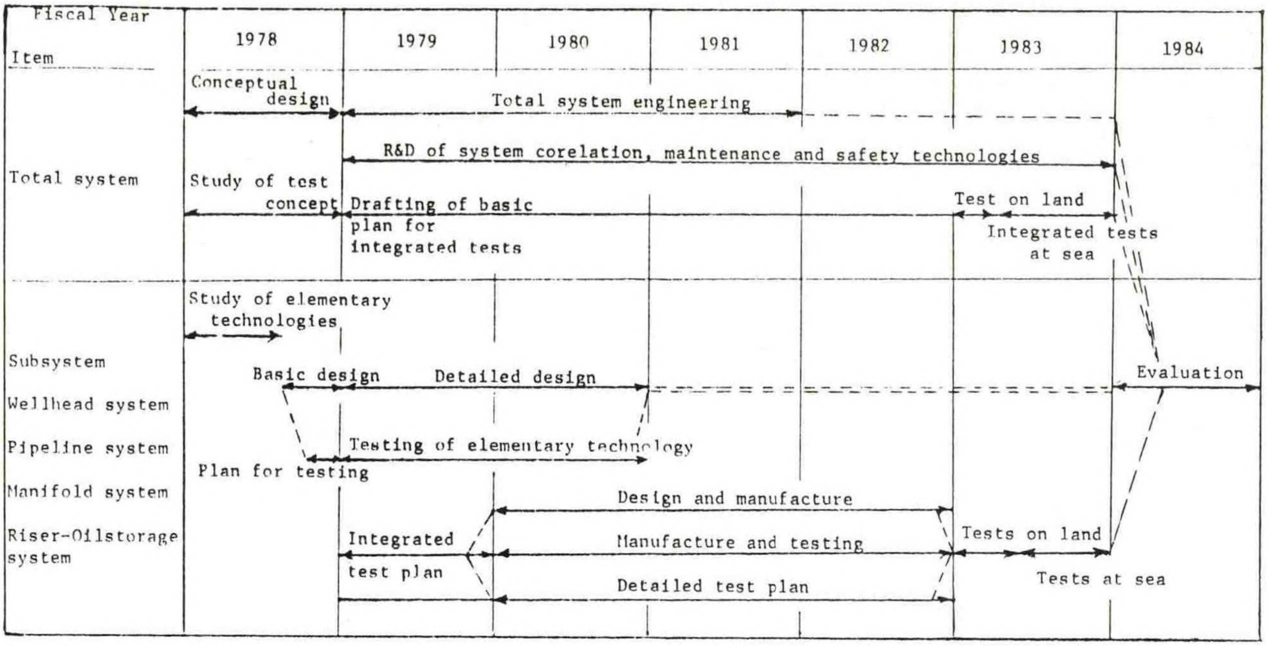


Fig. 3 Long Term Research and Development Plan

which gathers oil from manifold center and send it and store in a huge floating storage tank through riser system, and 5) total system to operate these subsystems in a good harmonization and to secure safety and reliability. At the end of the project, an integrated experiments at sea will be done in the fall 1983 using prototype systems which were developed and constructed during past five years.

1.2 Time schedule

The time schedule of the project is shown in Fig. 3.

2. Total system

As for the total system, the following items were investigated.

1) Engineering of total system
2) Development of technology for operation and maintenance.
3) Plan of the integrated experiment at sea
4) Evaluation of the project

All the items except 4) have been finished.

3. Wellhead system

The type of the well head is chosen to be of an independent, and wet type, and is to be buried under sea floor so as not to be damaged by fishing.

The system is also designed to be diverless and guidline less type. Valves of the production tree are designed to be of fail safe, i.e. a spring return system is adopted so as to be safe when the pressure of the working fluid dropped.

To enable operations of installation and re-entry from a supporting ship at sea surface without aid of divers and guidelines, computer aided automatic positioner and apparatus for reentry which can be controlled from a ship at sea surface were developed.

(see Fig. 2)

4. Pipeline system

This system is to lead high pressure gas and oil from each well head to the manifold. For this system, development of flexible pipes for high pressure liquid (350 kg/cm^2), development of light and compact umbilical cable which contains flexible pipes and cables for electric power and signals, development of unmanned pipe laying apparatus in deep sea (refer Fig. 4), and positioning system for pipe laying have been conducted.

5. Manifold system (refer Fig. 2)

The manifold system consists of pressure vessels forming flowline work cellar to which flow lines from well heads are connected, manifold center (Service and control section), and gathering line work-cellar. Inside of these pressure vessels is kept atmospheric pressure so as to make it possible for workers to operate the system in an atmospheric environment.

The manifold center contains several apparatus for oil production and valves, and gather produced oil from each well head and adjust flow rate and send oil to the floating oil storage tank. Such controlling can be done by a remote control system from the control center on the oil storage tank.

A service capsule to send and back workers to and from the manifold in an atmospheric atmosphere has also been developed.

Prototypes of these systems have been developed and constructed and is under preparation for the integrated experiments at sea.

6. Riser and oil storage system

This system is to send oil from the manifold to the riser base by gathering lines, and to send oil up to the floating oil tank of which capacity is 32,000m^3 through the riser which has three universal joints. Stored oil will be carried by tankers to proper consumers occasionary.

In this system, development of riser joints which is duarable for high pressure and repeated motions, and a storage tank which will have less movement in waves are essential.

Prototype of the developed riser joint was subjected to repeated oscillation under application of high pressure in connected pipes to assertain its performance.

Prototype of the floating tank was not constructed. Instead, a semi-submersible type control barge was constructed and will be used for a dummy tank and also for the commanding center of the experiment.

7. The integrated experiments at sea

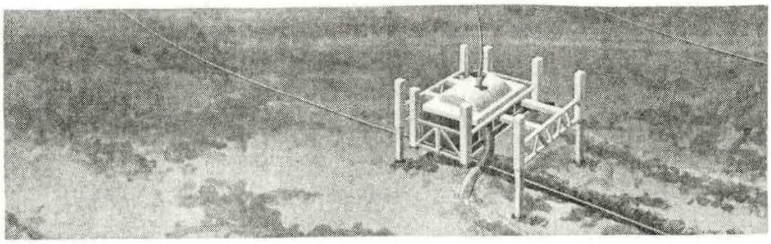
In the fall 1983, an extensive integrated experiments at sea will be done using developed and constructed prototypes of elementary sub system.

Constructed prototypes and associated items of the experiment are as follows:

1) Well head system
   - production well head assembly
   - well head control system
   - templets
   - installation and reentry apparatus

Operation tests of each system and apparatus as well as test operation of installation and reentry with be conducted.

Fig. 4 Automatic pipe laying apparatus



2) Pipeline system
   - flexible pipe
   - umbilical cable
   - wet cable connector
   - apparatus for wet and dry connection
   - pipe laying apparatus
   - pig for drift tool

Operation tests on each apparatus and tool with be performed.

3) Manifold system
   - manifold center
   - recovery system including service capsule
   - recall busy

Performance test for each apparatus will be done.

4) Riser and oil storage system
   - riser base
   - universal joints and riser

Test installation of the riser base, appending test of the riser and connection test of the riser and the riser base, connection test of the riser and the floating tank (control barge at the experiment) recovery of the riser etc. will be performed.

A conceptual drawing of the experiment is shown in Fig. 5.

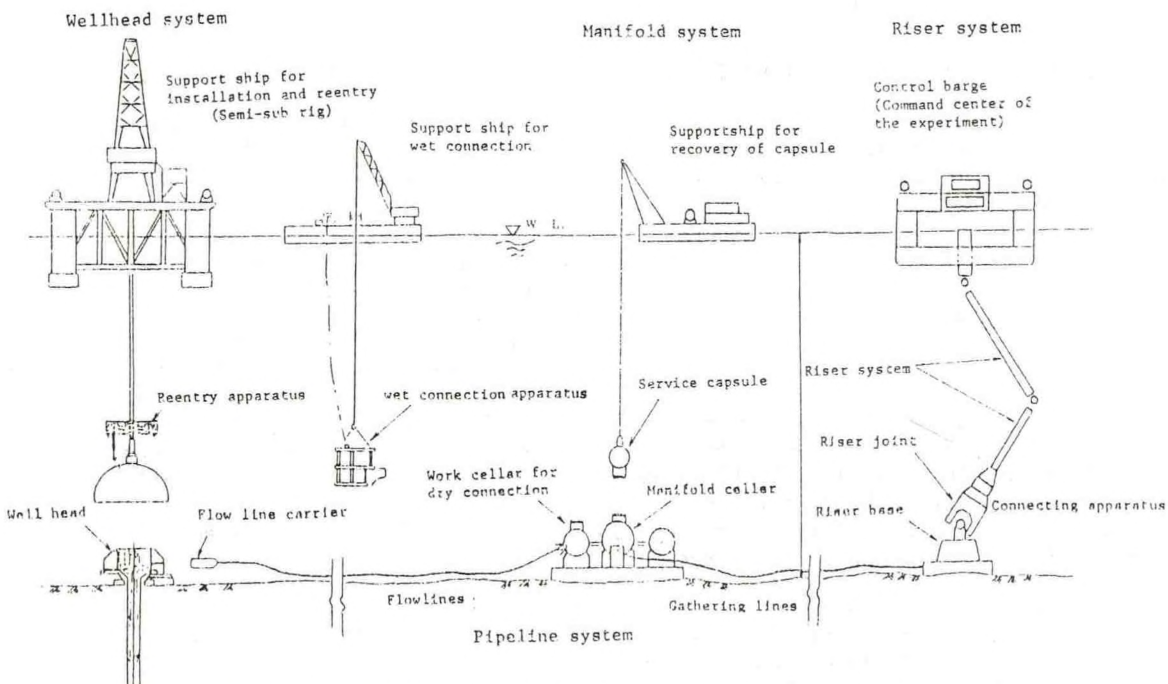


Fig. 5 Conceptual scheme of the integrated experiments at sea

THE NATIONAL UNDERSEA RESEARCH PROGRAM

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ABSTRACT

The University of Southern California, through its Institute for Marine and Coastal Studies, in cooperation with the National Oceanic and Atmospheric Administration, is developing a new temperate-water saturation diving complex for use by the marine scientific community.

The program is one of four major elements of NOAA's National Undersea Research Program. The other three include HYDROLAB, a seafloor habitat located in a submarine canyon in the Caribbean Sea; the submersible MAKALII, with its associated launch, recovery and transport (LRT) vehicle operated in the vicinity of the Hawaiian Islands; and a highly mobile surface-supported open bell mixed gas diving system operated along the eastern seaboard of the United States.

Introduction

During the past 20 years, underwater research facilities have been increasingly supported by developed countries as a means to enable scientists to spend longer periods of time under water than can be achieved by more conventional diving techniques. The system currently under development for emplacement at the Catalina Marine Science Center will provide a second operational underwater laboratory in United States waters for qualified marine scientists. The other habitat system, HYDROLAB, is located in the coastal waters of St. Croix, U.S. Virgin Islands.

These facilities, along with the open bell diving system operated by a consortium of universities along the southeastern coast of the U.S. and a manned submersible system operated by the University of Hawaii, and their related research programs, constitute NOAA's National Undersea Research Program.

This paper will briefly review the research requirements for and principal elements of the four systems.

Research Requirements

In 1979, NOAA requested the Ocean Sciences Board of the National Research Council of the National Academy of Sciences to conduct an independent and detailed study to: (1) identify important scientific needs and ocean research topics requiring undersea research activities; and, (2) define the types of facilities and techniques needed to support these scientific requirements. Two major recommendations were made as a result of this study: First, the establishment of a research program exploiting the use of existing underwater facilities, including saturation diving systems and submersibles, that would be operated by selected oceanographic institutions with research interests and capabilities relevant to the types of research conducted; and second, a program establishing new operational facilities that would be mobile, adaptable to different scientific configurations, and make use of the latest technology and past experience in undersea activities.

Based upon this report and continuing input from other federal agencies and the scientific community, NOAA undertook, through its National Undersea Research Program Office, the development of a series of national underwater research systems. While initially sitted at specific geographic locations to respond to the most pressing current needs, each of the systems is also designed to be relocatable as these needs change and expand.

Research requirements which dictated design of the four systems stemmed from NOAA's responsibilities for managing and protecting living marine resources and their habitats, monitoring and conducting research in marine pollution and managing marine sanctuaries. Specific objectives of NOAA's undersea research program include:

(1) Acquisition of basic scientific information about the marine ecology and environments in U.S. coastal waters;

(2) broadening support of research efforts requiring advanced undersea facilities and capabilities;

(3) enhancing the ability of researchers to complete successfully selected undersea tasks and to extend classical land-based laboratory scientific methods and capabilities to the seafloor;

(4) ensuring continuity of effort and long-range funding for otherwise infeasible in-situ research efforts; and,

(5) providing training and facilities to develop a cadre of scientific personnel proficient in the use of underwater laboratory facilities and advanced undersea research techniques.

Systems Design

It is anticipated that the habitat system under development for initial emplacement at Santa Catalina Island will become operational in early 1985. A detailed engineering design was completed by Perry Oceanographics, Inc. in 1982.

Perry Oceanographic's primary consideration in all facets of the design was to make the habitat system a tool for the marine scientist to use in performing research tasks that could not be done from the surface. The system will allow researchers extended periods in situ in which to make long-term and continuous observations and to conduct experiments independent of the surface. The scientists (perhaps better called aquanauts) must also be safe and relatively comfortable in order to carry out their work most effectively. The Perry design truly represents a "next generation" system - a quantum jump above any others in use today. It will operate anywhere in western coastal temperate waters, from the coast of California to the Gulf of Alaska.

The basic habitat will be a double-lock chamber capable of both bottom and surface decompression. It is designed to be mobile, (i.e., towable), with submersible-type ballast tanks and a haul-down system for routine submergence and recovery. A movable and negatively buoyant baseplate will be implanted on the seafloor at the research site for hauling down and anchoring the habitat. Water, electric power, communications, sewage disposal, heat, and breathing gas will be provided via umbilicals either from shore or a surface support unit. On shore, an operations room will monitor all critical functions and parameters of the operation, with override capability on life-essential functions only. Actual control of all habitat systems and activities within the habitat will be on board, with absolutely no outside or external control. The breathing air mixture will be nitrogen oxygen (nitrox), which will allow the saturation storage depth to vary from 60 to 120 feet of seawater (fsw) and permit the divers to make excursions to depths greater than 200 fsw. If an aquanaut develops decompression sickness, he or she can be treated right in the habitat. Since the system is a double-lock chamber with an internal pressure capability of 232 fsw, it permits the use of hyperbaric treatment tables. Attached to the system's entrance lock will be a diver's "wet porch," providing an entrance to the sea, along with a "wet lab" sorting tray for collected specimens. Because the habitat will be based in temperate waters, there is the possibility that an aquanaut could acquire an increasing body heat deficit after making repetitive dives in cold water; a diver rewarming tub is therefore also included in the wet porch area.

Inside the main lock, there are sleeping and galley accommodations for six aquanauts, with shower and bathroom facilities in the entrance lock. The main lock will serve not only as an apartment for the aquanauts, but will truly be a marine laboratory. It will have two large 24-inch in diameter viewports, with a number of smaller 8-inch ports. The larger ports will have trays positioned on the water side on which experiments can be set up to be viewed from the inside. An area will be set aside as a dry lab, with appropriate scientific equipment such as microscope balances, dissection equipment, and whatever else is needed. Connected to shore by hardwire will be an onboard computer terminal permitting real-time analysis of data, such as cataloging of samples/specimens, and plotting of trend graphs, which should be particularly useful in determining whether the data or approach taken in an experiment is fruitful. Data analysis on the spot will allow experiments or methods not considered appropriate to be modified right there. In addition, the computer can be used administratively to run the habitat system by monitoring vital parameters, setting off alarms in situations dangerous to the aquanaut (i.e., fire, low PO_2,), Keeping track of dive profiles and physiological data on each of the aquanauts and innumerable other tasks.

Once in the water, the aquanaut/scientists will be allowed to work not only in the near vicinity of the habitat itself but at distances far greater than previously allowed under NOAA Diving Regulations; this feat will be accomplished by using diver way-stations. A way-station is actually an open diving bell that consists of a heavy metal base with a plastic bubble or dome mounted above by metal struts. The bubble is continuously filled with nitrox from the main habitat, allowing the divers to enter the station, remove their masks, talk, rest, refill their tanks from a high-pressure air hose, and communicate with the main habitat or the operations base on shore if need be. Breathing gas, power, and communications will be supplied from the main habitat via an umbilical. In an emergency, the way-station could also be used as a diver refuge.

The Marine Science Center operates a double-lock hyperbaric chamber for physiological research, training and hyperbaric therapy for diving accidents. The chamber is on-call at all times, with a five-man crew on standby. This operation will be available for use by the NURL program. An intermediate chamber will be attached to the existing chamber to act as the entrance lock for the habitat's personnel transfer capsule

(PTC). The PTC acts as a life boat for the habitat and is placed nearby on the seafloor. In the event of an emergency requiring that the habitat be evacuated, the aquanauts would swim to the PTC, climb inside, and rise to the surface - still at the ambient pressure of the habitat. From the surface, the PTC would be transported to and locked onto the chamber on shore, allowing the aquanauts to carry out normal decompression inside the larger chamber.

The program anticipates accommodating 12 to 16 saturation missions per year, each lasting from 7 to 10 days. Construction is planned to begin in the late Fall of 1983.

Southeastern Undersea Research Facility

The Southeastern Undersea Research facility, which became operational in 1982, consists of a unique and highly mobile research diving system designed to accommodate a wide range of scientific needs, ranging from SCUBA and surface-supplied umbilical systems to open-bell and mixed-gas operations. The science projects emphasize mobility and the use of mixed-gas diving for in-situ research within its operational area, including the Atlantic Continental Shelf, the Florida Keys, and the Gulf of Mexico's coastal areas. The diving system uses surface supported mixed-gas umbilical units, with a wet bell acting as an in-water elevator, diving stage, and emergency refuge. The primary mode of operation will use nitrox breathing gas to a maximum depth of 150 fsw. However, this system has been used to depths greater than 200 fsw with helium-oxygen breathing gas. The program will not have to be interrupted to accommodate the seasons, and the diving facilities will be operated throughout the year. Approximately 150 dive days are planned each year.

Hawaiian Undersea Research Laboratory

The undersea research laboratory operated in Hawaiian waters was initiated in 1980 by pulling together various resources including those of NOAA and the State. The program is centered around the submersible MAKALII (formerly the STAR II), and its base of operations is located in Makapuu Point on the island of Oahu.

The MAKALII is a one-atmosphere , two-person (pilot and scientist) vehicle capable of operating at depths up to 1,200 fsw. It allows a scientist to observe directly, take pictures, gather samples and implant instruments on the seafloor, and has a life-support capability of 48 man-hours maximum. The submersible can cruise underwater at 1 knot for up to 10 hours.

The launch, retrieval, and transport vehicle (LRT) - designed specifically for launching and retrieving the MAKALII in rough Hawaiian waters - is itself a towed, wet submersible controlled by SCUBA divers. It submerges to a depth of 50-100 fsw with the MAKALII positioned on its deck, releases the submersible in calm sub-surface water, and resurfaces. When the MAKALII returns from its mission, the LRT is towed into position and resubmerged, after which the submersible lands and is secured on the deck for surfacing. The LRT may also be used for diver support, salvage, or for launching other oceanographic equipment in rough waters where the use of surface equipment might be dangerous.

To date, HURL has conducted over 103 scientific mission dives, not only in the Hawaiian Islands area, but also in the Western Pacific.

Caribbean Undersea Research Laboratory

The central facility of NOAA's ongoing program at St. Croix in the Virgin Islands is the habitat HYDROLAB, located at the head of a submarine canyon and fixed to the bottom during missions at a site depth of 44 fsw, approximately one-half mile off the north central coast of the island. At present, HYDROLAB is the only operational habitat system in the world dedicated exclusively to marine science. Since its first scientific mission in May 1978, the program has averaged 14 missions a year, with both American and international researchers participating.

HYDROLAB consists of a single chamber housing living quarters, laboratory facilities, and a wet diving area that will support four aquanauts for as long as 14 days. A large 36 inches in diameter viewport and additional smaller ones allow researchers to observe marine life and their experiments directly while remaining inside the habitat. The life supporting air, power and communications are supplied via an umbilical connected to a life-support buoy on the surface. As a backup, a submerged high-pressure air hose and hardwire communications line run directly from the habitat to the operations base on shore. Way-stations containing pockets of air are located near the habitat to permit divers to talk, rest, or obtain refuge during excursion dives. In addition to the various support equipment and capabilities, a double-lock chamber is maintained on shore for treating injured divers if the need arises.

Since the program began at St. Croix, it has been extremely successful. More than 56 scientific saturation missions representing over 165 different scientists from more than 27 organizations and institutions have been conducted, with the aquanauts performing excursion dives totaling more than 13,000 hours, and saturations involving more than 59,000 hours of underwater living. During all of these activities and missions, no accident has occurred that required emergency procedures. The HYDROLAB system has proven to be an extremely safe, cost-effective, and valuable scientific tool.

Summary

In the development of these undersea research programs and NOAA's Undersea Research Office, the science programs have been the driving force. Timely, pertinent and useful science is the product of all of the program's activities and efforts; the program's facilities and support are available not only to NOAA but also on a national and international basis to all research organizations, institutions, agencies, and industry. The use of these facilities by international teams and the development of cooperative undersea programs among interested countries is actively encouraged. Interested parties are required only to submit a proposal to the appropriate peer review panel for consideration and review.

In addition to these existing and planned undersea research facilities, NOAA anticipates that its involvement in the use of other undersea tools for scientific efforts, such as remotely controlled vehicles and specialized submersibles, will increase and will further expand the array of research facilities available to the international community of marine scientists.

INVESTIGATIONS IN ADVANCE TO THE PILOT PROJECT ON CLEANING-UP BAY BOTTOM MATERIALS IN JAPAN.

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ABSTRUCT

A big project on cleaning-up of bay bottom sediments is under investigation by the Ports and Harbours Bureau of Ministry of Transport in Japan for the purpose of the restoration of the self purification ability of the sea. Test dredging, test earth covering and excavating of test trench were operated in selected five sites. Effects of these test works have been followed from many points of view.

This paper reports on the abstruct of these investigation works.

I. INTRODUCTION

The pollution problems of the sea water is growing seriously in bay areas in Japan, such as Tokyo Bay, Ise Bay and Seto Inland Sea, because in addition to lower rate of water exchange between the open sea, these bay area have a large amount of load of pollutants discharged from big cities around these bay areas.

Since a few years ago, the legal basis of the restriction of pollutant discharge has been changed from the concentration of pollutants to the total amount of it in Japan. But, it is difficult to say that this policy obtained the disired result.

One of the reason to this result is considered that the self purification due to secondary production by materials released from polluted bottom sediments deposited during long period. Therefore, the Ports and Harbours Bureau of Ministry of Transport in Japan

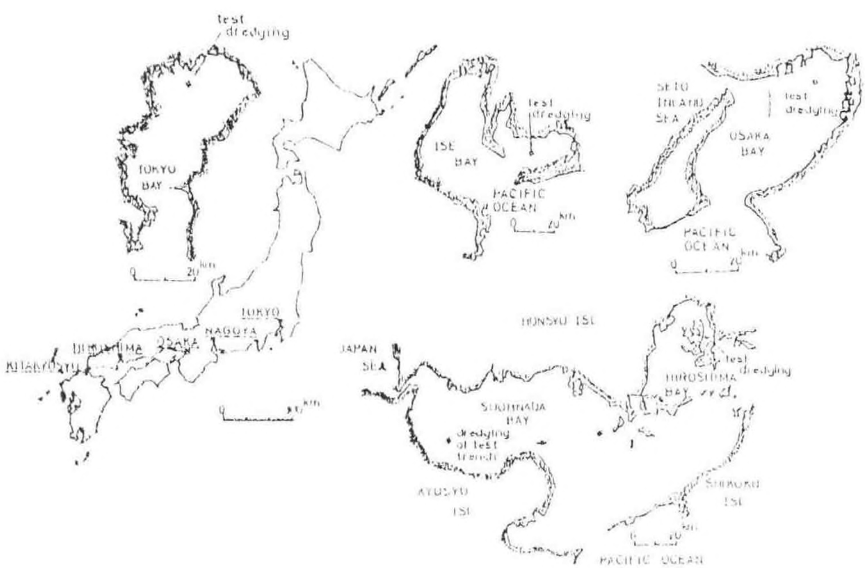

Fig.-1 Selected site for the pilot project on cleaning-up bay bottom sediments.

has a plan to start the project on cleaning-up polluted sea bottom sediments for the purpose of restoration of the self purification ability of the sea by means of removing or of earth covering of bottom sediments.

However, a great cost is required for this project. Therefore- it is considered desirable that nation wide developement of the project would follow behind the pilot project which will be executed after deep advance investigations in several selected sites of most severe situation with respect to the pollution of bottom sediments.

These investigations in advance to the pilot project have been performed since 1979 in five sites in Japan. In each site, test works of removing, of earth covering and excavating of test trench were carried out, and the effects of these works have been followed up continuously.

II. SELECTED SITES OF THE PILOT PROJECT.

Five sites, that is, Tokyo Bay, Ise Bay, Osaka Bay, Hiroshima Bay and Suohnada Bay were selected for the pilot project as shown in Fig.-1. The area behind these sites is the most important zone for the economic activity of Japan called as the Pacific Belt Zony. More or less of sixty percents of the population and the industrial production in Japan distribute along this area. On the other hand progress of enviromental destruction is also severe in tgese area as the distribution of the area having the level of COD more than 30 ppm is shown in Fig.-1.

III. SUBJECTS AND ADMINISTRATION OF THE INVESTIGATION.

a). Test Work of Removing and Earth Covering of Sea Bottom.

As the possible means of cleaning-up of

Table-1. The pricipal items of the test work in each investigation site.

Site	Tokyo Bay	Ise Bay	Osaka Bay	Hiroshima Bay	Suohnada Bay
Tested method	Test dredging	Test dredging	Test dredging	Test earth covering	Test trench
Year of test work		Jul. 1980	A,B;Mar.1980 C-E;Aug.1980	A;Oct. 1979 B;Jul. 1980	Oct. 1981
Horizontal scale of test work	5m, 5m	100m, 100m	A, B, C, D, E; 40m, 40, 40m; 40m 40m40m	260m; 200m B; A; 200m 160m	20m; 120m; 100m; 40m
Vertical scale of test work		0.6 m	A;0.8m, D;0.8 B;1.0 E;1.2 C;0.4	A; 0.5 m B; 0.3	2.0 m
Natural depth at tha test site.		-13.8 m	-16 m	-21 m	-9.9 m

polluted bed sediments, three methods were selected such as removing of sediments by direct dredging, earth covering by fresh sediments and removing by dredging sediements trapped into trench excavated on sea bottom. Some of these methods were selected in each investigation site considering natural and social conditions of the site. Positions of these test works are shown by star marks in the Fig.-1, and the principal items of the test works are listed up in Table-1.

b). Subjects of the Investigations.

In addition to test works and follow up studies on effects of it in each site, the investigations cover wode items such as a basic study on the mechanism of bottom materials movement as well as the development of disposal method of dredged olluted materials as listed in Table-2.

c). The Organization for Operation of Test Works and for Administration of Investigation Work.

This investigation is performed through the administrative flow among the Ports and Harbours Bureau of Ministry of Transport, four Harbour Construction Bureau and the Port and Harbour Research Institute as shown in Fig.-2. Besides of these routine flow, a working group by members of these offices has been organized in order to exchange informations obtained in each site, to discuss common problems and to develope standard methods of observations and measurements. Moreover, committees by members of knowledge and experience are organized for every investigation site to discuss the plan and results of the investigations.

d). The Expenditure of the investigation works.

During five years since 1979, 2,880 millions yen (about 120 millions dollar) was expended for this investigation project as listed in Table -3.

Table-2. Items of the advance investigations.

* Execution of test removing and test earth covering.	* Studies on execution method of test works. * Studies on enviromental influences due to execution of test works, such as generating turbidity.
* Follow up studies on effects of test works.	* Follow up studies on the variation of the concentration of pollution index parameters in sediments, in void water and in water near the bottom. * Estimation of the rate of release of nutrient salts into water from bottom sediments in field and laboratory. * Follow-up studies on the variation of the number s and kinds of benthos and bacteria.
* Investigations on the durability of effects of test works.	* Estimation of the rate of accumulation of newly deposits. * Estimation of the rate of transport of suspended sludge. * Estimation of the rate of release of nutrient salts into sea water from newly deposits.
* Development of the estimation method of feasibility of the project on cleaning-up bottom sediments.	* Development of a numerical simulation model including chemical and biological variation of pollutants. * Studies on the value of coefficients in the above mentioned model.
* Investigations on incidental problems for execution of the project.	* Development of the disposal method of dredged polluted sediments. * Development of the method of assessment on environmental influences due to operation of the project such as generation and diffusion of turbidity.

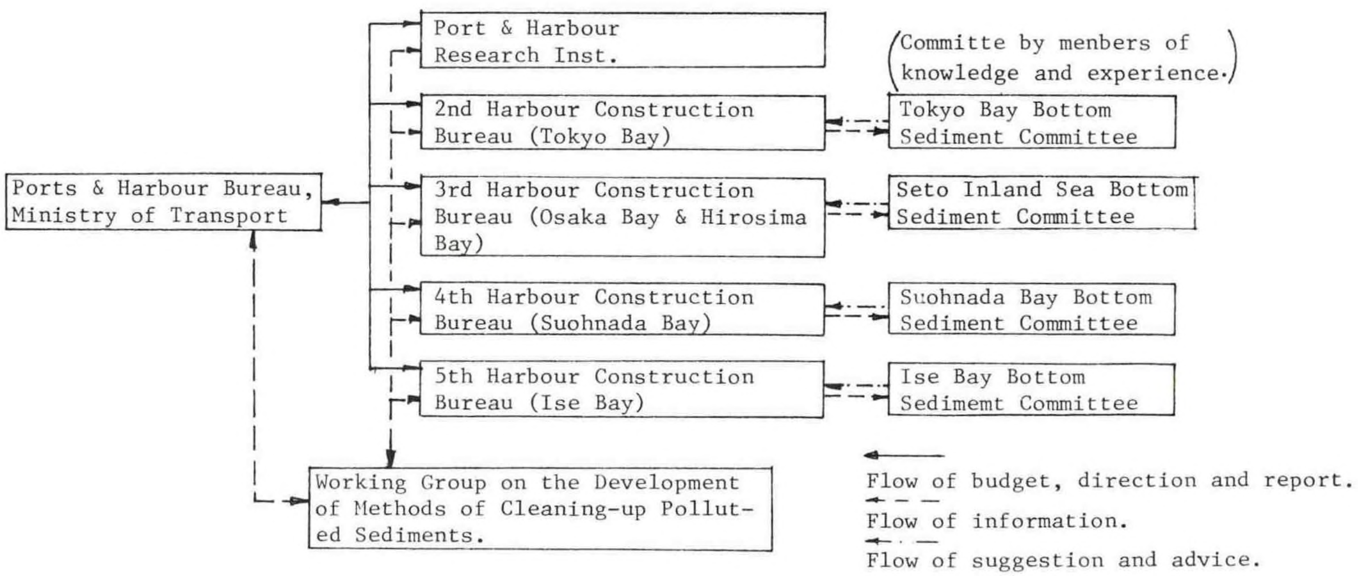

Fig.-2 The organization for the advance investigation for the pilot project on cleaning-up bay bottom sediments.

Table-3 Trends of the Expenditure of the investigations works in advance to the pilot project on cleaning up polluted sea bottom sediments.

Site	1979	1980	1981	1982	1983	Total
Tokyo Bay			50	110	105	265
Ise Bay		100	100	110	115	425
Osaka Bay	150	150	170	185	180	835
Hiroshima Bay	150	200	200	145	125	820
Suohnada Bay		50	150	155	180	535
Total	300	500	670	705	705	2,880

unit: million yen

TECHNOLOGY NEEDED FOR SAFE DISPOSAL
OF RADIOACTIVE WASTES IN THE OCEAN

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ABSTRACT

Future technological activities and improvements to be emphasized include a series of in situ experiments at depths greater than 4000 meters. The experiments include in situ heat transfer experiment (ISHTE), radiation regime study, & deep-sea species metabolic activity. The experiments should be coupled with information-processing technology. Concomitant development of a deep ocean vehicle to the depth of 6000 meters is needed to service these experiments.

INTRODUCTION

Recently we have edited a book entitled Radioactive Wastes and the Ocean with Bostwick H. Ketchum (1912-1982)[1]. During this process we have become keenly aware of the need to develop adequate ocean technology that will insure safe disposal of radioactive wastes at sea. In the United States the land disposal option is receiving greater attention; the oceanic disposal option is considered as an alternative to land disposal. However, we believe that successful waste management must include continuing evaluation of disposal alternatives if existing disposal methods encounter environmental or technical limitations.

In 1973 William P. Bishop of the U.S. Sandia National Laboratories and Charles D. Hollister of the Woods Hole Oceanographic Institution conceived the idea of subseabed disposal of high-level radioactive wastes[2]. At present the U.S. Subseabed Disposal Program (SDP), supported by the U.S. Departmentof Energy (DOE), is forging ahead to assess and develop the technical feasibility of engineered emplacement of high-level wastes within the deep-sea sediments[3]. The SDP has four phases:

1. Estimation of technical and environmental feasibility (completed 1976).
2. Determination of technical and environmental feasibility from newly obtained oceanographic and ecological data.
3. Determination of engineering feasiblity.
4. Demonstration of disposal capability.

Concurrently, the U.S. National Oceanic and Atmospheric Adminstration (NOAA) assessed technologies applicable to monitoring radioactive waste disposal on or in the deep seabed[4,5]. In addition, the U.S. Environmental Protection Agency (EPA) has been determining the fate of low-level radioactive wastes dumped in the past[6]. In this report we describe the engineering development activity of the SDP and the EPA.

THE SDP ACTIVITY

We have been impressed very much by the thoroughness of the SDP. Rather than studying the waste management problems in a descriptive manner, the SDP begins each phase of investigation with a postulate, a supposition without proof. It is followed by development of a mathematical model, prediction based on the model, and finally field verification [3].

During phase 3 of the SDP, the engineering feasibility of subseabed disposal will be determined. Included is the initiation of a long-term (15-year) in situ heat transfer experiment (ISHTE), now scheduled to commence in 1986. Already a modelling and laboratory experimental study has been carried out using a waste canister having an initial power of 1.5 kW and resulting in 200 to 250 ^{o}C [7]. This study has yielded several important results. Among them are:

1. The high temperature region in the sediment of over 100 ^{o}C surrounding the waste canister is limited to 0.8m radius X 3.6m long for up to 35 years.

2. Total fluid displacement due to the convective velocity is about 3% at a burial depth of 30 m.
3. Hydrothermal alteration of the sediment yields a hot, acidic, oxidizing environment around the waste canister.
4. Fission products, such as ^{137}Cs and ^{90}Sr, will decay in the sediment with no release.
5. Long-life radionuclides, such as ^{239}Pu, have almost negligible release rates from the sediment.
6. Nuclides that migrate as anions, such as ^{129}I and ^{99}Tc, will take several thousand years to diffuse through a 30-m sediment layer.

Other SDP engineering developments include:

1. Development and demonstration of various emplacement methods that include penetrometer, injector, trench, and drill.
2. Development of a transportation system to move suitably packaged wastes or spent fuel from the originating plant to the dock facility and to the dumpsite.

THE EPA CANISTER RETRIEVAL STUDY

One of the major products of the EPA program is a comprehensive study of a radioactive waste package retrieved from the U.S. Atlantic 2800-m dumpsite [8,9]. On 31 July 1976 a 300-liter radioactive waste drum was retrieved from a dumpsite centered at 38° 30'N, 72° 06'W. At Brookhaven National Laboratory the drum was subjected to container corrosion, matrix leach rate, and matrix degradation studies. The drum was made of mild (carbon) steel with 0.121-cm thickness; it was manufactured in June 1959. The radioactive package was disposed in 1961, therefore, 15 years had elapsed when it was retrieved. Although from only a single drum, several findings reported include:

1. Little dissolution of the concrete waste form occurred; a conservative estimate is a maximum of 0.3% annually.
2. The measured compression strength of the concrete is in the range expected for comparable concrete formations, indicating the absence of appreciable sulfate attack.
3. Corrosion rates for general attack on the upper portion of the steel drum, assuming a constant rate with no induction period, were 0.032 to 0.049-mm per year. Therefore, the mild steel drum would require 25 to 37 years before integrity loss due to corrosion occurs.

FUTURE PERSPECTIVE

In concert with scientific researches, concomitant development of essential equipment and instrumentation must continue. Triplett and his coworkers prepared a comprehensive report on the need of engineering development of radioactive waste disposal [4]. Bishop and Tyce made an assessment of available engineering and technology capability[5]. They recommend that we expand the application of ocean technology to meet the distinctive needs of deep-sea marine biologists. The needs include: acoustic systems for remote sensing of bio-population sizes and for tracking individual organisms; pressure and temperature retaining traps to collect deep-sea fauna; and *in situ* measurement devices of deep-sea species metabolic activity. A prevailing theme throughout the recommendations of Triplett and his coworkers is the increasing use of *in situ* analysis methods which are integrated with information-processing technology. They advocate the development of an automated seafloor monitoring system [4]. We quote:

> "While much of the technology is available now, we recommend significant improvements in several key areas: A deep ocean (greater than 4000m capability) vehicle to service and monitor in-situ experiments; in-situ gamma radiation detector system for use from manned or remotely operated vehicles; surficial sediment sampling systems that retain only the surficial materials of the first few centimeters of sediment for radionuclide distribution and analysis; seafloor current and sediment resuspension measurement systems capable of autonomous operation for periods of 1 to 5 years; current meters for both vertical and horizontal currents capable of 1 to 5 years operation; sensors for detection of changes in sediment physical and chemical properties, including pore pressure, gas formation and conductivity; and improved sensors to detect and measure ocean floor seismic activity for long periods of time."

We also need to determine the radiation regime of the deep sea *in situ*.

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LARGE-SCALE TEST FOR DEVELOPMENT OF PORT AND HARBOUR TECHNOLOGY

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ABSTRACT

The high utilization of sea space in Japan will be stepped up in the future. Under these circumstances, large-scale development of technology, notable port and harbour technology, is being actively conducted under the leadership of the Bureau of Ports and Harbours, Ministry of Transport, with the object of estabilishing the technology of marine civil engineering. In applying development results to work projects, large-scale test using full-size or near full-size models are carried out insofar as possible to fully confirm the safety and reliability of technology in advance.
This article summarily describes three cases representative of the large-scale test projects that are now in progress.

NECESSITY

(1) Establishing the technology of marine civil engineering is very much in demand as supporting technology necessary to advance exploitation of the sea into the 21st century. Particularly, technology to which port and harbour technology are central must be vigorously developed to accelerate the efficient utilization of sea space reaching scores of meters underwater.

The Bureau of Ports and Harbours, is keeping with this situation, is proceeding with technical development, spending nearly six billion yen each year, to solve the following major issues of technical development:

a. Development of technology for the efficient use of sea space.
b. Development of technology for constructing marine structures. (Ex. Offshore ports, offshore airports, etc.)
c. Development of technology concerning the assurance of safety in using coastal space.
d. Development of technology concerning the protection and the creation of coastal environments.

Technology unique to Japan and in accord with Japanese conditions are being developed on a long-term and comprehesive basis and efficiently while coordinating with the Port and Harbour Research Insititute, the District Port Construction Bureaus, etc.

(2) The larger of these projects require drastic technical development since methods developed as more extension to existing technology involve many problems. So, in applying results of development to execution of projects, it is necessary to make demonstrative tests using full-size or near full-size models and thereby thoroughly confirm the safety and reliability of methods in advance.

This large-scale technical development can produce great achievements but private companies can hardly tackle it because of the wide range of technology concerned and the high development risks due to the large scale of development. That is why it is being actively conducted under the leadership of the Government.

PRESENT TRENDS

The large-scale test projects that are now being executed by the Bureau of Ports and Harbours are as listed in Table 1. Of these, three: a) - b) are outlined in this article.

FIELD TEST ON NEW TYPE CAISSON BREAKWATER

(1) Purpose of test: i) To confirm the execution capacity of a fairly practical breakwater of a new type structure (the caisson composite breakwater) by actually constructing a prototype so as to cope with increase of water depth and the increase of wave height at the site of construction. Also,ii) to confirm its safety and functions under real wave condition. Further, iii) to investigate its effects on the properties of water and the biological environments in the vicinity of the structure.

(2) Place of test: About 1 km off Funakawa Port in the Akita Bay. Water depth approx. -11 m. (Geology: soft rock.)

(3) Details of test

a) As the shapes of caissons for the test breakwater, four types, namely, three types selected in hydraulic model experiment etc. as being not only suitable for the satisfactory outer-sea ground but also practical and a conventional type serving for comparison were used. (See Table 2)

b) Layout of Test breakwaters: See Fig. 1.

Table 1. The large-scale test projects executed by the government

Subject	Project	Budget (x100 million yen)	Period of development	Place Port (Prefecture)
Construction in deep water and high wave	a. Field test on new type caisson breakwater	6	1979 - 83	Funakawa (Akita)
	b. Field test to measure bearing capacity of rubble mound			
	i) allowable bearing capacity	4	1980 - 83	Onahana (Hukushima)
	ii) uneven rubble mound	5	1982 - 85	"
	c. Field test on development of floating breakwater	5	1977 - 83	Kumamoto-shin (Kumamoto)
Improvement of soft ground	d. Field test on construction of improved ground			
	i) by deep mixing method using lime or cement	9	1981 - 82	Sakai-Senboku (Osaka)
	ii) by sand compaction pile method	3	1982 - 83	Maizuru (Kyoto)
Construction method and working craft	e. Model test on development of red tide recovering vessel	2	1978 - 83	Seto Inland Sea
	f. Test on development for improving technology to construct the rubble mound	13	1980 - 85	Kamaishi (Iwate) etc.
	g. Model test on development of vessel to remove structure in the sea	2	1980 - 81	Tokyo bay
Investigation	h. Test on development of shore investigation technology used the piled pier	5	1981 - (10 years)	Kashima (Ibaragi)

c) Method of measurement: A system where basically measurement and recording are made by measuring instruments installed on the breakwater and some data are transmitted by radio to measuring instruments installed ashore is used to demonstrate the design method and assess the behavior.

The items of measurement include waves, wave pressure, member stress caused to reinforcing bars in caissons, structure motion, toe pressure and mound shape. For this purpose, the breakwater is provided with a total of 183 measuring instruments.

(4) Present conditions

a) Measured data are now being obtained but data for cases with large wave height are rather scarce. The largest of incoming waves ever is $H1/3 = 3.5$ m and $T1/3 = 7.6$ sec (October 25, 1982).

b) Facts including the distribution of wave pressures working on test caissons and the distribution of stress of reinforcing bars have been grasped.

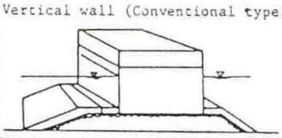
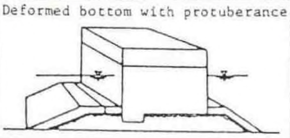
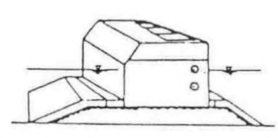
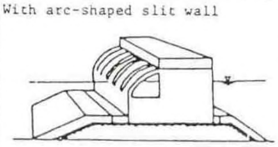
c) It has been found that the measured values of external force fairly well agree with its theoretical values.

(5) Future schedule

a) Measurement will be continued through fiscal year 1983. Also, the details of data already obtained will be hurriedly analyzed and the measuring instruments will be checked for operation.

b) In fiscal year 1984, the test breakwater will be removed and data will be consolidated as a whole.

Table 2. The shape and characteristic of test caisson

Mark	Caisson type & Sketch	Characteristic
T-1	Vertical wall (Conventional type) 	Standard caisson composite breakwater. Provided for comparison with the other types. This contains an observation room.
T-2	Deformed bottom with protuberance 	The caisson bottom has protuberance to increase slide resistance. This makes reduction of the section possible and helps to cut construction cost. It can be applied to types T-3 and T-4.
T-3	Front: Slope wall at top Rear : With porous retarding part 	The wave force that works is reduced by the effect of the slope wall at the top; thereby, the section is reduced and the reflected waves are also reduced. The porous retarding part alleviates harbour disturbance due to wave overtopping and dissipates waves on the harbour side. Further, it expedites the aeration of sea water and provides a breeding place for seaweeds and shellfish and the action of these organisms is believed to help maintain water envrionments.
T-4	With arc-shaped slit wall 	Both the wave force and the reflected waves are reduced by the effect of the arc-shaped slits. These slits can also check transmitted waves in the harbour. Furthermore, these slits are believed to help maintain water environments by a similar action to T-3.

(5) Future schedule

a) By the end of fiscal year 1983, the 3rd test will be carried out to i) confirm the limit bearing capacity of the rubble mound and observe the phenomenon of attaining high density, ii) observe the phenomenon of shear destruction of the mound and the foundation ground system and iii) compare materials composing the mound.
Thus, comprehensive analysis will be carried out, using the results of this test along with the results of past tests.

b) Preparations are being made to conduct a field test on two cases with utmost uneven rubble mound in fiscal year 1985.

FIELD TEST ON DEVELOPMENT OF FLOATING BREAKWATER

(1) Purpose of test: Complicated technical problems remain to be solved to be able to use floating structures as port facilities capable of meeting such conditions as soft ground, large tidal level difference and great water depth.
This test is concerned with the floating breakwater and its purpose is to elucidate its wave dissipating effect, its mooring capacity and other factors as well as problems in work performance.

(2) Place of test: approx. 5 km off Kumamoto-shin port, water depth: approx. -8 m
(Geology: Clayey soil (0 ~ -40 cm), tidal level difference: 4.5 m, design wave: H1/3 = 2.1 m, T1/3 = 5.5 sec, Hmax = 3.8 m, tidal current: 1.3 m/s)

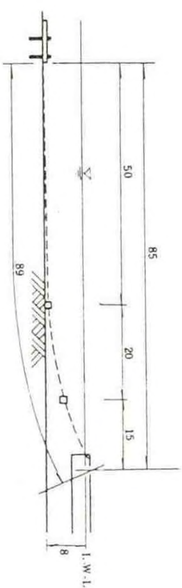
(3) Details of test

a) The floating part of the breakwater was made of prestressed concrete by the side-float structure. It was manufactured by the method of joining four RC precast block caissons with PC steel lines in the direction of face line.

Data
i) Main body: 10.0m(Width)x40.0m(Length)x 4.0m(Height)
Weight: 907.6t Draft: 3.06m
ii) Sinker: 9.5m(W)x10.0m(L)x1.0m(thickness) Weight: 222.4t 350mm H-shape steel 5.0m(L)x21pcs
iii) Intermediate sinker: 1.74m(W)x1.75m(L) x1.75m(H) Weight: 9.1t (Weight in water: 5.1t)
iv) Chain: NK Type No.3 with stud 76 φ About 89m

b) Measurement was made after installing the floating breakwater at the field site as indicated in Fig. 3. The items of measurement included wave height (incident wave and transmitted wave), wave pressure, tidal level and current, wind direction and velocity, oscillation of floating body, member stress and chain tension, etc.

(4) Present conditions and future schedule: Measurement was started in November 1982 and various data are still being collected. In the past analysis, the wave dissipating effect is unexpectedly high.
If circumstances permit, measurement will be continued and measured data will be consolidated and analyzed in the future, as hitherto.



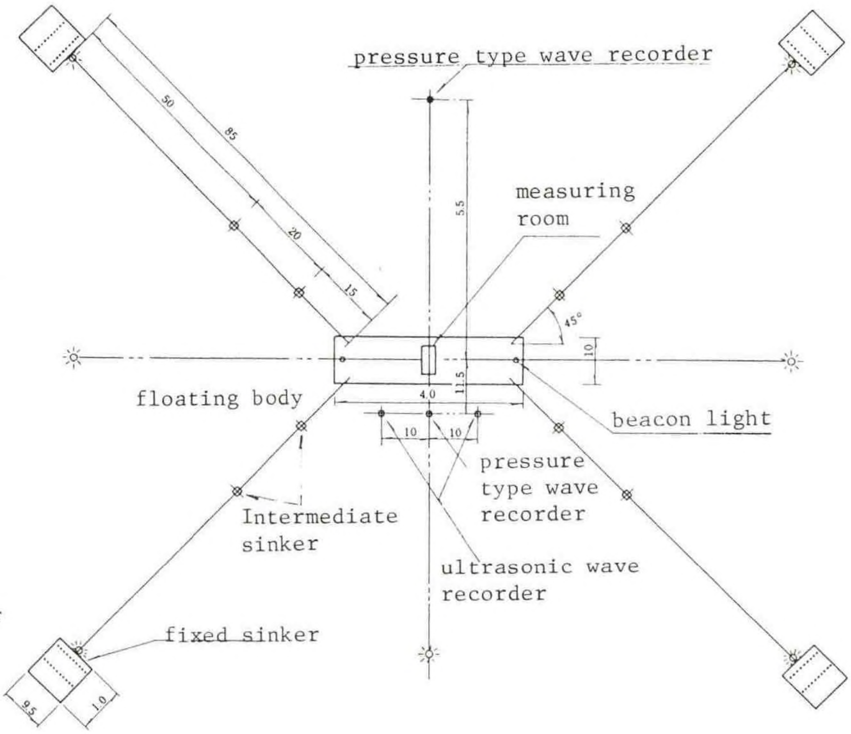


Fig.3 Layout of floating breakwater at the field site

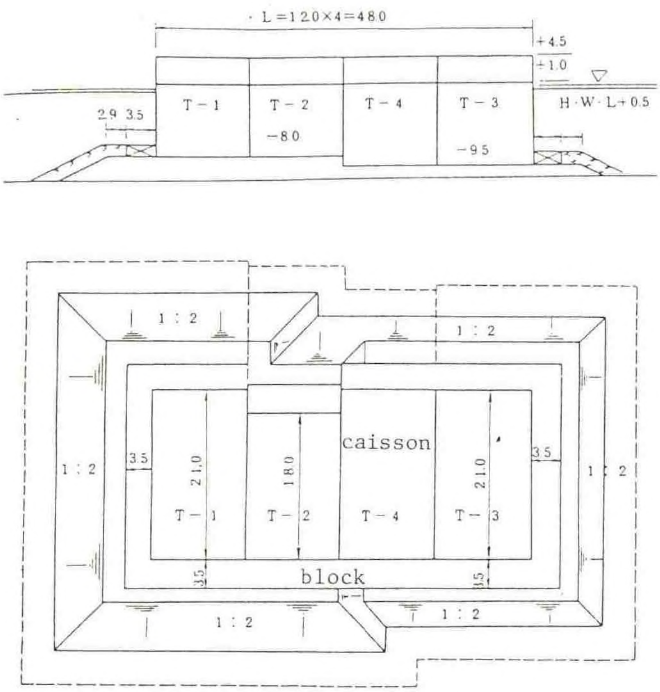


Fig.1 Layout of test breakwaters

FIELD TEST TO MEASURE BEARING CAPACITY OF RUBBLE MOUND

(1) Purpose of test: With the increase of the water depth at which breakwaters are provided, the caisson section is often determined by the restriction of the allowable bearing capacity of the rubble mound (currently 50 t/m2). This value is based on experience and has hardly any theoretical ground. From the study of damage examples, on existing breakwaters, greater bearing capacity probably can be expected.

The purpose of this test is to investigate mound bearing capacity and caisson bottom reaction in field tests and thereby contribute to the design of deepwater caisson breakwaters.

(2) Place of test: Harbour side of breakwater (existing) off Onahama Port

(3) Details of test (See Fig. 2)

a) A mound is constructed on the harbour side of the existing breakwater (a water depth of -16.5 m), test caissons are installed there and using an existing caisson as reaction, lateral load of up to 3,200 t is exerted by means of 16 oil jacks and thereby a great toe pressure is exerted at the caisson bottom. (Target exerted toe pressure: 150 t/m2).

b) The exerted toe pressure is determined by calculation after measuring reinforcing bar stress in the bottom slab of the caisson.

c) The bearing capacity of the mound is determined by compositely analyzing from the exerted toe pressure and the measured values of caisson subsidence and displacement, inclination, jack load, reinforcing bar stress, etc.

d) The test is repeated three times with varied top of slope width. (1st (March 1982): 10 m, 2nd (February 1983): 25 m, 3rd (FY 1983) : Not yet decided.)

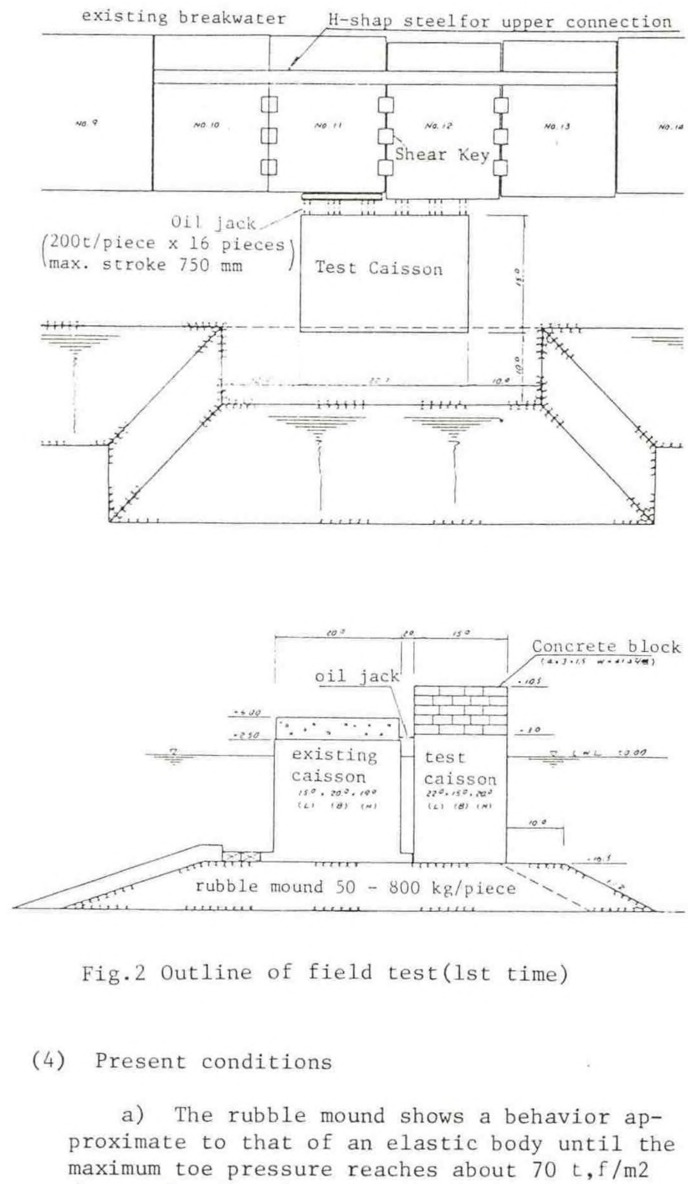


Fig.2 Outline of field test(1st time)

(4) Present conditions

a) The rubble mound shows a behavior approximate to that of an elastic body until the maximum toe pressure reaches about 70 t,f/m2 (assumed triangular distribution). It has been further disclosed that if the load exceeds this level, the displacement suddenly increases and that most of it remains even after unloading.

b) At least 100t,f/m2 or more probably can be expected as calculated maximum toe pressure. Since, however, the displacement is unexpectedly great, in studying allowable bearing capacity it will be necessary to consider the allowable range of displacement, too.

JAPANESE OCEAN POLICY IN AN ERA OF REGIME CHANGE

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ABSTRACT

Japan had a difficult time adapting to ocean regime change that has been occurring through the 20th century, culminating in UNCLOS III. After following an "Except One" policy, Japan was forced to accommodate to enclosure by enacting extended territorial seas and a 200-mile Economic Zone. A study was done by a binational team on Japan's ocean policy. This paper reviews some attributes of Japanese decision style and the nature of ocean policy of developed states, and assesses the successes and failures of Japanese ocean policy regarding UNCLOS, ODC, decision-making in ocean science and technology, fishing, shipbuilding, manganese nodule policy, offshore oil and gas jurisdiction, and coastal management and nuclear power.

Introduction

Through much of the 20th century we have witnessed the undermining of the conceptual framework -- freedom of the sea -- by which man has governed his seagoing activities. The Third United Nations Law of the Sea Conference Treaty, with its 200-mile economic zone and other sets of expanded coastal states rights, advanced world ocean enclosure -- a notion which is opposite to freedom of the seas, but which did not replace it completely. Thus, at present we may still be in transition. At any rate, we now have a "mixed" system.

Among the major ocean-using developed states, Japan had the most difficulty initially in adapting to the changes required to move to the new regime. However, some of the eventual adaptive mechanisms were both appropriate and creative. Thus, Japan's experience became an interesting case for the study of regime change with potentially important lessons for both developed and developing ocean-using states. I led a research team that examined both overall Japanese ocean policy and policy-making as well as its key sectors. The binational research team included Professor G.O. Totten, III (University of Southern California), H. Fukui (University of California, Santa Barbara), T. Akaha (Bowling Green University, Ohio), M. Takeyama (Chuo University), M. Koga (Aichi University of the Arts), and H. Nakahara (Research Institute for Ocean Economics, Tokyo). This report is a summary of the major findings concerning the nature of regime change, the attributes Japanese decision-makers bring to ocean policy, national ocean policy as a phenomenon, and how well Japan has done in restructuring her policy.

Japan and an Ocean Conceptual Framework

Conceptual frameworks are important for public policy because they are used as the general guidelines to orient decision-makers to the parameters of the world in which they operate. They help create legitimacy and certainty. The attack upon, crumbling, transition, and reformation of a new conceptual framework is a major set of events in public affairs.

Through much of the 20th century we have witnessed the assault upon freedom of the seas as the conceptual notion that guided ocean policy-makers in day-to-day implementation of ocean policy. It was a result of changing technology allowing access to ocean areas and resources never before accessible, and of increased pollution, and was accelerated by the concerns of the many newly independent developing states that have radically transformed the international system since 1955. The major manifestation of this assault was national enclosure of ocean space, perhaps as much as 42% of the ocean through the enlargement of territorial seas and economic zones (200 nautical miles) in some cases out to 350 nautical miles. These have resulted in restrictions on distant-water states of the right to fish, search for oil and gas or minerals, and conduct scientific investigations. However, in UNCLOS III, the clashing forces did not move in a consistent direction. Indeed, some rights under freedom of the sea were strengthened, such as rights of transit through international straits or through archipelagos. The confusion was compounded when the potential mineral resources of the deep ocean were "internationalized" rather

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High steam velocity significantly decreases the required demister cross sectional area which, in turn, impacts the total plant area and cost.

Several analytical models of the mist lift process were developed. Two steady-state computer algorithms calculated the maximum achievable lift height for various drop sizes, flashdown temperatures and warm seawater inlet mass flow rates. Including provisions for droplet coalescence and breakup reduced the predicted maximum lift height, but the degradation was better than predicted by models which only account for droplet coalescence. A maximum droplet size of about 0.5 mm was predicted and "rainout" of large droplets was not a major problem. A transient model was developed to examine the stability of the process when evaporator and condenser conditions change with time. Results indicated the lift process is stable when operated within reasonable bounds.

Several small scale test columns were constructed to investigate the two-phase flow of OTEC mist and foam lift cycles. Results were obtained from a 3.7 mm high mist lift experiment which examined the effects of fluid injection velocity and vapor-fluid slip, and led to expansion of the test program to include tests using seawater. Plans for further tests, including a larger lift tube and various liquid injector geometries, are being formulated.

CLOSED-CYCLE POWER SYSTEMS DEVELOPMENT PROGRAM ELEMENT

The Closed-Cycle Power Systems Development Program was instituted in response to a need to develop low-temperature difference heat exchangers. The performance of these components and associated biofouling and corrosion are the major areas of investigations.

The heat exchanger effort has used two facilities to test advanced designs and configurations. A laboratory test facility was constructed at Argonne National Laboratory and has been used to obtain performance data on 13 heat exchangers provided by industrial and university designers. The 25KWe facility has separate loops for warm water, cold water, and the working fluid.

The OTEC-1 was a converted T2 tanker and was designed to test heat exchangers for 1MWe plants under actual ocean conditions. Plain and enhanced evaporator tubes as well as plain condenser tubes in a 1MWe shell and tube configuration were tested. While the plain-tube bundle evaporator performed as predicted under static conditions, the enhanced-tube bundle evaporator did not. This was apparently due to fouling of the high flux surface. Performance of the condenser tested was in agreement with predictions based on single-component (water) flow in the tubes. The evaporator, configured to represent one quadrant of a 4 MWe unit, functioned without excessive droplet entrainment on the interface with the ammonia spray feed. Additionally, evaporator tubes enhanced with a High Flux (nucleation-promoting) surface performed poorly, thus demonstrating the vulnerability of this coating in an open ocean environment. The motion of the ship did not affect the performance of the heat exchangers. Liberation of dissolved gases in the cold water did not affect condenser performance.

The results from the heat exchanger testing effort have been significant. Heat exchanger performance has been improved by a factor of 2.5:1 for both evaporators and condensers over SOA plain tube designs. Because contamination of ammonia by water in excess of about 0.1% results in an appreciable degradation of performance, ammonia purification systems are now included in OTEC plant designs. Additionally, it has been shown that the performance of plate-frame evaporators designed originally for liquid-to-liquid service can be improved by a factor of 2 with the addition of nucleation enhancement to the ammonia side aiding in the boiling heat transfer process. Finally, brazed aluminum plate-fin exchangers offer a powerful combination of high performance and low initial cost. At the initiation of the test program, it was projected that heat exchangers would contribute half the cost of an OTEC plant. Current cost estimates are projected to account for 30% of the total plant cost.

As seawater flows through an OTEC heat exchanger, the heat transfer surfaces are fouled by the gradual deposition and growth of colonies of micro-organisms. Uncontrolled biofouling leads to degradation of the heat exchangers' performance and eventual plant shutdown. Furthermore, seawater created corrosion limits component life.

Over the last three years, the program has conducted biofouling and corrosion experiments at: Wrightsville Beach Test Facility (near shore); Punta Tuna, Puerto Rico, Open-Ocean Test Facility; and the Hawaiian Seacoast Test Facility (STF). As part of the research effort, Carnegie-Mellon University (CMU) developed a heat-transfer monitor for circular channels which was later modified for noncircular channels, including those with enhanced heat-transfer promoters on the surfaces. It allows accurate, on-line measurements of the biofouling buildup on heat exchangers. The rate of corrosion of heat exchanger materials is measured using sample units installed in the flow system. The rate of biofouling was found to be comparable for titanium and aluminum surfaces. Biofouling is negligible in the deep, cold seawater environment.

Biofouling buildup can be controlled for several months using brushes, sponge balls or chlorination. Intermittent chlorination (0.05 ppm for 1 hr/day) can keep titanium heat exchanger surfaces sufficiently clean for at least one year. In addition, chlorination can be used to clean already-fouled surfaces. In studies on corrosion and biofouling of aluminum alloy surfaces three basic types of aluminum were tested: a 3004 alloy, with and without cladding containing zinc, a zinc-coated 3003 alloy, and a 3003 Alclad alloy. Intermittent chlorination is less effective for preventing biofouling on 3003 Alclad than on titanium for near shore water, but equally effective for open ocean water. The rate of corrosion is sensitive to the frequency and intensity of brush or Amertap ball cleaning. While the initial rate of corrosion for the aluminum surface is high, the assumption value is low. The corrosion rate for zinc-coated surfaces was found to be comparable to that of Alclad surfaces.

The Seacoast Test Facility at Keahole Point, Hawaii, has been in operation since June 1981. It is the first permanent land-based OTEC facility built for conducting biofouling, corrosion, biocontrol and other related tests. There are several objectives that the program hopes to achieve at STF during these tests. They include efforts to: (1) develop coating and cladding for aluminum to extend its service life to 25-30 years, (2) develop biofouling control methods for waterside enhanced heat exchanger surfaces and for compact heat exchangers, (3) determine the minimum chlorination required to keep the biofouling resistance below 0.0001 hr-ft^2-°F/Btu (which would represent a heat transfer degradation of about 10% in a high performance heat exchanger), and (4) evaluate alternatives to chlorination as a biofouling control method. Initial experiments used warm surface water, but more recently the first notable cold water data base has begun to emerge. The present seawater supply systems are temporary and plans for conversion to a more permanent supply are being developed.

Enhanced heat transfer in the cold water heat exchanger on the seawater side through application of ceramics and water mist flow could reduce plant costs by another 10% but needs to be experimentally verified. Increases in the life expectancy (corrosion, fouling, structural integrity, materials) of low-cost heat exchangers would also have a dramatic cost impact.

ALTERNATIVE ENERGY SYSTEMS DEVELOPMENT PROGRAM ELEMENT

The alternative energy systems development has centered on plantships and energy intensive products. OTEC plantships would cruise through tropical waters using the thermal gradient to run a heat engine, produce electricity, and synthesize energy-intensive products such as ammonia, hydrogen or methanol. The baseline design for a pilot plantship was completed in FY 78 for a 10-20MWe sized ship and modified in FY 80 to provide for operation in either a cruising or moored plant mode. This design alteration allowed for an increase in the net power capacity from 20MWe to 40MWe. Scale-model tests were conducted to verify the design parameters of the 40MWe plantship components and overall design. The results were matched against computer models of the designs and a 1/30 scale model built and tested.

Since mobility is the major feature of the plantship design, a technique for distribution of power other than electrical cable-to-shore is required. One approach is the on board production of energy intensive materials such as liquid hydrogen, ammonia, and methanol, or solid aluminum and lithium. Ammonia and methanol were the main products of investigation.

Ammonia is a synthetic fuel that can be readily produced at sea on cruising OTEC plantships, utilizing hydrogen from seawater and nitrogen from the air. Hydrogen is freed from the seawater through distillation, deionization, and electrolysis. Ammonia can be used either in fuel cells or as a fuel for other engines. An investigation was performed to determine the feasibility of ammonia OTEC production and its economic feasibility. Results indicated that ammonia may become a viable OTEC commercial product, but is not competitive with ammonia made from natural gas today.

Production of OTEC methanol involves the transport of coal to the plantship. Combustion of the coal on the plantship with electrolytic oxygen then forms carbon monoxide (CO). Finally, a reaction of the CO with electrolytic hydrogen on the plantship forms methanol. Early studies based on liquid CO_2 as the carbon source indicated that the production of methanol on an OTEC plantship by combining CO_2 with the H_2 and O_2 from the electrolyzers, would be more costly than ammonia. However, by using coal as the carbon source, the plant can produce 2 1/2 times as much methanol as ammonia at equal OTEC power capacity. Another advantage of methanol is its compatibility with existing fuel storage and handling systems.

An appraisal of the physical requirements, sizes, and constraints for an OTEC methanol-from-coal plantship was addressed. This resulted in a conceptual design of an OTEC 160MWe plantship producing 1000 metric tons/day of fuel grade methanol. Preliminary analysis indicated that methanol from such a plantship would be marginally competitive with methanol from other sources. The design was based on a Texaco gasifier design using a coal slurry fuel. Several inhibiting features of this process are the presence of excess CO_2, H_2S production and large quantities of waste water. A study made, utilizing the Rockwell Molten Carbonate gasifier design which produces a gas relatively free from CO_2 and H_2S, indicated this gasifier would produce methanol that is economically competitive. The use of coal slurry requires expensive land based water treatment, as well as coal slurry preparation and loading facilities.

ENVIRONMENTAL RESEARCH PROGRAM ELEMENT

The net environmental impacts resulting from OTEC development are expected to be minimal compared to the impacts of fossil fuel and nuclear power production. OTEC development on a commercial basis also can be acceptable if proper attention is paid to design. During FY 80-83, the OTEC Environmental Program has provided baseline information during the exploratory design phases for deep-water closed-cycle OTEC systems to ensure that such designs are survivable and environmentally sound.

In FY 80 the major effort was in field measurements and environmental compliance assessment. In FY 81 the program emphasized the integration of the various test and field studies to ensure uniformity in the data base and completion of the benchmark studies while cooperating with the OTEC-1 tests and insuring permit compliance. During FY 82, efforts were directed towards data analysis, completion of the OTEC-1 benchmark reports and preparation for the marine research and compliance activities associated with the OTEC Pilot Plant. In FY 83, the focus was in support of the Pilot Plant activities including participation in and analysis of the State of Hawaii Common Base Program, and maintenance of the permit compliance schedules. Research activities were limited to the evaluation of bottom assessment strategies and updating an existing computer flow model.

The shift in program emphasis from off-shore deep-water moored to near-shore shallow-water bottom-seated plants with long bottom mounted cold water pipes requires new consideration of near-shore and along the bottom environmental design concerns. This suggests more emphasis on marine geology than water column oceanography. Slumping, due to the passage of Hurricane Iwa, along the proposed pipe line route of the Pilot Plant off Kahe Point highlighted the lack of knowledge of the impacts of extreme events in deep water In general, further research is required to validate coastal flow models and to determine the scope of chronic and acute toxicity to ambient populations of ammonia, chlorine, and trace metals.

OCEAN ENGINEERING PROGRAM ELEMENT

The Ocean Engineering activities address cold water pipes (CWP), Sea-water Systems (SWS), Moorings/Foundations and Platforms.

The CWP is a major component of all OTEC systems. It has been by far the most difficult engineering challenge addressed by the program because of its unique characteristics, which primarily stem from its size. Typically, 40MWe land-based or shelf-mounted baseline designs require a CWP on the order of 10,000 feet in length and 30 feet in diameter. These dimensions for an underwater structure are unprecedented, and industrial experience in the required fabrication, deployment, installation, inspection, maintenance and repair techniques is lacking. Thus, an extensive research and engineering effort has been pursued in cold water pipes.

In FY 80, the program focused on developing baseline designs and computer model codes for defining and evaluating physical stresses on the CWP. Further development and model testing validated these codes. Numerous CWP concepts were evaluated. Of these concepts, six were selected to enter a baseline design phase. One design, the Fiber-Reinforced Plastic (FRP) sandwich, exhibited the greatest potential for long-term system life expectancy and economic viability. This potential is due to its high strength-to-weight ratio, flexibility, resistance to electrochemical interaction, relative low cost, and ease of deployment. Subsequent work concentrated on FRP materials for cold water pipes.

The basic FRP design is a monolithic cylindrical structure with a sandwich wall composed of two equal thicknesses of FRP laminate material separated by a syntactic foam core. Materials testing efforts were performed on the FRP design to provide engineering data on static and fatigue performance.

Several modeling activities were undertaken to analytically predict the environmental loading and subsequent stresses acting on the CWP. A three-dimensional design methodology was developed around a computer-aided analytical model which provides a time-domain dynamic simulation of the coupled CWP response to hydrodynamic loading of the CWP/Platform/Mooring systems caused by waves and currents. The output of this model is a statistical summary which predicts the interaction of a variety of forces including: CWP/platform motions, hydrodynamic forces, pipe loads and internal pipe stresses.

As part of the validation process, a CWP at-sea model test was performed off the coast of Catalina Island. The model was 1 foot in diameter, 70 feet long and constructed of polyvinyl chloride. Five axial stations along the pipe held instrumentation that measured the structural effects of waves and currents. The CWP was suspended from a 1/30th scale OTEC barge platform and was analyzed in grazing and moored moes. This at-sea test and subsequent analysis supplied insight to the relationship between vortex shedding and CWP structural response. A small-scale CWP tow-out and deployment project model test was performed to validate analytical methods for calculating CWP response during deployment operations. This test utilized numerous scaled CWP models. The maximum size of the models was 1:50 scale for a 30-foot diameter prototype CWP, and ranged to 1:110 scale for turning and swing-down tests. Upon investigating tow stability, resistance, heading limitations, maneuverability, and swing-down loads in afloat, awash and submerged modes, the study concluded horizontal tow-out and swing-down was technically feasible. However, loads experienced during the tow-out procedure, caused by waves and currents directed at high angles, were critical. Improved transportation loads analysis techniques will be required to increase design confidence.

The culmination of these efforts is a three-phased FRP Scaled CWP At-Sea Test Program. The objective is to design, fabricate and test a scaleable FRP CWP in suspended and slope-mounted configurations. The planning and design stage of the project included overall design, analysis of static dynamic loads, laminate design, materials test, determination of environmental loading parameters, mooring and deployment procedures definition, and instrumentation requirements. Upon completion, a CWP 8 feet in diameter and 400 feet in length was fabricated. The suspended pipe test was conducted by attaching a bottom weighted CWP (20 lb/ft water weight) to a scaled platform barge through a gimbal. Five 80-foot-long pipe segments were joined dockside. The test article was towed to the site by two tugboats while horizontally suspended beneath two barges. The vertical deployment test has been completed and data analysis is underway. The intent of the next Phase is to investigate hydrodynamic loads on slope-mounted pipes and joining techniques. Two 80-foot-long segments of CWP will be connected through a male/ female joint configuration and tremie concrete will be poured over the joint after the deployment. The joint assembly will also serve as the foundation. This test article is scheduled for recovery during FY 83.

The major focus in sea-water systems was to develop an analytical code to predict the performance of the OTEC water loops. This involved development of a dynamic analytical computer model that simulates the performance of the SWS components and parametric sensitivity studies applied to the Johns Hopkins University/ Applied Physics Laboratory Grazing Plantship, the Gibbs & Cox Spar Plant, and OTEC-1. Model response predictions were compared to measured data to fine tune the model.

A substantial research effort was performed in the Moorings/Foundations area through FY 82 including a preliminary design analysis of two types of stationkeeping subsystem, the Multiple Anchor Leg (MAL) Mooring System for the OTEC floating barge configuration and the Tension Anchor Let (TAL) Mooring System for the spar configuration. The MAL consists of catenary-type anchor moorings arranged in pairs at each corner of a barge, whereas the TAL incorporates a solid spar configuration moored with taut lines. In general, TAL appears to be less costly but MAL is closer to SOA and entails less risk. Two assessments of mooring technology were performed to summarize and evaluate the mooring SOA and evaluate the feasibility of using scaling techniques to determine relative forces associated with mooring system/ocean environment interactions. It was found that the scaling of mooring systems would not be an accurate procedure if the relative depth of the scaled system to a full-size system was greater than an order of magnitude apart.

An analysis of platform construction techniques was developed with respect to the floating platform configuration. The baseline scenario investigated was a 400 MWe commercial OTEC plant in the ship hull and spar hull configurations. Hull materials evaluated included steel and concrete. The CWP material choices were steel, concrete, FRP and elastomeric. Three deployment locations were evaluated: Florida west coast, Puerto Rico and Hawaii. Construction requirements were compared with current industrial capabilities. Results were then integrated with the potential deployment locations. In general, the study concluded that present United States industrial capabilities meet the construction requirements for concrete and steel hulls. If segmented construction techniques are applied to the steel hull area, present U.S. facilities are adequate. Facilities for concrete hull construction, are not presently available in the United States. Notably, concrete was deemed to be the most advantageous material for hull construction.

The cable subsystem is a critical development area with respect to the overall feasibility of the moored/floating OTEC plant configuration. The basic design consists of a long cable suspended in a catenary configuration from the platform and attached to the connector between the plant and the bottom transmission cable. The environmental loading (i.e. waves, currents, and hydrostatic pressure), platform motion, and the weight of the cable itself define the complexity of the design considerations. Additionally, the design must be life cycle cost effective. Two cable designs were developed and evaluated in the OTEC Program. The self-contained oil-filled (SCOF) design used a laminated oil-impregnated paper insulation and the extruded solid insulation design featured cross-linked polyethylene (XLPE). Both cable systems included four single conductor cables (three-phases and a spare) capable of carrying of 100MWe load. The program also addressed the cable gimbal component (platform/cable interface), mechanical cable termination, electrical termination, and emergency disconnect procedures. The SCOF cable may not be suitable for the OTEC application due to its laminated construction. Test failures occurring in this design were due to "sleeving, " i.e., relative motion between the cable conductor and the laminated insulation which leads to paper tape slippage and premature cable breakdown. An ideal cable termination scenario, where each cable component is terminated in a plane perpendicular to the cable axis, has been proposed to eliminate the sleeving problem. Until the SCOF cable is tested in this scenario however, its suitability for the OTEC application cannot be determined.

ENGINEERING DEVELOPMENT PROGRAM ELEMENT

The Engineering Development Program Element involves large experiments such as the OTEC-1 ocean-based engineering test bed and the 40 MWe Pilot Plant Proof-of-Concept. Both efforts were initiated pre-FY 80. The OTEC-1 project fostered a broad spectrum of engineering evaluations on key OTEC components and provided valuable input to all areas within the DOE/Ocean Energy Program. The Pilot Plant Program is a natural technological progression from OTEC-1, and may culminate in the deployment and operation by industry of a 40MWe closed-cycle OTEC plant.

The major objectives of the OTEC-1 test facility tests were to assess heat exchanger technology, provide power system performance data, evaluate biofouling countermeasures, assess the environmental effects of OTEC-1 operations and provide the pilot plant program ocean integration data on hulls, mooring and cold water pipes. The United States Naval Ship (USN) CHEPACHET, a mothballed WW II tanker, was selected for use as the test bed vehicle. After inspection, repair and reactivation of shipboard systems, and installation of the CWP attachment equipment, a 1MWe heat exchanger test article and experiment support systems were installed. The CHEPACHET (referred to as OTEC-1) was deployed at a site located approximately 12 nautical miles off the west coast of the Island of Hawaii. This activity involved: placement of the deepest moor of this size ever performed; design, fabrication, deployment, operation, release and recovery of the CWP; OTEC operation in a grazing mode; operation in a single point mooring array; and demonstration of the near surface mixed effluent discharge as an option. The test period lasted four months and demonstrated the feasibility of deployment and at-sea operations of a large-scale OTEC plant.

The OTEC Pilot Plant Program Opportunity Notice (PON) was issued late in FY 80. Responses to the PON in FY 81 exhibited significant interest in shelf-mounted systems. Two proposals were selected for one year conceptual design beginning in mid-FY 82. Both proposals were sited adjacent to the existing Kahe Point power station, owned by the Hawaiian Electric Company (HECO). HECO and the State of Hawaii were members of both consortia and contributed to the cost-sharing.

One contractor proposed to design a 40MWe net power plant on a fixed tower. The plant would be located one mile off-shore from Kahe Point, Oahu, HA in 328 feet of water. The design employed current SOA off-shore oil rig technology for the tower and included condensers located at a depth of 150 feet, evaporators located at a depth of 280 feet and a steel CWP. The CWP was 33 feet in diameter and extended to the bottom (328 feet) runing into the deep ocean for a total length of 9,800 feet. The heat exchanger design proposed was aluminum flat plate using freon-22 as the working fluid. A single turbine-generator was located atop the tower and was nominally rated at 50 MWe. The net power produced was to be transmitted to a land-based distribution station via trenched and buried submarine cable.

The second contractor proposed a 40MWe plant constructed on an artificial island. This island would be located 600 feet off-shore from Kahe Point, Oahu, HA, in 28 feet of water. The OTEC plant warm water intake would utilize the HECO's 600MWe fossil fuel plant effluent condenser coolant to enhance the warm water temperature. The system would include four 10MWe electrical power modules (each with two condensers and two evaporators and one four-stage axial turbine-generators), and a composite lightweight concrete and fiberglass reinforced plastic CWP, 30 feet in diameter and 13,100 feet in length. The heat exchangers are titanium tube construction employing a horizontal tube and shell design and ammonia as the working fluid. The proposed deployment technique uses a combination of floatation tanks and anchors for installing the CWP on the sloping sea floor.

The conceptual design has been completed and included tradeoff analyses, the preparation of layout drawings, design reports, environmental impact statements, cost estimates, commercialization plans and the initiation of environmental data accumulation. The landbased design has been selected to advance to Preliminary Design. This 18-month effort is scheduled for completion during the first quarter of FY 85.

STATE OF TECHNOLOGY ASSESSMENT AND REMAINING AREAS OF UNCERTAINTY

A evaluation of the state of development of ocean energy systems has been completed. Each subsystem of the various options such as landbased OTEC-closed cycle, wave, etc. was considered. This evaluation for closed and open cycle landbased OTEC is shown in table I. A part of this evaluation was the determination of areas of uncertainty in the technologies as shown in table II. The subjects in table II are those presently under consideration in the DOE FY 1984 oceans program formulation.

TABLE: I. ASSESSMENT OF STATE OF TECHNOLOGY FOR CLOSED AND OPEN CYCLE OTEC

KEY (STATE OF TECHNOLOGY):

1. PRELIMINARY FEASIBILITY
2. ADVANCED CONCEPT
3. CONCEPTUAL DESIGN
4. CONCEPT VALIDATION
5. PRELIMINARY DESIGN
6. SCALED FIELD TEST
7. CRITICAL ENGINEERING DESIGN
8. FULL-SCALE DEMONSTRATION
9. OFF-THE-SHELF

S-1. EXPLORATORY
S-2. CONCEPTUAL UNDERSTANDING
S-3. PRELIMINARY RESEARCH
S-4. FOCUSED RESEARCH

"N/A" – NOT APPLICABLE TO THE SITUATION
"*" – SITE, DEPTH OR SIZE DEPENDENT

ENERGY TRANSFER MODE				
OPEN-CYCLE OTEC	CLOSED CYCLE OTEC			
"N/A"	"N/A"	POSITION CONTROL/MOORING		SYSTEM STRUCTURE
2	3	PLATFORM/FACILITY/HULL		
2	3	FOUNDATION		
7-9*	7-9*	CW PUMPS AND MOTORS		
7-9*	7-9*	WW PUMPS AND MOTORS		
6-9*	6-9*	SEA WATER SYSTEM		
7	7	BIOFOULING & CORROSION CONTROL		
		I M & R		
5	5	PIPE STRUCTURE		COLD WATER PIPE SYSTEM
6*	6*	INTAKE MECHANISM		
5	5	CWP/PLANT TRANSITION		
3	3	BUOYANCY/BALLAST SYSTEM		
3	3	MOORING/FOUNDATION/EMBEDMENT		
6	6	BIOFOULING AND CORROSION CONTROL		
		I M & R		
3	3	DEPLOYMENT AND INSTALLATION		
6-9*	6-9*	PIPE STRUCTURE		WARM WATER PIPE SYSTEM
4-7*	4-7*	INTAKE MECHANISM		
5	5	WWP/PLANT TRANSITION		
6	6	BUOYANCY/BALLAST SYSTEM		
7	7	MOORING/FOUNDATION/EMBEDMENT		
5	5	BIOFOULING & CORROSION CONTROL		
		I M & R		
7	7	DEPLOYMENT AND INSTALLATION		
6	6	PIPE STRUCTURE		DISCHARGE WATER PIPE SYSTEM
3	3	DISCHARGE MECHANISM		
5	5	DWP/PLANT TRANSITION		
5	5	BUOYANCY/BALLAST SYSTEM		
4-6*	4-6*	MOORING/FOUNDATION/EMBEDMENT		
9	9	BIOFOULING AND CORROSION CONTROL		
		I M & R		
4-5*	4-5*	DEPLOYMENT AND INSTALLATION		
3	4-6*	EVAPORATOR		POWER SYSTEM
2	4-6*	CONDENSOR		
N/A	4-6*	WORKING FLUID SYSTEM (CC)		
3	N/A	LOW PRESSURE STEAM CONNECTIONS (OC)		
N/A	4-5*	PURGE SYSTEM (CC)		
2	N/A	DEAREATION SYSTEM (OC)		
2	4-6*	POWER GENERATION		
3	7	AUXILIARY SYSTEMS		
*	7	INSTRUMENTATION & CONTROL		
3	4-6*	BIOFOULING AND CORROSION CONTROL		
		I M & R		
9	9	POWER CONTROL AND BUS		ENERGY TRANSFER SYSTEM
9	9	POWER CONDITIONING		
N/A	N/A	RISER CABLE		
8	8	BOTTOM CABLE		
9	9	ABOVE WATER CABLE		
9	9	SHORE GRID STATION		
9	9	FITTINGS & CONNECTIONS		
8	8	BIOFOULING & CORROSION CONTROL		
		I M & R		
9	9	MATERIAL HANDLING		ENERGY UTILIZATION
4	4	PRODUCTION SYSTEM		
9	9	PRODUCT TRANSFER		
9	9	AUXILIARY SYSTEMS		
		I M & R		
S-2	S-2	THERMAL RESOURCE	RESEARCH ACTIVITIES	ENVIRONMENTAL/REGULATORY
S-3	S-3	METEOROLOGICAL		
S-2	S-2	PHYSICAL OCEANOGRAPHY		
S-2	S-2	GEOLOGICAL/GEOTECHNICAL		
S-2	S-2	BIO-ECOLOGICAL		
S-2	S-2	CHEMICAL		
S-4	S-4	INTERNATIONAL LAW	REG COMP	
S-4	S-4	FEDERAL REGULATIONS		
S-4	S-4	STATE REGULATIONS		

TABLE II. AREAS OF UNCERTAINTY

- Cold Water Pipe and Foundation Deployment Techniques
- Geotechnic and Soil Mechanics Factors (including slope stability) for Soil/Platform and Soil CWP Interactions
- Improvement of Heat Exchanger Water Side Heat Transfer to Decrease Size of Heat Exchanger and Analytical Modeling
- Life Expentancy of Low-Cost Heat Exchangers as a Function of Corrosion, Fouling, Structural Integrity, and Materials
- Understanding Coastal Zone Impacts, Including Validation of Analytical Models for Prediction of Recirculation and Discharge Plumes
- Statistical Variability of the Ocean Thermal Resource and other Fluctuating Environment Conditions (meterological, chemical, geological, physical oceaographical)
- Operational Scalable Data From a Fully-Integrated OTEC System in a Seawater Environment
- IM&R and Retrieval of Submerged Components – Up to 5000 foot depth and 70° slopes
- Validated Computer Codes for Predicting CWP (Shelf-Mounted and Suspented) Loads and Responses
- Distribution of Non-Condensible Gases in a Plant and Their Impact on Open Cycle System Performance
- Long-Term Materials Characteristics for CWP
- Electrical Cable Termination Design
- Effect of Redistribution of Oceanic Properties
- Hydrodynamic Loads on CWP (suspended or shelf-mounted) Above Reynolds' Number of 10^6
- Scalable Open-Cycle OTEC Turbine Performance Data
- Electrolysis Efficiency for Plantships
- CWP Platform Connection Hinge and Seal Validated Design Test
- Direct Contact Heat and Mass Characteristics of sea water at OTEC Conditions
- Major Effects of Impingement/Entrainment on Plant Design and the Environment
- Anchor Hardware for Both Steep Slopes and Rock Conditions

DEVELOPMENT OF A WIND ENERGY SYSTEM FOR USE AT REMOTE LIGHTHOUSES

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ABSTRACT

Previous work conducted by the U. S. Coast Guard, Office of Research and Development focused on analyzing the technical and economical aspects of using alternate energy sources at remote lighthouses presently powered by diesel-electric generators. This work has shown that wind energy systems appear to be very attractive in all locations except the coastal areas of Florida where photovoltaic systems appear to be most attractive.

Major questions to be answered regarding the use of wind energy at remote lighthouses are discussed including system configurations, operating modes, control schemes, battery management, component sizing, component selection, instrumentation and data collection.

1. INTRODUCTION

The U. S. Coast Guard currently operates 65 major lighthouses at remote sites using diesel-electric generators. Due to the escalating cost of diesel fuel as well as the shortage of trained personnel needed to maintain these lighthouses and generators, a research and development project was initiated to explore the use of solar energy.

A previous paper[1] discussed the results of a feasibility study[2] that analyzed the technical and economical aspects of using wind machines and photovoltaic arrays to supplement the diesel-electric generators. The major results of the feasibility study, which used a computer simulation model, were that hybrid systems using a wind machine and a diesel-electric generator set inconjunction with battery storage would be from 40-85% less in life cycle costs than the current stand-alone diesel system. Generally, the feasibility study showed that for the present, wind systems are more economical than photovoltaic systems everywhere except in the coastal areas of Florida.

The second phase of the work, which is now in progress, involves the design, development, fabrication, test and evaluation of an experimental system at a lighhouse. The purpose of this work is to verify the results predicted by the feasibility study and identify and solve technical problems that arise in implementing wind energy systems at lighthouses. In the final analysis the basic measure of performance will be life cycle costs. Some specific technical problems that will be explored are electromagnetic interference, component compatibility, and safety considerations. The actual development of the system will focus on four general areas:

1. System configuration and operating modes.
2. Control schemes and battery management.
3. Component sizing and selection.
4. Data collection and analysis.

Each of these topic is discussed in the next section.

2. CRITICAL ISSUES IN DEVELOPING A WIND ENERGY SYSTEM.

Using the results of the feasibility study, a general system design has been prepared and a wind machine has been selected and installed at the Cape Henry Lighthouse in Virginia Beach, Virginia. A complete system, including diesel-electric generator, wind machine, battery storage, inverter, and a microprocessor controller, is expected to be in place by September 1983. Based on experimental data collected from operating the system and updating and re-running the computer simulation we expect to make important determinations about the overall system design and operation.

2.1 SYSTEM CONFIGURATION AND OPERATING MODES

Figure 1 gives a general description of a hybrid system. Major components of the hybrid power source are the wind machine, diesel-electric generator, main storage battery, battery charger, inverter, and a microprocessor controller.

The first step in determining an efficient detailed design is to minimize the lighthouse load requirements. Obvious measures that can be employed include daylight control of the light, use of more efficient lights such as gas discharge or flashtubes (if these are acceptable), use of more energy efficient equipment such new solid state radio beacons, operating as many components on DC power as possible. The use of DC power may prove to be problematic for lighthouse components that were designed to operate on AC power. For the lighthouses we are interested in, the average power is in the range of 500W to 2000W and this makes 120 volts the most practical operating DC voltage. Smaller lighthouse could be operated at 48 volts or possibly 12 volts DC.

It is important to operate the diesel as efficiently as possible when it is running which equates into keeping it heavily loaded. Operating the diesel at partial loads causes two problems. First, it is inefficient for a diesel to operate at partial loads. Second, operating a diesel at below 75% capacity for prolonged periods leads to carbon buildup inside the diesel and eventual maintenance problems. Therefore one operating mode should be with the diesel charging both the main storage battery and powering the lighthouse load. This would occur when the main storage battery is approaching a 100% state-of-charge (SOC). In this operating mode the inverter would be off and the diesel would be powering the AC load directly.

A second operating mode would be when the battery has been deeply discharged and requires a high level of power from the diesel. Then the diesel would power only the battery charger. A third operating mode would have the diesel off and all power would go to the load from the battery. Other operating modes are possible but the major emphasis should be to limit the running time of the diesel, avoid inefficient transfer of power through the battery charger and the inverter, operate the main storage battery at as low a SOC as possible so energy can always be accepted from the output of the wind machine (or photovoltaic array).

2.2 CONTROL SCHEMES AND BATTERY MANAGEMENT

The basic strategy for controlling the system must have as its first priority the development of a battery management criteria. Managing the batteries involves monitoring the SOC so that routine charging and discharging of the batteries can be carried out in a timely and efficient manner. Furthermore, proper management prevents severe physical and electrical abuse to the batteries and extends life expectancy. Major conditions that can shorten battery cell life are:

- Overcharging - causes gassing that can lead to plate damage, water loss, and hydrogen gas dangers.
- Overdischarging and prolonged periods at partial discharged - leads to sulfation problems.
- Temperature excursions - leads to possible freezing and cracking at low temperatures; leads to sulfation at high temperatures.
- Electrolyte specific gravity excursions - leads to sulfation.

The SOC of the individual cells must also be kept in balance. Voltage measurements across the entire battery array may not give a good indication as to the SOC balance of all the cells. If they become imbalanced, problems in individual cells may develop unnoticed and irreversible damage may occur. Monitoring of individual battery voltages can help to detect problems. Also, a systematic method of occasional heavy overcharging will probably be necessary to bring the cells back into balance.

There are three methods for the actual measurement of battery SOC. First, ampere-hours can be counted during charge and discharge. Proper consideration must be given to battery inefficiency (both coulombic and voltage inefficiencies). This method can be very accurate for short periods but tends to drift over a large number of cycles and must therefore be adjusted periodically. Second, voltage measurements can be used to estimate SOC. Although somewhat inaccurate, particularly if the battery is in a state of nonequilibrium, voltage measurements are a more fundamental measurement of the SOC than ampere-hour counting. Using voltage measurements in combination with ampere-hour counting is a reasonable approach to obtaining relatively accurate SOC measurements with an adequate level of certainty. Both methods are highly amenable to microprocessor monitoring. Third, specific gravity readings using hydrometers can yield accurate measurements of SOC as well as indicating whether the electrolyte is vertically stratified in the battery cells. Electrolyte stratification causes the type of plate damage due to specific gravity excursions previously mentioned. Hydrometers readings are taken manually so this method of measuring SOC can not be used to automatically monitor and control the batteries, but is useful for collecting test data and evaluating the usefulness of the automatic SOC measurement using combined ampere-hour counting and voltage measurement methods.

Having determined a basic battery management criteria for avoiding damage to the batteries and measuring SOC, the next step is to examine possible control schemes which will lead to optimum life cycle costs. The present plan is to collect experimental data by operating the system with a variety of control schemes and then updating and running the computer simulation model based on this data to project life cycle costs over long periods of operation. This approach maximizes test results by expanding short term test data into long term computer representations.

A great deal of flexibility in testing is obtained using a microprocessor to control the system and collect data. For example, changes in the type of data to be collected or the control schemes to be used can be accomplished by simple changes to microprocessor software. Control scheme parameters include, limits of battery SOC for charge/discharge when operating the diesel, schedules for overcharging of the battery to prevent electrolyte stratification, voltage regulator settings of the wind machine (and photovoltaic array if applicable) to most efficiently charge the battery or prevent unwanted overcharge, and battery charger settings. In a very sophisticated system decisions regarding diesel operation could be based on projected wind machine (or photovoltaic array) outputs.

2.3 COMPONENT SIZING AND SELECTION

The size of the components selected has a critical effect on the life cycle cost of the system. Estimates of optimum component sizes were made in the feasibility study using the computer simulation model to analyze the expected wind machine output, battery and inverter performance, and diesel usage. Estimates were made for varying sizes of lighthouse loads at a number of geographical locations. Based on the experimental data to be collected with the predetermined component sizes planned for testing, the computer simulation model will be updated and rerun. Interpolations, using the computer, can then be made to confirm component sizing that will yield optimum life cycle costs.

Selection of the individual system components calls for a great deal of practical consideration and attention to detail. A brief discussion of selection criteria for wind machines, batteries, and inverters is given below (the Coast Guard already has standards for diesel-electric generators). Beyond the careful selection of individual components, additional planning must be made to insure that all the components are compatible. Examples of compatibility questions that must be investigated are:

. Can the inverter operate all the AC modules in the lighthouse load? Can the load tolerate current surges or voltage spikes generated by the inverter? Will the inverter meet all the peak load requirements?

. Does the microprocessor controller require special shielding from electromagnetic interference or protection from power transients?

. Can the inverter input tolerate the varying voltage inputs it experiences across the main storage battery array from the battery charger?

. Is the voltage regulation sufficient in the wind machine to prevent damage to the battery array?

Selection of a wind machine was limited to DC output generators that can directly charge a main storage battery. DC machines are generally simpler and more efficient than constant speed AC machines that produce a controlled output frequency of 60 Hertz. Because the most practical battery array voltage was 120 volts, the wind machine must likewise be a nominal 120 volt system. Other than these basic requirements the selection of a wind machine must be based on extreme reliability with a simple rugged design as proven in a rigorous test program. Results of wind machine testing are available from the U. S. Department of Energy, Rocky Flats Test program.

Just as important as selecting a good wind machine is the issue of properly siting a wind machine. Proper siting is essential for good power output with minimum machine wear and maintenance. Two basic questions must be addressed in the siting of a wind machine, (a) where is the best, or at least the most acceptable, location for a machine in the vicinity of the lighthouse, and (b) what are the estimated wind characteristics at the site. By answering these two questions a site can be found that minimizes turbulent wind forces on the machine and allows the designer to predict the wind energy resource at the site which in turn allows for the optimum design and sizing of the overall system.

Selection of main storage batteries involves identifying batteries with a long service life when deeply discharged up to several hundred times per year. Although there are several different generic types of batteries to choose from the lead-acid has several major advantages that currently make it the first choice: (a) it has a demonstrated energy efficiency and functionality that are well understood, (b) it has the lowest overall material costs, (c) it is a recyclable product, (d) there has been more field experience with lead-acid than any other system. The specific type of lead acid battery that most closely fits our application is the motive battery as used for example in industrial fork lifts. Recently, low maintenance motive power batteries, which are designed to reduce water loss have become available.

Selection of an inverter is critical to overall system efficiency particularly if the load is primarily AC which means most of the power will need to flow through the inverter. In general, there is a direct trade-off between wave form quality and inverter efficiency. Inverters with very high efficiencies (greater than 90%) tend to have non-sinusoidal waveforms which may be acceptable for heavy current components such as motor drives but unacceptable for sensitive electronic components. On the other hand, inverters with high quality sinusoidal waveforms tend to be less efficient. In this case a very low efficiency inverter would cancel all cost savings that could be achieved with a hybrid system over the use of straight diesel system.

2.4 DATA COLLECTION AND ANALYSIS

As was previously mentioned, the system under development will use the microprocessor controller to carryout the secondary function of data collection. The microprocessor design consists of a complete portable microcomputer system including terminal, tape drive, memory, and CPU with ten slots for STD bus cards. The microprocessor provides three functions:

. Fundamental microprocessor operations including: CPU, interfacing to peripherals (printers, tape recorders, etc.), RAM memory, ROM for operating codes.

. Measurement and I/O capability for data collection including: A to D voltage conversion for voltage measurements, shunt voltage to frequency conversion for current measurements, and a buffer for input to the CPU.

. Data logging and display including: a non-volatile real-time clock and an interface to the CRT.

Actual data to be collected will be individual battery voltages, battery charger output, windmachine current, inverter current (input) lighthouse power, diesel starts, wind speed/direction, temperature (ambient and battery). Also, specific gravity measurements of the battery electrolyte will be manually taken periodically.

The analysis of the data collected will be used inconjunction with the computer simulation model to predict long term technical and economical performance.

3. CONCLUSIONS

Initial test results will not become available until early 1984. Fabrication of the experimental system for Cape Henry is proceeding on schedule. Although some design questions are still being answered there appear to be no major technical problems in terms of developing a successful wind-diesel hybrid system for use at remote lighthouses.

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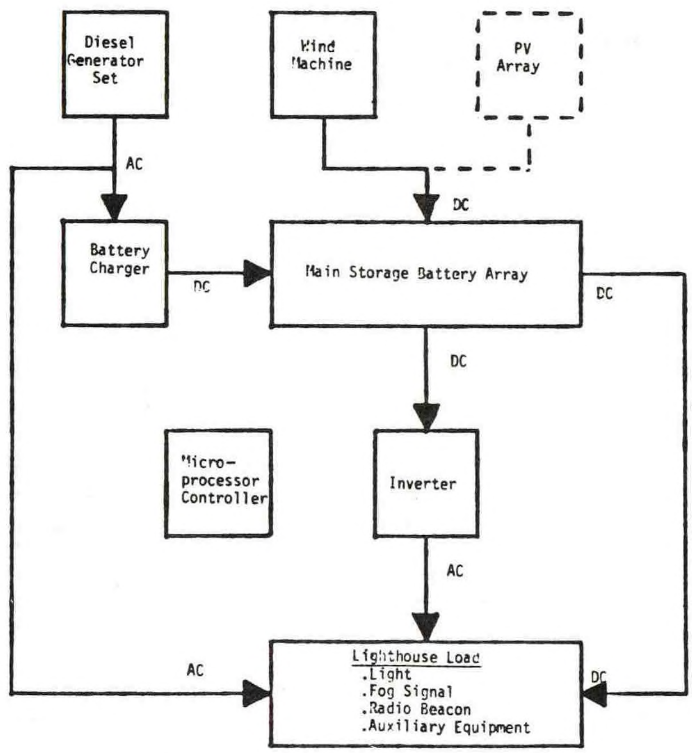

Figure 1 - Flow of electric energy in a wind-diesel hybrid system

SHIP SIMULATORS DO NOT TRAIN - INSTRUCTORS DO

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ABSTRACT

Research conducted since 1977 on simulator training for mariners establishes that no hardware feature of ship simulators has as large an impact on training effectiveness as instructors do. Ship simulators tend to be designed and built to duplicate the real world as well as feasible. We should focus our concern far more on: (1) instructor support features in simulators, (2) functional validity rather than face validity, and (3) the value and retention of trainee skills enhanced through simulator training.

THE BASIS FOR SIMULATOR TRAINING OF MARINERS

The direction of ship movements is an applied skill involving knowledge, perceptual skills, judgement, alertness, decisiveness and caution. Only the knowledge segment of the requirement is tested in licensing examinations. The ability to conduct a ship safely is inferred from knowledge demonstrated on a test plus records of training and work experience. Some people worry about the lack of specific evidence that proper perceptual and decision skills have actually been learned by an individual who is nominally trained and experienced.

There are three reasons to doubt the adequacy of mariner training:

First, some individual mariners tell us that they received no instruction whatsoever in the handling of ships during their early years as an officer. An uncommunicative master merely let them observe, rather than practice, shiphandling.

Second, progress in reducing ship casualties is unsatisfactory, according to analyses by the U. K. Nautical Institute [1] and others.

Third, modern ships tend to be larger with respect to restrictive waterways than previously and to carry more cargoes which are hazardous to crews, shoreside populations and the maritime environment. Therefore, greater levels of skill are needed now than previously.

Visual ship simulators have only been available since 1970, although radar/electronic navigation simulators have existed longer. Because visual methods provide the most accurate bearing and position data - and ships are normally piloted visually when feasible - visual navigation skills are very important to ship and public safety.

RESEARCH INTO SHIP BRIDGE SIMULATOR USE

The U. S. Coast Guard and Maritime Administration began a joint project on simulators for mariner training and licensing in 1977. The initial study [2] examined mariner tasks, existing training systems, use of simulators in other industries and potential for maritime use. Of 74 training objectives examined, 71 were judged to be more suited to simulator training than to alternative methods. In a few cases, simulators were preferred because practice of certain skills at sea would involve excessive risks. Most generally, however simulators were preferred because they offered better control of the training, professional instructors, better feedback on trainee performance and greater flexibility than at sea training.

During the mid-1970's much of the concern with ship bridge simulators focused on design features, particularly those involving the face validity of the visual scene. Point light source, model board, spot light and computer generated imagery systems were tried using various fields of view and projection systems. The second phase of our project involved experiments to determine whether the highest cost features produced commensurate advantages in training effectiveness. All experiments in this project were conducted at the Computer-Aided Operations Research Facility (CAORF) in Kings Point, NY.

The major finding was that differences between instructors (who had apparently equal qualifications) were much more significant than any variations in field of view, day versus night, color versus black and white, means of feedback to the trainees or flexibility of traffic ship maneuvers relative to own ship. It was concluded that emphasis should shift from face validity to functional validity and that more attention should be paid to instructor support features and training techniques.

*This paper is the sole responsibility of the author. It does not necessarily reflect official U. S. Coast Guard policy.

A persistent problem during the first two phases of study was the proper selection of performance measures which would distinguish between good and poor mariner skills and habits. An effort was made in the third phase of the study to identify objective performance measures which could be used to establish standards of functional performance useful for licensing. [4]

The experiments in this third phase tested 14 expert pilots against 14 chief mates who were ready to become masters. Five harbor/harbor entrance scenarios were used because most accidents preventable by simulator training occur in such waters. Findings were that:

First, the distinguishing performance measures are different for various scenarios.

Second, for experienced mariners, only demanding scenarios can distinguish performance; it is important that tests be at least moderately difficult.

Third, many numerical performance measures do not distinguish performance, but Yes/No measures specific to a scenario are often valuable. (For example, did the mariner recognize that a buoy was off station? Did the mariner complete the transit safely?)

Fourth, maximum measures seem to be more revealing than average measures. The maximum swept path is likely to be more useful than average swept path and maximum deviation from average trackline may be more useful than average deviation.

Aside from the research with ship senior officers, studies of cadet training showed very beneficial results also. Although U. S. National Merchant Marine Academy cadets get ample time at sea on commercial vessels, they tend not to be allowed actual control of the ship. Simulator training gives the cadets invaluable "hands-on" skills and confidence in decisions about when to call the master and how to evaluate collision risks. Interestingly, cadets who take the training prior to sea experience seem not to retain the skills. Those who have sea experience are more motivated and able to integrate the simulator training into their overall perspective of bridge watchstanding. That factor appears to make the major difference between simulator training as a video game versus learning it as a professional skill.

SIMULATOR TRAINING GUIDELINES

It does not seem currently practical to set numerical performance standards for evaluating simulator training courses and the trainees. Yet some means is desirable to allow the U. S. Coast Guard to certify a simulator training course so that its graduates can receive partial credit toward licenses.

The solution we adopted was to specify many critcal characteristics of simulator training systems. (See Table 1.) Each characteristic has two to four levels of capability identified. Depending on the category of material to be taught, one level is designated as minimum and one as a recommended level. A Coast Guard regulator can use this guide to audit a simulator training program. If the facility and its program meet at least the minimum levels of the critical characteristics, then the program(s) can be approved for partial credit toward licenses.

TABLE 1. CRITICAL CHARACTERISTICS OF SHIP BRIDGE SIMULATOR TRAINING PROGRAMS

Simulator Design

- Geographic Area
- Horizontal Field of View
- Vertical Field of View
- Time of Day
- Color Visual Scene
- Visual Scene Quality
- Radar Presentation
- Bridge Configuration
- Ownship Dynamics
- Exercise Control
- Traffic Vessel Control
- Training Assistance Technology
- Simulator Maintenance/Availability

Training Program Structure

- Skill Levels After Training
- Skill Levels Prior to Training
- Training Objectives
- Training Techniques
- Knowledge of Requirements
- Positive Guidance
- Adaptive Training
- Post Problem Critique
- Instructor's Guide
- Classroom Support Material
- Simulator/Classroom Instruction Mix
- Training Program Duration
- Class Size
- Scenario Design
- Number of Scenarios
- Stress
- Overlearning

Instructor Qualifications

- Mariner Credentials
- Instructor Credentials
- Subject Knowledge
- Instructor Skills
- Instructor Attitude
- Student Rapport
- Instructor Evaluation

Such guides [5, 6] do not necessarily depend on official action. Designers of simulator training programs can use these guides to help assure that those programs will be effective . The guides allow considerable flexibility in terms of facility details, specific training objectives, course organization and scenario design. These same documents can be used by ship fleet operators as consumer guides to simulator training. By comparing alternative simulator programs on these criteria, company executives can determine which programs best meet Coast Guard criteria, if they choose to accept these criteria.

It should be noted that the guides do not rely solely on this one research program. Several principles of effective training are based on recent cognitive and experiemental psychology literature.

Two guides have been produced to date, one for cadets and the other for senior mariners. Research to produce a guide for simulator training for ship pilots is currently underway. Guides for simulator training of towboat operators and offshore supply vessel operators are planned in later years.

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RIGID HULL INFLATABLE BOAT TESTS AT CAPE DISAPPOINTMENT, WA
FEBRUARY 1982

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ABSTRACT

The surf rescue capabilities of three rigid hull inflatable boats (RHIBS) were tested and evaluated in comparison with the USCG Prototype 30 Foot Surf Rescue Boat (30 FT SRB) at Cape Disappointment, WA in February 1982. The test crews indicated that any of the boats tested was adequate to perform surf rescue missions, although a strong preference was expressed for the larger heavier boats.

INTRODUCTION

In December 1981 the Search and Rescue Division (G-OSR) of the Office of Operations requested the assistance of the Marine Technology Division (G-DMT) of the Office of Research and Development in conducting a side-by-side test and evaluation (T&E) of various rigid hull inflatable boats (RHIBs). A test program was developed that had a threefold purpose. First, to determine the capabilities of this type of boat in a breaking (bar) surf environment. Second, to evaluate features of the various boats participating in the tests for their application to the Coast Guard Search and Rescue Mission. Third, to act as an information exchange for the participants and other interested parties. As things turned out, the Marine Technology Division developed and conducted a test program to accomplish these goals.

The T&E program was scheduled for 19 February 1981 through 28 February 1981. Familiarization and testing actually started on Monday, 22 February 1982 and finished on Friday, 26 February 1982. The tests were conducted at the mouth of the Columbia River using the facilities of the National Motor Life Boat School at Cape Disappointment, Washington. Coast Guard Group Astoria, Oregon, and Coast Guard Station Cape Disappointment, Washington also provided support.

DESCRIPTION OF THE BOATS TESTED

Four boats were tested: The Arctic 24, a 24 foot RHIB, manufactured by Osborne Rescue Boats, LTD; the Pacific 22, a 22 foot RHIB, manufactured by Osborne Rescue Boats, LTD; the 6 Meter Searider, a 19 foot RHIB, manufactured by Avon Inflatables, LTD; and the USCG Prototype 30 Foot Surf Rescue Boat (30 FT SRB).

The Arctic 24 has a fiberglass (G.R.P.), deep "V" planing hull, fitted with removable, inflatable, flotation collars. The boat tested was powered by twin 90 horsepower (HP) Johnson outboard motors. It has a length over all of 24 feet, a beam overall of 8 feet, 7 inches, and a draft of 2 feet, 4 inches (with the motors down). The boat weighed about 4,009 pounds, as tested. The coxswain sits at a control console. Two crewmen may sit, facing forward, immediately behind and to either side of the coxswain. The boat tested is currently in service at the Coast Guard Station Beach Haven, New Jersey. It is fitted with a towing bit and a self-righting inflation bag.

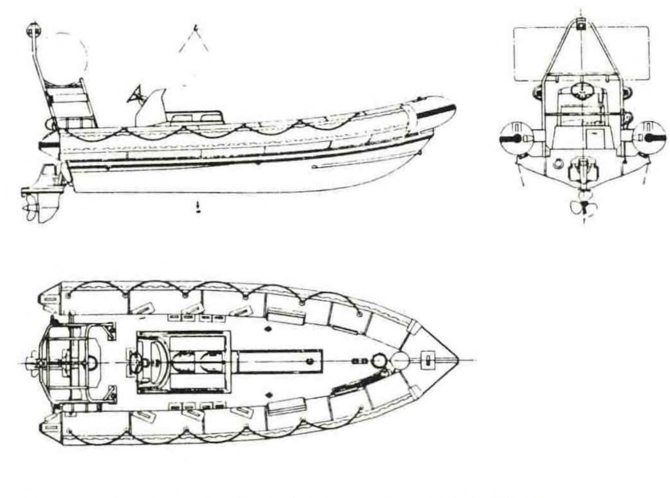

Figure 1 The Pacific 22, a Typical RHIB.

The Pacific 22 has a fiberglass (G.R.P.), deep "V" planing hull, fitted with removable, inflatable, flotation collars. The boat tested was powered by a 155 HP, Model AQAD-40, Volvo diesel engine, through a Volvo Model 280 outdrive unit. It has a length over all of 22 feet, 1 inch, a beam over all of 8 feet, 4 inches, and a draft of 3 feet, 1 inch (with the outdrive unit down). The boat weighted about 3,955 pounds, as tested. The coxswain stands at a control console, leaning against a backrest. Two crewmen may sit side saddle on the engine casing, facing forward, immediately ahead of and to either side of the coxswain. The boat tested is currently used by Osborne Rescue Boats, LTD as a demonstration boat. The boat may be fitted with a self righting inflation bag. Figure 1 is a drawing of the boat.

The 6 Meter Searider has a fiberglass (G.R.P.), deep "V" planing hull, fitted with inflatable, flotation collars that are bonded to the hull. The boat tested was powered by twin 70 HP Mariner outboard motors. It has a length over of 19 feet, 11 inches, a beam over all of 7 feet, 7 inches, and a draft of 2 feet, 3 inches (with the motors down). The boat weighed about 2,110 pounds, as tested. The coxswain sits at a control console. A crewman may sit immediately behind him. The boat tested is currently in service as a ship's boat on the USCGC CHEROKEE (WMEC 165). This boat may be fitted with a self righting inflation bag. The boat tested was not equipped with this feature.

The Prototype 30 Foot Surf Rescue Boat (30 FT SRB) is a high speed personnel rescue boat, designed by the Coast Guard, and manufactured by the Willard Boat Company. It is a fiberglass (G.R.P.), hard chine, deep "V" planing hull, with a self righting capability. The 30 FT SRB was designed for search and rescue work under moderately heavy sea and surf conditions (approximately 8 feet to 10 feet surf) with high transit speed. The boat

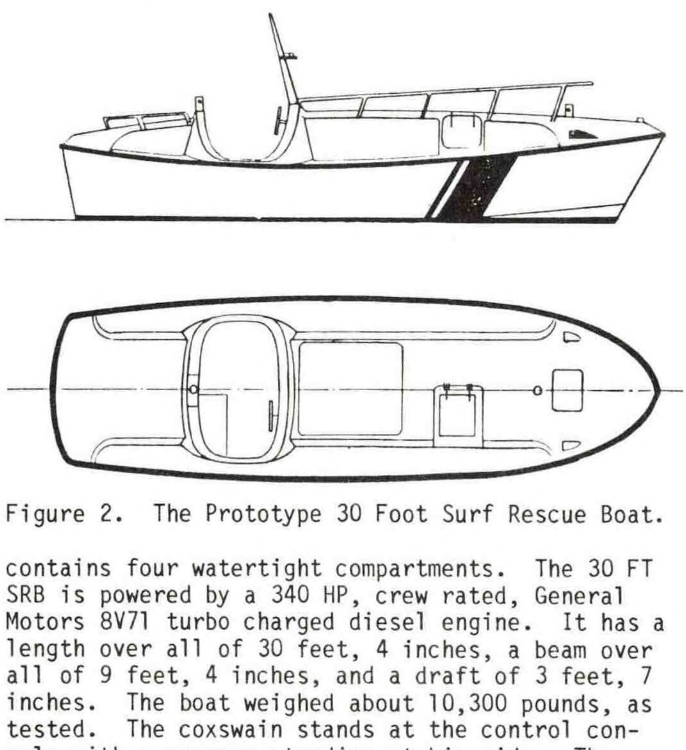

Figure 2. The Prototype 30 Foot Surf Rescue Boat.

contains four watertight compartments. The 30 FT SRB is powered by a 340 HP, crew rated, General Motors 8V71 turbo charged diesel engine. It has a length over all of 30 feet, 4 inches, a beam over all of 9 feet, 4 inches, and a draft of 3 feet, 7 inches. The boat weighed about 10,300 pounds, as tested. The coxswain stands at the control console with a crewman standing at his side. The coxswain and crewman are harnessed to the boat so that they will stay with the boat if it rolls over. The boat tested is currently in service at the Coast Guard Station Tillamook, Oregon.

TEST PROGRAM

This was an operational evaluation program not a technical test program. Nevertheless, the need to take some engineering measurements was apparent. These included speed versus engine RPM tests, taking noise level measurements, and measuring the vertical accelerations experienced during bar crossings. This information would quantify some of the basic performance characteristics of the boats, and provide a data base for objective comparisons.

We had to decide whether to try and have individual coxswains, with a great deal of experience with one particular boat, demonstrate the merits of the individual boats; or to have experienced heavy weather coxswains, with little or no experience driving RHIBs or the 30 Foot SRB, evaluate the relative merits of all of the boats. We felt that the objectives of the test program would be served best by adopting the latter alternative. This required that a program of training and familiarization be incorporated into the test plan.

There is a triad of related elements that interact whenever you test a boat. These elements are the boat, the coxswain, and the environment. The coxswain and the environment are subject to change during the course of a one week evaluation program. Therefore, the Graeco-Latin Square technique of experimental design was used extensively in these tests. The evaluation depended heavily on the answers to questionnaires which were given to the coxswain and crewman immediately at the end of each test. The Graeco-Latin Square technique, or the round robin as it was called at Cape Disappontment, gave each coxswain and crewman an equal opportunity to be in any given boat, at any given time. It prevented one man from having a steady influence on the opinion of another. Finally, it allowed the results to be analyzed statistically to remove individual bias.

The formal program of RHIB familiarization and test began on Monday, 22 February 1982. The coxswains and crewmen were given the objective, history, and scope of the program. Operating areas were located on charts, dangerous areas were identified, and the philosophy and approach of the program discussed. The men were given an overview of the test plan and schedule. The nature of the questionnaires was explained and their importance to the operational evaluation stressed. Technical representatives covered the design, manufacture, and general capabilities of each boat.

The practical portion of the familiarization phase of the program began in the afternoon. Each of the coxswains and crewmen was given a chance to take a calm water familiarization run in each boat in accordance with a Graeco-Latin Square design. A technical representative was assigned to each boat to answer questions and give advise to the coxswains. The coxswains were told to get the feel of each boat, and each was asked to determine if each boat could perform a quick turn at maximum speed without accident. Each boat was brought to a dock to practise docking and slow speed maneuvering.

Tuesday morning was devoted to the following series of calm water tests. First, acceleration from a standstill to maximum speed. Second, acceleration from a speed of 10 MPH to maximum speed. These tests were run in two directions along a channel. Third, quick turn tests at maximum speed to both port and starboard. Finally, a zig-zag test turning quickly first to port and then to starboard, and then a zig-zag test turning quickly first to starboard and then to port. These tests were also conducted in accordance with a Graeco-Latin Square Design. None of the boats had any difficulty performing these tests.

The afternoon was devoted to a relatively unstructured familiarization and training exercise in waves. Crews switched from boat to boat, but a strict round robin was not followed.

Wednesday morning was devoted to a series of towing tests. Each of the RHIBs took the 30 FT SRB under stern tow, from the Coast Guard Station, out the channel, into waves and returned. Upon returning to the area of the Coast Guard Station, each RHIB took the 30 FT SRB under side tow, and brought the boat alongside the dock. None of the RHIBs had any trouble towing.

The operational evaluation program was secured after lunch because the water was too calm. Speed versus RPM tests were run on each of the RHIBs, and some noise level measurements were made on Wednesday afternoon.

Thursday morning was spent evaluating the ease with which people can be recovered from the surf using the RHIBs and the 30 FT SRB. Each boat practiced maintaining a heading in the surf, and then went in to retrieve a dummy. This was done in accordance with a Graeco-Latin Square design. At the end of the round robin a volunteer went into the water three times, and was rescued in turn by each of the RHIBs. The RHIBs were vastly superior to the 30 FT SRB for pulling people out of the water.

Thursday afternoon each of the boats left the fuel dock, ran out the channel and crossed the Columbia River Bar to run in deep water in areas around the sea buoy. A bank of vertical acceleration counters was mounted on each of two Stokes litters, which in turn were mounted on the Avon 6 Meter, and the Arctic 24 RHIBs. Each of the RHIBs did a practice Stokes litter hoist with a Coast Guard helicopter.

Friday morning the weather was foul. Each of the boats left the fuel dock, ran down the channel and out into open water. The boats rendezvoused with a 44 Foot Motor Life Boat, which acted as a safety and rescue boat, and returned to the dock. A bank of vertical acceleration counters was mounted on each of two Stokes litters, which in turn were mounted on the Pacific 22 and the 30 FT SRB. We had planned to switch crews and make another run, but rain squalls limited visibility and we stopped testing.

Friday afternoon was spent filling out questionnaires and discussing the capabilities of the RHIB for search and rescue work in the breaking, bar, surf environment. The men were enthusiastic about the RHIBs.

ENGINEERING TEST RESULTS

A short series of tests were run in which the speed (MPH) of each RHIB was measured at a series of engine speeds (RPM). The tests were run in calm water, in two directions, and the average speed calculated. Speed is reported in MPH rather than knots because it was measured with a radar gun which was calibrated in MPH.

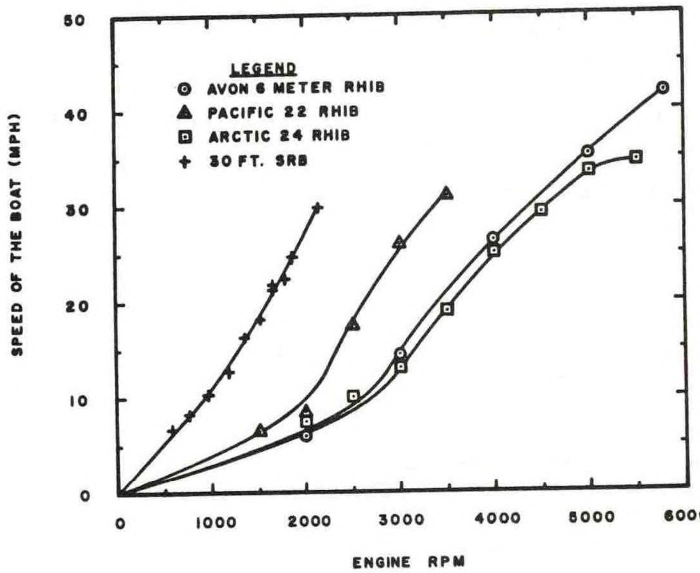

Figure 3. Speed Versus Engine RPM for all Test Boats

The results of the tests are presented in Figure 3. The curve drawn through the 30 Foot SRB data is a second degree polynomial, least squares fit. The curves drawn through the data for each of the RHIBs came from a single master curve which was drawn through all of the RHIB data. The master curve, shown in Figure 4, was drawn on the basis of the following hypothesis. The engine speeds of the various RHIBs at any planing speed are in common ratio, e.g. at 20 MPH, the Pacific 22 engine RPM = 0.772 x the Avon 6 Meter engine RPH, and the Arctic 24 Engine RPM = 1.044 x the Avon 6 Meter Engine RPM. It is felt that, in a gross sense, this master curve indicates that we were testing variations of the same basic rigid hull inflatable boat. The performance of the Arctic 24 RHIB appears to fall off at an engine speed between 5000 RPM and 5500 RPM. The propellers probably started to cavitate at this point.

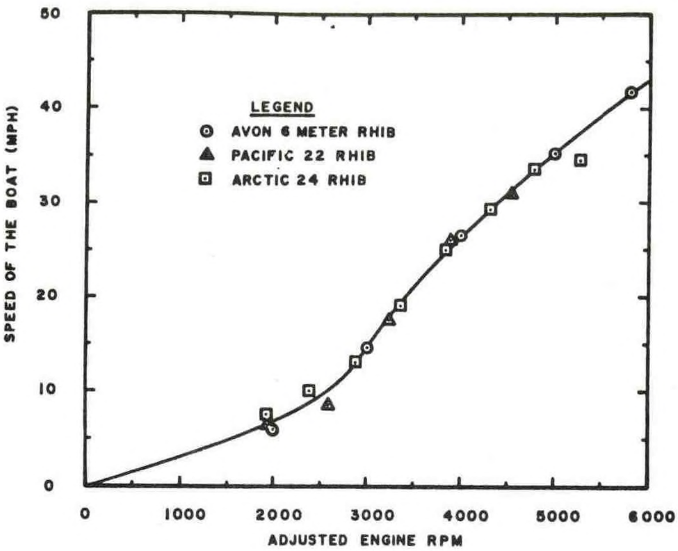

Figure 4. Master Curve for RHIBs

Noise level measurements were made on each boat. The measurements were made in order to provide an objective standard of comparison for use in evaluating the reasonableness of the coxswain's and crewmen's answers to questions about noise. They were not made to provide definitive noise level values for the boats. Unfortunately, the sound level meters were not equipped with a wind screen.

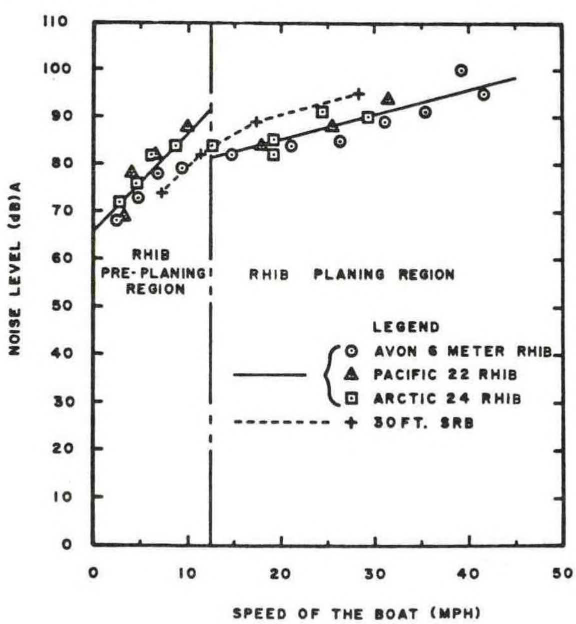

Figure 5. Noise Level Versus Speed of the Boat

The noise levels measured are presented in Figure 5. Two regions have been defined for the RHIBs: A RHIB pre-planing region, and a RHIB planing region. Data taken at speeds below 12.5 MPH (10.9 knots) falls into the pre-planing region. Data taken at speeds equal to, or greater than, 12.5 MPH falls into the planing region.

Two, discontinuous, solid lines have been drawn through all of the RHIB data. The lines were fitted to the data by the method of least squares-one for the pre-planing region, and one for the planing region. A single dotted line connects all of the 30 FT SRB data.

The noise level for the RHIBs increases with the speed of the boat, in the pre-planing region, as the boats work to climb up on plane. The noise level then drops sharply as the boat begins to plane. The noise level increases with speed, once again, as the boat continues to plane. Note that there is no appreciable difference between the noise level for a RHIB, at a given speed, and the type of engine used for propulsion. Although the sound level measurements made during these tests were not definitive, there is reason to believe that a noise exposure problem may exist for any of the boats operated at speeds in excess of 25 MPH (21.7 knots).

The safe and comfortable transportation of injured victims is an important aspect of adequately performing the search and rescue missions. Therefore, the vertical accelerations that a victim in a Stokes litter would experience were measured during the bar crossings on Thursday, 25 February 1982 and Friday, 26 February 1982. Sea conditions were worse on Friday than they were on Thursday. The surf was building to 12 foot breakers in the open water by the end of the day on Thursday, while some 15 foot breaking waves were encountered on Friday.

TABLE 1. VERTICAL ACCELERATION DATA FOR THE OSBORNE ARCTIC 24 RHIB

Range of Acceleration	Frequency of Occurrence	Probability of Occurrence	Cumulative Probability
$1 \leq g's < 2$	419	0.6683	0.6683
$2 \leq g's < 3$	116	0.1850	0.8533
$3 \leq g's < 4$	55	0.0877	0.0410
$4 \leq g's < 6$	21	0.0335	0.9745
$6 \leq g's < 8$	11	0.0175	0.9920
$8 \leq g's < 12$	4	0.0064	0.9984
$12 \leq g's$	1	0.0016	1.0000

TOTAL NUMBER OF COUNTS = 627.
DATA TAKEN 25 FEBRUARY 1982.

The vertical acceleration data taken on Thursday for the Arctic 24 is presented in Table 1. The Arctic 24 was traveling at about 27 MPH on Thursday. Vertical acceleration data taken on Friday for the 30 FT SRB is presented in Table 2. The 30 FT SRB was traveling at about 19 MPH on Friday. It is significant that the number of acceleration counts registered on the 30 FT SRB is an order of magnitude lower than that registered on the Arctic 24. Note that a small number of counts for accelerations equal to, or greater than, 8 g's were registed on both boats. This was true on all boats. One count of an acceleration equal to, or greater than, 12 g's was registered on the Arctic 24. Two such counts were registered on the Pacific 22.

TABLE 2. VERTICAL ACCELERATION DATA FOR THE USCG 30 FOOT SRB

Range of Acceleration	Frequency of Occurrence	Probability of Occurrence	Cumulative Probability
$1 \leq g's < 2$	29	0.5918	0.5918
$2 \leq g's < 3$	7	0.1429	0.7347
$3 \leq g's < 4$	7	0.1429	0.8776
$4 \leq g's < 6$	1	0.0204	0.8980
$6 \leq g's < 8$	3	0.0612	0.9592
$8 \leq g's < 12$	2	0.0408	1.0000
$12 \leq g's$	0	0.0000	1.0000

TOTAL NUMBER OF COUNTS = 49.
DATA TAKEN ON 26 FEBRUARY 1982.

The existance of levels of acceleration as high as 8 or 12 g's not only raises the possibility of further injury to the victims being transported during a search and rescue mission, they pose problems for the crew. The measured values can be supported by theoretical calculations and they are believed to be valid. The only way to prevent these high values of acceleration, is to reduce the speed at which the boats travel.

RESULTS FROM QUESTIONNAIRES

Two types of questionnaires were developed. The first made use of a four category rating scheme where respondents were asked to rate a characteristic as either excellent, good, satisfactory, or poor; and simple yes or no responses. The second type of questionnaire was designed to force each rater to rank order the test boats from one to four with instructions that there should be no ties.

Two non-parametric tests were chosen to analyze the data. The first type of questionnaire was analyzed using the Chi-Square statistic. In addition, the median response was computed for each question and used to compare statistically significant responses. For the second type of questionnaire, a program was written which computed the Kendell Coefficient of Concordance, W. This statistic is essentially a non-parametric correlation coefficient which assumes a value from zero to one, where zero indicates no correlation and one indicates a maximum correlation.

The results of the questionnaire analysis are presented accordinging to category and not specific questionnaires. Only statistically significant responses are discussed.

Maneuverability and Steering: The only significant responses were in regards to bow on docking and astern maneuverability. In both cases the Pacific 22 and the 30' SRB were rated less than the two outboards.

Power and Speed: Initially, in the Familiarization and Training period, there was a significant response to the question relating to acceleration; both from a dead stop and when underway. Again, there was a break between the diesels and the outboards; the outboards being preferred. During man overboard trials (Scenario I) there was no significant difference noted between the boats. The median scores are close and there is no break between diesels and outboards.

Human Factors: The largest number of questions with significant responses were in the human factors sections. The questions are discussed by category below:

a) Visibility: Both the coxswains and crewman found the near visibility of the SRB to be poor. The coxswains noted the Pacific 22 to be satisfactory but the other RHI's good to excellent.

b) Accessibility of Electronics: The coxswains rated the SRB as poor, the two RHI's with electronics as excellent.

c) Feeling of Comfort and Security: Following the Quick Turn/Zig-Zag maneuvers, the crewman indicated that they felt in danger of being thrown overboard.

d) Man Overboard Retrieval: With regard to Gunwale Height and Ease of Retrieval the RHI median scores indicated a rating of "good" while the SRB was reated "satisfactory".

The Boat Comparsion Questionnaires were intended to force each rater to rank order the boats according to personal preference. Initially, significant results were found only in the questions dealing with visibility, course keeping and acceleration. Both coxswain and crew rated the boats in the following order for visibility: (1) Avon 6M, (2) Arctic 24, (3) Pacific 22 and (4) SRB. For course keeping, the coxswains rated the boats (1) Pacific 22, (2) Arctic 24, (3) Avon 6 M and (4) SRB. And for the acceleration (1) Avon 6 M, (2) Arctic 24, (3) SRB and (4) Pacific 22.

For victim retrieval, both the coxswains and crewmen were in agreement and rated the boats by preference (1) Pacific 22, (2) Arctic 24, (3) Avon 6 M and (4) SRB. For size preference there was no agreement among the crewmen but the rating given by the coxswains was (1) Pacific 22, (2) Arctic 24, (3) SRB and (4) Avon 6M.

The question relating to noise yielded an interesting result. They agree with the decibal measurements taken while the boats were operating and show that at least in terms of perceived noise level there is no noticeable difference among the boats.

CONCLUSION

The present state-of-the-art for the RHIB affords the Coast Guard a major opportunity to extend its operational effectiveness beyond its present state. The RHIB can become an extremely valuable resource. It is a fast, highly maneuverable and extremely seaworthy boat.

A SEAKEEPING ANALYSIS OF SURFACE EFFECT SHIPS

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ABSTRACT

Seakeeping data on Surface Effect Ships (SES) indicate two major ride quality characteristics. The crafts tested have excellent roll and pitch stability at all speeds; however, vertical accelerations are quite severe in high speed ranges. The Coast Guard is concerned with defining SES vertical accelerations and evaluating their effect on both crew fatigue and crew proficiency. Tentative plans are progressing to install a digital ride-control system onboard an operational SES to attenuate vertical motions and improve the overall mission effectiveness of the vessel/crew combination.

INTRODUCTION

The Coast Guard operates a division of surface effect ships in Key West, Florida. The SES division consists of three vessels. Two of these vessels have been operating for about six months and the third vessel was scheduled for delivery on 17 June 1983. These boats are being used for drug interdiction in the Gulf of Mexico and Florida coastal area.

This paper looks at SES motions (primarily vertical accelerations) in head seas. Recent research has attempted to link ship motion with motion sickness and crew fatigue. Most of this research has concentrated on motions in the 0.1 to 1.0 HZ range. Many studies have proposed fatigue boundary limits in this range, but no one method has ever been universally accepted. The SES at low speed responds to wave encounters in low frequencies (0.1 - 0.6 HZ the motion sickness range). However, the area of concern for the SES is at high speeds where we can expect the worst motions. SES motions in head seas, above a hump speed of 19 to 22 KTS, occur at a relatively "high" frequency of 1.8 to 2.0 HZ. Vibrations in this frequency range cause human fatigue. Reference 1 details acceptable vibration limits for fatigue and exposure in the 1.0 to 80.0 HZ range.

It is important to ensure that SES ride quality does not cause fatigue and reduce crew efficiency. The ride quality of the SES can be characterized by comparing vertical accelerations against recommended limits. No attempt has been made to compare SES ride quality to other vessels operating in similar environments.

HEAVE ENERGY

Figure 1 shows the dramatic shift of heave energy from 0.4 to 1.8 HZ with a speed increase from 22 to 28 KTS. This figure also shows how the SES response is not dominated by a single frequency like a conventional craft. The SES is characterized by a response over a spectrum of frequencies. The one-third highest heave accelerations, corresponding with this speed change, increase from 0.2 to 0.4 G's.

HEAVE SPECTRUM CGC SHEARWATER (WSES 3)

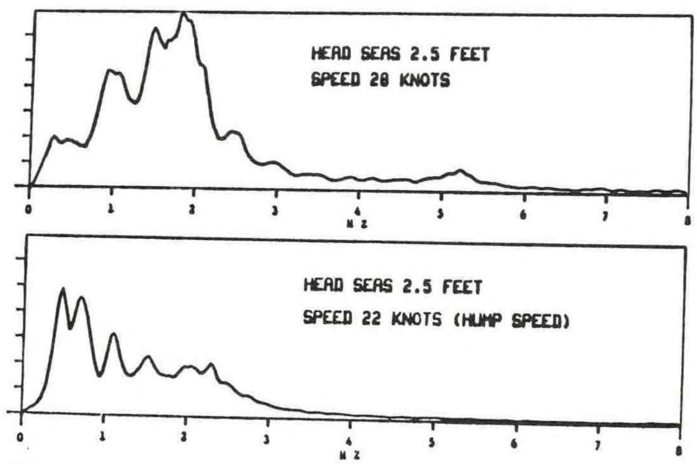

Figure 1. Heave Spectrums (G's RMS).

Severe motions in the range of 1 to 80 HZ cause human fatigue and eventual loss of proficiency over a period of time. The SES heave motions are within this range and future research should consider the possible degradation of crew safety and mission effectiveness. The relatively "high" frequency (1.8 HZ) and intensity of whole body vertical accelerations (0.4 G's at 28 kts head seas) are most likely related to the natural frequency of the vessel on cushion above hump speed. The heave energy was reduced to 0.2 G's and shifted downward to the wave encounter frequency (0.4 HZ) when the vessel reduced speed to 22 kts. At this speed the vessel responds more like a conventional displacement hull craft, and consequently ship motions fall within the motion sickness frequency range (0.1-0.6 HZ). The shift of heave energy with change of speed, which is most pronounced in head seas, was also observed when transiting at all other headings relative to the sea direction.

The magnitude of this shift can be seen by comparing the root mean square (rms) power lost in a 1 HZ band centered around the 1.8 HZ peak prevalent at 28 kts that disappears at 22 kts. Heave power in that band decreased 88% when speed was reduced from 28 to 22 kts in head seas (Figure 2 and 3). In addition, the power concentrated at 1.8 HZ is very dependent on sea direction as well. There was a 67% decrease of heave rms power when the vessel changed relative headings from head seas to bow quartering seas at 28 kts (Figure 2 and 4).

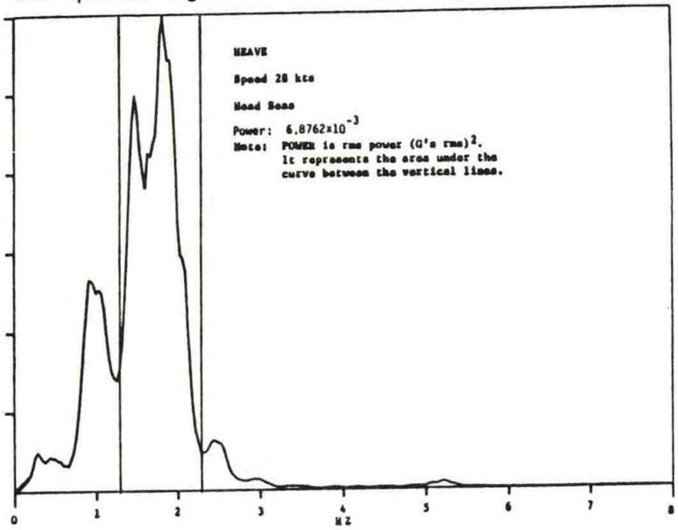

Figure 2. Heave Spectrum (G's RMS).

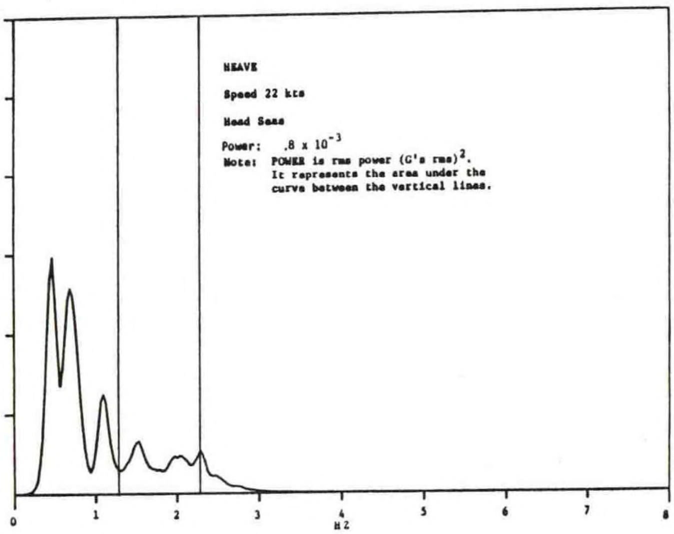

Figure 3. Heave Spectrum (G's RMS).

In Figure 4 it is interesting to note that there are two frequencies where power appears to peak. The peak at 0.25 HZ corresponds to an expected frequency of encounter with the seas off the bow quarter. The peak at 1.8 HZ is once again related to the natural frequency of the vessel when on cushion above hump. This peak is probably caused by an interaction between the natural frequency of the vessel and the frequency of encounter.

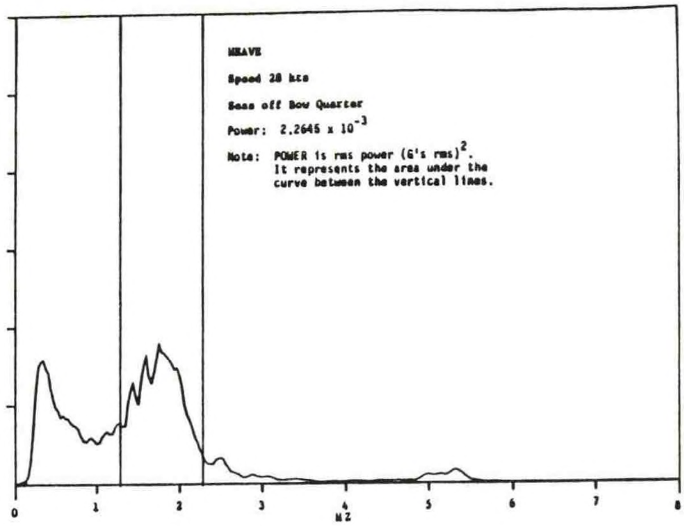

Figure 4. Heave Spectrum (G's RMS).

MOTIONS

Figure 5 shows curves of SES vertical accelerations for various sea state. These curves were generated by a regression analysis using data taken from CG testing and data presented in references 2 and 3. The trends exhibited by Figure 5 confirm the rise in acceleration levels that we expect with increasing sea state and speed. The severity of accelerations in sea state 0 (significant wave height of 0.2 ft or less) at speeds above hump is noteworthy. These accelerations are probably the result of a small sea state with shorter wavelengths driving up the frequency of encounter to somewhere near the natural frequency of the SES in heave (1.8 HZ). The level of accelerations experienced above hump speed in sea state 2 or larger is also of significance and may be cause for concern.

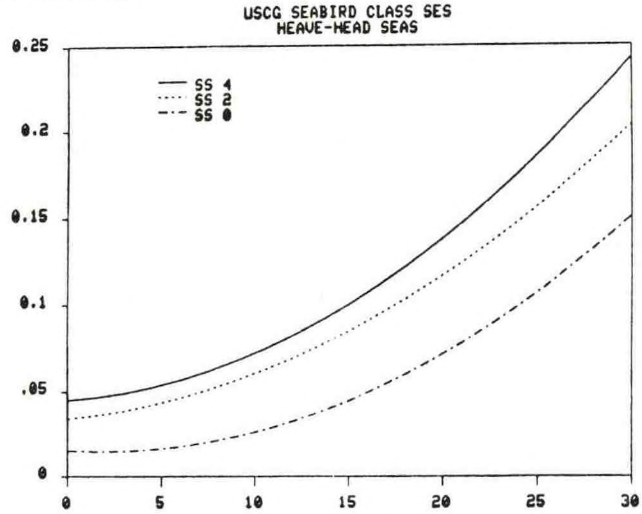

Figure 5. 110-FT SES Vertical Accelerations (G's RMS).

The frequency of response for the SES in heave has been shown to shift dramatically with high speed operations. As the response frequency increases beyond 1.0 HZ the level of accelerations become more critical in regards to human exposure to whole-body vibration. Reference 1 places an increased emphasis on vibrations that approach the frequency of the human body (standing - 5.0 HZ). This leads us to believe that SES heave motions may carry a higher weight (i.e. may be more critical) than motions from a conventional displacement hull craft because of the higher frequency response of the SES in heave. At the same time when we characterize SES vertical accelerations using the rms evaluation method we may be underestimating their severity. Vibrations having a high crest factor (i.e. greater than 3) are often underestimated using the rms evaluation method. These vibrations are expected to occur with the SES when the forward cushion vents as a result of the right combination of sea state and speed.

RIDE CONTROL SYSTEM

As the SES operates in a seaway, the waves pump the cushion volume. This causes the cushion pressures, which support the craft, to rise and fall inducing heave motions. Figure 6 illustrates how the ride control system modulates cushion pressure to reduce heave. The ride control system uses cushion pressure as a feedback variable. In low sea states vertical accelerations and cushion pressure are directly proportional. Various control laws can be instituted for various sea states. Typically, the control laws are designed to vent air to the atmosphere to counteract a wave induced pressure rise. The U. S. Navy in concert with Maritime Dynamics, Inc. has shown that significant improvement in SES habitability can be expected using ride control. Test results from ride control installations on the XR-1D and the SES-200 have been encouraging.

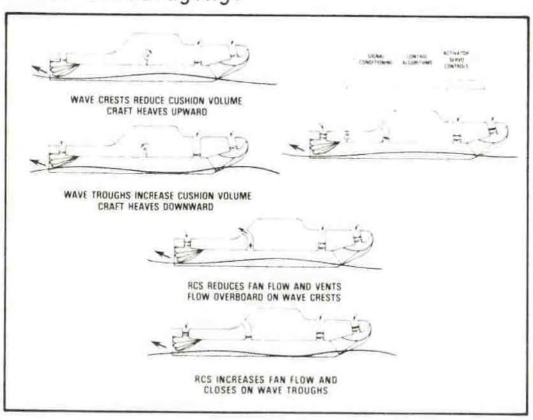

Figure 6. Illustration of Ride Control System Operation.

The CG 110 FT SES experiences high vertical accelerations in relatively calm seas. Figure 7 shows the frequency of occurrence of different waveheights for the Gulf of Mexico and Southeast United States. This data was taken from reference 4. For this area there is a 60% probability that the expected waveheight will be less than 3.3 FT. Likewise, there is a 90% probability that the waveheights encountered will be less than 6.6 FT. In this environment a ride control system would be extremely effective. Reductions in heave on the order of 50% could be expected in sea state 3 or lower. And a reduction of 30-40% could probably be expected for sea state 4 conditions.

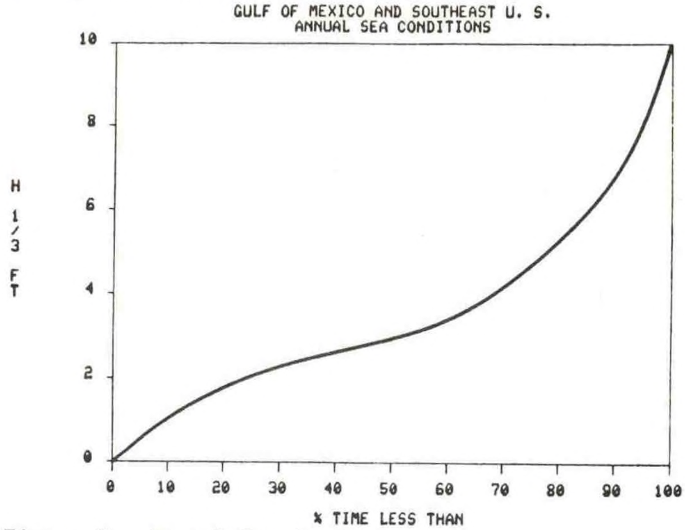

Figure 7. Annual Sea Condition.

Assuming vertical accelerations to be the best criteria for SES ride quality, a ride control system could maximize the effectiveness of a CG SES performing its assigned mission in its intended environment.

The most jarring motion for an SES occurs when the bow crests over an oncoming wave. As this occurs the forefoot comes out of the water and the cushion vents to atmosphere. This action causes a large amplitude spike to occur as the cushion pressure is lost and builds back up again. An effective ride control system would reduce the frequency of this occurrence. Additional ride benefits will occur such as better flow to the propeller due to less broaching and an ability to better maintain speed in a seaway due to a reduction in pitch and heave. Reduction in motion will partially offset the loss of speed (calm water) associated with ride control usage.

CONCLUSION

Crew comfort, safety and mission effectiveness are primary concerns. The implication of severe motions causing crew fatigue, adversely effecting health and safety, and decreasing performance cannot be ignored. Preventative measures such as ride control have to be investigated. Some undesirable motions can be accepted when we send our crews out in severe weather. On a military vessel we can expect to compromise crew comfort in performing certain missions. However, crew fatigue and decreased proficiency should be addressed whenever possible.

The CG Office of Research and Development is continuing full-scale SES testing trying to shed light on these areas of concern. Future testing will be involved with looking at various motions and trying to identify and control the forcing function behind the motion. Current emphasis is on assessing the capabilities and potential for a ride control system onboard a CG SES.

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NEW TECHNOLOGIES FOR SEARCH AND RESCUE

CDR. JAMES R. WHITE

U. S. COAST GUARD

The United States Coast Guard Office of Research and Development has been actively investigating the use of new technologies to improve its Search and Rescue capabilities. Major projects underway include, development of an all weather, day/night, multi sensor system for the HU-25A medium range search aircraft; development of Forward Looking Infrared systems for both ships and helicopters; and investigation of a satellite aided Search and Rescue system. Taken together these systems have the potential of dramatically improving our ability to locate vessels and downed aircraft in distress. Initial testing has already resulted in many successful rescues.

AIREYE

AIREYE is the designation of an advanced ocean surveillance system that is currently being developed for the HU-25A medium range search aircraft. It is a multi-sensor system that includes a Side Looking Airborne Radar (SLAR), infrared/ultraviolet linescanner, reconnaissance film camera, Active Gated Television (AGTV), airborne data annotation system, and a control and display console. Current plans are to acquire six AIREYE sensing systems, which will have the capability to detect and identify vessels and detect and map oil spills. The aircraft are modified Falcon 20G (military designation HU-25A), which are currently being purchased by the Coast Guard. The first of 41 aircraft was delivered in early 1982.

SIDE LOOKING AIRBORNE RADAR (SLAR)

The SLAR to be integrated into the AIREYE system is a new generation of the AN/APS-94 SLAR which has been in the Department of Defense inventory for 15 years in various versions. It was manufactured by Motorola Incorporated and has been designated as AN/APS-131.The SLAR has been the backbone of past generation Coast Guard integrated sensor systems, and is expected to continue as the "key" sensor in the system. The operating characteristics which distinquish the SLAR as the prime AIREYE sensor are:

a. Long Range - Detection of discrete targets depends upon their radar cross secton. A 1 square meter radar cross section would be equivalent to a small boat or life raft, 10 square meters to a cabin cruiser and 100 square meters is equivalent to a small cargo ship. Small boats and life rafts should be detected at ranges up to 22 nautical miles on each side of the aircraft, Cabin Cruisers up to 39 nautical miles and small cargo ships up to 68 nautical miles. In addition, the SLAR is useful for detecting oil slicks. Oil slick detection range with the new generation AIREYE SLAR is estimated to be between 24 and 40 km depending on sea state and aircraft altitude. This could provide an oil detection swath width of up to 80 km.

b. All-Weather Day/Night Operation- the SLAR can produce good imagery in most weather conditions and is unaffected by clouds or darkness. Since the detecion of oil slicks by SLAR depends on the damping of capillary waves by the oil, slicks normally cannot be detected by SLAR on flat calm seas or on very heavy seas.

c. Wide Area Mapping - The output imagery of the SLAR is a wide area map on 23 centimeter dry-silver film, and video for presentation on the Multi-purpose Display.

INFRARED/ULTRAVIOLET (IR/UV) LINE SCANNER

The IR/UV line scanner has a two fold purpose on AIREYE. It is used to scan the area directly below the aircraft that is missed by the SLAR. In addition, targets detected by the SLAR can be overflown and imaged by the IR/UV line scanner. With data from three portions of the electromagnetic spectrum (SLAR, IR, UV), wake scars and kelp beds can be differentiated from oil slicks. The output imagery from the line scanner will be recorded on film and also can be shown in real time on the multi-purpose display. The optical/mechanical portion of the line scanner will be pod mounted from the starboard wing of the HU-25A.

AERIAL RECONNAISSANCE CAMERA

The Aerial Reconnaissance Camera will be a KS-87B camera which is presently in Department of Defense inventory. It is produced by Chicago Aerial Industries and is a pulse operated frame camera containing interchangeable lens cones, high speed focal plane shutter, integral automatic exposure control, data recording and forward motion compensation. The film handling system will be a combination cassette-magazine drive capable of operation with full 150 meter (m) standard film spools. An optical window in the HU-25A will permit operation of the camera in two positions, either vertical or 30° below horizontal. Table 4 lists detailed camera characteristics.

ACTIVE GATED TELEVISION (AGTV)

The AGTV sensor is required to provide nighttime identification of vessels and their activities. It was developed by General Electric's Aerospace Electronic Systems Department in Utica, New York. The AGTV is a small, light weight, low power, system that will be pod mounted under the left wing of the aircraft. It will have a 39 cm turret with a stabilized pointing system. In the passive mode, it will function as a low light level television and have a maximum field of view of 18°. It will be capable of detecting deck lights of 320 candella at a range of 21 Kilometers (km). As the aircraft approaches the ship at approximately 150 m altitude and a speed of 250 km/hr, the field of view is reduced to 6.5° and finally to 2.3°. At a slant range of 4 km, the AGTV is switched to the active mode, and at this range small ships (6 X 18m) can be observed.

In the Active mode, illumination is provided by a 0.8 watt, pulsed gallium arsenide laser operating at 855 nanometers (nm). At a slant range of 500 meters, 35cm. high letters can be resolved and 20cm. high letters are readable at 300 m. The imagery will be presented on the AIREYE multipurpose display and recorded on a video tape recorder. This will enable the operator to play back the passes on the ship and "freeze" a frame to identify it.

CONTROL DISPLAY AND RECORD CONSOLE (CDRC)

The CDRC is the control point for the integrated sensor system. The "heart" of the CDRC is the sensor computer. The sensor computer will perform the following primary functions:

1. Automatic pointing of the Active Gated Television.

2. Generation of a map displaying search and target positions.

3. Implementation of display and control functions.

4. Digital interface of the Data Annotation Sytem to the Aircraft Data Buss.

5. Monitoring of sensor and system performance and failure alerting.

The display functions which will be available to the sensor operator at the console are:

1. Real-time imagery from the Side Looking Airborne Radar, Infrared Linescanner, or Ultraviolet Linescanner displayed in the form of a moving map in the Multi-purpose Display.

2. Real-time Television imagery will also be available on the Multi-purpose Display.

3. A computer generated map can be called up by the Control and Display Unit and presented on the Multi-purpose Display. It will depict relative positions of up to 10 Search Radar Targets and 10 Aircraft Waypoints.

4. A cursor, displayed as a unique symbol, such as a triangle, will be used to designate important targets. The Sensor System Operator will be able to move the cursor anywhere on the Multi-purpose Display using the trackball.

5. A vector can be displayed as a line with one end fixed, normally at the sensor aircraft position, and the other end varying with the cursor.

6. Full resolution stop action/frame freeze recording and playback of any video displayed on the Multi-purpose display will permit frame-by-frame examination of the imagery.

In addition to the individual sensor functions, the AIREYE computer will have on board image processing capabilities to improve the probability of correctly detecting marine targets and idenifying vessels.

AIREYE OPERATIONS - The AIREYE system will be a powerful tool for search and rescue. The SLAR will allow swath widths up to 44 nautical miles for life rafts and small boats and up to 136 nautical miles for small cargo ships. Vast ocean areas can be searched with probabilities of detection of over 90% in much shorter time than visual searches. Once a target is detected it can be observed and its activity recorded on video tape. This will enable positive identification of the target in either day or night.

SARSAT

The U. S. Coast Guard is also actively investigating the use of satellites to improve distress alerting and locating for search and rescue.

In 1976, joint U. S. and Canadian efforts defined a mission to demonstrate a satellite-aided SAR system which had been designated SARSAT (Search and Rescue Satellite-Aided Tracking). During 1977, France's Centre National d'Etudes Spatiales (CNES) became a participant in the SARSAT joint demonstration project. In August 1980, the Union of Soviet Socialist Republics also became a member in a joint COSPAS/SARSAT project team and, during June 1982, they sucessfully launched a COSPAS satellite into orbit. Since then Norway has also joined the SARSAT team and England is considering becoming a participant.

The SARSAT program will use the U. S. National Oceanic and Atmospheric Administration (NOAA) E, F, and G spacecraft in the TIROS-N spacecraft series to provide a repeater for the detection and locaton of ELT/EPIRB's. The first SARSAT satellite was launched into orbit on 28 March 1983 and began tests on 1 May 1983.

The objective of the SARSAT project is to demonstrate and evaluate the capability of satellite-aided search and rescue system to improve monitoring, detection, and location of distress incidents alerted by ELT/EPIRB's carried on commercial, military, and general aviation aircraft, and some marine vessels. The goal is to reduce the notification time that an ELT/EPIRB has been activated and to reduce the search time through accurate position information. Since being launched into orbit, the Soviet COSPAS satellite has validated the SARSAT concept with the relay of distress information to SARSAT receiving sites which has led to the rescue of 23 persons.

SARSAT SYSTEM CONCEPT

The SARSAT system provides two modes of operation, a local or regional coverage mode and a global mode. Spacecraft instrumentation consists of a three-band repeater for the regional coverage system, and a receiver and pre-processor for the global coverage system.

In the regional coverage system, the spaceborne repeater relays distress alerts in real-time, which may be transmitted from existing 121.5/243 MHz ELT/EPIRB's presently carried by aircraft and vessels, to local user terminal (LUT) ground stations. The regional system will also include a spaceborne repeater for real-time relay of experimental

ELT/EPIRB's which will operate in the 406 MHz band. The regional coverage system requires mutual visibility among the ELT/EPIRB and the satellite, and the ground receiving station and the satellite. Position information can then be determined from the Doppler profiles between the ELT/EPIRB's and an 850 to 1000 km altitude, polar-orbiting satellite tracked by the ground system. This information will then be forwarded to a Mission Control Center and the appropriate rescue coordination center (RCC).

The full-orbit global coverage SARSAT system will operate only with the experimental 406 MHz ELT/EPIRB's. This system will provide global coverage by storing information, which is received from a 406 MHz ELT/EPIRB distress alert transmission, aboard the satellite in view of the ELT/EPIRB. When the satellite orbits into visibility with a ground station, the on-board stored information is transmitted on command to a NOAA Control and Data Acquisition (CDA) ground station which forwards the distress alert information to an MCC for dissemination to RCC's. For the global coverage mode, the spacecraft on-board instrumentation includes a 406 MHz receiver and a pre-processor which computes and time-tags the Doppler profile relating to the ELT/EPIRB position and stores this information. Recovery and storage of the distress alert data from the 406 MHz ELT/EPIRB transmission is also performed on-board the spacecraft, as described later. This system will also work in real-time if there is mutual visibility with the ground station.

The key elements of the SARSAT system are:

1. NOAA TIROS-N Series Spacecraft

2. A satellite-borne repeater for the existing ELT/EPIRBs
(121.5 and 243 MHz)

3. A satellite-borne receiver and pre-processor for the experimental
(406 MHz) ELT/EPIRB

4. An experimental 406 MHz ELT/EPIRB

5. Local User Terminals (LUT)

6. Mission Control Centers (MCC)

Ground Processing Stations

Local User Terminals (LUT). When the spacecraft comes into view of a LUT, the LUT receives the phase modulated L-band downlink from the satellite. At the LUT, special processing will be used to search for the weak 121.5/243 MHz signals. Once the signal is detected, its frequency is recovered and time tagged. This time tagged Doppler information, in conjunction with the spacecraft orbit information, is used to calculate the ELT/EPIRB position. The position information is then sent to the appropriate Mission Control Center for transmission to the Rescue Coordination Center.

Mission Control Centers

The Mission Control Centers (MCC) will be responsible for;

Monitoring overall SARSAT status in their area

Receiving stored 406MHz data and ephemeris data

Distributing the ephemeris data to the LUTs

Processing stored 406MHz data to determine ELT/EPIRB location

Distributing ELT/EPIRB location information to RCCs

ACCURACY

The location accuracy of an ELT/EPIRB is governed by many factors, one of which is the geometry between the ELT/EPIRB and the spacecraft. Additionally, various frequency error sources affect the ability to measure the received frequency. These include at least the following seven items:

. Reference Oscillator Drift

. ELT/EPIRB Oscillator Drift

. ELT/EPIRB Altitude Uncertainty

. Ionospheric Effects,

. RF Link Interference or Noise,

. Measurement Precision, and

. Ephemeris Knowledge

Performance analysis indicates that the SARSAT 121.5/243 MHz system will be able to detemine position to within 10-20 km (rms). Initial experiences with the COSPAS satellite reveal that the position determining accuracy has been on the order of 12 miles for 121.5/243 MHz. The 406 MHz system will be able to locate an ELT/EPIRB to within 2-5 Km (rms).

The U. S. Coast Guard Office of Research and Development is conducting an extensive evaluation of the SARSAT system to determine its actual performance as an operational system. Commencing with the satellite launch, NASA began a three month system checkout. For the next two years, the Coast Guard will conduct a number of tests concentrating on the assessment of SARSAT's ability to detect and locate 121.5, 243, and 406 MHz EPIRB signals. Specifically the evaluation period is designed to:

. Demonstrate the ability of the SARSAT system to identify, process, and determine the location of single and multiple 121.5/243 MHz and 406 MHz EPIRB's in the regional mode of operation.

. Determine the degree to which the SARSAT system may reduce times between initial incidence occurrence and visual sighting of the distress incident.

. Evaluate the degree to which 121.5/243 MHz EPIRB assisted SAR operations may be improved by SARSAT.

. Demonstrate the ability of the SARSAT system to identify, process and determine the location of single and multiple 406 MHz EPIRB in global mode of operation.

. Compare the demonstrated performance of the 406 MHz EPIRB with that of the 121.5/243 MHz EPIRB with respect to both SAR and SARSAT system performance parameters.

. Evaluate the potential improvements in future SAR operations using 406 MHz EPIRB's.

. Determine the communications requirements necessary to utilize SARSAT effectively in an operational environment.

. Characterize SARSAT system performance parameters.

. Determine cost benefits/disadvantages due to SARSAT.

. Determine the increase/decrease in Coast Guard workload produced.

. Evaluate recurring costs or operating SARSAT ground system network and facilities, equipment reliability and maintenance requirements.

The evaluation commenced in the fall of 1982 with the launch of the Soviet COSMOS 1,383. That satellite has been credited with saving more than 15 persons in downed aircraft and maritime accidents. Coverage has been increased with the launch of the United States' satellite NOAA 8 on 28 March 1983 and another COSMOS satellite in spring 1983.

First Successful SARSAT Rescue.

On 9 September 1982, the Canadian rescue requested that the Canadian Mission Control Center assist them in their search for an overdue aircraft. The next day the SARSAT Mission Control Center reported detecting a signal. Its location was in an area that had already been searched and there were no plans to conduct additional search efforts there. Responding to the SARSAT information, the downed aircraft was located in a deep ravine surrounded by 8,000 foot mountains on each. The 3 persons were rescued at a position only 14 miles NW of the position predicted by SARSAT. They were reported to be in a weaken condition and probably would not have survived another night.

FLIR

One of the largest obstacles to conducting an effective search has been the onset of darkness. Night searches have historically been ineffective, unless the vessel or persons in distress were equipped with lights or pyrotecnic devices. The U. S. Coast Guard has equipped some helicopters with powerful search lights, but they have been of limited value. However, it now appears that the rapidly improving technology of night vision devices is clearing away the cloak of darkness. In addition to the Active Gated Television system that was discussed earlier as part of the AIREYE system, the U. S. Cost Guard Office of Research and Development is also investigating the use of Forward Looking Infrared (FLIR) sensors for search and rescue applications. In conjunction with Northrop Corporation, the Coast Guard has developed a prototype FLIR system that has been installed on an HH-52A helicopter. Additionally, an inexpensive "off-the shelf" FLIR has been installed on an HH-52A helicopter for test and evaluation, and plans are under development to test and evaluate a shipboard installed FLIR in the near future.

Coast Guard/Northrop FLIR development

The Coast Guard Northrop FLIR has been designed specifically for the search and rescue mission. It is attached to a support on the nose of the aircraft and is enclosed in a turret assembly that is 16 inches in diameter and weighs about 85 pounds. It will slew at 180^{o}/second and has gimbal limits of $+30^{o}$ and - 80^{o} in elevation and plus or minus 90^{o} in azimuth. A stow mode is also provided whereby the FLIR window is rotated upward for stowing under the turret support structure. This protects the optics from damage during take-offs and landings, and because most Coast Guard flying is done at low altitudes over the water, the FLIR is further protected from water damage. Complete submersion of the turret will not damage the FLIR.

The FLIR provides two fields of view (FOV) - Wide and Narrow. The Wide Field of View (WFOV) has an elevation of 30^{o} and an azimuth of 40^{o}. This view is a compromise between viewed area and detail. The viewed area should be large enough to permit a reasonable time to cover a search area and still be detailed enough to enable a person in the water to be seen. A second FOV is provided to for more detail. This Narrow Field of view (NFOV) is 10^{o} elevation by 13.3^{o} azimuth which is a magnification of three and gives much better detail. The procedure is to use the WFOV for location and NFOV for identification.

Two monitors are furnished for the helicopter crew. A 10" display is located in the cabin and a 5" display in the cockpit. Each monitor has its own handgrip control which enables the crewman and the copilot to manipulate the FLIR. The monitors have symbology that shows:

1. What station has FLIR control
2. The track windows
3. NFOV limits when WFOV is selected
4. Gimbal limits of turret
5. Direction the FLIR is pointing in relation to nose of aircraft.

EXPERIENCE

The FLIR equipped helicopter has been in operation since July 1981. During this period it has proven highly reliable and effective. Two days after the Coast Guard formally accepted the FLIR from Northrop, it was used at night to locate a 10 foot Boston Whaler that had been blown out to sea. The helicopter crew sighted the small boat on the FLIR long before they could see it visually. They could actually see the persons in the boat waving their arms!

A second rescue involved locating a capsized boat with three people on-board. This rescue occurred at midnight with 1/4 mile visibility and with a 4000 ft ceiling. The crewman, using the cabin display, located the overturned vessel within 30 minutes after arriving on scene, and vectored the helicopter to the capsized position. The pilots never visually saw the victims until the helicopter was in hovering over them.

SRR FLIR Program

Based upon the successful FLIR demonstration on the HH-52A, the Coast Guard has decided to equip each of its 90 new HH-65A Short Range Recovery (SRR) helicopters with FLIR systems. The HH-65A helicopters, manufactured by Aerospatial in Grand Prairie, Texas, are scheduled for delivery beginning late 1983. The Office of Research and Development plans to release a request for proposals in the summer of 1983 to develop a prototype high performance FLIR for the HH-65A. A contract will be awarded in FY84 to each of the two highest rated proposers to develop prototype systems. A "fly off" will be conducted between the two prototypes prior to the award of a production contract.

The HH-65A FLIR will be a high performance sensor with three fields of view - 30^{o} x 40^{o}, 10^{o} x13.3^{o}, and 5^{o} x 6.5^{o}. It will be stabilized and weigh less than 150 pounds as installed on the helicopter.

Coast Guard Evaluation of FLIR Systems Inc.
Model 1000 FLIR

In addition to the Northrop FLIR development, the Coast Guard Office of Research and Development has also investigated the utility of a low cost off-the-shelf FLIR as an interim helicopter night vision sensor for use until the completion of the HH-65A FLIR production in 1988. A commercial FLIR System Model 1000A was purchased and installed on an HH-52A helicopter at Coast Guard Air Station Miami in November 1982. The model 1000A is a small, lightweight system that is easily installed on the helicopter's might sun searchlight mount. Its characteristics are:

Fov
27^{o} x 17^{o}

Resolution
1.87 mrad

MRTD
0.2^{o}C

Spectral Range
8-12 UM

Weight
26 kg

Power
12 VDC at 7.5 amps.

The FLIR systems model 1000A has performed surprisingly well while at Miami. Although its lower thermal sensitivity and optical resolution generally resulted in shorter ranges for detection and observation of targets, and it lacked such features as a stabilized turret, automatic tracking, narrow field of view, and cockpit display, available on the high performance FLIR, it did provide a good basic night vision capability. Also, the manufacturer has recently introduced an upgraded version that now includes a second narrow field of view.

Conclusion

The emerging new technologies of remote sensing systems have wide applicability for all Coast Guard search and surveillance missions. They have the ability to turn night into day and enable the Coast Guard to patrol vast ocean areas more quickly and efficiently.

AIRSHIP EVALUATION FOR COAST GUARD MISSION PLATFORM

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ABSTRACT

The Coast Guard Office of Research and Development is investigating the use of airships as a possible mission platform for the future. The U.S. Navy used non-rigid airships extensively up until the mid 1960's when their military needs shifted to other air and surface craft. The Navy experience with nonrigids, or "blimps", included many impressive capabilities in maritime operations, yet not without a few problem areas that need to be improved in a modern design. The Coast Guard program has been planned to build on the experience of the past and apply the advances in technology of the present into a modern airship system for the 1980's and 90's.

INTRODUCTION

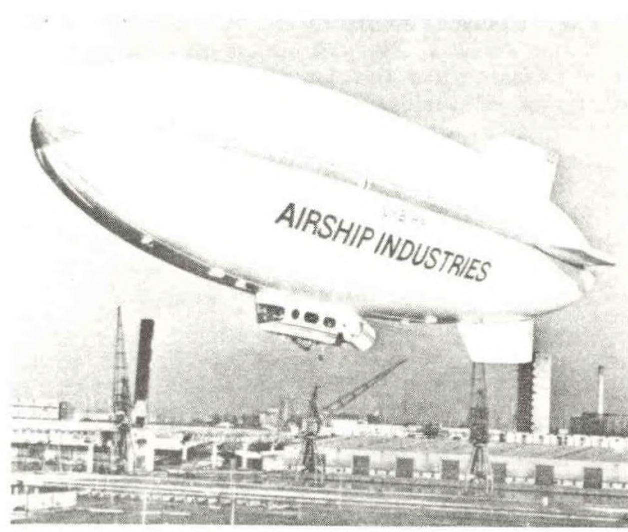
The U.S. Coast Guard has been working side by side with the U.S. Navy since 1977 in order to update the subject of Lighter-than-Air vehicles. An extensive study effort was conducted to examine the entire spectrum of today's mission needs and to develop a theoretical system of airships and complete infrastructure to perform the missions. At the same time the Coast Guard has worked with NASA on technology development. This work has focused on the aspects of new materials, new propulsion configurations, new control systems and computer simulations of vehicle dynamics and controllability. The current effort will be a first step in evaluating available hardware for validation of the study conclusions and the simulation programs. This effort has taken the form of a lease contract funded jointly by the Coast Guard and the Navy to evaluate an existing modern technology airship, the Airship Industries Ltd. model AI-500.

The overall goal of the evaluation is to validate the results of the previous studies and to demonstrate the performance improvements of the new materials and vectored thrust propulsion of the AI-500 airship. The evaluation will concentrate on two aspects of lighter-than-air vehicles. The performance, flying qualities, vibration environment and acoustic noise levels will be tested and documented at the Naval Air Test Center at Patuxent River, MD in late June and July, 1983. Following this will be a series of mission capability demonstrations in the coastal region of North Carolina near Kitty Hawk in August.

The result of the testing and demonstrations will assist future development of vehicle designs, mission adaptations, and determination of total system logistics and costs.

The AI-500

The AI-500 airship is quite similar in size to the Goodyear Blimp. Its envelope volume is nominally 5000 cubic meters with a length of 59 meters. It is powered by two Porsche gasoline engines of 200 hp each, driving ducted, controllable pitch, reversible propellers that can be rotated in a vertical plane to provide vertical thrust during take-off, landing and "hovering". The envelope is made of lightweight dacron material for strength, a mylar film on the inside for retention of the helium, and a polyurethane film on the exterior for protection from ultraviolet radiation. The rigid structure of the gondola and tailfins are made of glass reinforced plastic and the internal suspension cables for the gondola are of Kevlar. The manufacturer has recognized the trend toward reduced radar signatures in military aircraft and has gone to great lengths to reduce metallic structures and components to the absolute minimum. The result of this effort is a virtually non-metallic airship. Provisions are made inside the envelope of the AI-500 for a radar antenna of up to 100 inch size.



The previous studies of Coast Guard mission scenarios led to a hypothetical airship that was properly sized to accomplish nearly all missions currently being performed. This airship was called the Maritime Patrol Airship (MPA) and was about five times the volume of the AI-500 being evaluated this summer, about 24,000 cubic meters. Past U.S. Navy patrol blimps ranged in size up to about 40,000 cubic meters. The following chart shows the comparison between the AI-500 and the fully mission-capable MPA.

	AI-500	MPA
Length	164 feet	324 feet
Envelope volume	181,200 cu. ft.	875,000 cu. ft.
Diameter	46 feet	73.4 feet
Lift from helium	10,150 lb.	52,164 lb.
Maximum gross wt.	11,550 lb.	60,644 lb.
Useful load	4,400 lb.	22,500 lb.
Maximum altitude	9,500 ft.	10,000 ft.
Horsepower	408	2,400
Maximum speed	55 knots	97 knots
Cruise speed	45 knots	60 knots
Cruise fuel consumption	80 lb./hr.	300 lb./hr.

It is fully recognized that the AI-500 does not have the speed, range, endurance or load capacity to be an effective mission platform for the Coast Guard. However, the data obtained during the tests and the results of the mission capability demonstrations will be scaled up to the MPA size so that a more accurate picture of the capabilities of a full sized airship can be obtained.

PERFORMANCE AND FLYING QUALITIES

One of the major problem areas of past Navy airship operations was a proportionately high accident rate during launching and recovering the airships from their operating bases. This can also be said of any aircraft, helicopter or surface vessel since this phase of operation is inherently the most demanding in controllability and when the control effectiveness is generally diminished by lower operating speeds. The helicopter is a notable exception to this generality since it maintains good control at virtually zero airspeed.

A "hover" capability of some degree in an airship would be a great improvement in the ability to avoid loss of control in take-offs and landings. It would also enable the airship to directly interact with a surface vessel at sea to perform a greater range of missions. The extent of hoverability to be included in a future MPA design is clearly a significant exercise in optimization since the benefit is only achieved at the expense of system complexity and an extra weight penalty.

The performance and flying qualities tests are planned so that a thorough documentation can be obtained of dynamic characteristics, control response, and performance parameters. These will include linear acceleration and deceleration rates from engine thrust and envelope drag, turn radius and yaw rate obtained from rudder deflection and from differential engine thrust, the inherent airship's static and manuveuring stability (or instability), roll, yaw, and pitch rate response to control movements, undesirable motions such as flutter, buffeting and vibrations, and low speed/hover flying qualities and controllability. (It may be of interest to note that an airship can be trimmed fore and aft by shifting the contents of two large air bags or "ballonets" that are in the front and rear of the envelope interior. The pilot has direct control over yaw and pitch through conventional rudder and elevator control surfaces. The rolling motion of an airship is a purely pendulous response to lateral accelerations in turns and side gusts.)

These results will be compared to predicted characteristics of the AI-500 derived from modeling the airship on the NASA computer simulation. Validation of the computer model will then allow simulation analysis of virtually any size airship with a wide range of control systems and power plant configurations.

MISSION DEMONSTRATIONS

The previous study efforts identified the full range of mission categories performed by the Coast Guard from search and rescue and law enforcement on the high seas and coastal waters to lesser known tasks such as port safety and military operations when required. Each mission category was carefully analyzed and divided into a series of elements common to most all of the categories. These elements were identified as transit, patrol or search, station keeping or loiter, escort, and delivery/retrieval of personnel or equipment from the surface. By assuming the future availability of a suitably sized, "hoverable" airship a mission comparison with traditional ships and aircraft proved encouragingly favorable.

Although the AI-500 is not large enough to have the endurance, range or speed to perform actual missions effectively, it will provide an excellent opportunity to demonstrate some measure of the more general attributes of LTA vehicles of modern design. The effectiveness of patrol and search scenarios (both day and night) will be investigated on a mission comparison basis with ships and aircraft. Fuel consumption, man-hour commitment, crew fatigue/stress, and an overall measure of patrol/search effectiveness will be considered. The advantages or disadvantages of airships in station keeping or loiter will depend on fuel consumption and endurance, crew fatigue and stress as well as ease of maintaining visual or electronic contact with the surface unit. The endurance of a fully capable airship would be reckoned in days and would allow a long-term escort of a distressed vessel or law-violating vessel and avoid the costly practice of providing a series of short-term fixed-wing surveillance flights to maintain a long-term escort or "hot pursuit".

The ability to achieve a reasonable measure of hover capability and low speed control seems to be crucial to the usefulness of a Coast Guard patrol airship. The modern helicopter, of course, is the perfection of the ability to interact directly with a surface vessel, yet its range is limited and operating costs are generally high. The AI-500 tests will try to demonstrate the ability to hoist from and lower people and equipment to a boat under way. The tests will investigate the ability to lower a manned, rigid-hull inflatable boat to the ocean surface to perform some task and then to retrieve it at sea, and winch it up securely under the gondola. At a range beyond helicopter capability the ability to deliver equipment to a boat with a high success rate would be a distinct advantage over fixed wing aircraft with often low probability of success and over ships with slow enroute speeds with similar difficulties in delivering equipment.

SUMMARY

This summer's tests of the AI-500 are being viewed as a "proof of concept" effort. We are evaluating the lighter-than-air concept more than the particular vehicle since it was not designed for maritime patrol effectiveness. It will be the task of the evaluators to distinguish between the AI-500 limitations and the broader limitations and expected abilities of LTA vehicles in general.

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SWATH BUOY TENDER CONCEPT

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ABSTRACT

The U. S. Coast Guard's Advanced Marine Vehicles Program is assessing the potential of non-conventional vessel concepts for the performance of existing and projected mission needs. The present fleet of ocean going buoy tenders, the 180 foot WLB class constructed 40 years ago, will be up for replacement in the 1990's. One concept currently being assessed for the offshore buoy tending role is the SWATH (Small Waterplane Area Twin Hull) Ship. Recent efforts by the Office of Research and Development include conducting demonstration trials and the development of SWATH buoy tender design concepts and comparative cost estimates.

DESCRIPTION OF CONCEPT

The ocean going buoy tender mission of the U.S. Coast Guard requires that the vessel be able to transport 50 tons of buoys, chains, sinkers, spare parts and associated equipment for distances of from 1,000 to 4,000 miles at a speed of 14-16 knots to service buoys weighing as much as 9 tons. To assure the capability to handle flooded buoys, the hoisting crane should be rated for a static lift of twenty tons. The vessel should have a buoy deck area of at least 1600 square feet and the ability to transport 31 tons of fuel and 56 tons of water to remote sites. The vessel should not have a list of greater than 10 degrees when working the larger buoy systems or a roll period of less than 8.5 seconds. Whether or not a SWATH buoy tender can effectively be constructed to satisfy the Coast Guard's needs at a reasonable acquisition and life cycle costs is a critical question.

DEMONSTRATION TRIALS

In order to make a direct assessment of the SWATH buoy tender concept, a decision was made to compare an existing SWATH vessel, the SSP KAIMALINO, with a 180 WLB offshore buoy tender (See Table 1). The selection of the SSP involved several factors. The primary reason was that the SSP KAIMALINO has successfully operated for almost 10 years as a range support vessel performing tasks not unlike those of an ocean going buoy tender. The second reason was that the SSP could be utilized as a large model for a SWATH in the 600 to 1200 ton range. A comparison of the two vessels' characteristics indicated that the SSP lifting a second class buoy sinker and chain (with a total weight of 8,000 pounds) would experience almost the same heel angle as the 180 foot WLB lifting the largest Coast Guard buoy (9x32) with sinker and chain (with a total weight of around 33,000 pounds).

TABLE 1. COMPARATIVE CHARACTERISTICS

	180' WLB	SSP
Length	180 feet	89 feet
Beam	35 feet	49 feet
Draft	13 feet	15 feet
Displacement	1,025 tons	220 tons
Estimated GM	3 feet	3 feet

The SSP, for the purposes of this assessment, was considered to be a one-fourth to one-fifth scale model of an actual buoy tender. The demonstration trials were held off the island of Oahu in March 1983. They were conducted on a side-by-side basis with the Coast Guard's 1,025 ton, 180 foot long, ocean going buoy tender MALLOW. These trials examined several aspects of comparative performance on a side-by-side basis including steaming in a seaway, stationkeeping, leeway (drifting), and buoy tending.

The side-by-side steaming tests were conducted to compare the vessels' motions in a typical seaway during transit. The stationkeeping tests were performed to give a relative comparison of each vessel's ability to maintain a fixed position in beam and bow wind conditions as might be experienced while setting or approaching a buoy. The leeway or drift tests were attempts to estimate the effects of wind force on each vessel. The buoy tending tests were intended to illustrate differences between buoy tending operations conducted aboard a SWATH vessel and those conducted aboard a traditional monohull buoy tender.

The results of the steaming trials indicated, as expected, that the SSP has a superior seakeeping capability. Motions measurements, made by the Coast Guard Research and Development Center, indicated that for all headings the SSP's roll was a fraction of that measured aboard the WLB which steamed simultaneously alongside at the same speed and heading. (See Figure 1 for polar comparison plots). The seakeeping capabilities of a SWATH buoy tender in the 600-1200 ton range should greatly exceed those of the 220 ton SSP.

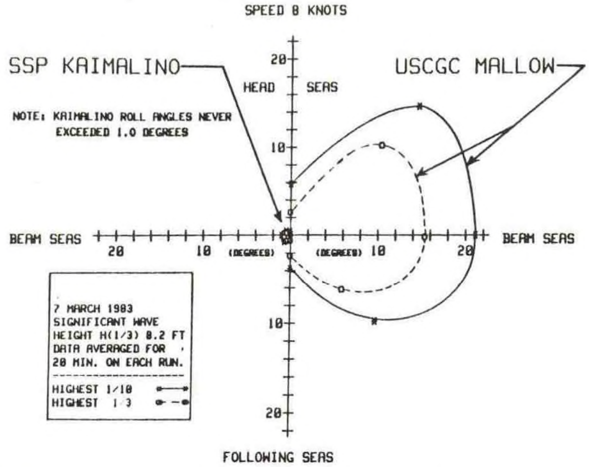

FIGURE 1. ROLL AMPLITUDE POLAR PLOT

Stationkeeping tests were conducted in the absence of currents to obtain estimates as to the relative abilities of the two vessel concepts to maintain a fixed position using controls against the wind. The WLB was moved over twice the distance off station by the wind in the same time interval as the SSP. In the leeway tests each vessel drifted about the same distance in the same time interval except that the SSP, after a short delay, tended to behave similarly to a sailboat with a keel, eventually drifting almost beam to the wind. This tendency appears to be related to the high lateral resistance of the SWATH concept.

In the buoy tending tests the SSP was able to conduct operations at all five desired headings to the seaway (i.e., head, bow quartering, beam, stern quartering, and following sea conditions). The WLB completed three operations in approximately the same time interval. An analysis of the time intervals required to conduct the buoy tending operations aboard the two vessels indicated that significant time savings occurred aboard the SSP. The greatest savings (averaging about 6.25 minutes per evolution) was associated with the technique employed to hoist the sinker and chain to the deck edge from the bottom. The SSP employed a deck edge roller chock and a horizontal axis winch to draw a large (35 foot) bight of chain across the deck. The conventional WLB used its overhead boom and special deck edge stopper to draw smaller (15 foot) bights of chain. The longer chain bights require less chain handling by the deck crew. The cross deck operation avoids crew activity underneath the hoisting mechanisms. The second greatest time savings (averaging about 4.5 minutes per evolution) involved the interval required to manuever the vessels for buoy placement. Many of the current Coast Guard WLB vessels employ bow thrusters to assist in manuevering. However, neither vessel in these trials had bow thusters. The SSP did employ reversible fixed pitch propellers driven by hydraulic motors. The WLB propulsion is a diesel- electric driven single, reversible, fixed pitch propeller. Additional time savings (averaging about 2.5 minutes per evolution) occurred in the interval during which the buoy with attached chain is slewed across the deck, then positioned on its side in wooden chocks and securely fastened to the deck to prevent movement due to vessel motions.

Observations of buoy handling aboard each vessel indicate that buoy deck safety is closely related to minimizing roll, which, on the WLB, means maintaining a bow-on heading into the sea until the buoy is secured to the deck or placed over the side, where pendulum motion remains a problem. Comments from experienced Coast Guard and Navy personnel who served as observers repeatedly stressed the inherent safety and desirability of a stable working platform.

EXPLORATORY DESIGNS

To be effective in the mission arena in which the Coast Guard's 180 foot WLB class has operated for the last forty years, a replacement buoy tender design should have a modest draft, a length of less than 200 feet to work in narrow channels, a lift capacity of 20 tons and the ability to transport 50 tons of buoys and equipment and 87 tons of fuel and water to remote sites. While the 180 WLB class contains ice-strengthened hulls that conduct limited ice breaking operations, it is anticipated that the majority, if not all, of the WLB's historical ice operations will be performed by the new 140 foot WTBG Harbor Tug class vessels.

Table 2 presents the primary considerations used in establishing a nominal SWATH buoy tender design.

TABLE 2. NOMINAL DESIGN CAPABILITIES

Design Speed	15 kts
Range (with 20% Margin at Design Speed)	2,500 n. miles
Deck Payload	30 tons
Minimum Deck Area	1,600 sq ft
Water + Fuel for Remote Sites	31 + 56 tons
Maximum List during hoists	10°
Minimum Natural Roll Period	8.5 seconds
Hoisting Capacity	20 tons static lift
Endurance	12 days
Crew	48

The reader is reminded that the data presented in this section is preliminary and is subject to refinement. No stability studies or detailed structural analyses were made. Design parameters were taken from assessments of existing SWATH vessels including the steel hull vessel Duplus, and from a collection of design studies performed for the Coast Guard and U. S. Navy. However, this work is considered sufficiently accurate for early decision making activities.

Several exploratory design concepts were considered. The most promising configuration is a SWATH of around 750 tons nominal displacement which trades off various combinations of ballast, payload, fuel, and speed to achieve a wide range of operational capabilities. The design presented employs all steel construction, elliptical, contoured lower hulls, European diesel propulsion, and four automatically controlled canards for additional stabilization.

Table 3 presents general SWATH buoy tender characteristics which satisfy the desired capabilities identified in Table 2.

TABLE 3. 750 TON SWATH BUOY TENDER CHARACTERISTICS

Displacement (nominal)	750 tons
Length	152 feet
Beam	73 feet
Installed Horsepower	1,750 hp
Fuel	63 tons
Ballast	73 tons
Fuel + Ballast + Payload	166 tons
Hull Clearance	11 feet

A number of operating options are readily available with this design which provide additional range, additional payload, or reduced draft to accommodate a specific operational situation. A portion of the operating capabilities available to the operator by selective use of the concepts' ballast/payload/spead/draft options are presented in Table 4.

TABLE 4. 750 TON SWATH BUOY TENDER OPERATING OPTIONS.

Speed (kts)	Range w/20% Margin(n mi)	Payload (tons)	Initial* Draft (ft)	Initial Deballasted Draft (ft)	Fuel (tons)	Ballast (tons)
15	2500	30	15.1	11.3	63	74
15	1720	50	15.1	11.3	43	74
15	1280	30	13.4	9.8	32	74
15	5400	30	15.1	15.1	136	0
15	6600	0	15.1	15.1	166	0
12	2500	50	15.1	12.1	55	61
12	2500	30	15.1	11.0	55	81
12	7500	0	15.1	15.1	166	0

*As fuel is consumed, it may or may not be replaced with ballast to maintain a constant draft.

A diesel electric propulsion configuration is currently under analysis. It is expected to increase the vessel's gross displacement by about 20 tons.

A cost analysis was conducted to estimate gross relationships for comparing the replacement cost for the existing WLB design with the diesel-electric SWATH and the lightweight diesel SWATH buoy tender designs. The interactive computer program ASSET (Advanced Surface Ship Evaluation Tool) developed by the Boeing Company for the David W. Taylor Naval R&D Center was employed. This cost model is designed for use in exploratory and feasibility design cost estimation. The cost pattern which emerged is that for both SWATH buoy tender designs, there is no class acquisition cost penalty of any significance relative to the existing mono- hull design. For ships which would operate for 2400 hours per year for 15 years, there is a fuel cost penalty associated with the increased speed capability of the SWATH design. Lead ship costs are higher for the SWATH vessels. However, follow ship costs are expected to be comparable. Also, there appears to be no major difference in cost between the European diesel and the diesel- electric SWATH designs.

CONCLUSIONS

There appears to be a high probability of success for the SWATH buoy tender concept based on innovative application of current technology. The benefits of the SWATH concept, i.e., seakeeping-both underway and at low speeds, the ability to transit without speed loss in a seaway, and deck steadiness can be acquired at no significant cost differential because a lower displacement vessel can be utilized. The SWATH buoy tender offers considerably more deck area and operational flexibility than the current WLB vessel.

Conventional wisdom would lead the casual observer to the conclusion that the SWATH concept is not suited for the buoy tender mission because of its draft and hydrostatic characteristics. The experience of the recent Coast Guard demonstration trials and the analyses conducted in developing the exploratory designs indicate that the SWATH concept is a good, practical match for satisfying the ocean going buoy tender mission needs of the U. S. Coast Guard.

ACKNOWLEDGEMENTS

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