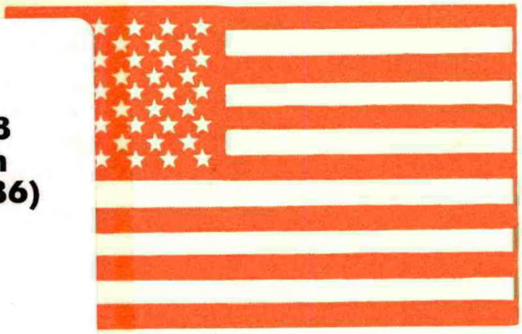

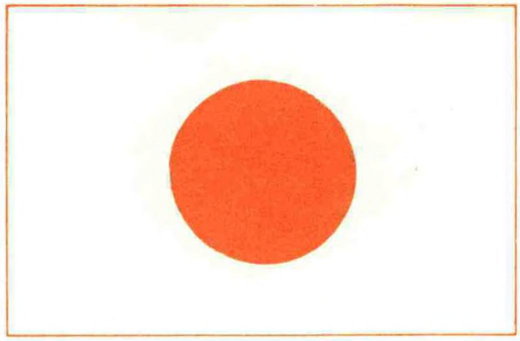

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UJNR

U.S./Japan Cooperative Program in Natural Resources

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14TH MEETING U.S.–JAPAN MARINE FACILITIES PANEL

SEPTEMBER 1986

CONFERENCE RECORD

14th Meeting of the United States-Japan Cooperative Program in Natural Resources (UJNR) Panel on Marine Facilities

September 1986

PREFACE

This document contains technical papers and special reports presented at the 14th annual meeting of the Marine Facilities Panel of the United States-Japan Cooperative Program in Natural Resources (UJNR), held September 19-20, 1986 in Bethesda, Maryland.

In addition to the two-day meeting, the Panel attended the MTS-IEEE annual conference, Oceans '87, in Washington, D.C. From September 25 - October 3, the panel toured numerous marine facilities in Louisiana and California. A final meeting of the joint panels was held September 30 at Scripps Institution of Oceanography in San Diego, California. A complete schedule and more detailed summaries of the meetings and tour are provided in this conference report.

The UJNR was established in 1964 to facilitate cooperative efforts and technology exchange in the field of natural resources between key scientific and technical representatives from Japan and the United States.

Seven of seventeen UJNR panels deal with marine science and technolgy and are a part of the Marine Resources and Engineering Coordination Committee (MRECC) of the UJNR. The National Oceanic and Atmospheric Administration of the U.S. Department of Commerce has the responsibility for leading and administering the marine panels. The Marine Facilities Panel has met 14 times, alternating annually between the U.S. and Japan. Each panel meeting has been documented in the form of a proceedings in order to provide a permanent record and to enable a wider dissemination of the technical information presented and exchanged at the meeting.

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

Participating governmental agencies in the United Stated have included: the Department of Agriculture; the Department of Commerce; the Department of Energy; the Department of Interior; the Department of Transportation; the Department of State; the Department of Defense; and the Environmental Protection Agency.

Special recognition is given to Dr. Morton Smutz for his valuable contributions as Editor in the initial preparation of this conference record, and to Mr. John A. Pritzlaff who provided many of the photographs.

W. E. Hudson
Editor

Marine Facilities Panel Charter

The UJNR Marine Facilities Panel consists of senior level engineers, scientists, and managers from the U.S. and Japan involved in advanced technology associated with the research, design, development, evaluation, and operation of marine facilities for a wide variety of applications in the assessment, development, utilization, and management of ocean resources.

The scope of technical topics is broad and includes: ocean and coastal engineering; facilities and techniques for ocean resource exploration and development; shipbuilding and marine transportation; undersea systems, submersibles, and remotely operated vehicles; seafloor engineering and offshore construction; port and harbor facility development; ocean environmental measuring and observational systems; and, pollution and waste management systems.

Panel members engage in equitable exchanges of technical data and information to: avoid unnecessary duplication of ideas; promote cooperative projects and joint ventures; and produce results which are mutually beneficial.

Meeting at Hyatt Regency, Bethesda, MD

IN MEMORIAM

This conference record is dedicated in remembrance of the contribution and participation of Isao Ueno in the Marine Facilities Panel activities of the U.S.-Japan Cooperative Program in Natural Resources.

Isao Ueno, 1921-1986

Panel Member: 1974-1982
Consultant, Ship Building Research Association of Japan
Former Director of the Ocean Engineering Division, Ship Research Institute
Major contributions were in the areas of wire rope research, ship engineering, and ocean technology
Major achievements include a feasability study on the concept of a floating offshore airport and a study on the Onomichi-Maru Disaster

OPENING REMARKS

Joseph R. Vadus
U.S. Panel

Distinguished members and advisors of the UJNR Marine Facilities Panel, on behalf of the U.S. Panel, it is my pleasure to extend our warmest welcome and best wished to Mr. Kousei Watanabe, Chairman of the Japan Panel, and to each of the members and advisers of the Japan Panel. We are pleased to be participating with you in this 14th joint meeting, and we are delighted for this reunion with our many friends from past meetings and for having the opportunity to make new friends.

I would like to express our appreciation to Mr. Watanabe and the Japan Panel for their cooperation in planning and organizing an excellent technical program. I would also like to give special recognition to Dr. Hitoshi Nagasawa for his past cooperation and achievements as Chairman of the Japan Panel, as well as for his contributions in preparing the preliminary plans for this meeting.

I am sad to report that Mr. Isao Ueno died on August 29, 1986 of cancer. He was a member of the Marine Facilities Panel for ten years, from 1974 to 1983, during his service in the Ship Research Institute as the Director of the Ocean Engineering and Ship Structure Divisions. He served afterwards in the Shipbuilding Research Association of Japan. His valuable contributions and participation in the Marine Facilities Panel meetings were deeply appreciated. We pray for the repose of his soul. In his memory let us share in a moment of silence (pause).

Mr. William Nicholson, past chairman of the U.S. Panel, was unable to attend but sends his best wishes for a successful meeting. In his letter, he stated the following which reflects the sentiments of our panel activities:

> "The Marine Facilities Panel has been one of the most rewarding of all my professional experiences. It is a positive force for better understanding between the U.S. and Japan. I like to think it is a tribute to the desire of all the engineering fraternity to make the world a better place."

The U.S. Panel has appreciated the cooperation, technical ability, and cordiality of the Japan Panel. We find the meetings and facilities tours to be very informative and valuable in providing an equitable technology exchange with mutual benefits for both sides.

The proceedings of our 13th meeting in the U.S. were printed in Japanese and English. In order to improve our technical exchange, we have distributed preprints of the U.S. and Japan papers before this meeting to enable more effective discussion of the topics presented.

We are seeking opportunities for more cooperative efforts between the two panels, especially in development of joint projects and ventures in government and industry. This meeting and facilities tour will provide an opportunity to engage in discussions leading to closer cooperation. We sincerely hope that both panels will find this 14th meeting and marine facilities tour mutually beneficial and successful.

Meeting at Hyatt Regency, Bethesda, MD

OPENING REMARKS

Kousei Watanabe
Chairman, Japan Panel

Distinguished members and advisors of the UJNR Marine Facilities Panel, on behalf of the Japan Panel, it is my pleasure to extend our warmest greetings and best wishes to Mr. Joseph Vadus, Chairman of the U.S. Panel. The success of the 13th joint meeting in Tokyo, Kyushu, and Tsukuba is still quite fresh for us, and we participate with great pleasure in this 14th meeting here in Bethesda, Maryland.

I would like to express our appreciation to Mr. Vadus and the U.S. Panel for their effort and cooperation extended to us in planning and organizing an excellent technical program and study tour to the various facilities.

It is an honor and priviledge for me to serve as Chairman of the Japan Panel, succeeding our former Chairman, Dr. Nagasawa, and to cooperate with Mr. Vadus. I would like to take this opportunity to acknowledge the distinguished accomplishment of Dr. Nagasawa and to say that I will do my best to cooperate with everyone in order to meet the objectives of this year's panel.

I am saddened to report to you that Mr. Isao Ueno died on August 29. He was, as you know, a member of this panel for ten years until his retirement in 1983. He participated in joint meetings many times including the 8th meeting in Annapolis and Honolulu. We appreciated his contributions to the UJNR activities and will always remember his liveliness and generosity of spirit. We pray for the repose of his soul.

The change of economic circumstances affects ocean development. The fall of oil prices puts off the schedule of new sea bed drilling and government deficits become a constraint on new projects. I believe, however, that we should not be to scrupulous about the short-term condition. The scope of this panel is wide and it should be continually challenged to confront the demands of progress.

The Japan Panel appreciates the cooperation, technical ability, and cordiality of the U.S. Panel. I sincerely hope that both panels will find this 14th meeting and study tour mutually beneficial and successful as well as a good opportunity to make new contacts and friends.

AWARD

Joseph R. Vadus, U.S. Panel Chairman, receiving a plaque from Kousei Watanabe, Japan Panel Chairman, with former Japan Panel Chairmen, Muneharu Saeki and Hitoshi Nagasawa on the left and right, respectively.

The plaque inscription reads, "To Joseph R. Vadus in recognition and appreciation of distinguished service as Chairman of the U.S. Panel and for contributions leading to the success of the Marine Facilities Panel of the U.S.-Japan Cooperative Program in Natural Resources."

PARTICIPANTS

United States

Members

Mr. Joseph R. Vadus (Chair)	National Oceanic and Atmospheric Administration
Mr. John Carey	National Oceanic and Atmospheric Administration
Mr. Charles N. Ehler	National Oceanic and Atmospheric Administration
Mr. John Freund	Naval Sea Systems Command
Mr. John D. Hightower	Naval Ocean Systems Center
Mr. James U. Kordenbrock	David Taylor Naval Ship Research and Development Center
Mr. Richard B. Krahl	Minerals Management Service
Dr. Zelvin Levine	U.S. Department of Transportation
Dr. Jerry McCall	National Oceanic and Atmospheric Administration
Mr. Richard E. Metrey	David Taylor Naval Ship Research and Development Center
Mr. Donald Perkins	National Academy of Sciences
Capt. Daniel K. Shorey	U.S. Coast Guard Headquarters
Dr. Morton Smutz	National Oceanic and Atmospheric Administration
Dr. Howard Talkington	Naval Ocean Systems Center
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Dr. John P. Craven	University of Hawaii
Mr. John E. Flipse	Texas A&M University
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Mr. Ronald L. Geer	Shell Oil Company
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Mr. Clifford E. McLain	Systems Planning Corporation
Dr. Alan Powell	University of Houston
Mr. John A. Pritzlaff	Westinghouse Electric Corp.
Mr. Robert R. Rupp	Sperry Corporation
Mr. Carl H. Savit	Western Geophysical Co.
Dr. Richard J. Seymour	UCSD's Scripps Institution of Oceanography
Mr. Richard M. Shamp	Engineering Service Assoc., Inc.
Dr. Don Walsh	International Maritime, Inc.
Mr. James G. Wenzel	Maritime Development Associates

Meeting at Hyatt Regency, Bethesda, MD

Japan Panel members (l to r): R. Tojima, N. Hamada, Y. Takaishi, K. Watanabe, H. Nagasawa

U.S. Panel members (l to r): C. McLain, M. Smutz, J. Vadus, C. Ehler, J. Flipse

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Dr. Yoshifumi Takaishi	Ship Research Institute

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Mr. Yukihiro Narita	JAMDA
Mr. Ryoji Tojima	JAMDA
Prof. Seizo Motora	Nagasaki Inst. of Applied Science
Mr. Masanao Oshima	Mitsui Engineering and Shipbuilding Co., Ltd.
Mr. Masao Ono	Mitsubishi Heavy Industries, Ltd.
Mr. Muneharu Saeki	JAMSTEC
Mr. Ikuo Mutoh	Mitsui Ocean Development and Engineering Co., Ltd.
Dr. Shinkichi Tashiro	Nippon Kaiji Kyoukai
Mr. Yasuo Hisada	Nippon Steel Co., Ltd.
Dr. Hitoshi Nagasawa	Imabari Zosen Co., Ltd.

Observers

Mr. Shinichi Takagawa	JAMSTEC
Dr. Nobuo Moritani	Japan Weather Association
Mr. Hiroshi Noda	Nippon Steel Co., Ltd.
Mr. Junichi Inoue	Nippon Steel Co., Ltd.
Mr. Tadahiro Fujita	NKK America, Inc.

Special Guest

Mr. Kaname Ikeda	Embassy of Japan

Japan Reception, National Academy of Sciences
(l to r): Y. Takaishi, J. Freund, I. Mutoh

Japan Reception, National Academy of Sciences

Y. Narita, M. Watanabe, H. Smutz, K. Watanabe

J.Flipse, G. Vadus, R. Ehler, C. Ehler

ITINERARY

Date	Time	Event
Sept. 18		Arrivals: Japan and U.S. members
Sept. 19	0830-1700	Plenary Session I Hyatt Regency Hotel, Bethesda, MD
Sept. 20	0830-1700	Plenary Session II Hyatt Regency Hotel, Bethesda, MD
Sept. 21	Open 1700-2000	Free Day U.S. Reception, Potomac, MD
Sept. 22	0830-1700 1830-2030	Washington, DC visits Japan Reception National Academy of Science
Sept. 23	0800-1700 0830-1130 1400-1700 1800-2000	OCEANS '86 - Sheraton Hotel Opening and Technical Sessions Exhibits Tour & Technical Sessions OCEANS '86 Awards Reception
Sept. 24	0800-1700 0800-1130 1400 1600-1730	OCEANS '86 - Sheraton Hotel Exhibits and Technical Sessions Depart for National Airport Flight to New Orleans
Sept. 25	0830-1700	Visit National Space Technology Laboratory (NSTL) Station (including Navy, NOAA, NASA)
Sept. 26	0800-1800	Travel to Morgan City. Visit American Oilfield Divers, Inc. Visit Taylor Diving Co., Belle Chasse, LA Return to New Orleans
Sept. 27	0858-1154	Flight to San Diego
Sept. 28	0830-1600 1830-2000	Visit San Diego area Reception at Seymour's, La Jolla, CA
Sept. 29	0830-1100 1130-1330 1400-1600	Visit Hydroproducts, Inc. San Diego, CA Visit Seaport Village Visit Ametek Straza, Inc., El Cajon, CA

Date	Time	Event
Sept. 30	0830-1100	Visit Scripps Institution of Oceanography, La Jolla, CA
	1100-1230	Final Meeting
	1400-1630	Visit Naval Ocean Systems Center San Diego, CA
Oct. 1	0945-1230	Leave for Los Angeles
	1400	Arrive Hotel Queen Mary, Long Beach, CA
	1500-1800	Tour local facilities
Oct. 2	0900-1145	Boat tour of Los Angeles Harbor
	1300	Depart for Port of Long Beach
	1400-1600	Land tour of Port of Long Beach
Oct. 3	0830-1000	Travel to Pasadena
	1000-1200	Tour Jet Propulsion Lab
	1330-1500	Return to Los Angeles
Oct. 4	1300	Flight departure for Tokyo

U.S. Reception, Potomac, MD

U.S. Reception, Potomac, MD

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U.S. Reception: M. Watanabe, G. Vadus

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Mr. Junichi Inoue
Mngr. Civil Engineer
Nippon Steel U.S.A., Inc.
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Special Guest

Mr. Kaname Ikeda
Counsellor
Embassy of Japan
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U.S. Reception, Potomac, MD

STUDY TOUR

National Space Technology Laboratories
September 25, 1986

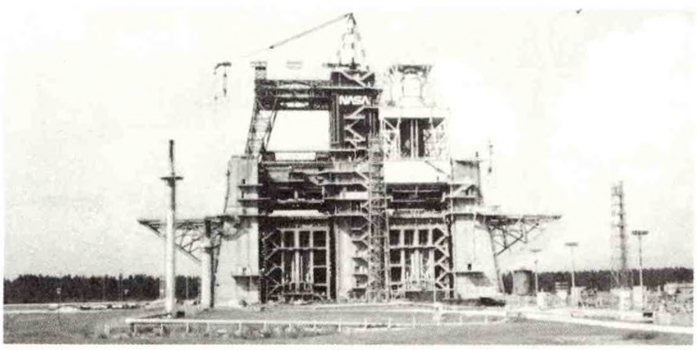
The National Space Technology Laboratories (NSTL) is the home of about 20 governmental, educational, and commercial organizations. Spread over 139,000 acres in southern Mississippi, the huge site was acquired in the early 1960's when it was originally named the Mississippi Test Facility. The first and second stages of the Saturn V rocket were assembled and tested here in the mid-1960s and the early 1970s before being barged to Cape Canaveral to launch astronauts to the moon.

When the Apollo moon program was concluded, the site's name was changed to NSTL, and the facilities and services were made available to other government agencies. The National Aeronautics and Space Administration (NASA) is host to the other organizations, including the National Data Buoy Center (NDBC) and the Naval Ocean Research and Development Activity (NORDA).

NDBC is the United States' focal point of environmental buoy technology. The Center operates and maintains moored and drifting buoys and fixed coastal headland stations in support of the National Oceanic and Atmospheric Administration (NOAA) and other national programs. NDBC is at the frontier in the development and testing of automated remote environmental sensing systems.

NORDA is the U.S. Navy's center for ocean environmental research and development. Its programs in developing remote sensing systems and computer modeling are aimed at gaining a better understanding of the oceanic environment and its effects on Navy systems and operations. Much of NORDA's research is also of interest to the nonmilitary community.

The NASA test facility is used to certify the United States' large rocket propulsion systems. Since the end of the Apollo program, all of the main engines used to boost the Space Shuttle into near-earth orbit have been flight-certified at NSTL.



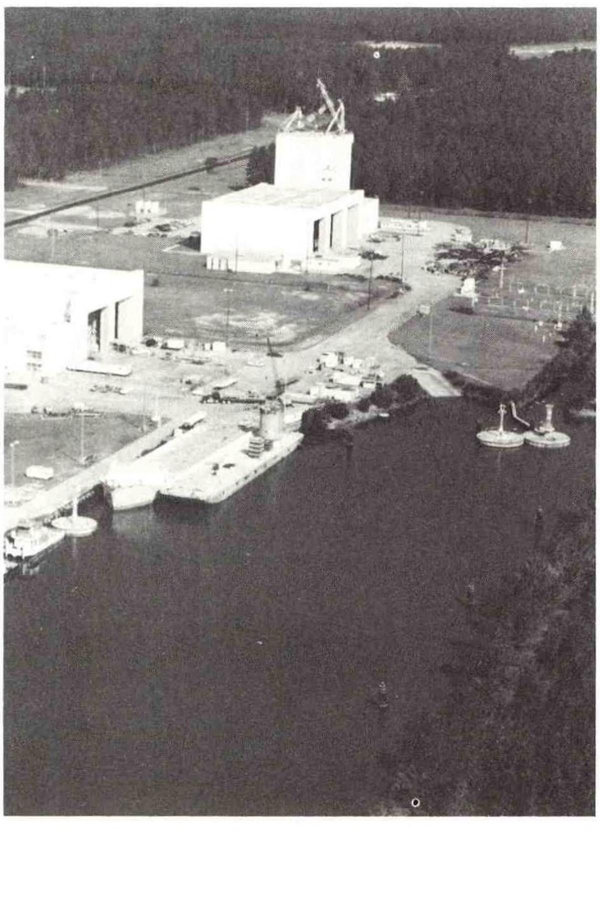
NASA Rocket Test Facility

NSTL Visit

Japan Panel Chairman, K. Watanabe

At NORDA: J. Vadus, R. Krahl, M. Watanabe, K. Watanabe

NSTL Visit



NSTL Visit

Taylor Diving and Salvage, Inc.

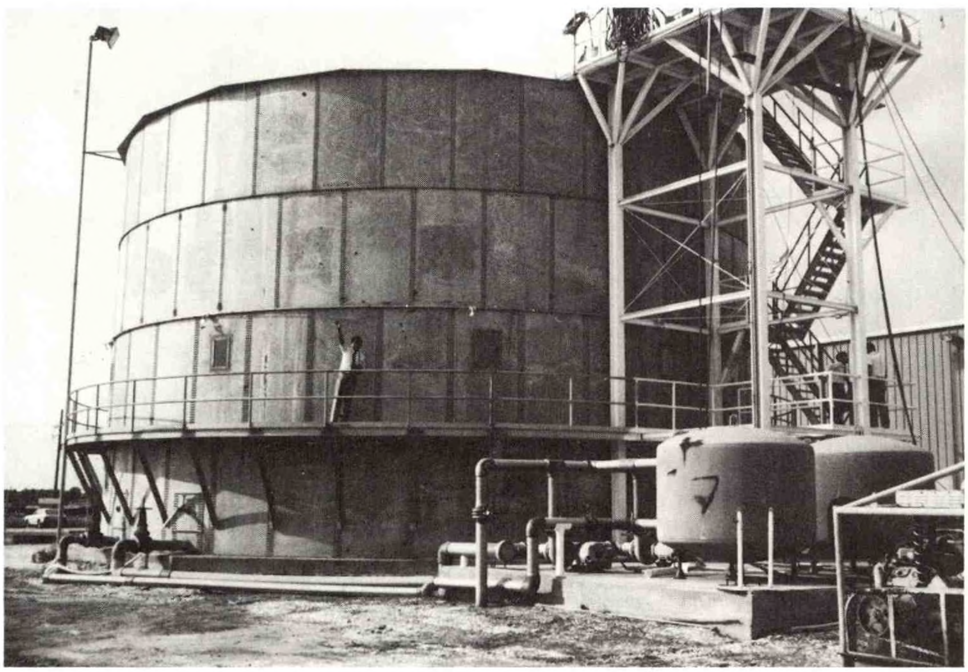
September 26, 1986

Taylor Diving and Salvage, founded in 1957, originally had its headquarters onboard a 93' schooner called Jesting. As the company grew, a new office and workshop were constructed which, since 1969, have provided worldwide base headquarters for underwater diving and construction activities.

The base, located in Belle Chasse, Louisiana, is built on a six-acre site and incorporates both office and workshop space. The workshop supports the construction and/or manufacturing of specialized diving equipment as well as maintenacne of existing equipment. Incorporated into the facility are a hyperbaric diving and research facility rated to 2300' of sea water and half-million gallon test tank used to test diving and remotely operated vehicles in near-field conditions.

The base load of Taylor's work has been the installation of support platforms and pipelines with Brown and Root. Currently, Taylor participates in construction diving, inspection maintenance and repair diving, remotely operated vehicles for drill rig support, and contracting for management and engineers of various marine civil engineering projects.

In almost 30 years of business as an underwater contractor, Taylor has completed thousands of projects in depths up to and exceeding 1000 feet of sea water. Taylor has played an internal role in the implementation of saturation diving to the oilfield as well as the development of reliable, safe, cost-effective solutions to underwater construction problems.



Sonat Subsea Services

September 26, 1986

Sonat Subsea Services was part of Sonat Inc., a company headquartered in Birmingham, Alabama. When the UJNR panel visited the facility, it had just been bought by American Oilfield Divers, Inc. Sonat Subsea Services' major activity was in assisting in the finding, producing, and transporting of oil and natural gas.

Sonat Subsea Services was formed in 1957. In 1961, members performed underwater wet-welding, and more recently, performed the first underwater wet (nonhabitat) radiography of a 16" valve in 206' of water. Since 1983, the company had expanded internationally with the acquisition of the Remotely Operated Vehicle assets of Santa Fe Underwater Services which provided a North Sea Operation. Subsequently, an Asia Pacific operating base was established in Singapore.

Hydro Products

September 29, 1986

For over two decades, the blue seahorse has represented Hydro Products as a leading manufacturer of harsh environment viewing systems. The company's philosophy of growth through applied science and creative engineering has led to the development of systems that have become benchmarks for the offshore and utility industries.

Since its founding in 1960, Hydro Products has been developing systems that meet a broad spectrum of underwater equipment requirements; closed circuit television and lighting systems, advanced RCV (remotely controlled vehicle) systems, as well as radiation-tolerant television and lighting systems for the nuclear power industry.

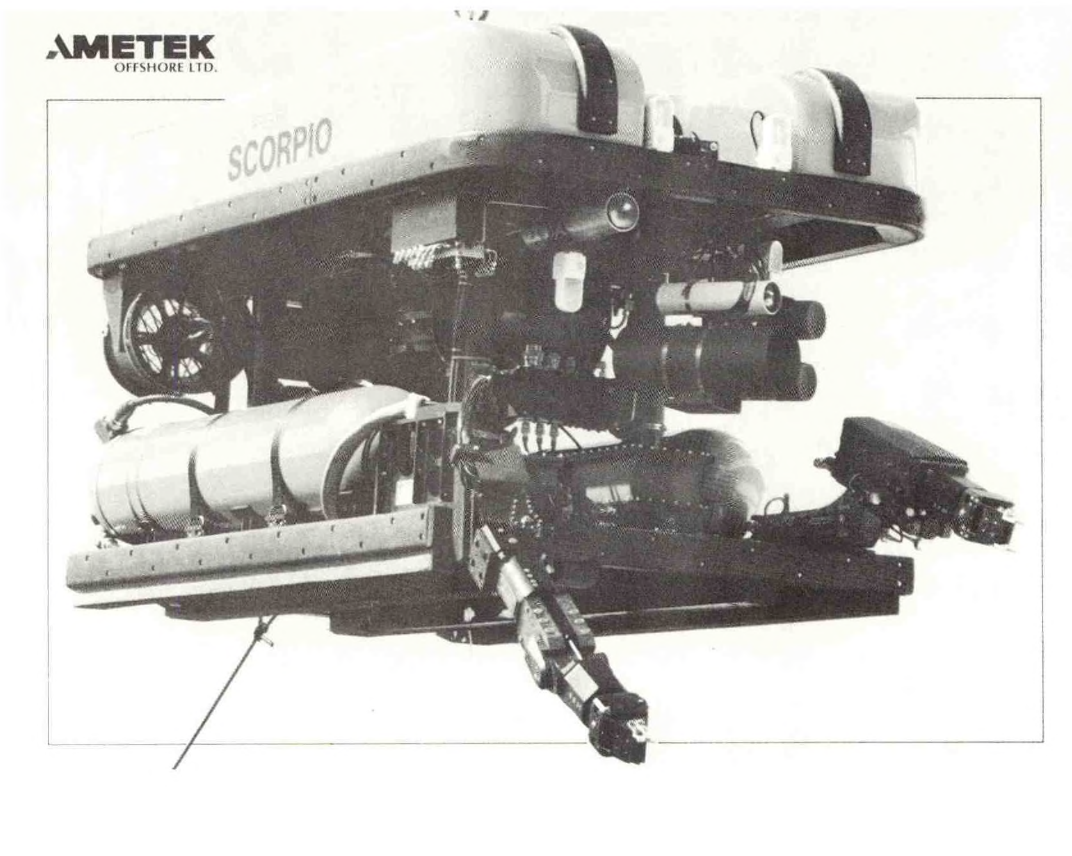
AMETEK, Straza Division

September 29, 1986

AMETEK, Straza Division is a research, engineering, design, and manufacturing company engaged in electronic, electromechanical, and metal fabrication activities. Specialized capabilities are primarily applied in manufacturing components for the aerospace industry and electronic systems for military and commercial marine applications.

AMETEK has been in the deep-ocean technology and acoustic system business for more than 25 years. AMETEK pioneered the development of compact commercial CFTM sonar systems and is a supplier of sonar, communication, and navigation equipment.

AMETEK is one of the suppliers of both military and commercial ROV systems. AMETEK systems, which range from inspection and light-work vehicles to large search and work vehicles capable of complex manipulation tasks, are currently in use throughout the world. Some of these systems, such as the Scarab, were designed to perform specific complex subsea tasks requiring sophisticated suites of specialized manipulators and tools. Others, such as Scorpio, were designed to meet a broad range of requirements in various fields of undersea technology.



Naval Ocean Systems Center

September 30, 1986

The Naval Ocean Systems Center (NOSC) mission is to be the principal Navy research, development, test, and evaluation center from command control, communications, ocean surveillance, surface- and air-launched undersea weapons systems, to submarine Arctic warfare.

The two main groups hosting the UJNR study tour were the Engineering and Computer Sciences Department and its Ocean Engineering Division. The OED conducts research, development, test, and evaluation of systems and techniques that provide the Navy with safe and reliable means for the accomplishment of engineering projects in the sea. The OED develops deep submergence technology in general support of present and future Navy operational re quirements. It applies principles of ocean engineering to the design of systems for the Navy's combat and noncombat missions. And, it supports the Navy's Fleet operations by satisfying their quick-response needs in hardware for undersea operations.

UCSD's Scripps Institution of Oceanography

September 30, 1986

Scripps Institution of Oceanography (SIO) is an academic department of the University of California San Diego and also one of the foremost oceanographic research institutions in the world. SIO operates a fleet of research vessels and undertakes research in the fields of biology, chemistry, physics, geophysics, geology, and ocean engineering.

The La Jolla campus includes the principal laboratory facilities as well as the hydraulics laboratory and the satellite oceanography facility. The Marine Physical Laboratory and the Visibility Laborator, where significant research is performed in ocean engineering and applied technology, are located approximately 20 km away adjacent to the Naval Ocean Systems Center.

Capabilities of interest to the Marine Facilities Panel include the Deep Tow Survey System, the RUM III seafloor work system and an oscillatory flume for full-scale sediment transport studies.

Reception at Seymour's, La Jolla, CA

Los Angeles Harbor

October 2, 1986

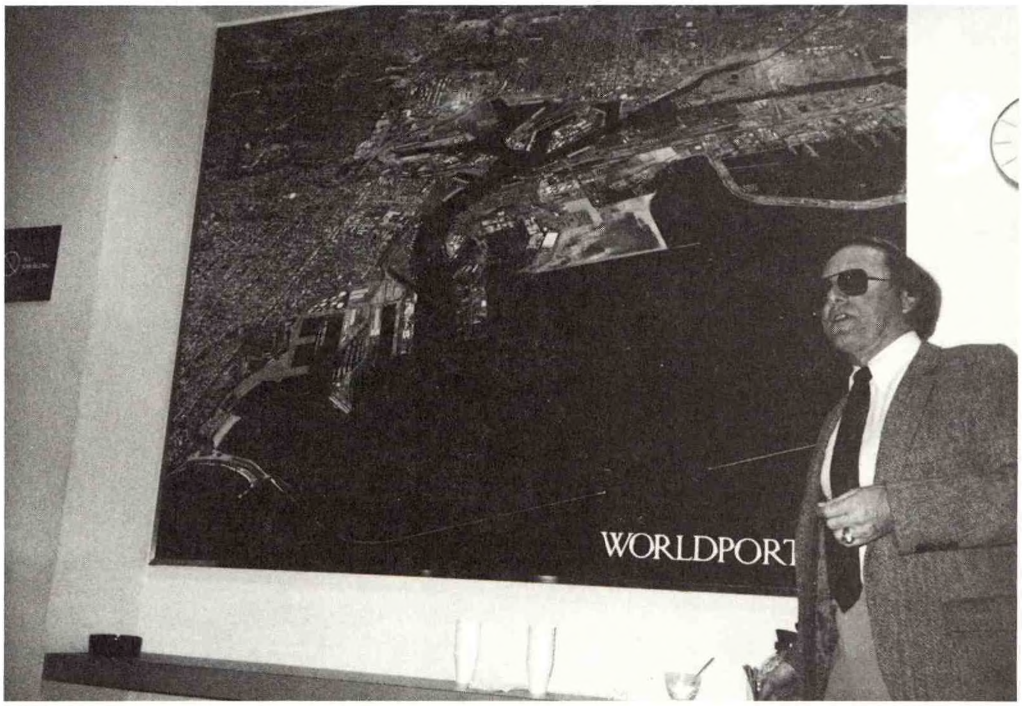
Over a five-year period, nearly $100 million annually have been committed to some 50 projects included in the harbor's overall development. The additional depth of the harbor, now at 45 feet, has helped the port meet the needs of over 70 international shipping lines, with increasingly larger vessels, currently calling at the port. Thirty-five percent of the world's container fleet was previously unable to use the facilities, but can now do so without lightering.

Completion of the dredging not only opened the harbor to increased trade, but also provided the impetus for the $500 million investment in the harbor over the five-year period. With the completion of a dike to contain 14 million cubic yards of material from the channels, the resultant 190 acres of land created by the dredge spoil is now being used for maritime business and may also become the site of the port's major bulk handling facilities.

The Ports of Los Angeles and Long Beach have projected increases in container traffic of between 8 and 15 percent annually over the next 20 years as San Pedro Bay increasingly becomes the load center for the southwestern United States.

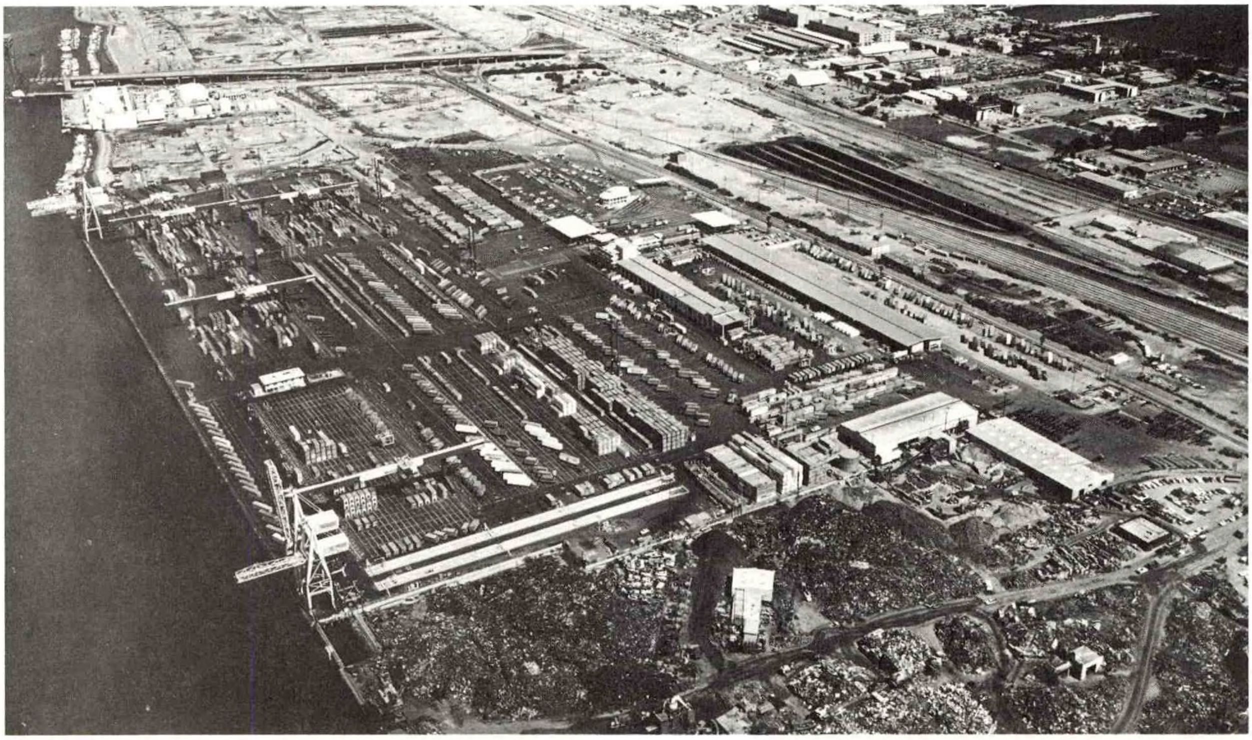
With the arrival of the Korea Shipping Line and the combining of two container facilities, the port's number of container terminals now stands at seven. These include the newly completed American President Lines Terminal, the largest single-operator facility on the West Coast, and APL's key transfer point for its expanded sea and rail systems.

Glen Hughes presenting Port of Los Angeles plaque to Japan Chairman, K. Watanabe

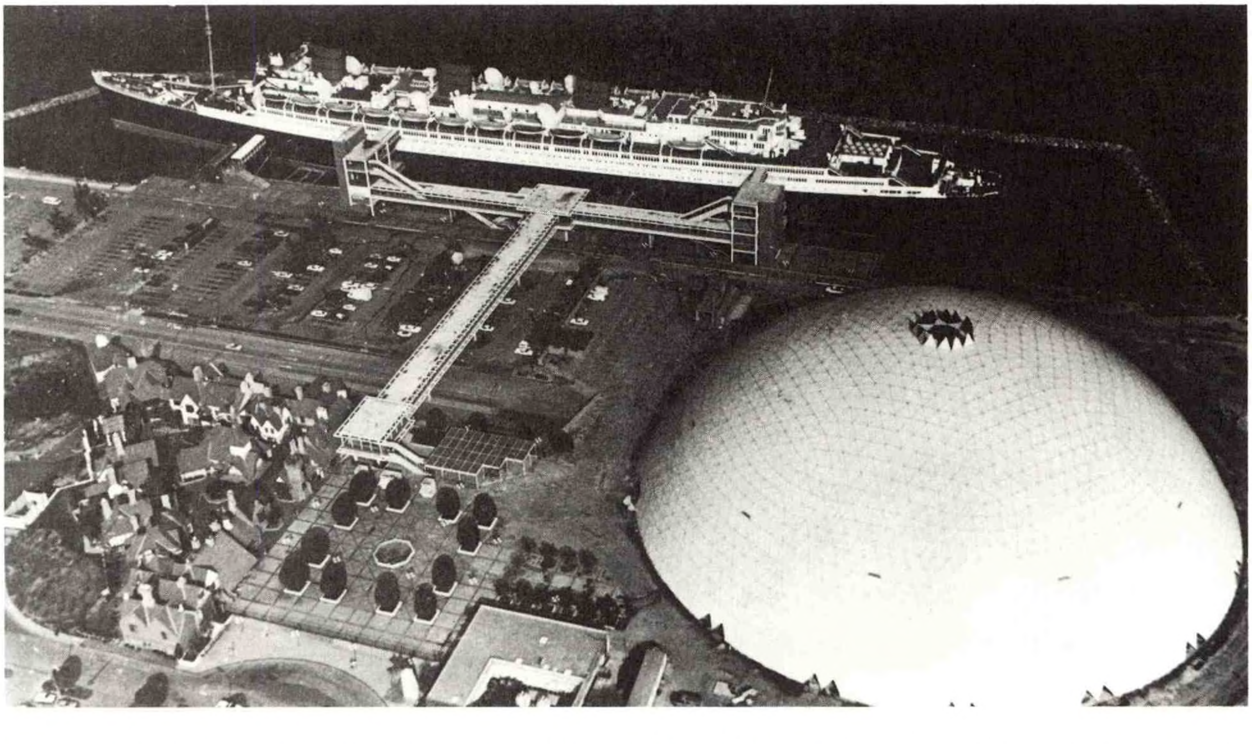


Don Walsh briefing Japan Panel

Boat tour of Los Angeles Harbor



Matson Terminal, Port of Los Angeles



Queen Mary Hotel and Spruce Goose Facility, Wrather Port Properties

Jet Propulsion Laboratory

October 3, 1986

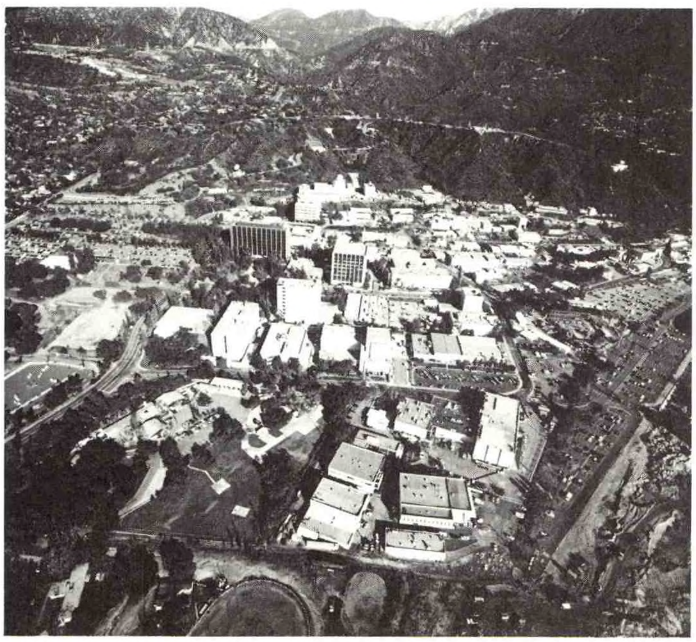
The Jet Propulsion Laboratory (JPL) is both a government-owned installation (NASA) and an operating division of the California Institute of Technology. It employs 5,800 engineers, scientists, and support personnel.

JPL's primary role for NASA is the investigation of the solar system using automated spacecraft. The laboratory is also responsible to NASA for supporting research and development related to the space missions, and the design and operation of the global Deep Space Network of tracking stations. Over 75 percent of the laboratory's resources are devoted to these activities.

During the past two decades, JPL has managed for NASA the Ranger lunar photo-reconnaissance missions; the Surveyor lunar landers; the Mariner series that explored Mars, Venus, and Mercury; the Viking orbiters; and the Voyager missions to Jupiter, Saturn, and Uranus. Voyager II will pass Neptune in August 1989.

JPL is managing four other NASA missions to be launched in the 1988 to 1991 period: the Galileo mission to orbit Jupiter and to send a probe into the planet's atmosphere; the Magellan mission to map the surface of Venus with imaging radar; the Ulysses mission to study the Sun's poles; and, the Mars Observer to study the martian atmosphere, weather, and surface minerals.

A JPL radar similar to the Magellan instrument has been used to map the Earth's surface topography from the Space Shuttle. The first JPL radar instrument was flown aboard the Seasat Satellite in 1978 - a mission managed by JPL for NASA.



FINAL MEETING

Mr. Vadus summarized the program and activities of the 14th Meeting and study tour, and thanked Mr. Watanabe and the Japan Panel for their cooperation and contributions.

Mr. Vadus discussed briefly the procedures that were used in preparing for and conducting the technical sessions of the meeting. The procedure of exchanging U.S. and Japan papers at least one month before the meeting allowed sufficient time for review and formulation of questions. A major improvement in the conduct of the two-day meeting was achieved by limiting the length of each paper to ten minutes. This allowed sufficient time to summarize the objectives, findings, conclusions, and recommendations. It also enabled time for questions and discussion following each paper. As a result, this meeting provided for a better exchange of technical information while maintaining speaker schedules. In general, both sides were pleased with these procedures and will follow them for the 15th meeting.

Special recognition was given to the following U.S. Panel members who served as regional chairmen in organizing, planning, and leading the study tour in their regions:

Region	Chairmen
Bethesda-Washington, D.C.	Morton Smutz and Richard Shamp
New Orleans	Richard Krahl and Ronald Geer
San Diego	Richard Seymour and Howard Talkington
Los Angeles	Don Walsh

U.S. and Japan members expressed their appreciation to the regional chairs.

Mr. Watanabe expressed his appreciation to Mr. Vadus and the U.S. Panel for their efforts in making the meeting and study tour both successful and enjoyable. Mr. Watanabe requested receiving copies of the viewgraphs/slides used in the presentations made at the National Space Technology Laboratory. (Ed. Note: the requested material was sent.)

Mr. Watanabe also requested that the National Data Buoy Center (NDBC) provide a reply to questions on measurements of wave directional spectra raised in the letter by Dr. Y. Goda, Director-General, Port and Harbor Institute of the Ministry of Transport. (Ed. Note: Dr. J. McCall, Director of the NDBC has sent a reply.)

In order to fulfill Dr. Y. Takaishi's request to meet with Mr. W. J. Nordell, Director, Ocean Structures Division, Naval Civil

Engineering Laboratory in Port Hueneme, California, arrangements were made for a meeting at International Maritime, Inc., in San Pedro, California on October 2, while the Japan Panel was visiting the Port of Long Beach. The purpose of their meeting was to exchange information on at-sea experiments of floating structures.

Mr. Vadus presented a preliminary plan for the 15th meeting to be held in Japan. The plan was based on informal discussions with Mr. Watanabe and between U.S. and Japan members during the study tour. It was tentatively agreed that the study tour in Japan would focus on three regions:

1. Tokyo-Yokohama-Yokosuka
2. Kobe-Osaka
3. Hokkaido

In order to accommodate visits to facilities in Hokkaido, it was recommended that the study tour be scheduled for May 1988 to avoid bad weather.

Mr. Watanabe offered to identify several marine facilities in the Hokkaido area that would be of interest to the Panel. (Ed. Note: U.S. and Japan chairmen are refining the schedule to identify facilites in the three regions.)

Chairmen Vadus and Watanabe concluded that the 14th Meeting and study tour were very successful and beneficial to all participants. They agreed that conference records in both Japanese and English will be published and distributed early in 1987.

Mr. Vadus adjourned the final meeting with best wishes to the Japan Panel and great expectations for the 15th meeting in Japan in 1988.

Final Meeting at Scripps

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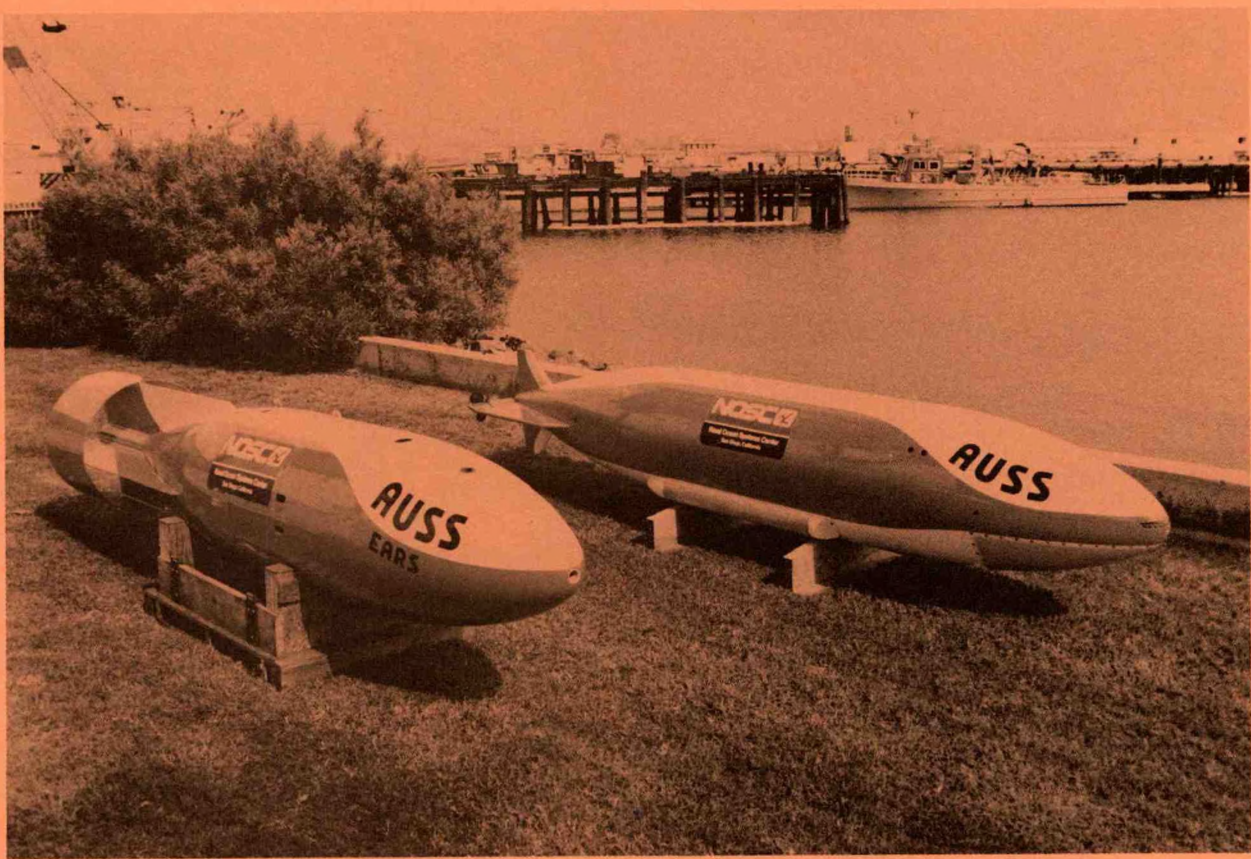


Advanced Unmanned Search System (AUSS)
Vehicles at NOSC, San Diego, CA

Marine Facilities for Ocean Resource Development

Highlighting Technological Concerns
for Oil and Gas Development in the
Deep Oceans and Arctic Frontier Areas

Richard B. Krahl
Deputy Associate Director
for Offshore Operations

Minerals Management Service

As we look back over the past quarter century of ocean engineering development, we quickly realize the vast improvements which have been made. In those "primitive" post war days of the 1950's, most of the routine offshore operations we now take for granted were not possible: ships could not moor in deep water, cable systems were not very suitable for oceanographic usage, ocean structures could only be implanted in relatively shoal water, etc. However, in the United States, largely as a result of Navy funding for ocean science and technology in the 1960's, and the vast investment by the oil industry in the 1970's and 1980's, an enormous number of engineering problems have been worked out, leaving us to wonder if there is anything that cannot be accomplished in the ocean. Whatever the answer is, it will depend upon two factors: time and money. In the near term, there is much confidence that large-scale developments in the offshore technologies will be feasible and of economic advantage. However, these pioneering efforts are not without their technological problems.

This paper highlights the more predominate problems pertaining to offshore oil and gas technology and the solutions which are being sought in the frontier areas now under scrutiny. In the deep oceans, there are two kinds of frontiers--afloat exploratory drilling and permanent production platforms. Whereas afloat drilling has progressed to 2,000m, and seems almost unlimited, fixed production platforms are now on the continental slopes, i.e., from the "hundred" fathom (200m) curve of the continental shelf, down the slope to 300m or so. One aspect of deep water afloat drilling, i.e., well control, will be highlighted later in this paper, the balance of which is devoted to fixed structures. In the Arctic, the emphasis is in the shoal waters of the Beaufort Sea which are covered by pack ice from fall through spring. However, pending discoveries in the Bering Sea, another set of technological problems based upon severe economic realities, will be encountered. These latter problems pertain to the storage and transportation of produced hydrocarbons.

Let us look at the critical path technologies, first on the continental slopes.

Over the last few years, we have been reading and hearing about the various techniques for pushing development further offshore. Conoco favors the tension leg platform (TLP) for providing a solution to the economics of development in the Green Canyon area, Gulf of Mexico. Exxon is said to have favorably considered another guyed tower, this one in deeper water, and Shell is reported to be considering the well-proven Gulf of Mexico jacket concept even beyond their new Bullwinkle platform which is designed for about 400m water depth. Other companies are in various stages of concept evaluations of subsea and floating production systems. These concepts are chosen by the various companies because of the size of the fields being developed, their need for agreement with their partners, and last but not least, the familiarity with and preference for engineering methodologies. Ocean engineers, like naval architects, favor the technologies with which they are most comfortable.

It is expected that decisions regarding the fabrication and installation of a jacket platform beyond 400m will consider only economic concerns and, therefore, no new structural technologies will be required. In the case of compliant production systems, there are concerns because of the relative newness of the concepts.

The TLP (Figure 1), a buoyant production platform, pulled taunt to the ocean floor by tensioned legs (tendons) so as to greatly lessen wave response and consequently highly restrict its watch circle, has two critical areas of concern--the tendons and the pile foundations. Conoco, the foremost proponent of the concept in this country and the only company with field experience in the technology, having installed the Hutton-TLP in the North Sea 2 years ago, is presently performing significant research on these aspects. Like aircraft and ship designers, TLP engineers are greatly concerned about dead weight. Thus, the hulls, legs, equipment, etc., must be closely figured and controlled. For the legs, various TLP concepts have assumed the use of high-strength steels, i.e., steels having a yield strength over 80KSI. Some of high-strength steels exhibit a brittle fracture malady known as stress corrosion cracking when subjected to tensile loads in a corrosive environment. The

Navy's program to develop high-yield steels for its deep-diving submarines has encountered this problem and has had to avoid the use of steels having a yield point in excess of 80KSI, though a decade ago it appeared that yields of 120-140KSI would be possible. The phenomenon of stress corrosion cracking is not fully understood, and platform designers must assure that the various alloys used in the welds, connectors, and tubulars of the tendons are not susceptible. In addition to simple tension, there are the additional low frequency, relatively low-level load variations caused by wave loadings. Researchers at the Naval Research Laboratory, who are analyzing various TLP tendon candidate high-yield strength steels, term this "ripple load," and at this point in their testing, do not know its effect on stress corrosion cracking. As mentioned, stress corrosion cracking requires a corrosive environment, and if the tendons could be perfectly coated or plated with an insulation material, the problem would be solved; but like so many things in nature, achieving a practical and economic solution (what the scientists leave for the engineers to accomplish) does not appear feasible. If there were a scratch in the coating, the likelihood of corrosive failure would be greatly enhanced. Once fabricated and installed, there must be an inspection program of some sort to assure a high probability of detecting and monitoring cracks, at least until operating experience with tendons is proven satisfactory. Designers need to make provision for internal or external (or both) inspection. Present tendon concepts include tubulars from 0.3 to 1.5m outside diameter. Conoco's Tension Leg Well Platform (TLWP), planned for the Green Canyon area, appears to be using tendons of about 0.5m internal diameter thus allowing the use of internal ultrasonic transducer probes, used on welds and joints to detect cracks. A tendon study presently is determining what minimum size cracks need to be detected and what the probability of detection is. If there are joints (one concept proposes a jointless single length sealed tendon), the threaded connections are the most likely sources of cracking; and it is in the root of the thread where the acoustic transducer needs to "see," rather formidable problems. Operating experience will ultimately determine the effectiveness of this nondestructive test method.

The second technical issue regarding TLP structural integrity pertains to the tension pile foundation. The writer is unable to think of structures whose foundations tend to pull out of the ground, with the exception of buoyant structures such as oceanographic moorings and TLP's. In addition, the windward side of a jacket platform could see tensile loads during heavy storms. However, compressive loading is the overriding design consideration for conventional ocean platforms, buildings, bridges, etc. Even in the case of suspension bridge abutments and ship moorings, these exert mostly horizontal restraint to the cables or chains pulling against them in catenaries. As a result of the newness of the concept of fabricating tensioned structures (it would do an injustice to structural engineers to refer to a TLP as being moored) there are insufficient criteria for pile foundation design. Several organizations are participating in theoretical analyses and experimentation to determine tension pile design criteria. Involved in this expensive Conoco-lead project is the pulling of small- and large-scale pilings. Conoco has modified an out-of-service jacket platform in the Gulf of Mexico where the soil conditions approximate Green Canyon area conditions and has performed driven piling pull-tests on a 0.8m diameter piling.

Pile technology is also hampered by the ability to economically drive piles in deepwater. To get around this problem, Conoco has also tested at large scale a drilled and grouted pile. It is speculative as the holding capacity of such pilings in tension and the results are anxiously awaited. What also is awaited is the quantification of the effects of hydrates (clathrates to geologists) on tension-pile capacity. Hydrates are lenses or layers of frozen methane gas and water. Whereas the industry has experience drilling and producing oil through onshore permafrost there does not appear to be relevant information available on the potential for a hydrate problem; nor has there been acknowledged engineering testing. Soils engineers in the oil industry and scientists who are studying hydrates as a form of energy have been queried without learning of useful data regarding the effects of hydrates on pile capacity. Hydrate lenses are found around the world and, of interest to this paper, in the very important Green Canyon area of the Gulf of Mexico where they are known to exist within pile depth.

TLP's, unlike steel jackets or bottom-founded concrete structures, are not rigid but are termed compliant because under the varying loads imposed by the sea and wind, they move or comply noticeably. These excursions need to be controlled so as to maintain proper station above a drilling or production template. Another form of compliant structure which has been receiving wide press recently is the floating production system. Problems with this proposed system result not so much from the concept as from the difficulties coping with the ocean waves and currents. But, if successful, floating systems can prove to be an economic production platform alternative. The particular concept discussed here is the use of a modified semisubmersible drilling rig, converted to produce hydrocarbons. One proposed configuration, Figure 2, has been announced by Placid Oil Company to be installed in the Green Canyon area in 470m of water within a year or so. Of most interest to engineers is production riser which is reported to be "free standing" although it is constrained at its apex by festooned flexible hose-type pipe risers and a vertical tensioning member between diver depth (50m) and the platform above. The semisubmersible drilling rig, Penrod 72, is to be converted to perform both drilling and production operations and consequently is being increased in buoyancy to accommodate these operations. The riser package is 1.2m diameter, though it is encased in an annulus of syntactic foam buoyancy to extend the effective diameter to 2m. The engineering analysis of the riser package will have to consider the dynamics of the whole structural system, i.e., the 8-point mooring, hull, flexible pipe bundles, riser package, and the ultimate riser-template connection. The configuration of the system is very interesting to engineers, and the degree of interest will be, as mentioned above, determined by the design current profile, which is reported to be in excess of 1½ knots tapering downwards in the usual manner. In addition, there are the eddy currents which are known to exist in the Green Canyon area. In the analysis of the interaction of the subsystems, there is a need for analyzing the flexure of the riser package itself, which is not only subjected to the very substantial drag forces of the ocean currents (which vary with the square of the velocity) but also with the unstable vortex flow around the riser and the nonuniform momentum of the produced hydrocarbons in the tubulars. It is a very complex problem.

In some areas of the open ocean Outer Continental Shelf (OCS), notably California and the Aleutians, there is another forcing function for which platforms need to be designed, i.e., earthquakes. Whereas much engineering research has been accomplished ashore on seismic loads and the design of structures to withstand them, that is not the case offshore. There, proper design practice is understood, but the seismic loads remain unquantified. Geologists do not consider that such quantification can be adequately extrapolated from onshore events. Instead, accelerometers must be buried in the seabed and signals need to be measured and, for most conclusive results, correlated with responses on nearby structures. The reason for this latter measure is that the structures must not only withstand the direct seismic shock wave but also the propagation of wave energy through the water (seaquake) which reflects off the surface and the bottom causing energy reinforcement like water hammer. Off southern California, the Sandia Corporation has implanted a specially devised seismometer near the Shell platform, Elly. The seismometer rests on the ocean floor and is electrically connected to a probe, Figure 3, inserted 5m below the mud line where the soil is stiffer and where a reasonably accurate seismic reading can be obtained. The seismometer known as Seafloor Earthquake Measurement System (SEMS) records strong motion data and can be interrogated from the sea surface periodically. In addition, platform Elly is instrumented to acquire structural response data. SEMS has been implanted for about 15 months and as yet no significant readings have been obtained. In addition to that installation, because of the geologic variations in the seabed along the coast, several additional SEMS units are needed off California and the Aleutians. Seismic data are not easily acquired and need to be obtained when available, which may take years. The cost of, say, seven instruments per year is estimated to be over $1 million.

As previously mentioned, afloat drilling operations seem to progress on demand to whatever water depths are of economic interest to the oil industry. But one aspect, well control or the control of potential blowouts, should be mentioned. As water depths increase, well control problems become increasingly tenuous. The shear weight of the drilling mud (used to counterbalance the formation pressures and lubricate the drill bit) provides a heavy overburden and needs to be controlled very accurately, lest the formation fracture and a "blow in" occur. Figure 4 illustrates the effect of water depth on fracture gradients expressed in terms of the maximum mud density which can be sustained under normal operations. In addition, the long flow lines from the drilling floor to the blowout preventer stack on the seabed, hundreds or thousands of feet below, present high fluid friction losses which severely attenuate the "feel" of hydrostatic kicks in the borehole. Expert drillers, thus far, reportedly have been able to avoid loss of well control in deep drilling, but from experiences reported in very deep ocean drilling no severe kicks have been encountered as yet. It would be a very great improvement for drillers to be able to observe pressure fluctuations at the bit, while drilling, and to respond by controlling the bottom hole pressure in a timely manner, thus precluding kicks from resulting in lost control. At Louisiana State University, a project is directed at such a reality. The project is examining the use of a "high speed" mud pulsing system which can be positioned above the bit so that it can take measured bottom hole pressures and telemeter them acoustically (water hammer) through the drilling fluid to the drillfloor above. By feeding these on-line pressure pulses through a programmed computer, which in turn operates the surface choke, it is anticipated that deep ocean drilling operations will be much safer.

The next set of engineering problems are those associated with Arctic operations. These are highlighted in Figure 5 and a few will be discussed herein.

The primary problem of any structure implanted in the ice pack is survival. Even if the structure is a gravel island, its beaches can be eroded and its shoreline overrun by rafted broken sheets of pack ice. Oil companies have been examining ways and means for holding back this seemingly limitless force and have devised a number of schemes including the fabrication of man-made reeflike ice berms around structures. These berms are built by spraying sea water during winter until a large hill of it sinks to the sea floor creating a bottom-founded barrier around the structure.

But what is most important in "pack ice management" is not so much what to do but how much because the composition and behavior of the ice is still not sufficiently quantified for engineering application. Specifically, designers need to know the pressures which buildup against an island as the ice pack is driven by wind and current shear. Secondly, a better understanding of the mechanical properties, i.e., the strength of ice, needs to be known in order to design against it. Thirdly, the modes of ice sheet failure against structures need comprehensive analysis. After several years of concentrated effort, there seems to be a feeling that perhaps the worry of designing for the almost irresistible force is not warranted and that the failure mode of the ice in flexure will preclude the attainment of these very high forces. But the evidence is not conclusive. Ice is a very nonhomogeneous solid containing pressure ridges which can extend 10 to 20m or more from the bottom of their keels to the ridge tops. The data are being gathered and gradually improved design criteria are resulting, though not in neat stress-strain curves but in envelopes of highly scattered points. Many tests are necessary to improve data confidence. One of the problems in measuring ice-force buildup is that the instruments frozen into the ice sheet are not yielding anticipated results. Either the pack ice fractures, wrecking the instrumentation cables or the ice does not move sufficiently during the testing. Like the measurement of seismic events, it takes time and money to test and retest until good data are obtained. Figure 6 shows a field team instrumenting the ice pack around the Mukluk gravel island. Note the build-up of ice around the island.

On the other side of the problem, i.e., the "what if" side, designers are wondering if concrete structures, for example, would not only be subjected to global ice loads but to highly intensive point loads from jagged ice salients punching or shearing the concrete walls. A study at the National Bureau of Standards presently is examining, through theory and experiment, the size and placement of reinforcing steel ("rebar") using the various combinations of lighweight agrigate likely to be used in the Beaufort Sea. There, the water is quite shallow (say 10-20m) and structures need to be light enough to float into place and ballasted down, sometimes upon prepared foundations.

One arctic problem which is addressed on a continual basis is that of storage and transportation of hydrocarbons. Toward the western Arctic Ocean shoreline, erosion becomes quite severe, eroding 1-2 meters or more a year, thus presenting a formidable problem to the landing of pipelines. It is not clear how hydrocarbons would be stored and transported in the Arctic Ocean but in the Bering Sea, where platforms may someday be installed far offshore, it is probable that produced oil will be stored either in bottom-founded production platforms or storage platforms for periodic transport to shore. These storage facilities are likely to be of concrete which may develop leaks causing oil pollution. What will be needed is a nondestructive test system to determine the integrity of the concrete and, subsequent to that, a means for prompt repair.

Lastly, the question of drilling and producing hydrocarbons in the deeper waters of the Beaufort Sea ice pack (which at this writing appears far into the future) has spurred much conjecture, even to the point of suggestions of drilling from submarines. Figure 7 illustrates the progression of drilling and production platforms into the deeper waters of the Beaufort Sea. Whatever the mechanisms, it will be another engineering fete accomplished only after a number of other intermediate engineering problems have been sorted out. The Arctic and the deep waters leading down the continental slopes present an ever increasing number of these costly engineering problems, of which only those of the greatest magnitude have been highlighted in this paper.

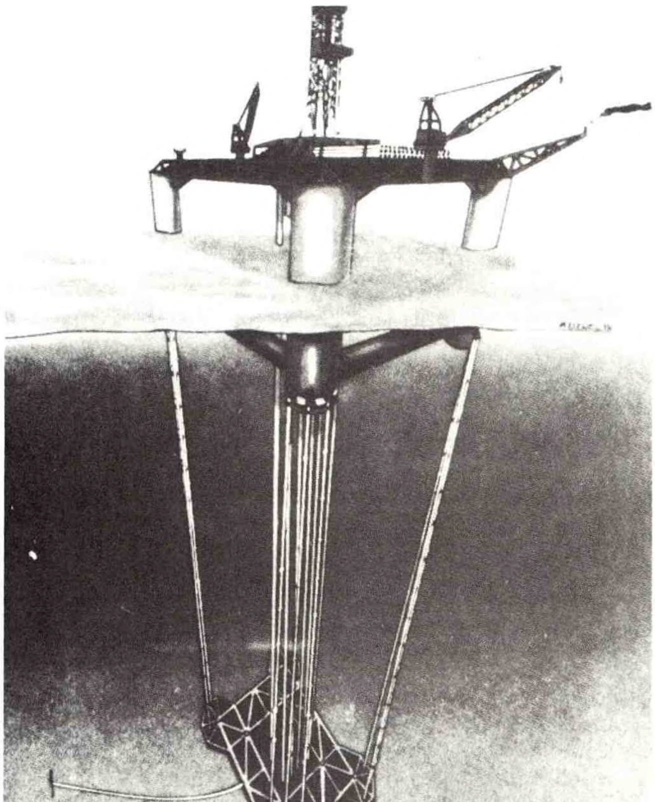


FIGURE 1. Artists' concept of the Conoco Tension Leg Well Platform planned for the Green Canyon, Gulf of Mexico. (courtesy "Oil & Gas Journal")

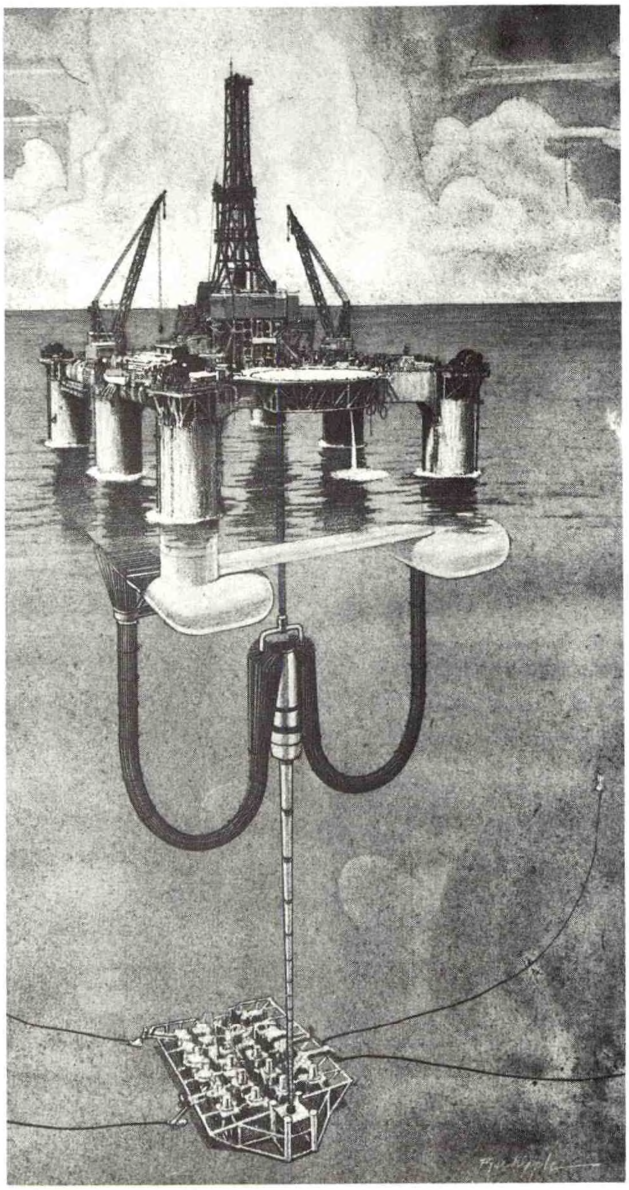


FIGURE 2. Artists' concept of the Placid Oil Company floating production system planned for the Green Canyon, Gulf of Mexico. (courtesy "Petroleum Engineer International")

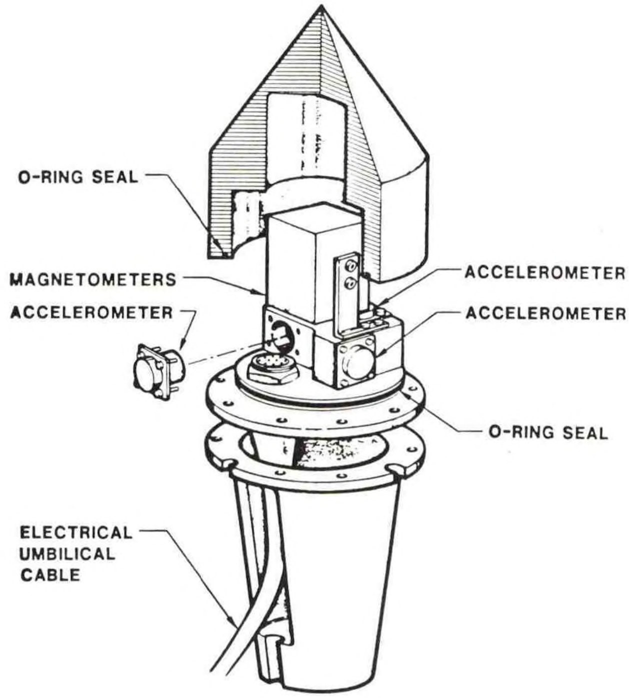


FIGURE 3. Drawing of the Sandia seismic probe inserted 5m below the mudline.

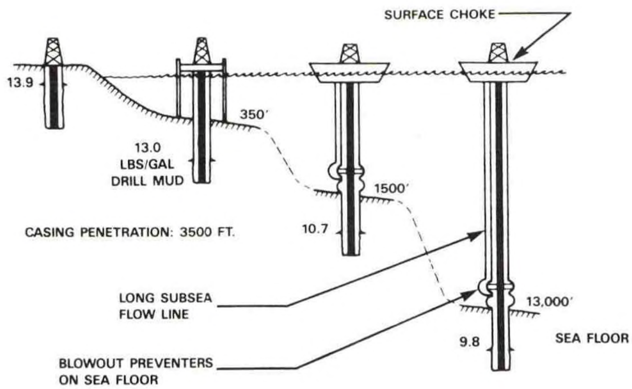


FIGURE 4. Illustration of the effect of water depth on fracture gradients expressed in terms of maximum mud density which can be sustained under normal drilling operations.

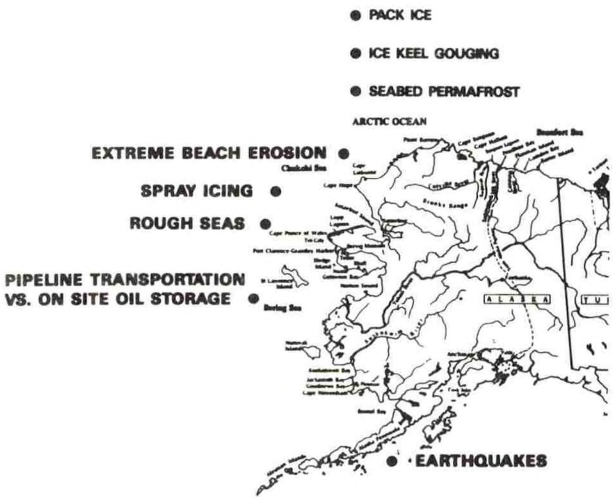


FIGURE 5. Highlights of engineering problems in the Arctic.

FIGURE 6. Instrumenting the ice pack around the Mukluk gravel island.

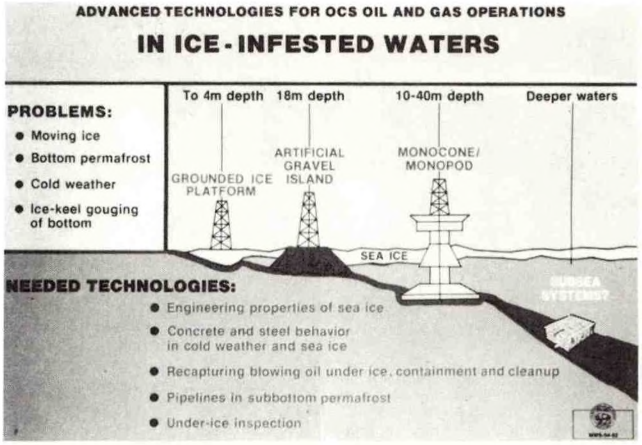


FIGURE 7. The progression of drilling and production platforms into the deeper waters of the Beaufort Sea.

R & D on Deepwater Artic Rig

The development of AMDP-Artic Mobile Drilling Platform

Nippon Kokan K.K.

1. DEVELOPMENT OF AMDP

In 1984, OCS lease sale 87 took place and as many as 232 tracts were leased in the Beaufort Sea. More than half of these tracts were located in areas with water depths of 20m to 60m. Because at that time, neither drilling rigs or design of rigs capable of operating in these areas existed, it was clear that there would eventually be a need for such rigs.

To aim at this market segment, NKK, in joint efforts with Ocean Drilling & Exploration Co.(ODECO), a U.S. drilling contractor, decided to develop an "Arctic Mobile Drilling Platform" (AMDP) capable of operating in the Arctic in the water depth range of 20m to 60m. This product development commenced in August, 1984, and was completed in April, 1985. More than 400 sheets of drawings were developed and during this period, numerous research studies carried out to verify design concepts and to further advance our understanding of ice mechanies.

This report provides a description of the AMDP and summarizes some of the research carried out.

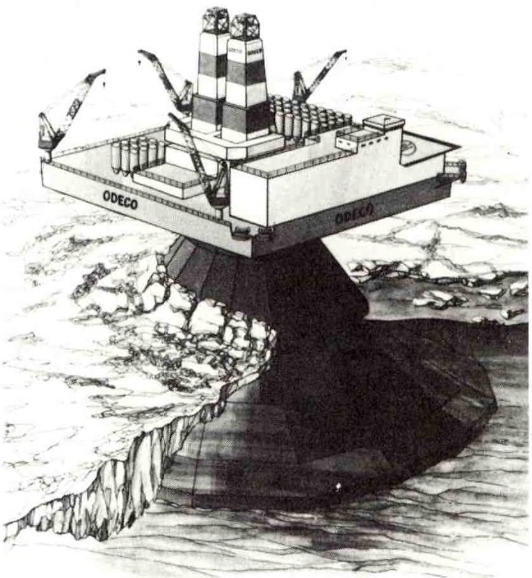


Photo 1 Appearance of AMDP

2.DESCRIPTION OF AMDP

The AMDP is designed to engage in explotation and development drilling in water depths of 20m to 60m in the Alaskan Beaufort Sea and can be converted to a production platform with minimum efforts.

The AMDP is an all steel structure with a 16 sided multi-sloped cone shaped lower hull, 200 meters in diameter at its base and 86 meters in height. On top of this lower hull, it has an upper hull of 120m x 107.5m x 10.2m. Thus, it has an elevation of 96 meters from bottom to main deck and 155 meters from bottom to the top of the derrick.

The steel hull weighs as much as 178,000 tonnes and the gross weighs reaches 190,000 tonnes. It is equipped with two rigs and provides accommodations for 200 crew members and therefore is ideally suited for exploration and development well drilling activities.

The ice wall which is supported by many vertical web sections. These web sections provide an efficient path for transferring the enormous ice loads from the ice wall through the base of the structure and into the seabed.

The material used in the lower hull and in other exposed areas is NKK's 36 Kg high tensile steel for low temperature service produced by controlled cooling method.

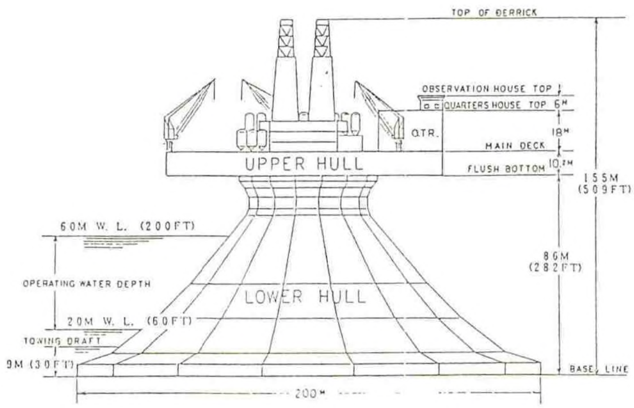


Figure 1 AMDP Section

The AMDP has the capacity to complete 8 wells without resupply of drilling materials and provides a template for drilling up to 48 wells at the same location. To make this possible, the AMDP provides onboard, a tubular storage space of 7500 sq.m., 85 sets of pressure tanks which totals to the capacity of 7800 cu.m. of dry bulk materials, fuel oil tanks totalling 30,000 tonnes, drill water tanks of 10,000 tonnes and potable water tanks of 4800 tonnes. To resupply such large quantities of consumables during the short summer months, the upper deck is ourfitted with 3-108 tonne cranes and 3-75 tonne cranes.

To protect people and machinary from the hash weather and low temperature of the winter, the AMDP's working spaces are totally enclosed. To suport all systems and operate reliably in this hash enviroment, the AMDP has a redunant capacity of power sources provided by 4 sets of 4.0 MW gas turbine generators, 2 sets of 900 KW emergency diesel generators and 3-8.2 MW heaters.

PRINCIPAL CHARACTERISTICS

BASE DIAMETER	:	200 M	(656FT)
NECK DIAMETER	:	51 M	(167FT)
TOTAL HEIGHT	:	155 M	(509FT)
MAIN DECK HEIGHT	:	96 M	(315FT)
FLUSH BOTTOM HEIGHT	:	86 M	(282FT)
AIR GAP AT GOM W.D.	:	26 M	(85FT)
MAIN DECK	:	108 M X 120 M	(354 FT X 394 FT)
MOON POOL AREA	:	152 SQM X 2	(1636 SQ FT X 2)
ACCOMMODATION FOR	:	200 MEN	
STEEL WEIGHT	:	178.000 TONS	
TOTAL HULL WEIGHT	:	190.000 TONS	

TABLE 1 Principal Characteristics

AIR TEMPERATURE	:	-50 TO 25 C
WATER TEMPERATURE	:	-3 TO -10 C
MAXIMUM WAVE HEIGHT	:	13.6 M(45 FT)
CURRENT	:	3.0 KNOTS (SURFACE) 1.5 KNOTS (BOTTOM)
TIDE	:	0.3 M
STORM SURGE	:	1.22 M
WIND	:	100 KNOTS
GLOBAL ICE LOAD	:	
		BY RETUREN PERIOD ANALYSIS
		25 YEARS FOR EXPLORATION
		100 YEARS FOR PRODUCTION
FOUNDATION	:	
		S.F FOR SLIDING ≥ 1.5
		S.F FOR BEARING ≥ 2.0
		MINIMUM Cu : 0.6 KSF TO 1.0 KSF
		MINIMUM ϕ : 25 DEG. TO 40 DEG

TABLE 2 General Design Criteria

3. RESEARCH STUDIES

To make this development work possible, the following engineering items had to be addressed.

Design criteria
Geometry
Ice loads
Foundation stability
Sinking stability
General arrangements
Hull structure design
Outfitting & pipings
Quarter arrangement
Construction method
Towing

Of the items listed above, Ice Loads, Hull structure Design and Construction Method studies are outlined here:

(1) Global Ice loads

Since ice loads generated by the environment can be extremely large, it is important to accurately define design loads in order to provide an efficient and economical structure. Unfortunately engineers are faced with a general lack of ice load data, especially full scale data. To overcome this problem in the AMDP project, theoretical analyses and physical model tests were combined to establish realistic ice load estimates.

Physical model tests of the AMDP were carried out in ice tanks at Arctec Canada Ltd, located in Calgary, Canada and at NKK's TSU Research Center.
The estimations/calculations of global ice loads are based on the following scenario.
1) A multi-year ice ridge is embedded in a multi-year ice floe.
2) The multi-year ice floe is surrounded by a first-year ice sheet.
3) The first year ice sheet is driven by wind and current.
4) The complex of multi-year ice ridge and floe is pushed by the first-year ice sheet.
5) And thus creating the possibility of the complex drifting towards and hitting the structure.

The calculation results are shown in Figure2.

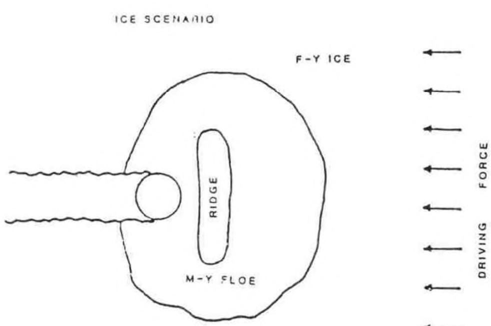


Figure 2 Ice Scenazio

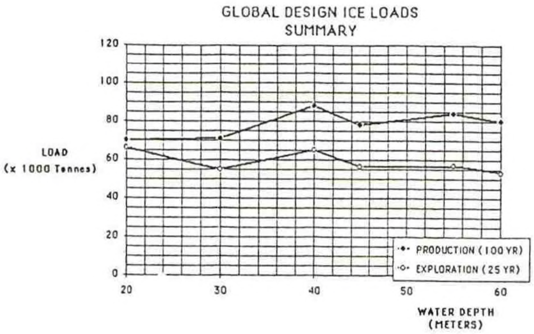


Figure 3 Global Design Ice Load

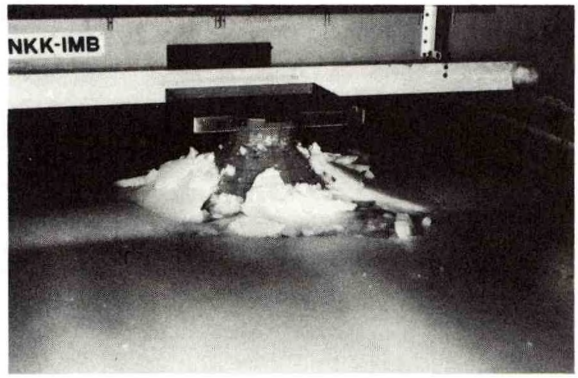


Photo 2 ice Test

(2)Hull structure

Since the total ice load is tremendous, the evaluation of the strength of the structure is also very important, and considering the size of the structure the preciseness of such analysis is critical.

Keeping these two factors in mind, the first step in designing the structure of the AMDP was to carry out simplified finite element analyses to evaluate what kind of structure was the most economical. Once a tentative configuration was chosen, NASTRAN's cyclic-symmetry 3-dimentional FEM analysis method was used to evaluate the global stresses acting on the structure.

Using this approach, the precision sought in the analysis was achieved with minimum data processing and analysis time.

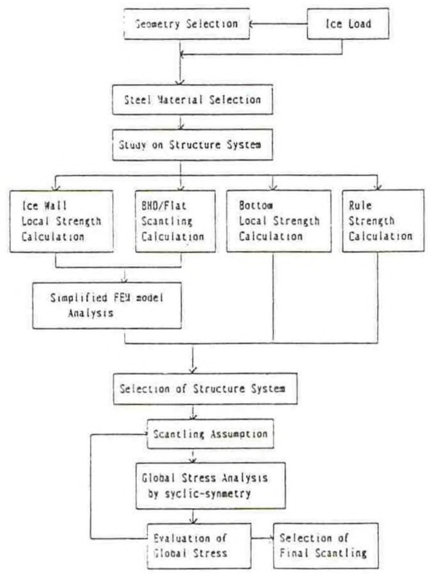


Figure 4 Structure Study Flow Chart

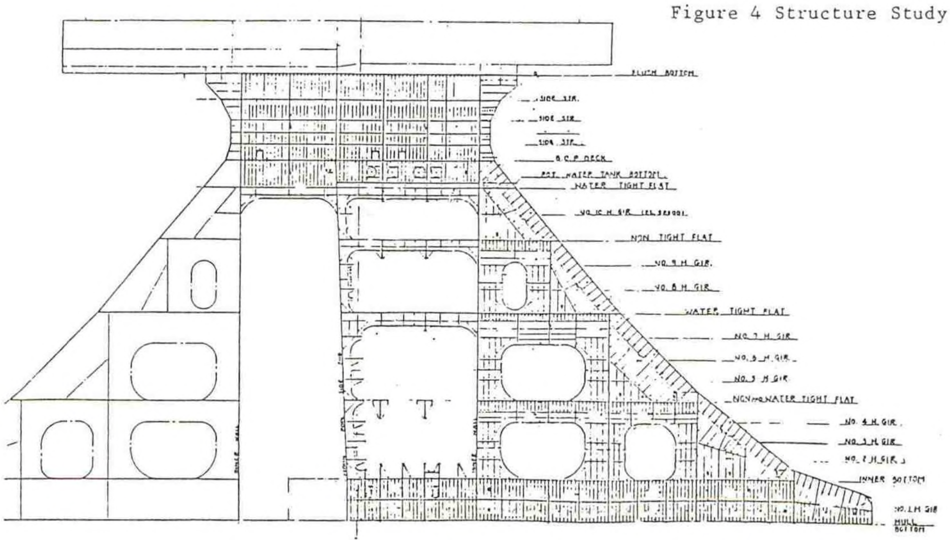


Figure 5 Web Section Structure Plan

Photo 3 NKK's Huge Dry Dock

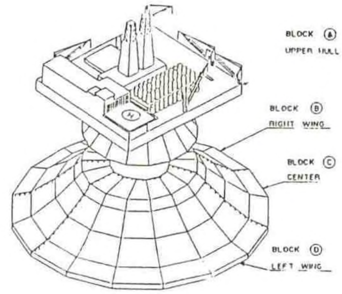


Figure 7 Block Division Plan

(3)Construction Method

When it comes to a very large structure like this one, it is critical to study the method of construction. After studying a number of alternatives it was concluded to divide the lower hull into three sections as showen in figure 7 "Block Division Plan".

As shown in figure 8 "Construction Sequence", a center block and two wing blocks will be erected in building docks, towed to NKK's huge dry dock, and joined together. The lower hull section will then be towed to a site of 75 meters water depth and the upper hull block with neck part will be stacked by using floating cranes and support barges. After stacking and final work, it will be towed to a drilling site in the Beaufort Sea.

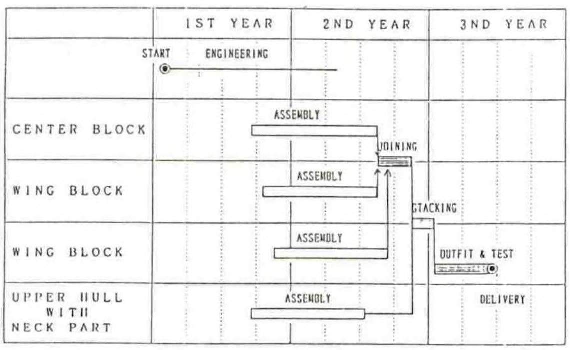


Figure 6 Construction Schedule

4. CONCLUSION

As described in this report, the design of a mobile drilling unit capable of year round explotation, field development and production operations in the Beaufort and in water depths of up 60m has been successfully developed.

This success is largely due to the U.S.-Japan cooperation of ODECO and NKK. The close cooperation of the two companies, each contributing its own expertise, proved to be a very effective in the development of the AMDP design.

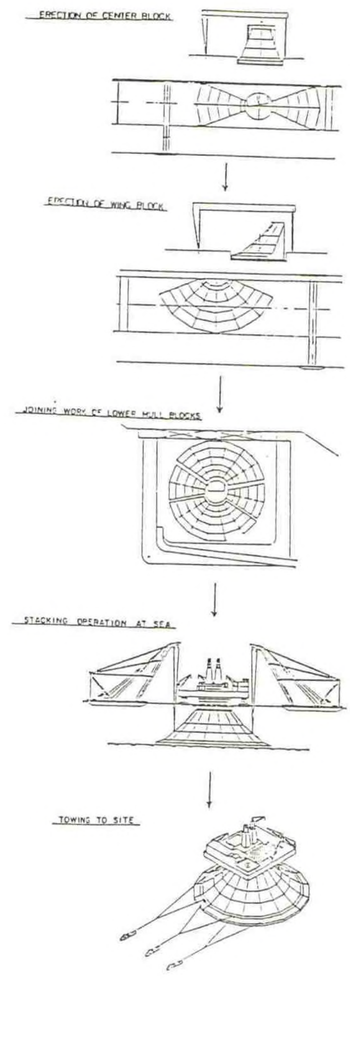


Figure 7 Construction Sequence

TECHNOLOGY FOR STEEL-CONCRETE HYBRID STRUCTURES

Ben C. Gerwick, Jr.

University of California, Berkeley

Interest has recently accelerated in the development of steel-concrete hybrid structures in the offshore environment, especially for those exterior structural elements subject to impact from sea ice, icebergs, and vessels. Such a hybrid system has already been used in enhancing the sides of the VLCC vessel during its conversion to the SSDC-1 drilling vessel, which as been operating for several years in the Beaufort Sea.

The rationale for the hybrid construction is an attempt to combine the advantageous properties of steel plate construction with those of concrete shell structural elements. The critical design problems are to ensure full composite action even up into the ductile range (large deformations) and to ensure a sufficient shear capacity to prevent this occurring as the initial mode of failure.

Considerable laboratory and investigation has been carried on in the last few years in Japan, the United States, Canada and Germany. A report was presented on the current status of one Japanese program by Nojiri, Y., Koseki, K., Yoshiki, T., and Sawayanagi, M., Offshore Technology Conference, Preprint OTC 5292, 1986.

Concurrent relevant development is being carried out in Germany, on hybrid bridge girders for their high-speed railway and in both Canada and Germany on means of enhancing the shear resistance of heavy duty industrial floor slabs. Work on shear transfer in reinforced concrete walls has been carried out at Delft University in the Netherlands, and at the University of California at Berkeley.

To inhibit shear failure, reinforcement must extend across all potential shear cracks. A truss analogy is usually employed, with the steel required to carry all the diagonal tension once the stress-strain path departs from linearity (a pseudo-yield point). Vertical steel, in the form of plates or overlapping studs are usually employed. However, with high percentages of transverse steel, shear failure can occur on a steep or even vertical plane (as usually represented). Longitudinal reinforcing steel at mid-height can be beneficially employed to resist in-plane tension and thus inhibit shear failure, while at the same time maintaining a relatively thick zone of concrete for arch effects. Spacing of transverse steel, whether plates or studs, must be sufficiently small as to prevent buckling of the external plate under compression.

Because of the arch mode of resistance which develops after initial flexural yielding, the ultimate behavior is highly dependent on the strength of the concrete. Use of super-plasticizers and condensed micro-silica fume admixtures can enhance the strength by a factor of 1.5 or more.

Constructibility of a hybrid structural element requires careful examination. Steel fabrication must be modularized. The two steel plates of sandwich construction must be tied together so as to avoid excessive deflection during concrete placement and vibration. Means must be developed for placing the concrete so as to allow for escape and displacement of entrapped air and bleed water.

In order to effectively utilize these new concepts in offshore construction, a design basis must be developed. The behavior of an exterior concrete shell element is dependent not only on its internal characteristics but also on its support (or boundary conditions). The previously referenced paper by Nojiri et. al., attempted such a basis. It is a good initial step but in our opinion not fully adequate.

Under a proprietary program for the oil industry (AOGA Project #321) we have been developing a rational basis for design and analysis. While it is not yet ready for publication, we believe it will prove a simple and effective method for design and verification.

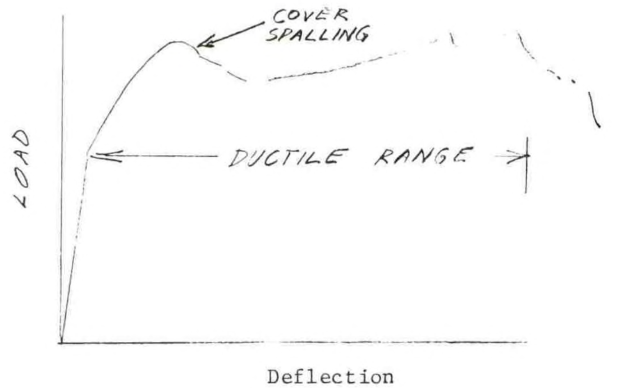
The results of large-scale model tests have been extremely encouraging; not only because they followed predicted paths to yield and "ultimate" but especially because of the high ductility that has resulted under overload, with deflection ductilities up to 30 and more being achieved because of the confinement of the concrete.

The application of hybrid steel-concrete structural elements need not be limited to the exterior walls of structures subject to impact. We find it technically and economically adaptable to interior diaphragms and walls of offshore Arctic structures, where the dominant forces are membrane compression, membrane shear, and out-of-plane bending, the latter due to unequal loading of the peripheral ice wall.

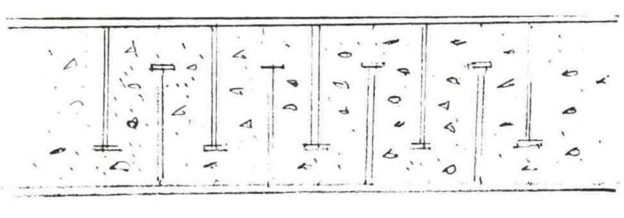
We also find it adaptable to the base slab of gravity-base offshore structures, which must resist high local concentrated forces.

We find it adaptable to pressure hulls, where relatively thin plates can be more easily formed in double-curvature. We also find potential application in marine structures where a liquid or gas tight membrane, in this case steel plate, it required.

The hybrid steel-concrete structural element appears to have a significant role to play as we extend our activities into even deeper water and more hostile environments. It is hoped that in the future, even greater coordination of the research in Japan, U.S., and Canada can be effected.



1. Load-Deflection Behavior of Hybrid Structural Slab.



2. Steel-Concrete Hybrid Construction.

ICE STRUCTURE INTERACTION - CURRENT RESEARCH IN ICE FORCES ON STRUCTURES

Ben C. Gerwick, Jr.

University of California, Berkeley

The development of structures and vessels for Arctic operations requires an evaluation of ice forces from two aspects: the global load on the structure and the local loads exerted over the contact area. Most investigations to date, while usually proceeding from small scale tests of sea ice, has been directed to the global forces. There has been a wealth of research studies, and a great number of published papers and reports, but the results are very disappointing.

A major problem, of course, is that of getting an adequate data base for correlations of our analytical models. Vessels, even icebreakers, avoid the most formidable ridges and seek out leads. Structures are artificially or naturally protected by rubble or frazil ice. In our opinion, more attention needs to be directed to the latter possibility. Since ice forces are so highly variable, depending on a wide range of parameters, even a few years adequate data collection doesn't permit a statistically valid extrapolation. Hopefully, data from the structures now operating in the Arctic will soon be published. It has been widely reported that the actual ice forces developed from existing structures and from the proprietary tests at Hans Island are significantly lower than would be computed from a simple application of Korzhavin's equation.

In the U.S. there is considerable research both at the University of California (Berkeley) and at the Massachusetts Institute of Technology. I especially call attention to the following paper:

Salavaggio, M., and Rojansky, M., "The Importance of Wave-Driven Icebergs Impacting an Offshore Structure", Offshore Technology Conference, Preprint OTC 5086, 1986.

It seems appropriate to examine this interaction problem by listing the various phenomena involved which do, or could, reduce the impacting force of multi-year ice floes and icebergs. Our list includes:

- Non-simultaneous crushing of the ice.
- Eccentric forces at contact points.
- Discontinuities in the ice.
- Elastic strain and short-term creep in the far field.
- Dynamic compression wave attenuation.
- Hydrodynamic cushioning immediately prior to full contact.
- Eccentricity of impact in horizontal and vertical planes.
- Elastic and plastic strains in the soil: lateral deformation and tilting (may be limited by inertial effects).
- Rotation of ice mass in horizontal (rotation) and vertical planes (rolling).
- Lifting or submergence of the ice mass in the vertical plane.
- Low cycle-high amplitude fatigue of the ice on a local basis under "ratcheting".

The above are in addition to the traditional failure modes of the global ice feature in flexure, shear, and crushing.

It has been noted by several investigations that global loads are not highly dependent on ice strength since soft ice envelopes a greater portion of the structure.

In our opinion, inadequate attention is being given to the development and distribution of local forces at the contact area between the ice feature and the structure. The phenomena which take place need to be investigated in more detail to determine how loads are redistributed within the ice, just as we now do within the structure.

Here however, we do have some guidance from published reports on icebreaker vessels. These appear to indicate a lower value (perhaps half to two-thirds) of that which we've so far been using in design as a maximum.

Although activity in the Arctic is temporarily at a low pace, this may not be entirely without benefit. It will give time for publication of data and reports, for serious reflection, and for the results of on-going research to be assimilated into design practice.

RESEARCH PROGRAM ON HYBRID OFFSHORE STRUCTURES IN SRI

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ABSTRACT

A five year program of steel-concrete hybrid offshore structure which is now under way in Ship Research Institute is outlined. The program involves many items of technological problems to be solved to establish the hybrid offshore structure technology; such as material, analysis, fabrication, construction, non-destructive inspection, etc.

INTRODUCTION

In Ship Research Institute, a five year research program of steel-concrete hybrid offshore stractures started in 1985. The purpose of the program is to provide technical background for design and construction of the hybrid offshore structures for which no inspection in dock is necessary, and to establish standard or guideline for its design and construction from the viewpoint of safety at sea.

The program consists of three parts: In the first part of the program, reasonable arrangement of reinforcement, assessment of strength of slab, and fabrication of the hybrid modules and assembly to the offshore structures are investigated. Structural strength and dynamic response of the hybrid structures in the ocean are also investigated in this part. In the second part, strength of materials in ocean environment is investigated; for example, stress corrosion and corrosion fatigue of wire strand, cracking characteristics of concrete, etc. The last part of the program is for development of effective non-destructive testing technique for hybrid structures. The first two parts are now under way, starting in 1985. The last part is scheduled to start in 1987.

In 1985 fiscal year, as the first year of the program, light weight and high strength hybrid slabs were designed, and were tested in bending and in other loading conditions. Creep testing machines for the wire strands were fabricated, and creep and stress corrosion tests started.

RESEARCH ON STRUCTURAL STRENGTH

The yearly schedule of the first part of this program, research on structural strength of the hybrid offshore structures, is shown in TABLE 1. Bending tests and water leakage resistance tests are having been carried out since 1985.

*[1] Director of the division.
*[2] Senior technical officer.
*[3] Senior technical officer, Dr.Eng.

TABLE 1 YEARLY SCHEDULE (STRUCTURAL STRENGTH)

YEAR	EXPERIMENTAL APPROACH	ANALYTICAL APPROACH
1985	DESIGN OF HYBRID SLAB	
	BENDING STRENGTH WATER LEAKAGE RESISTANCE	
1986	BUCKLING STRENGTH LOCAL CONTACT STRENGTH	DYNAMIC RESPONSE
1987	SHEAR STRENGTH STRENGTH OF CONNECTION	STRUCTURAL BEHAVIOR
1988	TRANSVERSE STRENGTH OF HULL SECTION	
1989	LONGITUDINAL STRENGTH OF FULL STRUCTURE	

Buckling tests of steel members connected with concrete slabs, such as webs, flanges and face plates, started in 1986. Assuming striking a rock, landing on sea bed and collision, local contact test on concrete slabs also started in this year. For the analytical aspect of the research, study of dynamic response of the structure is now carried on.

The rough sketch of the local contact test is outlined here. A typical test model and the test setup are shown in FIGURE 1. The test model has a concrete slab, on whose longitudinal direction 4 PS-ducts are arranged. On the hunch of the slab, steel face plates are set, and are connected to the reinforcements of the PC-slab with steel rods. On the face plates, steel webs and flanges (steel girders) are fixed with welding. The rigid conical jig is push into the model, set on the anvils. This local contact test have just started. Appearance of the tested model is shown in FIGURE 2 & 3; FIGURE 2 shows the face side of the slab, and FIGURE 3 the back side.

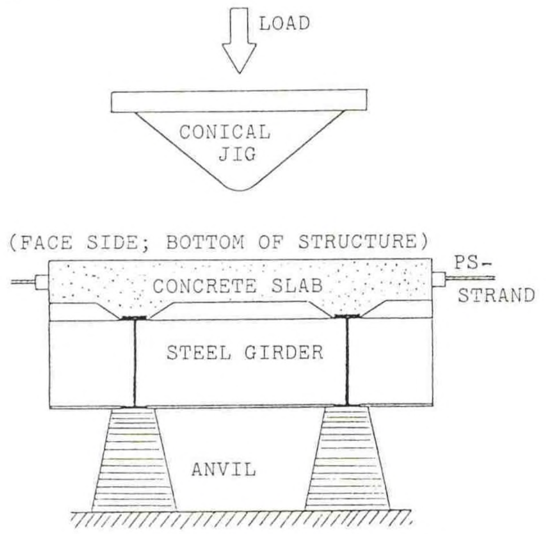

FIGURE 1 Test model and test setup.

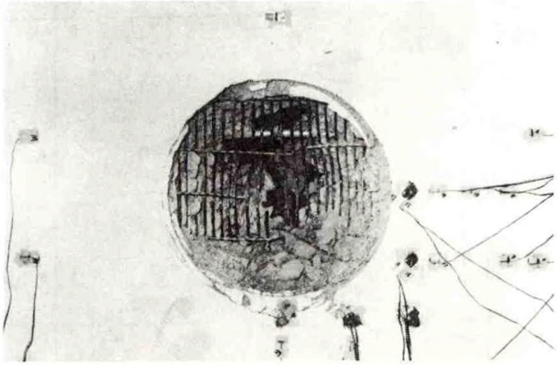

FIGURE 2 Face side of the slab.

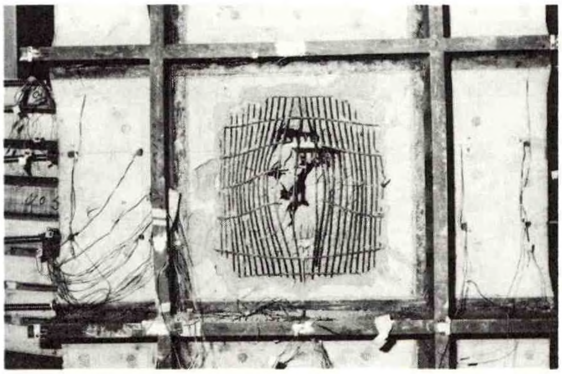

FIGURE 3 Back side of the slab.

RESEARCH ON STRENGTH OF PRESTRESSING STRAND IN OCEAN ENVIRONMENT

For the offshore prestressed concrete, it is necessary to maintain a stable prestress over a long period of time. For this reason, it is important to grasp the strength and deformation characteristics of prestressing strand in design and construction of prestressed concrete structures.

Deterioration of structure by the ocean environment, especially corrosion of reinforcement in concrete, comes up as an important problem for structural design. Corrosion of reinforcing steel occurs at such spots as the incomplete grouting, the cracking of concrete, the anchorage point, and incomplete connection of structural element, etc.

The purpose of this study is to obtain the design data based on the strength characteristics of prestressing strand in ocean environment. Items of the experiment are as follows;

1. Static creep test.
2. Dynamic creep test corresponding to ocean wave load.
3. Stress corrosion test.
4. Corrosion fatigue test.

Some of these tests are also planned to perform on the strand embeded in concrete.

These tests are carried out on stabilized strands. Stress relaxation value of a stabilized strand is about 1/3 - 1/5 lower than that of a bluing treatment strand.

Test strands are made according to JIS G 3536; type B (7 wire elements). Specimens are 12.7 mm in diameter and 650 mm in span length, as shown in FIGURE 4. Ultimate tensile strength and 0.2% proof stress are 19500 kgf and 17700 kgf, respectively. In FIGURE 4, two specimens are shown; usual post tension grips at both ends are used for one specimen, and the special anchoring grips strengthened with resin for the other. It has been confirmed that the anchoring grips with resin do not fail during fatigue tests of wire strands.

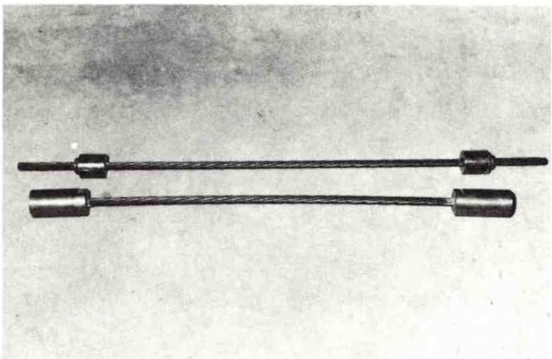

FIGURE 4 Test specimens.

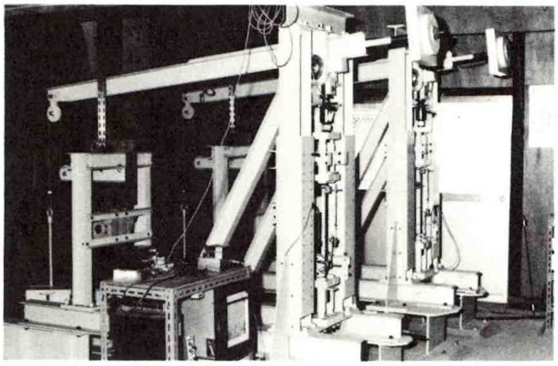

FIGURE 5 Creep testing machine.

Before stress corrosion tests are performed in NaCl corrosion environment, creep test continues in the air. The creep testing machine is shown in FIGURE 5. Maximum load capacity of this machine is 20 tons. Applied load and elongation are recorded.

FOR THE FUTURE

Research work has been carried out almost on schedule, and the development of non-destructive inspection technique is now in the course of feasibility study aiming at starting experimental work in 1987.

The safety at sea is the main concern of the Ministry of Transport, and with the completion of the research program in 1989, drafting of a standard or a guideline for the hybrid offshore structure will begin in some way or other.

Marine Geophysical Technologies for Ocean Resources Exploration

Carl H. Savit

Western Geophysical Company of America (Retired)

ABSTRACT

Marine geophysical techniques in use today are largely confined to reflection seismic exploration primarily for hydrocarbons. Improved sound sources are complemented by receiver systems that effect analog-to-digital conversion at or near the sensor, freeing the telemetry systems from many sources of interference. Recent trends to three-dimensional surveys from the familiar profiles in two-dimensions have provided sufficiently detailed geologic information to make such surveys cost-effective for exploitation of the resource. For example, erratic and disjunct oil-bearing sand bodies have accurately been distinguished in a shale matrix. Computer technology facilitates interactive interpretation of both 2-D and 3-D surveys and allows the interpreter to take full advantage of his geologic knowledge and experience.

Recent developments in marine geophysical technology have radically altered not only the actual technologies of prospecting but have concomitantly improved the quality of the obtained results.

This discussion will be limited to methods of exploring beneath the ocean bottom and, in particular to marine geophysical exploration by the reflection seismic method since virtually all resource exploration at present is conducted by that method.Furthermore, the reflection seismic method is superior to other geophysical methods in the quantity and resolution of data that can be obtained concerning the resources of the earth beneath the sea. A considerable sum has been invested in the research and development of the marine reflection seismic method in the past few years to the extent that there has been a proliferation of improved technologies and instrumentation. Other geophysical methods have not so benefited largely because those methods have inherently a lower resolution and lower information content. Also to this date, more than 90% of all offshore exploration has been conducted for the purpose of finding oil and gas and no technology has proved itself superior in that search to the seismic method.

One of the most important developments in marine geophysical technology has been the recent trend to utilization of seismic reflection techniques as a guide to exploitation of oil and gas deposits. Up until two or three years ago, no such use of the reflection technique was even contemplated. Seismic methods were exclusively used in exploration while well-logging techniques, core analysis, and other downhole geologic tools were used for exploitation. One can, however, contemplate a not too distant future in which expenditures for geophysical techniques used in exploitation would far exceed similar expenditures for exploration.

DEEP WATER TECHNIQUES

Seismic techniques are classified on the basis of depth of water. When the depth of water, free of underwater obstacles, permits of surveying while underway, the survey is classed as a deep-water survey. In a deep-water survey a ship tows both a source of sound and an array of sound receivers while proceeding along a line of survey which may extend to several hundred kilometers. The sound source is typically an array of air guns which periodically discharge compressed air at 150-350 atmospheres. Normally, the sounds are produced at intervals of about ten seconds for hour after hour along the line of survey. The sounds are emitted a few meters below the surface of the water. They travel in the water and penetrate the earth beneath the bottom to depths of ten kilometers and even more. The sounds are reflected from geologic strata and return through the water to be picked up by a receiver system that consists of hydrophones arranged in an oil-filled plastic tube that extends three or four kilometers behind the vessel. Thousands of hydrophones may be contained in the plastic tube and as many as 480 separate information channels are transmitted electrically to the ship. All of the received sound waves are recorded in digital code on magnetic tape for later processing in large-scale computer centers ashore.

Improvements have recently been made in sound sources largely in the case of air guns that were mentioned previously. Different sizes of air guns are arrayed in specific configurations, both laterally and vertically, to optimize the downward directivity of the resulting signal. Another result is improved sharpness of the sound pulse in the face of complexities inherent in the discharge of air into the water and reflections of sound waves from the air-water interface. The details of the improvements in sound sources can be obtained from the geophysical literature and would not be appropriate for inclusion in this survey paper.

Within the last year or so, experimental geophysical surveys have been performed with hydraulically driven sound sources that produce the equivalent of a continuous sinusoidal, swept-frequency signal. These systems are inherently more controllable than are the air gun systems and they have immunities to certain types of backscatter noises. A further advantage of such systems is the ability to encode these continuous signals so that simultaneous transmission of two or more signals may be effected without one signal interfering with another. As a result, two separate surveys can be conducted simultaneously. It is even contemplated that a ship can tow two continuous sources separated from each other by paravanes and generate two simultaneous and independent survey lines with only one receiver system. Some thought has been given to towing two receiver systems and two source systems all separated from each other and thereby to generate four simultaneous survey lines.

The most recent advances in the technology of receiver systems began to be employed in the early 1980s. Prior to that time, virtually all receiver systems consisted of hydrophones in an oil-filled plastic tube, a streamer cable, in which signals from the hydrophones were transmitted to a ship in analog form over individual copper wires. It was not until the signals reached the ship that conversion to digital form was effected. Such analog streamers reach a limit in the number of independent channels that could be transmitted to the ship. About 200 independent channels were being transmitted when the technology reached its climax. 200 channels of data require 400 individual wires for transmission. With spares and auxiliaries, such cables eventually contain about 500 copper wires. The problems of breakdowns and discontinuities and the flotation required by the weight of copper effectively put a stop to this technology.

In the 1980s, the trend has been to convert from the analog electrical signals to digital code in the cable itself. The digital signals can thus be multiplexed and transmitted by any of a number of high-capacity varieties of transmission lines. Coaxial cables, optical fibers, and small bundles of shielded, twisted pairs of copper wires have been used. In the typical cables used today, the electronics required for conversion to digital codes are contained in modules between sections of cables so that signals travel in analog form only from the hydrophone to the module. In a typical instance of these modern cables, 480 channels are transmitted with 12 channels being digitized per module. A cable consists of 40 modules and 40 cable sections plus, of course, suitable lead-ins, tow cables, auxiliary devices, etc. In addition to the seismic channels, 4 auxiliary channels per module are supplied. One for internal error checking, one for a detector to determine the depth of the cable, one for determining the orientation of the cable by means of magnetic compasses, and one for additional auxiliary functions.

Most recently, an experimental cable has been designed that produces digital signals directly at the hydrophones so that there is no analog transmission of the signal. Another feature is that, unlike the older cables which produced floating-point data, this cable produces fixed-point data with a dynamic range in excess of 120 dB. The resolution of the data is thus the same for full scale data as for the weakest signal. Such a cable will be particularly useful in conjunction with the above-mentioned hydraulic -swept -frequency sound sources because signals will have to be subtracted from one another to yield interference-free reflection data.

SHALLOW WATER TECHNIQUES

When the depth of the water is less than about 6 or 7 meters, streamer cables cannot be used. A number of stratagems have been employed to cope with bays and estuaries, tidal flats, surf situations, and natural or manmade obstacles to the passage of a streamer. Hydrophone sensor cables have been devised that can be dragged along sandy or silty bottoms. Such techniques are of limited applicability. Until a few years ago, one of the prime solutions was to suspend the hydrophone from a buoy and to transmit the signal from the hydrophone to a mother ship (or a shore based truck) by radio. Transmission of the hydrophone signal was analogue from the hydrophone to the radio link and to the receiver and it was only then that the received signal was digitized. These systems with hundreds of buoys and hydrophones were in use for a number of years but they were subject to noise interference, primarily in radio transmission, and were severely limited in dynamic range.

Newer systems consist of hydrophones also suspended from buoys but in which digital conversion takes place in the buoy and the signal is digitally transmitted for recording by the mother ship. Some of these systems transmit the signals from the buoys to the ship on one frequency so that each of the buoys necessarily contain enough memory for the storage of an individual seismic "shot". Such digital memories can have a capacity exceeding 25,000 bytes. A newer system transmits the signals from the individual buoys on separate frequencies . Such a system can, at present, transmit 120 channels on 120 separate frequencies simultaneously. Needless to say, to receive and unscramble all of these data requires a high-speed, sophisticated computing device on the mother ship. Experimentally the newest such devices (as discussed in connection with the experimental streamer) are taking advantage of the latest digitizing system which can obtain a resolution and dynamic range of more than 120 db.

THE TURN TO GEOPHYSICS IN EXPLOITATION

Early in the 1980s, active use of three-dimensional seismic reflection surveying was begun. Two-dimensional surveys typically are conducted along lines that form a grid. Grid spacings can range from 1 km or less to 10 km or more. Interstices of the grid are filled by manual interpolation and much imagination. Three-dimensional surveying, on the other hand, fills in the grid with lines that may be 25 to 100 meters apart and computes the resulting volume of data as a whole. By manipulating the entire data volume, features that are outside the vertical plane defined by the line of survey are properly located in space. In heavily faulted regions, or in regions of irregular stratigraphic changes, such results can be invaluable. Experience has shown that three-dimensional surveys conducted over oil and gas fields at an early stage of development are extremely cost-effective in saving dry holes.

A further advantage of the three-dimensional surveys is that computer systems can produce a cross section in any direction through the data volume, as well as horizontal slices. The advantage that the freedom to choose any section for viewing is enormous. For example, a cross section can be made to connect the discovery well to a potential development well location.

Modern systems can present the data on line to a computer video terminal so as to make it possible to cut images along faults and move them up and down relative to each other and thus to correlate across the fault. A useful further process is "horizon flattening". By this means, the section can be viewed as if one particular formation is horizontal. Thus, one may exhibit the depositional history of the geologic section. That is, the section can be viewed as it would have appeared at the time the flattened horizon was being deposited. Many other capabilities have been built into such computer presentations. The general field of seismic stratigraphy (that is paleo-stratigraphy) has advanced many fold by these computer display processes.

A further recent improvement in exploitation, and for that matter exploration, seismology is a process that interacts the human interpreter and computer processes to achieve a far higher degree of resolution and stratigraphic interpretation that is possible without that interaction. In the process, the seismic section or data volume is interpreted by the human interpreter in relatively crude fashion so as to produce a model of the underlying geologic section. The model is characterized by identifying presumed seismic velocities and densities for every layer. If applicable, faults as well as borehole information are included in the model.

The computer then produces the seismic section (or volume) that would have resulted from the model if instrumentation had been used that was equivalent to that used in the seismic field data. A measure of goodness of fit, for example a correlation coefficient, is calculated between the real data and the model data. Model parameters are varied by computer and the calculation is repeated. A few successive iterations can usually produce correlation coefficients in excess of 0.9 between the model and the actual data.

Because the computer is not required to make a model without any prior knowledge or information and because the human interpreter knows about what can be plausibly expected in the area, the result of the process has a much higher degree of resolution than is normally expected from seismic data. The result, furthermore, is stable, that is, interpreters with quite different, though plausible geologic interpretations, will produce essentially the same final result. The process has been spectacularly successful in such diverse areas as the Northeast Caribbean and Northern Canada defining porous reefs, in one case, and irregular riverine sands in the other case.

EPILOGUE

In the forty-year history of marine geophysical exploration, vast progress has been made. Progress can be evaluated in terms of increased information on the geology beneath the bottom of the sea. By common measurement standards, the quantity of information available per square kilometer of intensive survey today, is at least 10,000 times as great as was available forty years ago. Improved information benefits the user in terms not only of resolution and depth of penetration, but in terms of additional earth parameters and the ability to achieve results in areas that were formerly intractable.

For this proliferation of information, the geophysical industry is indebted to improvements of computer technology, navigation procedures, ship design, instrumentation, data presentation techniques, and the general level of technology in the industrialized world.

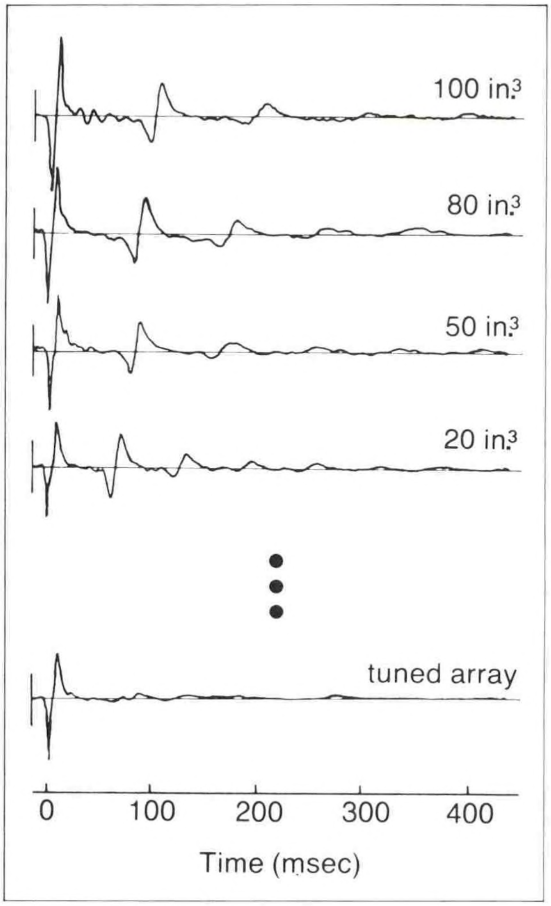

Fig. 1 Air-gun pressure signatures showing the combination of different air capacities in a "tuned" array. The tuned-array signature is simpler than any signature of an individual gun.

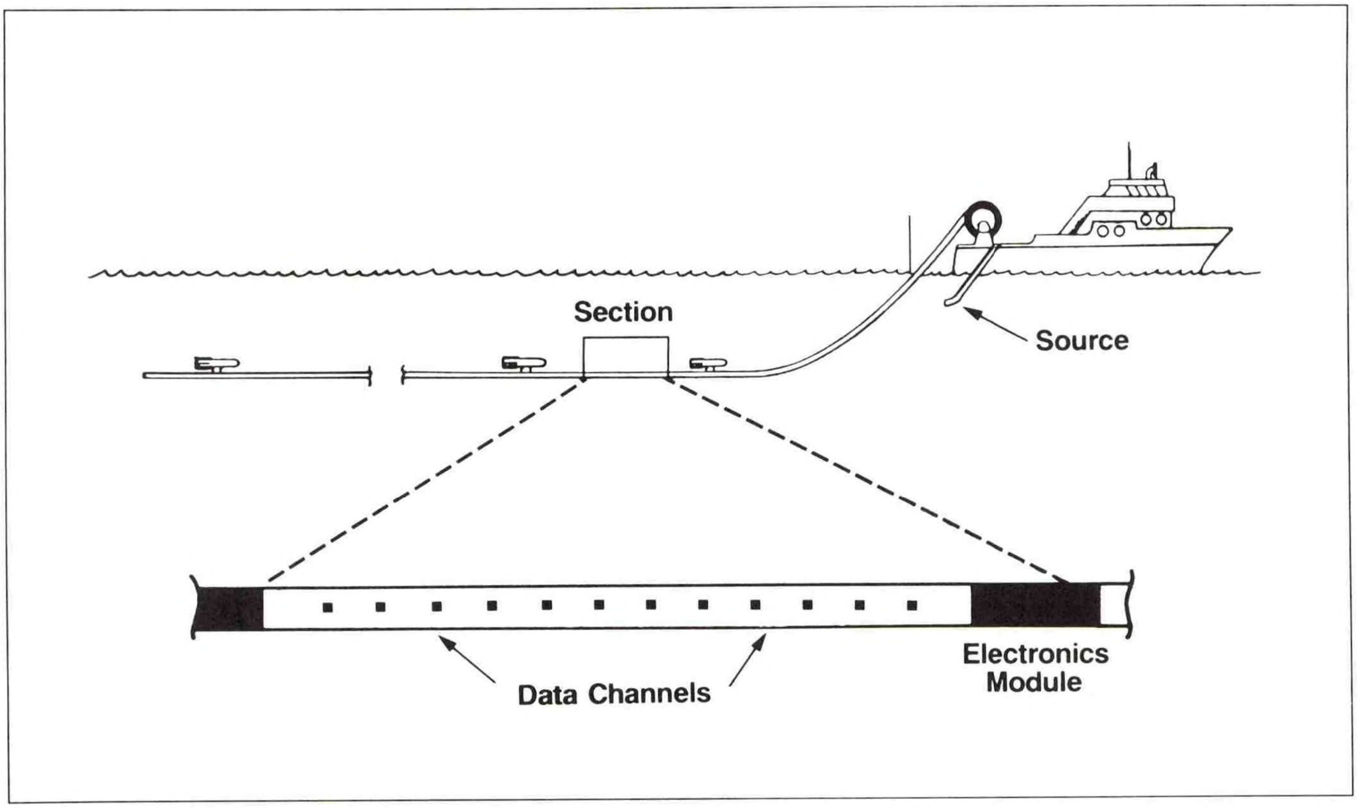

Fig. 2 Schematic view of a "digital" streamer cable system. The torpedo-shaped objects on the cable are servo-controlled devices to maintain desired cable depth within a meter or two over a typical cable length of three to six kilometers.

OCEAN MINING TECHNOLOGY

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Abstract

The field of Ocean Mining, over the last 20 years, has gone from scientific interest to an area of major Industry technology investments; from International political turmoil and market price collapse, to Industry discouragment. With the continuing needs for strategic materials, and the exciting promises emerging from seafloor spreading research, ocean minerals continue as a promising future source of these materials.

With ocean mining technology investment now resting largely with governments of industrialized nations, it is worthy to examine where we are and the foreseen requirements for new fundamental technology for ocean mining. This paper attempts to briefly summarize our status in such technology and define future needs, focusing on those particular deposits showing potential availability in this century.

Introduction

When we consider the subject of ocean mining, or seafloor research and technology, with a view towards assessment of where we are and what needs to be done, one can be filled with discouragement and say "Why Ocean Mining? --- even the oil Industry cannot make money in todays markets!" Or --- one can be entranced by the scientific and technological challenges and potential coming out of seafloor spreading research, and live in an enthusiastic and exciting dream world. In planning the future of ocean mining, one certainly needs wisdom and patience, for both of these positions are very real and important.

It is almost trite to say, but very true, that the direction for the near term technology thrust can be far different between government planners and those of private Industry. In Ocean Mining, the choices are fairly easy and fundamental for Industry, but they are much more difficult to define for governments. International trade and economic factors have become so vital, so dynamic, and so involved in the strategic materials areas, that aggressive long-range technology planning for resource availability is very important and highly complex.

When it comes to government activity in long-range, non-military technology development, i.e. fundamental engineering research vice basic science, Japan has been much more aggressive than the U.S.. We have left this activity much to private Industry, who are far more seriously affected in the short-term by markets and other critical investment factors. And U.S. Industry investment in non-military ocean technology has come almost to a stop. The National Science Foundation and to some extent, NOAA, have begun to address the issue, but we have a long way to go.

In the brief time that we have today, I would like to summarize where I think we are in the development of Ocean Mining technology, and outline a few suggestions regarding fundamental technology needs for the future.

Technology Assessment

If we break down the principal marine mineral deposit potential into three areas; namely, dissolved minerals, unconsolidated minerals, and consolidated deposits, as done by Cruickshank (Figure 1), we can display the mineral potential as understood today. We can further subdivide the unconsolidated deposits, i.e. materials that are capable of being dredged, into typical depths of location; namely, the Continental Shelf (0-200 meters), the Continental Slope and the Deep Sea. On the Continental Shelf zone, note the valuable construction materials, the high potential heavy minerals (including the black sands), and the well known precious minerals. We find the much discussed phosphorite nodules and the metalliferous muds on the Continental Slope, and the ferromanganese nodules in the deep sea. Consolidated deposits include the newly discovered polymetalic sulfides and the promising cobalt-rich manganese crustal deposits.

One can make a qualitative overview, a summary, of the principal constraints currently faced in these key mineral areas of interest. In Figure 2, the constraints are categorized into two broad areas of immediate interest, namely market factors and technology. Market factors include such things as potential ore quality and cost, market price, strategic material value and there alternatives, geo-politics, etc., and they obviously place serious constraints on essentially all opportunities. Ocean Mining has experienced all of these factors and they differ for each Resource Venture. I will not discuss this aspect in any detail, but they are important.

Technology can be broken down further to Exploration tools and physical definition of the deposit characteristics, the Mining System components and system optimization, and Processing and its associated Waste Management. Looking at this simple summary, one can see the reason for the active Industrial programs and interest in construction materials and placer deposits. The required technology is essentially on-hand and the Market factors fairly straightforward. In the exciting deep-water deposits, all except the Red Sea metaliferous muds and manganese nodules have significant constraints in exploration, i.e. adequate tools and definition of the physical and economic value, and the characteristics of the deposits for mining system definition. This is particularly true for polymetalic sulfides where we have "mineralized showings subject to further assessment" (Reference 2), and a long way to go in exploration and scientific research before a sound mining technology program can be defined.

To go into more meaningful detail I would like to concentrate briefly on placer heavy metals, manganese nodules and the cobalt-rich manganese crustal deposits.

Technology Needs

Heavy Metals

Significant deposits of rutile, ilmenite, zircon, monazite, gold and platinum are found in many places in the world, including promising sites on the Atlantic, Pacific, and Alaskan Coasts of the U.S.. With the very significant problems in South Africa, and the strategic importance of materials like chrome and the precious metals, these are deposits of growing interest.

Some of the U.S. black sands deposits were mined on land for chrome during World War II and proved quite profitable. These post-war operations ceased when high-quality deposits were mined and marketed at lower costs in South Africa. However, chromite processing advances made in recent years have the potential of making the lower quality ilmenite deposits highly attractive, when consideration is also given to the accompanying gold and platinum. As shown in Figure 2, the specific offshore deposits characteristics need to be defined, and the new processing technology confirmed and scaled to economic plant sizes, to realize this promising potential. Exploration technology is well in hand and applicable shallow water dredging techniques have already been extended out to 300-foot water depths by the Japanese.

Manganese Nodules

Although manganese nodules are almost 30% manganese, major interest has been in the nickel, copper and cobalt contained therein. Market factors related to all four strategic materials, and particularily to nickel, have largely controlled development activities. Under favorable conditions in the late '60's and 70's, we experienced tremendously aggressive and exciting exploration and technology development activity, conducted by major Industry and government-funded Consortia.

In examining our current technology status in nodule mining, it is important to note that, to be profitable, or even practical, it is a very large-scale operation, at 3 to 4 million tons annually, and large systems. Also mining the seafloor, in 15-17000 feet of water, 300 days of the year, is a major total systems technology demand. In preliminary system development, we have had to apply all that we have learned in deep-water oil ocean engineering and deep submergance technology. The results have been encouraging and deep-sea nodule mining, in my estimate, based on consortium at-sea testing results, is not held up in any manner by the lack of fundamental engineering technology, including processing.

A major technical question however, differing between consortia, and a typical "hard-end technology" consideration, for future planning, is one of mining efficiency requirements. In spite of the amount of exploration done to date, the specific knowledge of a given mine site (Figure 3) is minimal. Occasional rock outcrops, parallel scarps too steep to negotiate, and modest slopes of up to 10 degrees are known to exist. The accepted objective to minimize exploration and mining operational costs, makes it highly desireable to have as much versatility and maneuverability as possible, within the state-of-art, designed into the mining system.

Differences of thinking in implementing this objective were clearly evident in the test miners utilized in initial at-sea operations. The Japanese (Figure 4) used the continuous line bucket system. Deep Sea Ventures (Figure 5) used a towed, sled-type suction dredge head. The Ocean Minerals Company's test miner, shown in Figure 6, was self-propelled, highly maneuverable, and with major side slope capability. In test-mining operations, all of these systems worked and were reported to be successful. So, what is the impact on future system concepts?

Arguments of towed vs. self-propelled, between advocates, are as fruitless as the old straight, vs. swept, vs. delta wing wrangles of the '50's, or the manned vs. unmanned vehicle arguments of the '60's and '70's. In this case, the choice depends mostly on the mining site characteristics and on program peculiar economic and mining operations criteria.

Needless to say, however, I am somewhat parochial. I sincerely believe that any mining machine, and particularly one operating remotely in 16,000 feet of water, needs to be rugged, reliable, and highly controllable to handle unique situations. There will always be significant unknowns in nodule abundance and local detail terrain that will cause the operator to treasure control of speed and direction, good side slope capability, with minimum turning radius and maximum trafficability over varying soil properties. An operator cannot afford to only mine out the center of the valley floor. High grading, so common in on-land mining, will be essential for good production control and cash flow.

The system technology and optimization issue is the trade-off between mining swath width, speed of the miner, speed of the lift pipe through the water to avoid vortex shedding, and the flexibility and freedom of the miner to move laterally independent of the lift pipe. The decision criteria however, is the economic impact and not a requirement for new fundamental technology.

Cobalt-Rich Manganese Crusts

One of the most exciting high-technology deep ocean mining opportunities for the future is the cobalt-rich ferromanganese crustal deposits on the Pacific seamounts. The exciting part is that manganese nodules and crusts are very similar in ore characteristics and much of our store of technology developed for nodules is applicable, including processing. The deposits are concentrated in thick pavements (Figure 7) and have been found in thicknesses up to 14 cm. (Figure 8). Cobalt is the high value product in nodule mining (Figure 9), and its increase in content of almost a factor of 4, for crustal deposits, is economically very attractive. Platinum content of crusts (not shown) will also enhance this difference. Attractive deposits are formed in 800-2400 meter water depths, significantly less demanding than for nodules. However, the slopes are up to about 20 degrees, high enough to require significant side slope capability, but low enough to utilize maneuverability and control technolgy developed for nodules.

Another exciting factor is that highly promising deposits are found within the 200-mile EEZ of many nations. However, the major constraint of low mineral product value in current world markets remains.

Within the U.S., the Minerals Management Service (MMS) and the state of Hawaii are carrying out an aggressive EIS program for the Hawaiian archipelago and the Johnston Island areas. As part of this effort, it was necessary to define a feasible Mining Development Scenario, including the seafloor mining system, the lift and transport system, processing options and shore-based facilities (Reference 4).

We sized the candidate mining system (Figure 10), to deliver approximately one million tons of wet manganese crust per year to the processing plant. The seafloor system will probable consist (Figure 11) of a controllable bottom-crawling tracked vehicle attached to a mining ship on the surface by a hydraulic pipe lift system and an electrical cable.

A major technology difference between mining of manganese crusts and nodules is the manner in which the crust must be removed from the substrate, which may be basalt, complex hyaloclastites, or rock. For the "base case" mining scenario, technology similar to that used for surface continuous coal mining was assumed, whereby a thin layer of crust would be "stripped" from the seabed using rotary cutting tools, such as shown in Figure 12. This is an unconventional high-risk method for ocean dredging, and increases the level of engineering sophistication required and cost for a manganese crust miner design.

A crucial factor for the economics of the mining operation is the amount of substrate dilution that must be dealt with in addition to crustal ore. The preliminary resource assessment shows that the crust thickness and coverage are quite variable and that the strength of the attachment of the crust to the substrate depends on the nature of the particular underlying material. The miner will have to cut, gather, crush and may partially separate the ore before it is lifted to the surface. Various estimates have been made as to the fraction of substrate material which will be entrained in the seafloor collector, and they range from 20 to 42% after shipboard dewatering.

In looking at fundamental technology requirements for crustal mining, it is important to note that we need much better exploration tools (Figure 13). The dredging equipment can be much improved, and a large 2-foot diameter core sampler is required to obtain basic crust/substrate material properties. The experimental corers available today are only adequate for taking a 1-inch core.

A very high priority must be given to the technology required to establish the technical feasibility of insitu fragmentation of the crust. For example, if an ROV could carry a short range, high intensity acoustic device, or some other scheme, that was capable of separating the crustal ore on the seafloor from the substrate, the mining machine design could become much more simple. For example, the CLB approach could then be attractive for the ore pick-up and lift system. All system elements, including transportation and processing would be favorably affected and system economics much improved. Before such research could advance very far, however, we need to know the crustal ore and substrate mechanical properties at deepsea water pressure. Manganese nodule mechanical properties were proven to be significantly different on the seafloor than in the Laboratory.

If we cannot fragment the crust from the seafloor in this foremat, even with a device mounted on the miner itself, then we will need to address the more complex problem of optimizing the cutter head and its instrumentation and control, if we wish to minimize the dilution problem at the mining machine.

Finally, if we can achieve neither of these, it would be attractive to be able to beneficiate the combined crust/substrate ore at the mining site aboard ship. Returning the substrate waste directly to the seafloor and reducing the dilution of the ore, before it is delivered to the metallurgical processing plant, would be highly desireable. Progress is being currently made in this area by the U.S. Bureau of Mines.

Conclusion

In summary, the field of Ocean mining over the last 20 years has gone through major changes, from mere scientific interest to intense commercial investment; from an International political quagmire and metals market collapse to industrial discouragement. And now, as a result of facinating implications of seafloor spreading research, we are back to even more exciting ocean mining options within the EEZ. But future fundamental technology required to exploit these deepsea opportunities will fall largely to government action until the market price situation reflects the true material needs. I have not lost my enthusiasm, nor my confidence, that Ocean Mining will exist, and there are many positive factors for encouragement in that direction.

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Figure 1

Marine Mineral Deposits

Dissolved	Unconsolidated: Continental Shelf 0-200 M	Unconsolidated: Continental Slope 200-3500 M	Unconsolidated: Deep Sea 3600-6000 M	Consolidated
<u>Seawater:</u> Fresh Water Metals & Salts of Magnesium Sodium Calcium Bromine Potassium Sulphur Strontium Boron Uranium Other Elements <u>Metalliferous Brines</u> Concentrations of Zinc Copper Lead Silver	<u>Nonmetallics:</u> Sand & Gravel Lime Sands & Shells Silica Sand Semiprecious Stones Industrial Sands Phosphorite Aragonite Glauconite <u>Heavy Minerals</u> Magnetite Ilmenite Rutile Monasite Chromite Zircon Cassiterite <u>Rare & Precious Minerals</u> Diamonds Platinum Gold Native Copper	<u>Authigenics</u> Phosphorite Ferromangese Oxide & assoc. minerals Metalliferous Mud with: Zinc Copper Lead Silver	<u>Authigenics:</u> Ferromanganese nodules with: Cobalt Nickel Copper <u>Sediments</u> Red Clays Calcareous Ooze Siliclous Ooze	<u>Disseminated, Massive, vein, tabular, stratified</u> Coal Ironstone Limestone Sulfur Tin Gold Metallic Sulfides Metallic Salts Phosphorite <u>Deep Seabed Surficial</u> Metalliferous Oxide Crusts Metalliferous Sulfide Chimneys or mounds

Cruickshank, 1978

Figure 2

Ocean Mining Development Constraints

Resource	Market Factors	Technology Assessment					
		Exploration		Mining		Processing	
		Tools	Deposit Definition	Components	Systems	Process	Waste Mangm't
<u>Continental Shelf</u>							
• Sand and Gravel	–	–	–	–	–	–	–
• Placers							
• Precious Metals	–	–	–	–	–	–	–
• Heavy Metals	●	–	●	–	–	●	–
<u>Deep Water</u>							
• Phosphorites	●	–	●	●	–	–	–
• Metaliferous Muds	●	–	●	–	–	●	–
• Manganese Nodules	●	–	–	–	●	–	●
• Polymetalic Sulfides	●	●	●	●	●	–	●
• Manganese Crusts	●	●	●	●	●	–	●

● Indicates Significant Market or Fundamental Technology Constraint

Figure 3

Artist's Concept of Deep Ocean Floor
Manganese Nodule Deposits

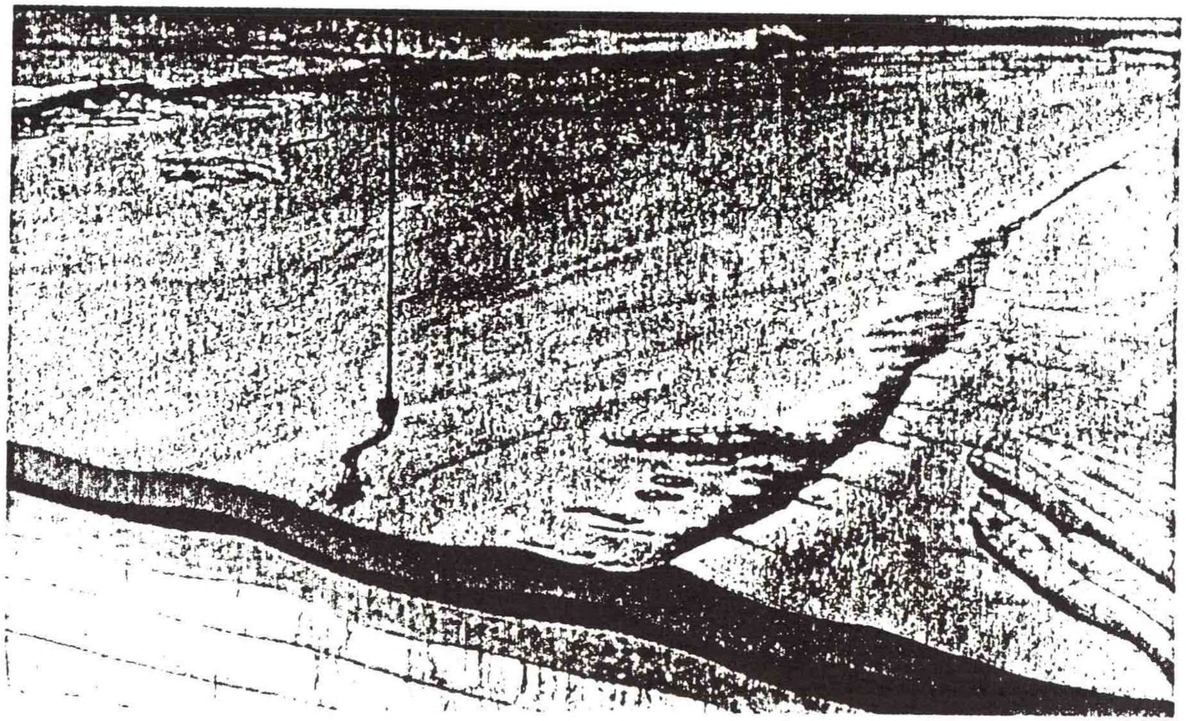


Figure 4

Continuous Line Bucket (CLB) System
(Pearson)

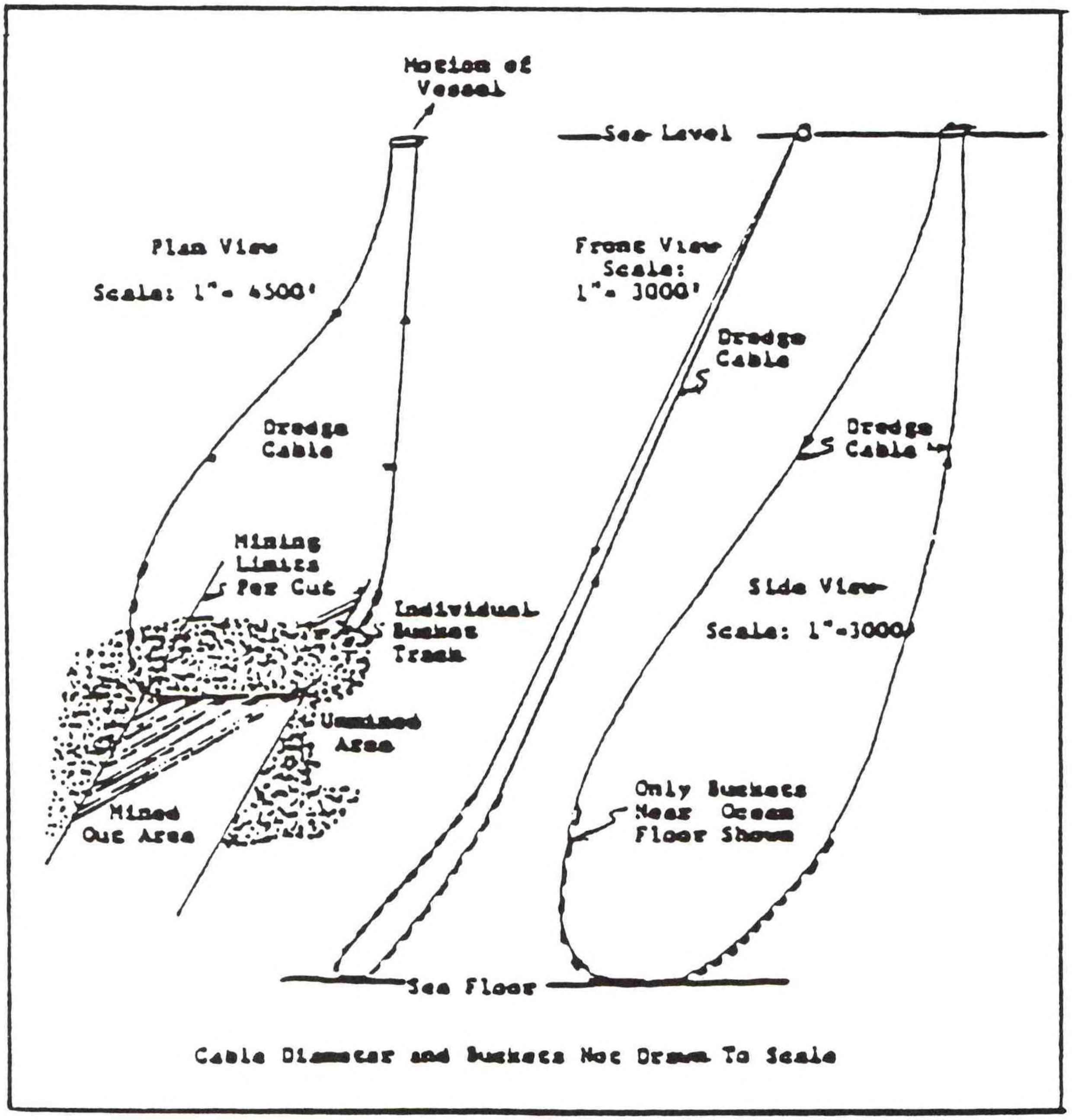
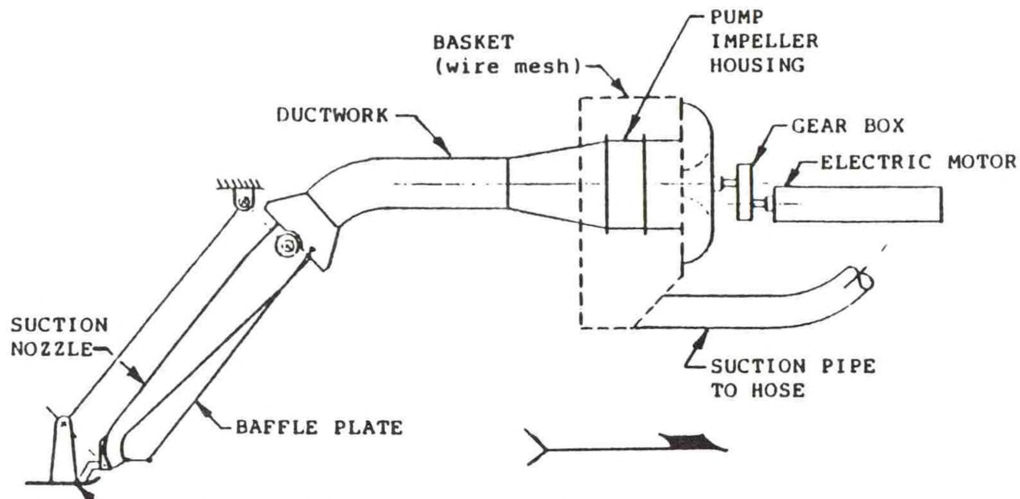
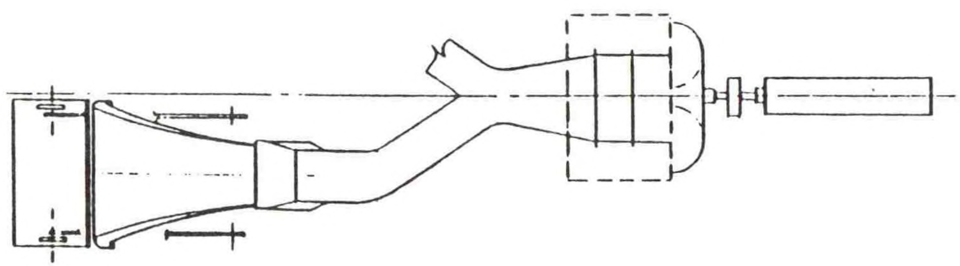


Figure 5

Suction Module-Test Collector
(Kaufman-Deep Sea Ventures)



ELEVATION



PLAN

Figure 6

Ocean Minerals Company's Deep Ocean Mining System

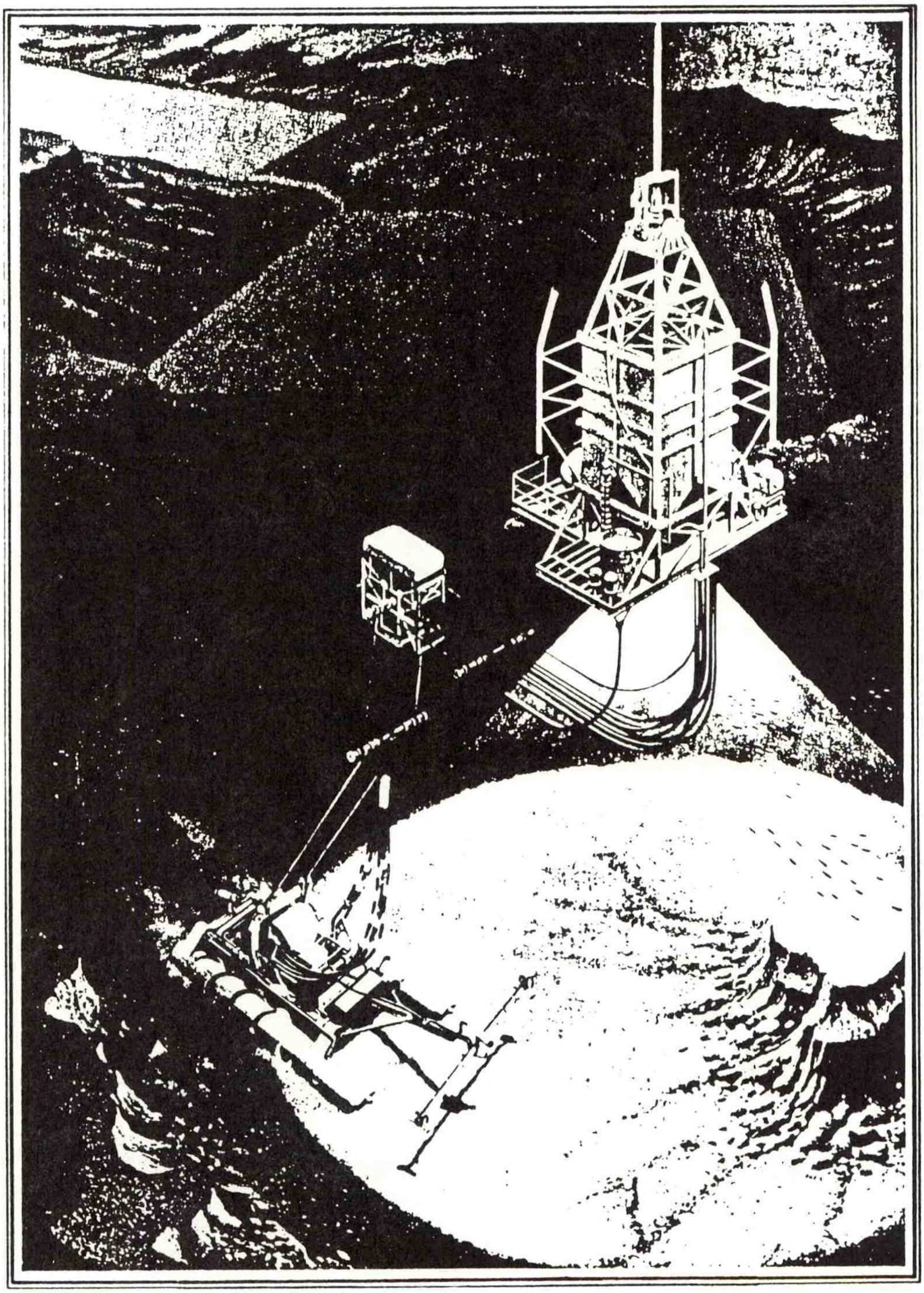


Figure 7

Manganese Crustal Pavement
(C. Johnson)

Figure 8

Manganese Crust

Figure 9

COMPARISON OF METAL CONTENT IN CRUSTS AND NODULES

	First Generation Mine Sites	
	Crusts (percent)	Nodules (percent)
Cobalt	0.95	0.28
Nickel	0.60	1.30
Copper	0.07	1.10
Manganese	25.0	29.0

Figure 10

MANGANESE CRUST MINING SYSTEM
REQUIRED COMPONENTS

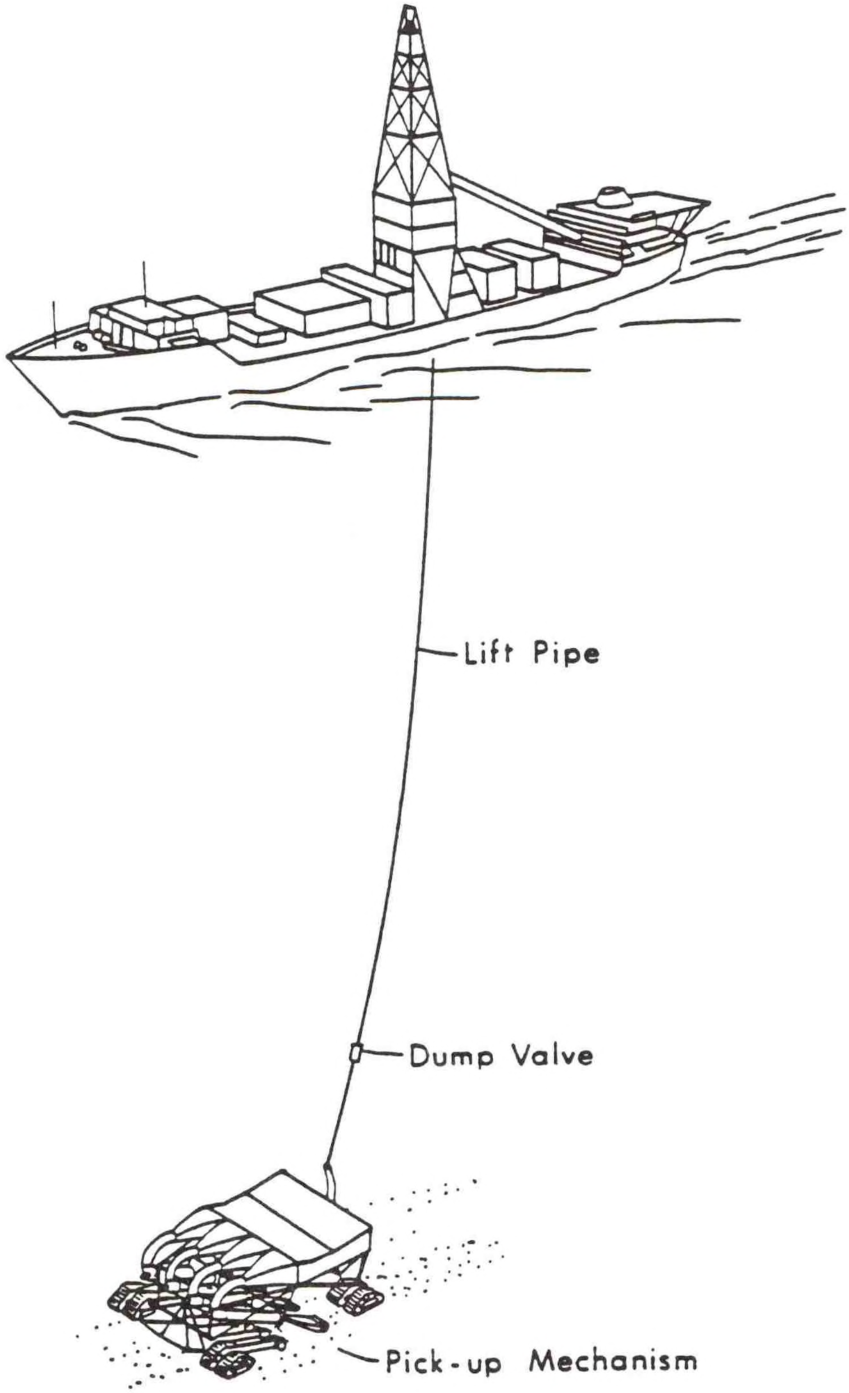


Figure 11

MANGANESE CRUST MINER

Major Dimensions

Length:	13 Meters
Width:	8 Meters
Height:	6 Meters
Weight:	100 mt.
Installed Power:	900 KW

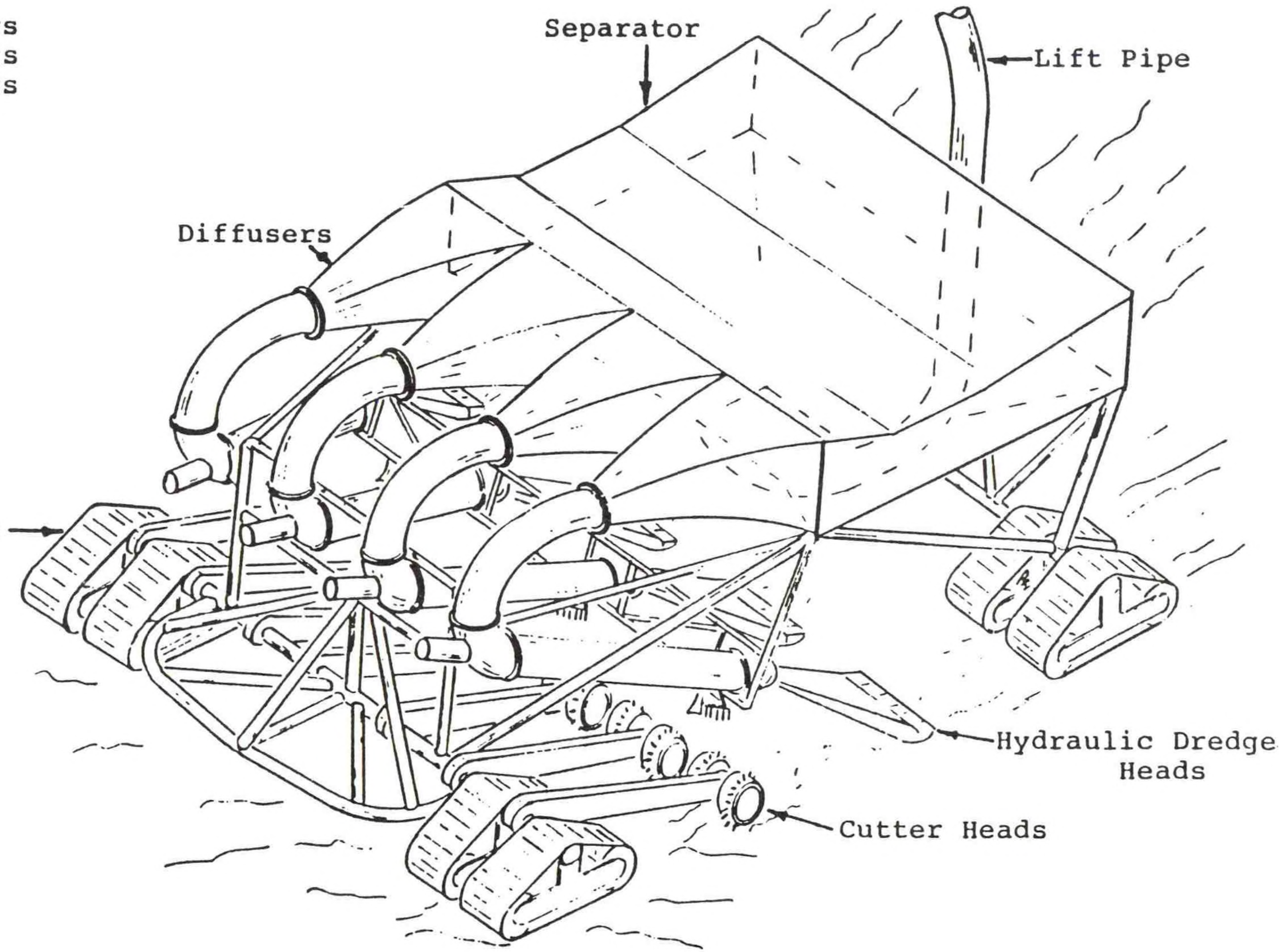


Figure 12

CUTTER HEAD

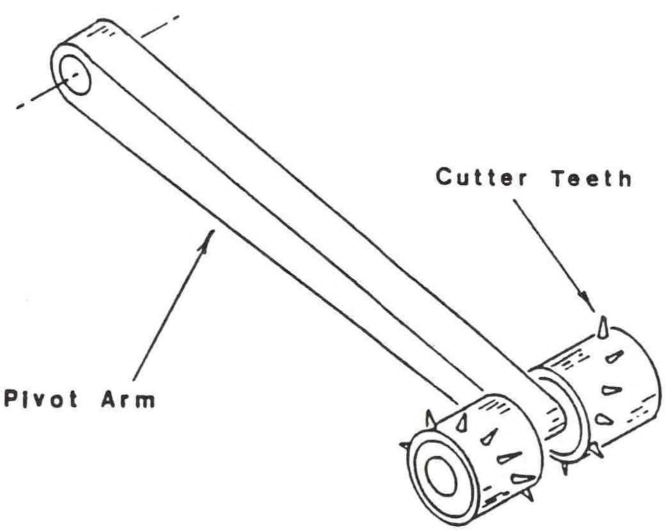


Figure 13

FERROMANGANESE CRUSTAL MINING-
FUNDAMENTAL TECHNOLOGY REQUIREMENTS

Resource Assessment

- High Resolution Microtopography-
  Stereo Optic & Acoustic Surveys
- Insitu rapid measurement of crust thickness
- Improved deepsea dredge systems
- Development of a large diameter coring device

Mining System Development

- Measurement of crust/substrate rubble or fragment properties at deepsea water pressure.
- Development of insitu fragmentation device.

Processing

- Effective shipboard beneficiation through removal of substrate by froth flotation, or other means.
- Improved shipboard removal of crustal ore sea salts.

EXPERIMENT OF DEVELOPING AN ARTIFICIAL SEAWEED FARM PLANT IN THE JAPAN SEA

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Kawasaki Heavy Ind., Ltd.

INTRODUCTION

Hyogo Prefecture submitted a plan of "Off-Tajima Artificial Continental Shelf Project" in 1978. In the project they advocate to develop a large-scale artificial continental shelf and promote a cultivating fishery by utilizing the technology of such basic industries as steel mill and shipbuilding in the prefecture so as to secure fishery resources on the coast of Tajima [1].

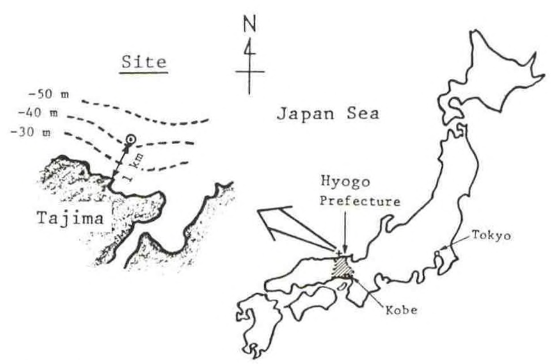

Fig. 1 Location of the site for experiment

The coast of Tajima in Hyogo Prefecture, which is on the coast of the Japan Sea (Fig. 1), has those characteristics that the seaweed beds are narrow as mountains are close to the shore and the seabeds have a steep gradient in general and that the algae are hard to grow in the shallow water as the sea is very rough in the wintertime. The coastal fishery aims at catching such migratory fishes as Horse Mackerel, Mackerel, Squid, etc., but the coast has few natural reefs and the stay of the school of fish or the fishing season is short. Accordingly, the main fishery on the coast was offshore fishery by large fishing boats rather than inshore fishery. However, the offshore fishery has been limited by the 200 nautical mile problem and the inshore fishery has been necessary to be promoted to secure fishery resources.

Under these circumstances the plan of "Artificial Continental Shelf Project" was presented to build up a large-scale seaweed bed on the shelf.

The seaweed bed acts an important role in the fishery, that is, it has a function of fishes' places for spawning, growing, feeding, sheltering and the like. The sea area where the algae grow is required to have such bottom conditions as the sunlight can reach the bottom sufficiently and as seaweeds are liable to attach.

PLAN OF THE EXPERIMENTAL ARTIFICIAL SEAWEED FARM PLANT

In order to realize the plan of the Artificial Continental Shelf, it is necessary, first of all, to make such biological researches as (1) whether the algae can be cultured sufficiently on the shelf and (2) whether the fishes swarm around the cultured seaweed bed.
For this purpose the three-year researches were decided by Hyogo Prefectural authorities, who began to collaborate with the seven companies in steel mill and shipbuilding industries in a plan of the artificial seaweed farm plant in 1978.

A fixed structure is intended as a permanent plant in the Artificial Continental Shelf Project, while a floating structure was taken up in this experiment considering the term and expenses of the experiment. Kawasaki Heavy Industries, Ltd. (KHI) took charge of its design, manufacture and setting, and began the work in 1979.

A point which is about 1km off Tajima and about 43m deep was selected as its setting place (Fig. 1). The site has a climate that the waves grow severely under a seasonal north or northwesterly wind in the winter but that the current is not so great.

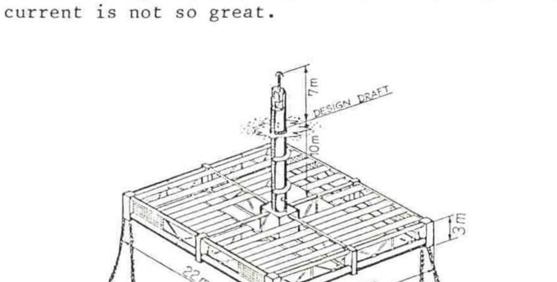

Fig. 2 Artificial seaweed farm plant

OUTLINE OF AN ARTIFICIAL SEAWEED FARM PLANT

The experimental plant is a floating steel structure which consists of a framing structure, 22m wide, 22m long, 3m high with a shelf (a mimic seabed) on the upper part, and a buoyancy tower in the center, 2m in dia., 13m high, moored at the two points with chain cables. Its configuration is shown in Fig. 2.

The main buoyancy is given by a pipe structure, 500mm in dia., around the shelf, the square pillars in the four corners, and the central buoyancy tower. A pipe structure, 1,000mm in dia. constituting the lower part of the frame is used as a float when the plant is towed to the site from the construction yard, and is filled with water when it is set.

The shelf of the experimental plant is designed to stay at the depth of 10m and to maintain the same draft by discharging seawater in a water ballast tank of 27m^3 in the lower part of the tower, when the weight increases owing to the adhesion of sand or shells or the attachment of base plates mentioned later.

On the upper part of the frame, shelf plates are fixed, to which about 330 sheets of steel plate (1.5m long, 0.3m wide each) with algal seedlings planted on can be fastened with bolts. The shelf is so devised as the fastening can be done easily by a single diver. Further, to observe the depth effect on the culturing of the algae a small shelf is furnished at each level of 3m, 7m, and 13m deep besides the 10m shelf.

An observation in a culturing experiment of the algae is usually done by a diving, but in this experimental plant the observation can be done also through the two underwater windows equipped on the buoyancy tower. The windows are double - glazed with the inside and outside hoods; the outside hood can be opened and closed at the top of the buoyancy tower.

A signal light is located at the height of 7m above the sea level, automatically switched on-and-off at night. Further, it is equipped with a radar reflector in full consideration of the safety of the ships sailing thereabouts.

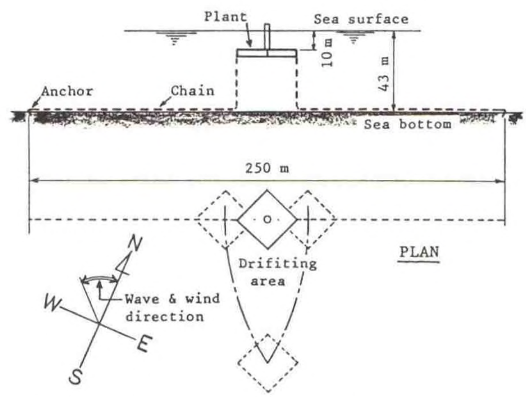

Fig. 3 Mooring system for the experimental plant

The mooring system for the experimental plant, two points catenary mooring with chain cables (Fig. 3), has such characteristics as the movement of the plant is not restricted by the mooring system and it becomes very large in heavy sea in the same order of the wave height, but the line tension does not increase even in such a great movement, because of very soft mooring by deploying mooring lines at a right angle to the main wave direction [2]. This mooring system displays its efficiency under the following conditions:

(1) A fluctuating external force is great.
(2) The fluctuating external force has almost a fixed main direction.
(3) A stationary external force is comparatively small.
(4) A little movement is allowed.

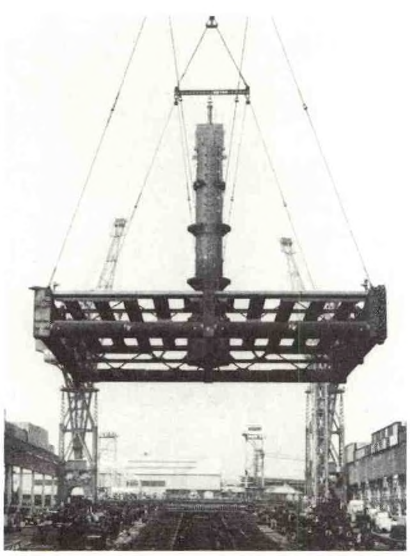

Fig. 4 Plant before launching

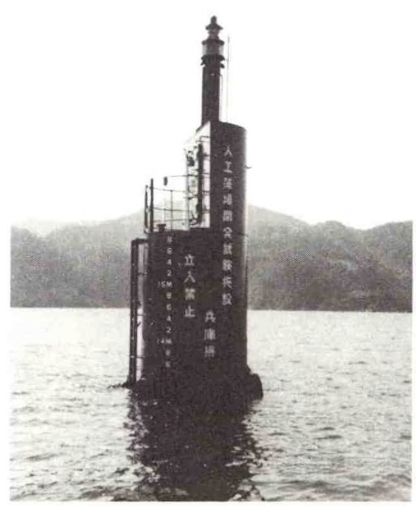

Fig. 5 Plant after setting

SETTING OF THE PLANT

The plant was built ashore (Fig. 4) and towed to the site by a tug boat with a draft of about 1.4m using a pipe structure around the lower part of the frame as a float. The mooring lines had been deployed at the setting place and were connected with the plant on the sea upon its arrival. After that the float was gradually filled with water, then, water was poured into the water ballast tank, and the plant was settled at the designed draft (Fig. 5).

EXPERIMENTAL CULTIVATION ON THE ARTIFICIAL SEAWEED FARM PLANT

The following is a general analysis of the results of the examinations made by Hyogo Prefectural Fisheries Experimental Station as a leader for three years after the setting of the plant [1]:

Ecklonia kurome and Sargassum horneri, forming the principal seaweed beds on the coast of Tajima, were used in the experiment on the formation of a seaweed bed. In an investigation of the natural seaweed beds it was recognized that Ecklonia kurome were distributed at the depth of 2 to 15m, forming seaweed beds chiefly at the depth of 4m or more, and Sargassum horneri forming seaweed beds mainly at the depth of 5m or less.

A transplantation of seedlings and fronds of Ecklonia kurome and Sargassum horneri was tried on the plant.

After the transplantation of their seedlings, the growth up to the mature fronds was not observed. For this reason, it was supposed that the intensity of arriving sunlight necessary for their initial stage of growth was not sufficient since the solar energy to the layer of 10m deep, a depth for the transplantation, damped to 30% or less than that on the surface of the sea.

While in the transplantation of the fronds of Ecklonia kurome, their survival for a long period and re-attachment to the shelf were observed (Fig. 6). The development of young fronds of 4 to 12 indiv./m^2 was observed on the shelf. They grew up to the mature fronds at the end of the experiment and formed seaweed beds.

In the transplantation of the fronds of Sargassum horneri, a considerable number of fronds were recognized to fall, but each of the existing fronds had a remarkably developed receptacle and was regarded as able to grow into groups.

As a conclusion, a method of the transplantation of fronds of Ecklonia kurome and Sargassum horneri experimented this time was found one of the effective methods of developing an artificial seaweed farm plant.

Fig. 6 Attachment of Echlonia kurome on the shelf

RESEARCH FOR FISHES AROUND THE PLANT

Diving was performed totally 33 times in the past three years around the artificial seaweed farm plant to research species, the number of individuals, and actions of the fishes swarming there.

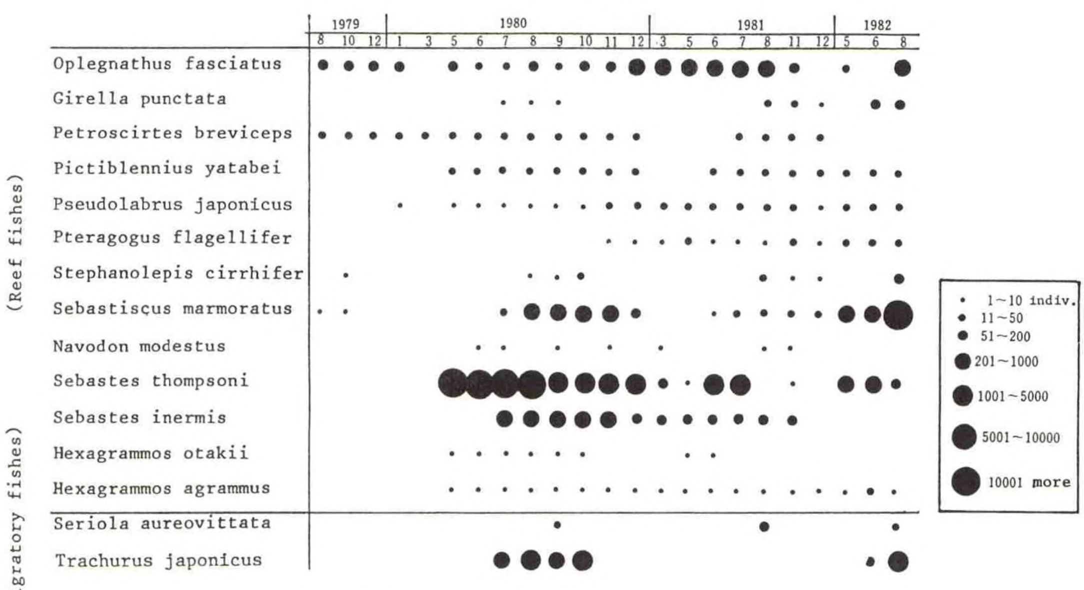

Fig. 7 Swarming time and amount of fishes

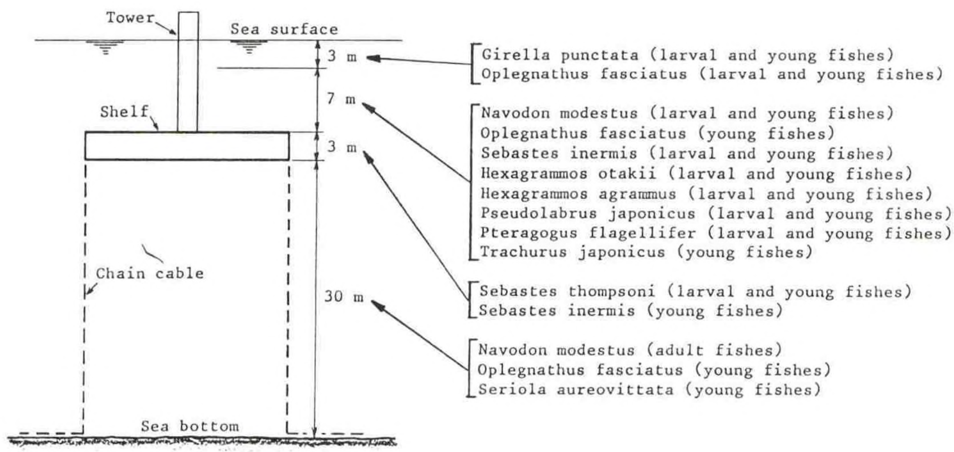

Fig. 8 Swarming habitat of fishes

From the results the plant was found to have different functions from those of the conventional floating fishing reef or the bottom lying artificial reef: the plant could swarm fishes in three dimensions deep to the sea bottom, and give larval and young fishes a long stay on it.

For example, the appearance time and volume of swarms (volume of swarms given in a rectangular parallelepiped of about 22m x 22m x 20m from the surface down to a depth of 20m) are shown in Fig.7, and the swarming habitat of fishes is shown in Fig. 8. Table 1 shows a change in the existing amount of reef fishes in the plant.

Table 1 Change of existing amount of reef fishes

months	indiv./m^2	kg/m^2
1	0.3	0.003
12	8.3	0.2
24	4.1	0.6
36	20.7	0.4

An experiment of stocking the plant with young shells of Blue Mussel Mytilus corsucus, Itaya Scallop Pecten albicans, and Spiny Whelk Batillus cornustus was carried out. The result was those shells were found to attach to and grow on the plant.

By researching in detail the diurnal - nocturnal transition of the distribution aspects of 17 fish species which swarmed around the plant such as Goldstriped Amberjack Seriola aureovittata, Striped Beakperch Oplegnathus fasciatus, Darkbanded Rockfish Sebastes inermis, Black Scraper Navodon modestus, Bambooleaf Wrasse Pseudolabrus japonicus, and Threadsail Filefish Stephanolepis cirrhifer, etc., Mr. Okamoto [3] reported there were two distribution aspects---all day dependent type fishes are distributed chiefly within 20 m vertically and horizontally to the plant, and daytime dependent type fishes are distributed in the range of 30 m or more. He also pointed out this plant was an effective fishing reef structure applicable to various kinds of fish.

CONCLUSION

It was recognized the plant formed a seaweed bed mainly of Ecklonia kurome, and that it had a function of a fishing reef swarming fishes including reef and migratory fishes from the surface of the sea to the bottom.

However, in order to get more effective function of the plant as an artificial seaweed farm, it is necessary to increase the intensity of arriving sunlight on the shelf to cultivate young fronds or to form a seaweed bed with several species of algae such as Sargassum, etc. For this purpose the following ways will be proposed:

(1) To make the depth of the shelf shallower behind a floating breakwater or some other structures for moderating the sea
(2) To make the sunlight reach the shelf more extensively using a sunlight collecting system with an optical fiber or pipe and the like.

The plan of an Artificial Continental Shelf Project has been suspended because of budgetary limitations, while there is a strong tendency to consolidate and develop the fishing ground in the 200-nautical-mile waters of Japan, and an expectation that a new plant should be developed based on the knowledge obtained in this experiment.

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Undersea Technology and Systems

NEW TECHNOLOGIES IN U.S. NAVY UNDERSEA VEHICLES

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ABSTRACT

Two underwater vehicle systems are described. The Advanced Underwater Search System (AUSS) is a free-swimming search platform which communicates with the surface via an acoustic telemetry link. This link carries slow-scan video as well as the usual command and control signals. The Advanced Tethered Vehicle (ATV) is a tethered platform equipped to do work on underwater objects under the control of surface operators. Its tether cable contains fiber optic components for the real-time transmission of video signals. These components greatly reduce the weight and diameter of the cable.

INTRODUCTION

The U.S. Navy has a continuing requirement to search for and locate objects on the seafloor at any depth. In some cases it must also repair, replace, recover or even destroy them. Several systems have been developed to meet these requirements and improvements in their performance have been made as new technologies have become available. For search systems the emphasis has been to increase search rate. At present, search systems exist which can operate at great depths, but search rates are limited by cable drag. Work systems can now perform a variety of underwater tasks, but their operating depths are limited. This is because longer tethers, especially those which must carry broadband video signals as well as power, usually become unacceptably large as length increases.

The problems of cable drag for search systems and cable size for work systems are being addressed in the development of two new Navy systems, AUSS (Advanced Unmanned Search System), and ATV (Advanced Tethered Vehicle). AUSS eliminates cable drag completely by using a free-swimming, untethered sensor vehicle. ATV reduces cable bulk by replacing the coaxial elements in the tether with optical fibers. These not only reduce cable size and weight but increase bandwidth substantially. The following sections describe each system.

ADVANCED UNMANNED SEARCH SYSTEM (AUSS)

In addition to the free-swimming sensor vehicle, the AUSS system consists of a high-rate digital acoustic telemetry system, a surface handling system for launch and retrieval, and a group of vans for operation and control, maintenance, and spares, all carried aboard a surface support ship.

The vehicle itself is battery-powered (silver-zinc) and carries a search sensor suite consisting of a forward looking sonar and a side-scan sonar as well as a video camera and a 35-mm still camera. It also carries a transponder for use in a long-baseline acoustic navigation field (separately deployed), and a receiving/transmitting transducer (Figure 1).

The use of a composite material has made it possible to construct the pressure hull with a lower weight-to-buoyancy factor (<0.5) than could be achieved with an all-metal hull. The wall thickness of the cylindrical portion is 6.3 cm (2.5 in) and its length is 152 cm (60 in). The overall diameter of the hull is 78 cm (30.7 in), which makes the vehicle small enough to be carried by a wide variety of ships of opportunity.

The acoustic system is used not only to exchange commands and operating data between the vehicle and the surface but also to transmit video information. To minimize error rates a streamlined towbody is deployed behind and below the support ship. The towbody serves to isolate the transducer from ship noises and also provides shielding from multipath interference. It is hardwired to the control van and contains an acoustic transducer similar to the one carried on the vehicle. Both transducers are mounted in special baffles which maximize the amount of energy radiated/received in the forward direction. The beam pattern of each is a 90° cone, so that the surface unit can remain in contact with the vehicle anywhere within a circle whose radius is equal to the depth of the vehicle . To test the system experiments (Figure 2) have been conducted using a transducer fixed to the seafloor.

In operation, the vehicle normally follows a search pattern pre-programmed in its on-board computer and adjusted by commands sent via the acoustic telemetry system. Navigation is based on bottom distance and heading information derived from an on-board doppler speed sensor and a gyrocompass. During the transits the surface operators view the video images generated by the sonars/TV camera and interrupt the search pattern if a sighted object warrants closer scrutiny. The vehicle is then commanded to hover near the object while it is inspected and if necessary photographed. The exact location of the object is recorded and the vehicle returns to its automatic search mode. The process continues in this fashion until either the search is completed or the vehicle is recalled to the surface for battery renewal.

Launch and retrieval are accomplished by means of a tiltable ramp deployed off the fantail of the support ship (Figure 3). To launch, the vehicle is placed on the ramp which rests horizontally on deck. The ramp is rolled aft and tilted into the water. The vehicle slides down the ramp and its propulsion is activated. Retrieval reverses the process. Upon surfacing, the vehicle automatically deploys a flashing light, radio beacon, and nose float with an attached retrieval line. The support ship steams into position and deploys the ramp. The retrieval line is grappled and the vehicle is pulled up the ramp. Restraints on the inside walls of the ramp are used to hold the vehicle in place if it cannot be brought aboard at once. Once loaded, the ramp is pulled forward and allowed to tilt to the horizontal. It is then rolled forward onto the deck and the vehicle released.

ADVANCED TETHERED VEHICLE (ATV)

The ATV system consists of a tethered vehicle with appropriate thrusters and control devices integrated with a work package with manipulators, tools, and a TV viewing system. Surface support includes a tether handling system, a launch and retrieval system, and an operating van, all carried aboard a ship of opportunity with sufficient deck space to accommodate all of these components (Figure 4).

The tether cable is specially designed to provide full operating capability for the vehicle and work system without becoming excessively large or heavy. It must transmit 60 kilowatts of 3-phase power as well as video information with a 23 Mhz bandwidth. It must also be strong enough to sustain any snap loads (dynamic loads) encountered during launch, operation, or retrieval.

Several innovative approaches have been taken to meet these specifications (Figure 5). The strength member for example consists of contra-helically wound Kevlar fibers located outside the electrical core. The major size and weight saving comes from the use of three fiber optic components for the video transmission channels. Each component consists of a buffered, graded-index fiber which is surrounded by void-filled Kevlar and jacket. The diameter of each is 4.11 mm (0.162 in). They are installed in the spaces between the three electrical power conductors and make a negligible contribution to the overall diameter and weight of the complete assembly. The result is a cable which weighs 7700 kg (17,000 lbs) and has a diameter is 3.0 cm (1.2 in). By contrast, if coaxial cables were used instead of optical fibers the weight would be over 20,000 kg (45,000 lbs) and the diameter 5.0 cm (1.9 in).

The work system (Figure 6) consists of an integrated suite of manipulator, tool, and visual subsystems as well as a surface control station. Three manipulators are used. One is a simple unit used for gripping the target work piece. The other two are 7-degree-of freedom units intended to do complex work tasks, both directly and using tools. The tools are accessible to either of the dexterous manipulators. They can be interchanged without moving the vehicle and work system from the site. At present they are driven electro-hydraulically with conventional fluids, but they may be modified in the future to use seawater as a working fluid. Such tools are coming into use in diver tool packages today.

The TV system, which transmits close-up pictures of the work to the operators on the surface, includes a stereo pair of cameras on a pan-and-tilt platform, a single camera with a zoom lens, also capable of pan and tilt, and a fixed camera for position reference. A 35 mm still camera is carried to provide documentation.

In operation the vehicle with the work system is driven to the bottom and navigated to the work site. Navigation on the bottom utilizes a long baseline acoustic transponder field already deployed. A forward-looking sonar is used for the preliminary approach; the TV cameras are used to position the work system and monitor the work itself. When the work is finished the system is disengaged and guided clear before it is retrieved to the surface.

The on-deck handling system consists of a traction winch and storage reel for the tether cable, and an A-frame, winch, and ram-tensioner for a separate vehicle launch and retrieval line. The ram-tensioner acts as a tension compensation device to reduce the snap loads imposed on the line as the vehicle is pulled from the water. Once the vehicle is clear, the A-frame, which is pivoted at its base, swings back over the deck to move the vehicle inboard. In the meantime, the tether cable, which is slack, is winched in and stored on its reel.

CONCLUSION

These two systems represent an advance in U.S. Navy capabilities over what has been available in the past. In the past 15 years computer hardware has become steadily more compact while memory capacity has increased. As a result, systems such as AUSS and ATV can now make use of microprocessor-based control algorithms, automatic data handling methods including compression, recognition, and interactive displays, and various supervisory control methods suitable for robotic systems. Furthermore, these capabilities can be steadily improved as newer software techniques are developed without significantly altering the hardware configurations of the systems. In this way the Navy can meet its ongoing operational needs while the systems in use are being improved in capability.

Figure 1. AUSS vehicle with smaller towbody (left) which contains surface acoustic transducer

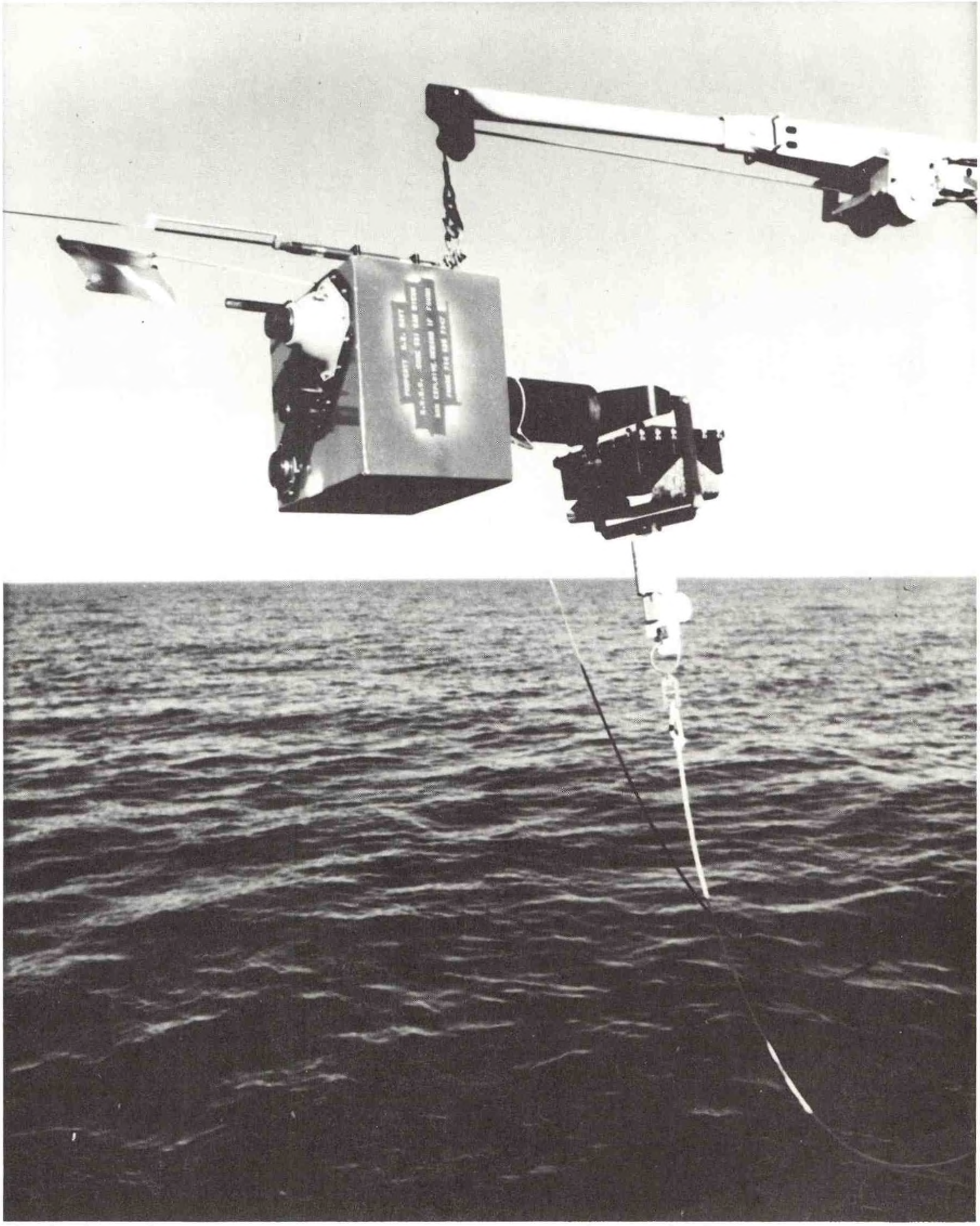

Figure 2. Benthic Untethered Multipurpose Platform (BUMP) used for acoustic telemetry tests

Figure 3. Retrieval of AUSS vehicle showing use of tiltable ramp

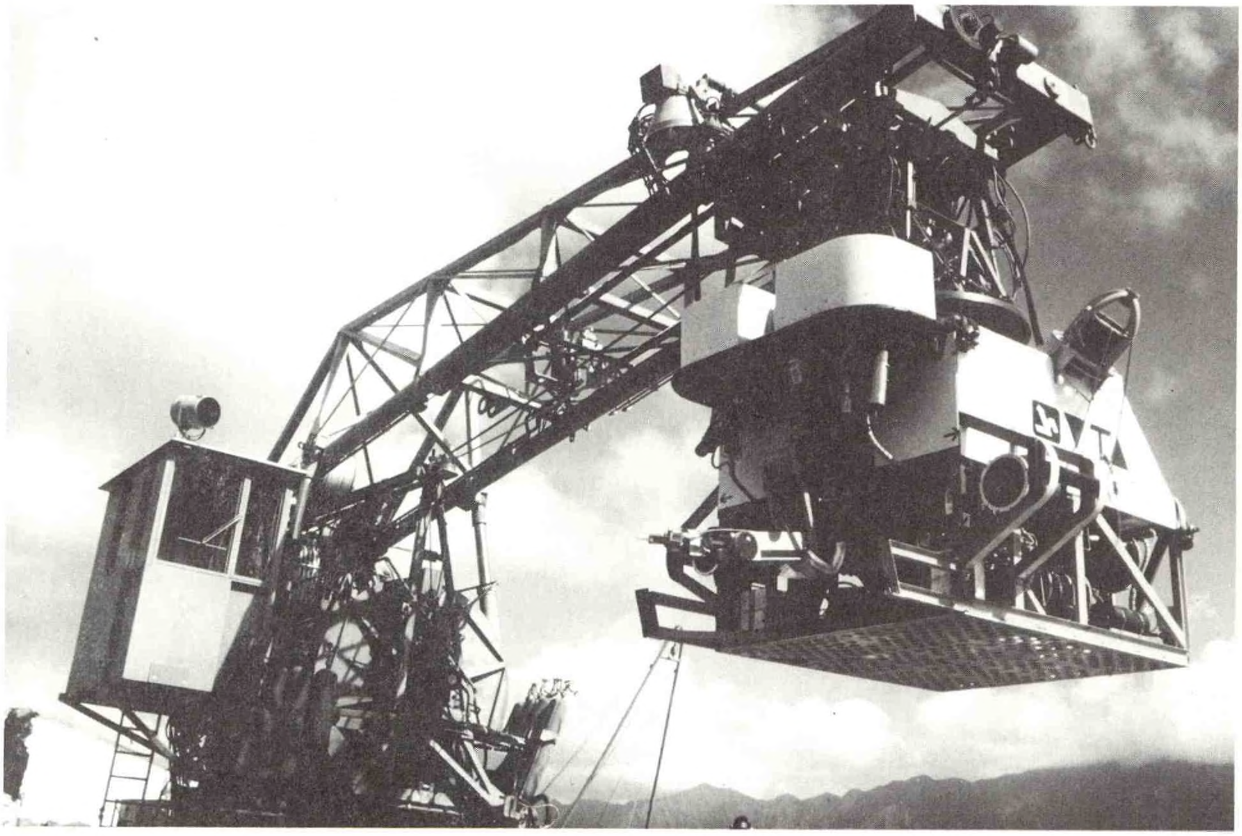

Figure 4. ATV demonstration vehicle with Motion Compensated Handling System

TETHER CABLE DESIGN

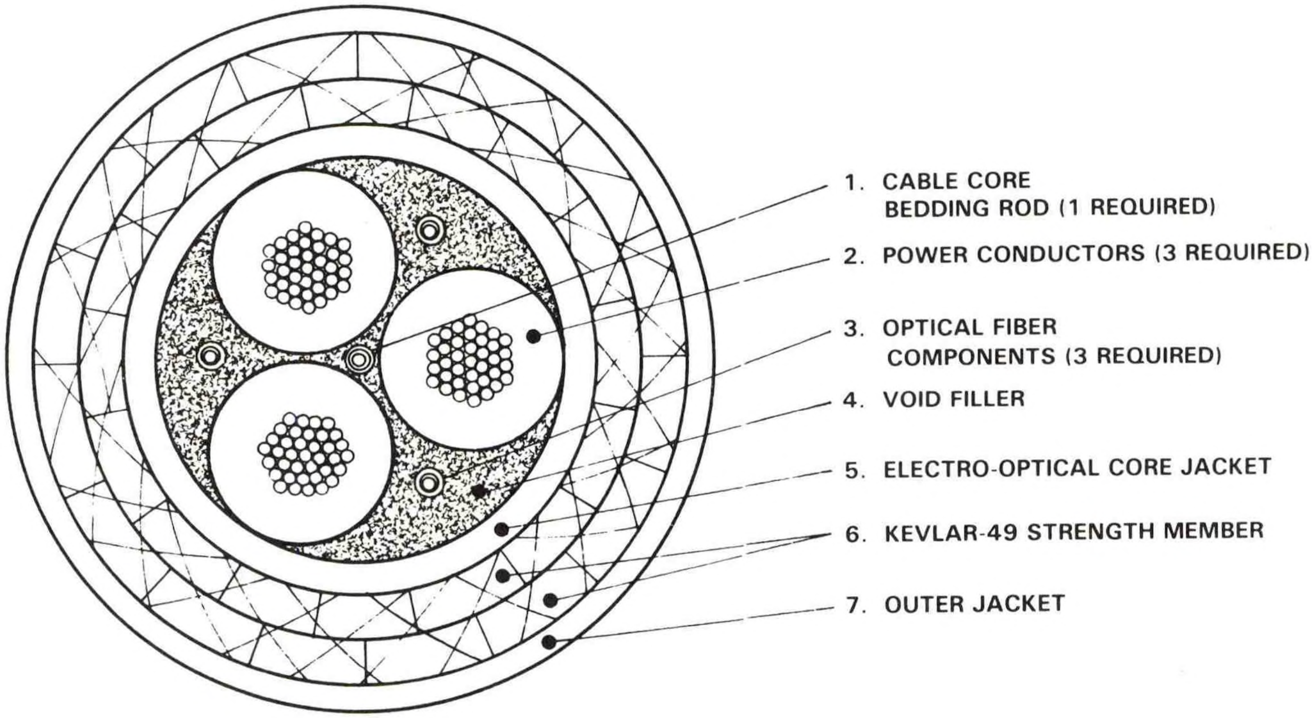

Figure 5. ATV tether cable cross-section

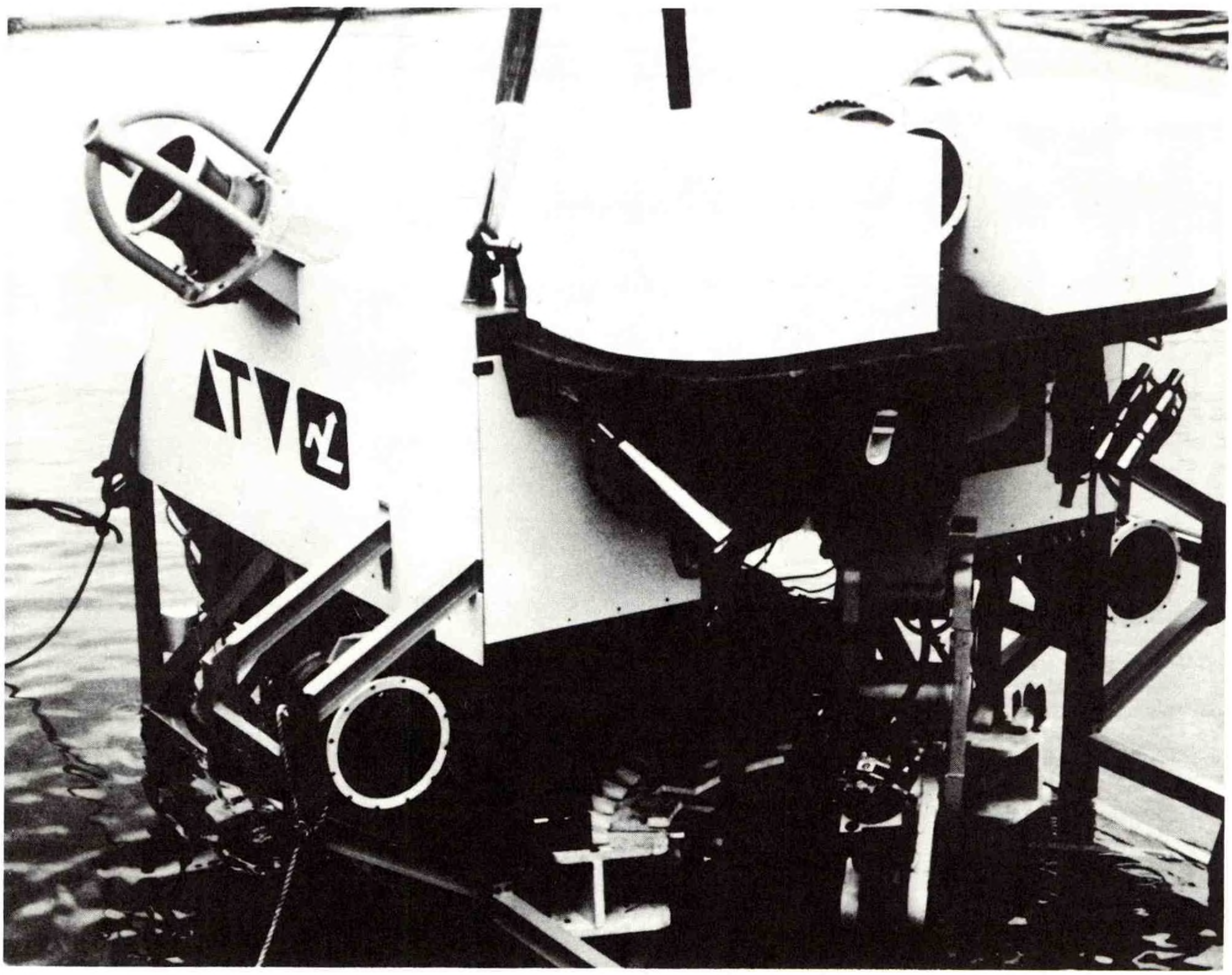

Figure 6. ATV demonstration work system and vehicle

CURRENT ACTIVITIES OF JAPAN MARINE SCIENCE & TECHNOLOGY CENTER FOR RESEARCH & DEVELOPMENT

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ABSTRACT

Japan is a country of scarce natural resources, limited land area, and frequent earthquakes. Therefore, our government believes that the study and development of the ocean are very important, and has promoted various marine development policies. Meanwhile, under the direct control of the Science and Technology Agency of the Japanese Government (STA), JAMSTEC has promoted, since its inception in 1971, research and development activities in the following areas: (1) Exploration technology for the deep sea (manned research submersible, remotely operated vehicles, and the deep sea floor survey systems), (2) Undersea work systems (diving operaion technology and construction of the underwater work test vessel), (3) Wave power generation, and (4) Marine observation systems (oceanographic observation system, ocean remote sensing technology and ocean bottom earthquake observation technology).

INTRODUCTION

As a country with scarce natural resources and limited land area located in a region of frequent earthquakes, Japan has paid special attention to the availability of various marine resources and recognized the importance of the study and development of the ocean, including elucidation of the diastrophism of the ocean bottom.

Government ministries and agencies have thus promoted marine development policies according to their specific administrative purposes. Government budget for marine science and technology in Japan for FY1986 amounts to 62.6 billion yen (about $370 million by the rate Yen/$=170).

Since its founding in 1971 as a research and development organization in marine science and technology, directly supervised by STA, JAMSTEC has promoted various activities involving its 143 employees. JAMSTEC's budget in FY1986 is 7.4 billion yen (about $43.5 million).

Current major research and development activities at JAMSTEC can be described in four categories:

1. Deep sea exploration technology including manned submersibles and remotely operated vehicles.
2. Undersea work system including diving technology and an underwater work test vessel.
3. Wave power generation.
4. Marine observation systems including an oceanographic observation system, ocean remote sensing technology and ocean bottom earthquake observation technology.

EXPLORATION TECHNOLOGY FOR THE DEEP SEA

In addition to the research outlined below in the areas of manned submersibles and ROVs, JAMSTEC has a plan to construct an ROV with an operating depth of 10,000m to be used in a joint study with a 6,500m manned research submersible.

Manned Submersible Research

As a result of efforts from 1978 to 1981, JAMSTEC completed SHINKAI 2000 with the maximum operating depth of 2,000m, and its support vessel NATSUSHIMA. Succeeding to training dive activities, we have successfully conducted undersea studies around Japan since July 1983.

SHINKAI 2000 was originally equipped with a manipulator, a set of stereo cameras, and a black and white TV camera. Later, water samplers (for mid-water and bottom-water), sediment samplers (core type and grab type), sub-bottom profilers, water quality sensors (depth, dissolved oxygen, pH and acoustic velocity), three 1kW underwater lights and a low light color TV camera have been developed and added.

SHINKAI 2000 is also equipped with a rescue buoy system which can be used in an emergency. This system allows the mating device to slide down along the guide rope attached to the buoy, and mate with SHINKAI 2000 so that it can then be pulled up to the surface. Tests of the mating device at a depth of 2,000m were successfully completed in 1982.

Following to the experience on the development and operation of SHINKAI 2000, JAMSTEC plans to develop a 6,500m deep manned research submersible. We are currently working on the preliminary design which will be completed on 1986. After then, the construction of the new submersible will be started and completed by the end of 1989.

The principal characteristics of the new submersible are shown in Table 1.

Table 1. Principal Characteristics of the New Submersible

Maximum Depth Capability	6,500m	Weight in Air	ab.25ton
Length	ab. 9.4m	Person on Board	3
Width	ab. 2.7m	Speed	2.5kt
Depth	ab. 3.2m	Payload	200kg
Life Support	9 hours (for 1 Diving) + 5days		
Material of the Pressure Hull	Ti-6Al-4V ELI		
ID of the Pressure Hull	2.0m		

In addition to the construction of the new submersible, JAMSTEC plans to construct its support vessel to operate the new submersible effectively.

The vessel should be completed before the sea trial of the new submersible which starts from the beginning of 1989.

Remotely Operated Vehicles

JAMSTEC initiated research and development of ROVs around 1979, and as of May 1986, JAMSTEC has developed four ROVs, one of which is still under construction. Table 2 shows specifications of the three major ROVs. Their

TABLE 2. REMOTELY OPERATED VEHICLES DEVELOPED BY JAMSTEC

	JTV-1	HORNET-500	DOLPHIN-3K
DIMENSIONS(cm)	52(L)x64(W)x50(H)	120(L)x96(W)x56(H)	285(L)x194(W)x190(H)
WEIGHT(kgf)	43	130	3300
DEPTH(m)	200	500	3300
CABLE DIA.(mm) x LENGTH(m)	ø16mm x 200m	ø7mm x 800m Electro-Optical	ø30mm x 5,000m Electro-Optical
TRANSMISSION	Coaxial, Asynchronous Bi-Directional	WDM, LED, Optical Fiber	WDM, LD, 400MBPS CPM Optical Fiber
POWER	AC100V, 2kW	AC110OV, 3kW	AC2500V, 40kW, 5kW
INSTRUMENTATION	CCD Color TV, Still Camera Compass, Depth Meter, 2 x 150W Lights, Automatic Depth/Direction Control	Color TV, LLL Aft TV, Still Camera, 4x300W Lights 2x150W Lights, Manipulator (3 d.f.), Flux Gate, Rate Gyro, Automatic Depth/ Direction Control	Color TV, Stereo B/W TV 6 Lights, B/W Aft TV, OAS, Direction Finder, Manipulator(7 d.f.), Grabber(5 d.f.), SSBL Acoustic Nav., Gyro

specific purposes are discussed below.

JTV-1: JTV-1 was developed as a small, lightweight, inexpensive vehicle. It has been commercialized. Twenty units of this type have thus far been produced, fifteen of which were sold on the market. Three of these fifteen are being used for salvage and harbor-related operations, and the other twelve are being used in biological and geological survey and diver assistance capacities.

Hornet-500: Development was completed in 1984 on the Hornet-500, a vehicle with a maximuam operating depth of 500m. A sea-going test of the vehicle was carried out in June 1984 at depths between 30 to 300m. All systems operated satisfactorily, however, the vehicle was lost due to an accident. Hornet-500-2 is completed in 1985. The characteristics of this vehicle are that it employs 2-line, 2-wave division multiplex optical communi- cation with an electromechanical optical cable which is equipped with a broadcasting color TV with high resolution as well as a low light level black and white aft TV. Both JTV-1 and Hornet-500 use cylindrical magnetic torque coupling with a samarium- cobalt magnet for each thruster.

Hornet-3 is under construction by Sumitomo Heavy Industries.

Dolphin-3k: This is the first deep submergence vehicle in Japan which will be used to perform preparatory studies for SHINKAI 2000 as well as studies on hydrothermal deposits. Its construction period is scheduled to be from 1983 to 1986.

The chracteristics of Dolphin-3k are the realization of wide-band, high speed communication through an electro-mechanical optical cable, and the development of advanced peripheral technology such as an optical rotary connector and a submersible optical connector. As for operational modes, both towing/self-propulsion and self-propulsion are availabie.

The main parts of the Vehicle were constructed in 1985, they were assembled and tested.

Sea-going tests shall be carried out in January to March, 1987.

Deep Sea Floor Survey System

The major components of a deeply towed sea floor survey system down to 6,000m depth are detailed in Table 3. Its development has been in progrees since 1977. Especially unique is the Gimbaled Sheave, which has eliminated the problems of the towing cable jumping the sheve and wear by the sheve.

The system was used in the site survey for SHINKAI 2000, and it also played an important role in the study of submarine earthquakes which occurred in the central Japan Sea during 1983.

Table 3. Composition of the Deep Sea Floor Survey System

(1) Open-frame type towed body with a side scan sonar, sub-bottom profiler, color or black and white TV camera, still camera, strobe,pressure sensor, STD,transponder, and magnetic compass
(2) Air-conditioned van containing the surface equipment of the sonar, TV, and acoustic navigation system
(3) Long baseline acoustic navigation system
(4) Traction winch and stock-drum winch including an 8,000m double armored coaxial cable
(5) Onboard towing gear consisting of an A-frame and Gimbaled Sheave

UNDERWATER WORK SYSTEMS

Principally, there are two significant areas of research and development, outlined below.

Diving Technology

SEATOPIA PROJECT: Since its founding, JAMSTEC has promoted the research and development of saturation diving technology. It produced saturation diving technology up to a depth of 100m by SEATOPIA-system (100msw rated saturation barge) in 1975. After that, the system was used for practical job related to the construction of the Honshu-Shikoku Connecting Bridge.

SEADRAGON PROJECT: This is an onshore simulatation dive to research medical and physiological effect of saturation diving. Totally six dives were conducted between 1976 and 1984. Diving depths were 140m, 200m and 300m(four times).

NEW-SEATOPIA PROJECT: Since 1985, new diving project was started. JAMSTEC's target is to establish offshore saturation diving technology up to 300m using undersea work test vessel "KAIYO" by the end of 1988.

First phase is two 300m simulation dives, for diver training, emergency procedure, medical study and so on. First dive was conducted in 1985 as a project of UJNR (U.S. Japan Cooperative program on Natural Resources) and

next dive is scheduled in early 1987.
Second phase is offshore diving. Diving depth will be increased from 60m to 100m, 200m and 300m. Totally eight dives are scheduled by the end of 1988. As for FY1985, 60m diving was conducted.

KAIYO-Surface Support Vessel

Since 1982, JAMSTEC had been constructing KAIYO, as a support for various on-site experiments such as research and development related to diving technology. KAIYO has been completed in May 1985. The vessel has a gross tonnage of 2,800 tons, and is the largest semi-submerged catamaran or SWATH vessel in the world.

KAIYO has the following features:

1. Employing a semi-submerged catamaran hull, it has excellent stability in the open sea, which is necessary for safe and secure operations.
2. It has a large deck area, enabling the flexible arrangement of facilities and equipment on the deck.
3. It is capable of maintaining its location within a specific range using a dynamic positioning system.
4. The sources of vibration and noise are located on the deck above sea level, and it employs an electric propulsion system and low-noise propellers, so that underwater noise can be reduced.
5. A well in combination with an A-frame crane is located in the central area of the work deck in order to secure the handling of SDC.
6. It is equipped with a multi-narrow beam echo sounder enabling efficient and precise investigation of the submarine landscape.

JAMSTEC is now operating the vessel for research and development after the completion.

WAVE POWER GENERATION TECHNOLOGY

In order to utilize wave energy which is abundant in the ocean, JAMSTEC has been promoting field experiments with the wave power generator KAIMEI as an international joint project of the International Energy Agency (IEA).

In the first phase of the experiment (1976-1982), the viability of wave power generation and connection with shore based public commercial power sources were confirmed by experiments with KAIMEI.

In the second phase(1983-1986), the possibility of increasing the power generation using a new power generation method (tandem valveless turbine, phase control) was studied in order to reduce the unit cost of electricity. Experiments using KAIMEI were carried out on 1985 in the same location used for the first phase.

In addition to the above, during 1983-1984, experiments were conducted with an onshore fixed-type tandem valveless system and a Wells turbine. A power generation record of 40kw was achieved.

MARINE OBSERVATION SYSTEMS

As with underwater work systems, marine observation systems have been three significant developments which are discussed below.

Oceanographic Observation System

JAMSTEC is involved in an advanced oceanographic observation system development project. The purpose of this system is to realize rapid, precise mesurements in three dimensional oceanic space. The system consists of the following four subsystems.

1. Air-launched expendable CT profiler(AXCTP).
This is a small, lightweight system which quickly measures water temperature and electric conductivity in the water, down to a maximum depth of 2,000m, using an aircraft. It consists of a surface float, sensor probe, and an airborne data collection device.
2. Underwater sliding vehicle.
This is a system to be used to measure water temperature, salinity, depth, chlorophyll-fluorescene, and light scattering simultaneously by using a towed vehicle which moves up and down between the ocean surface and a depth of 200m. It is expected to contribute to the observation of ocean fronts. The underwater part consists of a depressor , a vehicle (including various sensors), and a cable with fairings. The vehicle can move up and down along the cable and can change velocity according to a command from an onboard control unit.
For its communication, the system uses a magnetic coupling which does not require mechanical contact between the vehicle and the cable. This does not only make the part of communication unit and the moving pattern of the vehicle extremely simple, but also provides high reliability, motion control and real-time data collection.
3. Towed sensor chain system
This is a system to be used to measure and monitor water temperature, electric conductivity and water depth at many different depths in real time by using multi many sensor units.
A sensor unit can be easily attached and detached to any desired points along an insulated towing wire through which measured data are transmitted by means of magnetic coupling. Therfore, it is easy to handle the system manually on deck and to exchange sensor units.
This is suitable to measure the complex structures of the ocean such as fronts easily and in detail.
4. Acoustic doppler current profiler
Development of a ship-mounted acoustic doppler current profiler is now underway. The instrument can measure reliably vertical profiles of ocean current and acoustic backscattering strength in 32 layers to a depth of 400 meters, and can track the ocean bottom up to 1000m deep.
The system consists of a transducer unit (four-beam, 70kHz), a data processing unit, a navigation unit (gyrocompass, LORAN-C and GPS navigation system), and a displaying unit (a personal computer, magnetic tape recorder).

Ocean Remote Sensing

JAMSTEC has been conducting studies on ocean remote sensing by aircraft and satellites since 1975. This project involves other related organizations and will be continued through 1987.

In this project JAMSTEC is responsible for identifying optimum wavelengh for observation of oceanic phenomena in microwave regions. These analytic technologies are expected to be applied for marine observation with a series of marine observation satellites, which Japan plans to begin launching in 1986.

Ocean Bottom Earthquake Observation Technology

Large scale earthquakes in Japan usually occur somewhere around the ocean trenches along the Pacific coast.

Prediction of a large-scale earthquake, which is supposed to occur sooner or later in the Tokai area, an area between Tokyo and Nagoya in Central Japan facing the Pacific Ocean, has now become a matter of real necessity.

For the purpose of detecting earthquake precursors and contributing to earthquake forecasting and warning, JAMSTEC has developed Ocean Bottom Magnetometer, Ocean Bottom Gravity meter and Ocean Bottom Seismometer.

1. Ocean Bottom Magnetometer

A Ocean Bottom Proton Precession Magnetometer

This type of magnetometer is designed to detect changes in the geomagnetic field on the ocean bottom near the expected hypocenter of large-scale earthquakes. The geomagnetic data is trasmitted periodically from the ocean bottom to land through cable. Its accuracy is 1 nanotesla and sampling time is 1 minute. The depth of operation is shallower than 6000 meters.

B Ocean Bottom SQUID Vector Magnetometer

This SQUID magnetometer is designed to observe time variation of each component of geomagnetic field on the ocean bottom and to detect changes in subterranean electrical conductivity. It consists of two underwater parts, underwater cable and a land station. The data can be stored on magnetic bubble memory cassets or trasmitted to land through an underwater cable. Helium gas evapolating from liquid helium is driven into the sea by a small helium gas venting pump. The accuracy is 10 picotesla and the depth of operation is about 100 meter.

2. Ocean Bottom Gravity Meter

This gravity meter is designed to detect gravity changes due to the up-and-down of the bottom and the change in density of oceanic crust. The data is transmitted continiously from the bottom to land throughby an optical fiber cable. The gravity sensor utilizes string vibration based on the TSSG surface ship gravity meter. The error is less than 0.2 mgal. The depth of operation is less than 6000 meters.

3. Ocean Bottom Seismometer

Detection of a large scale earthquake at the closest possible location to the hypocenter would give warnings to big cities prior to an attack by an actual earthquake by the utilization of the difference in propagation velocity between the seismic wave (approximately 4km/s) and the electro magnetic wave (200,000km/s in an optical fiber).

This seismometer is designed to be an ocean bottom sensor of the early alarm seismograph system. The sensor utilizes reliable mechanism of the conventional seismometer, and optical fiber technology. It does not require any electrical power at the ocean bottom because the light source and receptors are placed on land and only the light is trasmitted through some fiber glasses. The earthquake vibrating signal is transmitted to land through these optical fibers and demodulated to normal seismic wave.

U.S. NAVY ROV's (REMOTELY OPERATED VEHICLES)

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UNDERSEA VEHICLES

The explosion in numbers of remotely operated vehicles (ROV's) of which there are now more than 700 in operation world wide indicates the interest in the development and operation of undersea work systems. In compliance with the request of the Japanese team of the UJNR, the following is a report on the status and description of the particular systems requested.

CABLE CONTROLLED UNDERWATER RECOVERY VEHICLE (CURV) II

This system is based at the Naval Ocean Systems Center (NOSC), San Diego, California, and is utilized primarily to support the local test range operations. This system, along with the CURV I and CURV III, are the pioneers in remotely operated undersea work systems. The characteristics follow:

The improved CURV II is an unmanned tethered submersible capable of operating to 6,000 feet. It is the successor to CURV I which recovered the H-bomb off the coast of Spain in 1966. In configuration, CURV II is typical of most unmanned vehicles; it has an open rectangular framework to support the sensors and tools, two horizontal propulsion motors to drive and steer the vehicle, one vertical motor for close vertical control, and buoyancy of approximately 25 pounds. The vehicle is 6.5 feet wide and 15 feet long, weighs 3,000 pounds in air, and operates submerged at speeds to four knots. The sensors include an Applied Research Lab active/passive sonar, acoustic altimeter and depthometer, compass, two Hydroproducts television cameras with lights, and an EG&G 35mm still camera with strobe. One major feature of all surface powered vehicles is that their bottom time is restricted only by the ability of the surface support craft to remain on station.

The CURV II system consists of the vehicle, control cable, and control console. Although it often operates from the YFNX 30 surface support ship, the system can be air transported to operate from any surface ship of opportunity. It is primarily used for recovery of practice torpedoes from NOSC ranges.

CABLE CONTROLLED UNDERWATER RECOVERY VEHICLE (CURV) III

This system was utilized for more than ten years for response to undersea emergencies such as the recovery of the PISCES III submersible along with the rescue of its two pilots. It also has done inspection, documentation, and recovery of numerous objects including aircraft, helicopters, and weapons from the sea floor. This system is currently in storage under the custody of the Supervisor of Salvage of the U.S. Navy and is available as back up to his other assets. The CURV III characteristics follow:

CURV III, a greater depth version of CURV II, is capable of operating at depths to 7,000 feet at a submerged speed of four knots. It has been modified for emergency operations to 10,000 feet. The CURV III system consists of the vehicle, control cable, and control console. Although it often operates from the YFNX 30, the system is designed so that all major operational components can be disassembled, air transported to a work site, and installed on any surface craft that has adequate deck space. The vehicle normally carries a hydraulically operated claw for attaching and recovering items such as ordnance from the ocean floor. For special tasks, the claw is removed and replaced by a variety of grasping, cutting, or working tools. The vehicle also contains the necessary equipment for searching, locating, and documenting the lost item. Control of the vehicle and monitoring of operations are performed in the control van. The vehicle is 6.5 feet high, 6.5 feet wide, 15 feet long, and weighs 4,500 pounds in air. Its instrument suite includes a Straza 500 active/passive sonar with transponder interrogation capability, acoustic altimeter and depthometer, compass, two Hydroproducts television cameras with lights, and an EG&G 35mm still camera with strobe.

CURV III is a versatile underwater vehicle that can be readily modified to accommodate a wide variety of underwater tasks. It has demonstrated its search and recovery capabilities in the Pacific Ocean, the Mediterranean Sea, and the Atlantic Ocean.

DEEP DRONE

This undersea work vehicle was developed by Amtec-Straza in San Diego, California for the Supervisor of Salvage of the U.S. Navy. It is maintained on a constant ready basis and operated by contract personnel for the Supervisor of Salvage Office. DEEP DRONE characteristics are:

It is an open frame vehicle propelled by three 5 horsepower electric thrusters and one lateral thruster. The vehicle weighs 2,700 pounds in air. It can operate to a depth of 7,000 feet at a maximum speed of three knots. It can lift up to 350 pounds and is equipped with a seven function manipulator. The vehicle is equipped with a CTFM 360° search sonar with a range of 3,000 feet. It also has an acoustic navigation system. DEEP DRONE has a photo/video capability using a 35mm camera and a black and white television.

The DEEP DRONE is an air transportable system that can load out on a C-130, C-141, or C-54 aircraft. Ground transportation consists of one 40 foot flat bed truck.

SUBMERSIBLE CABLE ACTUATED TELEOPERATOR (SCAT)

SCAT was built originally to act as a test bed demonstration vehicle primarily for the purpose of evaluating head coupled television. It currently has been reconfigured as a light duty inspection/work vehicle capable of operating to 3,000 foot depths.

SCAT is tethered by a multiconductor cable and carries a black and white television camera with one 250 watt quartz iodide lamp and a 50 frame 35mm camera and strobe mounted on a pan and tilt assembly. Sensor capability also includes a sonar system, depth sensor, and compass. A specially designed electrohydraulic system consisting of an electric motor, fixed displacement pump, relief valve and reservoir drives hydraulic motors connected to ducted thrusters and provides maneuverability in both horizontal and vertical directions. In addition, five two-way servo valves have been added to the system to allow for various work functions, which may include a rudimentary manipulator of special purpose tools. While seated at the control console, the SCAT operator views on a conventional TV monitor the image relayed by the vehicle's television camera. The orientation of the camera is controlled by a hand operated pan and tilt control. The entire SCAT system (vehicle, control console, power distribution unit, main cable, and power generator) is designed for transportation by commercial aircraft and can be accommodated by their handling systems and cargo spaces. SCAT has a dry weight of 975 pounds and is 39 inches wide, 71 inches long, and 52 inches high.

DEVELOPMENT OF REMOTE PRESENCE TECHNOLOGY FOR TELEOPERATOR SYSTEMS

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ABSTRACT

The Naval Ocean Systems Center has a broad spectrum research and development program to establish the technology base required to provide remote presence to teleoperated systems. This paper briefly describes the overall program and various key technology areas being pursued. Program direction emphasizes integration of controls and displays with maximum sensory channel communication with the human operator to provide human like work capability and greatly improved efficiency.

INTRODUCTION

The Naval Ocean Systems Center (NOSC) has been engaged in the development and utilization of teleoperated, or remotely manned, vehicles for undersea application for nearly three decades (Talkington, 1976; Wernli, 1979; Wernli, 1982). Ongoing work at the NOSC Hawaii Laboratory is concentrating on the development of teleoperated systems which possess a characteristic which we refer to as remote presence. **Remote presence**, the perception or "feeling" of actually existing at the remote location, requires careful integration of operator control and display systems with the sensor suit and operational capabilities of the remote unmanned unit. The degree of "presence" achieved is determined by the degree of fidelity of sensory feedback provided to the operator.

Clearly, the relative importance of human capabilities are environmentally and task-dependent; thus, adaptive display and control systems are needed to establish and maintain remote presence. Though many specific work tasks can be performed by telerobotic systems which provide little or no remote presence, such systems are often much less productive when performing complex or novel tasks in unstructured environs. Thus, there is a pressing need to develop systems that can capitalize upon the remarkably adaptive problem solving and manipulative skills of humans. For these reasons our laboratory is addressing theoretical and applied technological problems which must be overcome if practical and more effective teleoperated systems are to be produced.

BACKGROUND AND TERMINOLOGY

The initial interest in remote presence began more than thirty years ago. The nuclear research community needed to protect human operators from the risks inherent with manipulation of radioactive materials. Early efforts resulted in the direct-drive, force-reflective, "telemanipulator" systems which are still in use today. As technology progressed, scientists and engineers tasked with working in the more remote hostile evirons, such as deep sea and space, developed mobile telemanipulator platforms. Although a number of terms have been used to describe a mobile telemanipulator platform which is not directly linked to a master controller (e.g. telechirics, telesymbotics, telemation), *teleoperation* is most often used by current investigators (Johnson and Corless, 1967).

In the early 1970's our laboratory experimented with a helment-mounted, head-coupled television (HCTV) system on an undersea vehicle (Remote Unmanned Work System (RUWS)). The HCTV system, which evolved from previous work at the Naval Weapons Center, China Lake, enabled operators to complete difficult manipulative tasks while hovering in the water column. Experienced gained with the HCTV system, and later demonstrations, showed that remote presence could greatly improve teleoperator system performance.

The Remote Presence Demonstration System utilized a remote unit with a head, arms and torso, and the man-machine interface featuring exoskeleton arm and torso controllers, and a head-coupled display controller described earlier (Hightower and Smith, 1983). This system allowed the operator's head, arm and torso motions to be coupled to the remote unit in real time. Incorporation of stereo vision and binaural audio displays with a head and body coupled torso provided the operator with sufficient remote presence to enable untrained operators to complete difficult tasks to a much better degree than had been expected.

The merits of using remote presence for reconnaissance and surveillance applications using a mobile land vehicle have also been assessed. A radio-controlled land vehicle shown in Figure 1, referred to as the Advanced Teleoperator Technology Vehicle (ATTV), was remotely driven by operators within a vehicle cockpit mockup which contained controls required for vehicle operation and displays for reconnaissance (See Fig. 2). An anthropomorphic head, shown in Figure 3, was placed in the ATTV at the approximate location of the driver's head. The remote anthropomorphic head (controlled in pan, tilt, and roll) was equipped with color TV cameras providing a 60 degree field of view with full overlapping stereo presentation of the area surrounding the vehicle, and binaural audio microphones. A rugged 4 km full-duplex fiber optic cable system provided a non-line-of-sight, wide-bandwidth telemetry system which was inteference resistant. Based upon successful demonstrations in 1985 we have expanded efforts toward ATTV development.

Fig. 1. The Advanced Teleoperator Technology Test Vehicle.

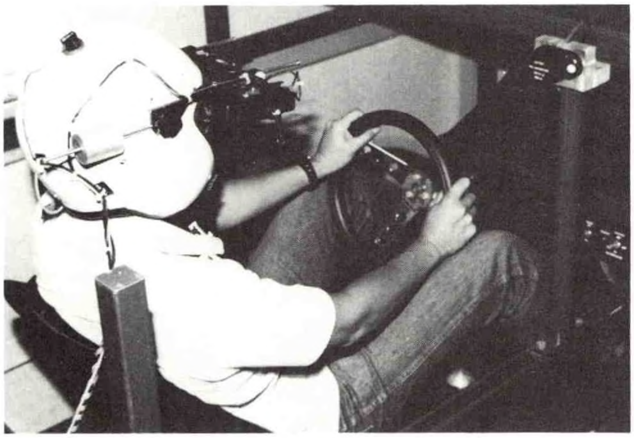

Fig. 2. The ATTV teleoperator's control and display station.

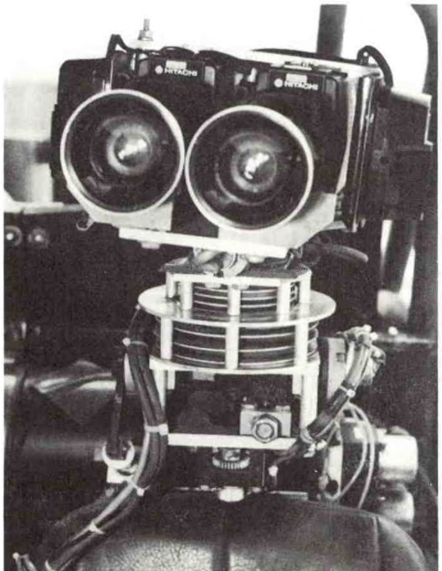

Fig. 3. The ATTV anthropomorphic head containing stereo cameras and microphones.

CURRENT NOSC EFFORTS

In addition to engineering accomplishments, NOSC, Hawaii has been actively pursuing a program of advanced technological development and basic science research in areas which enhance teleoperator capabilities for U.S. Navy and the Marine Corps missions. As part of this program we are pursuing development of a general theoretical model of teleoperator performance which will guide future research and provide a basis of comparison with existing and proposed teleoperator system designs. The following paragraphs briefly describe the ongoing basic science and technology projects at NOSC, Hawaii.

Fiber-Optic Communication Linkages

For a number of years the Advance Fiber Optic Systems Branch has been engaged in the development of deployable fiber optic data links specifically for teleoperator applications. Fiber optic data links are a significant subsystem of teleoperators which are responsible for shuttling bidirectional sensor and control information between the teleoperator and unmanned remote unit. Ongoing research and development efforts are focussing upon advancement of fiber and cable construction, high-speed digital telemetry system design, and canisterization for cable payout.

Present studies of optical fiber design are being supported under a NOSC Independent Exploratory Development (IED) program. Fiber designs have been optimized for the 1.5 micron band and similar results are sought for smaller diameter fibers. To date, a 100 micron diameter optical fiber has been constructed with optical parameters optimized at 1.5 microns.

Needs for cost-effective, deployable, cables and fibers than can survive in hostile environments have driven development of lightweight, Kevlar™ - reinforced designs. Cables with diameters ranging from 1.2 mm to 1.8 mm have been prototyped, wound into canisters, and have been successfully deployed from a variety of vehicles. A major design goal is to achieve uniform application of a suitable elastomer jacket for abrasion and crush resistance of a 1.5 mm cable for improved land vehicle applications. Undersea applications of fiber optic cables has proven to be very successful for data or low power transmissions; however, construction of cables which combine high strength, high power transmission, and large bandwidth capabilities is a major challenge.

Adequacy of current telemetry systems have been challenged as the requirement for stereoscopic video has driven data rates up to and beyond 200 Mb/s. While such data transmission rates are a factor of 10 below the fiber's transmission capacity in deep ocean applications, fiber bandwidth will be the principal limitation facing advances in sensor technology. For this reason we are searching for methods to reduce signal bandwidth requirements for high fidelity sensor suits and controls.

Stereoscopic Visual Displays

Operators of teleoperated systems often use stereoscopic television (TV) displays to provide realistic three-dimensional visual images. Studies thus far have concentrated upon the impact of stereo displays upon operator learning, visibility conditions, and visual task factors which are important to remote manipulation (Pepper, Cole, and Spain, 1983; Spain, 1986). From these studies several conclusions have been drawn. Stereo television displays provide substantial performance advantages over conventional television displays when:

- aspects of the remote scene are unfamiliar or are frequently changing
- rate of learning of new tasks is important
- visibility is poor
- tasks have significant depth positioning requirements.

Following successful demonstrations of stereo television's advantages, the effects of several stereo television parameters on additional perceptual measures such as depth resolution and depth interval estimations were investigated. The stereo TV parameters investigated included:

- camera interaxial separation
- lens magnification
- introduction of motion parallax produced by coupling operator head movements with of a remote pair of cameras.

In all cases, specific values for each of the parameters were found to improve system performance over and above levels typically used in stereo TV viewing systems.

Our scientists and engineers have also developed a hybrid viewing system consisting of a stereo pair of TV cameras transmitting images to a beamsplit polarized display. One eye is presented with a high resolution black and white image. The other eye is presented with a low-resolution color image. All other features of the images (e.g. linearity, brightness, contrast, screen size) have been equalized. Thus, the hybrid viewing system can produce three views depending on the perceptual requirements of the task, the operator's preference, and bandwidth availability: monoscopic black and white with high-resolution, monoscopic color with low-resolution, and a composite color and black and white stereoscopic view with intermediate resolution. Bandwidth can also be adjusted by lowering the frame rate of either or both channels.

Several problems regarding the features of hybrid images and their effects on the operator are being studied. Parameters of immediate concern included:

- video resolution level
- chromatic fidelity
- qualitative and temporal features of retinal rivalry
- potential for retinal rivalry distraction or irritation to the operator
- veridicality of depth perception
- rate of manipulator performance
- production of eye strain, fatigue or discomfort
- judged quality and preference for the system.

Preliminary results suggest that high-resolution black and white information represented to one eye will combine with lower resolution color information to the other eye to produce a stereoscopic percept containing color cues with a resolution level midway between those of the two channels; thus, saving substantial channel capacity. Current efforts are directed toward the formulation of mathematical models for characterizing visual performance with stereo TV displays, selection of appropriate parameters for remote terrestrial reconnaissance, and for the assessment of fatigue effects produces by prolonged usage of such viewing systems. Figure 4 shows the video display, master-slave arms, and stimulus set currently used in the hybrid vision research project.

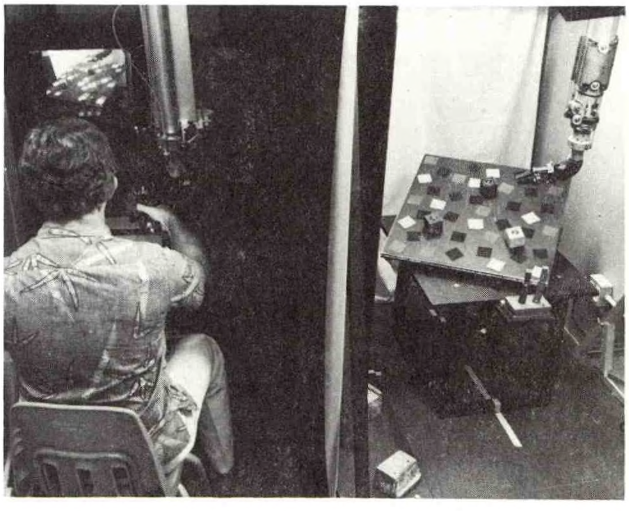

Fig. 4. Hybrid vision video display, control station, and stimulus set.

Computer Image Processing

Human vision provides an excellent model for computer vision systems that must operate in situations in which operators cannot be present. We are pursuing an extensive program of basic perceptual research in which the visual processes that guide our detection, discrimination, and recognition performance are being measured, described, and modeled Uttal, 1985; Uttal, in press). For this, a simplified visual universe of dotted, three-dimensional stimulus-forms is used in order to avoid complications arising from conflict between different visual cues. The stimulus-forms embedded in random arrays of dots also distributed throughout the three-dimensional viewing space are presented to observers. Upon completion of the appropriate psychophysical experiments, mathematical models similar to those used in the image processing field are developed to simulate the major visual processes and to stimulate the design of new computer vision systems.

A set of empirical "Rules" of visual form perception has been developed that, in large part, have been successfully modeled with mathematical algorithms. A major empirical result is that some forms are much more easy to see than others when obscured by noise. This work is expected to lead in the long run to new computer vision systems for automatic scene interpretation.

FUTURE DIRECTIONS AND PLANS

Teleoperators can perform a variety of tasks in environments or situations where human health and safety risks are high (e.g. military reconnaissance, hazardous material handling or cleanup, fire fighting, damage control, ordinance disposal, deep sea and space equipment maintenance and construction, etc.). Pursuit of improved remote presence will serve to expand the scope of future teleoperations and to improve productivity and utility of existing systems.

To augment our research in teleoperator visual display design NOSC has joined in a cooperative research and development effort with NASA to develop principles for design and construction of tactile display systems for the purpose of enhancing remote presence and manipulative performance in telerobotic systems. Presently a flexible computer-driven virtual arm and tactile sensor display system is under construction. Once finished, the simulator will be used to experimentally determine:

- end-effector force display requirements needed for determination of grasp force and grasp integrity
- sensor blend and resolution requirements needed for reliable discrimination of functional shapes and surfaces of parts or tools
- sensory display priority criteria between tactile, proprioceptor, and visual feedbacks for specific tasks given present and anticipated bandwidth limitations.

In addition to tactile display research, NOSC has begun to study the issue of manipulator actuation in collaboration with DARPA. Under diverse and unpredictable environments destructive impulse loading of heavy and slow remote manipulators is frequently encountered. Under such circumstances actuators, links, or objects manipulated may be damaged. Recent scientific advances suggest that novel materials such as magnetic fluids, polymer gels, and other technologies might be used to produce light-weight, forceful, smooth-acting, durable, and energy efficient actuators. The potential for replacement or augmentation of conventional actuator systems using such exotic materials to produce more "life-like" actuation of telerobotic manipulators is the goal of this newly programmed study.

The Naval Ocean Systems Center, Hawaii Laboratory will continue its basic science and engineering efforts directed toward enhancement of remote presence in teleoperated and supervised autonomous systems. To produce a effective remote presence for teleoperators, as conceptualized in Figure 5, is an exciting and challenging undertaking which offers great benefit to the Navy, Marine Corps, as well as other military and industrial communities.

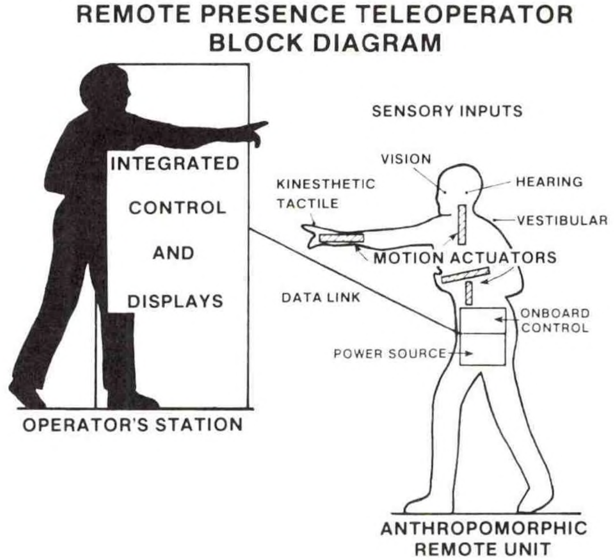

Fig. 5. Diagram illustrating an ideal remote presence system produced through effective integration of teleoperator controls and displays.

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DEEP ROV DOLPHIN-3K AND ROVS DEVELOPED IN JAPAN

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JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER

ABSTRACT

Dolphin-3K, a largest and a deepest tethered ROV in Japan, is now under construction and will be completed in the early 1987.

The maximum operational depth of the vehicle is 3300 meters, the dimensions of the vehicle are 285(L) x 194(W) x 190(H) cm, the weight of the vehicle is 3300 kg and the total shipping weight of the system is about 35 tons. This paper describes about the sybsystems of the Dolphin-3K ststem already completed, and the tests already carried out.

Total 42 vehicles were constructed in Japan, 5 were retired and 2 were lost. More than 4 vehicles are under development. The status of those vehicles are reported.

INTRODUCTION

Dolphin-3K is planning to use for pre-site surveys of the manned submersible "Shinkai 2000" which under operation by Japan Marine Science and Technology Center(JAMSTEC) and the scientific reconnaissance surveys. The design of the Dolphin-3K system, fabrication and testing of some subsystems were already reported(1),(2),(3). The major subsystems such as (A) control and telemetry unit, (B) cable and surface handling system, (C) vehicle were discussed.

The activities concerning development and utilization of ROVs (tethered free swimming) were rather moderate in Japan. Total of 42 vehicles were built by 8 companies and organizations. 5 were retired, 2 were lost and 35 is active but some of them are not so frequently used. 20 of 42 are small size ROV, DLT-300 which is manufactured by Q.I.Inc. 10 of 42 are low cost ROV, RTV-100 which is manufactured by Mitsui Engineering and Shipbuilding Co.Ltd.(MES). The other manufacturers or developpers were MODEC, KDD RD Laboratories , Sumitomo Heavy Industries, Mitsubishi Heavy Industries and Kawasaki Heavy Industries. MODEC developed 3 vehicles, they are MURS-100(retired) , MURS-300 and MURS-300 MKII. KDD Laboratories developed MARCAS and is developping MARCAS-2500. Mitsubishi and Kawasaki Heavy Industries are also engaging on researches of some ROV development. MITI is promoting the Advanced Robot Project.

DOLPHIN-3K

Dolphin-3K(Fig.1) is now under construction and the entire hardwears of the system will be completed in this August. Then assembly of the total system and testing will be completed until this December. Sea going tests will be carried out January to March 1987. The major subsystems already completed and tested are discussed below.

(A) Control and telemetry unit

Control and telemetry unit is installed in a control van (6.4(L) x 2.4(W) x 2.4(H) m). The unit is composed of an operators console and a data processing, control and telemetry station. Fig.2 shows operators console which provides 2 operator stations. A pilot at one operator station (left side) flies vehicle using a joystick and a footpedal(up and down motion) while monitor 3 displays which provide a color TV, 2 black and white TV pictures from the vehile. Those 3 displays also provide vehicle position and informations for sensors mounted on the vehicle and the surface handling gears. 1 display mounted on the central part of the console provides a picture from an obstacle avoidance sonar (OAS-2, Edo Western). The other pilot at the right side operator station controls two manipulators and winch. The pilot monitors stereo black and white TV display with glasses of electronically synchronized shutter when controls the two manipulators.

Control and telemetry station composed of a control unit which has 3 CPUs, 2 system control CPUs and a data management CPU, and a telemetry unit which converts parallel vehicle control signasls to a train of serial signals. The sation also contains a optical fiber transmission unit which transmits all necessary informations by digital PCM (400 MBPS) and 2 light wave division multiplex.

(B) Cable and surface handling unit

To ascertain a necessary cable and cable stop technology for Dolphin-3K, cooperative studies were carried out between JAMSTEC, MES and Fujikura Ltd., since 1984. After 3 years study, sea going tests were carried out in this April using a long cable (length 5000 m, diameter 30 mm) provided by Fujikura Ltd. Fig.3 showns cable and winch on board the Swath ship Kaiyo. The cable was lowered to the depth of 3300 m, optical transmision loss and digital code error rates were measured. It was ascertained that the optical transmission loss and the digital code error rates were very small. The testing was successful and the results of the 3 years cooperative works were fruitfull.

(C) Vehicle

Parts of the vehicle already fabricated were as follows.

(a) frame made of titanium
(b) hydraulic power unit and valve unit
(c) 6 thrusters
(d) 3 pan and tilt units, 1 color TV, 1 black and white stereo TV 1 black and white aft TV, 6 lights
(e) 1 master slave force feed back manipulator (7 d.f.) and 1 rate control manipulator/grabber (5 d.f.)
(f) obstacle avoidance sonar (Edo Western OAS-2)

Those manipulators, pan and tilt units and TVs were mounted on the frame (Fig.4). Then an acceptance test and other trials were carried out. Those trials included a fine work test of manipulator arms using stereo TV viewing system.

The vehicle has 2 pressure resistant canisters which are a canister for power source (internal diameter 40, length 140 cm) and a canister for telemetry and interfaces (internal diameter 40, length 180 cm). Those canisters which were made of Al-7050 were fabricated and pressure tested. The assembly of the vehicle started at the Chiba Shipyard of MES.

ROVS DEVELOPED IN JAPAN

Total list of ROVs developed and under development are shown in Table 1.

DLT-300 (Fig.5) is a commercial type of JTV-1 which was developed by JAMSTEC in 1980. 20 of DLT-300 were manufactured and 15 were delivered. DLT-300 is mainly used for geological and biological surveys, fisheries, diver assist and engineering of harbours.

RTV-100 shown in Fig.6 is a small low cost vehicle developed by MES. 10 of the vehicle were delivered and a numbers of the vehicle will be fabricated.

MODEC developed 3 vehicles, they are MURS-100, MURS-300 and MURS-300 MKII. MURS-300 is already retired. MURS-300, a largest vehicle in Japan, is not so active. MURS-300 MKII is a medium size vehicle which is now used for inspections of the facilities of Hydraulic Power Plant (4). KDD Laboratories developed MARCAS (Marine Cable Search System) and the vehicle is now highly active for cable maintenance works (5). KDD Laboratories is now developping MARCAS-2500 which is a deeper version of MARCAS and will be completed in 1987.

JAMSTEC completed HORNET-500-2, HORNET-500-1 was lost in 1984 by an accident, HORNET-500-2 is shown in Fig.7. HORNET-500-3 is now under construction by Sumitomo Heavy Industries who got the license about HORNET-500 from JAMSTEC. The vehicle will be completed in the early 1987. JAMSTEC owns 4 vehicles, they are JTV-2, dual DLT-300 and HORNET-500-2. 3 vehicles were retired, they were JTV-1, Mosquito and RTV-400. Dolphin-3K is under construction and a battery powered vehicle is under construction. The vehicle shall be controlled by an expendable optical fiber line such as Eave East and will be completed in 1988.

MITI is promoting the " Research and Development of Robots for Critical Environment " Project in which 3 items are included. They are " Robots for works in nuclear power plant " , " Robots for undersea operations " (8). The " Robots for undersea operations " shall be the Advanced Robot for Support of Offshore Oil Exploitation (9). The Project initiated in 1983 and after development and testing of the essential technologies, the design, trial production and experiment shall be carries out until 1990.

CONCLUSION

ROV activity in Japan was rather moderate but it seems to grow in recent years. Technologies concerning small ROVs and large deep ROVs are growing rapidly. 2 deep ROVs, Dolphin-3K and MARCAS-2500 shall be completed early in 1987.

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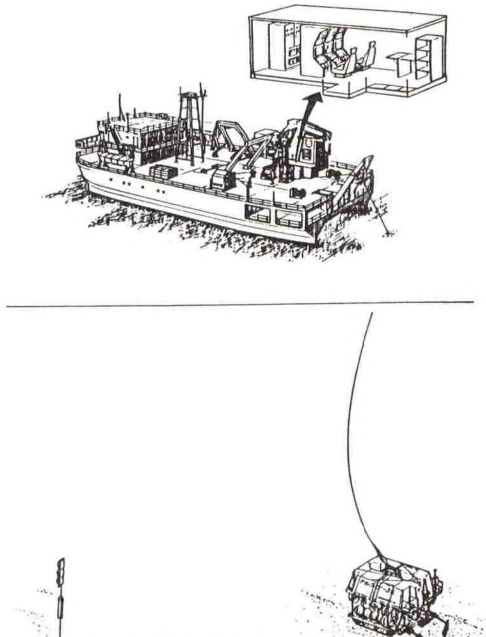

Fig.1 Dolphin-3K system

Table-1. Tethered Free Swimming ROVs in Japan

	Built	Underconstruction	Retired	Lost
Small	33 (20) DLT-300 (10) RTV-100 (2) JTV-1,2 (1) Mosquito	2	1 (1) JTV-1 (1) Mosquito	(1) DLT-300
Medium	7 (2) HORNET (1) MURS-100 (1) MARCAS (1) MURS-300 MKII (1) RTV-400	1 (1) HORNET	2 (1) MURS-100 (1) RTV-400	1 (1) HORNET
Large	2 (1) MURS-300 (1) Test vehicle	3 (1) Dolphin-3K (1) MARCAS-2500 (1) Advanced Robot	1 (1) Test vehicle	

Fig.2 Operators console of Dolphin-3K

Fig.3 Cable and store winch of Dolphin-3K

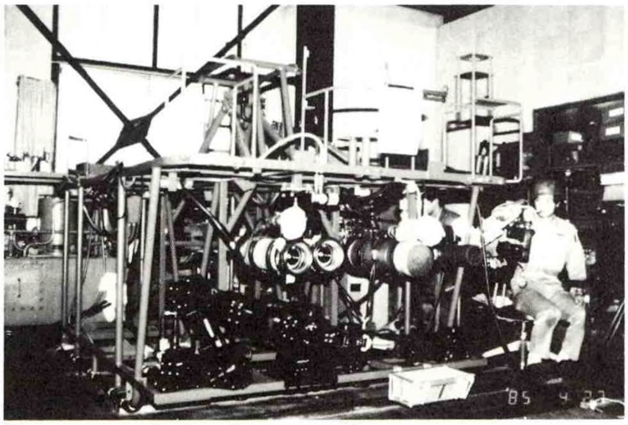

Fig.4 Testing of the manipulators of Dolphin-3K

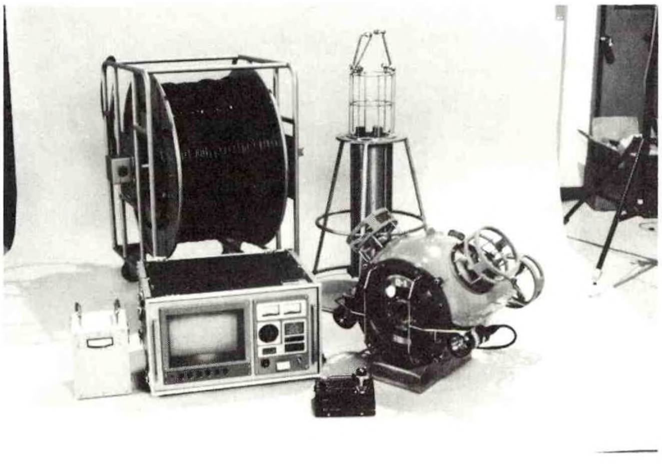

Fig.5 DLT-300

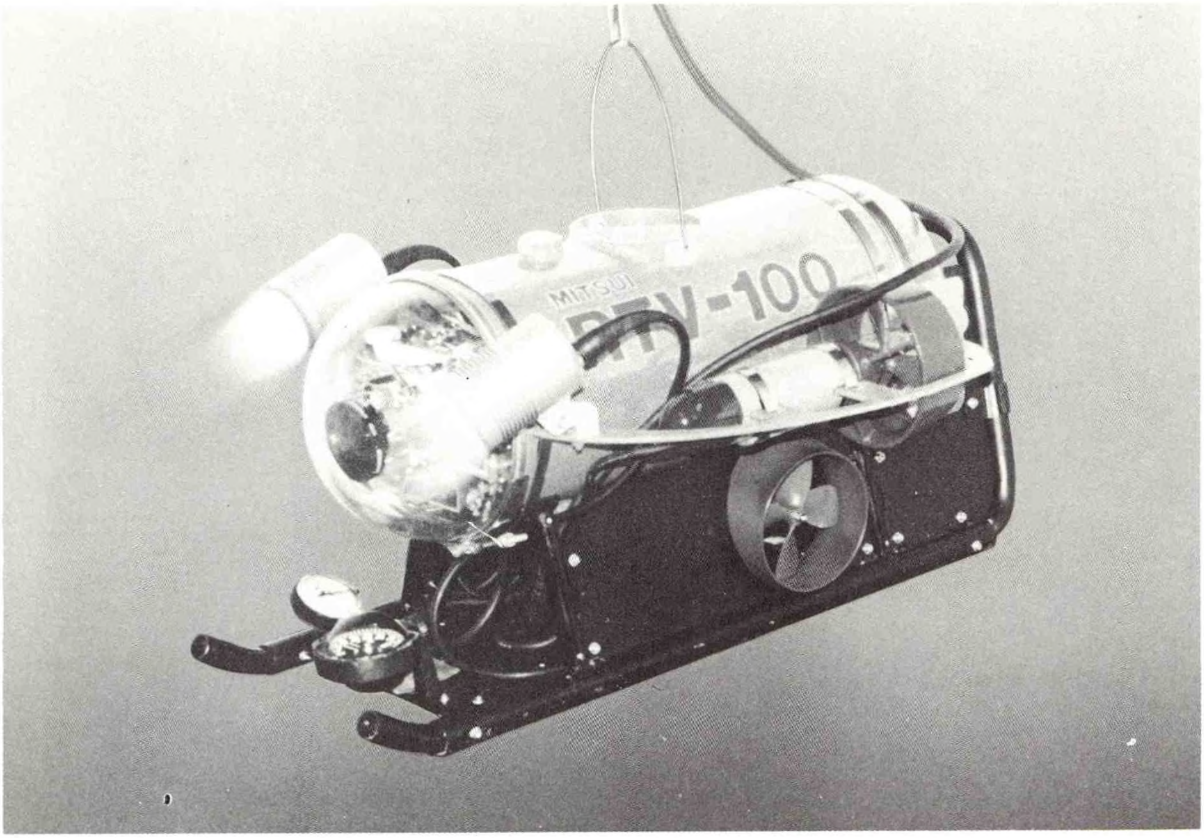

Fig.6 RTV-100

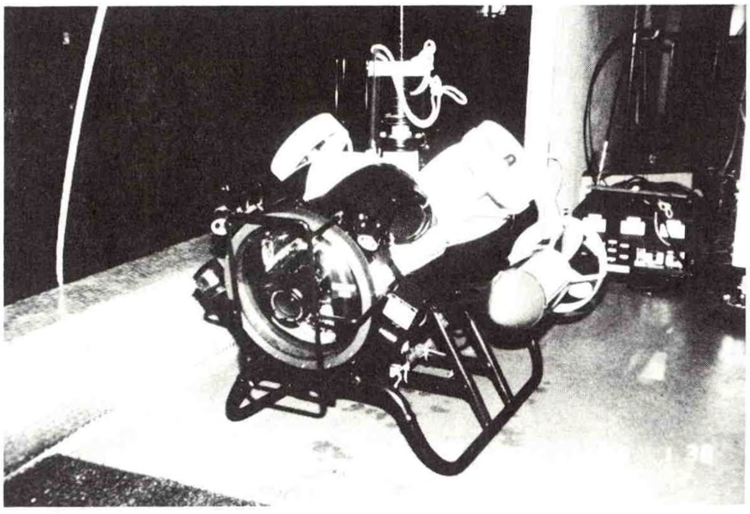

Fig.7 HORNET-500-2

THE LOW COST REMOTELY OPERATED VEHICLE (LCROV)

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The growth of remotely operated vehicle (ROV) technology, capabilities and operations has been remarkable over the past decade. In 1975 there were nine operational ROV's that had been constructed for commercial service; since then more than 500 have been developed. Presentations at SUBTECH in the U.K. and ROV conferences in the U.S. have abundantly documented the vital and growing importance of ROV's to support offshore work and military applications. Over the past three years it is apparent that ROV technology is taking two distinct paths. One direction is towards larger, complex and more specialized machines configured for non-destructive testing (NDT), maintenance, repair and other specialized work tasks. This is one evolutionary path coming from the past decade of ROV development. The second path is in the direction of a low cost, simplified ROV This is the "low cost ROV" or LCROV.

I. THE LOW COST REMOTELY OPERATED VEHICLE DEFINED

First, it is important to define "low cost" since, in the ocean industry, low cost is a relative concept. IMI believes that ROV's in the cost range of less than $30,000 for the basic machine are LCROV's.

This reasoning is based on IMI's estimate of the potential new markets that $30,000 or less, opens up. Generally these new market sectors are very price-sensitive. This does not imply that those who are offering, what they call a LCROV, for $50,000 to $60,000 are in error. It is simply a reflection of what our studies have shown an ROV must be priced at to enter a volume market, as opposed to the conclusions of others. When one reflects that most ROV systems range from about $200,000 to over $1 million per unit, $50,000 is indeed low cost. But to the new customer we forsee it is still an inhibitively high figure.

The LCROV is designed to price. It is essentially an inspection vehicle with little work capability. However, its positive characteristics greatly outweigh the negatives. For example:

o Low cost opens up new underwater work opportunities not possible in the past due to the much higher acquisition cost of conventional ROVs. Because the LCROV is affordable, growth of ROV applications beyond present emphasis on offshore oil and gas and the military is assured. Many new ROV operators will enter underwater services activities through the use of LCROV's.

o Using LCROV's in high risk situations will be more acceptable than using large ROV's costing hundreds of thousands of dollars or more. An operator, or his client, may not wish to risk a $300,000 system on a task, he may be willing to take that risk with a $30,000 vehicle.

o LCROV systems are compact and light weight simplifying logistic support requirements. Most are designed to be carried as airline baggage. At the operations site their light weight permits hand tending, with minimum support crew, from any type of platform of opportunity.

o With respect to quality, low cost does not mean cheap. LCROV design and manufacture take full advantage of new technologies in electronics, electrical, mechanical and materials areas where trends are towards reduction in size, greater efficiency and reduced costs. One of the few production ROV's to use fiber optics is a LCROV (Mitsui's RTV-100).

o Understanding that less sophisticated operators will form the majority of LCROV users, the builders of these units are designing them for simplified field maintenance and reduced depot support.

o Because of rigid cost, weight, logistic, and maintenance constraints, the design and manufacturing lessons learned by LCROV manufacturers will also benefit large ROV manufacturing.

Some LCROV limitations are:

o The power to weight ratio is excellent, but overall thrust is not comparable to the large ROV. Thus the LCROV is limited as to how much current it can work in without risking the vehicle.

o Because of lower thrust, the amount of umbilical that can be 'towed' by the LCROV limits depth capability. At present the maximum LCROV depth capability does not exceed 1000 feet. Lighter umbilicals using fiber optics, on board (battery) power, more efficient thrusters, or more electrical power to the vehicle are means to increase depth capabilities of the LCROV.

o The LCROV is essentially a swimming tv camera, not a work vehicle. It has little on-board room and electrical power for extra payload. Judicious use of syntactic foam and new developments in sensors should permit future LCROVs to do a great many measurement tasks such as NDT.

Summing up, it's clear the LCROV has an important place in the spectrum of "undersea work systems". But one should be very careful to define this place to avoid over-optimism.

II. THE EVOLUTION OF THE LCROV

It is difficult to say when and where the LCROV began. For at least five years engineers and designers have considered development of such systems. However difficulties were experienced in designing to a final price that was low enough to attract new market opportunities.

A few short-lived 'LCROVs' were developed for use in nuclear reactor inspection work. They had to work with great precision, but for short periods of time. At end of the inspection period they were junked due to radioactive contamination. It's not apparent any present LCROV development came from this area.

There were economic factors which helped to limit introduction of the LCROV. Up through the early 1980's the offshore oil and gas industry, largest single employer of ROV's, was bullish. Manufacturers of ROV's found a better market and larger profits in making and servicing larger vehicles.

Offshore operators wanted more powerful vehicles with greater work capability. This was especially true for emergency work tasks where a platform or floating drilling operation might be shut down to make essential repairs. Operational costs for a large ROV system was trivial compared to down time on the rig. Both the drilling contractor and ROV operator were not interested in limited capability (i.e., LCROV) ROV systems at this point. For routine tasks the ROV operator could put his vehicles on jobs at good rates of profit. There was little need to be concerned with acquiring and using lower capital cost equipment when there was plenty of work for all.

Much of this changed when the worldwide economic recession struck and an increasing glut of oil appeared throughout the world. While recession has eased, the oil glut may affect us until the 21st century. The result has been a major worldwide cutback in present and projected offshore oil and gas operations. Offshore operators have suffered. Diving service companies cut back their personnel, offered services at break-even prices, and attempted to diversify their services by going outside oil and gas operations. A similar path was followed by ROV and submersible operators (many also employing divers) as they dealt with a shrinking market for their services.

The high cost of large, specialized ROV's became a matter of considerable concern. Alternative, lower cost systems were sought to help reduce operating costs and improve competitive position. Some service companies developed and manufactured their own ROV's. Many large ROV's began to show up on the used equipment market thus depressing new vehicle sales for the ROV manufacturers.

This is not to say the offshore market collapsed. Inspection, maintenance and repair of existing structures and pipelines and drilling support will continue. However, the numbers of these structures and pipelines will begin to decrease as new construction projects are cut back and older, obsolete structures are removed.

Near the start of this period of reduction and rationalization in the offshore services industry the practical LCROV was born. In this context "practical" defines a vehicle which was put into serial production and offered for sale on the open market.

The first practical LCROV was the MINIROVER developed by Deep Sea Systems International of Falmouth Massachusetts, and introduced at the San Diego ROV 84 conference in May, 1984. Since that time 15 LCROV s have been introduced into the market by companies in six different countries.

III. NEW MARKET OPPORTUNITIES FOR LCROV

The availability of ROV capabilities in a package costing less than $30,000 opens up several new operational areas and potential user groups for LCROVs. However, as noted earlier even within the $30,000 price range there is potential buyer differentiation by price. Some potential users consider $30,000 too high!

In the following section we will see in a general way how each potential user group might apply the LCROV to its activities. In attempting to define how each potential user group might use LCROVS, no priority is suggested in the order of the following list. Definitive market studies of each area are required, but describing IMI s work in this area is outside the scope of this paper.

IV. THE LCROV USER GROUPS

A. Offshore oil and gas industry

The immediate market for the LCROV, of the eight user groups identified, this and "national defense" are the only groups somewhat familiar with ROV technologies, capabilities and costs. However offshore oil and gas will not be the largest market for the LCROV manufacturer, but it will provide a place where immediate sales can be made to help offset initial development and production costs of the product.

B. National defense

Present application of ROV's to naval operations is a relatively new and small scale activity. However in the past three years there has been an increasing interest, especially in the mine warfare applications.

Areas of naval application, outside mine warfare, are ship husbandry, object location and recovery, surveillance and monitoring, inspection, maintenance and repair. The LCROV could be put aboard most naval vessels to facilitate these tasks.

For military ground forces the LCROV could be used for search, inspection and explosive ordinance disposal (EOD) tasks in waterways, lakes and harbors.

C. Coastal and inland civil works

Power plants conventional and nuclear all require cooling water intake and discharge lines Nuclear power plants have added requirements for inspections of their reactor containment structure and other water pool components of the plant. For coastal and inland utility companies LCROVs provide a low cost capability that is affordable and relatively easy to operate. Many of these organizations depend upon outside contractors for inspection services but few contractors in the past have been able to afford the expensive, large ROV systems.

The situation is the same with public and private agencies responsible for the operation of hydroelectric dams water storage reservoirs and dams, and sewage treatment facilities. In addition there are offshore outfalls along the coast that should be inspected each year. Often, inspections are not done on an annual schedule simply due to cost factors. When inspections are made the companies use divers and surface-lowered inspection equipment to monitor condition of underwater structures. Compared to the use of conventional ROV's these techniques are less costly...and less effective. LCROVs offer the possibility of greater efficiency at less cost than divers or surface lowered equipment.

A new area of inspection using divers and ROV s has been in petroleum storage tanks at refineries and storage depots. To drain the tanks and place scaffolding in them can be a very expensive and time consuming operation. The use of contract divers and LCROVs in tanks filled with water ballast can reduce time and cost factors.

D. Marine transportation, ships, harbors and ports

Ship husbandry requires the use of divers for inspection, cleaning, maintenance and repair of the underwater body of a vessel. Large ROVs can do many of these tasks but their high acquisition and operating costs prohibit almost all harbor diving companies from owning this type of equipment. LCROVs can change this. While they are not capable of heavy work tasks they can inspect and do simple non-destructive testing work. Also they can assist in planning a work task, through direct inspection, before a diver is put into the water. Less diver time in the water means lower cost for a job.

Eventually the LCROV could become part of every large (>1000 GRT) vessel s shipboard equipment. Certainly the cost of the LCROV is comparable to other shipboard equipment such as life boats and navigation devices In this way the ship s engineering staff can do documented (TV) self-inspection of the underwater body in both emergency and routine situations.

The inspection, maintenance and repair requirements for port and harbor structures are similar to those in the coastal and inland civil works category. Harbor departments either have their own divers or contract for these services. The use of the LCROV as the inspector and the diver as the worker could help to reduce the overall costs of this work.

E. Law enforcement and emergency services

Law enforcement agencies often search underwater to locate and recover materials relating to criminal activity. Their bomb disposal units sometimes have to operate underwater to carry out their missions. Most major U.S. police agencies, located near major bodies of water, have formed diving units.

Fire department units working in harbors find it extremely important to observe burning structures (e.g. docks, piers boats and vessels) close up during firefighting action. A remote vehicle is the safest and most efficient equipment for this purpose.

National marine police agencies, such as the United States Coast Guard, have coastal and harbor responsibilities in diverse areas such as fisheries protection, smuggling detection, drug interdiction harbor security and maritime safety. Much of this work involves underwater inspection tasks.

In each of these activity areas the LCROV would provide the initial inspection capability prior to placing a man (diver) into the situation to perform work tasks. The LCROV would help the police/emergency team work smarter and with greater safety. With the acquisition cost of the LCROV being in the order of that of a fully equipped emergency vehicle (i.e. ambulance) it is not hard to appreciate the potential size of this market.

F. Fisheries

A major use for LCROVs here would be inspection of fishing gear while it was deployed from the vessel. This is especially important in areas where there is the possibility of snagging gear on bottom obstructions. Because some fishing is in deep water a 1000 foot operating depth would be important. In addition basic ship husbandry inspections could be undertaken with the on board LCROV.

A limiting factor in this user area would be cost of the LCROV. Even at $30,000, the vehicle is probably too expensive for most fishing vessel operators. A customized LCROV should be developed or adapted for this market sector.

In aquaculture applications the LCROV is an ideal platform for quality and quantity assessment of certain kinds of stocks in ponds and pens. For example shellfish beds could be inspected to determine potential yield through LCROV television surveys.

G. Ocean science and engineering research

So far ROVs have been used very little in oceanography work. The preferred platforms have been manned submersibles surface vessels and remote sensing spacecraft. The present high-cost platforms used by oceanographers tend to be government owned and their operations subsidized by government agencies. But governments do not have marine research ROV s This lack of capability is reflected in the civil scientific community The LCROV's low cost would permit marine scientific institutions to own these vehicles independent of government support

H. Marine recreation

Marine recreation is a multi-billion dollar a year industry. In the U.S. recreational boating alone is a major ocean industry. Boat owners buy a wide variety of expensive (and often redundant) equipment for their boats, including satellite navigation systems LORAN C units, high powered radio setups and on board computers.

Having a swimming tv camera on board would permit TV footage to be taken of family and friends diving on reefs and seafloor; the boat owner could self-inspect the condition of his boat s hull, and the owner and his guests could watch the marine life at night from the safety of their chairs on board.

Price in this area is a very severe limiting factor. A $30,000 unit cost for the LCROV is simply too high. IMI s studies showed that a recreational vehicle would have to be priced at below $10,000 to be attractived to this market. With careful design and continued reductions in the costs of key components (such as the color tv camera) it may be possible to realize a LCROV that could be affordable to millions of boat owners. It s interesting to note that there are presently four LCROVs on the market that are in the recreational price range[1].

Another recreational use would be for sport diving activities, through organizations such as dive shops and resort hotels. Many sport divers would pay to have their underwater exploits made into a holiday record through the video camera on a LCROV "diving buddy".

Basically the market for the LCROV has been identified but not yet developed. The market education task will not be easy nor will it be cheap. However the business potential is formidable.

V. SUMMARY: THE FUTURE OPPORTUNITY

Little of the information given in this paper is new or particularly surprising. However little has been written on the full spectrum of future LCROV market opportunities beyond the offshore oil and gas industry. It is important to note that price and user group education are critical to gaining access to the new market opportunities.

The major future opportunity lies not with the offshore gas and oil services industry, although it is important. Opportunity will be found in the new user group areas noted above. Before this market can be fully exploited, considerable effort and investment must be made to educate potential user groups about how the LCROV can help them. There is little evidence that present builders of LCROVs are developing this type of thorough marketing campaign.

The practical low cost remotely operated vehicle is less than three years old but its development to date suggests significant future benefits to those companies who will build, sell and operate them. This new area can provide significant absorption of present excess capacity as well as the development of new capacity in the international ROV business.

The table below summarizes the status of LCROV's that are now, or soon will be, in production. Note there are some 'LCROVs' listed which exceed the $30,000 cost figure. These are shown to give a comparison between <$30,000 units and those costing up to $70,000. Costs shown in the table are based on the manufacturers catalog prices. However it should be remembered that there can be significant price variation depending upon how much equipment is furnished with the LCROV at its basic price. Some manufacturers do not include enough basic system components to permit vehicle operation if it s bought at catalog price.

SUMMARY STATUS OF CURRENT LOW COST ROVS

LCROV	MANUFACTURER	YR INTRODUCED	DEPTH(FT)	PRICE
C CAT	Undersea Australia, Ltd	1986	100	$ 4,500
SUPER C CAT	" "	"	600	$14,500
MINIROVER	Deep Sea Systems Int l (U.S.)	1984	400	$24,850
MINIROVER MKII	" " " " "	1986	500	$34,850
PHANTOM 300	Deep Ocean Engineering (U.S.)	1986	300	$14,500
PHANTOM 500	" " " "	1985	500	$28,400
PHANTOM HD	" " " "	1986	1000	$36,800
PHANTOM S	" " " "	1986	1000	$54,000
PROVE	Seascape Vehicles, Ltd. (U.K.)	1986	1500	$40,000
RTV-100	Mitsui Eng. & Shipbuilding	1985	330	$24,000
RCV-100	Hydro Products/Honeywell (U.S.)	1986	330	$35,995
SEA SCANNER	Sea Scan Technology (Canada)	1986	250	$11,500
SEA WHIP	" " " "	"	500	$18,000
SEA EYE 600	Seaeye Marine (U.K.)	1986	600	$27,000
SPRINT 101	Robertson Tritech A/S (Norway)	1985	1000	$70,000
TOMCAT	Seavision Enterprises (U.S.)	1986	200+	<$ 4,000
VICTOR	KBA, Ltd. (U.K.)	1984	1000	$35,000

UNDERWATER INSPECTION OF OFFSHORE PLATFORMS IN JAPAN

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1. INTRODUCTION

There are many oil/gas production platforms and drilling rigs operating offshore in the United States and Europe as in the Gulf of Mexico or in the North Sea. They have history of nearly 40 years and have become operating in deeper depth to about 310 m. Based on these circumstances, technics for inspection, maintenance and repair (IMR) of those offshore platforms have been accumurated their experiences in abundance and their technical researches and developments as well as on their facilities have also been performed eagerly. On these situations Mr. J. R. Vadus presented a valuable paper "Underwater Inspection for Deep Ocean Platforms" at 11th joint meeting UJNR Marine Facilities Panel in 1985 1/.

Comparing to these circumstances, the offshore platforms which are operating near Japan for both oil/gas production and drilling are relatively a few in number, although Japanese shipbuilders have built a number of offshore platforms with various types as export for operating overseas. They have only about half the history of nearly 20 years and are operating within only about half the depth of nearly 150 m.

The structures which require underwater IMR are considered to be either the one fixed under the water surface or the one that is unable or difficult to drydocking or landing. The structures belong to these categories which have been involved by Japan are oil/gas drilling rig, oil/gas production platform, offshore platform for civil engineering, sea berth, plant barge, observation tower underwater, semi-submersible exhibition platform, etc.. There are also oil storage offshore tank, air port in sea, etc. as the one under construction or plan. Some of these structures have been introduced on the meeting U. S. - Japan Marine Facilities Panel. 2/, 3/ As previously stated, many of these are for export and are now operating abroad while a few comparing to those in the Gulf of Mexico and the North Sea are operating near Japan under the control by companies or organizations of Japan. Among such a few experiences two instances of underwater inspection on a drilling rig and a production platform are taken for explanation in the following.

2. UNDERWATER INSPECTION

(1) Oil/Gas Drilling Unit

There are two types in oil/gas mobile offshore drilling unit: semi-submersible type and self-elevating platform type. They are both the objects prescribed by the Ship Safety Law in Japanese Government. But, as most of them are registered in Nippon Kaiji Kyokai (NK, classification society in Japan) their IMR are made to be in accordance with the "Rules and Regulations for the Construction and Classification of Ships" of NK. According to the Rules mobile offshore units including oil/gas drilling units are required special surveys (SS) at 4-yearly intervals, intermediate surveys (IS) at 2-yearly intervals and annually surveys (AS) at intervals of one year in the same manner in ships. They are generally required to be drydocked or landed in SS and IS, however it is specified especially in mobile offshore units that the docking surveys may be substituted by in-water surveys in case where approved by the Society submitting necessary information on the occasion of plan approval for Classification Surveys.

An example of a survey history of a semi-submersible type oil/gas drilling rig are shown in Table 1. As you find from this table, underwater inspection in lieu of drydocking had been performed at IS in no. 3, 7 and at

Table 1. Survey history of a semi-submersible drilling rig

no*	time	kind of survey	condition
1	Aug. 1977	complete	
2	Aug. 1978	AS	afloat
3	Jun 1979	IS	"
4	July 1980	AS	"
5	Sep. 1981	SS	"
6	Oct. 1982	AS	"
7	Sep. 1983	IS	"
8	Sep. 1984	AS	"
9	Apr. 1985	SS	drydock

* This is not the official survey number

SS in no. 5 respectively depending on the above mentioned regulations. At these underwater inspections the rig was placed in light condition and the submerged outside shell plates were examined by divers. In addition to divers' inspection, the rig's underwater bodies were examined by the surveyor using colour television with remote control system which was operated by the divers. Some parts of connections of braces etc. were inspected by magnetic particle method. After these inspections it is reported "found satisfactory" for instance. In no. 9 at the time Apr. 1985 SS had been performed in drydocking condition. At the inspection miror cracks were found in way of the welding connections between columns and braces. They were chipped out to sound metal with magnetic particle testing, preheated and rewelded. Upon completion of the welding, the repaired parts were examined with magnetic particle testing and ultrasonic testing and found satisfactory.

The surveys of self-elevating type oil/gas drilling platforms registered in NK have also been conducted in the same way as in semi-submersible types.

(2) Oil/Gas Production Platform

There are three oil/gas production platforms in offshore around Japan: off-Aga (water depth 80 m), off-Aga-Kita (90 m) and off-Iwaki (154 m). These production platforms are under the provisions of the Safety Rules of Oil Mine of Japanese Government. The provisions take control of platform and its periodical inspection as the safety matters, which are made to be approved by the master of the Board of Safety Supervision of Japanese Government. Among these three production platforms, I will present the IMR of the off-Aga platform because it is the oldest - about 10 years since the production started - based on the paper 4/.

Practically the IMR of the platform have been made by the owner voluntarily and the reports submitted thereafter to the Authority mentioned before. The inspection consists of three kinds of daily, periodical and special. Daily inspection is a simple visual check around the platform by operators. Special inspection is the one performed after such unusual condition as storm or earthquake to the extent specified by the owner standards. Periodical inspection is the one in detail performed annually in about calm season of the location (April - June) and aims to assure that the platform has no such any defects as to cause severe damage until the next periodical inspection and is in satisfactory conditions. As important parts in periodical inspection are the nodes connecting structural members of the platform, the inspection standard of off-Aga platform plans to finish the inspection about 30 % of all main nodes during 5 years. All these nodes are graded by punching shear unity value U according to API 5/.

$$U = V_p / F_v$$

V_p : punching shear stress

F_v : allowable shear stress

The grade distribution of these nodes is shown in Fig. 1 and the nodes over class B are made to finish the inspection within 5 years.

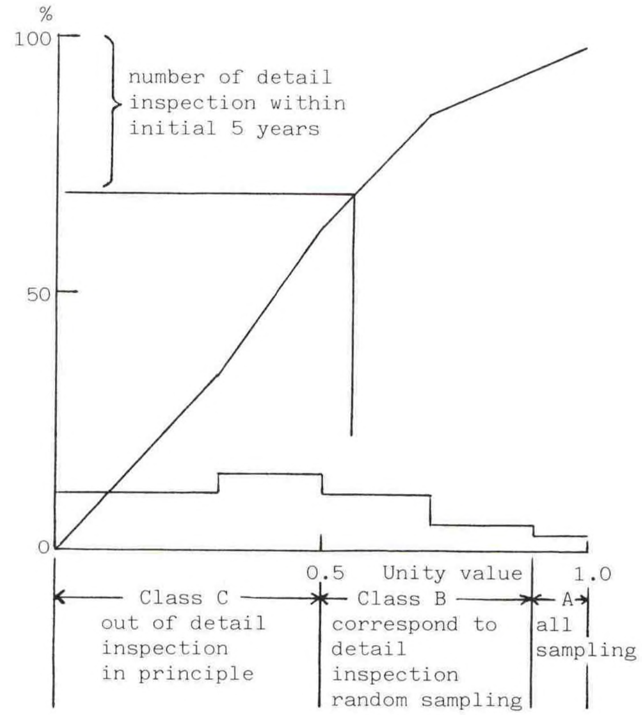

Fig. 1. Example of Grade Distribution of Nodes

The inspection has performed by divers with qualification of NDT. Diving facilities used are open bell, DDC etc. and both scraper and water jet method are used for cleaning. Methods of NDT used are mainly magnetic particle and ultrasonic flaw detection device. All cracks detected by these NDT methods have been repaired by divers using underwater welding in drying atmosphere in the chamber which fabricated in water the parts originally separated. Welding parts are assured to be satisfactory by using NDT as magnetic particle or ultrasonic method.

3. RESEARCH AND DEVELOPMENT

Following the general increasing trend of development in offshore structures technics and facilities necessary for underwater IMR have also been developed in Japan. Some of them were introduced in this Panel 6/, 7/. In addition to these developments collection of the information both inside and outside of the country on IMR about offshore structures have been continuing by various organizations and the reports were published. A paper furnished us an outline of the matters concerned, results of examination of the market in this field and concept design for IMR of offshore structures useful to our country 8/. Another research committee deals with systematic research to aim the establishment of technics on durability and maintenance of large scale offshore structures in a four-year program starting from 1984. The reports covering the first 2 years have been published 9/, 10/.

4. CONCLUSIONS

This paper introduced mainly the present status of underwater inspection in Japan. As being understood from the above mentioned descriptions the market scale on IMR of offshore structures seems to be premature in our country comparing to the U. S. and Europe. The method of IMR in underwater practically depends on the divers in many cases. ROV are now used mostly for visual purposes and will prevail in future according to the increase of water depth and the progress of workability functions in lieu of the divers. These technology and devices on the IMR should be integrated into the overall design process as Mr. J. R. Vadus pointed out in his paper 1/.

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UNDERWATER STRUCTURAL INSPECTION: AN OVERVIEW

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ABSTRACT

Implementation of British and Norwegian government requirements for periodic underwater inspection of offshore production platforms produced two major side effects: 1) a multi-million dollar inspection market was generated and 2) a virtual revolution in the tools and techniques employed in underwater structure inspection ensued.

The goals of the inspection programs which the govenrment and the offshore oil industry itself has imposed is to assure the continued safe and productive capability of production facilities and pipelines. The tools and techniques developed to reach these goals range from direct visual observation to sophisticated acoustic emission monitoring and vibration analysis. The intervention techniques to deploy these devices encompass the diver and every known form of underwater vehicle.

STRUCTURAL INSPECTION REQUIREMENTS

Until the discovery and extraction of oil and gas from the North Sea, inspection requirements for the underwater portion of fixed production platforms and pipelines were essentially those which the offshore operator himself elected to impose. This situation, with some exceptions, still holds true in U.S. waters today. The states of California and Texas and the Federal government's Office of Pipeline Safety (Dept. of Transportation) require periodic overflights of the water surface above a pipeline to observe for any leakage. The Federal government also requires annual testing of each pipeline under cathodic protection to determine whether or not it meets the government's requirements.

Platform operators in U.S. waters developed a set of guidelines for underwater inspection which was published in 1977 by the American Petroleum Institute under the title "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms" (API RP 2A). As the title states, these are recommendations, not requirements, consequently, the operator may elect to follow or ignore these recommendations or establish his own inspection program. The development of new or improved tools for underwater structural inspection proceeded at a relatively leisurely pace since the operator had, by and large, only his own requirements with which to comply. Significantly, there have been no reported failures of fixed offshore production facilities in U.S. waters due to lack of underwater structural integrity.

In the North Sea a different approach to inspection was taken. In the mid-seventies the British and Norwegian governments established underwater inspection requirements and schedules to which the platform operators are obliged to adhere in order to continue operations. Although their requirements vary in details, the general goals of the inspection programs are similar. The initial requirements were aimed at fixed, (i.e., bottom-founded) production platforms, these later grew to encompass underwater pipelines and, more recently, are tending towards requirements for Subsea Production Systems (SPSs). The goals of the programs seek to identify and/or locate the following:

- Broken or bent structural members
- Cracking and/or pitting
- Corrosion
- Marine growth (type, thickness, density)
- Debris accumulation
- Scouring at platform/pipeline base
- Suspended pipeline sections
- Corrosion protection systen effectiveness
- Overloading, rebar corrosion deterioration or sulphate attack in concrete

In addition to the natural forces which act to degrade or endanger a structure's integrity over an extended period, the inspection requirements also call for special inspections to detect for damage that might be caused by more catastrophic events when they are known or are suspected to have occurred. These include damage incurred by ramming of the platform by a support vessel, objects dropped from the surface, anchor dragging, trawling activities, earthquakes and (proposed for the arctic regions) damage due to bottoming icebergs or ice islands. Also, an inspection is required in some jurisdictions if changes in the condition or operation of the structure have been made in any way that affects its safety or a part of its scope of certification.

Further inspection requirements call for more detailed examination at points on the structure that are considered most vulnerable and/or that can be taken as representative of the structure overall. At such points the structure must be cleaned and techniques employed to detect any cracks, pitting or corrosion.

Under the British regulations five professional societies have been recognized to evaluate the inspection data collected and to issue a "Certificate of Fitness" which will permit the platform to continue production. (Under the British requirements a Certificate of Fitness must be obtained once every five years.) These societies are: The American Bureau of Shipping (US); Bureau Veritas (France); Det Norske Veritas (Norway); Germanischer Lloyds (West Germany); Lloyds Register of Shipping (UK) and Halcrow Ewbank and Associates Certification Group (UK). Several of these societies have published guidelines regarding procedure and scope for underwater inspection of fixed structures and pipelines. Det Norske Veritas is the only one to date to also address the subject of SPSs.

UNDERWATER INSPECTION EQUIPMENT

(The following sections of this overview are extracted primarily from three studies conducted by Busby Associates: 1) "Underwater Inspection/Testing/Monitoring of Offshore Structures" 1978; 2) "Arctic Undersea Inspection of Pipelines and Structures" 1983, and 3) "Undersea Inspection of Subsea Production Systems" 1985. These studies were funded by the U.S. Dept of the Interior, Dept. of Commerce and Dept. of Energy. Copies of these reports still in print are available on request.)

Non-Destructive Examination (NDE) or Non-Destructive Testing (NDT) of underwater structures is performed externally by visual means or by using one of many magnetic or ultrasonic devices; NDT is performed internally through the application of "intelligent" pipeline pigs. The following is a brief description of the various NDT devices now available or in development which are used almost exclusively on steel and/or concrete structures.

EXTERNAL NDT EQUIPMENT

Equipment in this category includes visual inspection (either directly or via closed-circuit TV), still photography, magnetic methods, corrosion-potential (c-p) monitoring probes, ultrasonic thickness and flaw detection devices, plastic replication methods, hardness testing, radiography, tomography, and vibration analysis monitoring. This equipment is termed external equipment because it is employed on the exterior of a structural member or pipeline, as opposed to internal equipment, such as pipeline pigs, that are employed in the interior of the member or pipe.

Visual Observations

Visual observations are performed by divers or by the occupants of a manned vehicle. If lighting and water clarity are suitable, the observer is afforded a 3-dimensional view and the capability to comprehend and react to the situation in situ and in real-time. There is no surrogate viewing technique equal to the human. The lack of a permanent record and the need for water clarity are the main limitations.

Television

Underwater TV is the most widely used viewing technique. Worldwide there are at least 28 different manufacturers of underwater TV cameras and camera systems. The cameras are black & white or color, horizontal line resolution can be as high as 600 lines, any ocean depth can be accommodated and they can be deployed by the diver, an ROV or a manned vehicle. Recently TV cameras have been developed that are combined with still cameras to offer both cabilities within a single instrument.

Stereoscopic TV has been available for at least five years, but has yet to see widespread acceptance by the comminity. Although the capability to view in 3-dimensions seems desireable, no one has seen the need for it in underwater inspection.

Photographic (Still) Cameras

Still cameras are used for high resolution, graphic documentation and for mensuration purposes by employing stereophotography. There are also numerous manufacturers of underwater still cameras and the models available meet virtually any inspection requirement. Recent developments in this area include stero cameras that employ only one lens, instead of the more comventional two-camera arrangement. Measurement accuracies of 0.1mm in a one square meter field of view are reported.

Magnetic Techniques

a) Magnetic Particle Inspection (mpi)

To perfom conventional mpi the object tested is first intensely magnetized. Finely divided magnetic particles are then applied to its surface. When properly oriented to the induced magnetic field, any discontinuity creates a leakage field which attracts and holds the particles to form a visible indication of the discontinuity. The object being tested must be thoroughly cleaned before the testing can be performed. All mpi systems now in use are used by divers. This is a widely used NDT method on North Sea structures.

b) Magneto Marine Method

This method is based on the magnetic stray flux principle. Magnetized, homogeneous, ferromagnetic materials guide the magnetic field lines. If there is any inhomogeneity, such as a crack, magnetic field lines are forced to leave the material and form a stray field above the crack. This field deformation is used to detect the surface cracks. In practice, the Magneto Marine Method employs a flexible magnetic recording tape that is stretched slightly over the weld area to be inspected. It is secured at both ends by small magnets. A magnetizing yoke is placed on the tape and presses it into the grooves of the weld. Magnetization is provided by very short, strong pulses from the yoke, which is forwarded step-by-step. Field deformations originating from cracks are recorded on the tape which is subsequently examined on the surface.

c) Fe Depth Meter

The Fe Depth Meter is used to locate and measure the depth of steel reinforcement - or any magnetic material - in concrete structures. The instrument is designed for diver application but can also be used by an undersea vehicle. The device operates by generating a magnetic field between two poles at either end of a probe shaped akin to a telephone receiver. The meter measures any disturbance caused by magnetic material passing within the magnetic field generated by the probe. The magnitude of the disturbance is indicated on the instrument meter which may be calibrated to read directly in bar size and distance of the reinforcing bar from the probe.

Cathodic Potential (c-p) Monitoring

This measurement is taken to determine the effectiveness of a structure's or pipeline's cathodic protection system. The level of protection being provided by the c-p system is determined by the value of the metal/electrolyte potential. Since it is not possible to measure this value directly, a potential measurement is made between the metal and a standard reference electrode immersed in the electrolyte.

Two techniques are currently in use for c-p monitoring. One involves remotely monitoring a permanent reference electrode from which the data is transmitted by hardwire to the surface or through the water via an acoustic link. The other technique involves carrying a suitable reference electrode to the anode and making direct physical contact with the anode to obtain the potential value. For convenience, these techniques are categorized as remote and direct monitoring, respectively.

a) Remote Monitoring

Two techniques are employed in remote c-p monitoring. One, which has been used for many years, involves attaching reference electrodes to a structure and connecting them by cable to the surface where they are monitored. The cables may be placed inside conduits or inside the structure members for protection. This technique is quite straightforward and will not be discussed further.

A second, more recent technique involves monitoring the reference electrode acoustically thru-water. One such system was developed by the British firm Wilson Walton International and is called the Remote Potential Monitoring System (RPMS). The system uses two reference electrodes, one is zinc and the other silver/silver chloride. The use of two electrodes provides the operator the capability to check the validity of the data. The RPMS employs a number of self-contained subsea monitors (SSMs) and a surface display unit (SDU). Each SSM contains both types of electrodes which are connected to an electric circuit comprised of two comparators, an encoder, an acoustic transmitter and a battery pack. The comparators are also connected to a the watertight SSM housing. When installed the housing becomes electrically common with the steel structure it is monitoring. The SDU consists of the display unit and an acoustic transducer which interrogates the SSM and receives its data. Each SSM may have an individual code to distinguish it from its neighbors. The underwater units can be monitored from distances as great as one mile.

b) Direct Monitoring

Two techniques have been developed to conduct c-p monitoring of anodes on structures and pipelines. One entails making contact with a point probe to the metal under test. The other involves measuring the vertical components of the local cathode protection current density vector over a pipeline without making physical contact with the pipe. The first technique can be performed by a diver or an undersea vehicle, the second by vehicle only.

There are several commercial available c-p probes for underwater use. These devices employ a silver/silver chloride half cell and a voltmeter. The positive side of the voltmeter is connected to the half cell, the negative side is connected to a probe which is directly applied to the metal under test. A direct reading is displayed on the meter which is lighted for use in murky or otherwise subdued lighting conditions. Most of the current c-p probes can be deployed by a diver or a vehicle, some, however, can be used only by one or the other.

The French company Intersub Services developed a c-p monitoring system that could be used to measure potentials on buried and unburied pipelines, and does not require making physical contact with the pipe. The system is deployed from a ROV or a manned submersible, its two major components are a current density sensor and a pipe tracking sensor. The current density sensor is sensitive to current lines which are parallel to the core axis. The two major measurements of interest along a pipeline are the vertical and the horizontal components of the local current density vector. Theoretically, the vertical current density component should display a positive peak over an anode and be slightly negative over the pipe. Where the insulation of the pipe has broken a negative current should be induced to protect the pipe at around -50 mA/sq m.

In operation the cathodic protection current is changed into a pulsed DC current. The pulsed DC current induces an AC magnetic field in the core, which, in turn, produces an AC voltage in the detection coil which is directly proportional to the DC cathodic protection current. The current density system is integrated with a pipetracker. The pipetracker provides the distance from the pipe which then allows continuous density curves to be processed, corrected for distance to the center of the pipe and integrated into current output.

<u>Ultrasonic Measurements</u>

Ultrasonics are employed for two purposes in underwater NDT: 1) for for determing thickness of a member and 2) for flaw detection in steel, concrete or wood. Ultrasonic techniques require that the surface being tested be thoroughly cleaned before testing can proceed.

In the ultrasonic method an electric pulse is generated in the test instrument and transmitted to a transducer which converts the electric pulse into mechanical vibrations. The vibrations are transmitted into the object being tested where they are scattered, attenuated, reflected or resonated. A portion of this energy returns to the transducer where it is reconverted into electrical energy and transmitted to the test instrument where it is amplified and displayed on a cathode ray tube (CRT). All materials have a characteristic sound velocity which must be known for interpretation purposes. Calibration blocks of the subject material containing variously sized holes may be employed in situ to calibrate the test device. The sound frequency emitted by the transducer for metals testing is high, generally in the range of 3.5 to 5mHz. For concrete and wood testing it is lower and ranges from 20 to 250kHz.

Two different techniques are used in ultrasonic NDT: resonance techniques and pulse techniques. Resonance techniques are employed for measurements of object thickness by measuring from one side only. Pulse techniques are used for flaw detection and may be classified as pulse echo, wherein a single (transmit/receive) transducer is used, or through transmission where two transducers (one transmit, one receive) are employed. Also, two test methods are used: immersion amd contact. In immersion testing the transducer is separated from the object. In contact testing the transducer is placed directly against the object under test. Contact testing is used in underwater inspection.

There are a wide variety of underwater ultrasonic thickness and flaw detection devices. Some provide the data readout directly to the diver, while others transmit the data to the surface via hardwire. Some devices provide a combination of both techniques. There are several developmental projects underway to provide more accurate and rapid ultrasonic measurements, and others to permit cracks to be detected with out first cleaning the structure.

<u>Impression System</u>

This technique was developed by BP Chemicals and is called Aquaprint. It consist of applying a polymer (consisting of an activator and a base) over a weld and allowing it to cure for a period of about ten minutes. The cured product is a resilent rubber matrix which gives a permanent 3-dimentional replica of the weld surface. (The polymer can be used on any steel, concrete, wood or plastic surface.) The product is peeled off and taken to the surface where it can be examined in detail. Surface defects down to 5 microns are recorded by Aquaprint. It can be applied by a diver or, with some modification, by a vehicle.

Tomography

This technique can be used on steel, wood, concrete and various synthetic materials. Internal features as small as 1mm can be detected and densities measured to better than +/-1% accuracy.

A "tomogram" is a cross-sectional slice of an object obtained by the analysis of the transmission properties of radiation. The reconstruction of the properties of the matter investigated is accomplished in a computer by calculating the interaction of the radiation with the material per unit volume as observed from various angles of view. The tomographic inspection system consists of a dector array and a photon emitter (which perform the active scanning) and a computer with related peripherals connected by hardwire to a remote location. The system is unique in underwater inspection, in that, it does not require cleaning of the structure before inspection begins.

Vibration Analysis Monitoring

There are a variety of techniques available that are designed to monitor a fixed structure's integrity by measuring natural or induced vibrations. These techniques can be categorized as: global mode monitoring; local mod monitoring and flexibility monitoring. Development of these techniques began in the early 1970s and is still underway. Several commercial firms offer vibrational analysis services, however, the acceptance of these techniques as a substitute for - even to augment conventional underwater NDT has been slow.

Acoustic Emission Monitoring

Acoustic emission analysis technology utilizes the minute acoustic emissions produced by discontinuity regions in materials under stress to analyze a structure for physical integrity. The acoustic emissions are given off from discontinuities under stress conditions; hence, stress must be applied to the structure. The cyclic stress imposed by wave loading on an offshore structure provides adequate stress for acoustic emission analysis.

Acoustic emission analysis underwater is an emerging technique, although it has been used in land-based applications for many years. The underwater sensing equipment generally consists of sensitive piezoelectric transducers attached to the structure underwater. Cables transfer the received signals to the surface where they are amplified, conditioned electronically and processed by computers to identify the location and significance of the discontinuities. Much like vibrational analysis monitoring, acoustic emission monitoring has not seen extensive offshore application at present.

INTERNAL NDT EQUIPMENT

Equipment designed to conduct internal NDT of pipelines and risers is generally referred to as pipeline pigging equipment. The major utilization of pipeline pigs is for tasks such as gaging and cleaning. In recent years a type of pig known as an "intelligent pig" has been developed which perform such functions as wall thickness measurements, x-rays of weldments, photography of the pipeline and the weldments and mechanical deformation of the pipe. Intelligent pigs are designed for use in both gas and oil pipelines, the propulsive force for the vehicle is generally supplied by the product flow while the line is in service.

Space does not permit a description of each available type of pipeline pig, consequently, the following list will serve as a general overview of their capabilities.

Company	Pig Function
BIX International	X-ray of welds
British Gas Corp.	Locate defects and corrosion
Det Norske Veritas	Riser wall thickness
General Descaling Co.	Gaging, cleaning and internal/external corrosion mensuring
GEO Pipeline Services	Photography
Knapp Inc.	Cleaning
Magnesonics Inc.	Corrosion and wall thickness measuring
F.H. Maloney Co.	Gaging and cleaning
MatEval NDT Co.	Riser wall thickness and corrosion
Mustang Services	Gaging and cleaning
MYOCO	Gaging and cleaning
Oilfield Inspection Services Ltd.	X-ray welds
Peabody Testing	X-ray and photography
Plessey Co., Ltd.	Leak detection, flow rate measurements
Select Industries	Cleaning
Shell Oil Co.	Pipe stability and wall thickness
Tuboscope Inc.	Corrosion & defects
VETCO Services	Corrosion, mechanical damage, gouges, dents and bends
T.D. Williamson	Gaging and cleaning

EQUIPMENT DEPLOYMENT TECHNIQUES

There are three major capabilities employed for underwater structural inspection: the diver; the manned submersible and the ROV. Since the deepest producing structure is at a depth of about 309m (the Cognac platform in the Gulf of Mexico), these capabilities can accommodate any depth requirement at present. However, if future plans materialize, the depth of structures to come will be beyond the diver's capabilities and a greater reliance on manned vehicles and ROVs will follow.

In the mid-seventies, when inspection became a legal requirement, virtually all of the devices available for underwater NDT were designed for application by the diver, that is, the human hand. Later, with the wider acceptance of ROVs, many of the devices were designed for application by mechanical manipulators as well. Today, except for mpi which requires dexterity beyond the capabilities of present manipulators, all of the underwater devices described above can be used by ROVs and manned vehicles.

While almost any ROV can be used to perform inspection to one degree or another, there are several which have been exclusively designed for this purpose. For example, Exxon has developed the MMS (Manipulator Maintenance System) for the express purpose of conducting inspection and maintenance on their Subsea Production Systems; the ROV DAVID was developed to assist the diver in inspection and maintenance; and the ROV MAGNUM was designed exclusively for structural cleaning preparatory to inspection. These are but a few examples of vehicles designed exclusively for underwater inspection. On the divers side, schools have been established to teach the techniques of NDT and qualify individuals in its performance.

There is a recent trend in structure design that will improve the inspection performance of vehicles substantially. This trend is in designing the structure and its components to be inspected by ROVs and/or manned vehicles. The proposed SPS for the Montanazo Field at 762m depth was in large part designed from the point of view of being inspected and maintained by a pre-selected ROV. The same procedure was followed on one of the Petrobras structures offshore Brazil, except that the inspecting/maintaining vehicle was to be the Atmospheric Diving Suit JIM.

Once again, space does not allow a detailed account of the strengths and weaknesses of the various intervention techniques used in underwater NDT, for such critiques the aforementioned publications are recommended. Likewise, space does not permit a description of the many and varied vehicles that might be employed in underwater inspection. For this information the "Undersea Vehicles Directory - 1985" published by Busby Associates is recommended.

NDT PERFORMANCE AND LIMITATIONS

Reported overall performance of present inspection techniques ranges from adequate to inadequate. A major complaint has been that virtually all of the devices employed are adaptions of shore techniques to the underwater envirinment, a practice with inherent shortcomings. Other inadequacies include: cumbersome equipment; too much reliance on divers untrained in underwater NDT; inadequate fault detection capabilities; little repeatability in measurements; inordinate time required to prepare the surface for examination, and a wide variety of other minor and major capability problems.

Adding to the uncertainties of the NDT device and its data are the problems encountered by the techniques used to deploy them. The diver is strong in the areas of viewing, manipulative dexterity, maneuverability and responsiveness. His weaknesses are in lack of NDT training (although this is improving), limited payload, and an unknown degree of judgement degradation brought about by the psychological aspects of working in a cold, oftimes dark and lonely environment. The ROV on the other hand presents no danger to the inspector or operator, it generally has unlimited operating duration, depth capability and its results are presented in real-time which can be viewed by an almost unlimited number of qualified inspectors. Conversely, the ROV presents only a two-dimensionsal view, its manipulative capabilities fall far short of the diver and to several NDT tasks, it is subject to cable rupture and fouling and can be quite unreliable in its performance. The manned vehicle offers advantages and disadvantages common to both the diver and the ROV. Since no individual intervention technique is adequate in all circumstances, most of the major underwater service companies offer all three capabilities.

Pipeline pigs are similarly attended with advantages and disadvantages, the latter includes limitations in pitting depth measurements, weld interference with defect measurements, inability to measure certain longitudinal defects and the laborious chore of manually interpreting many of the resultant records. Paramount is the possibility of the pig becoming stuck in the pipe, in which case an exceedingly time consuming and costly effort is generally required for its removal.

In spite of the many and varied shortcomings in present underwater inspection techniques and devices, they do provide a capability for overall and sometimes highly detailed examination of structures. Improvements have been rapid over the past decade, especially in the North Sea bordering countries where structure inspection is a multi-million dollar market.

COLLAPSE STRENGTH OF A SPHERICAL PRESSURE HULL FOR THE 6000m-CLASS DEEP RESEARCH SUBMERSIBLE MADE OF TITANIUM ALLOY

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ABSTRACT

Titanium alloy is one of the best candidates for materials of the pressure hull of a deep research submersible, and it was applied to the pressure containers, a variable ballast tank and vessels for inverter system, installed in the Shinkai 2000 (a 2000m-class deep research submersible). The 6000m-class one is planned to have the pressure hull of titanium alloy (Ti-6Al-4V ELI) housing 3 crew members on the basis of the previous experience, but further investigations of manufacturing process and collapsing strength are required.
For this purpose, a full sized model pressure hull was fabricated successfully from thick hemispherical shells of titanium alloy using the electron beam welding, and the collapsing strength of spherical shells was investigated experimentally and theoretically. The latter will be discussed in the present paper. For the decision of material of the vehicle, there are several points to be investigated: In the case of titanium alloy, (1) the thickness/diameter ratio is large, (2) energy absorption by charpy impact test is relatively low, which influences collapsing behaviour, and (3) it shows room temperature creep in a range of higher stress level, which may be influenced by a loading duration and cyclic loading. To settle these points, experiments with four models of Titanium alloy were carried out for investigations of collapsing strength, and they revealed that the titanium alloy met the condition for materials of pressure hull of a deep research submersible.

Experimental Models

The experimental models are shown in Table 1. The models MT-1, MT-2 and MT-3 are 500 mm in diameter and 16 mm in thickness. The MT-1, a perfect sphere, was tested to confirm the basic collapse behaviour (the collapse pressure and the mode of collapse) and the MT-2 with a view-port coaming was pressurized to collapse after 160 hours' continuous pressurizing in order to confirm the effect of long-term continuous pressure loading. The MT-3 with a conical seat hatch was tested to confirm the effect of sliding behaviour which might occur on a boundary between the hatch plate and the spherical part. The MT-4, 700 mm in diameter and 26 mm in thickness, was pressurized to collapse after 1500 cyclic loadings from 0 to 680 kgf/cm^2 in order to confirm the effect of the cyclic loading on the collapse behaviour, local stress distribution and water-proof characteristics. To investigate these effects, the MT-4 was fitted with a conical seat hatch and viewport coaming. The number of cyclic loading (1500) was determined on the basis of the maximum operation times which was estimated to be 1000.

The fabrication process for the models followed the process of the actual pressure hull of the 6000 m-class deep research submersible. Titanium alloy material is produced by the same production method using the same facility which has the capacity for 9 ton ingot melting and a rolling mill. The basic process are as follows: rolling of a very thick titanium alloy plate, hot forming, solution treatment and overaging, penetrator welding (EBW), post-weld heat treatment, three dimensional precise machining, equator welding (EBW), post-weld heat treatment, final machining, adjusting and surface rubbing of the hatch and viewport.

The chemical composition is shown in Table 2, the material characteristics of the mother plate in Table 3 and of the welded joint in Table 4. The results of shape measurement are shown in Table 5.

COLLAPSE TEST RESULTS

The collapse tests of the MT-1, MT-2 and MT-3 were carried out at the Takasago Institute of M.H.I. and for the MT-4, at the High-pressure test tank facility of the Japan Marine Science and Technology Center. From the conditions of models after collapse, there was observed a fully deformed part with enough plastic deflection over a large area and some cracks around it. An example of the models after collapse is shown in Fig.1 compared with the models made of high-tensile strengh steel 10Ni-8Co steel and 18% nickel maraging steel. The after-collapse configuration of the model made of titanium alloy (Ti-6Al-4VELI) is similar to

Table 1 Spherical models of Ti-6Aℓ-4V ELI for callapse test

Model		MT-1	MT-2	MT-3	MT-4
Outline		Simple sphere	(1) Sphere with viewport (2) Model for collapse test after 160 hours' continuous pressurizing	Sphere with conical seat hatch	(1) Sphere with conical seat hatch and viewport (2) Model for collapse test after 1500 cyclic loading from 0 to 680kgf/cm²
Configuration	Diameter (mm)	500 (outside)	500 (outside)	500 (outside)	700 (inside)
	Nominal thickness (mm)	16	16	16	26
Model Figure (Unit in mm)					

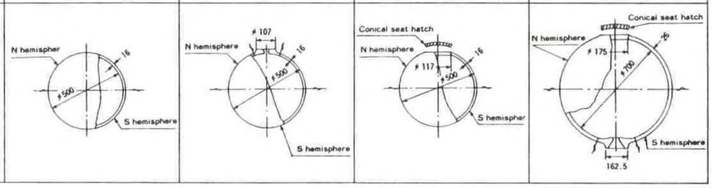


Table 2 Chemical composition

(unit in Wt%)

Model \ Specification \ Element	N	O	H	Fe	C	Aℓ	V	Ti
Specification	0.05 max.	0.13 max.	0.0125 max.	0.25 max.	0.08 max.	5.50 ~ 6.50	3.50 ~ 4.50	Re.
MT-1,2 & 3	0.0026	0.107	0.0025	0.191	0.014	6.31	4.03	Re.
MT−4	0.0036	0.100	0.0022	0.212	0.014	6.30	4.14	Re.

Table 3 Tensile properties

Model	Tensile direction	Sampled position	Tensile strength (kgf/mm²)	0.2% proof stress (kgf/mm²)	Elongation (%)	Reduction of area (%)
(Specification)	—	—	≧ 88	≧ 81	≧ 10	—
MT-1,2 & 3	L	Center of plate thickness	94.1 93.8	87.2 87.2	14 13	32 34
	T		95.8 94.5	88.9 87.5	14 13	32 38
MT-4	L	Center of plate thickness	94.8 95.0	88.0 88.4	18 18	33 33
	T		95.4 96.6	88.4 89.8	17 15	33 38

L : Rolling direction of plate

T : Perpendicular to rolling direction of plate

Table 4 Tensile properties of equator joints

Model	Sampled position	Tensile strength (kgf/mm²)	0.2%proof stress (kgf/mm²)	Elongation (%)	Reduction of area (%)
(Specification)	—	≧ 88	≧ 81	≧ 5	—
MT-1,2 & 3	Center of plate thickness	100.1 99.8	86.5 85.7	11 13	30 28
MT 4		100.2 100.5	89.0 90.4	10 10	19 15

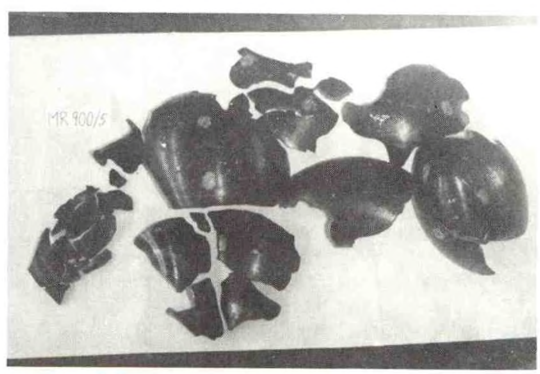
Specimens were obtained from a Ti-6Aℓ-4VELI plate welded under the same welding condition as the actual equator joint.

Table 5 Results of shape measurement

Model		MT-1	MT-2	MT-3	MT-4
Sphericity		1.004	1.004	1.003	1.004
Thickness	N-hemisphere	15.88~16.14	16.01~16.19	16.05~16.25	25.79~26.13
	S-hemisphere	16.00~16.12	16.07~16.19	16.11~16.26	25.80~26.11

(Ti-6Al-4V ELI MT2)

(10Ni-8Co Steel)



(18% Ni Maraging Steel)

Fig. 1 Models after callapse

that of high tensile strength steel, 10Ni-8Co steel, which collapsed with enough plastic deformation showing a different tendency from the models of 18% nickel maraging steel which collapsed into pieces. From these experimental results, the models made of titanium alloy can be said to have collapsed with enough plastic deformation which reveals sufficient toughness level almost similar to 10Ni-8Co steel.
In addition, at the test of the MT-2, there was observed no difference in strain and sphericity between before and after the continuous pressure loading of 160 hours. And the MT-3 collapsed at a spherical part not at a conical seat hatch opening showing no influence of the opening on the collapse behaviour.

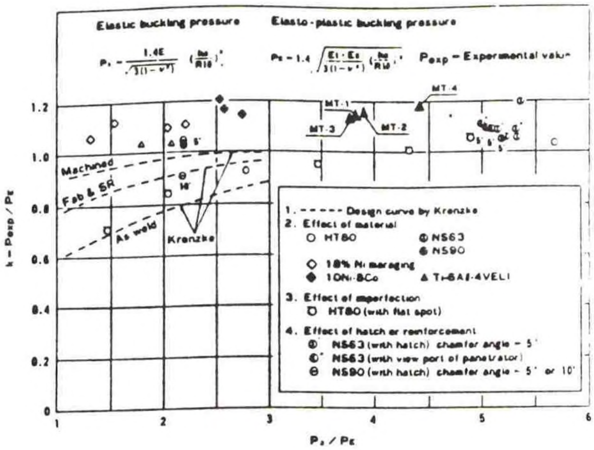


Fig.2 Collapse test results

THEORETICAL CONSIDERATIONS

The collapse pressure was calculated by Krenzke's method using the tensile properties and compressive properties obtained from the specimens of the same material used for the model. A comparison of the previous collapse test results and those of titanium alloy models is shown in Fig. 2 on the basis of tensile strength. The collapse pressure of titanium alloy models satisfies the analytical result and reveals a relationship similar to the results obtained on the models made of high-strength steel. As a conclusion, Krenzke's method can be applied to the estimation of the collapse strength of titanium spherical shells.

The collapse pressure can be obtained from large deflection elasto-plastic analysis with the aid of the finite element method. A comparison of analytical and experimental results is shown in Table 6. The result obtained by large deflection elasto-plastic analysis shows closer agreement than that by Krenzke's method. An example of mesh division is shown in Fig. 3.

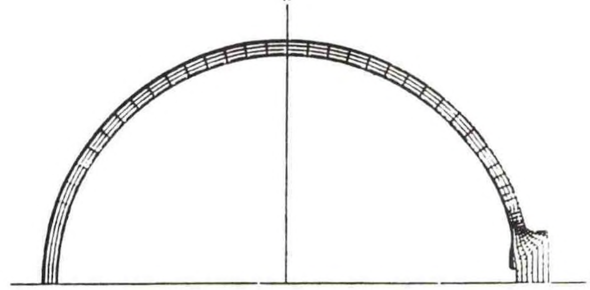


Fig.3 Mesh division

Table 6 Theoretical and experimental results of collapse strength

(Unit in kgf/cm²)

Model		MT-1	MT-2	MT-3	MT-4
Experiment		1230	1260	1274	1397
Krenzke	T	1085	1112	1129	1160
	C	1177	1207	1210	1280
FEM	T	1150	1180	1170	1200
	C	1220	1250	1270	1350

T & C : indicate the mechanical properties used for analysis obtained from tension and compression test respectively

To investigate the effect of room temperature creep under constant pressure on the collapse strength, a creep analysis by the finite element method was carried out for the MT-2. The condition considered for the calculation was 625 kgf/cm^2 x 5000 hours and for the relationship between creep strain and loading time, Norton-Bailey's law (Eq.(1))was applied.

$$\varepsilon_c = \left(\frac{\sigma}{k}\right)^n \times t^m \qquad (1)$$

ε_c : creep strain
σ : working stress
t : loading time
m, n, k : material coefficient

The relationship based on the creep test using the specimens obtained from the material of models is shown in Fig. 4.

The relationship ① in Fig. 4 is determined on the basis of an experimental result using tensile test specimens which tested under the 70% of 0.2% proof stress, and the relationship ② is also determined under the test condition of 90% of 0.2% proof stress. These stress levels of experiment are determined on the basis of the maximum stress level working on the actual pressure hull as shown in Table 7.

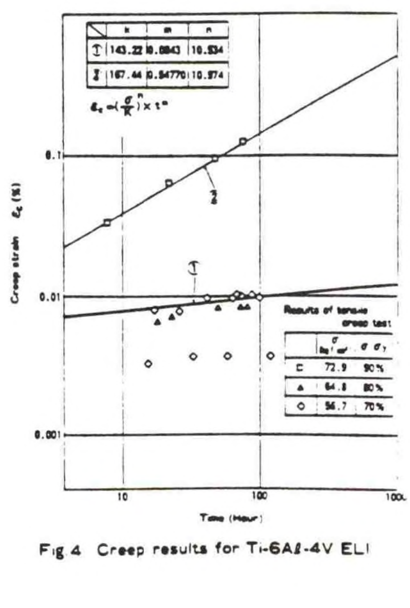


Fig.4 Creep results for Ti-6Al-4V ELI

Table 7 Stress level of pressure hull

		Pressure equivalent to 6000m depth (625kgf/cm²)	1.05times pressure equivalent to 6000m depth (655kgf/cm²)*	
Pressure hull (Inside Diameter 2m Thickness 68mm)	Membrane stress	50.7kgf/mm² (0.626σy)	—	$\sigma = \frac{PR_o^2}{2R_m h}$ P: External pressure R_o: Outside radius h: Thickness R_m: Mean radius σ: Membrane stress
	Maximum of membrane plus bending stress	60.8kgf/mm² (0.751σy)	—	1.2 times mean membrane stress based on the result of stress analysis by F.E.M
MT-2	Membrane Stress	50.5kgf/mm² (0.623σy)	52.9kgf/mm² (0.653σy)	
	Membrane plus bending stress	60.6kgf/mm² (0.748σy)	63.5kgf/mm² (0.784σy)	Based on stress of analysis by F.E.M

σy : 0.2% proof stress (=81kgf/mm² in specification)

* : Pressure applied for continuous loading of the MT-2

As the analytical collapse pressure reveals no difference between before and after 5000 hours loading (Collapse pressure is 1250 Kgf/cm^2 on the basis of compression test result using specimens obtained from the same material as the model.) and the experimental result of the MT-2 and the analytical pressure show good agreement, it is concluded that the long-term pressure loading does not influence the collapse strength. The relationship between pressure and displacement is shown in Fig. 5. The collapsing deformation starts from any position except the viewport coaming where the maximum bending stress occurs.

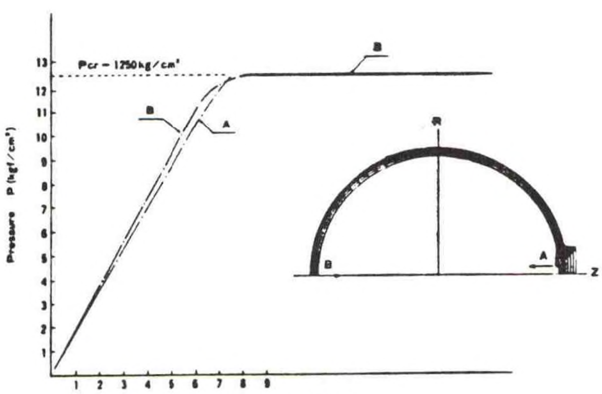


Fig.5 Pressure-displacement Relationship

EFFECT OF CYCLIC LOADING ON COLLAPSE BEHAVIOUR

The collapse test of the MT-4 was carried out after 1500 times of cyclic pressure loading from 0 to 680 kgf/cm^2. The relationship between strain and pressure loading cycle is shown in Fig. 6-1 and 6-2. Except the strain around the hatch, the range of variation of the strain between before and after cyclic loading was only 2% and no substantial strain variation was observed . The strain around the hatch,

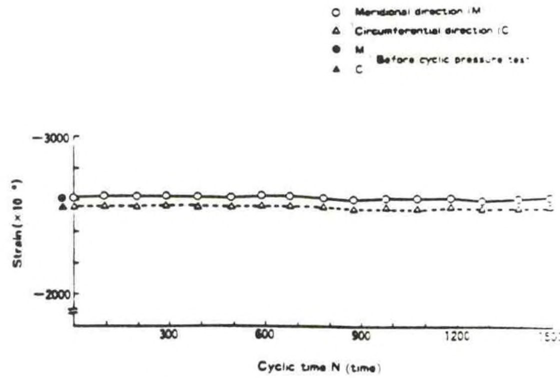


Fig.6.1 Strain during cyclic loading (example at any point except hatch)

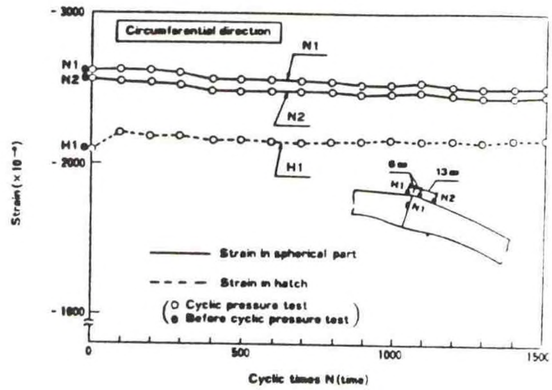


Fig.6.2 Strain around hatch boundary

however, showed some variation, which was estimated to have occurred by slight change of the hatch plate position.

Before and after the cyclic pressure test, the sphericity measurement and the surface dye penetration test were carried out showing no change in configuration and no crack. After the cyclic pressure test, there was observed no leakage.

ANALYSIS OF COLLAPSE DEFORMATION AND FRACTURE MODE

Using the MT-4, analysis of collapse deformation, crack initiation and fracture mode were carried out. Figure 7 shows the crack initiation and propagation diagram. The fracture surface shows a dimple pattern along the cracks which results from plastic deformation as shown in Fig. 8. The example of crack initiation shown in Fig. 9 reveals that the crack started with enough plastic deformation. Some separation was observed among the collapse pieces as shown in Fig. 10. By fracto-analysis of the separated surface, a white-zone caused by shearing force due to the impact following the collapse was observed, as shown in Fig. 11. It is concluded that the collapse is accompanied with enough plastic deformation and that the impulsive post-collapse deformation caused separation away from the deformed part.

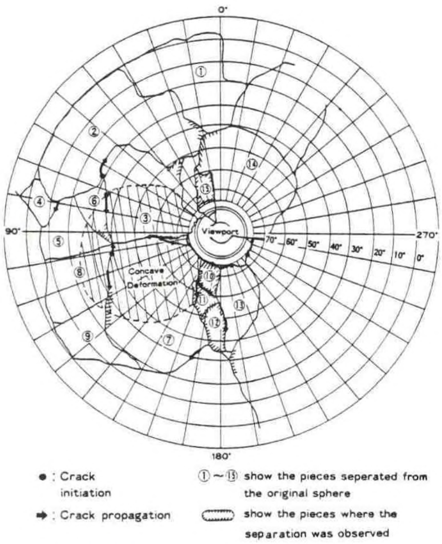


Fig.7 Collapse diagram of MT-4 (N-hemisphere)

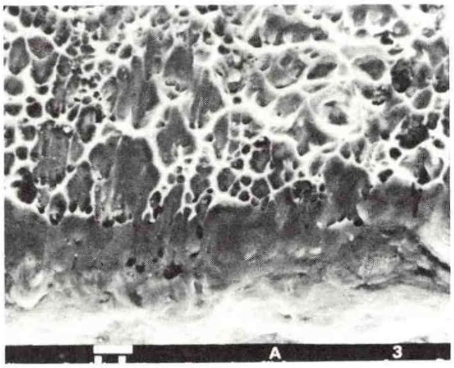


Fig. 8 Fracture surface of crack imitation (X400)

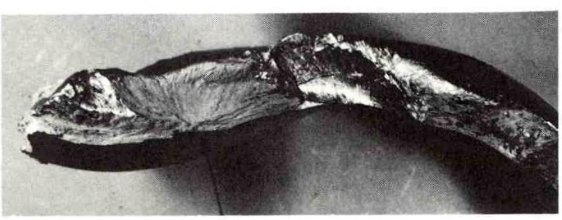


Fig. 9 Crack initiation

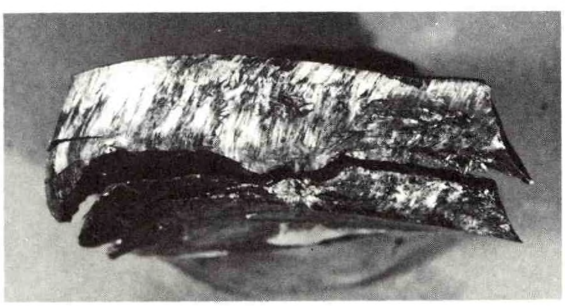


Fig. 10 Separation

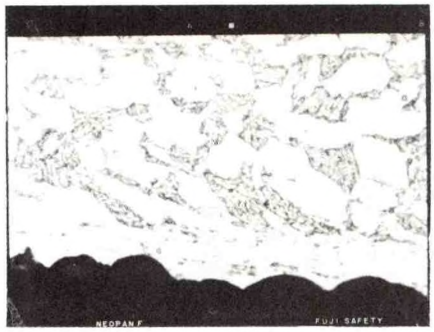


Fig. 11 Shear band observed along the separation

CONCLUSIONS

The conclusions of this study are as follows.

(1) For the collapse strength analysis of a pressure sphere made of titanium alloy (Ti-6Al-4VELI), Krenzke's method can also be applied as in the case of steel, and the analytical result obtained from large deformation elasto-plastic analysis with the aid of the finite element method shows better agreement with the experimental result.

(2) No effect of pressure loading duration on the collapse strength was observed for the model MT-2 in theoretical analysis and in experiment. By a proper design procedure to reduce the stress level due to discontinuities, the effect of room temperature creep on the collapse strength can be ignored.

(3) No effect of cyclic pressure loading on the collapse strength was observed for the model MT-4. No variation was observed between before and after cyclic loading, in strain distribution, configuration, surface integrity, and waterproof characteristics. The effect of cyclic pressure loading can be also ignored as long as the proper design procedure for the MT-4 is followed.

ACKNOWLEDGEMENT

The authors wish to express their appreciation to Dr. Yoshiyuki Yamamoto, Professor Emeritus of the University of Tokyo, for his valuable suggestion for this study.

JAPANESE 6,500M MANNED DEEP RESEARCH SUBMERSIBLE PROJECT

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ABSTRACT

JAMSTEC (Japan Marine Science and Technology Center) is now planning to develop a 6,500m deep manned research submersible. The Japanese Government approved a budget for the construction of the submersible, and JAMSTEC is now working on preliminary design so as to complete the construction on FY1989.

Rough characteristics of the vehicle have been decided following to the operational experiences on "SHINKAI 2000", and also by accepting various requirements from various researchers and by applying many of the advanced technologies.

In this paper, several features of this submersible system are presented.

INTRODUCTION

It is an urgent program for Japan, the island country with scarce on-land natural resources and with many earthquakes, to develop and utilize the ocean which contains large amount of living and mineral resources and energy, and has vast space.

In the late 1960th, the Japanese Government had decided to develop a 6,000m deep manned research submersible. However, at that time, Japan had no experiences on the development or the operation of such deep submersible, therfore, it was decided to develop a medium depth submersible to get experiences on the development and operation. There, the 2,000m deep manned research submersible "SHIKAI 2000" was born by JAMSTEC on 1981. JAMSTEC started its research program since then getting various important data.

Through the development and operation, JAMSTEC obtained a confidence to develop and operate a new 6,000m-class deep manned research submersible.

Meanwhile, needs for deep sea research in the world are going to deeper ocean for the purpose of hydrothermal deposits research and research of slope of trench for the earthquake prediction. So it is urgently required for Japan, the maritime nation, to develop 6,000m-class deep research submersible system so as for Japan to have a capability to carry out research up to 98% of the world ocean or 94% of the EEZ ocean around Japan.

Now the Japanese Government approved a budget for the development of the 6,000m-class research submersible, JAMSTEC is now working on preliminary design of the submersible so as to complete the construction on FY1989.

PRINCIPAL REQUIREMENT ON THE SUBMERSIBLE

Generally speaking, submersible should be small and light so as to make launch and recovery work easy. Also the mobility should be good so as to make the research mission effective.

Major mission of a submersible shall be a research of deep ocean floor, therefore, the traveling time from the surface to the bottom and from the bottom to the surface shold be as short as possible.

For the maximum depth capability of our submersible, JAMSTEC considered it at the first stage to be 6,000m because such depth capability could cover the 98% of the world ocean. However, Japan and the surrounding ocean have aspecial condition for the determination of the depth capability. Japan islands are surrounded by the several deep trenches and these trenches are considered to be places where large scale earthquakes occur frequently. Geophysicists consider it to be the most important to survey not only the bottom (ab. 10,000m deep) or the top of the trenches (ab. 6,000m deep) but the bending part of the ocean floor plates just below the top of the trenches. Accordingly, the maximum depth capability was decided to be 6,500m.

Divig to 6,000m deep takes a lot of time (nearly 5 hours for one way) if the vertical speed is same as SHINKAI 2000. So the effort should be paid for reducing the travelling time. JAMSTEC studied how to make the travelling time shorter, and as the result, it was decided to make the body of the submersible slim for the vertical movement after hydrodinamical calculations and wind-tunnel experiments. By this body, it is expected that the travelling time to 6,500m deep for one way is about 2.5 hours.

The normal diving duration was decided, followingly, as 9 hours (=3 hours for research +5 hours for descent and ascent +1 hour for launch and recovery), and the maximum life support duration was decided as 129 hours for three crew members by adding 5 days to the normal diving duration.

SUBSYSTEMS

1. Shape of the Submersible

To descend or ascend as rapid as possible is very important for deep manned research submersible as mentioned above. Therfore, the researches of hydrodynamic performance were carried out on both SHINKAI 2000 and the new models and finally a model with vertically slim type was selected.

The other requirement on the shape was to look at the upward through one of the viewports. SHINKAI 2000 couldn't do it because of her long eaves. Eaves shortening affects the weight distribution of the vehicle. After the research on weight ditribution, the eaves shortening was realized by transferring heavy subsystems afterbody. The eaves was not only shortened but also inclined. This shape not only allows the operators to look at upward clearly but also contributes to reduce the hydrodynamic drag for vertical movement.

Another request from the operators was to eliminate the auxiliary thrusters protruded from the body and instead, to adopt tunnel thrusters for vertical or horizontal use from the viewpoint of avoiding entanglement.

Thus, propulsion system became very similar to NAUTILE of IFREMER, France.

2. Pressure Hull

The weight of the pressure hull occupies large amount of the total weight of the submersible and to reduce the former reduces the latter significantly. During the construction of SHINKAI 2000, Japan had no facility to produce a titanium alloy pressure hull of submersible. At present, Japan has already the facilities and technology to produce it, and it was decided to adopt a titanium alloy (Ti-6Al-4V ELI) pressure hull. Moreover, to reduce the hull diameter reduces the total weight of the submersible significantly. However, the pressure hull should have enough space for crew to operate the vehicle and to carry out researches for long hours without pain. So the inner diameter of the pressure hull was tentatively decided as 2.0m and many human-engineering experiments were carried out in order to grasp the feasibility of such size.

Feasibility of the 2.0m ID depends on how to fit equipment in the pressure hull, and, the test results showed that such size was feasible enough. Thus, the pressure hull was decided to be 2.0mID with titanium alloy.

Titanium alloy hull is quite a new one for Japan and it was requqired to make sure about its strength. JAMSTEC carried out pressure tests for scale model pressure hull (700mm ID) made of titanium alloy which was fabricated by the same way as the actual pressure hull would be fabricated. Test results showed that the pressure hull received no effects from the cyclic pressurization (1500 cycles) up to the pressure equivalent to 6,500m depth and the collapsing pressure after the cyclic test was 1397kgf/cm^2, and it was confirmed that this titanium alloy could be applied to the pressure hull of the new submersible.

Details of the pressure hull will be discussed on the other paper presented on this UJNR-MFP.

3. Inside the Pressure Hull

As the size of the pressure hull is 2.0m ID, the same equipment as SHINKAI 2000 cannot be introduced to the new submersible. Therefore, a drastic re-arrangement or renewal of equipment inside the pressure hull should be done. JAMSTEC carried out a feasibility study on the arrangement of equipment and established a plan following experiences of operators. One major drastic change is to eliminate the control console and instead, to introduce an integrated navigation and maneouvering control system which is a graphic and character display by CRT (or in future liquid crystal TV). Another big change is that a pilot controls the vehicle looking directly at the outer-world through his own viewport just as ALVIN. When he wants to check some of the equipment, necessary informations are shown just around his own viewport.

The pressure hull has 3-ø120mm viewports, one at the center-fore with 15° inclined from horizontal plane, two at 50° left and 50° right of the sphere with 25° inclined from horizontal plane.

4. Exostructure

Materials of the frames of the new submersible are titanium or titanium alloy. SHINKAI 2000 also uses titanium and titanium alloy frames, but they are connected by bolts because welding technologies for the complicated space frame structure of titanium was not sufficiently established when SHINKAI 2000 was under construction. Nowadays, Japan has developed the welding technology, so JAMSTEC will use it for the frame construction. It contribute to reduce the weight.

5. Batteries and Electric Equipment

SHINKAI 2000 uses silver-zinc battery for her energy source and it has been working well. The new submersible will also use silver-zinc battery whose capacity and life will be increased.

Motors of SHINKAI 2000 are induction motors and direct current of battery is inverted to alternating current by power transistor inverter in order to control and drive the motors. At the time of the construction of SHINKAI 2000 there were no technologies to immerse power transistors into oil so as to compensate the ambient pressure. Nowadays, Japan has already developed such technology and JAMSTEC will use oil immersed pressure compensated power transistor inverter.

Only the control circuit for the inverter will be contained in a pressure vessel.

6. Observation Sonar

The weak point of a submersible is that it cannot look objects some distance away from it because of the light absorption by sea water. Underwater acoustic signal can reach very long distance and sonars are frequently used for submersibles. However, sonar information usually shows only that there is something but cannot show what the shape is. JAMSTEC is now developing under cooperation with a Japanese company for the new submersible an observation sonar system which can show the shape of the target just like a TV image. The principle is the same as acoustic tomography. The maximum detection range will become 200m.

7. Manipulators

SHINKAI 2000 has one manipulator. However, its operators requested to fit the new submersible two manipulators with easier handling after their experiences. JAMSTEC decided to fit the new submersible two manipulators, one of which is 7 degree-of-freedom master slave type with force feed-back system, and the other will be 5 degree-of-freedom joystic control type.

8. Buoyancy Material

Buoyancy material is an important part of the submersible system. It should bear against the pressure and also it should be light enough.

JAMSTEC developed alreaady the buoyancy material whose collapse pressure was more than 1,200kgf/cm^2 and whose density was 0.54gr/cm^3 by adopting binary microbaloon mixture method. JAMSTEC will use this buoyancy material for the new submersible.

9. Others

SHINKAI 2000 uses a shot ballast system for the control of its weight. The reason to adopt such a system is that this system can control the weight very minutely. However, by getting experiences on operations, operators says that to jettison weight blocks is enough for the weight control if weight increase by sampling is cancelled by variable ballast tank. So, JAMSTEC decided to adopt the system which operators recommended.

The location of SHINKAI 2000 is detected by using underwater acoustic transponders. But the new submersible dives to deeper depth and the distance becomes very longer. Such long distance makes the signal level small and there often occurs receiving misses. In order to avoide such signal receive misses, the new submersible will have synchronized pingers just as ALVIN.

10. Principal Particulars and General Arrangement of the New Submersible.

Table 1 and Fig.1 show the tentative principal particulars and rough general arrangement of the 6,500m submersible.

Table 1. Tentative Principal Particulars of the New Submersible

Length(OA):	ab. 9.4m	Speed:	1 kt(Cruise)
Breadth:	ab. 2.7m		2.5 kt(Max.)
Depth:	ab. 3.2m	Crew:	2 Pilots
Draught:	ab. 2.7m		1 Observer
Weight(Dry):	ab. 25ton	Life	9hours + 5days
Maximum Depth		Support:	for 3 persons
Capability:	6,500m	Payload:	200 kgf

SUPPORT VESSEL

To operate the new submersible effectively requires its support vessel. NATSUSHIMA, the support vessel for SHINKAI 2000, is a very quiet vessel so as to avoide disturbances by noise emitted from ship hull to the underwater acoustic communication/locating. However, the support vessel for the new submersible should be more quiet than NATSUSHIMA by more than 10dB because of the longer distance for the communications.

Diving area of SHINKAI 2000 system is rather limited to the area close to shore because of its depth capability. However, the new submersible can dive to deeper ocean, so the diving area of the new system will become far from shore and operational sea state condition shall become severer than NATSUSHIMA.

JAMSTEC is now planning to construct the support vessel whose noise emission is fairly small and which can bear against severer sea conditions.

UNMANNED VEHICLE DOLPHIN-10K
FOR SITE SURVEY AND RESCUE

JAMSTEC has a plan to develop an unmanned vehicle named Dolphin-10K whose maximum depth capability is 10,000m. This vehicle will be used to survey the bottom of the deep trenches, to survey the diving area beforehand of the research dive of the new manned submersible, or to carry out the rescue operation for the new manned submersible.

CONSTRUCTION SCHEDULE AND CONCLUSION

Construction schedule for the new manned submersible is shown in Table 2, and completion is expected to be on FY1989.

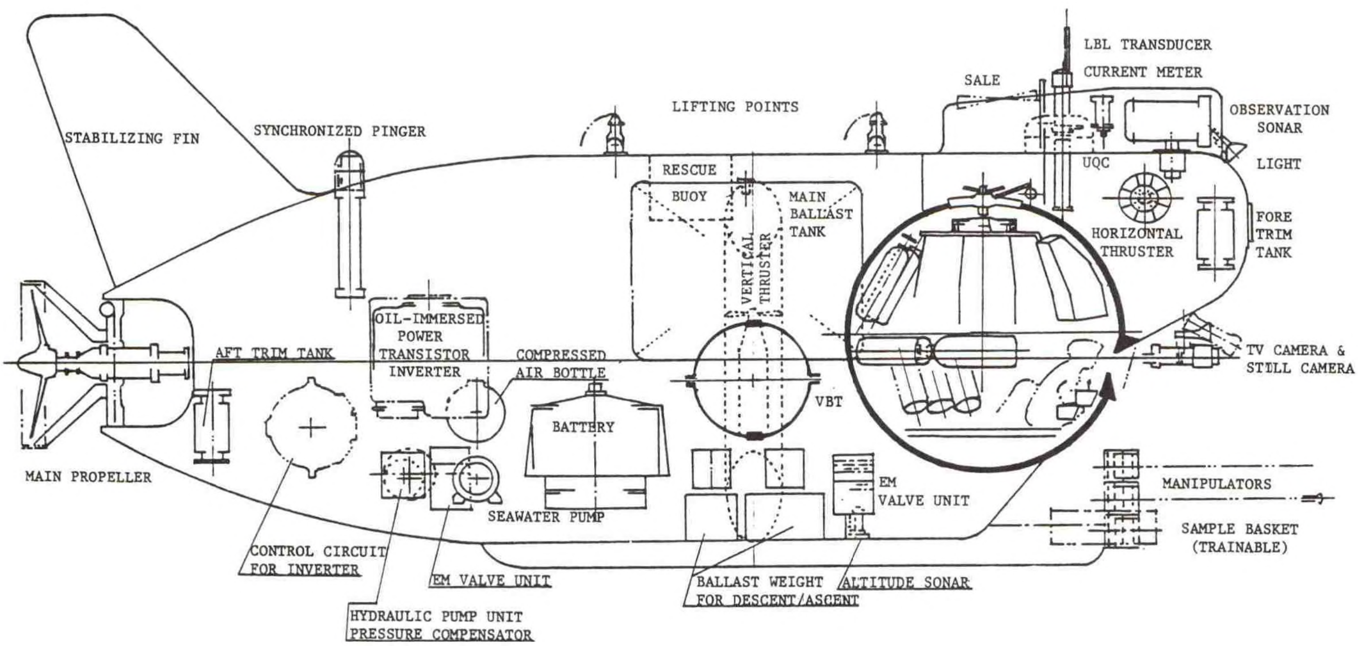
Sea trials of the new submersible is expected to begin from late FY1988, therefore, the construction of the support vessel should be completed before then. And JAMSTEC is working to realize the support vessel.

By the completion of this system there will be three countries in the world which will have deep manned submersibles. Japan wishes to establish an international cooperative program for deep sea research and also wishes to establish a mutual rescue program for deep submersible with countries which have submersibles of the same depth capabilities.

TABLE 2. CONSTRUCTION SCHEDULE OF THE NEW SUBMERSIBLE SYSTEM

FISCAL YEAR	1986	1987	1988	1989	1990	1991
NEW SUBMERSIBLE		CONSTRUCTION	SEA TRIAL	COMBINED SEA TRIAL	TRAINING DIVE / PERIO-DICAL SURVEY	MISSION DIVE
SUPPORT VESSEL		CONSTRUCTION	SEA TRIAL			

FIG.1 ROUGH GENERAL ARRANGEMENT OF THE NEW SUBMERSIBLE



Mobile Offshore Platforms

An Overview of recent Safety and Stability Activity

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The "Offshore Accident Review" published by Veritec of Oslo, Norway, reports that for the period 1980-1985 there were 37 cases of severe platform damage and 27 platform losses. These incidents and the loss of life associated with the Alexander Kielland and Ocean Ranger accidents have focused significant attention on the issues of mobile offshore platform safety and stability.

Most recently, the 5th International Symposium on Offshore Mechanicas and Arctic Engineering held in Tokyo, Japan on 13-17 April 1986 included a panel session on the "classification and certification for Offshore Platform and Installation".

Panel chairmen were S.G. Stiansen, American Bureau of Shipping; Paramus, NJ, USA and Y. Akita, Society of Naval Architects of Japan; Tokyo, Japan.

The session included five papers by representatives of major ship/offshore classification societies and covered their role in offshore platform safety.

1. "Role of Classification Societies in Offshore Safety", J. Conlon, American Bureau of Shipping, Paramus, NJ, U.S.A.

2. "Certification for Offshore Structures and Equipment Including Classification and Verification", F.H. Atkinson, Lloyd's Register of Shipping, London, England.

3. "General View on the Design Appraisal of Offshore Structures", A. Nitta and H. Arai, Nippon Kaiji Kyokai, Tokyo, Japan.

4. "Underwater Inspection and Monitoring Systems", P. deLivois, M. Huther, and D. Bury, Bureau Veritas, Paris, France.

5. "Implementation of Realiability Concepts in Classification Rules", E.M.Q. Roren, H.O. Madsen, and J. Lereim, Det norske Veritas, Hovik, Norway.

Work within classification and technical societies is also looking at various aspects of mobile offshore platform safety through stability and motion analysis.

1. "Stability for Offshore Drilling Units", Phase 1 by D. Liu, Hsao Hsin Chen, Yung Sup Shin, G. Shark, T.D. Grove; Research and Development Division, American Bureau of Shipping; Sept. 1985 (Technical Report #RD85014).

2. "A Realistic Approach to Semi-Submersible Stability"; by D. Vassalos, G. Konstantopoulos, C. Kuo, Y. Welaya; Society of Naval Architects and Marine Engineers Transactions, Vol. 93, 1985, pp 95-128.

3. "Evaluation of Semisubmersible Motion Characteristics", by S. Sengupta, M.K. Chatterjee; Society of Naval Architects and Marine Engineers, Marine Technology, Vol. 23, No. 3, July 1986, pp 217-225.

There appears to be several basic problems in the assurance of safety for Mobile Offshore Platforms.

- o The basic designs are complex and there are many different types.
- o The modeling of the platform motion is complex and often involves simplification and approximation.

- Even if modeling could be done with considerable accuracy how best should the data and information be applied to achieve the desired degree of stability to assure a reasonable degree of safety. i.e., should the platforms have greater initial stability or should they have greater damage control (pumping) capacity, or what degree of both approaches is best.

- Perhaps the most difficult question of all to answer is how safe is "safe". i.e., what degree of risk is acceptable with proper consideration for the overall design, construction and operational costs.

Each damage or loss incident contributes additional knowledge and factors for inclusion in the analytical study cycles that are in progress within the technical community of offshore platform design construction and classification.

The referenced papers, particularly the two SNAME papers, the ABS study and the Norwegian reliability concept contain a total of 74 additional references with respect to this overall area of platform safety, stability, motion and stress analysis.

Silver-Iron Technology Report

Westinghouse Electric Corporation
Research and Development Center

BACKGROUND

The Research and Development Center of the Westinghouse Electric Corporation has been actively involved in electrochemical battery technology development since the early 60's. Technology development in the 1960's was focused on Ni-Cd batteries, Fe-Air and Ni-Fe batteries, for Electric Vehicles. Technology development intensified in the 1970's focused with corporate support on Ni-Fe, Fe-Air, Ag-Fe, Molten Salt Batteries and large capacity improved Pb-Acid batteries for electric utilities. In the 1980's battery technology was redirected and focused on Ni-Fe, Fe-Air, Ni-Al (primary battery) and increasing effort on Ag-Fe cell development for specialized application.

Westinghouse currently has over 40 patents in battery and electrode technology areas and is licensing Ni-Cd technology to three battery manufacturers around the world. The Research and Development Center maintains the Westinghouse electrochemistry technology for Ni, Cd, Fe, Air and Ag electrodes and Ni-Fe, Fe-Air, Ni-Al and Ag-Fe cells batteries and other systems of concern or interest to the Corporation's needs.

In 1985 a directed effort in Ag-Fe technology was initiated that has drawn from the previous Ni-Fe and Ag-Fe demonstration efforts and led to the production of high capacity, long lived and extremely abuse tolerant Ag-Fe cells. The Research and Development Center is currently contacting organizations/agencies of the Government that we feel would benefit from this proprietary Westinghouse Ag-Fe technology for the solution of their high enerty density battery requirements. While not interested in entering the traditional commercial battery business Westinghouse is expressing an interest in solving specialized or customized battery problems for selected customers.

Westinghouse at its R&D Center can and will make available the personnel, facilities and necessary equipment to solve the specific problems or provide the necessary hardware for demonstration objectives.

SILVER-IRON COUPLE ELECTROCHEMISTRY

The theoretical energy density of the alkaline silver-iron couple is comparable to that of the silver-zinc couple at 370 W hr/kg (170 W hr/lb). The lower specific weight per unit capacity (g/Ahr) of reaction products in the silver-iron case, i.e. 3.65/Ahr (vs 4.48 g/Ahr for silver-zinc) and the lower terminal voltage of the Ag-Fe couple (avg theoretical discharge voltage of 1.34 v for Ag-Fe and 1.68 v for Ag-Zn) is compensated for by the higher capacity/lower weight of the iron electrode as compared to a soluble zinc electrode and required electrolyte. Recent experiments and demonstration Ag-Fe cells produced, provide an equivalent or higher specific energy density cell than the present Ag-Zn cells. The state-of-the-art Ag-Fe cells are about 30% smaller in size and also lighter than a fresh Ag-Zn cell of equivalent capacity. A significant difference between the electrochemistry of the Ag-Fe cell and the Ag-Zn cell is that the Fe plate is not soluble in the KOH electrolyte. As a result Ag-Fe cells are characterized by very long cell cycle and shelf life. Full size Ag-Fe production cells have produced their rated capacity at greater than 300 cycles. Unique combinations of state-of-the-art separator materials have been developed that indicate cell life of 500-1000 cycles is a possibility. The inert nature of the Fe electrode also contributes to the ruggedness of the Ag-Fe cell in that total cell voltage reversal and full recovery is possible and has been demonstrated in production cells.

IRON ELECTRODE TECHNOLOGY

Westinghouse has developed and patented both a fiber grid and a sintered iron electrode system. Current interest has been focused on the sintered iron electrodes and production facilities for the production of these iron electrodes are in place at the Research and Development Center. The porosity and processing of the iron electrode dictates how closely the sintered electrode approaches the theoretical capacity of 0.962 A h/g for iron. Westinghouse has determined both the pressing and sintering conditions for iron electrode fabrication in the late 1970's and produced large quantities of 140 A hr Ag-Fe cells for 1975-1980 batteries using these high performance electrode structures.

Since the start of a more focused Ag-Fe effort in 1985 the efficiency of the iron electrode has been improved, new unique separator materials have been incorporated that also provide very long life for the Ag-Fe cell. Current electrodes have been cycled in three and five plate cells and full sized cells to demonstrate a life of about 5 times that of the current high capacity Ag-Zn cells.

Ag-Fe BATTERY DEVELOPMENT

Westinghouse has most recently moved into Ag plate technology development in the period since 1985 in order to produce a high capacity Ag electrode that can be matched to its high capacity Fe electrodes. This Ag plate technology is patent protected as is the Fe plate cell technology. The objective is to produce a total Westinghouse Ag-Fe cell with high capacity electrodes and a very long lived separator system. This Ag-Fe cell development is proceeding in the midst of on-going development research effort on the effects of temperature extremes on capacity, voltage and gassing. One current objective is to develop and demonstrate a cell with greater "useful capacity" (capacity at average voltage).

Considerable experience in Ag-Fe cell design, fabrication and environmental testing within the last year has provided Westinghouse with the ability to "tune" the electrochemistry to specific user needs and requirements. It is expected that on-going Ag-Fe testing will further expand this Westinghouse pre-eminence in Ag-Fe technology to enhance the system for broader use where other systems have been unsuccessful.

Advanced Ship Technology Development

SEMISUBMERSIBLE SAFETY RESEARCH (DAMAGED STABILITY)

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ABSTRACT

The project for safety research at the S.R.I., especially for the damaged stability, is introduced. The overall research plan had been discussed in the last UJNR meeting.

Since the disastrous accident of semisubmersible may not be brought about by a single incident, there will be several potential causes. A research method is proposed by the idea of composing a scenario for a disaster. To this purpose, the peculiar phenomena in the damaged condition have been investigated. And some results are presented.

1. INTRODUCTION

The first phase of stability research in the S.R.I. has been devoted to the intact stability. Several experiments have been conducted and computer programs have been developed. The research plans for stability research in the S.R.I. was reported in the paper submitted to the last UJNR meeting (1).

It becomes clear that an intact column stabilized semisubmersible may not be capsized if it remained in the intact state under permissible environmental forces. The disaster such as foundering or capsizing will occur on a damaged semisubmersible. Therefore it may be necessary for certifying societies and governmental organization to consider upon rules which will cover either the prevention of damage for an intact condition or the prevention of catastorophy for an damaged condition. However, the mechanism of the process of capsizing of a damaged semisubmersible is not known well and the research for disaster has not made progress. These are research items of the next phase in the project.

In the rules of the certifying societies and the governmental organizations, only the essences extracted from the immense heap of reseach data are usually depicted. Thus the wording used in the rule is wide and deep in the meaning. When an accident occurs actually, many autholized regulation bodies have to take a relevant counter action usually with very few technical data available. The regulation apts to be drastic when the enough volume of the data is not available.

In order to prevent a damaged semisubmersible from becoming disastrous, it is necessary to have enough knowledge about the behavior of a damaged one from the rational researches. In this paper the research project of the damaged stability in the S.R.I. will be introduced. (Fig.1)

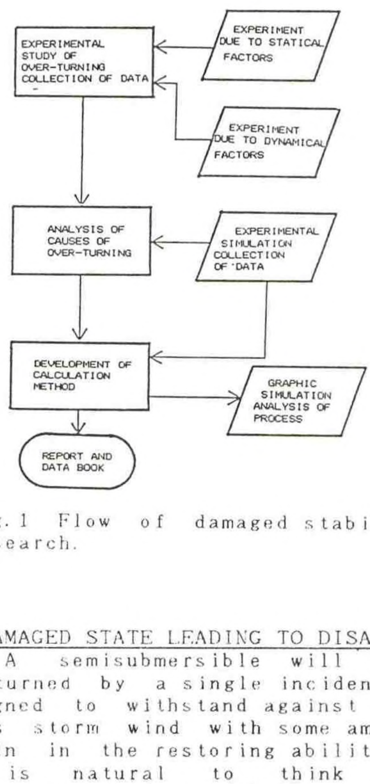

Fig.1 Flow of damaged stability research.

2. DAMAGED STATE LEADING TO DISASTER

A semisubmersible will not be overturned by a single incident. It is designed to withstand against the 100 knots storm wind with some amount of margin in the restoring ability. Thus it is natural to think that a disastrous accident will be caused by a successive series of potential causes of disaster. The chain of these causes makes a semisubmersible vulnerable to harsh environmental disturbances and finally leading to a catastrophic disaster. The succession of the causes are named as the scenario for a disaster. (2) The only causes concerned hydrodynamic origin are to be considered. They are categorized as shown in Fig.2 follwing three causes to which a few phenomena are attached.

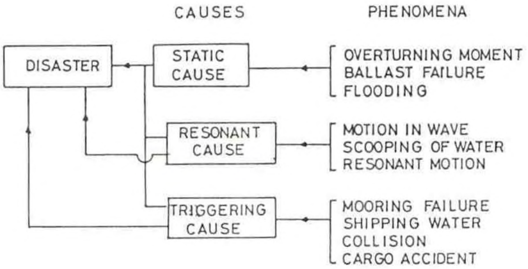

Fig.2 Relation among causes and phenomena.

One of triggering causes is actually realized by the breaking of mooring line and scooping of water over the deck induced by a large motion. The rapid change of equilibrium state of forces and moments gives this cause. In Fig. 3 a typical example is shown for which the breaking of mooring line is corresponding. The motion can be simplified by the following differential equation.

$$I\frac{d^2x}{dt^2} + N\frac{dx}{dt} + M_r(x, t) = M_e(x, t)$$

In actual phenomena the damping and restoring force terms are nonlinear. This equation is very similar to what the dynamical stability is derived. Thus defining the dynamical stability as

$$\int_0^{x_0} M_r(x)\,dx = \int_0^{x_0} M_e(x)\,dx$$

With this similarity we can explain the amount of the damage as the energy absorbed by the semisubmersible. Thus the concept of the equivalent overturning moment is defined which includes all the same moments equivalent to the absorbed energy.

One of the static causes is explained by a ballast faili re. The variation of the trim angle due to the transfer of the ballast water in a lower hull is shown as function of GM value in Fig. 4. For a large amount of ballast,Gm values exist apparently over the danger criterion. The maximum GM exceeds the danger criterion defines the minimum allowable GM value.

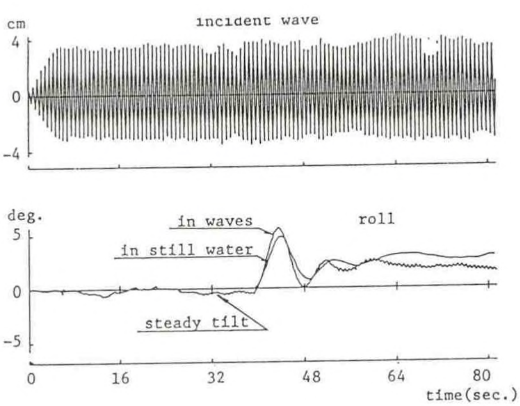

Fig.3 Roll motions after the breaking of mooring line.

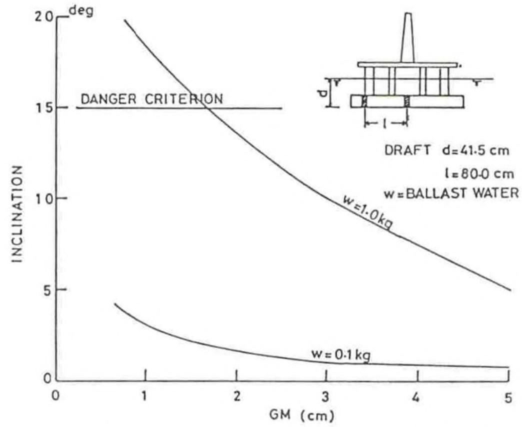

Fig.4 Inclination due to ballast transfer.

Therefore, for a given draft the minimum GM will be determined to the allowable maximum transfer of ballast which will be occured at the worst incident on the ballast system. The consideration above is for still water case without environmental forces. When a severe storm is exerted, the wind overturning moment must be added to the damaged vessel.

We show the cause followed by the accumulative effect. In actuality, a flooding into water tight compartment corresponds to this case in which the mass increases with time having the following simplified mathematical modelling.

$$(M+\alpha t)\frac{d^2x}{d^2t} + (N+\alpha)\frac{dx}{dt} + kx = f+At$$

The general solution of this equation shows the almost linear increase with time. From this solution we can know the essential feature of the linear mass accumulation that is an approximation for successive flooding. In Fig.5 the model test of the continuous flooding into a lower hull compartment is shown. Because of the nonlinear restoring force coming from the large change of the attitude of the semisubmersible model, the region of

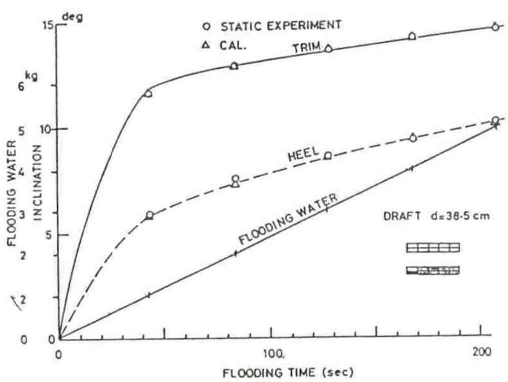

Fig.5 Inclinations during flooding into lower hull in still water.

linear change is confined in relatively small time. At large inclination GM value which is a function of semisubmersible's attitude usually becomes large suggesting slowly increase of inclination at large time in Fig.5. In the same figure, the calculated values are plotted by triangle obtained assuming that successive flooding at the fixed time can be replaced by the same amount of weight as the accumulated water. Therefore, as seen in the figure, successive flooding in calm water is to be analysed by the quasi-static manner.

3. TEST SYSTEM FOR DAMAGED STABILITY

In order to investigate into the damaged stability of semisubmersibles experimentaly, it is necessary to prepare equipments to study each phenomenon attached to the potential disaster causes. The general arrangement of the test for the breaking of mooring line and simulation of flooding is shown in Fig. 6.

The behavior of damaged semisubmersible in waves is different from that in calm water, especially the resonant phenomenon is peculiar one. (3) Such resonant motion can be seen at the natural frequency of the model other than the wave frequencies. The potentail danger of such resonant motion for a damaged semisubnersible is advocated and some experimental researches are to be planned. For the purpose of such experiments, an apparatus is prepared which can control the movement of weight over a deck arbitrarily making a model resonant with its natural frequency.

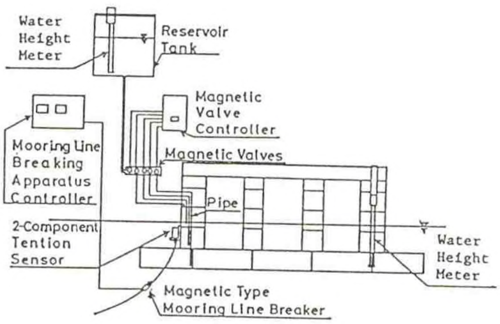

Fig.6 Test arrangement for flooding and breaking mooring line.

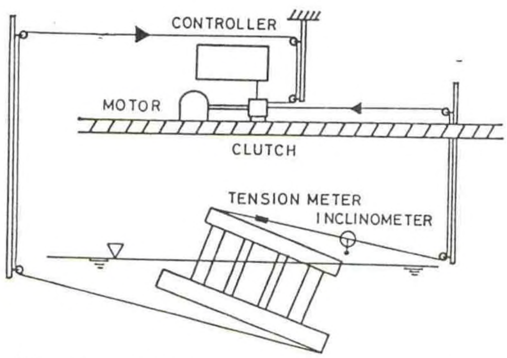

Fig.7 Test arrangement for overturning of model.

For the capsizing study of semisubmersible, that is, in order to investgate under what conditions a semisubmersible actually overturns, an apparatus shown in Fig.7 has been developed. It generates enough moment to turnover a model in damaged condition. The amount of moment that overturns a damaged semisubmersible in various situations is measured and a sinusoidal moment upon the model can be imposed. The process of the overturning is, at present, recorded only by a video recorder and analysed by a video digitizer system. In the near future, the motions of a overturning body are to be recorded by a self-contained recorder system.

4. RESULTS OF DAMAGED STABILITY RESEARCH

Some results on damaged stability obtained from experiment and calculation are introduced here.

The roll motions after a one of four corner mooring lines breaks has been shown in Fig.3. The energy released by the breakage of line tension may be related with the dynamic stability. As shown in the figure, the transient zone is significant for the potential disaster which may become a new cause for the other causes.

The ballast failure is demonstrated for an exaggerated condition in Fig.8 together with corresponding GZ curves. In this stage, if a ship made motions and there were openings over deck going through such compartments as chain locker and lowehull tanks, more serious disaster would progress further. The calculation in this figure includes a deck of water tight component, thus showing large GZ value at large inclination angle. A trial overturning test with apparatus shown in Fig.7 cannot capsize a semisubmersible model in such condition, thus proving large restoring force due to water tight deck structure.

A flooding into column compartment at near the water surface is shown in Fig.9 tested in calm water. In this case only flooding into one column compartment does not lead to so serious disaster. Then proceeding to further allowing flooding into entire colums at the front end, the attitude will be changed as shown in Fig.10. Same as the previous example, the deck is assumed water tight in this case. Then we need large overturning moment to overturn further.

These cases do not consider the effects of mooring lines because its effect gives usually conservative result.

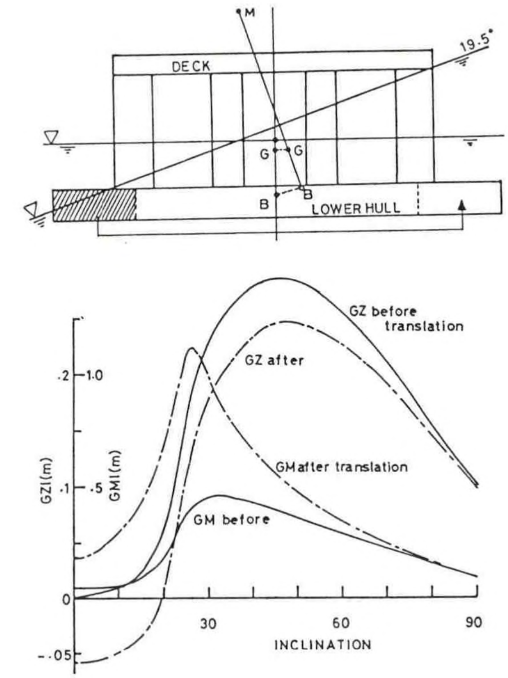

Fig. 8 Simulation of severe ballast transfer with GZ and GM curves.

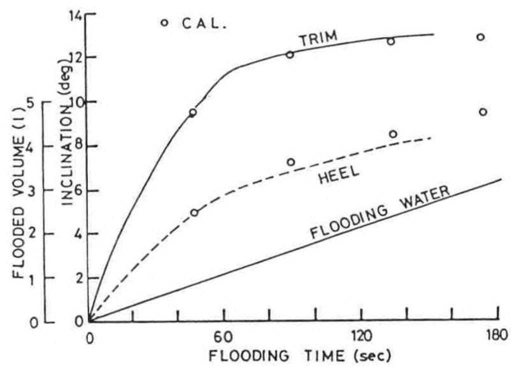

Fig. 9 Inclination during flooding into column in still water.

5. POSSIBLE SCENARIO

It is rare that only one phenomenon leads a semisubmersible to a catastrophic disaster. Combination of several casuses followed by attached phenomena in relevant order will result in a serious disaster. The order of the combination is said to be a scenario for a disaster. In Fig. 11 an example is shown. Here we confine ourselves to the hydrodynamic causes. However in actuality other causes than these hydrodynamic ones have to be speculated, such as structural failure, electricity breakdown and so forth. For the preliminary attempts to seek for the means to prevent catastrophic disaster of semisubmersibles, it will be worth while to investigate scenarios

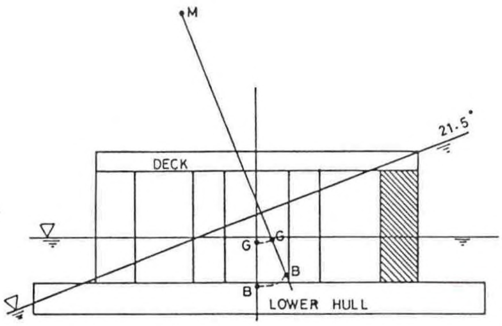

Fig. 10 Simulation of flooding into forward two columns.

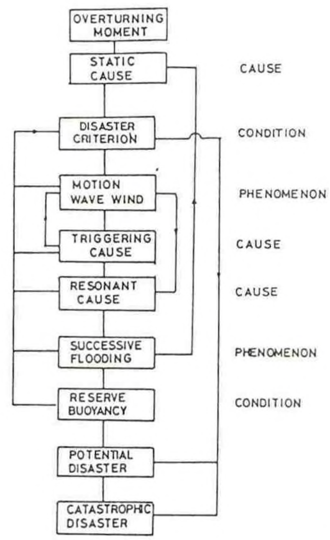

Fig. 11 Schematic flow chart for a scenario of a disaster.

of hydrodynamic origin. To break the chain of the succession of causes of potential disaster, it sure is necessary to make research for each phenomenon and conditions for prevention of disaster possibly at the minimum cost.

The accumulation of research data will also become reflected in the regulation of certifying societies and governmental organizations.

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MAJOR STUDIES BY THE NATIONAL ADVISORY COMMITTEE ON OCEANS & ATMOSPHERE

SHIPPING, SHIPYARDS AND SEALIFT: Issues of National Security and Federal Support

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ABSTRACT

The National Advisory Committee on Oceans & Atmosphere issued two major reports and three position papers between July 1, 1985 and June 30, 1986. The reports include the following: "Shipping, Shipyards and Sealift: Issues of National Security and Federal Support 1985" and "The Need for a National Plan of Scientific Exploration for the Exclusive Economic Zone." NACOA's three position statements, include one of the coastal Zone Management Act (CZMA) reauthorization, another on the data classification issue with respect to detailed bathymetric mapping on the Exclusive Economic Zone (EEZ), and one on acid rain. The findings of several of these studies and the recommendations made by the committee are presented and discussed below.

Background

In its January 1983 report, "Marine Transportation in the United States: Constraints and Opportunities," NACOA presented a number of findings and recommendations concerning the U.S. shipbuilding industry. Of the many areas addressed in this 1983 report, the U.S. shipbuilding base appeared to have the most critical and immediate problems. A number of shipyards were reported to be facing imminent closure, and NACOA believed the situation was serious enough to warrant a follow-on study focussing on the problems of the shipbuilding industry and the possible national security implications. Thus, in May of 1983, NACOA initiated a study which resulted in the July 1985 NACOA report, "Shipping, Shipyards and Sealift: Issues of National Security and Federal Support."

In the course of this study, NACOA examined the present Department of Defense conflict scenario related to shipbuilding requirements, mobilization and sealift needs, and the recent substantial changes in the Defense Department's approach to sealift and mobilization. At the same time, NACOA considered numerous congressional proposals designed to improve the Nation's sealift assets or to preserve its shipbuilding base. Throughout this review, NACOA considered the present national fiscal and budgetary climate. As a result, NACOA reaffirmed some of the conclusions from the 1983 report, but found it necessary to change some of the Committee's previous recommendations. None of the recommendations in our current report call for new appropriations. Indeed, NACOA opposes proposals for a Federal shipbuilding program for commercial sealift vessels requiring major increases in Federal funding.

Two considerations provided the major theme for this review. First, United States maritime policy, pertaining to shipping and shipbuilding is embodied in the Merchant Marine Acts of 1920 and 1936, and their accompanying package of tax credits, loan guarantees, ship construction and operating subsidies, limited cargo preference, protected domestic trade policy and build-U.S. requirements. It is increasingly clear that this policy has had limited success in preserving a viable U.S.-flag fleet and merchant marine.

Second, relating this issue to national security needs, the primary Department of Defense (DOD) requirement for the U.S. shipping and shipbuilding industries is to provide increased sealift and Naval combatant capacity in case of national emergency. More specifically, during a conflict, the DOD requirements call for (1) naval combatant ships to wage war at sea, (2) adequate merchant sealift capacity to transport military equipment and supplies overseas while concurrently providing critical shipping to support our economy, and (3) sufficient shipyard capacity to support both. In addition, shipping assets would be needed to import critical materials and maintain essential foreign and domestic trade.

Based on these considerations, NACOA defined the issues for the purposes of this study as follows:

* What is the most effective and least costly way to ensure that adequate sealift capacity will be available in the time frame required for a major modern conflict?
* What level of shipbuilding capacity would ensure an adequate base for mobilization and new ship construction and repair in a major conflict?
* To the extent that shipping and shipbuilding capacity is required, what

level and type of Federal support are needed or appropriate?

The range of solutions offered by public and private interests for solving the Nation's sealift problems fall into three broad categories:

* Preserving excess shipbuilding capacity (surge capacity) through increased support for U.S. shipyards in peacetime, so that warships and sealift vessels can be activated, repaired and built during a major conflict.
* Increasing the government-controlled merchant fleet to have immediate and direct control of needed sealift assets during a major mobilization.
* Increasing the number and military readiness of privately owned sealift assets through measures to aid U.S. ship operators.

NACOA opposes a Federal shipbuilding program for new merchant vessels to be chartered or laid up in reserve fleets, and also opposes a cargo preference scheme that would reserve a percentage of commercial cargos in U.S. foreign trade to U.S.-flag, U.S.-built vessels. Furthermore, NACOA opposes any increased Federal supports to the U.S. shipbuilding industry, because the industry has overcapacity for the commercial market it serves, and the present shipyard base is substantially in excess of the capacity needed for defense mobilization. Overall, NACOA opposes the range of proposals initiated for the most part by Congress to preserve excess shipbuilding capacity, and opposes further growth in the government-controlled active and reserve sealift fleets without fully exploring other alternatives.

On the other hand, NACOA supports more concerted efforts to increase the military usefulness of private merchant vessels and to increase the shipping tonnage in the active commercial U.S.-flag fleet. The Committee favors increased use of private vessels as sealift assets rather than preserving excess shipbuilding capacity or increasing government control of sealift assets.

Conclusions and Recommendations

NACOA concludes the following:

1. Under current defense scenarios, sealift requirements for the initial stages of a modern major conflict depend more on the sufficiency of U.S.-controlled shipping -- and on trained U.S. crews -- than on shipbuilding capacity. Shipyard facilities can be expanded for new shipbuilding during a prolonged conflict. National efforts should, therefore, emphasize developing a viable Federal and commercial sealift fleet in peacetime, rather than preserving excess shipyard capacity.
2. Despite several recent major shipyard closures, the United States still has a very large shipbuilding and ship repair capacity, one of the largest in the world. There is sufficient surge capacity within those yards expected to survive economically, without dire government supports to satisfy wartime needs as defined by current defense scenarios. No Federal support of shipyards is necessary beyond the peacetime defense contract work.
3. Requirements to build in U.S. shipyards have, in recent years, impaired the competitiveness of U.S. operators of oceangoing, self-propelled cargo vessels, and have contributed to the decline in the U.S.-flag fleet. Through subsidies, tax credits and increased freight rates, these measures also have imposed costs on the U.S. public at large. Despite their intent to support the domestic shipbuilding industry, the build-U.S. requirements have failed in recent years to create substantial commercial work in U.S. shipyards.

NACOA, therefore, recommends the following:

1. NACOA RECOMMENDS OPPOSITION TO PROPOSALS FOR A FEDERAL SHIPBUILDING PROGRAM FOR COMMERCIAL SEALIFT VESSELS -- OR ANY OTHER PROGRAM REQUIRING MAJOR FEDERAL FUNDING -- DESIGNED LARGELY TO PROVIDE PEACETIME WORK FOR U.S. SHIPYARDS AND TO PRESERVE THE PRESENT EXCESS CAPACITY IN THE SHIPBUILDING BASE.

NACOA finds that all additional surge capacity required for mobilization currently exists within the yards doing Navy peacetime construction, and Navy and commercial repair work, and that this work will preserve an "irreducible minimum" shipbuilding base that will be adequate in future mobilization. This smaller shipbuilding base might initially be inadequate for wartime construction, but shipyard expansion would begin immediately and would continue as needed throughout the conflict. The major constraint on expansion of wartime shipbuilding would not be shipyard capacity, but delayed availability of major components, e.g., propulsion plants for Navy and merchant vessels, and complex weapons systems for combatant vessels; increases or decreases in the shipbuilding base would not affect this problem.

2. WITH RESPECT TO GOVERNMENT-OWNED MERCHANT SEALIFT VESSELS, NACOA RECOMMENDS THAT:
   (a) IN ORDER TO DECREASE THE NATION'S DEPENDENCE ON A GOVERNMENT-OWNED AND MAINTAINED READY RESERVE FORCE, THE NAVY AND THE CONGRESS PLACE GREATER EMPHASIS ON EXAMINING ALTERNATIVES FOR INCREASING THE NUMBERS AND THE MILITARY USEFULNESS OF THE OPERATING U.S.-FLAG COMMERCIAL FLEET.
   (b) THE NAVY AND THE MARITIME ADMINISTRATION CONTINUE EFFORTS TO REDUCE THE SIZE AND INCREASE THE READINESS OF THE RESERVE SEALIFT FLEETS, INCLUDING CONTINUED SCRAPPING OF THE WORLD WAR II VICTORY SHIPS AND DISPERSING OF THE READY RESERVE FORCE VESSELS TO LOCATIONS NEARER TO PLANNED ACTIVATION SITES.

NACOA supports the approach of adapting modern, active commercial vessels to military purposes, because maintenance costs are borne by the operator in trade, the vessel provides training for U.S. crew, and the ship would have a ready crew if it were called up for service. In the long run, we believe this is a more efficient and less costly alternative than Federal building, acquiring or serving of an outmoded reserve fleet.

3. WITH RESPECT TO PRIVATELY-OWNED U.S.-FLAG MERCHANT VESSELS, NACOA RECOMMENDS THAT:

   (a) THE DEPARTMENT OF DEFENSE AND THE CONGRESS INCREASE THE EMPHASIS ON RESEARCH AND IMPLEMENTATION OF METHODS FOR ADAPTING MODERN COMMERCIALLY EFFICIENT VESSELS TO MILITARY PURPOSES -- RATHER THAN ACQUIRING SHIPS THAT HAVE IN THE PAST BEEN CONSIDERED MORE "MILITARILY USEFUL" BUT CAN NO LONGER BE EFFECTIVELY USED IN PEACETIME TRADE.

   (b) THE NAVY, THE SMALL BUSINESS ADMINISTRATION AND THE CONGRESS CAREFULLY EXAMINE THE POSSIBILITY OF COST REDUCTIONS IN THE PROPOSED CONTAINERSHIP MODIFICATION PROGRAM.

   (c) THE CONGRESS FUND DEPARTMENT OF DEFENSE PLANS FOR SEALIFT ENHANCEMENT FEATURES TO BE ADDED TO U.S. FLAG MERCHANT VESSELS IN PEACETIME, WITH VESSEL OWNERS FULLY COMPENSATED TO THE EXTENT THAT SUCH MODIFICATIONS INTERFERE WITH COMMERCIAL USE OF THE VESSEL DURING INSTALLATION AND SUBSEQUENT OPERATIONS.

Continued research is needed to develop cost-effective ways of adapting modern commercial vessels to military sealift needs. In addition, funding should be provided to do such conversion and activation work on U.S.-flag commercial ships during peacetime to enhance their readiness, reduce the shipyard conversion time required at mobilization, decrease the shipyard base required and decrease the need for expanded government-controlled sealift fleets.

4. NACOA RECOMMENDS THAT THE NAVY TAKE STEPS TO ENSURE THE AVAILABILITY, TRAINING AND READINESS OF U.S. CREWS NEEDED FOR MOBILIZATION OF RESERVE AND FOREIGN-FLAG SEALIFT VESSELS; AND THAT THE NAVY SEEK, AND THE CONGRESS APPROPRIATE, FUNDING FOR AN ENHANCEMENT OF THE NAVY'S MERCHANT MARINE RESERVE.

Requirements for increased numbers of ready crews are being generated by the expanding size of the Ready Reserve Force, and increased reliance on the U.S.-owned, foreign-flagged vessels. In addition, the greater readiness requirements for sealift vessels require better training and more rapid availability of crews to staff them.

5. NACOA RECOMMENDS THAT THE ADMINISTRATION AND THE CONGRESS CONTINUE TO UNLINK NATIONAL SHIPPING AND SHIPBUILDING POLICIES BY ELIMINATING ALL REQUIREMENTS FOR U.S.-FLAG OPERATORS RECEIVING GOVERNMENT SUPPORTS TO BUILD VESSELS IN U.S. SHIPYARDS. WE RECOMMEND SPECIFIC AMENDMENTS TO THE MERCHANT MARINE ACT OF 1936 TO:

   (a) ALLOW PERMANENT AUTHORITY FOR U.S. OPERATORS TO BUILD VESSELS IN FOREIGN SHIPYARDS AND STILL RECEIVE OPERATING DIFFERENTIAL SUBSIDY, OR WHATEVER SUPPORTS OR INCENTIVES MAY REPLACE THAT SUBSIDY, FOR OPERATING IN THE U.S. FOREIGN TRADES.
   (b) ALLOW CAPITAL CONSTRUCTION FUND DEFERRAL OF TAXES ON SHIPPING IF REINVESTED IN FOREIGN-BUILT, AS WELL AS U.S.-BUILT NEW VESSELS.

   IN ADDITION, NACOA RECOMMENDS:

   (c) REVISION OF REGULATIONS AND ADMINISTRATIVE PRACTICE TO ALLOW TITLE XI FEDERAL SHIP LOAN GUARANTEES FOR FOREIGN VESSEL CONSTRUCTION, WITH PRIORITY ON LOAN GUARANTEES THAT WILL PROVIDE GROWTH AND REPLACEMENT IN TRADES NOT ALREADY OVERTONNAGED.
   (d) AMENDMENT OF THE PROVISIONS IN VARIOUS LAWS REGARDING ELIGIBILITY TO CARRY GOVERNMENT-IMPELLED CARGOS -- TO ALLOW IMMEDIATE ELIGIBILITY TO A FOREIGN-BUILT VESSEL RATHER THAN THE PRESENTLY REQUIRED 3-YEAR WAIT.

NACOA believes that requirements to build new vessels in high-cost U.S. shipyards has increased the capital and operating costs of the U.S. shipping industry; has discouraged modernization and expansion of the U.S.-flag fleet; and has contributed to the long-term decline of domestic and foreign waterborne trading opportunities for the U.S. fleet. For this reason, NACOA supports permanent authority for U.S. shipowners to operate foreign-built vessels in the foreign trades while receiving Federal supports, to improve the competitive position, and thus the size and sealift capacity, of the U.S.-flag fleet.

6. NACOA RECOMMENDS THAT CONGRESS AMEND CURRENT MARITIME STATUTES THAT IMPAIR THE COMPETITIVENESS OF U.S. VESSELS IN FOREIGN TRADE. SPECIFICALLY, WE RECOMMEND;
   (a) ESTABLISHMENT OF A NEW FORM OF OPERATING INCENTIVES, UNDER SHORT-TERM (5-YEAR) CONTRACTS THAT ARE LINKED TO THE SUCCESS OF MEASURES TO REDUCE CREW SIZE AND OPERATING COSTS.
   (b) AMENDMENT OF THE AD VALOREM TAX PROVISION IN THE TARIFF ACT OF 1922 TO EXEMPT OCEANGOING, SELF-PROPELLED CARGO SHIPS FROM THE DUTY ON NON-EMERGENCY FOREIGN SHIPYARD REPAIRS.
   (c) AMENDMENT OR REPEAL OF SUCH SHIPBOARD MANNING LAWS AND REGULATIONS AS THE "CROSSOVER LAW" AND THE "THREE-WATCH LAW" TO ALLOW REDUCTIONS IN U.S. VESSEL CREW SIZE COMPARABLE TO THOSE OF MOST OTHER MAJOR SEAFARING NATIONS.

Federal supports must decrease crew size and other operating costs if the U.S. fleet is to become competitive in the world market and grow to provide increased sealift assets under private control. The supports should definitely not be linked to the U.S./foreign cost differential.

Rather, they should be annual fixed payments, based on some fair measure, such as vessel tonnage, and bonuses for improved efficiency, as do the Navy's "incentivized" shipbuilding contracts. Other costs of U.S. operation would meanwhile be reduced by our recommendations that building and repairing of ships in foreign shipyards be allowed for U.S. operators in foreign trades.

7. NACOA RECOMMENDS THAT THE ADMINISTRATION AND THE CONGRESS DEVELOP A PACKAGE OF INCENTIVES, IN ADDITION TO THOSE IN RECOMMENDATIONS #5 AND #6, TO ATTRACT FOREIGN-REGISTERED VESSELS--UNDER U.S. OR FOREIGN OWNERSHIP -- TO THE U.S. FLAG. WE RECOMMEND THAT SUCH SET OF INCENTIVES INCLUDE A LIBERALIZING OF REGISTRY REGULATIONS FOR REFLAGGED VESSELS, GIVING ASSURANCES TO OWNERS THAT THEY MAY EASILY "FLAG OUT" AGAIN DURING A CERTAIN NUMBER OF YEARS.

NACOA proposes a number of measures to encourage reflagging to the U.S. registry of vessels now under foreign registry. For example, amendment of laws to reduce the required crew size, repeal of requirements for shipbuilding and repair in high-cost U.S. yards and implementing a grace "flag-out" period for vessels reflagged under the U.S.-flag. Although large-scale reflagging is not likely in the near future, even a small-scale reflagging would be desirable from a national defense standpoint, because these ships would provide work and training for U.S. crews, would be available for pre-mobilization installation of Sealift Enhancement Features, and would thus increase the sealift readiness of the U.S.-flag fleet.

8. NACOA RECOMMENDS AMENDMENT OF THE JONES ACT TO ALLOW A 10-YEAR "CO-PRODUCTION" PERIOD OF SOME U.S. AND SOME FOREIGN BUILDING OF NEW COMMERCIAL CARGO SHIPS FOR THE JONES ACT DOMESTIC TRADE. WE RECOMMEND THAT THESE PROVISIONS BE APPLICABLE ONLY TO LARGE OCEANGOING, SELF-PROPELLED, CARGO-CARRYING SHIPS THAT ARE CAPABLE OF CONTRIBUTING TO THE NATION'S SEALIFT NEEDS IN THE CASE OF A NATIONAL EMERGENCY.

This recommendation provides for a transitional period and protects the inland waterway, tug and fishing boat builders.

A REVIEW OF THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

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Abstract

This paper traces the development of the National Shipbuilding Research Program (NSRP) from its beginning in the early 1970's to the present time. The goals sought, the approach used, and the organization established to achieve the goals are described. A listing of current projects is provided followed by a discussion of results achieved in technical, organizational, and market areas.

Introduction

Founded by shipborne immigrants from various seagoing nations, and blessed by deep rivers and natural harbors along their eastern coasts, the North American colonies early in their history developed a vigorous and successful shipbuilding industry. The ships produced in these shipyards not only supported a thriving trade among the colonies and between them and Europe, but also formed the backbone of the fledgling navy of the American Revolution. Since that time, U.S. shipyards have continued to serve both the commercial and defense needs of the Nation.

By the beginning of this century, however, two factors had developed which had detrimental effects on the U.S. shipbuilding industry. The first was the continued westward expansion during the nineteenth century which decreased the relative role of shipping in the national economy as domestic resource development and trade increased. The second was the competition of foreign technology -- specifically, iron hulls and steam propulsion -- which gradually displaced the wooden-hulled sailing vessels at which U.S. yards excelled. The result was that by the beginning of World War I, U.S. shipyards were hard put to meet the demands of war shipping.

For the first time, in the Shipping Act of 1916, the Government found it necessary in the national interest to pass legislation "for the purpose of encouraging, developing, and creating a naval auxiliary and naval reserve and a merchant marine to meet the requirements of the commerce of the United States and its Territories and possessions and with foreign countries...." Subsequent legislation, namely, the Merchant Marine Acts of 1920, 1928, and especially the landmark Merchant Marine Act of 1936, greatly increased the role of the Federal Government in the maritime industries, including shipbuilding. Supported by this body of legislation and under wartime demands, U.S. shipyards produced ships at an amazing rate during World War II. By 1945, the United States possessed a navy and merchant marine unequalled in world history.

By 1970, however, the maritime industries once more found themselves in a depressed state, and additional legislation was deemed necessary to stimulate them. One of the specific results of this legislation was the establishment of a greatly expanded research and development (R&D) program under the Maritime Administration (MARAD), which had emerged in 1950 as the Agency responsible for maritime policy. One of the new R&D programs begun in 1971 was the National Shipbuilding Research Program (NSRP).

Goals of the NSRP

The initial goal of the NSRP was to respond to the direction given to the Secretary of Commerce in the Merchant Marine Act of 1970 to "collaborate with ... shipbuilders in developing plans for the economic construction of vessels" [Section 212(c)]. While the content and technical thrust of the NSRP have varied over its 15-year life, its basic goal has remained the same: to reduce production costs and to accelerate deliveries through improved shipbuilding methods.

In addition to responding to the Congressional mandate, the Government had other valid reasons for wanting to improve shipyard efficiencies. Title V of the 1936 Act provided for payment of Construction Differential Subsidy (CDS) of up to 50 percent of the cost of constructing a new vessel in a U.S. yard. While the CDS program is now inactive, large sums were expended on this program each year for a number of years. As the administrator of the program, MARAD had an obvious interest in reducing construction costs, and hence CDS payments. Furthermore, reduced construction costs result in lower domestic shipping costs and contribute to the competitive position of U.S. shipping companies operating in the foreign trades -- hence contributing to the viability of the U.S. merchant marine. Finally, in recent years, improvements introduced through the NSRP have resulted in substantial savings to the U.S. Navy's shipbuilding program.

Program Approach

Shipbuilding in the United States is carried out by a number of independent private companies in competition with each other. While each company obviously has an interest in improving its products and reducing its costs for competitive reasons, the fragmented nature of the industry and the severe variations in work load over time have made it very difficult for even the largest shipyards to maintain formal R&D programs. Furthermore, anti-trust laws have discouraged companies -- until recently -- from banding together in cooperative R&D programs. At the same time, however, shipyards in both Europe and the Far East have improved their construction technologies dramatically through cooperative and government-sponsored research programs.

The NSRP seeks to overcome these disadvantages to U.S. yards by establishing a framework for a cooperative, cost-shared program across a wide spectrum of shipbuilding activities. The Government (MARAD, and more recently Navy) provides broad guidance and direct funding of a number of technical projects each year. Projects are selected and monitored by technical panels of the Ship Production Committee (SPC) of the Society of Naval Architects and Marine Engineers (SNAME) (see Figure 1). These projects are performed on a cost-sharing basis through contracts with shipyards and, in one case, an academic institution. Results of all research projects are made available to all participants through panel meetings and formal reports.

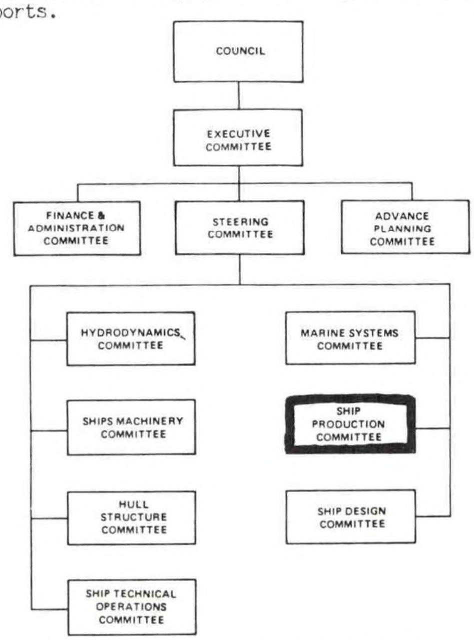

Fig. 1 Organization of the SNAME T&R Program

Program Organization

The organization of the NSRP is designed to provide for a high degree of industry involvement in the program's technical direction and execution. While the SPC includes representation from the Government and academic institutions, the majority of its members are senior officials of the major U.S. shipyards. It assists MARAD in setting program priorities, assigning responsibility for projects, and providing technical direction. By involving industry personnel in the planning activities and using shipyards as laboratories, the program reflects real-world perspectives and virtually assures implementation of research results.

Detailed planning and control is performed by 10 technical panels of the SPC. Each of these panels is responsible for providing guidance and direction of those projects in its specific area. An additional panel (SP-11) provides program management support. Each year these panels make recommendations to the Ship Production Committee for future projects. The Ship Production Committee reviews all panel recommendations and then submits a finalized list of projects to MARAD and the Navy with a request for funding support (see Figure 2).

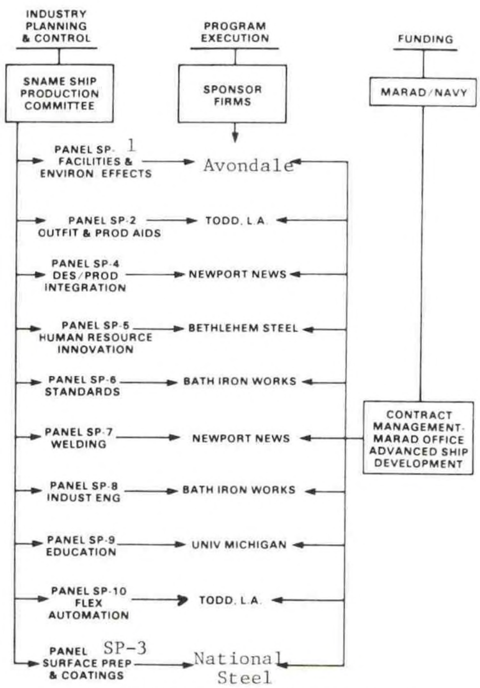

Fig. 2 The National Shipbuilding Research Program

As indicated, there is also a lead shipyard assigned to each area. The lead shipyard acts as full-time program manager and is responsible for the administration and management of its assigned projects. Each lead yard works very closely with its respective panel members to ensure that all shipyards are kept fully informed of project status and results.

Projects currently underway include the following:

SP-1 Facilities

- Group Technology/Flow Application in Production Shops
- Portable Flushing System for Ship Piping System Cleaning
- Sheet Metal Shop Analysis
- Moving Personnel and Light Material Onto and About a Shipyard
- Pipe Storage and Movement
- Development and Implementation of an On-Line Material Control System
- Comparison of U.S. and Foreign Cost for Shipbuilding Material & Components, Ph. I
- Cost Effective Maintenance and Repair of Air Compressors
- Evaluation of Smoke Extraction vs. Ventilation
- Staging System for Ships During New Construction and Repair

SP-2 Outfitting and Production Aids

- Zoned-Oriented Scheduling
- Indices for Monitoring Manhours, Program and Productivity
- U.S. Shipbuilding Accuracy - Ph. I
- Analytical Quality Circles
- Safety & Health Management Program
- U.S. Shipbuilding Accuracy - Ph. II
- Product Work Breakdown Structure for Overhauls
- Precut Electric Cable Lengths

SP-3 Surface Preparation and Coatings

- Work Planning for S/Y SP&C Trng.
- Overcoating of Zinc Primers
- Citric Acid Cleaning - Ph. II
- Ph. II - Waterborne Coatings
- Economics of S/Y Painting
- Perf. Testing of Marine Coatings
- Cathodic/Partial Coating Eval.-Op.III
- Design of Accel.Test Equip.
- Econ. of S/Y Painting - Pt. II
- Certification of Weld Through Primers
- Effect of Contaminants
- Cost Effectiveness of Flame Spray
- Automated Painting of Small Parts
- Calcite-Type Coatings in S.W. Ballast Tks.
- Top Side Components & Equip. Corrosion
- Estimating SP&C Bids
- Degree of Coating Cure Effect

SP-4 Design/Production Integration

- Group Technology: Parts Classification and Coding - Ph. II
- Incorporating Modern Shipbuilding Technology Early in the Ship Design Cycle
- Computer-Aided Process Planning-Ph. I
- Study of Required Content/Format of Engineering Documentation for Productivity Enhancement
- Information Flow Requirements for Design/Procurement Processes
- Interface Impacts - System to Zone Transition
- Develop System for Specification Driven Pipe Arrangement Drawings & Pipe Details
- Investigation of Design/Planning Organizations
- Study of Application of Advanced Measuring Techniques to Shipbuilding
- Computer Aided Process Planning - Ph. II
- Interface Impacts - System to Zone Transition - Ph. II
- Workshop on Management of Advanced Technology in Shipbuilding

SP-5 Human Resources/Innovation

- Organizational Innovation & S/Y Safety
- Cross-Crafting, Semi-Autonomous Work Groups
- Problem Solving Teams in S/B - Ph. II
- Product-Oriented Workforce
- Organizational Correlates of Stat. Acc.
- Gainsharing in Shipbuilding/Ship Repair
- Employee Inv. & Org. Redesign in U.S. S/B

SP-6 Marine Industry Standards

- Development of Standard Equipment Purchase Specifications
- HVAC Design Configurations
- Accelerated Standards Development
- ISO TC-8
- Diesel Engine
- Shaft Alignment
- Window Standards
- Portlights
- Hull Construction Standards Development Support
- Cableway Standards for Surface Ships
- Standard Practice for the Selection and Application of Marine Deck Coverings
- Navy Document Conversion Program
  - a. Todd/LA
  - b. BIW
  - c. CASDE

- o Standards Development Support
- o Accelerated Publication of National Shipbuilding Standards - Other Subcommittees
- o Navy Document Conversion Program - Ph. II
- o Accelerated Publication of National Shipbuilding Standards - Ph. II

SP-7 Welding

- o Tracking System for Automatic Wldg.-Ph. II
- o Benefits of Low Hydrogen Wldg.
- o Plastic Weld Models for Vis. Ref. Stds.-Ph.II
- o Design & Planning Manual
- o Robotic Arc Welding Tech.-Ph.I
- o Automated UT Insp. Review
- o Substitute Eddy Current Insp. for Mag.Part.
- o Eval. Benefits of New HSLA Steel
- o Determination of Hydrogen in Weldments
- o Development of Fitting and Fairing Aids

SP-8 Industrial Engineering

- o Quality Defects Measurement & Control System
- o Project Support for Task EC-21
- o Applied Operations Research; Analytical Solutions to Complex Shipyard Scheduling Problems
- o Computer-Assisted Methodology for the Determination of the Optimal Number & Location of Tool Sheds
- o Improved Planning and Shop Loading in Shipyard Production Shops
- o Shipyard Training Packages for Indus. Engineering Procedures - Ph.I
- o Optimal Use of Industrial Engineering Techniques in Shipyards
- o Analysis of Current Manpower Estimating and Control Procedures
- o Shipyard Training Packages for Indus. Engineering Procedures - Ph.II
- o Materials Handling and Facilities Layout Training Module
- o The Cost of Quality - A Quality Assurance Cost Measurement and Control System for Shipyards
- o Analysis of the Impact of Workload Variability on Shipyard Productivity

SP-9 Education and Training

- o Video Lecture Course on Basic Naval Architecture for Trade Schools
- o Improving Communication Skills of Shipyard Workers
- o Industry Indoctrination Program for New Professional Employees
- o Instruction Syllabus for Course on Design for Production
- o Ship Production Textbook Publication
- o Journal of Ship Production - Ph.II
- o Microfiche Library Service - Ph.II
- o Indoctrination of New Professional Employees - Ph. II
- o Translation Services on Foreign Language Books, Reports, and Other Materials
- o Workshops on Management of Advanced Technology in Shipbuilding
- o Certificate in Manufacturing Engineering - Ship Production Specialist
- o Development of Improved Coordination of Community College Support for Shipyards
- o Case Studies on Welding Design
- o Survey of Available Instruments for Evaluating Shipyard Trade Applicants

SP-10 Flexible Automation

- o Plan for Implementing Flexible Automation in the Shpbldg. Indus.
- o Marking Plate Cut by CNC Burning Machines, Phase I
- o Plan for Implementing Flexible Automation - Ph. II
- o Families-of-Parts Robotic Welding Cell
- o Off-line Programming of Welding Robots

Program Accomplishments

Since the beginning of the NSRP, well over 200 individual projects have been completed and another 100 are ongoing. Results of completed work have been disseminated to the entire shipbuilding industry through seminars, written reports, books, and since early 1985, the Journal of Ship Production, a quarterly SNAME publication established with the support of the NSRP. Some of these projects, especially earlier ones, have been oriented toward hardware and shipbuilding processes. Later projects have tended more toward planning and organizational techniques, with generous attention given to education and better use of the human resources in the industry.

Technical Accomplishments

A comprehensive review of NSRP technical accomplishments --- even a complete listing --- is beyond the scope of this brief paper. However, it is appropriate to list a few of them to impart some flavor of the direction and scope of the program. Those listed below are examples of the early emphasis on hardware/process subjects:

- o Automatic machine for painting structural shapes (1975);
- o Improved vertical butt welder (1976);
- o Semi-automatic pipe handling and fabrication facility (1978-80).

Concurrently, other projects have sought to apply advanced scientific or engineering developments to ship manufacturing methods. Examples of such projects are:

- o Shipbuilding alignment using lasers (1974);
- o Photogrammetry in shipbuilding (1976);
- o Plasma cutting and welding processes for shipbuilding (1976);
- o Approved electrical cable splicing procedure (1979);
- o Evaluation of waterborne coatings (1981).

A special category of projects has focused on applications of computer-aided design and manufacturing techniques. Research projects in this category include:

- o Licensing of the AUTOKON automated plate cutting system for use in U.S. yards (1976);
- o Shipyard planning and scheduling applications using the MOST system (computerized labor standards)(1982-1984);
- o Software tools for shipbuilding productivity (1984).

As the program developed, and as knowledge grew of concepts developed in other industries and other countries to better utilize human resources, a series of exploratory projects was launched to determine the applicability of these concepts to the shipbuilding industry. These areas included: the development and utilization of **robotics** and **flexible automation** techniques; social technologies related to **human resources**, specifically worker participation/involvement; development of **national marine industry standards**; development of reports, texts and other learning materials to further **education and training** for all levels of shipyard employees.

However, one of the most significant areas of research and development to emerge has been the study and application of advanced manufacturing technologies to work organization using **group technology** principles. An impressive data base has been accumulated to help in the understanding and implementation of an integrated concept of design and production to permit **zone-oriented** ship construction. Projects in this area dealt with:

- o Outfit planning (1979);
- o Product work breakdown structure (1980);
- o Process analysis using accuracy control (1982);
- o Pipe-piece family manufacturing (1982);
- o Line heating (1982);
- o Integrated hull construction, outfitting, and painting (1983);
- o Design for zone outfitting (1983);
- o Product-oriented material management (1985);
- o Design-for-production manual (1986).

The results of these projects initiated in individual shipyards have rapidly spread and are now used intensively in all major U.S. shipyards. Their use has been directly responsible for large cost savings and significant schedule acceleration in the naval construction program, which from calendar years 1981 through 1985, placed orders totalling $19.3 billion to U.S. shipyards for major naval ship construction (vessels greater than 100 tons light displacement).

While solution of technical problems is an important element of progress, there are two other areas of equal importance, namely, **organizational support** and **markets**, which must be addressed.

Organizational Support

The Government's role in the support of the U.S. maritime industries has been alluded to in an earlier section which discussed related Federal legislation. It is not the purpose of this paper to discuss either national maritime policy or the support mechanisms required to implement it. It is appropriate, however, to discuss some serendipitous organizational benefits of the NSRP.

The NSRP organizational structure as it evolved was designed to facilitate the implementation of the program and to maximize its benefits by: (1) supplementing the minimum staffing (1-3 persons) of the MARAD program office; (2) obtaining the active participation of the shipyards which would use the results; while at the same time, (3) avoiding the appearance of industrial collusion. The attitude of the industry before the beginning of the NSRP, and indeed during its early years, could be described in two terms -- **mistrust and anti-trust.** Shipyard personnel -- especially management -- found it difficult to understand that cooperation in solving technical problems could be both mutually beneficial and legal.

These concerns were overcome largely by the patience and wisdom of the organizers of the program. By restricting early projects to basic common technologies such as welding, and by insisting that committee members work out organizational problems with minimum government involvement a set of strong, committed, and sometimes fiercely independent panels and program managers was forged.

The resulting organization has served the NSRP well. It has had two other benefits which, while not foreseen, are probably as important as the one originally sought. First, the organization provides a ready and active mechanism for **technology transfer.** "Hands-on" participation in the selection and management of research projects provides many opportunities for exchange of new technology, not only between participating shipyards, but also from foreign shipyards and non-maritime industries into the U.S. shipyard industry.

The second unplanned benefit is the **unifying effect** of this organizational infrastructure. Results achieved in a cooperative manner have generated a feeling of common purpose and a sense of pride in the quality of the American shipbuilding industry that other industry organizations had not achieved because of their different purposes. The NSRP organization forms a highly valuable link between the technical interests of individual members and the business interests of the corporate members.

Markets

Now, what about markets, and how does the NSRP relate to that issue? Certainly, the Navy shipbuilding program has benefited from the NSRP results. On the other hand, the Navy program has provided an opportunity for application of research results that might otherwise not have been available. There is no doubt that new technology without market application is sterile.

However, there is also no doubt that without technological refurbishment, new markets are hard to come by, and existing markets fade away. Certainly the benefits to the Navy of productivity improvement will be reflected in its relationships with U.S. shipyards, and **if properly publicized**, will not go unnoticed by U.S. commercial ship operators when they consider new buildings. Furthermore, increased interest in R&D and productivity improvement by shipyard management could lead to more aggressive pursuit of new markets, say, industrial plant vessels. Finally, the commitment of the yards to productivity improvement will certainly be a factor in the development of new maritime policies.

In summary, markets, organizations and technical improvements are all related and support each other. It will be a mistake to neglect further efforts to improve productivity, even though markets may be temporarily depressed, or to allow the valuable infrastructure already established to crumble and disappear.

Outlook to the Future

Two areas invite further attention in the future. One is the market development area addressed previously. The second is the ship repair and refit market. Previous conventional wisdom had it that productivity improvements in new construction could only be realized by design standardization or by multiple orders.

The repair and refit market was considered an even more difficult area for improvement. New concepts demonstrated under the NSRP and now widely in use in new construction make it clear that these concepts are also applicable to a large degree in the ship repair and refit market. In fact, they have been successfully applied to such work in U.S. Navy shipyards. As the Navy construction program draws to a close, this other market should be addressed much more seriously.

Finally, what will be the role of government in the future with regard to the NSRP?

Present Administration policy is clear that research and development for improvement of industrial technology is the primary responsibility of the private sector. On the other hand, it is also clear that both as a major customer (Navy) and as a responsible agent (MARAD) for ensuring an adequate merchant marine "supplemented by efficient facilities for shipbuilding and repair," as required by national policy set forth in the Merchant Marine Act of 1936 (as amended), the Government has an interest in the future quality of U.S. shipyards. While it is likely that future government involvement will be less direct than before, it seems unlikely that that involvement will cease entirely.

Acknowledgements

The success of this program is due to the hundreds of men and women from industry, government, and academia who have devoted long hours of hard work to formulating and carrying out the National Shipbuilding Research Program. Special credit is due to those, both past and present, who have served as chairmen of the Ship Production Committee, chairmen or program managers of the various technical panels, and government program managers. The support of senior officials of the shipbuilding industry, the Government, and the Society of Naval Architects and Marine Engineers is also recognized and appreciated.

THE U.S. NAVY'S ARCTIC/COLD WEATHER PROGRAM FOR SURFACE SHIPS

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ABSTRACT

The U.S. Navy's Maritime Strategy requires that its surface ships operate in northern geographic latitudes in order to accomplish its various strategic missions. Operational experience has highlighted some shortcomings of our ships in coping with the rigors of cold weather and icing conditions. Accordingly, an Arctic/Cold Weather Program for Surface Ships was initiated in 1985 to investigate methods for improving operational capability under these conditions.

INTRODUCTION

The United States Navy's Arctic/Cold Weather Program for Surface Ships was undertaken in July of 1985 at the direction of the Deputy Chief of Naval Operations for Surface Warfare. He recognized the need for providing the Fleet with the necessary instructions and hardware to operate ships in Northern Latitudes, in accordance with the Navy's Maritime Strategy. The impact of cold weather and topside icing were recognized as problems that the Fleet must be prepared to cope with in order to operate safely and successfully in Arctic regions. Responsibility for this program was assigned to the Ship Survivability Program Office under Captain Robert K. Barr, with Mr. James U. Kordenbrock as Staff Assistant.

A Ship Characteristics and Improvement Board Working Group (SCIB) was then established to implement this program. Representatives from all cognizant Navy departments were then assigned to this group to provide guidance and recommendations for carrying out the program. This group has met on a monthly basis since its inception.

Operational experience with a number of our surface combatants in recent times has highlighted some of the shortcomings of our ships in operating under the rigors of cold weather and icing. During a 1984 ASW operation in the north Atlantic, our ships experienced some difficulties with cold weather and icing conditions, particularly in high sea states. Although snow and ice events were minimal, their handling and removal highlighted some potential problems that could occur under more severe cold weather conditions. During the same year, two of our combatants visited an ice covered port in the Gulf of Finland and required assistance in reaching the port. In another incident in early 1985, the USS CAPADONNO was iced over during an ice fog off the Virginia Capes. Figures 1 and 2 show some of the topside icing that accumulated on the CAPADONNO. This incident highlighted the fact that severe icing could occur even off the Eastern coast of the United States. There have been numerous other incidents of rough weather and icing effects on our ships that emphasize the need for methods to cope with these problems.

ENVIRONMENTAL THREATS

The major environmental threats that this cold weather program must face include:

- Cold weather
- Topside icing
- Heavy seas
- Floating ice

Figure 3 amplifies on these threats and indicates the interrelationship between them.

OBJECTIVE

The objective of the Arctic/Cold Weather Program is to ensure that the surface navy can operate in an Arctic environment and that it can function as required to maintain its military effectiveness. Although the top level requirements of most of our ships require their operation in cold weather and heavy sea states, we must be explicit in defining these conditions to ensure adequate applications based on current knowledge. The resultant topside icing from ship generated spray could become a serious threat to the operation of the ship.

APPROACH

The approach to be followed in carrying out this program is to focus on the following tasks:

1. Establish operating limitations of existing ship classes.
2. Investigate, recommend, and implement improvements to existing ship classes.
3. Recommend specific design improvements

for new ships.

4. Implement Navy-wide training in cold weather operations.

5. Conduct the program within reasonable cost constraints.

Because it is considered expedient to operate in Arctic areas, the capabilities of existing ship classes in this environment must be established. Adequate instructions and proper equipment must be made available to the Fleet to permit maximum operational usage of our assets. Introduction of readily applied improvements to various ship systems could effectively extend these capabilities. New ship design requirements would then be formulated to provide an increased Arctic capability for newly constructed ships.

In the short term, it is considered expedient to transmit operating procedures and equipment preparation requirements to the Fleet in the form of training films and documents so that ship's crews will be prepared for most cold weather eventualities. Included in these instructions must be effective human factors considerations, including clothing and physical well-being.

Due to the accelerated initiation of the program and the lack of initial funding, it is necessary to conduct the program within reasonable cost constraints. Fortunately, a wealth of information is already available so that much progress can be made with this existing material.

We recognize, for example, that the Coast Guard has a large amount of experience in operating in both the Arctic and Antarctic and that this experience must be applied to the Navy's operations. Similarly, other nations, notable the Canadians, British, and Japanese have cold weather experience that is proving useful to us. We have representatives of both the Canadians and British on our Working Group. Following the application of known data, the resulting shortfalls in our knowledge will be investigated, as required, in various research and development activities.

CURRENT ACTIVITIES

A number of important tasks have been undertaken to date. A review of existing Navy programs has been made. Our Navy Laboratories have been looking at various low ice adhesion coatings, ice removal methods, hull plating resistance to ice impacts, and tactical decision aids for minimizing effects of sea state and spray by varying ship course and speed. The results of these and other efforts, as well as information from other sources, will be utilized to provide improvements in todays ships.

Additional undertakings have included an Arctic Surface Ship Symposium held in December of 1985 to exchange information among cold weather experts on various aspects of Arctic operations of surface ships. Valuable guidance was also provided for the overall Management Plan. Over 120 participants attended this two day event. An ASW deployment into the North Atlantic was also utilized for our benefit by placing observers on board several of the ships and conducting several material coating experiments. In April of 1986 a large contingent of Naval military and civilian personnel participated in a deployment into the Bering Sea on the U.S. Coast Guard Icebreaker POLAR SEA to investigate specific problems relating to surface ship operations. Figure 4 is a photograph of the POLAR SEA. The following tests were undertaken in the marginal ice zone during this deployment:

- o Collect ice impact load data on an instrumented bow panel.
- o Measure propeller ice impacts at the ice edge.
- o Record ship performance in broken ice.
- o Document topside icing events.
- o Evaluate anti-icing coatings and de-icing equipment.
- o Compare location of first ice encounter with forecasted ice edge.
- o Characterize the marginal ice zone.
- o Evaluate various items of cold weather clothing.

This three week deployment was considered very successful, and results are now being compiled and will be issued in a detailed report.

In January or February of 1987, a Ship Icing Experiment is planned wherein a ship at anchor will be subjected to sea water spray to simulate at-sea icing conditions. This experiment will permit the use of a controlled environment to evaluate the impact of icing on combat systems, hull and deck machinery, and helicopter support systems. Methods for anti-icing and de-icing ship's superstructure will also be investigated.

CONCLUSIONS

As a result of the efforts conducted to date on the Arctic/Cold Weather Program, the following conclusions may be made:

- o The program is organized and functioning well.
- o There is a need for providing an awareness of Arctic requirements to the Navy community.
- o Interest in Arctic ship operations must be actively pursued.

- o Solutions to important operating problems must be investigated and results disseminated.

- o Training documents and films must be provided to the fleet.

- o Immediate results are necessary to provide vital fleet improvements.

- o Existing fleet cold weather documents must be updated.

The importance of this Arctic program and the support it has received indicate that it will continue for the next few years in order to provide the necessary cold weather operational data and support to the fleet.

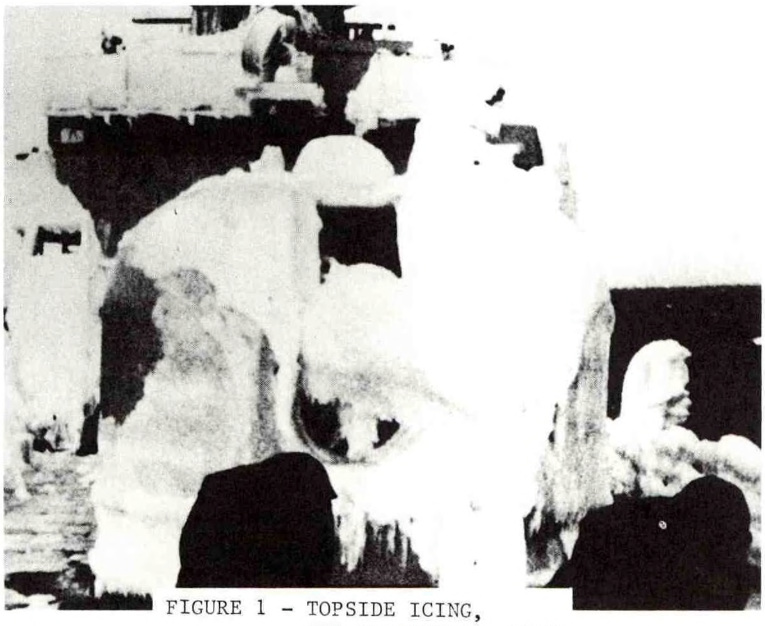

FIGURE 1 - TOPSIDE ICING, USS CAPADONNA - 1985

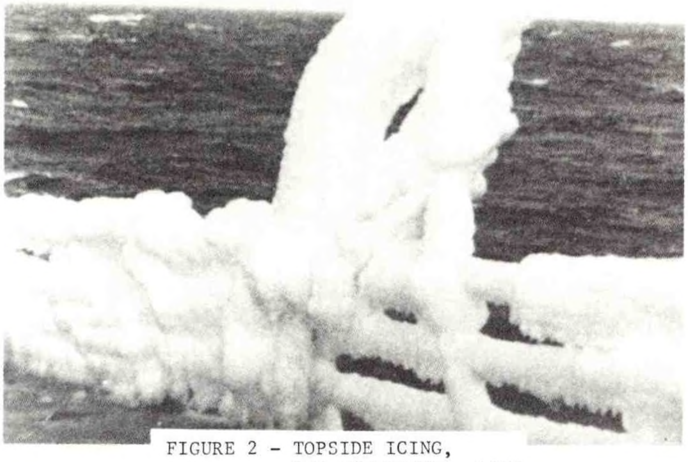

FIGURE 2 - TOPSIDE ICING,
USS CAPADONNO - 1985

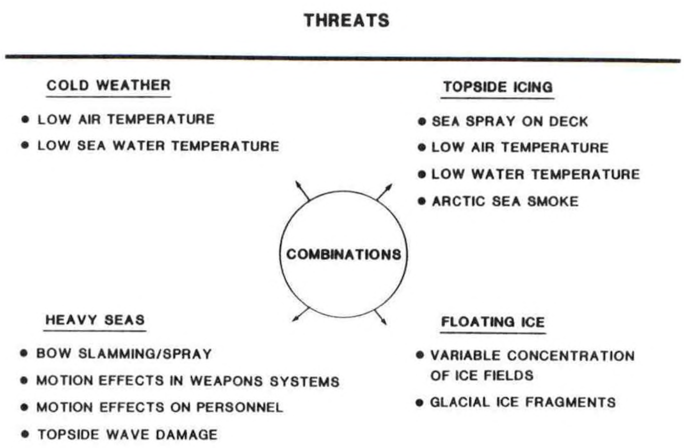

FIGURE 3 - ENVIRONMENTAL THREATS

FIGURE 4 - USCGC POLAR SEA

MODEL TESTING OF USCG FAST PATROL BOATS

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ABSTRACT

The resistance and seakeeping characteristics of two comparable fast patrol boat designs were measured in a towing tank. One design is for a 110 Ft. WPB with a length to beam ratio of about 4.0. The other design is for a 120 Ft. WPB with a length to beam ratio of about 5.5. The resistance divided by the displacement weight of the 120 Ft. WPB is consistantly lower than that of the 110 Ft. WPB at all volume Froude number tested. The seakeeping of the 120 Ft. WPB is also somewhat better than that of the 110 Ft. WPB at both displacement and planing speeds.

INTRODUCTION

The Naval Sea Combat System Engineering Station in Norfolk, Virginia completed a feasibility design study of two versions of a high speed patrol boat for the USCG Office of Research and Development in June 1983. One of the boats is a 110 Ft. (33.5 m.) WPB*, the other is a 125 Ft. (38.1 m.) WPB. Both designs have double chine planing hulls. The Outboard Profile, Plan View, and Body Plan for the 110 Ft. WPB are shown in Figure 1. Table 1 gives some of the principal characteristics of the design.

More recently, in December 1985, the USCG Office of Engineering completed a conceptual design study for a 120 Ft. (36.6m.) WPB (1)**. This design is described elsewhere in these proceedings, as well as in reference (1). The Outboard Profile, Plan View, and Body Plan for the 120 Ft. WPB are shown in Figure 2. Table 2 gives some of the principal characteristics of the design. Note that this design also has a double chine planing hull. We decided to attempt to validate the procedures used to predict the performance characteristics of these designs.

Note: * WPB is the USCG designation for a patrol boat.

** Numbers in parentheses refer to references which are listed at the end of this paper.

The Contracting Officer was requested to solicit proposals from prospective contractors to conduct a planing hull model test program on 3 April 1984. Part II of the Statement of Work for this solicitation required the testing of the two high speed patrol boats designed by the Naval Sea Combat System Engineering Station. The objective of Part II - Notional WPB Design Tests - was to verify the predicted resistance and seakeeping characteristics of the WPB designs. Provision was made to allow the Coast Guard to substitute a different WPB design for one of the two Navy designs.

The solicitation was issued on 16 August 1984, and a contract was awarded to the Davidson Laboratory, Stevens Institute of Technology, Hoboken, New Jersey to perform the model testing on 3 September 1985. Since the USCG 120 Ft. WPB design was well established at the time the contract was awarded, it was decided to substitute the USCG 120 Ft. WPB design for the Navy 125 Ft. WPB design. Model testing began in March 1986. This paper presents preliminary results for the resistance and seakeeping characteristics of the patrol boat designs shown in Figures 1 and 2.

DESCRIPTION OF THE MODELS

The models are models of the bare hull. They are made of fiberglass to a scale ratio of 1/18. The fiberglass lay-up consists of a gel coat, and three layers of fiberglass cloth and epoxy resin. The models have decking, and bulkheads at every station. The decking and bulkheads are made from 1/8 inch (3.18 mm.) marine plywood. Internal longitudinal platforms are made from 3/8 inch (9.53 mm.) marine plywood.

Particular attention was given to the construction of the chines, so as to assure a clean separation of the water from the model at the chines. The angles at the chines and keel are sharp - not rounded. The exterior finish is smooth, and white in color. The chines and keel have transverse black markings to assist in the determination of wetted lengths and areas. The 120 Ft. WPB model has a spray strip as shown in

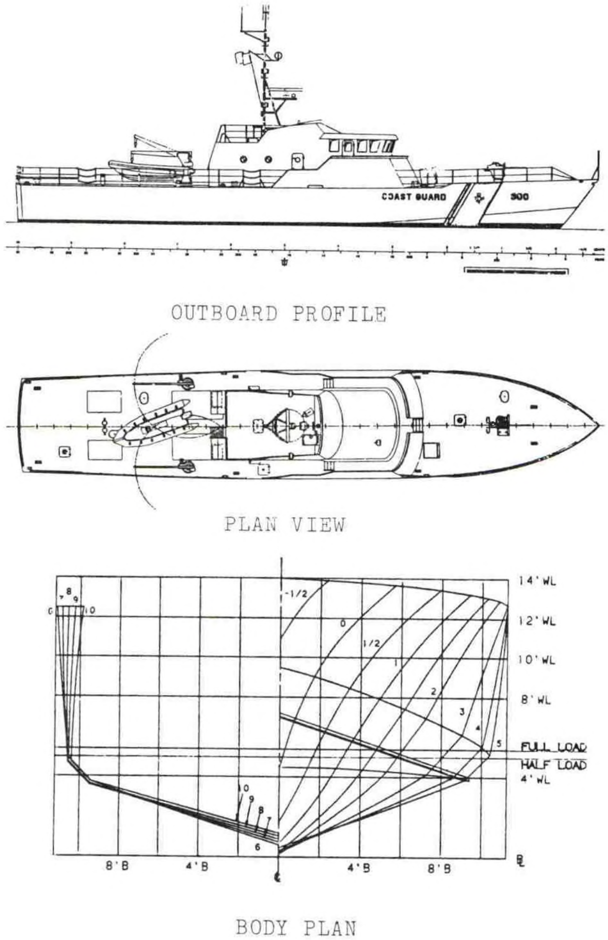

Figure 1. 120 Ft. WPB

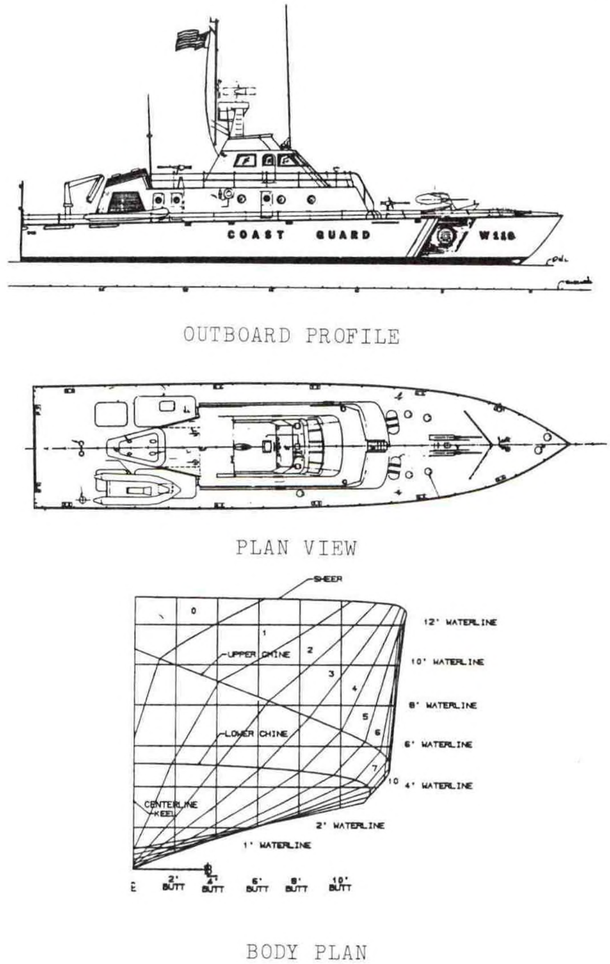

Figure 2. 110 Ft. WPB

TABLE 1.

PRINCIPAL CHARACTERISTICS

Length Overall	118.8 Ft. (36.2 m.)
Waterline Length	110.0 Ft. (33.5 m.)
Beam, Maximum	22.5 Ft. (6.86 m.)
Beam, Lower Chine	19.0 Ft. (5.79 m.)
Displacement, F. Load	157.0 L. Tons (159.5 Tonnes)
Speed, Max. Cont.	30.0 Knots
Speed, Economical	12.0 Knots
Endurance	5.0 Days

TABLE 2.

PRINCIPAL CHARACTERISTICS

Length Overall	110.0 Ft. (33.5 m.)
Waterline Length	104.0 Ft. (31.7 m.)
Beam, Maximum	26.3 Ft. (8.02 m.)
Beam, Lower Chine	22.3 Ft. (6.80 m.)
Displacement, F. Load	140.3 L. Tons (142.5 Tonnes)
Speed, Max. Cont.	29.4 Knots
Speed, Economical	10.0 Knots
Endurance	7.0 Days

the Body Plan in Figure 1.

The models were ballasted to achieve a condition of dynamic, as well as static, similitude between the model and the full size WPB, in accordance with Froude's law of scaling. Static similitude was obtained by modeling the half load displacement. Dynamic similitude was obtained by modeling a radius of gyration which was equal to 25 percent of the waterline lengths given in Tables 1 and 2. The 110 Ft. WPB was ballasted to model a full size displacement of 119 l. tons (120.9 tonnes) at a longitudinal center of gravity 37.1 feet (11.3 m.) forward of the aft perpendicular. The 120 Ft. WPB was ballasted to model a full size displacement of 135 l. tons (137.2 tonnes) at a longitudinal center of gravity 42.9 feet (13.1 m.) forward of the aft perpendicular.

DESCRIPTION OF THE TEST FACILITIES

The tests were conducted in the high speed towing tank at the Davidson Laboratory. This tank is 317 feet (96.6 m.) long, 12 feet (3.66 m.) wide, and 5.5 feet (1.68 m.) deep. There is a rigging dock at one end of the tank and a wavemaker at the other end. Waves generated by the wavemaker are absorbed by a large rectractable beach which is located between the tank and the rigging dock.

The towing carriage runs on a monorail which is 3 feet (0.91 m.) above the water surface and is cable driven at speeds from 0 to 100 feet per second (30.5 m./sec.). The drive control includes a digital feedback loop which keeps the towing carriage speed constant to within 0.1 feet per second (0.03 m./sec.).

A camera carriage travels with the model to provide visual coverage of the tests. All runs are monitored and recorded by means of a closed circuit television system. Underwater photographs of the model are taken through a surface piercing box using an automatic camera and a special 8 foot (2.44 m.) by 4 foot (1.22 m.) mirror. Synchronized underwater flash units are triggered by the passage of the model. This system is used to take underwater photoghaphs of the wetted area of the hull when calm water resistance tests are run.

A new, double flap, wet back, hydraulically driven wavemaker has been installed in the towing tank. This wavemaker is computer controlled and can produce regular and irregular waves. Although a train of irregular waves is a random phenomenon, for testing purposes the wavemaker reproduces the same train of waves to order. This assures that the seakeeping behavior of two different models is compared in exactly the same sequence of waves.

The principal transducer incorporated into force balances, accelerometers, etc., is the linear differential transformer. This device is a rugged high signal level transducer which has no sliding contacts, and therefore does not affect model motions.

During routine testing, up to 24 channels of information can be processed. The signals from the measuring equipment are carried by overhead cable to shore based amplifers. They are then carried to adjustable active band-pass filters, and in parallel to ultra-violet oscillographs and to a PDP 8e computer with an analog to digital front end converter and digital recording. Permanent analog time histories and digital records of each run are maintained together with associated video tapes. Tank data is available upon completion of each test run. Data summaries are listed every four hours.

TEST PROGRAM

The calm water resistance of each model was determined for speeds corresponding to volume Froude numbers of from 0 to a little over 5. Particular attention was given to determining the humps and hollows in these curves.

The models were free to trim and heave, but fixed in yaw, roll, surge, and sway. The trim and heave of the models were measured, along with the resistance, at each test point. The models were unloaded to compensate for the vertical component of propeller thrust. Underwater photographs were taken of the wetted areas on the models during each test. The wetted area, and the wetted keel and chine lengths were determined from these photographs.

Seakeeping was studied at the economical cruising speed (10 knots) as well as at planing speeds. Throughout the seakeeping test program the models were free to pitch and heave, but fixed in yaw, roll, surge and sway.

Response Amplitude Operators (RAOs) were measured for the pitch and heave motion of the models in regular waves at the cruising speed. A wave measuring devise was located in such a position as to measure a representative sample of the waves the model was traveling through when the ship motions data was taken. The waves had an International Towing Tank Conference standard steepness ratio of 1/50. The resistance in waves was measured. Data was taken for 10 wave encounters in head seas.

The principal of linear superposition does not apply to the motions of planing boats at planing speeds. Seakeeping must be determined statistically. Each model was run in random waves corresponding to a

Pierson-Moskowitz wave spectra. The same pattern of "random waves" was run for each model. The pitch and heave of the models were measured and RAOs calculated. Vertical accelerations were measured at five locations along the centerline of the model. The resistance in waves was also measured. A wave measuring device was located in such a position as to measure the waves the model was traveling through when the motion data was taken.

Data was taken at speeds corresponding approximately to 25, 50, and 65 knots, in spectra that had significant wave heights that were 40 and 60 percent of the beam of each model. 70 wave encounters were obtained for each test condition.

RESULTS AND CONCLUSIONS

The results presented in this paper are preliminary. Testing was completed in April 1986, but the data is still being analyzed. A formal report will be written.

The calm water resistance of the two WPB designs is presented in Figure 3. Note that the curves have two humps. The first hump occurs when the boat begins to plane. The second hump may be related to the inception of flow separation from the lower chine. All of the data must be analyzed before this can be determined.

The 110 Ft. WPB begins to plane at 23 knots, the 120 Ft. WPB at 25.5 knots. Planing is defined as the speed at which the center of gravity of the boat begins to rise above its still water elevation.

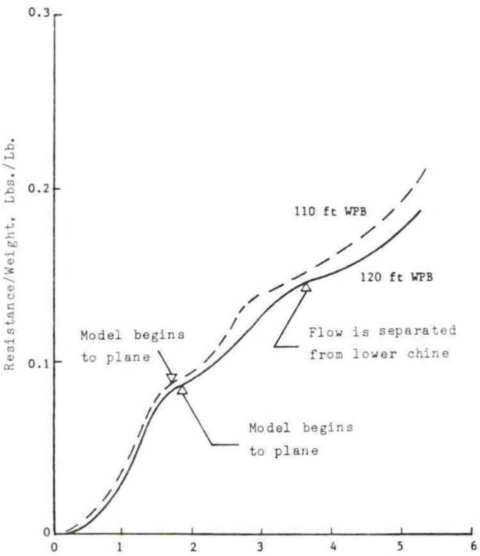

Figure 3. Calm Water Performance.

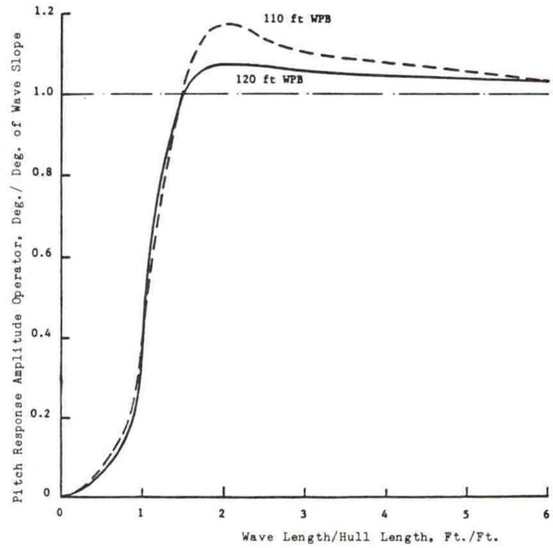

Figure 4. WPB Pitch Response at 10 Knots.

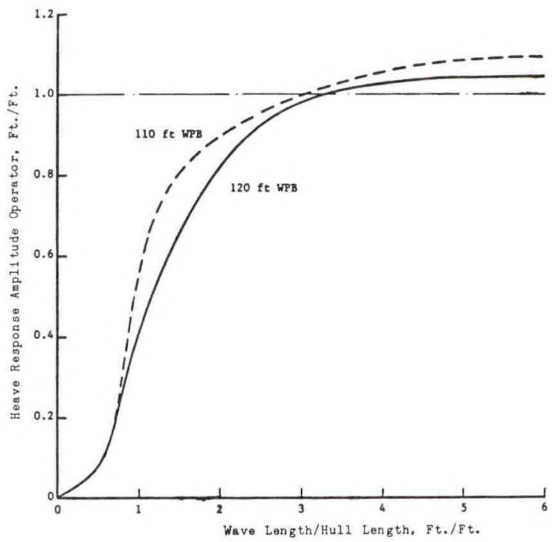

Figure 5. WPB Heave Response at 10 Knots.

The pitch and heave RAOs for both WPBs cruising at 10 knots into regular head seas are given in Figures 4 and 5. Pitch resonance occurs at a wave length that is about twice the hull length. Heave resonance is not well defined. The seakeeping of the 120 Ft. WPB is somewhat better than that of the 110 Ft. WPB.

Figure 6 shows the experimental spectra that were used in the 120 Ft. WPB irregular, head seas, seakeeping tests. The corresponding parent Pierson-Moskowitz spectra are also shown in Figure 6. The spectra with a significant wave height of 8.5 feet (2.59 m.) represents a low sea 5 on the World Meteorological Organization scale. The spectra with a significant wave height of 12.7 feet (3.87 m.) represents a high sea state 5. Therefore, in some sense, these two spectra bracket a range of conditions that might be encountered in a sea state 5. Similar charts exist for the 110 Ft. WPB tests.

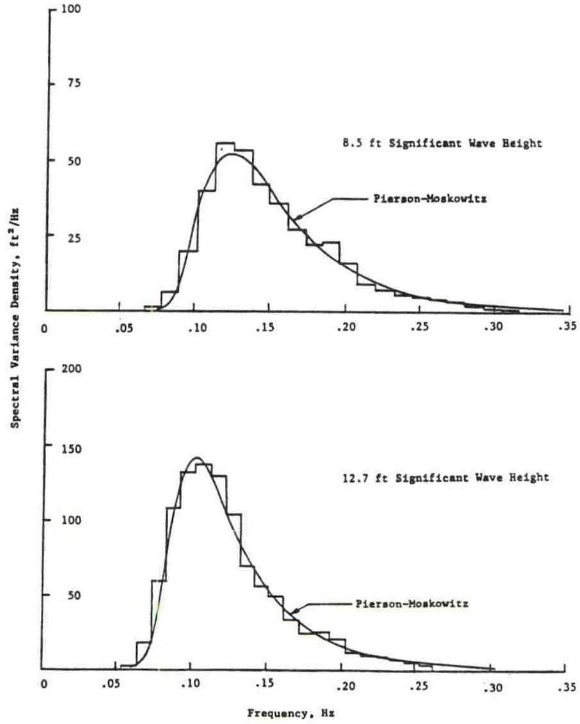

Figure 6. 120 Ft. WPB Test Spectra.

The significant accelerations measured for the 110 Ft. WPB are shown in Figure 7, while those measured for the 120 Ft. WPB are shown in Figure 8. The significant acceleration is the average of the one third highest accelerations measured for a given test condition. The significant acceleration at the center of gravity of both boats is on the order of 1g. This is high and indicates that the boats would have to voluntarily reduce speed in a sea state 5, unless the crew was isolated from the adverse effects of the boat motions.

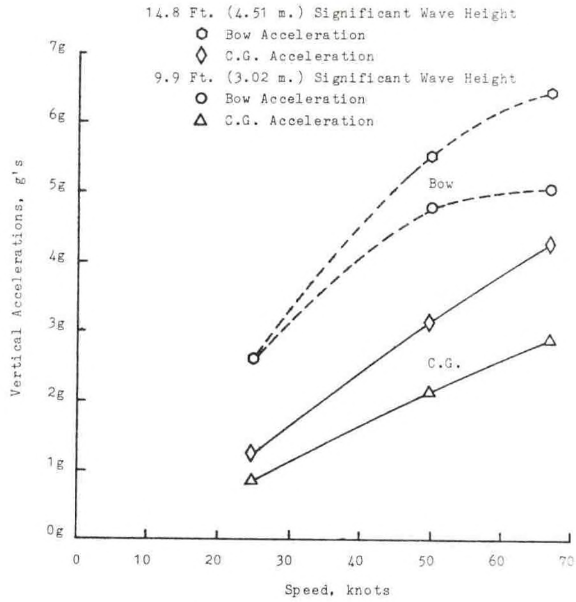

Figure 7. Significant Accelerations for the 110 Ft. WPB.

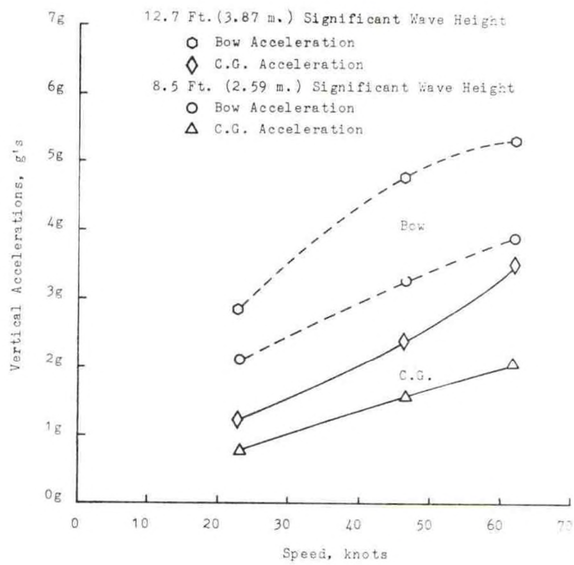

Figure 8. Significant Accelerations for the 120 Ft. WPB.

ACKNOWLEDGEMENT

This paper would not have been possible without the efforts of Mr. Peter Ward Brown, Mr. Walter E. Klosinski, and others at the Davidson Laboratory. They accomplished the testing described in this paper and furnished the author with Figures 3 through 8.

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1. Cohen, S. H., et. al., "United States Coast Guard Conceptual Design of an Offshore Patrol Boat", Trans. of Symposium, "Patrol Boats '86", ASNE and USCG March '86.

ELECTRIC PROPULSION SYSTEM OF SUPPORT VESSEL FOR UNDERWATER WORK EXPERIMENTS

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1. Introduction

Having little natural resources on land, Japan pins much hope on marine resources. She considers it, therefore, an urgent task to search for mineral deposits in continental shelves, secure energy sources and biological resources available from the sea, and to utilize ocean space. To carry out large-scale exploitation of natural resources in continental shelves, a high-performance specialized experimental vessel was urgently needed to support exploratory work in the sea and on seabeds. This vessel would help establish new diving techniques and achieve highly precise test results in various research and developmental projects and oceanographic surveys.

Based on the above circumstances, the Japan Marine Science and Technology Center (JAMSTEC) has built SSC (Semi-Submerged Catamaran) type Support Vessel for underwater work experiments. This ship has the function as a diver's support craft equipped with a submersible decompression chamber (SDC), a deck decompression chamber (DDC) and dynamic positioning system (DPS).

This ship has adopted the electric propulsion system of AC-AC-CPP type which is most suitable to SSC type ship with this kind of purpose. This paper describes the outline of electric propulsion system.

2. Outline of the Ship

This ship is as shown on the Fig. 1 and the brief descriptions are as follows;

1) Principal Particulars

Length b.p.	53.0 m
Breadth mld.	28.0 m
Depth mld.	10.6 m
Maximum draft	6.3 m
Navigation area	ocean/international
Gross tonnage	about 2,800 tons
Main propulsion system	
main generators	1,250 KW at 1,200 rpm x 4
prime movers to above	1,850 PS at 1,200 rpm x 4
Main propulsive motors	4 sets
rated output	4 x 860 KW
normal output	4 x 760 KW
Service speed under full load	about 12 knots

2) Main Intended Purposes

Research and development of manned underwater work technology

Research and development of deep ocean floor survey systems

Research and development of very fine scale deep-sea investigation systems

Research and development of data acquisition and monitoring systems

Pre-research for manned subsea research vessels

Group training and education on board

3) Special Equipment

Submersible Decompression Chamber (SDC) System Cylindrical SDC (for saturation diving to water depth of 300 m) .... x 1 set

Spherical SDC (for saturation diving to water depth of 300 m and atmospheric pressure diving for observation to water depth of 500 m) .... x 1 set

Deck Decompression Chamber (DDC) System

Living chamber .... x 2 sets

Transfer lock .... 1 set

Dynamic Positioning System (DPS)

Thrust units	:	Main propellers and bow and stern side thrusters
Control modes	:	Manual, semi-automatic, fully automatic and deep-sea automatic

Precise Navigation System

Radio navigation systems	:	Hybrid navigation functions combining satellite navigation system, Loran C system, and Decca system
Microwave positioning system	:	Range between master and slave stations is measured
Acoustic positioning system	:	Positioning function by supershort baseline system and long baseline system, based on sonic transponders installed on seabed

Multi-narrow beam echo sounder

High resolution bathymetric survey system

Meteorological system

Other oceanographic instruments

3. Electric Power Distribution System

The elementary electric power distribution system is shown on Fig. 2. As for the ship's electric power source, four (4) sets of main generators and one (1) set of auxiliary generator are installed.

The number of running generators shall be selected properly based on the load condition, and however, four (4) sets shall be run in parallel during ship dynamic positioning for the diving work, as a rule. The sufficient electric power can be supplied for the work, even if one set of four generator sets is out of order.

The electric power distribution system is of A.C. 440V, 60 Hz, 3 phases and 3 wires.

The main switchboard is adopted with split bus bar system and the generator panels are arranged in center of the switchboard. The constitution of the switchboard is as follows;

1) Generator Panel : 4 sets

Each panel is equipped with 1-air circuit breaker (magnetic operated type), 1-ammeter, 1-voltmeter, 1-power factor meter, 3-over current relays, 1-reverse power relay, 1-automatic voltage regulator, etc.)

As common use for 4-generator panels in addition to the above, 1-automatic synchronous device, 1-automatic load ballancing device and 1-automatic release device of abnormal set are provided.

2) Main Propulsion Panel : 2 sets

For the electric power supply to port and starboard propulsion motors, each panel is equipted with 1-air circuit breaker, 1-amperemeter, 1-electric power meter, etc.

3) Thruster Panel : 2 sets (1-port, 1-STBD)

For the electric power supply to eight thrusters of port and starboard, each panel is equipped with 4-moulded case circuit breakers, 4-ammeters, 4-electric power meters, etc.

4) 440V Power Panel : 3 sets

For the electric power supply to the various 440 loads, each panel is equipped with moulded case circuit breakers, voltmeter ammeter, etc.

4. Generating Set and Power Machines

4.1 Generating Set

Four (4) sets of generator are installed to feed electric power to propulsion motors, thrusters and other consumers and the principal particulars are as follows;

1) Prime-mover

Type	: V-type, 4 cycles, single acting super charged diesel engine
Rated out-put	: 1,850 PS
Revolution	: 1,200 rpm
No. of cylinder	: 16

2) Generator

Type	: Drip-proof, horizontal, self ventilated
Rated out-put	: 1,250 KW
Voltage	: A.C. 450V
Power factor	: 0.8
Excitation	: Brushless rotary excitor
Rating	: Continuous
Insulation	: F class

The generating sets can be controlled remotely from the control console in addition to the local controls.

4.2 Propulsion Motors and Control Devices

The ship shall be propelled by two propellers with 4-blades which installed in port and starboard 1 each as shown on Fig. 3.

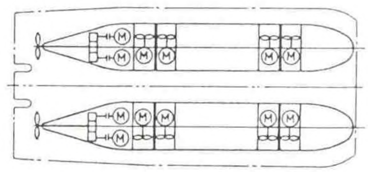


Fig. 3 Arrangement of propulsion and thruster motors

1) Electric Motors

Each propeller is driven by two induction motors through clutches and reduction gear.

The principal particulars of the motor are as follows;

Type	: Horizontal, totally enclosed cage type
Cooling	: Sea water - air cooled
Out-put	: 860/230 KW
Revolution	: 1,200/600 rpm (6 poles/12 poles)
Rating	: Continuous
Insulation	: F-class

Special attentions for designing the motors are paid on the followings;

(1) Matching slip characteristics of motors to balance load sharing.

(2) Adopting two speeds-motor to reduce cavitation noise of propellers underwater.

2) Control Gear

The control gears of propulsion motors are adopted with the reduced voltage starting method and have three running modes, i.e., DPS mode, low-speed navigation mode and high-speed navigation mode.

4.3 Thruster Motors and Control Device

As shown on Fig. 3, two bow thrusters and two stern thrusters are installed on each side lower hull, totally eight thrusters, and the type of each thruster is tunnel type with CPP.

1) Electric Motors

The principal particulars of the motors are as follows;

(1) For bow thrusters

Type	: Vertical, totally enclosed, cage type
Cooling	: Sea water - air cooled
Out-put	: 430 KW
Revolution	: 1,200 rpm
Rating	: Continuous
Insulation	: F-class
No. of set	: 4

(2) For stern thrusters

Type	: Vertical, totally enclosed, cage type
Cooling	: Self-ventilation by external fan
Out-put	: 250 KW
Revolution	: 1,200 rpm
Rating	: Continuous
Insulation	: F-class
No. of set	: 4

Each motor is provided with temperature sensors in the windings and monitored from the engine control room.

2) Control Gear

The control gears of thruster motors are adopted with the direct on line starting method and have interlocking devices which allow the starting of motor only when the CPP is on neutral position.

5. Postscript

This ship is of high grade and sophisticated as described before. And prior to building the ship, the special committee was established to investigate, discuss and decide many various items. Especially, from the view point of keeping divers safe during their underwater works, the electric propulsion system and the dynamic positioning system of this ship were studied and discussed in detail, as well as the reduction of underwater noises from the ship. During the sea trials, the these items were verified satisfactorily and the ship was delivered to JAMSTEC on schedule.

Fig. 1 Bird's eye view of the ship

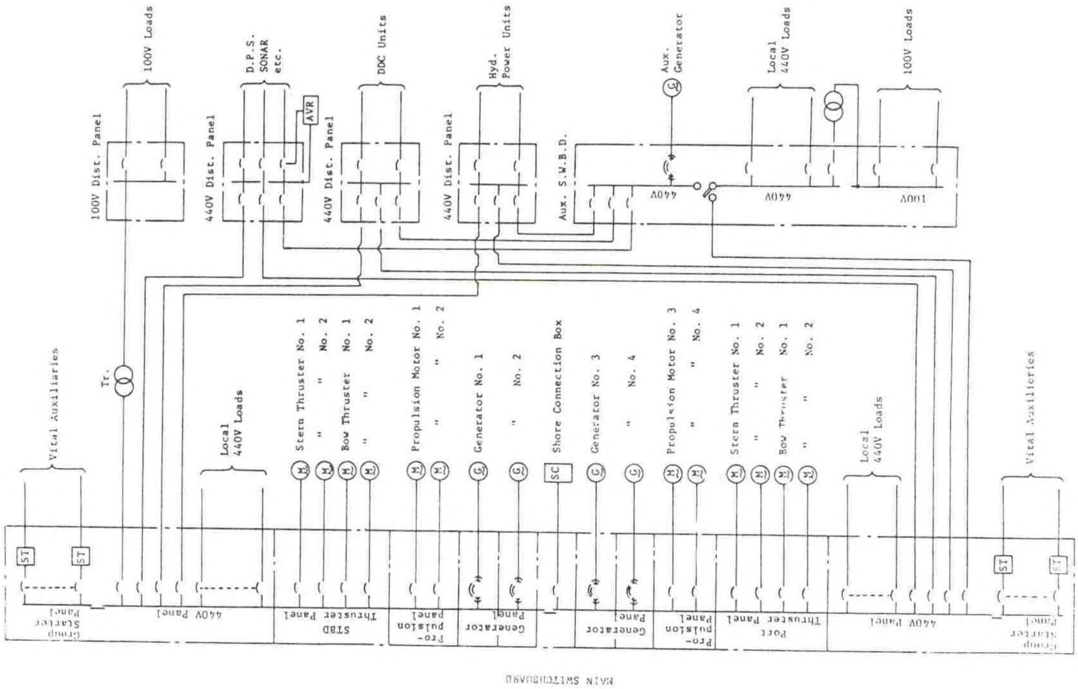


Fig. 2 Elementary one line diagram

Coastal Development / Ocean Space Utilization

A FIVE YEAR PROJECT TO DEVELOPE TECHNOLOGY FOR PRECISE INVESTIGATION OF COASTAL AREA

S. Motora
President
Nagasaki Institute of Applied Science

In view of probable coming into force of 200 miles economical zone, The Science and Technology Agency has been carrying out a five year project to develope technology and systems for precise investigation of coastal area. This year corresponds to the fourth year of the project. Outline of this project is as follows.

1 DEVELOPMENT OF HIGH RELIABILITY SENSORS

(1) Multiple sensor using optical fiber

a) Multiple sensor for measurement of sea-water temperature and pressure.

Both optical sensor and IC sensor combined with optical fiber have been tested with satisfactory results in both resolution and range.

b) Salinity and turbidity sensors

For the salinity sensor, difference of the index of reflaction, which will be less affected by temperature change, is used as the measure. As for turbidity sensor, a system suitable for ocean environment compareing intensity of scattered light and transmitted light is being developed.

Evaluation test of proto-type salinity sensor showed good linearity within the range of 0~40% and attained sensitivity is 0.02. As for turbidity sensor, linearity is maintained within the range of 0~100ppm, with sensitivity of 0.05ppm.

c) Development of optical fiber cable to be used in ocean environment

A trial model optical fiber cable was manifactured and is now being tested which consists of 0.6mmϕ quarts malti-mode fiber, Kevlar FRP as tension member, and ABS as pressure resistant. Outside diameter is 19.5mm, weight in air is 270kg/km, weight in water is 30kg/km.

It was shown by test that the cable stands for pressure of 100kg/cm^2, tension of 1.5ton and that minimum allowable radius of bend in 80cm.

(2) Development of ultra-sonic Doppler profiler for measurement of current speed

A Doppler profiler which will attain resolution of 50cm/s (at 1 knot) and 1.1cm/s (at 0.02 knot) and can measure current speed as deep as 400m is now being developed with satisfactory fundamental trial.

(3) Ocean acoustic tomography system (OAT)

A system to measure water temperature distribution in wide area using low-frequency sonic wave is now being developed.

It is estimated that if 2 sets of transmitters are used for an area of 300km square, the developed software will be capable of attaining resolution of 0.2°C when temperature difference within this area is of order of 1.5°C.

2 DEVELOPMENT OF DATA COLLECTING AND PROSESSING SYSTEM BASED ON MEASUREMENTS ON BOARD SHIPS AND BUOYS

Items included in this project are as follows ;

(1) Development and improvement of data collecting system

a) Investigation of respons of buoys in waves to improve performans of measurement of buoys

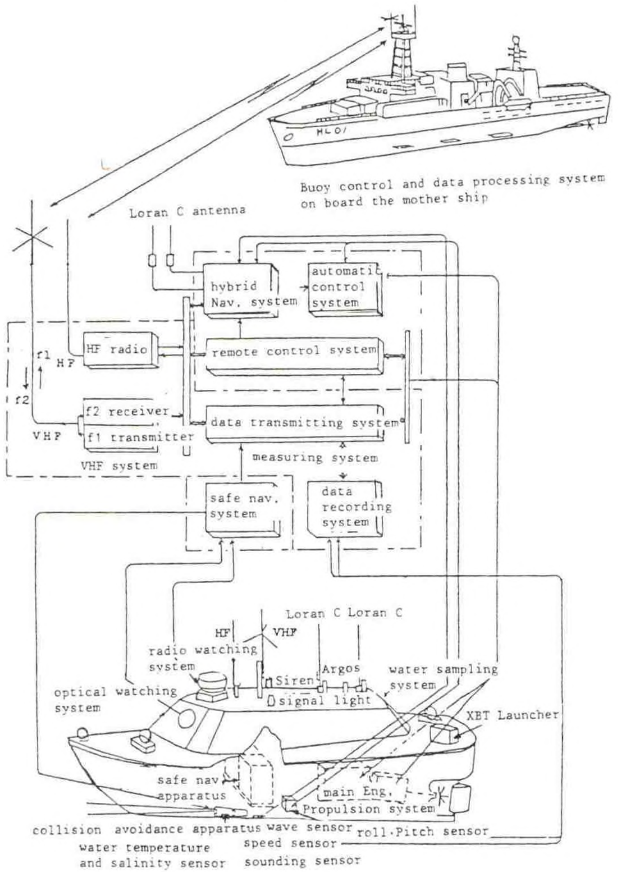
b) Utilizing solar energy to elongate buoy's life

c) Minimizing the size of anchored bouys and elongation of maintenance free period

d) Development of Self propelled and remote controlled buoys

A proto-type of self-propelled and remote conotrolled buoy was developed which can be used for measurements in dangerous area like a sub-sea volcano, and also can decrease man power to be necessary.

A scheme of the system is shown below.



e) Development of handy tools to measure and transmit data on surface temperature and salinity

3 DEVELOPMENT OF SYSTEMS FOR PRECISE MEASUREMENT OF SEA FLOOR TOPOLOGY AND STRATUM (FORMATION)

(1) It has been noticed that contour chart of an overlapped area measured by the sea-beam system in successive running does usually not coincide well due to mainly ray bending of sonic wave and in-accurate positioning. To overcome these difficulty, the following items were investigated ;

a) Correction of the effect of ray bending of sonic wave

b) Development of software to convert the co-ordinate fixed to the ship into the geodepic co-ordinate

Using the developed software, it was recognized that results of overlapped area agreed quite well, and that contouring (making mosaic) can be done very fast and efficiently.
An example is shown in the figures on the next page.

(2) Development of deep towed type seismic profiler

A seismic profiler of which only receiver system mounted by hydrophones and conbined with babble memory is towed near the sea bed, is being developed.

8 hours measurement can be done at offline state.

4 IMPROVEMENT OF RELIABILITY OF OBTAINED DATA AND IMPROVEMENT OF INTERCHANGEABILITY OF DATA

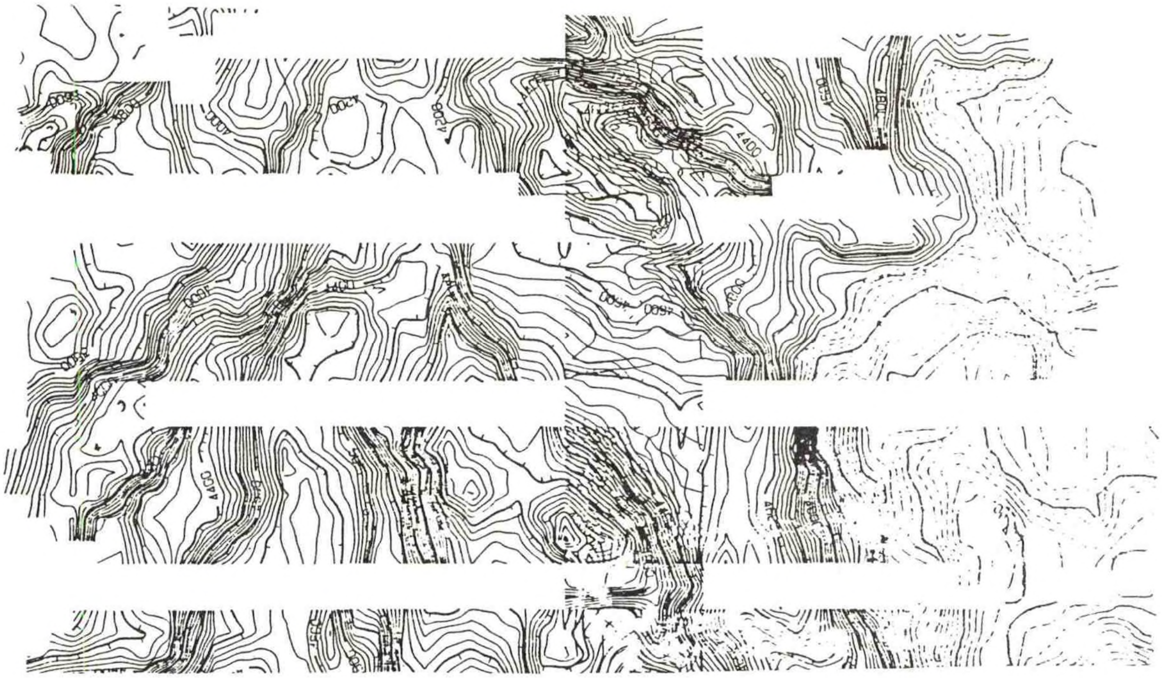
(1) Development of self calibulating system of sensors

a) Self calibulating system of an optical fiber sensor using the Brillouin scatter as the calibulating signal is developed.

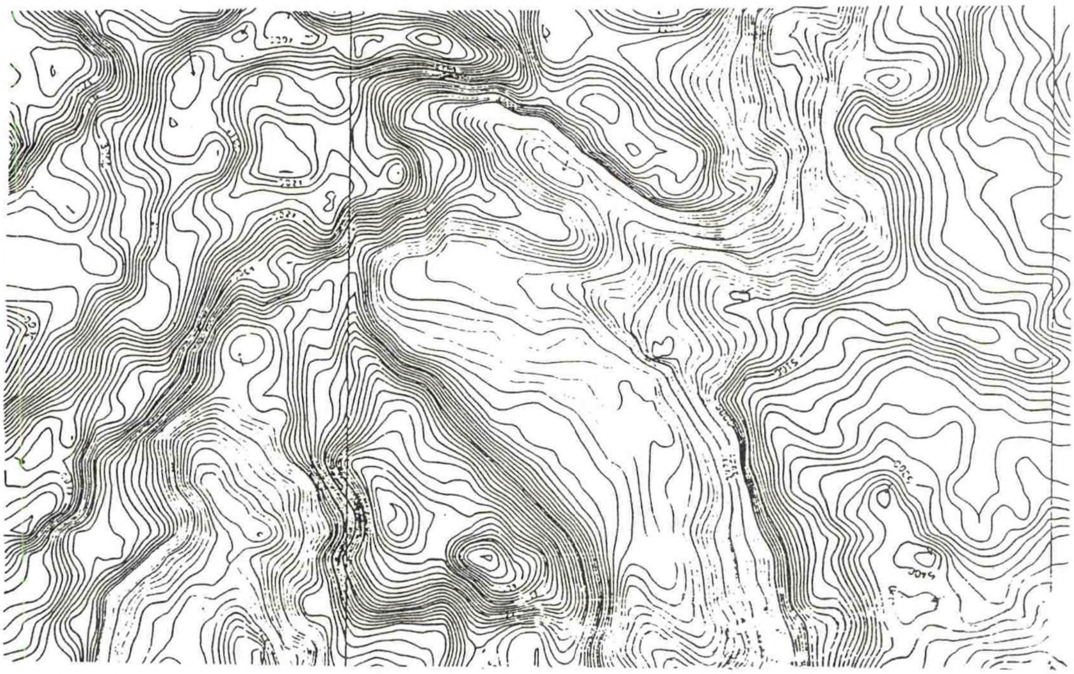
b) Calibulating electronics system for a sonic sensor to be fixed at sea bed is also developed.

(2) As for improvement of interchangeability of obtained date, though it will be ideal to standarize all the transmitters and recorders, it will not be practicable.

It is then suggested that development and use of tape readers of which output will be given in a standarized form would be one of the step to be taken to improve interchangeability of data.



An example of raw data obtained by successive running of the sea-beam system. Disagreement will be observed at an overlaped area between perpendicular running.



After the above data were treated by the developed software,i.e. ray bend of sonic wave is corrected, blanks are extrapolated, and faired.

MAJOR STUDIES BY THE NATIONAL ADVISORY COMMITTEE ON OCEANS & ATMOSPHERE

DETAILED BATHYMETRIC SURVEY DATA IN THE EEZ - THE CLASSIFICATION ISSUE

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ABSTRACT

The National Advisory Committee on Oceans & Atmosphere issued two major reports and three position papers between July 1, 1985 and June 30, 1986. The reports include the following: "Shipping, Shipyards and Sealift: Issues of National Security and Federal Support 1985" and "The Need for a National Plan of Scientific Exploration for the Exclusive Economic Zone." NACOA's three position statements, include one of the coastal Zone Management Act (CZMA) reauthorization, another on the data classification issue with respect to detailed bathymetric mapping on the Exclusive Economic Zone (EEZ), and one on acid rain. The findings of several of these studies and the recommendations made by the committee are presented and discussed below.

SCIENTIFIC EXPLORATION OF THE EXCLUSIVE ECONOMIC ZONE

Background

In its May 1984 report, "The Exclusive Economic Zone of the United States: Some Immediate Policy Issues," NACOA proposed the preparation of a coordinated Executive Branch plan of action, including participation and contributions by all appropriate public and private institutions, for an "expedition" of research, exploration, and survey of our EEZ. NACOA stated its intent to review the elements and the need for such a plan. In December 1984 a panel was formed with the goal of developing recommendations concerning this coordinated national plan. Accordingly, NACOA initiated a study that resulted in a report "The Need for a National Plan of Scientific Exploration of the Exclusive Economic Zone." The findings and recommendations contained in this report were approved in March of 1986.

The United States has vital concerns with respect to the scientific exploration of the Exclusive Economic Zone (EEZ) related to national security, resource development, environmental protection, and scientific inquiry issues. These concerns, exemplified by the President's EEZ Proclamation, point to the priority attention this region warrants.

Given the proper economic and political climate, the EEZ will provide the Nation with unique opportunities through the development of new industries, resources, and technologies that can lead to a significant increase in national economic growth. To take advantage of these opportunities, a national initiative is required that will jointly use the unique abilities of the academic, industrial, and governmental sectors.

The overall objectives of this study were to encourage the development of a coordinated, comprehensive 10-year program of scientific exploration, and survey of the U.S. Exclusive Economic Zone. It was not an objective to write the national scientific exploration plan but only to provide definition of important elements of such a plan.

A well-designed national plan for the development of scientific exploration of the EEZ should encourage private sector involvement and technological development, yet provide for environmental safeguards. Further, the elements of the national scientific exploration plan should be based on an analysis of the probable resources and uses of the EEZ with input from key public and private organizations. The completed plan should identify national priorities, gaps, and joint opportunities.

Given this background, the specific objectives of this study were to:

1) review the known resources that the EEZ has to offer to our Nation,
2) review the present components of our national EEZ scientific exploration, survey, and resource assessment efforts,
3) identify the elements of a national scientific exploration plan, and
4) make a series of recommendations for the development of an integrated and coordinated plan of action for the scientific exploration of the EEZ.

Findings and Recommendations

The present government EEZ effort is represented by a number of worthwhile programs which are making important contributions. However, NACOA finds that the present structure of programs, with each agency having objectives dictated by its own mission, is not acceptable. The benefits to the Nation could be extended by associating these efforts with a national plan. There is a need for a national scientific exploration program for the EEZ in order to satisfy data acquisition needs, reduce overlap, and increase fiscal responsibility. Such a plan would also provide a more certain environment for industry investment. There is no such plan now in existence nor is there any agency developing a coordinated plan. The general philosophy recommended by NACOA is to formulate a plan that builds on or redirects existing programs and activities and essentially does not require increases in Government resources and personnel.

For these reasons,

NACOA, RECOMMENDS, THE DEVELOPMENT OF A NATIONAL PLAN FOR THE SCIENTIFIC EXPLORATION OF THE EEZ, TO PROVIDE INFORMATION WHICH COULD ASSIST IN THE ORDERLY AND SAFE DEVELOPMENT OF THIS VAST REGION, INCLUDING THE FOLLOWING GOVERNMENT FUNCTIONS AND PROGRAM ELEMENTS.

1. GOVERNMENT FUNCTIONS:
   a. PROVIDE BASELINE ENVIRONMENTAL DATA,
   b. PROVIDE DATA AND INFORMATION FOR BROAD-SCALE RESOURCE AND POLICY EVALUATIONS,
   c. PROVIDE EFFECTIVE DATA AND INFORMATION MANAGEMENT AND EXCHANGE AMONG GOVERNMENT, INDUSTRY, AND ACADEMIA.
2. PROGRAM ELEMENTS:
   a. OCEAN BOTTOM MAPPING
   b. GRAVITY, MAGNETIC, SEISMIC MAPPING
   c. SEDIMENT CHARACTERIZATION
   d. SEA-SURFACE AND WATER COLUMN CHARACTERIZATION
      (1) BIOLOGICAL MAPPING
      (2) PHYSICAL DATA
      (3) CHEMICAL DATA
      (4) METEOROLOGICAL DATA
   e. DATA QUALITY AND INFORMATION MANAGEMENT

NACOA has reviewed the Nation's ongoing EEZ programs and activities, most of which are proceeding under the auspices of several agencies of the Federal Government. In total they represent a framework of an EEZ scientific exploration plan. In NACOA's review of these ongoing EEZ activities several observations were made:

- o NACOA fully supports the overall goals of the Secretary of Interior to develop an integrated and comprehensive scientific understanding of the EEZ. It further agrees with the U. S. Geological Survey (USGS) position that there is a clear and compelling need for basic scientific information concerning the resources and the geological process of the EEZ.
- o Of all the Federal, State, industry and special interest groups which gave briefings or other information to NACOA during its study of the EEZ, NACOA found the U. S. Geological Survey (USGS) is clearly the best organized and farthest along in the non-living resources aspects of the scientific exploration of the EEZ. The USGS has the necessary talent, personnel, and budget to lead a national scientific exploration effort.

NACOA, THEREFORE, RECOMMENDS THAT THE U.S. GEOLOGICAL SURVEY (USGS) BE GIVEN A CLEAR POLICY DIRECTIVE BY THE ADMINISTRATION TO LEAD THE FEDERAL EFFORT FOR SCIENTIFIC EXPLORATION OF THE EEZ. THIS POLICY DIRECTIVE SHOULD TAKE THE FORM OF AN OFFICE OF MANAGEMENT AND BUDGET (OMB) CIRCULAR TO THE HEADS OF EXECUTIVE DEPARTMENTS. IN GENERAL, THIS CIRCULAR SHOULD OUTLINE THE POLICIES AND PROCEDURES FOR THE COORDINATION OF ALL FEDERAL EXCLUSIVE ECONOMIC ZONE SCIENTIFIC EXPLORATION (EEZ) ACTIVITIES. SPECIFICALLY, THE DIRECTIVE SHOULD:

1. AFFIRM THE CENTRAL ROLE OF THE USGS WITH RESPECT TO EEZ SCIENTIFIC EXPLORATION,
2. CLARIFY THE RESPECTIVE RESPONSIBILITIES OF USGS, THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA), AND OTHER AGENCIES THAT HAVE IMPORTANT EEZ FUNCTIONS AND PROGRAMS,
3. ESTABLISH AN OFFICE WITHIN THE USGS TO COORDINATE THE SCIENTIFIC EXPLORATION OF THE EEZ. THE PRIMARY FUNCTIONS OF THIS OFFICE ARE TO WRITE A DETAILED 10-YEAR PLAN OF SCIENTIFIC EXPLORATION FOR THE EEZ AND TO DEVELOP AND COORDINATE THE IMPLEMENTATION OF THIS PLAN, AND
4. PROVIDE A MECHANISM FOR IDENTIFYING AND EVALUATING USER REQUIREMENTS IN A BALANCED AND INTEGRATED EEZ EXPLORATION PLAN.

The overall purpose of this OMB circular would be to integrate current and future scientific exploration efforts EEZ leading to the effective and economical accomplishment of mission requirements. In preparing, revising, and implementing the scientific exploration plan, the USGS EEZ Coordination Office will obtain the advice and assistance of the principal agencies, industry, and academic entities involved with EEZ scientific exploration activities. This lead USGS role recommended by NACOA will be one of coordination; and it is not intended to be autocratic. NOAA has an important EEZ leadership role regarding living marine resources and the physical sciences. NACOA believes that NOAA will take even more of a leadership role after the initial geological characterization of the EEZ has been completed by the USGS. NACOA thus believes that the excellent working relationship between the USGS and NOAA will not be adversely affected by the assignment of USGS to initiate this coordination role.

NACOA FURTHER RECOMMENDS THAT THE SECRETARY OF INTERIOR SHALL TRANSMIT TO THE PRESIDENT AND CONGRESS WITHIN ONE YEAR, THE USGS 10-YEAR EEZ SCIENTIFIC EXPLORATION PLAN WHICH INCLUDES:

1. THE IMPLEMENTATION STRATEGY FOR THE NATIONAL PLAN,
2. A COMPILATION OF THE PROGRESS IN EEZ SCIENTIFIC EXPLORATION ACTIVITIES OF THE FEDERAL AGENCIES,
3. A STATEMENT GIVING A CLEAR DEFINITION OF THE ROLES OF THE GOVERNMENT, THE PRIVATE SECTOR, AND ACADEMIA REGARDING EEZ EXPLORATION, AND

4. A REPORT ON HOW THE PUBLIC IS BEING INVOLVED IN EEZ SCIENTIFIC EXPLORATION PLANNING DECISIONS.

NACOA concludes that a national scientific exploration plan cannot be carried out without sufficient Congressional oversight.

NACOA THEREFORE URGES CONGRESS TO EXERCISE THE APPROPRIATE CONGRESSIONAL STRUCTURE TO ASSIST THE EXECUTIVE BRANCH IN THIS PROGRAM AND THUS HELP GUIDE THE NATIONAL EFFORT.

The volume of data acquired through scientific exploration of the EEZ must be made available to users on a timely basis. Existing data banks appear to be inadequate to process and catalog new data from the EEZ. Data archival and data management activities represent an important element of a national scientific exploration plan. Industry, academia, and private organizations should be encouraged to submit their EEZ data to NOAA. In addition, government agencies, and government funded private industry and universities should be required to submit these data to the NOAA national environmental data centers. Accordingly,

NACOA RECOMMENDS THAT NOAA ESTABLISH AN EEZ DATA MANAGEMENT OFFICE TO:

1. DEVELOP A COMPREHENSIVE SET OF QUALITY CONTROLLED DATA FOR THE EEZ, INCLUDING A COMPLETE ASSESSMENT OF THE CURRENT DATA BASE,
2. DEVELOP, IN CONCERT WITH THE USGS OFFICE OF THE FEDERAL EEZ COORDINATOR, DATA MANAGEMENT POLICIES AND PLANS, AND
3. ASSURE AVAILABILITY OF DATA TO EEZ USERS THROUGH A SPECIFICALLY DESIGNATED DATA ACCESS SYSTEM.

In other matters related to ocean science, NACOA provided several specific recommendations urging the preparation of a comprehensive research plan by the USGS with broad participation, improvement of data handling and processing systems and the establishment of an identified office to coordinate these activities.

DETAILED BATHYMETRIC SURVEY DATA IN THE EEZ - THE CLASSIFICATION ISSUE

Background

As part of its plans to survey the Exclusive Economic Zone (EEZ), the National Oceanic and Atmospheric Administration (NOAA) decided to develop detailed bathymetric maps of the ocean floor. This program uses high resolution mapping technology, producing information applicable to minerals exploration, fisheries management, and scientific research. The U. S. Navy believes that publication of certain of these data is contrary to their interests. The Navy views potential military uses by unfriendly nations as a reason to classify the NOAA data. As a result, the publication of these data and resulting products are currently in dispute.

The two major reasons for conducting the NOAA EEZ mapping program are the need for high quality bathymetric base maps to support economic development (i.e., oil and gas exploration and seabed mineral mining) and to form a data base for scientific research. New data will improve the quality of existing maps, especially offshore where measurements are sparse and the resolution of the data is poor due to former use of less sophisticated data collection and navigational positioning techniques. In addition, bathymetric mapping has become the major NOAA effort in the EEZ. NACOA was told, in January 1985, by the NOAA Assistant Administrator for the National Ocean Service, that the original (1984) NOAA position was that these data should be unclassified and freely exchanged. As the controversy continued, NOAA did agree, as part of a compromise, to a minimal level of classification. Proposed procedures for dissemination of the data are undergoing review at this time.

NACOA was also briefed by the National Operations Security Advisory Committee (NOAC) of the National Security Council regarding the Navy position and concerns on this issue.

According to NOAC, the detailed bathymetric data now being collected by NOAA and its derivative products, have potential military applications. Unrestricted release of data or products in an unclassified manner could seriously damage the national security interests of the United States. The Navy is expressly concerned over the prospects of an adversary power gaining access to bathymetric data that reveal in fine detail the features and characteristics of our whole EEZ. Charts proposed for publication do present a security threat for those regions of the EEZ with suitable topography. Given this concern, the NSB concluded that a conflict exists between a significant national security interest and other interests in allowing open dissemination of these charts at the highest resolution. One position suggested by NSB is to allow NOAA to issue products at full resolution in non-sensitive regions and filtered products (to an agreed threshold) in sensitive regions. The NSB concluded that some form of data management and dissemination control will have to be agreed upon between NOAA and the Navy in order to balance the possible compromise to security against the benefits accrued from legitimate unrestricted use of the data.

The NACOA Position

NACOA has identified multibeam bathymetric mapping as a potential element of a national scientific EEZ exploration plan. NACOA realizes that adopting restrictions on multibeam bathymetric mapping, or other types of scientific data in the EEZ, could impede free exchange of scientific information. Scientific progress of our Nation is based on such freedoms. NACOA has also considered the national security argument on this issue and finds it to be more compelling than the argument for free exchange of scientific information and consequently recommends that security, on balance, should prevail. Thus, NACOA concludes that only the controlled dissemination of the NOAA multibeam bathymetric data be allowed. NACOA understands that certain interest may be somewhat impeded by this position, but the Nation must first protect its national security.

NACOA THEREFORE RECOMMENDS THE WIDEST PRACTICABLE DISSEMINATION OF THE NOAA MULTIBEAM BATHYMETRIC DATA, CONSISTENT WITH THE REQUIREMENTS OF NATIONAL SECURITY. IN THIS REGARD, A DATA DISSEMINATION MECHANISM MUST BE FOUND TO ALLOW, ON A CONTROLLED SELECTIVE BASIS, THE RELEASE OF THE NOAA DATA TO SUPPORT VALID SCIENTIFIC RESEARCH AND INDUSTRY EXPLORATION.

ACID RAIN

Issue

There is widespread concern, extending beyond the United States, about the effects of acid rain on ecosystems, based primarily on documented evidence of damage to fish populations from the high acid content in certain lakes. There is also evidence of damage by acid rain to man-made structures and perhaps to forests. Furthermore, there is concern that the major sources that contribute to acid rain, especially in the northeastern United States, are associated with industrial centers, largely concentrated in the Midwest.

The commonly suggested solution, embodied in most legislative proposals, is to further limit the emission of sulfur dioxide, primarily from plants in the eastern half of the United States. However, there are significant costs associated with further abatement of emissions, and these costs would be concentrated in a few States.

Moreover, there is disagreement on the total damages attributed to deposition of acid rain, and, therefore, there is opposition to initiate emissions control programs that are deemed to be too costly. The issue is further clouded by scientific disagreements concerning the extent of knowledge on source relationships of the acid rain, e.g., how much of Ohio emissions are deposited in the Adirondacks.

From an economic and political standpoint there are disagreements on what are the best steps, or combination of steps, to reduce and curb emissions -- for example, through the use of cleaner fuels; the application of pre-combustion technology; various post-combustion technologies, fuel-gas scrubbing; or through changes in the law that would permit industry to find more cost-effective approaches.

In view of the costs involved in implementing controls to abate emissions of sulfur and nitrogen oxides and volatile organic compounds, and in view of the scientific disagreements on quantitative relationships of acidity to the emitted pollutants and of the degree of ecological damage, the question arises as to what are the appropriate policy responses, both short-term and long-term, to reduce the causes of acid rain and ameliorate its effects.

Current Situation

The Review

During the past year, the National Advisory Committee on Oceans and Atmosphere (NACOA) has reviewed the principal controversial acid rain issues. The Committee has followed various legislative proposals to amend the Clean Air Act. Experts from government, industry, and environmental advocacy groups have given NACOA their views on the causes of acid rain, the adequacy of the Federal research program, the need for controls on emissions of sulfur and nitrogen oxides, and the extent of the ecological damage. NACOA has heard arguments that the Nation should wait or not wait for more information before acting to control emissions beyond what is now required by the Clean Air Act.

Findings

NACOA finds that:

1. There is widespread concern, extending beyond the United States, about the effects of acid precipitation on ecosystems. This concern is based primarily on documented evidence of damage to fish populations and to man-made structures.
2. A causal relationship can be postulated, with some degree of confidence, between man-made emissions and acid deposition.
3. There has, however, been difficulty in establishing quantitative relationships between, on the one hand, emissions of sulfur and nitrogen oxides and acid deposition at geographically distant locations and, on the other hand, between acid deposition and ecological effects.
4. Much of the difficulty in establishing these quantitative relationships arises because reliable, synoptic historical data on emissions and acid deposition are lacking. For example, there are varying published statements concerning the emissions trend of sulfur dioxide in the United States during the decade of the 1970's; synoptic data on acid precipitation before 1978 are scarce; and data on dry deposition are generally not available.
5. An additional difficulty in establishing these quantitative relationships come from the inadequate scientific understanding of the physical and chemical processes that convert the emissions of sulfur dioxide, nitrogen oxides, and volatile organic compounds into acid deposition -- generally far removed from the emission sources. For example, we are not certain what are the limiting factors in these processes -- factors whose reduction would affect the degree of conversion and reduce acid rain.
6. As a result, there is disagreement about the contribution of different sources to acid

precipitation, the quantitative relationship of acidity to the emitted pollutants, and the causes and degree of ecological damage, especially to forests.

7. The percentage of lakes with high acid content (pH of 5.0 or less) appears to be small, as established by sampling conducted by the Environmental Protection Agency. The observed trends of lake acidification are conflicting and seem to depend on the region of the country. For example, lakes in New England generally show a slight increase in acidity; there is unexplained variability in the amplitude as well as direction of acidification trends of New York lakes, while lakes sampled in Wisconsin show decreases in acidity.
8. Conflicting documentation exists of damage from acid rain to agricultural crops or human health, but no credible scientific evidence of these effects was presented.
9. The federally-sponsored acid-rain research program has expanded five-fold, from about $17.4 million in 1982 to $82 million for FY 1986. The collection of baseline information, acceleration of atmospheric process studies, and the development of suitable models should lead to a more complete understanding of the relationships between emission sources and ecological effects, thereby allowing additional appropriate corrective actions.
10. Congress recently enacted legislation for a 10-year $400 million clean coal technology program.
11. The Clean Air Act Amendments of 1977 prescribe a percentage reduction of sulfur emissions and/or specific control technology, rather than applying quantitative limits on emissions. This has led plants to use more high-sulfur coal, promoted the "grandfathering" of old plants, and has led to higher levels of emissions of sulfur dioxide than would have been the case, otherwise.
12. The Powerplant and Industrial Fuel Use Act of 1978, enacted at a time of perceived shortages, restricts the use of natural gas for new plants.

Recommendations

Although there appears to be enough evidence to identify causal relationships between emissions and acid deposition, quantitative relationships are not yet established. Therefore, it is not advisable to commit the Nation to high-cost policies to reduce emissions that may not turn out to be cost-effective.

However, recognizing the possibility of long-term ecological effects, NACOA believes that some low or moderate cost steps be taken now to reduce both sulfur dioxide and nitrogen oxide emissions, or to alleviate the effects on specific lakes, while continuing the ongoing Federal research program. Specifically, NACOA recommends:

(1) The continuation and completion of the ongoing 10-year Federal research programs and the continuation of the research programs funded by the States and industry, designed to clarify the causes of acid precipitation and to indicate the best methods for alleviating the problem.
(2) The development of economic solutions to controlling emissions of sulfur dioxide and nitrogen oxides using innovative control technology and/or management approaches.
(3) Consideration of interim, low or moderate-cost steps while the research program is being pursued. Such steps might include:
    a) a greater use of cleaner fuels; e.g. gas or oil alone or in combination with coal.
    b) the greater use of coal washing
    c) liming of small, sensitive lakes.
(4) Federal legislation, instead of prescribing percentage reduction and/or specific control technologies, should aim to:
    a) establish criteria for setting regional or source-specific quantitative upper limits to the emissions of various pollutants.
    b) allow more freedom in methods for meeting these limits.
    c) encourage the use of market forces to lower costs.

Future legislation should also include appropriate revision to the Powerplant and Industrial Fuel Use Act of 1978 to permit greater use of cleaner fuels.

On the Off-shore Man-made Island

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ABSTRACT

Throughout the history of Japan,the development of its society and economy have been restricted largely to the coastal areas of the country's mountainous islands. Today,the demand for space occasioned by further population growth and continuing economic expansion make it essential to promote the development of the ocean space around Japan.

The Ministry of Transport ,regarding man-made islands as an effective means of offshore space utilization, has carried out extensive research on this concept since 1980.

Man-made islands can offer much flexibility in choice of location and size of the space to be created for a given use. And they make possible the overall utilization of man-made island,coastal area and calmed sea area between them.

The technical feasibility of converting offshore space in severe environments to usable space in the form of man-made islands has been investigated. The results indicated that large man-made islands can be constructed with the aid of advanced technologies from fields such as harbor construction, undersea tunnel construction,long-span bridge construction,long-span bridge construction,offshore structures and high-volume earth and sand transportation.

A diversity of uses are foreseen for such man-made islands: industrial plant sites, distribution centers, energy bases, fishery bases, new media-oriented cities, Research and Developement cities and recreational areas.

I.Present Utilization of Offshore Space Surrounding Japan

1.1 Present Status

Japan is an island nation with a total area of 380,000 km .Steep mountains dominate the inland areas, and only about 20% of the land is inhabitable. Yet this small land area supports a vast population of 117 million. The population, it is estimated, will reach 140 million in the middle of the 21st century. To sustain the nation's society and economy, to continue providing jobs for the people, and to improve the living standard while maintaining the quality of the country's environment,vast new land spaces will be required. Existing flat areas,however,are already highly utilized, making it difficult to meet space demands within the limited land surface area.

For a land-short island nation,offshore space is a precious resource because of its enormous potential for the creation of new land space.

1.2 Creation of New Offshore Spac— An Offshore Man-made Island

This report proposed that offshore space utilization be advanced from the earlier stages of reclamation and man-made islands near the shore to the construction of man-made islands farther offshore, thus creating new functional space as well as new uses for space around these islands.

An offshore man-made island offers many advantages and meets many social needs,as follows:

- □The endeavor to utilize offshore space,while making the most of offshore locations and assuring enviromental preservation of inland regions,will also result in the expansion of the nation's land space and the improvement of the people's wellbeing.
- □The offshore man-made island concept provides a wider range of freedom in both site selection and choice of size.In the field of transportation ,it can also provide for accommodation of large vessels.
- □This concept will have less impact on the current and future use of seaboard areas and shorelines than other development concepts. Also, the calm water area secured between the island and the existing land can become an area for fishing industry use,recreation activities, and sea traffic.In this way,newly created land, existing land aand the sea aarea created between them can be utilized through total planning, thus making it possible to revitalize existing land areas.
- □The concept also permits the relocation or construction of facilities which are now difficult to build in cramped and very densely utilized existing land areas.This will help improve the environment and disaster-prevention provisions of existing land areas.
- □Judging from the in-depth know-how gained through the creation of space in the 1st and 2nd stage projects described above, and considering the outstanding level of technological standards attained by Japanese shipbuilders and port/harbor engineers, construction of offshore man-made islands has already reached the stage of technological feasibility.
- □When a man-made island is built by reclamation, the hill or mountain from which earth was taken for the reclamation then becomes usable flat land.

II. Applications of Offshore Man-made Islands

2.1 Range of Applications

Man-made islands can spur economic activity as part of local development programs through the use of such islands for industrial development,fishery promotion,tourism development and uses related to energy and natural resources.Man-made islands can also be utilized in the construction and improvement of city facilities and transportation facilities.

Particularly notable are applications based on social improvements,enhancing habitability and convenience by making better use of land and providing civic amenities. Equally important are applications based on national policies for the supply of energy.

In its case studies,the following objectives and concepts were investigated for the planning of man-made islands.

- ☐ Distribution bases of various kinds
- ☐ Islands for sightseeing and leisure activities
- ☐ Educational and scientific research bases
- ☐ New cities(residential area and hotels)
- ☐ Land for industrial development and for waste disposal
- ☐ Offshore mining bases
- ☐ Energy bases
- ☐ Farming and aquafarming land (marine farms and ranches and processing plant)
- ☐ Refuges for times of natural disaster
- ☐ Bases for the building of deep-sea structures
- ☐ Others

Clearly, militiple-purpose use of a man-made island is more advantageous than single-purpose use.An important approach in planning multiple-purpose use is to view the man-made island and the calmed sea area around it as a single unit of newly usable space.

2.2 Use of Calmed Sea Area Behind the Man-made Island

An offshore mand-made island calms the sea area between the island and the coast opposite. This fact opens great possibilities for use, particularly for combines use of the man-made island and the adjacent coastal and sea areas. The most important point in making use of coastal waters open to the sea is the control of waves. These sea areas can be calmed by constructing wave-dissipating facilities such as an offshore man-made island or a breakwater at a considerable distance from the coast. The result is a calmed sea area behind the island or breakwater.

III. Offshore Man-made Island Structures

Structural types possible for use in offshore man-made islands are as shown in Fig.1.

☐ Reclamation type

The man-made island is constructed by reclaiming the sea area enclosed by revetments using caissons, double-wall sheet piles, and other materials. An island of this is vulnerable to earthquakes, but resists waves.

☐ Piling type

A platform is fitted on top of piles driven into the seabed, and structures are built on the platform. This type is comparatively less susceptible to wave action,but is affected by earthquakes.

☐ Bottom-fixed type

A structure built on a caisson or a floating body is towed to the ocean construction site, where it is sunk and installed.This type is suitable for relatively shallow water ,but seabed readjustment is required prior to installation.

☐ Jack-up type

A structure built on a floating body is towerd to the ocean installation site,where the floating body is jacked up to the appropriate hight on legs fixed to the seabed. Structural weight is restricted by leg strength and jack-up capacity.

☐ Floating type

A structure built on a floating body is towed to the instllation site and moored there. This type is affected by pitching/rolling due to waves, but is comparatively less susceptible to earthquakes.

☐ Semi-submersion type

Part of a floating body is submerged, so as to decrease the pitching/rolling of the body. The draft line varies greatly with the structural weight.

When building an offshore man-made island, the optimum type should be sslected with due consideration given to the intended use, conditions at the construction site, and similar factors.

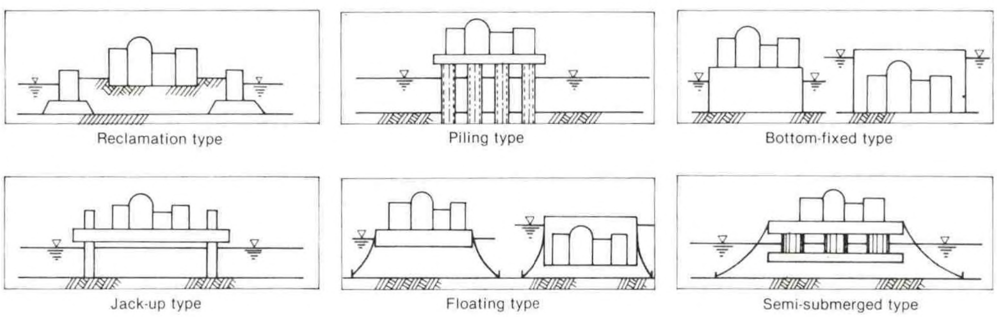

Fig. 1. Structural Types of Man-made Islands

IV. Model Plan for Offshore Man-made Island

4.1 Offshore Coal Energy Base

Due to interest in energy bases as a prospective us of offshore man-made islands, and in energy sources that could serve as alternatives to oil, coal was included in our case studies in 1980-1982.

For coal-fired power generation, which offers favorable supply-demand balance and economyics, the offshore man-made island provides the following advantages.

□As coal-fired power generation is developed further, we must rely on imports for most coal supplies. Efficient ocean transport of coal calls for the use of large coal carriers. A man-made island is well suited to such vessels, since it can be located so as to provide a deep-water harbor.

□Coal firing produces large amounts of ashes. The leading problem is to secure a place for dumping the shes— and such a place can easily be provided by an offshore man-made islnd.

□A very common requirement for a power station is that it be installed near a large city . An offshore man-made island is located freely, being able to offer proper sites for the construction of power plants in the vicinity of large cities.

□The place used as an ash dump can be put to better use at some future time.

Provision of a coal center, which is closely related to coal-fired power generation, is difficult if it is constructed independently. If constructed together with a coal-fird power station as a single project, it becomes economically feasible.

In the case study, two cases were assumed : (1) a 3 million-kW coal-fired power station built independently ; and (2) the same power station built together with a coal center with a storage capacity of 1.2 million tons.

Table 1 shows the basic design conditions of a man-made island for use as a floating type coal-fired power plant. Table 2 indicates the scale of a typical man-made island structure designed to meet these conditions. The Fig 2 is a layout of the man-made island.

1. Basic Design Conditions for Offshore Man-made Island for Coal-fired Power Plant

Uses	Coal-fired thermal power plant (with coal storage yard)
Structural type of power plant and coal storage facility	Floating
Power output capacity	1 million kw × 3
Coal storage	2.4 million tons (Annual handling: 15 million tons)
Ash dump	20 million m^3 (sufficient for 15 years of continuous operation)
Port facilities	100,000 dwt × 3 berths 10,000 dwt × 2 berths 5,000 dwt × 1 berth 2,000 dwt × 1 berth
Industrial water	Fresh water: 23,000 tons/day Seawater: 135 tons/sec
Number of employees	500
Water depth	17m ~ 23 m (average 20m)
Distance from shore	3 km (min.)
Seabottom soil	Sand ($N \geq 15$, $\phi = 35°$)
Wave, height, cycle	H1/3 = 9 m, T1/3 = 14 sec
Tide	H.H.W.L. + 2.10 m H.W.L. 1.50 m L.W.L. 0
Earthquake	Kh = 0.15
Maximum wind velocity	45 m/sec in 10 minutes
Bearing stratum	−35 m ($N \geq 50$)

2. Scale of Offshore Man-made Island for Floating coal-fired Power Plant

Facilities and others	Scale
Area	208 ha
Reclamation area	— ha
Multi-column administration yard	8 ha
Ash dump area	134 ha
Breakwater	1,370 m
Breakwater revetment (ash dump)	3,000 m
Breakwater revetment (reclamation)	— m
Bulkhead (ash dump)	1,750 m
Bulkhead (reclamation)	— m
Soil for reclamation	— m^3
Stone requirement	6,690,000 m^3
Sand requirement	10,130,000 m^3
Power-plant barge	420 × 80 × 27 m (3 barges)
Coal-storage barge	420 × 80 × 35 m (6 barges)
Barge mooring facility (number)	39
100,000-ton berth	1,100 m
10,000-ton berth	250 m
5,000- and 2,000-ton berths	250 m
Steel requirement	1,610,000 tons

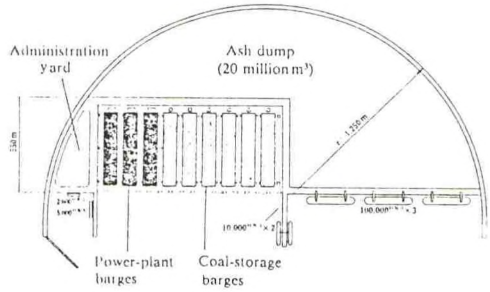

Fig. 2. Layout of Floating-type Man-made Island (watar depth 20 m, power plant with coal storage yard)

4.2 Multipurpose Offshore Man-made Islands

To examine the feasibility of using offshore man-made islands for multiple purpose, especially on utilization of offshore space for man-made islands, case studies were made in fiscal years 1983 and 1984 at six different sea aras in Japan. (See Fig. 3.4) Site selection was made with due consideration given to both natural conditions in coastal areas and the social and economical conditions of inland regions. (See Table 3.)

Based on the results of studies on the specific problems the six areas faced, such as natural conditions and economic and social conditions, and also by referring to existing develoment schemes, new concepts were studied, with major emphasis on the utilizatiiion of offshore man-made islands and on how offshore space should be used for the construction of offshor man-made islands and for other purposes. In addition, rough designs of main structures to be built on offshore man-made islands, studies of execution plans, and rough estimates of construction costs were also carried out.

Fig. 3.
Location of Case Study

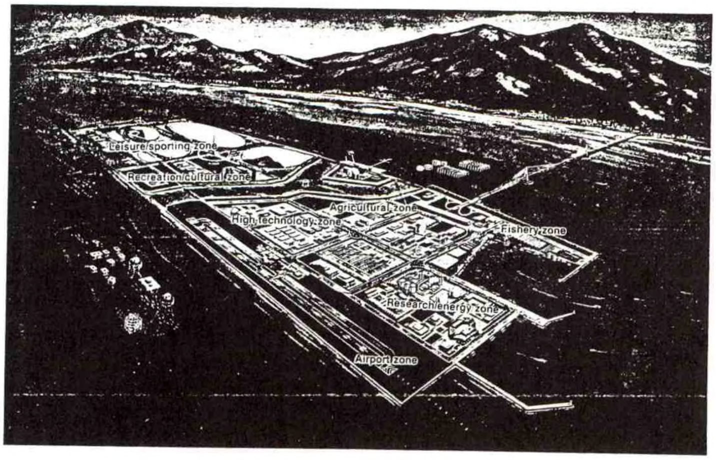

Fig. 4. Application Example of Offshore Man-made Islands

Table 3. Outline of Case Studies on Multi-Purpose Man-made Islands

	Shimonoseki Kitaura	Akita Bay	Shimizu Port	Omura Bay	Miura Peninsula	Muroran Offing	Tokyo Bay
Man-made islands □ Location □ Water depth □ Area	1.8 km off Shimonoseki 5-30 m 750 ha	7 km off Akita 25-30 m 470 ha	0.5 km off Okitsu 5-40 m 230 ha	2.4 km off Kotoume 20-22 m 1,000 ha	2 km off Yokosuka 20-50 m 350 ha	1.5 kmm off Muroran 20-30 m 700 ha	4 km off Banzu, Kisarazu 20-25 m 180 ha
Applications	Distribution center, fishery base	Refining plant for deep-sea mineral resources	Site for coastal area redevelopment	Marine city (business, resort, leisure)	Recreation, research and cultural centers	Sightseeing and recreation facilities	Moorings for refuge Recreation International exchange zone
Applications of nearby sea and land areas	Navigation route, stand-by area, anchorage for quarantine; site for fish and weed cultivation	Anchorage for refuge; site for marine recreation	Redevelopment of coastal area; improvement of transportation network	Key point for transportation; improvement of area transportation network; site for marine recreation	Key point for distribution and information gathering; site for marine recreation; anchorage; site for fish preserve	Research and cultural facilities; airport; site for fish and weed cultivation	Navigation route
Merits of man-made island construction	Provision of anchorage and site for fishery; dump for dredged earth; flexibility in site selection	Provision of anchorage and site for fishery; dump for slag; flexibility in site selection	Provision of long seashore lines; isolation of industrial sites; flexibility in site selection	Effect of development plan on coastal area; flexibility in site selection	Provision of anchorage and site for fishery; flexibility in site selection	Provision of anchorage and site for fishery; effect of development plan on coastal area; flexibility in site selection	Effective utilization of nearby sea areas Capacity for large vessel
Construction cost (infrastructure only)	¥780 billion	¥1,040 billion	¥370 billion	¥960 billion	¥460 billion	¥1,040 billion	¥ 450 billion

V. How to Materialize the Offshore Man-made Island

The offshore man-made island, conceived in the perspective of the 21st century, is a new frontier in social capital that promises more effective use of national land resources. Expectations are high for this concept as a means of meeting the many emerging needs of society.

The problems standing in the way of materializing the man-made island concept are:(1) coexistense with fishermen,(2) development of necessary techniques, (3) centralized management of information on ocean currents, depths, seabed conditions, winds and waves, (4) raising the huge construction funds required, and (5) coordination of all such factors.

In approaching these problems, it is important to consider ways of sharing the cost burden and of cooperation between the government and the private sector. Equally important is to examine the feasibility of introducing a new work execution system based on the efficiency criterion— obtaining the best results for the money spent — by utilizing the vigor of private enterprises.

In planning an offshore man-made island, the utilization of the space to be created must be examined strictly in terms of the demanding environment in which it will be created and the enormous construction cost of the man-made island. As technological development continues, the need will surely arise for completely novel urban functions. In highly developed cities, it will be difficult to find existing space to accommodate such functions. Man-made islands will fill this need. They must serve multiple purposes if their cost is to be justified. It is important today to pursue studies of offshore man-made island construction in the areas of both hardware and software.

Strategic Information for Coastal and Oceanic Resource Development

Charles N. Ehler
Director
Office of Oceanography and Marine Assessment
National Oceanic and Atmospheric Administration

I want to share with you some ideas this morning on developing a unique capability for producing strategic-level information that is useful for national policies on oceanic resource development. While this presentation might appear to be out of place in a meeting of marine technologists and engineers, I hope you will find it interesting, if not useful. I especially hope our Japanese colleagues who, as a Nation consume five times the amount of fish protein as the Americans do, can see the value of this information for coastal and oceanic resource development.

I just returned from a meeting last night in Seattle, Washington, that was an international symposium on the effects of toxic chemicals on aquatic life. There I learned a great deal about Japan and the United States and its problems of conflict between resource development and living marine resources. This morning I listened with interest to our last speaker who told us that, in fact, 85% of the wetlands of Tokyo Bay were filled between 1945 - 1978, and that 99% of the wetlands of Osaka Bay were also filled during that same period. We have similar problems in the United States in a few places, but nothing of that magnitude.

I'm going to state a problem and then define the need for strategic kinds of information about conflicts among coastal and oceanic resource uses. I'll define what a strategic assessment approach is. Then I'll use only one of a number of data bases that NOAA is developing as an illustration of what we're doing and how this information can be used. One theme that I would like to emphasize is that we know a lot more than we think we know, and we generally underuse existing information in making these assessments. In ten minutes or less, I can hardly scratch the surface of what we're doing, and since many of you will be attending OCEANS '86 next week, I would encourage you to visit the exhibit of NOAA's Office of Oceanography and Marine Assessment. Many of the things I am going to discuss today will be displayed. Before beginning my slide presentation, I would add that the Fall 1986 issue of Oceanus magazine will have a major article on the same kinds of capabilities I will discuss here today.

I said I would try to define the problem. As we all know, we are drowning in data. Over the next 10 years, or even sooner, we will be drowning even more as super computers, remote-sensing technologies, and communications technologies allow us to access more and more data--and less and less information. For example, this slide shows an AVHRR image of the Gulf of Mexico. I won't dwell on it, but it's just a sample that many of you have already seen that will allow us to view the earth and areas of our respective countries much more synoptically than we have ever been able to before.

We have heard several speakers talk about increasing rates of use of coastal and oceanic resources. We know also there are increasing rates of adverse effects from these uses. The decisions that we have to deal with are becoming increasingly complex. There is a widening gap between the kinds of problems we have to deal with, the knowledge with which we have to work, and the decisions to be made. And, there is certainly a continuing lack of information at the national level to deail with these kinds of complex issues.

What we are trying to do within one part of the Office of Oceanography and Marine Assessment is to develop an approach that is national in scale, that is comprehensive in its approach to problem solving, that focuses on synthesis, and that has an emphasis on developing operational capabilities with which to perform these kinds of analyses.

The areas in which we are interested essentially represent the entire exclusive economic zone (EEZ) of the United States. The four major regions of the EEZ outlined in the slide are those areas where we are currently working and developing data and information through strategic assessments. I have a sample of one of our major work products, the Gulf of Mexico Data Atlas with me and I would be happy to show it to you after this presentation. It is an atlas that tries to illustrate the best available information within broad categories of information. It is to be used for assessment purposes.

I'm going to go through these slides very quickly just to give you some idea of the kinds of maps that we are producing. One from the "Physical Environments" category, demonstrating the usefulness of AVHRR imagery in terms of interpreting ocean currents. This next slide on "Economic Activities" depicts information on discharges of pollutants along coastal areas, not only from point and nonpoint sources, but also from sources outside of coastal areas. These discharges must be a very important consideration in evaluating the entire mass balance of materials entering coastal waters. Finally, I show an illustration "Jurisdictions" section because in the United States, as in Japan, decisions are often made largely on the basis of political representation.

Now, I'm going to tell you in 2 minutes about 8 years of work on developing a data base on living marine resources that lies behind the maps appearing in the atlas. Just quickly summarizing, the atlas contains information on the life history of over 300 animals that reside in the coastal waters and EEZ of the United States. We know a great deal about individual species, but much of it is very poorly synthesized. We can now produce maps based on trawl surveys that tell us about abundance of species. But, more importantly, we can take those maps and sit down with a group of experts and try to synthesize the information in a more understandable way. After a long period of time, four years in the making of this map, we can produce very nice maps that have involved contributions from hundreds of scientists. This slide is of a map that synthesizes the best available information on the distribution of a particular animal. We have constructed over 300 of these maps for the entire continental United States and Alaska.

One unique thing that we are now doing, that should be of interest to anyone concerned with coastal development, is trying to add four-dimensional information to our maps. We already map the traditional two dimensions of most maps, plus a third dimension of time. On each of our new maps, we are including information on the vertical distribution in the water column and their distribution in bottom sediments of each of these animals, as appropriate.

Finally, I want to show you just a few of the computer tools we are developing for analysis. This slide represents one of our recent that is based on the use of a personal computer to manipulate the data that we have collected on living resources. This is relevant, I think, to you as technologists and engineers because often we are often asked to evaluate the effects of major development projects. Now, we have the capability, in a matter of hours or even minutes in some cases, to examine quickly the relationship between living resources and economic development projects.

What we are looking at here is the State of Alaska, turned on its side, and the Bering Sea. The reason we use this orientation is that it maximizes water area vs. land area. This capability doesn't only exist for Alaska and the arctic, in general, but literally now for the entire United States with the exclusion of Hawaii and the Pacific Trust Territories. What we are now looking at is information on the life history of a flounder. The various colors on this map represent different stages of its life history. If you can specify the area in which a development project will take place, or in which activities like ocean waste disposal or ocean incineration are proposed, we can quickly tell you what animals are present in that area, at what stage of their life history, and over what months of the year.

In this brief presentation, I have shown you briefly examples from eight years of work. My first conclusion to this talk is that there is simply no shortcut to developing this type of strategic information and the operational capability for its use. My second conclusion is that this is a massive undertaking, from the standpoint of using expert knowledge, and it requires the cooperation and trust of many marine scientists in the use and interpretation of their data. We have attempted to use the best available information processing and communications technology in terms of presenting this type of material. At OCEANS '86 you will see how a user can interact with these data bases to provide a very rich set of information on development decisions. It is absolutely critical in these synoptic data sets to make sure one can trace the quality of the information right back to the source; what we call an "audit trail." I will conclude by simply stating that in the last two years, we have Federal agencies, state agencies, the private sector, environmental interest groups, and an increasingly widening group of users literally lining up to get access to these data bases and information systems.

AT-SEA EXPERIMENT OF A FLOATING PLATFORM

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ABSTRACT

In the previous report at the 13th MFP of UJNR in 1985, the authors introduced the proto-type platform for the use of an at-sea experiment which will be performed in 1986-1987 and possibly further for four years long at the coast of the Japan Sea as the final stage of the research project on the huge floating off-shore structures for ocean space utilization.

The size of the platform is considered as a small portion of the huge platform and has a scale ratio of 1/3 as to the elementary size of the floating body so that the environmental conditions at the experiment site could correspond to the severest sea state for such offshore structures. In this report, the design procedures and the performance estimation results are described. The measurement instrumentation system of the experiment is also shown.

SCOPE OF THE AT SEA EXPERIMENT

Full-scale measurements at sea occupy today the significant portion in the design methodology of the ocean engineering, because validation of usefulness of model experiments as well as the theories concerned could be ascertained through such at-sea experiments conducted by use of the full-scale or the proto-type structure in the real environment of the ocean where the severer sea conditions are expected to encounter. [1] The test will be performed not only to measure the response of the structure itself but also to evaluate the reliability of it in the whole system in the real ocean environment which is so complicated that it could not be estimated by means of other methods as model experiments in the basin. We can find a number of such experiment at sea for various ocean structures which have been developed for ocean space or energy utilization and for the experimental purposes.[2] [3] [4] etc.

Recently, the huge offshore structure concept has been attracted increasingly attention as the base of the ocean space utilization, and some studies have been carried out in Japan, for example, the multi-purpose floating island or the floating airport. [5] [6] In the course of the research of such structures, the at-sea experiment has been planned.

The purpose of this at-sea experiment is to verify the prediction methodology achieved in the research project on the huge floating structures, i.e. the motions of the structure, wave loads and air gap including impact forces, mooring line tensions, stresses acting on the structure, precise measurement of the environmental conditions.

ENVIRONMENTAL CONDITIONS

It is necessary to choose the sea area where the environmental conditions are suitable to the test purpose, i.e. the severe sea conditions corresponding to the design criteria of the off-shore structures are expected to occur definitely within the test period. By considering the meteorological data in the past, the offshore of the northwestern coast of Honshu has been chosen as the test area. Here is a part of the eastern area of the Japan Sea and the relatively steady change of weather through the four seasons are expected, i.e. the severe wind and waves strike periodically the coast from the NW direction in the winter, while the relatively calm weather continues in the summer season. Such steady and foreseeable circumstances of the weather will enable us to install the test structure in the summer and to perform the experiment in the winter. In addition, the sea floor condition is also suitable for mooring the structure.

Fig.1 shows the monthly mean values of the significant wave height according to the wave survey in this area. [8] The maximum values of wind and waves observed in the past are as follows;

(1) Wind: Maximum wind speed (mean of ten minutes) is 32 m/sec. Sakata
(2) Waves: Maximum wave height (significant) $H_{1/3}$ is 7.0 m where $T_{H_{1/3}}$ = 11.7 sec., and H_{max} = 12.3 m. Atsumi
(3) Current: Maximum current velocity is 0.9 kt.
(4) Water depth: 40 m,
(5) The sea floor condition: Cray including sands.

STRUCTURE

The test structure consists of twelve columns which support the upper-deck. The structure is considered as one of the smallest part of the huge floating platform consisted of the minimum number of the elementary floating body, namely the column with footing, for keeping an enough stability by itself while on the other hand to enable us to investigate the response characteristics of the structure in wind and waves, taking into account of hydrodynamic interactions among the columns.

The plan and side view of the test structure are shown in Fig.2. The columns at the each corner are supported by two diagonal bracings respectively to sustain the mooring line tensions. The upper structure is constructed mainly by the box-type girders around the four sides which play a role of the strength member as well as the reserve buoyancies for the stability. The deck plating and a instrumentation house are arranged on the top of the structure. At the center a mast is elected for the base of annemometers. The principal dimensions of the structure are listed in Table 1.

MOORING SYSTEM

The main direction of installation of the structure is determined to be 292.5 degrees, i.e. WNW which coinsides generally with the superior direction of the seasonal wind in winter. The main mooring system consists of six catenary chain lines equipped with anchors at the each end of the lines. Among them two chain lines are attached on the each corners at the offshore side while one line on the corners at the shore side. The arrangement of the mooring lines is shown in Fig. 3 and the main items in Table 2. The lines are led through sheaves on the deck.

The tension leg mooring system is also tested by using this structure by the Japan Marine Science and Technology Center.[7]

RESPONSES OF THE STRUCTURE IN WAVES

(1) Stability: The static stability of the structure has been calculated and compared with the rule for the Mobile Offshore Drilling Units. Fig.4 shows the stability curves in the diagonal direction which is the severest condition for the stability. It is shown that the structure satisfies the stability criteria, that is

$$(A+B)/(B+C)= 1.49 > 1.3$$

The calculated stability curve has been confirmed by the inclination test of the model structure.

(2) Regular Wave Responses: The 1/14.3 scale model of the test structure has been used to measure various responses in waves in the model basin of the Ship Research Institute. The measurements have been carried out for surge, roll,pitch, heave motions, relative wave elevations and mooring line tensions in regular waves, which have been also estimated by the theoretical calculations. It is concluded that the theoretical predictions agree well with the experiments as to the motion responses while the mooring forces are overestimated somewhat.

The wave exciting forces acting on the individual column have been measured together with the total force acting on the structure so that the hydrodynamic interactions among the elementary columns be made clear.

(3) Irregular Wave Testings: The model has been also tested in irregular waves, the energy spectra of which are the JONSWAP type. The testing in irregular waves has a special meaning to deal with the so-called slow drift motions of a moored floating body. The measured responses have been submitted to the spectral analysis so that the slow drift motions and the motions in the wave frequency range can be separated.[9]

The other model smaller than the abovementioned model, the scale ratio of which is 1/40, has also used for observing the behaviours of the structure such as air gap, shipping water or wave impact in the severest sea conditions of the test site. By considering these test results, the height of the column above water lines has been determined.

(4) Towing Tests: The model has been subjected to the towing test in waves of various directions. The towing force has been measured, observing both directional and inclining stability under towing.

(5) Structural Responses: The loads acting on the strength members of the structure due to wave and motions have been estimated by using a grillage construction analysis method for both free-floating and moored conditions, and the strength of the structure against the buckling stresses of the members has been evaluated.

Through these model experiments and calculations the design conditions of the test structure have been confirmed.

INSTRUMENTATION OF AT-SEA EXPERIMENT

For mesurement of the responses of the test structure as well as the environmental conditions at the test site, various instruments have been prepared and installed on board, as shown in Fig. 5. In Table 3 the items to be measured and the devices used are summarized.

The measured signals are transmitted by the telemeter from the structure to the receiver on the shore. The data acquisition system on board is also used. The electric powers are supplied through the underwater cable from the shore as well as by the electric generator on board.

CONCLUDING REMARKS

The structure is towed to the test site in this summer and is moored. The test starts from this autumn and will be continued for four years.

This research project was performed through the Special Co-ordination Fund for Promoting S & R of the Science and Technology Agency of the Japanese Government, as a part of the Research on the Utilization of Marine Space by Coastal and Offshore Structures.

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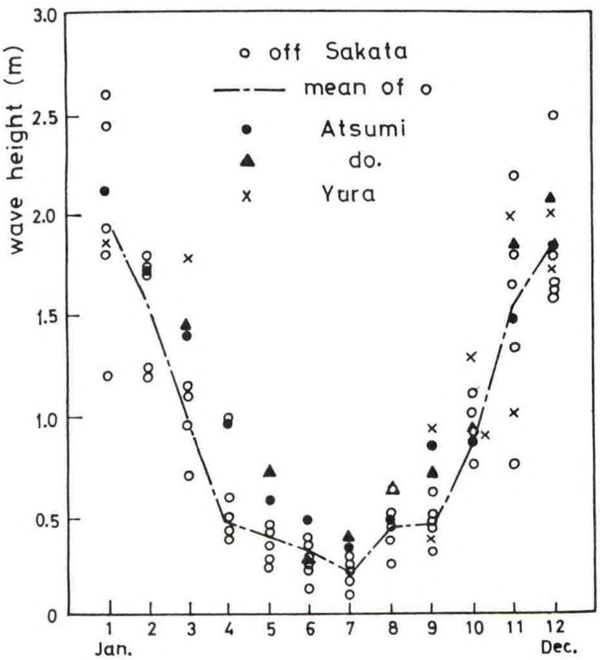

Fig. 1 Monthly Variation of Mean Value of Significant Wave Height

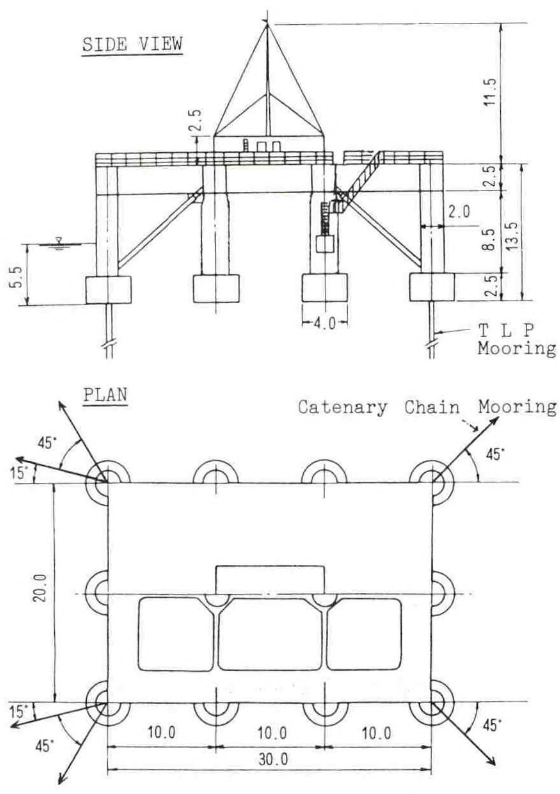

Fig. 2 Outline of the Test Structure

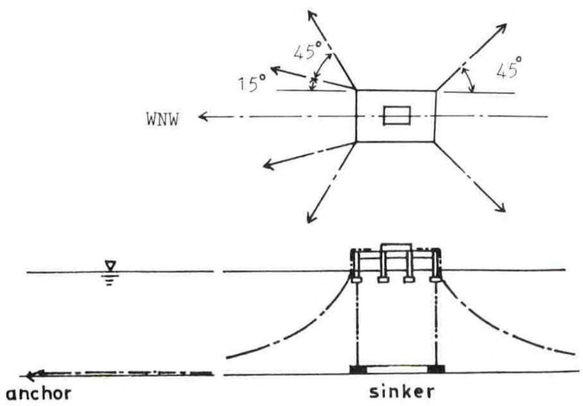

Fig. 3 Arrangement of Mooring System

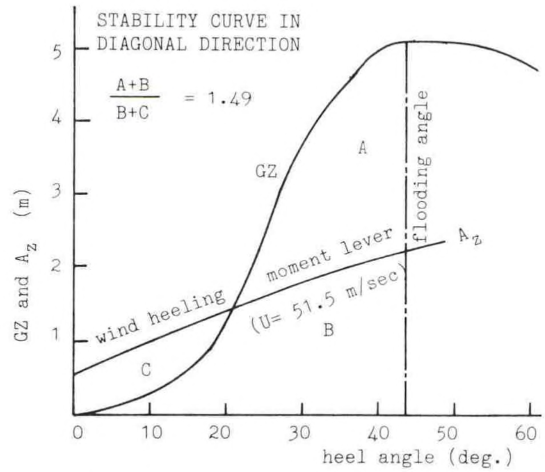

Fig. 4 Stability Assessment Curve

Table 1 Principal Dimensions of the Structure

Items		Dimensions	
Length overall		34.000	m
Breadth overall		24.000	m
Distance between columns		10.000	m
Height		13.500	m
Draught		5.500	m
Height of C.G.	(KG)	6.796	m
Displacement	(Δ)	527.54	ton
Metacentric Height			
Transverse	(GM_t)	1.633	m
Longitudinal	(GM_l)	4.897	m
Radius of Gyration			
Roll	(k_{xx})	9.797	m
Pitch	(k_{yy})	13.141	m
Yaw	(k_{zz})	14.655	m

Table 2 Main Items of Mooring System

Items	Type & Dimensions
Chain Lines	Stud link chain Grade 3 JIS F 3303 50 m/m diameter 6 × 225 m
Anchor chain	70 m/m diameter chain 6 × 55 m
Anchor	4 × 13 ton & 2 × 9.5 ton

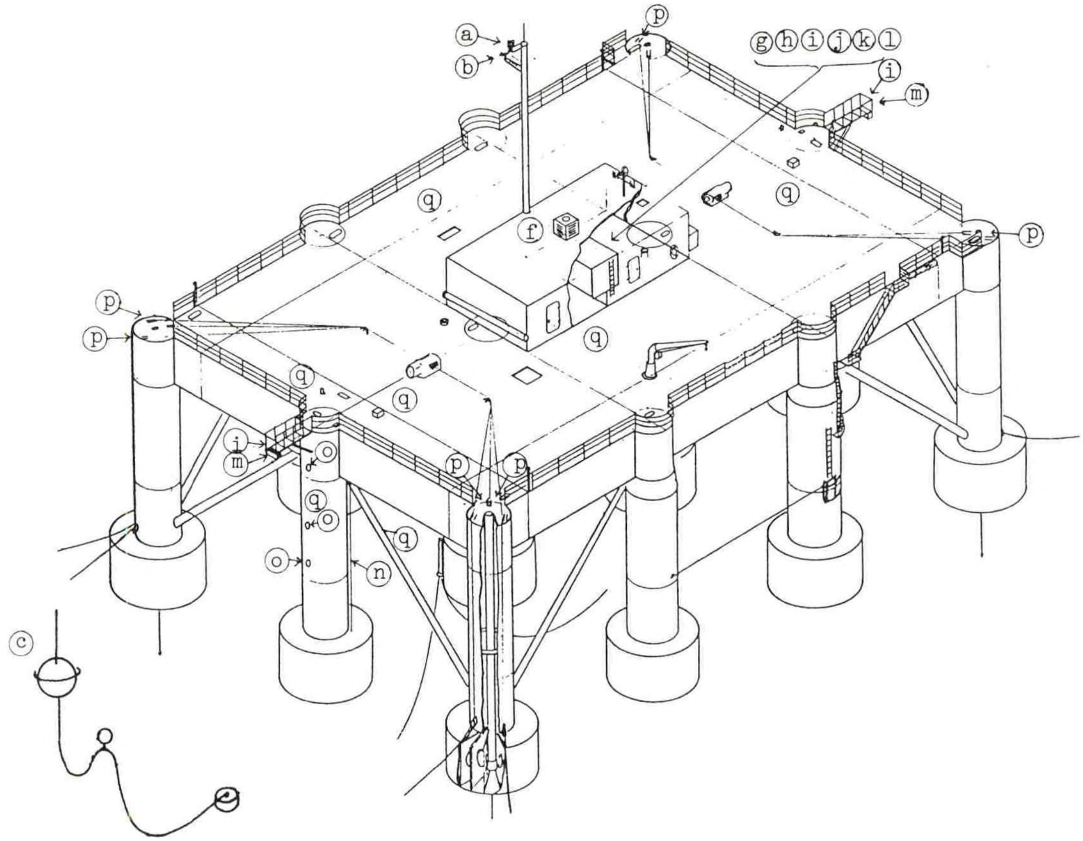

Fig. 5 Arrangement of Measuring Devices on Board

Table 3 Measuring Items and Devices for the At-sea Experiment

	Measuring Items		Measureing Devices	
Environmental Conditions	Wind	Direction Speed	Vortex Type Annemometer and Robinson Annemometer	ⓐ ⓑ
	Wave	Surface Elevation (Directional Wave)	Wave Rider Buoy (Supersonic Wave Height meters)	ⓒ ⓓ
	(Current)	Direction Speed	(Current Meter)	ⓔ
	Atmosphare	Temperature Humidity	Air, Water and the Deck plating	ⓕ
Motions	Surge		Accelerometer	ⓖ
	Sway		Accelerometer	ⓗ
	Heave		Accelerometer	ⓘ
	Roll		Vertical Gyroscope	ⓙ
	Pitch		Vertical Gyroscope	ⓙ
	Yaw		Directional Gyroscope	ⓚ
	Heel and Trim		Inclinometer	ⓛ
Induced Responses	Relative Wave Elevations	at Bow and Stern	Supersonic Wave Height Meter in Air	ⓜ
			Capacitance Type Wave Height Meter	ⓝ
	Impulsive Pressure on Columns		Pressure Gauges	ⓞ
	Mooring Forces on the Chain		Load Cells	ⓟ
	Stresses on the Structure		Strain Gauges	ⓠ
Corrosion	Observation of Paintings			

UTILIZATION OF OCEAN SPACE

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The limiting factor on the use of ocean space is at the present time the inadequacy of marine transportation and in particular the intermodal transfer of goods and people. Concepts and costs for various forms of ocean space utilization have been well developed and although real costs have been high the potential for construction costs which are equivalent to or less than those of the land based counterpart is good. At least four types of structure have been employed for the occupation of ocean space; the fixed platform, the displacement ship, the artificial island, the moored floating platform, the "soft landing" platform (slightly negative buoyant structure resting on a floating (in the mud) foundation) and the dynamically or environmentally positioned floating platform.

Two types of platform must be distinguished; the industrial facility in which human comfort and performance will be diminished to meet cost effectiveity requirements and; the urban and suburban facility which is designed to meet voluntary and elective requirements for human habitation. Experience indicates that for the latter situation long term habitation will not be tolerated unless the motion and acceleration spectrum is equal to or superior to that of the land based equivalent.

Historically, industrial development has evolved the technology from the fixed platform in shallow water to the dynamically positioned semi-submersible operating in water of great depth. The evolution associated with oil began with the stiff legged fixed platform in shallow coastal waters. These experienced many failures by, as yet uncompletely resolved, foundation problems of scour, fluidized beds, inadequate soil mechanics theories, corrosion, stress corrosion etc;. Due to the physical nature of the fluid, (incapable of sustaining static shear, conductive, and dissociated from the atmosphere) principles of platform construction proved to be inadequate or inappropriate or in many cases catastrophic. Substitutions appeared in the form of the moored displacement drill ship or the jack-up barge. The displacement ship had the disadvantage of being coupled to the free surface and as a result expensive gimbal systems were required to prevent unacceptable stresses and displacements of the drill machinery. The jack-up barges were successful once they were in place but were hydrodynamically unstable during transport and subject to capsizing in heavy seas. In addition the depths were limited to a few hundred feet which were realized at great cost.

The concept of semi-submerged platforms which are dynamically positioned was developed in connection with the National Science Foundation Mohole Project. Studies had indicated that mooring was prohibitively costly if allowance were made for the most severe sea states and that location possibilities were greatly constrained if it was necessary to slip the moor in the face of rising seas. Unfortunately funding constraints prevented the completion of the construction of the MoHole platform. The concept was however successfully adopted by the Japanese in their series of "Blue Water" drilling rigs.

A parallel line of stable platform development was associated with the need for offshore oil storage facilities. The first major facility to be constructed was the Ekofisk oil storage facility. This facility was constructed in a restricted bay and floated to the installation site. The structure was composed of nested cylinders of prestressed concrete surrounded by pre stressed concrete wave attenuation walls. The entire complex was ballasted to rest lightly on the sea floor. The follow on structures in the North Sea were the ConDeeps. These employed spar type semi-submersible columns in nests of threes.A very small waterplane area permitted waves to pas through the structure and thereby decouple the facility from the effect of the free surface. The adjustable buoyance of the columns was used in the construction process so that the superstructure could be floated above the submerged columns and then lifted into the air by reduction in ballast. The facilities were towed to the sites and like Ekofisk rest gently on the ocean floor.

The configuration of the modules of ConDeep were very similar to the configuration of the modules of the University of Hawaii floating City project. In this project the semi-submersible design took advantage of configurational flexibilities in the location and size of the "added mass" such that the added mass was anti-resonant for resonant wave frequencies. The resulting platforms were thus "super stable" as compared with most semi-submersibles and could thus meet the most stringent motion and acceleration requirements in the floating configuration.

This concept was employed by the Japanese in the demonstration of the "floating city" concept held at the Okinawa fair in 1974. Unfortunately constraints of time dictated the use of a conventional semi-submersible dynamically positioned drill rig as the simulated structure. The basic construction concepts behind the Hawaii Floating City and the Aquapolis have been employed in the concept design phase of Japan's "Marine Information City". This five by seven and one half kilometer complex has modules which have a very small waterplane area and columnar pontoons below the surface of the water. The complex rests on a hinged series of foundations which are floating in the sediments. The complex is ballasted and monitored on a continuos basis to keep the entire complex level and at the desired elevation above the seabed. A firm decision to proceed with this concept has not yet been made by the Japanese government but it seems certain that this concept will be developed in some form within the next twenty years.

The alternative to the semi-submersible in the form of the large waterplane displacement barge has not found favor because of the necessity of absorbing and/or reflecting the wave energy which impinges on the structure and the necessity of employing very large volumes to assure that motions and accelerations do not exceed the allowable maximums. The concept has been employed in the construction of power plants and factories where the object has been to float them from the manufacturing shipyard to the sheltered waters of an industrial site. Here they are moored or sunk in place on top of an appropriate foundation.

For the past decade or so there has been a design debate relative to the design of the Osaka airport to be located in the Inland Sea in the vicinity of Kobe-Osaka. Proponents of a "floating airport" point to the large industrial volume available beneath the runway, the decoupling from earthquake and resistance to tsunami and other wave effects. The proponents of an "artificial island" airport point to the lower cost (cost effectiveity of the floating complex being achieved only after the installation of a major city within the floating modules) and the ease of "repair after a major quake. The decision is not known to the writer but is believed to be in the direction of the fill structure.

Favoring this approach is the highly successful artificial island "Portopia" which is appended as a peninsula to Kobe city and projects into the Bay. The periphery is a container ship facility which is optimized and computerized to retrieve and disseminate containers from and to the rail network of Japan and to onload and offload them from container ships. These container ships (with displacements up to 40,000 tons) are themselves designed to interface with Portopia and one other overseas port (Rotterdam or Seattle for example). The interior of the island is partly dedicated to a major sport and stadium complex, a theme recreation park, a major hospital complex and a major pedestrian malled urban dwelling complex.

Similar islands have been proposed for the entrance to Rotterdam harbor. Fill breakwaters have been designed and proposed to produce a sheltered lagoon for the location of the Westinghouse floating nuclear power plants. Conceptually the floating power plants are decoupled from earthquake, are shielded by the water which may also be used as a "fail safe" medium in which to quench the reactor in the event of a major "Chernobyl" catastrophe.

With the combination of empirical experience, design experience, model test and theory it can be said with confidence that it is possible to design and build major floating structures of reinforced concrete and steel which will be stable under the most extreme storm conditions and whose cost per cubic foot of useable space will be less than the cost per cubic foot of useable space in an equivalent land structure. This being the case other factors must be involved as inhibitors to the use of ocean space for urban and industrial purposes.

Several simple illustration suggest that the major inhibitor is transportation. The first illustration is that of the OTEC 1 ship which was deployed approximately twelve miles at sea from Kawaihae harbor. The Natural Energy Laboratory of Hawaii is a land based research facility also located approximately twelve miles from Kawaihae Harbor. Workers living in Waimea (the nearest town to the Harbor) could easily commute to the Natural Energy Laboratory on a major highway at an average speed in excess of fifty miles per hour with a portal to portal transportation time of twenty to twenty - five minutes. Workers commuting to OTEC 1 had to board a work boat in the harbor which in calm seas had a maximum speed of about ten knots. In the rough waters which generally obtained in the channel in which OTEC 1 was moored the average speed was about six knots resulting in a two hour journey to the vessel. On arrival the relative motions between the work boat and the OTEC 1 ship made personnel transfer hazardous and difficult. A crane from the OTEC ship lowered a rope structure called a "Chauncey Pew" to the deck of the work boat. Four to five individuals would ling to this structure which snatched from the deck of the work boat was hoisted into the air, swung out over the sea, elevated above the bulwarks of the OTEC 1 ship, swung over the deck and then lowered. This precarious journey would take about ten minutes per trip with a resulting transfer time of approximately an hour for a shift. The resulting four to six hour round trip seriously compromised the effectiveness of OTEC 1 as compared with the land based alternative.

The second illustration is drawn from the Okinawa fair which was located at some distance from the International Airport at Naha. THe road trip from the airport to the fair was in general impeded by the density of traffic in the vicinity of Naha and the travel to the fair required from two to three hours. A hovercraft was located at the airport with a terminal specifically designed for the fair. The transit time directly to the fair accommodations was only one-half hour. Due to the extreme motions associated with the particular sea conditions encountered in Okinawa and the high percentage of passengers who experienced motion sickness the hovercraft was rarely used.

As a result of these and other transportation difficulties (High wind helicopter landings on off shore platforms) designers of "floating city" concepts have concentrated on the use of hydrofoils and high speed semi-submersibles and most importantly on intermodal transfer terminals (as developed for cargoes in Portopia). Other systems considerations (waste disposal, power, communications, es thetics, cultural lag, etc) are also inhibitors. When the political social and economic organizational factors are added it is clear that the use of ocean space will occur on an evolutionary basis and not on a revolutionary basis.

Several evolutionary paths can be identified. In the United States the primary mechanism appears to be through the development of "theme parks". A review of that most famous of all parks "Disney land" reveals that the most cost effective rides are all waterbased. These include "the Pirates Cove" the Mark Twain steamboat, the Jungle cruise, the submarines, and the "speed boats". In each in stance the water provides an avenue for the transport of large numbers of people at low cost. A throughput of approximately 12,000 people per hour is attainable in these water based rides. Land based rides such as "The Matterhorn" have a through put of only a thousand per hour or less. The Japanese have successfully built a number of underwater reef observatories which are reached by bridges from the land and the previously mentioned Okinawa Fair was primarily marine oriented.

A second path is through the semi-submersible ferry and the semi-submersible luxury liner. Although the development path is seriously truncated in the United States by virtue of the Jones Act and its stultifying effect on American shipbuilding, a commercial recreational semi-submersible has been built which is now employed as a chase boat in the preparatory trials for the America's cup race. In contrast the Mitsui shipbuilding has proceeded with the development of a series of semi-submersible ships. These have in cluded a four hundred passenger ferry, an oceanographic ship, an underwater engineering ship for support of deep submersibles, and an executive cruiser. It is believed that a small cruise ship is in development. The super-stable characteristics of these ships and their immediate public acceptance suggests that the luxury super liner in semi-submersible form may well be the first "floating city"

A third path is through the development of floating OTEC plants and floating industries for the consumption of the power thus generated. The Applied Physics Laboratory has already pioneered in the concept design of floating OTEC-ammonia and Methanol plantships. These are similar to other stable platform designs with the inclusion of many deep water pipes. The success of such plants is almost certain to lead to the development of less sophisticated semi-submersible factories utilizing OTEC power for the processing of minerals or for the generation of methanol derived petro-chemical products.

A fourth path is through the development of marine mass transit and marine transportation systems. Several studies have shown that "fixed guideways" in the form of canals, waterways, drainage structures, rivers and lakes are intertwined with the high density core of many American cities (New York, Boston, Philadel phia, Baltimore, Washington, San Francisco, New Orleans, Los Angeles, Minneapolis-St Paul, Chicago, St Louis, etc) As such they provide a low cost alternative to subway-train-bus systems for mass transit. When coupled with high speed hydrofoils or semi-submersibles in such oceanic cities as Seattle, San Francisco, Honolulu and New York, the requisite transportation network can be established in advance of any stable platform development. The introduction of a stable platform "theme park" would be a simple evolutionary addition to any modern marine mass transit system designed to serve one or more of these cities.

Much more modest precursors in the form of fish attractant buoys or the Norwegiian floating steelhead trout farms, or in floating marinas can be seen in any modern coastal community. It is these initial protrusions into ocean space that suggest that the beneficial occupancy of the watery portion of our watery planet is not too far away.

Vessel Traffic Services System for the Seto Inland Sea

by:

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SUMMARY

For the purpose of securing safety of navigation and improving traffic efficiency for vessels in Tokyo Bay, the Maritime Safety Agency started in 1970 to establish the Vessel Traffic Services System for Tokyo Bay and completed it in 1983.

The System has been established with an aim developing smooth traffic flow and thereby securing safety of navigation in Tokyo Bay and the local ports by monitoring vessels' movements using shore-based radar, television monitors and so on, collecting a variety of information which the vessels may need and providing such information to them when necessary. This will be carried out concurrently with traffic control.

The remarkable decrease in the number of marine casualties since implementation as compared to previous records has proven the effectiveness of the system. Following the Tokyo Bay areas, a decision was made to introduce such a system into the Seto Inland Sea areas, which have congested vessel traffic, and a number of narrow channels and small scattered islands.

The construction work started in 1982. Priority has been given to the Bisan and Kanmon areas which have high density vessel traffic and many large ports in the vicinity. Furthermore, a future plans will include the Akashi and Kurushima Straits (See Fig. 1).

This paper describes the Vessel Traffic Services System which is called the Maritime Traffic Information Advisory System for the areas of Bisan and Kanmon located in the Seto Inland Sea.

1. Introduction

In Japan, the recent progress in the development of key ports and traffic routes together with the increasing trend of traffic congestion and remarkable changes in traffic conditions due to expansion in the size and speed of vessels have made diversification of the services provided for the safety of navigation and improvement in the functions and reliability of aids to navigation.

In order to deal with such a situation, the Maritime Safety Agency has been proceeding with a project of establishing a Vessel Traffic Services system, which provides information advisory services and traffic control which has necessary functions for safe navigation, while taking account of the special local environment and conditions.

As a part of the project, the Tokyo Bay Traffic Information Advisory System was established, and it has been in its service since 1977, covering almost all of the Tokyo Bay areas. It provides the sole source of relevant information necessary for navigation on the basis of continuous surveillance and analysis over the traffic movements using shore-based radar and computer etc. It also carries out traffic control in accordance with the Maritime Traffic Safety Law and Port Regulations Law. Since the services were implemented, the number of collisions and strandings in the areas has decreased considerably as shown in Table 1 and 2. This illustrates the substantial contribution of the system.

On the other hand, the total number of the collisions and strandings occuring during the past seven years in the Seto Inland Sea areas averaged about 550 annually, accounting for approximately 35% of the total maritime accidents recorded throughout the coastal areas of Japan. (See Table 3)

Among the other areas, the straits of Akashi, Bisan Seto, Kurushima and Kanmkon besides Tomogashima and Tsurishima Channel are narrow channels, and a number of marine accidents occurred due to the considerable maritime traffic congestion.

As described above, those areas have a high casualty risk, and it may also be expected that complexity of marine traffic environment will further increase in the future due to such factors as construction of over-sea bridges, etc.

For this reason, in 1982 the Maritime Safety Agency began the construction work of the Seto Inland Sea Maritime Traffic Information Advisory System to insure the safety of navigation, especially in the Kanmon and Bisan areas, where accidents have frequently occurred.

2. Outline of the Annual Plan for Seto Inland Sea Maritime Traffic Information Advisory System

With regard to the Kanmon area, shore-based radar stations, vessel traffic signal station and signal stations have been constructed in Mutsure and Dokai Bay. This was the 1st Phase Project (1982 to 1984), and the traffic control service and provision of advisory information for the vessels entering and leaving Dokai Bay started in July 1984 together with the organization of the port traffic control office (located in the vessel traffic signal station) which carries out monitor of dragging anchor for the Mutsure sea berth.

Development of the 2nd Phase Project (1984 to 1990) is planned to implement a competent vessel traffic services system, taking into consideration a maritime traffic safety system covering the total areas of Kanmon district, based on the factural situations that the areas have the North Kyushu Industrial Areas behind and that this has brought about high congestions and varieties of vessel traffic in addition to such peculiar local conditions as narrow and bend channels as well as the fast current up to eight knots. The overall plan is shown in Fig. 2.

Regarding the Bisan waters, a phased implementation will be planned for these two regions of Marugame/Mizushima in the 1st Phase Project (1984 to 1987) and Ukoh in the 2nd Phase (1987 to 1989). The overall plan for the areas is shown in Fig. 3.

3. Outline of Services To Be Provided by the Seto Inland Sea Maritime Traffic Information Advisory System

The Seto Inland Sea Maritime Traffic Information Advisory System, which covers both the Kanmon and Bisan areas, consists of VTS centers, shore-based radar stations, a vessel traffic signal station (Kanmon area only), signal stations, weather observation stations and other associated facilities. However, services are to be provided by the VTS centers and the vessel traffic signal station. The service to be provided by the vessel traffic signal stations are limited to special waters such as traffic routes within ports.

For example, in the maritime traffic information advisory system for the Bisan area as shown in Fig. 3, although shore-based radar stations will be established at Aonoyama, Shimotsui and Hibi, the radar information from these stations is fed into the VTS center located in the Aonoyama Shore-based Radar Station, where computerized data processing is carried out after digitalization of these signals in order to select target vessels, classify their sizes and compute their positions, their tracing automatically. When necessary, additional real-time information such the computed results of vessels' speed and course, near miss (in terms of time and distance) expanded speed vector, direction and distance from specified points, etc. can be obtained through the operator's manipulation made on the radar display. In addition to the aforementioned radar information, plans will be made to obtain at the Center an overall picture of vessel movement within the areas on the basis of data collected using TV camera installations for the designated channels and their vicinity. Its purpose is to provide navigational warnings in case of such dangerous situations as collisions or strandings, and to conduct scheduled broadcasts on the movement of huge vessels, fishing operations, weather conditions and other information collected from the agencies and organizations concerned, and to provide advisory information, at the request of vessels, on the locations of other vessels and any others information required for safe navigation through VHF radio or ships telephone.

Signal stations will be established at Yoshima and Nabeshima in order to smooth the traffic flow in merging areas and also at Saino-saki for the purpose of regulating the vessel traffic in the Mizushima route where traffic is busy due to the narrowness of the channel. The traffic signals to secure the safety of navigation will be controlled by the Center through a remote control and monitoring radio line.

Further plans include the provision of warnings by radio telephone based on forecast data to draw attention of vessels navigating in the areas connecting Kanmon Strait and Bisan Waters if and when it is considered that they may possibly pass through the areas face to face, and provision of intermediary services for their radio-communications.

They also include the provision of information on avoidance of the potential dangers encountered by vessels due to head-to-head navigation for non-radio fitted vessels by means of a remotely controlled lighting lettered-display system to be indicated on the vessel traffic signal boards.

In the existing plans for the Kanmon area, a VTS center will be established at Mogi with the associated shore-based radar stations respectively at Mogi, Hino-yama and He-saki, and the signal stations at He-saki, Mogi and Hino-yama, in order to implement services similar to those in Bisan waters.

Figure 4 shows a schematic outline of Seto Inland Sea Maritime Traffic Information Advisory System.

A summary of the planned services to be provided by the Center is given below.

3.1 Services To Be Provided by the VTS Center

3.1.1 Aids to Navigation Services

The aids to navigation services to be provided by the VTS center can be categorized briefly in terms of the contents of the services to be offered into provision of general information, individual information and specific information. The details of the services and means of provision are described below.

(1) General Information

1) Scheduled Broadcasts

The following information will be broadcast according to a pre-established time schedule of twice an hour on a frequency (a slightly high frequency of broadcast band can be used) which will be received by a simple type of radio receiver.

a) Restrictions on navigation in the traffic routes; The details of restrictions which have been enforced on huge vessels during low visibility and bad weather.

b) Estimated time of arrival of vessels to the traffic routes; expected time of arrival of huge vessels, vessels carrying dangerous cargo, etc. at the entrance of the traffic routes.

c) Condition of vessel traffic; number of vessels of a certain length or over in specified areas of the traffic routes.

d) Weather conditions; such weather conditions as wind direction and velocity, atmospheric pressure, etc. observed regularly at local weather observation sites.

- e) Grouped fishing vessels in operation (in the traffic routes and their vicinity).
- f) Status of construction works and countermeasures
- g) Weather warnings and notices
- h) Status of aids to navigation; new installations, removal, disorder, etc. of the aids to navigation which may affect vessel traffic in the routes and their vicinity.

2) Unscheduled Broadcast
In case of such emergencies as accidents or changes in the contents of scheduled broadcast, unscheduled priority broadcasts will be made providing the following information.

- a) Details of marine accidents
- b) Details of restrictions enforced in the traffic routes

3) Telephone Service
Telephone services will be provided through ship telephones or home/office telephones giving the following information.

- a) Estimated time of arrival of huge vessels and vessels carrying dangerous cargo at the entrance of traffic routes
- b) Status of traffic restrictions enforced in the traffic routes

(2) Individual Information
At the request of vessels, the following information will be provided through radiotelephone (international VHF Radio; ch. 16, ch. 14, and ch. 22) or ship telephones.

- a) Location of other vessels specified by the requesting vessel; the position, heading and speed of specified vessels comparative to one's own, and the name of the vessel, tonnage, destination etc., if the vessel specified had made notification of entering the routes.
- b) Vessel's position; bearing and distance from fixed points
- c) Anchoring status
- d) Movements of vessels within a certain area under poor visibility
- e) Others

(3) Special Information
The following information will be provided through the radio telephone under radar surveillance.

- a) Anti-collision Information; When dangers can be foreseen between vessels navigating head-to-head, the following information will be provided to vessels of certain tonnage and over: approximate position, name, type and size of the other vessels, and estimated time and position of passing. Intermediary services will be provided for bridge-to-bridge communications when and where necessary.
- b) Emergency Avoidance Information; when dangers might be seen by vessels entering into accidents areas, the relevant information will be provided to the vessels concerned.
- c) Proper steering information; warnings will be provided when and where improper steering is envisaged.
- d) Face-to-face sailing information; the information will be provided to vessels when face to face sailing/navigation may arise between them in the areas connecting the Kanmon and Bisan areas.

3.1.2 Traffic Control Service

Acceptance of notifications of traffic routes and their amendments as well as instructions on amendments in estimated time of arrival to the entrance of traffic routes will be carried out. And also instructions on restrictions enforced on entering into the traffic routes and their cancellations will be issued. The outline of services is as follows.

- a) Acceptance of notifications of traffic routes and their amendments thereof; acceptance of such notifications as those for estimated time of arrival to the entrance of traffic routes, etc. and of their amendments, for vessels over a certain gross tonnage in writing or by telex, facsimile or radio telephone directly to the center or via MSA's offices.
- b) Instruction to estimated time of arrival to the entrance of traffic routes; instruction will be issued on amendments in the estimated time of arrival to traffic routes if and when situations that two vessels over a certain tonnage enter a designated traffic route almost simultaneously are foreseen.
- c) Restrictions on entering traffic routes under poor visibility; instructions against entering the traffic routes when visibility around the routes deteriorates to below a certain distance will be issued.
- d) Restriction on entering traffic routes in cases of emergency; instructions against entering traffic routes where dangers may exist due to occurence of marine accidents in the routes and their vicinity will be issued.
- e) Regulation of vessel traffic; traffic regulation will be carried out for vessels of certain length or over on specified routes while providing them with instructions to follow the traffic signals through control of the lighting lettered-display boards installed.

4. Facilities and Equipment of the Seto Inland Sea Maritime Traffic Information Advisory System

The Seto Inland Sea Maritime Traffic Information Advisory System consists of VTS centers, shore-based radar stations, signal stations, weather observation stations and other associated facilities. The schematic diagram of basic equipment for the maritime traffic information advisory system and the schematic diagram of system equipment for the VTS center for Bisan area are shown respectively in Fig.5 and Fig. 6.

The equipment configuration of the center is mainly comprised of radar equipment, radar data processing equipment such as radar image digitization unit, radar image compound units, data control equipment, broadcasting and radio-communication equipment, and power supply. The following explains the major functions and performance of these equipment.

4.1 Radar Equipment

The radar equipment consists of a transmitter, antenna, waveguide switch, receiver and control unit. A frequency band of 14GHz will be used. A study is now being made on the use of circle polarization in order to improve the masking effect on vessels' echoes caused by rain echoes.

(1) Performance

Frequency	14GHz band
Output power	40kW (P-P)
Pulse width	0.1μsec
Antenna directivity	Horizontal 0.25°
	Vertical 15°
Antenna rotation	10 r.p.m.

(2) Detection Capability of Radar Equipment
There is a limit of the size of vessels which can be detected by radar. This radar has a sensing capability for metal vessels of about 20 tons up to approximately 20km. However, it may be affected by such factors as weather conditions, shape of vessel, heading direction, etc.

4.2 Radar Data Processing Equipment

The radar data processing equipment consists mainly of a radar image digitization unit, radar image compound unit, graphic display unit and other associated units. The functions of each unit are summarized below.

(1) Radar Image Digitization Unit
This unit selectively chooses video signals of specified areas required for processing out of ones from the radar equipment, and then detects the signals which are greater in level and longer in horizontal length than a threshold for digitization. The specified areas to be processed refer to vessel traffic areas, and the signal to decide the area are produced through a video mapping device. The unit scale of digitized signal is 20 meters in range and 0.09 degrees in azimuth with the center on a shore-based radar station. Any signals displayed side by side through digitization will be recognized as a signal of single target, i.e., they will be specified as signals from the same target. The center position of those signals is then computed to trace the movement of the target. There is a plan to incorporate a mini-computer with a memory capacity of 256KB into the radar image digitization unit.

(2) Radar Image Compound Unit and Graphic Display

- a) The display of digitalized radar images are compounded of thoes from a number of shore-based radar stations. This is necessary because some problems may arise in Seto Inland Sea areas where radar dead areas or false echoes may be produced by islands and bridges if only a single radar station fed image information for processing.
- b) Heading and speed will be computed for up to 100 vessels detected by the radar, of about 20 tons or more per radar station. They will be displayed in vector form on a graphic display and also in figures for specified vessels.
- c) Vessels will be automatically classified into large, medium and small sizes according to pre-established standards, and displayed accordingly.
- d) An identification code (comprised of one letter and two digits) will be displayed together with vessel's image in order to specify the vessels. This code automatically moves in accordance with the vessel's movements.
- e) For up to 40 pre-selected vessels, if and when the possibility arises for vessels to approach other vessels within a certain distance (fixed value), the vessel images flicker and an alarm is also generated. Also, relative position, heading and speed of the other vessels will be computed and displayed.
- f) Computation will be made for any two vessels of the nearest distance and time. This information is displayed.
- g) Computation will be made on the direction and distance of vessels with reference to fixed points.
A mini-computer with the memory capacity of 512KB will be used in this radar image compound unit.

(3) Data Control Unit
This unit will be used in combination with the control planning console, data editing console, charactor display and other units. Necessary data will be pre-registered, and control of the information to carry out the services at the center will be made by displaying the relevant data on a character display unit or line printer in a pre-established format in order to carry out control planning and produce, broadcasting messages, various statistic data, etc. A mini-computer, with the memory capacity of 2MB will be used in this unit.

4.3 Broadcasting and Radio-communication Equipment

(1) Broadcasting Equipment
The equipment is to broadcast necessary information of common interest to all relevant vessels on a frequency receivable by radio (a slightly high frequency of the broadcast band will be used) according to a pre-arranged time schedule. An SSB transmitter with an output of W will be used.

(2) Radio-communication Equipment for Vessels Service
An international VHF Radio transmitter, 10W output, will be used for radio communication with vessels.

(3) Others
Optical cable, transceivers for the 7GHz and 2GHz bands, telex, facsimile and other units will be used for the transmission of radar images, TV images, weather reports and other data.

5. Conclusion

It will be extremly difficult to forecast and evaluate the economic effect obtaining from the implementation of this system. However, as seen in the case of a similar system already in service in Tokyo Bay, cases of traffic regulation violation in the areas have decreased to almost nothing. This has brought about a trend of decrease in the number of marine accidents in the areas. In the light of the above, people engaging in marine society have great expectations for the early development and implementation of the system. The Maritime Safety Agency plans to further implement such a system in other important areas with an aim to secure the safety of navigation at sea.

Table 1. Transition of Number of Ships/Marine Accidents (Collisions and Strandings) in Tokyo Bay

Item \ Year	1975	1976	1977	1978	1979	1980	1981
No. of Ships Entered (A)	126,014	131,920	159,660	160,679	176,639	179,620	176,451
No. of Collision and Strandings (B)	126	116	72	66	93	101	112
B/A	0.100	0.088	0.045	0.041	0.053	0.056	0.063

Source: Port and Harbor Statistics (20 Gross Tons or over)

Table 2. Transition of Collisions and Strandings Occurring within Radar Service Range of Tokyo-Bay Maritime Traffic Information Advisory System (No. of required rescue operations only)

Item \ Year	1974	1975	1976	1977	1978	1979	1980	1981
Less than 100 tons	0	1	1	1	2	2	6	4
100-500 tons	5	3	3	2	2	4	2	1
500-3,000 tons	2	1	0	0	0	0	0	1
3,000-10,000 tons	1	1	1	1	1	0	0	0
10,000 tons and over	3	2	3	0	0	0	0	0
Total	11	8	8	4	5	6	8	6
Gross tonnage of accidents	76,712	138,436	41,599	3,958	5,192	725	1,000	824

Table 3. Transition of Collisions and Strandings (Unit: number of ships)

Area \ Year	1975	1976	1977	1978	1979	1980	1981	Average in seven years
Seto Inland Sea	547	618	599	514	538	558	498	553
(Tomoga-shima Akashi)	27	18	22	23	25	22	12	21
(Bisan-Seto)	33	46	46	55	52	41	31	43
(Kurushima, Tsurishima)	20	18	26	28	14	24	12	20
(Kanmon)	78	80	88	55	64	55	48	67
Total in Japan	1632	1756	1713	1601	1546	1756	1531	1648

Source: SAR Statistics

Fig. 1 Development plan for Seto Inland Sea maritime traffic information advisory system

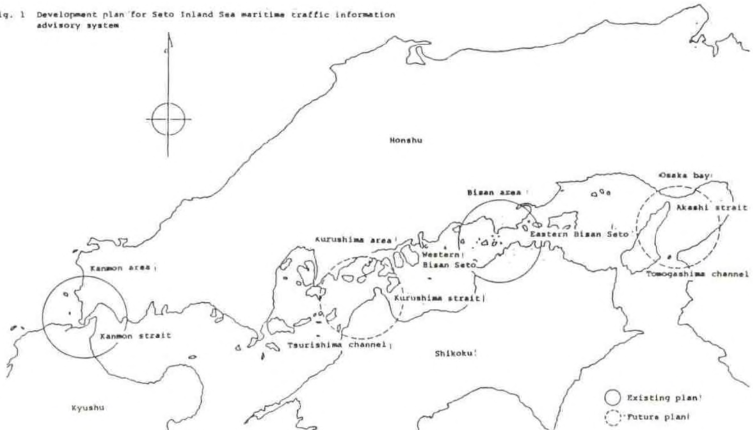


Fig. 2 Kanmon area maritime traffic information advisory system
(Overall plan)

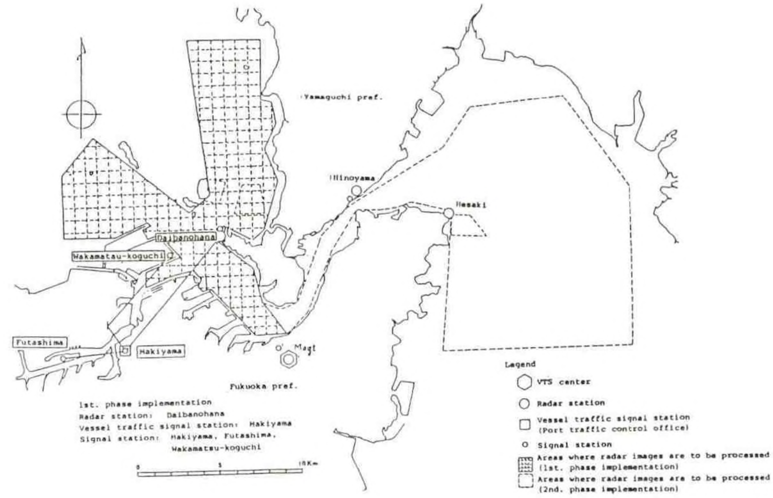
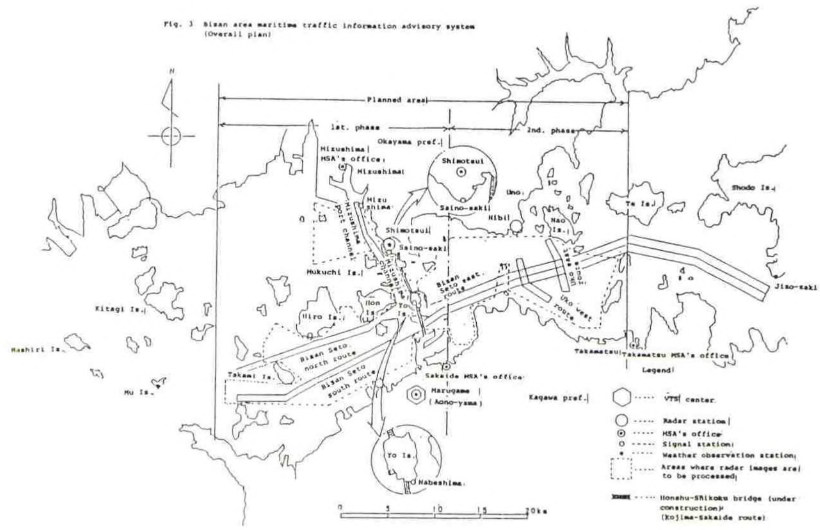


Fig. 3 Bisan area maritime traffic information advisory system
(Overall plan)



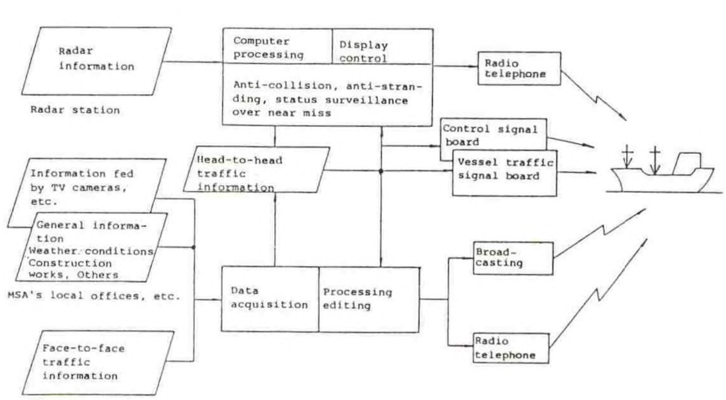
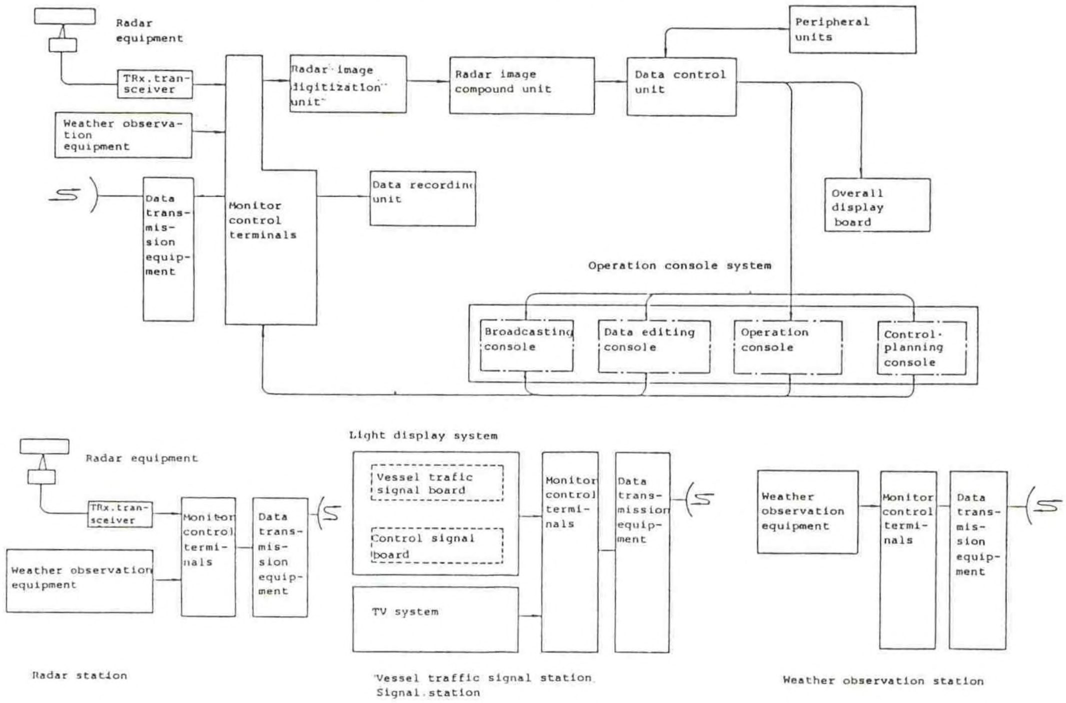


Fig. 4 Schematic outline of Seto Inland Sea maritime traffic information advisory system

Fig. 5 Schematic diagram of basic equipment, Seto Inland Sea maritime traffic information advisory system



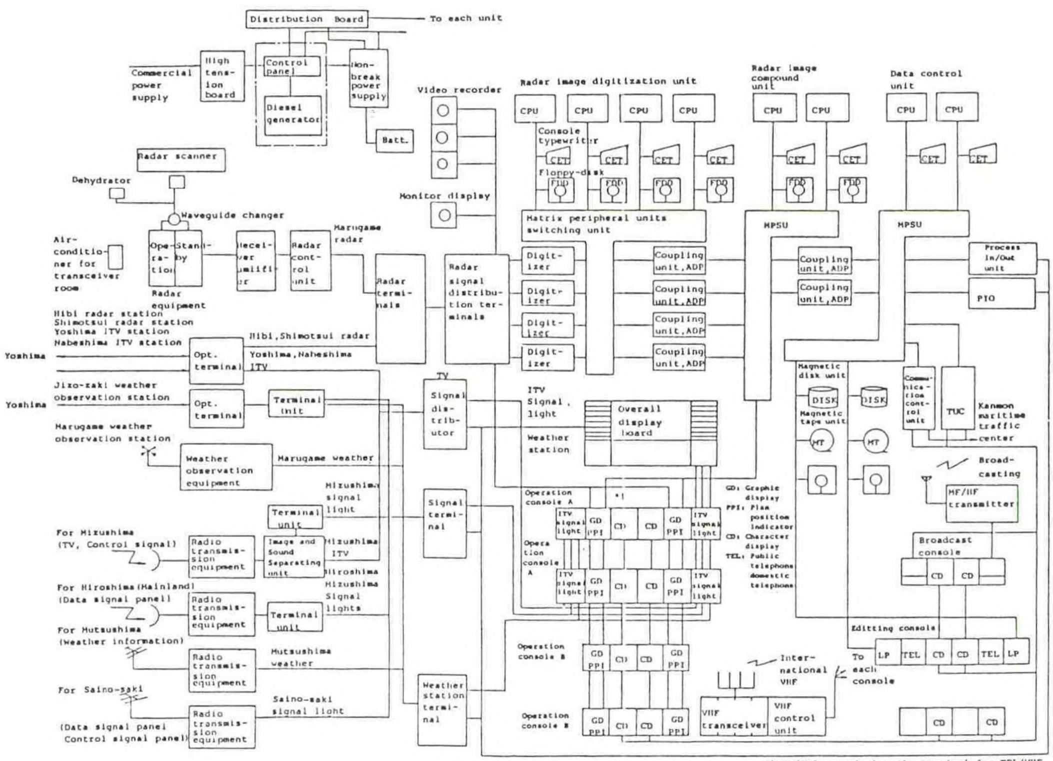


Fig. 6 Schematic Diagram of System Equipment for Maritime Traffic Center (for Bisan Area)

*1 GD/PPI console has the terminal for TEL/VHF.

Ocean Measurement Systems

IMPROVED PORT OPERATIONS WITH REAL-TIME DATA AND SHORT-TERM PREDICTIONS

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ABSTRACT

Few ports have implemented systems to measure water level, currents, winds, water density and other conditions which may significantly influence operations. None use active predictive models to forecast these conditions. The technology to make appropriate measurements and to forecast conditions for short intervals is available today. Simple collection, analysis and dissemination systems are within the state of the practice. A simple system measuring water levels, winds and bridge clearance is described and the effects on the economics of several shipping operations are considered. Favorable cost/benefit ratios are established for the system. Recommendations are made for establishing real time information systems.

INTRODUCTION

Pilots and masters have traditionally used their "weather eye", the summation of perhaps tens of thousands of hours of observational experience, to gauge those environmental factors that are critical to safe passage within ports and harbors. The technology exists to measure many of the physical parameters that can be critical to safe passage and to economical port operations. Further, most of these same factors can be forecast with reasonable skill for periods as great as 24 hours into the future. A variety of communication links are available to deliver observations or predictions to pilots, masters and fleet and terminal operators and others concerned with scheduling or directing vessel operations within ports and harbors.

THE NEED FOR INFORMATION:

Each port represents a unique combination of economic, environmental and geographical factors. No single information system can be expected to meet precisely the needs of all ports. However, the requirements of most ports for environmental data can be extracted from a list of only seven parameters.

1. **Underkeel Clearance.** The majority of American ports are depth limited. A study by the Marine Board (1985) found that most U.S. ports had not kept pace with foreign ports in meeting the depth requirements of modern vessels. This requires that the water level (comprised mainly of astronomical tides + wind-driven tides + river flows) as well as the position of the bottom be known or predicted.

2. **Winds.** Many operations can be severely impacted by strong winds, including docking, traversing narrow channel bends and most crane uses.

3. **Currents.** The magnitude and direction of currents can impact the safety or effectiveness of many vesselhandling operations. In particular it can influence the decision on how many tugs may be required to assist a large vessel.

4. **Waves.** Particularly at the entrance, wave height may control decisions on safe vessel operation. Under certain conditions, the depth of the troughs may limit the safe draft over the entrance bar. For a discussion of the significance of the wave climate within harbors, see Seymour (1977).

5. **Water Density.** In addition to the distance between the surface and the bottom, safe underkeel clearance requires a knowledge of the water density profile so that the vessel draft can be predicted accurately.

6. **Underbridge Clearance.** Ships with tall masts or superstructures can have a problem with clearance under bridges, cable crossings and other elevated hazards. In many cases, the bridge or cable span may respond to traffic loads or temperature variations such that its vertical position can vary significantly.

7. **Visibility.** Impairments to visual contact, particularly the effects of dense fog, are obviously of paramount importance in many ports. Areas of restricted visibility can be interspersed with clear areas and are often subject to rapid changes.

STATE OF THE ART IN OBSERVATION AND PREDICTION

A. **Underkeel Clearance.** The water level component may vary rapidly and must be observed at intervals of about 30 minutes. The bathymetry, or bottom position, may be stable over very long periods or it may be subject to relatively rapid (intervals of a few days) fluctuations because of interactions among waves, currents and sedimentation processes. The next generation water level measuring system under development by NOAA will provide satisfactory definition of water level at a point. The number of these instruments required depends upon the geometry of the harbor. The changes to water level attributable to astronomical forcing, or routine tides, are easily forecast as far ahead as required. In complex areas, this may require measurements over several months to calibrate the model, but the predictive skill will remain very high. Where winds can significantly affect water level, the predictive capability for this component is clearly limited by the ability to predict the wind direction and magnitude. Numerical models simple enough to run on modest computers in real time have been developed to predict the surge caused by the wind. In many harbors, river inputs can significantly affect water levels.

The second component of underkeel clearance, the position of the bottom, presents serious measurement problems. Chart depths are often quite unreliable because of the long intervals between surveys. It appears that substantial effort will be required to reduce the cost of bathymetric surveys before reliable underkeel clearance estimates can be universally available.

B. **Currents.** Because of the potential variability of currents in both the horizontal and vertical, there is no completely satisfactory method for measuring them within harbors. However, current measurement using a remote acoustic doppler system (often referred to as RADS) which can be deployed without obstruction of the channel provides a limited remote sensing capability. This appears to be the best choice among the available instruments. Numerical models exist for predicting harbor circulation and can be run in real time with updates from measured currents.

C. **Waves.** Wave heights can be satisfactorily measured by a number of in situ techniques [see Seymour (1981).] Surface following buoys would be the instrument of choice in deeper water outside the harbor entrance. Inside the harbor, bottom-mounted pressure sensors in locations away from structures, or wave staffs mounted on pilings are capable of reliable measurements. Technology is inadequate at present to measure wave direction with sufficient accuracy to make routine predictions throughout a complicated harbor. Further, there is no technique available to make deep water directional measurements outside the entrance, the point where direction is probably most critical. Wave height measurements must be made at each general location where these data are critical. Prediction falls into two categories. If the waves are locally generated only (protection from swell from distant areas) the wave prediction is limited only by the ability to predict the wind field. Accurate models exist to predict wave generation given the wind speed, direction and duration. If the site is strongly influenced by swell from distant generating areas, the estimate is dependent upon a wide-area model. These ocean basin wave generation models exist.

D. **Water Density.** In harbors with draft limitations and mixing of fresh and salt water, it is often necessary to determine the effective density of the water column in order to specify minimum underkeel clearance. Technology exists to install a pressure gage near the bottom below a water level (tide) gage. By knowing the height of the water column above the pressure gage and its weight (bottom pressure) the average density can be obtained. This provides no details on the density profile and would only apply to a vessel having a draft approximately equal to the depth of the pressure sensor. In principle, the pressure sensor could be made to traverse the water column in steps to give a profile. This instrument, if located at a dock, could reliably control vessel loading to achieve a maximum draft in a given density profile. Predictions of changes to density structure would require a very sophisticated 3-D circulation model that is not presently within the state of the art.

E. **Mast Clearance.** Vessels with tall masts and deep draft often find a very narrow window of possible water levels during which they can safely pass under bridges, cables or other obstructions. If the bridge roadway remains fixed relative to some datum, the problem is simply that of making a local water level measurement. Many long span bridges can vary their elevations significantly because of loading and temperature effects. If this is the case, a further measurement or estimate of the sag must be made to determine the clearance. The sag may be found to have a temporal pattern caused by predictable temperature and traffic shifts. If so, this could be predicted in advance and combined with a water level prediction model to give advance warning of future underbridge clearance conditions. In summary, measurements and predictions are feasible, but have not been demonstrated.

F. **Wind.** Wind speed and direction can be measured directly with a variety of reliable and relatively inexpensive commercial instruments. In addition, several remote sensing techniques are available (at significantly greater cost) using sonic, laser or radar equipment to measure wind at considerable distance from the instrument. The present capability for predicting winds within a harbor is very limited. Although great strides have been made in numerical modelling of large scale climate features, these fail to predict the small scale features that affect local winds.

G. **Visibility.** Instruments that are of moderate cost and with reasonable reliability are available to measure visibility. However, their range is sufficiently short to be of limited value in a harbor setting. No long range remote sensing type of instrument is available. Very large scale fog can be predicted with reasonable skill, but the local variation in visibility typical of many ports cannot be predicted except on a statistical basis. Further, there appears to be no research underway in this field.

DISSEMINATION OF INFORMATION

The system for distributing real time data or short term predictions to users can assume any level of complexity necessary to meet the local needs. In the narrowest view, the only users may be the pilots. In that case, information may be gathered and displayed at a single location (say the pilot headquarters) relayed to the pilot boats for more timely updates, or displayed directly on the bridge of the vessel when conditions can be expected to change substantially during the transit time. More broadly, the data may be used by fleet or terminal managers as an aid to scheduling, by police, Coast Guard, and firefighting units for emergency operations, by recreational boaters, and so forth. In that case, the dissemination channels must be broadened appropriately and might even include a cable TV channel or similar approach. The technology exists to distribute digital data (plots or tables) throughout the harbor and its approaches by utilizing telephone lines, digital RF transmission, radio or TV broadcasting, or any combination of these. The limits on dissemination appear to be purely economic and institutional.

EXAMPLES OF REAL TIME MEASUREMENT SYSTEMS

Several simple systems for disseminating real time observations within ports and harbors have already been undertaken. A complete

In order to evaluate the potential for benefits in any specific port, hypothetical examples have been generated and costs estimated for providing the services. Consider a simple port configuration. In this example it is assumed that there is a draft limitation problem throughout the harbor, wind is a factor in both the lightering and docking areas, and masthead clearance is a problem under one of the bridges over the channel. It is further assumed that three additional water level gages are required to augment an existing NOAA primary tide gage, two wind gages are installed at the appropriate locations and a sensor for masthead clearance is mounted at the limiting bridge.

Seymour and Vadus (1986) describes the cost elements of this system and defines three economic examples - a grain loading operation, a containership unloading operation and a within-harbor barging operation - that illustrate the potential cost savings. This paper shows that an annual savings of $200,000 (for the minimum system) are required to offset the system costs. The actual total savings, even in this hypothetical port, would depend upon a mix of traffic and an understanding of what fraction might actually benefit from the environmental data available.

The grain loading operation example assumes that among those sailings able to load to deeper draft because of better information that half can increase draft by 6 inches and half by 1-foot. Therefore, a total of 14 sailings with the assumed mix of draft increases would produce sufficient savings to offset the total cost of the system.

The containership unloading operation example assumes that a 1-inch draft increase was possible (6 containers) on certain sailings because of improved knowledge of the water depth, a total of 19 such arrivals would be required to show breakeven. This is an average of 0.6 arrivals per vessel per year for a 30 vessel fleet.

The in-harbor barging operation example found that if each tow boat was able to move an average of only one barge per week at an average 6-inch increase in draft, a favorable cost/benefit ratio would be achieved.

It should be noted that all of these examples utilized only the water depth capabilities of the system. The potential savings through eliminating unnecessary tugs through a good knowledge of wind conditions or from delays associated with bridge clearance problems for tall vessels would be additive to the benefits. This simple economic analysis is intended to show only that such a real time system may be very cost effective. Each port application must be carefully analyzed for its unique environmental problems and the economic significance of improved knowledge.

A detailed study of the technical and economic feasibility of these kinds of systems was reported in Marine Board (1986).

CONCLUSIONS AND RECOMMENDATIONS

Technology is available to allow the collection, analysis and dissemination of measured data on environmental conditions within ports and harbors that can improve efficiency and profitability. For many parameters of interest short term predictions (on the order of 6 to 12 hours) can be made with usable accuracy. Economic analyses of real time data systems using examples of hypothetical ports look very encouraging. Careful analysis of conditions in specific ports must be undertaken to determine the needs, costs and benefits.

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Wave Observation Using Navigation Radar Reflection

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abstract
A technique to use a marine radar to extract wave information is introduced. Wave length, speed and height are calculated through spectrum analysis on the digital values of radar echo.
A field experiment was made, in which a radar data were compared with the Tucker wave recorder

1. Introduction

The wave is an important information for the safety of ships. Usually, wave information which are provided from the authority is rather rough.
Then it is useful when the wave information can be obtained easily at each ships. In this report, it is shown that wave information can be extracted from conventional marine radar.

2. Radar reflectrion and wind wave

The radar reflection is dependent upon the ocean's slope. Then the horizontal distribution of the radar reflection intensity shows wave height distribution around the ship, and also time variation of those crests location shows the wave'sspeed.

One scan of radar data can be) expanded in two dimentional Fourier series as;

$$F_1(l,m)=\sum\sum f(j,k)\exp\left\{-2\pi i\left(\frac{jl}{M}+\frac{km}{N}\right)\right\}$$

Power spectrum is calculated as ;

$$p(l,m) = F_1(l,m)\cdot\overline{F_1(l,m)}$$

Cross spectrum is calsulated from the successive radar scan data;

$$P_c(l,m) = F_1(l,m)\cdot\overline{F_2(l,m)}$$

Wave length and wave direction can be calculated

$$L_w = (\text{length of area})/\sqrt{l^2+m^2}$$

$$D_w = \tan^{-1}(l/m)$$

4. Field experiment

A digital cassette recorder was added to the marine radar in survey vessel "SHOYO" of the hydrographic Department. In Dec 3, 1983, a field experiment was made near Izu - Ohshima Island. Ship-bone Tucker wave recorder was also used for reference
Fig. 1 shows the radar data obtained at 12:30 on Dec. 3, 1983. Fig. 2 and 3 are the calculated Power spectrums. In Fig. 4, the comparison between radar and Tucker recorder is shown. It seems that this method is promising for wave analysis.

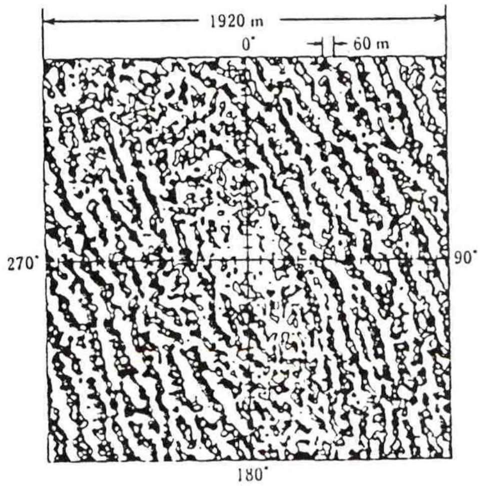

Fig.1 原データ
Original data

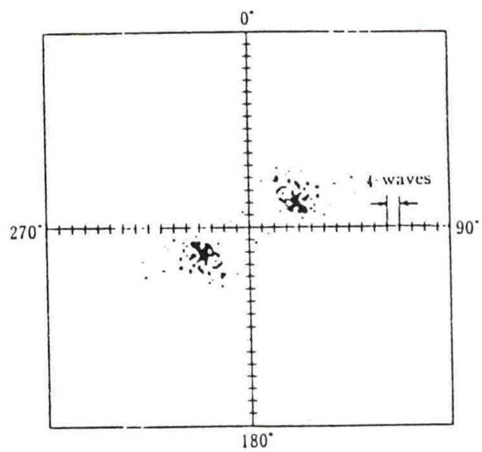

Fig.2 パワースペクトル
Power spectrum

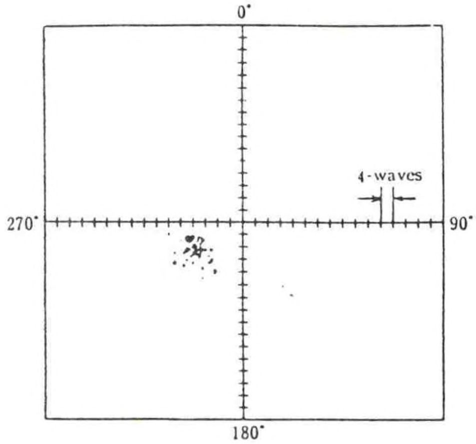

Fig.3 クロススペクトル
Cross spectrum

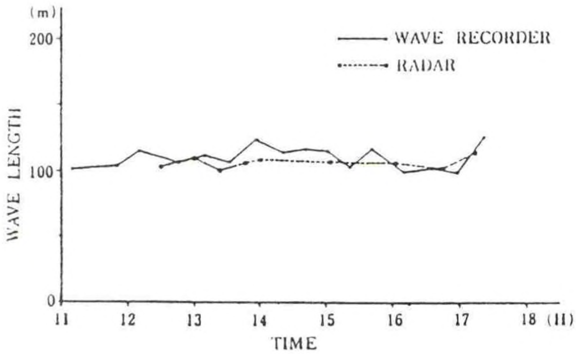

Fig.4 波長の時間的変化
Wave length versus time

THE NATIONAL DATA BUOY CENTER: EXPANDING HORIZONS

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ABSTRACT

The National Data Buoy Center is the focal point for technology related to the United States' data buoys and associated automated environmental monitoring systems. The Center's operational activities, which began with deep-ocean moored buoys, now include drifting buoys and permanent land stations along the nation's coastlines. Engineering and experimental activities are under way to make these systems more reliable, versatile, accurate, and cost effective. Recently, developmental programs have been undertaken to provide automated surface observations at airports and to measure wind velocity through the atmosphere by use of Doppler radar wind profilers. Most of the test and developmental programs are conducted in cooperation with other government agencies or private organizations.

INTRODUCTION

The National Data Buoy Center (NDBC) is the United States' focal point for data buoy technology and associated automated environmental monitoring system technology. NDBC is an outgrowth of the U.S. Coast Guard's National Data Buoy Development Project (NDBDP), begun in December 1967. The NDBDP was transferred into the National Oceanic and Atmospheric Administration (NOAA) in October 1970, when NOAA was created within the Department of Commerce. The NDBDP became the NOAA Data Buoy Office, and subsequently the National Data Buoy Center. NDBC became a part of the National Weather Service (NWS) in 1982.

Activities at the Center have grown considerably since 1970. Operations and research have expanded beyond moored buoy technology to automated coastal and surface observing stations, and drifting buoys. NDBC's experience in converting theory and basic technology into operational marine monitoring systems has led to projects with application on land as well, with efforts currently under way in the development and demonstration of automated surface observation systems and upper-air wind profiling Doppler radar. Measurement techniques and systems have evolved and become more efficient, dependable, and durable, while at the same time becoming less costly.

An extensive data quality control program assures that measurements remain of the highest quality. Data are constantly monitored to detect any degradation or failure of the stations or sensors. NDBC is able to edit or delete messages from the National Meteorological Center (NMC) when data problems occur.

References 1 and 2 provide a general history and overview of NDBC programs and history. This paper will provide an update to programs currently under way and being planned at the Center.

MOORED BUOYS

The moored buoy network consists of over 40 buoys located in the Atlantic and Pacific Oceans, the Gulf of Mexico, the Great Lakes, and the Bering Sea (Figure 1). NWS uses data from all of the buoys and funds most of them. The remainder are funded by other government agencies, such as the Minerals Management Service and the Defense

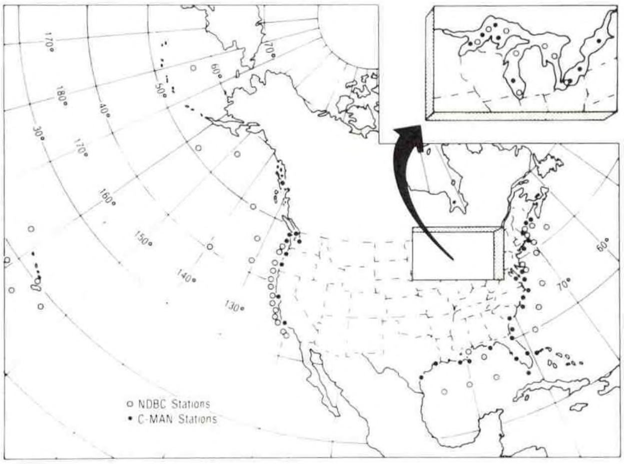

Figure 1. NDBC Network of Moored Buoys and C-MAN Sites.

Department in support of various research programs. NDBC also conducts some of its engineering development activities using moored platforms. The deep-ocean moored stations are primarily 10- and 12-meter discus buoys, and 6-meter boat-shaped NOMAD buoys. Successful tests in 1985 on smaller 3-meter discus buoys showed their applicability in regions where sea conditions are not extreme and where servicing is less difficult. Much of their future use will be in or near coastal areas, and for special applications in support of scientific experiments and studies.

A recent special program involved a 12-meter discus buoy that was deployed in September 1985 in the Bering Sea 560 kilometers (km) north of Adak Island, Alaska. NDBC designed and prepared the buoy and mooring, and is providing buoy logistics, support, and data archival throughout a 5-year program, which is part of a cooperative venture including the National Ocean Service and the Alaska Oil and Gas Association. Special preparation included additional batteries, extra sensors to report temperature within the battery compartment, antifreeze in the ballast water, and a heavy-duty mooring line. The buoy has operated at greater than 98 percent reliability, reporting meteorological and wave data in spite of the extreme environment (Table 1). In addition to weather analysis, forecasting, and climatology,

Table 1. Extreme Values Measured at Buoy 46035 (57°N, 177°W) Since Deployment on 13 Sep 85.

PARAMETER	VALUE
Highest Waves ($H_{1/3}$)	10.7 m
Highest Sustained Wind Speed	20.2 m/sec
Highest Wind Gust	28.6 m/sec
Lowest Air Temperature	-7.4°C
Lowest Water Temperature	2.8°C

the data are being used in determining structural design requirements for offshore platforms.

Efforts are under way by both the U.S. Coast Guard (USCG) and NDBC to develop buoys that can withstand ice and instruments that are able to supply basic meteorological data in severe winter conditions. Severe winter weather and ice have caused significant problems for data buoys, requiring the annual retrieval and redeployment of eight buoys on the Great Lakes each autumn and spring. This is a major operation in terms of cost and logistics. Because the number of available USCG buoy tenders and icebreakers is limited, the buoys sometimes have to be retrieved well before freeze-over, and typically are not redeployed until well after the ice has melted. Thus, environmental observations are not available at the end and beginning of each shipping season on the Great Lakes.

The USCG and NDBC are each using different approaches in trying to solve this problem. The Coast Guard has developed a small buoy (2.2-meter diameter, 6.1-meter length) that is designed to ride up on light ice cover, or to submerge under the ice during a hard freeze-over. Such a buoy might be instrumented with expendable sensors that would be lost each winter. NDBC decided on a different approach: using the huge, heavy, discus buoy (12-meter discus, 47,000-kilogram weight unballasted) that has survived the harsh North Pacific and North Atlantic Ocean environments. Computer simulations by engineers at NDBC indicated such a buoy would survive all but the rarest, most severe combination of ice, wind, and waves that could be expected on the Great Lakes.

The 12-meter ice buoy concept was tested on Lake Superior during the winter of 1985-86. The buoy, mast, and instruments survived the severe winter with no apparent damage. Although at times covered with tons of ice (Figure 2), most on-board systems continued to operate as designed. A wind direction problem did occur, but this was determined to be the result of a compass compensation error unrelated to the harsh environment. More significantly, the buoy began to move in mid-February. As it dragged its mooring, the buoy was tracked for two months along a path that zig-zagged over some 480 km. The nylon-line, inverse-catenary mooring finally failed, and the buoy stabilized its position in shallow water east of the Keweenaw Peninsula of upper Michigan. After another winter test, which may involve two buoys, a decision will be made whether to create a network of 12-meter "ice buoys" in the Great Lakes. The experiments will use all-chain moorings, which may prevent a similar failure. If the all-chain mooring is successful, it also would provide an easier system to retrieve and redeploy.

The role of smaller, 3-meter discus buoys is expected to grow in the coming years (Figure 3). In tests that compared measurements between the 3-meter and NDBC's larger buoys, identical sensors were used. Data received from the two systems compared closely, and

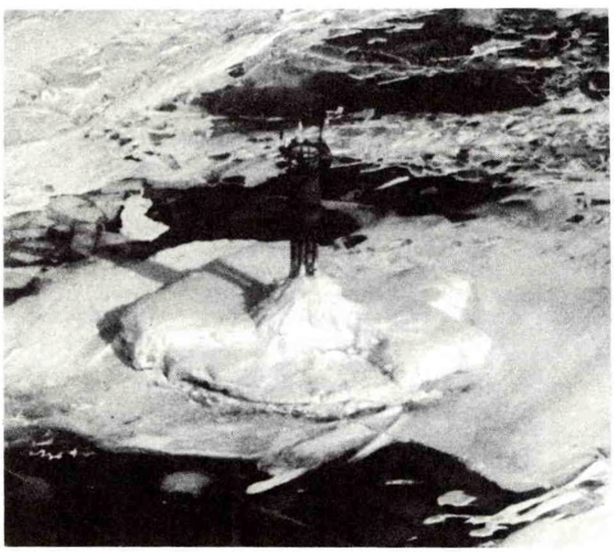

Figure 2. Buoy 12D07 at Station 45001 During the Winter 1985-1986 NDBC "Ice Buoy" Experiment.

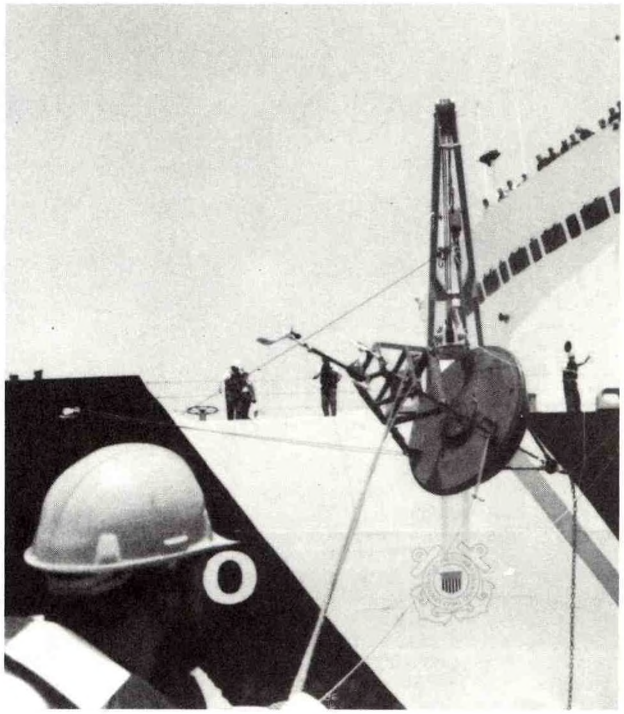

Figure 3. Three-Meter Buoy in a Very Rare Deployment Over the Side of a U.S. Coast Guard Ice Breaker in Late 1984.

plans are to begin deploying 3-meter buoys in the Great Lakes next season to replace most of the NOMADs currently in use. This will result in significant savings in construction, dockside preparation for deployment, and maintenance. More important, it will free several NOMADs for use far offshore in the Atlantic and Pacific, and where sea conditions are typically more severe.

Early in 1986, two 3-meter discus buoys were deployed off the west coast of South America in support of the Tropical Ocean Global Atmosphere (TOGA) research program. Deployment and maintenance of these buoys are conducted in accordance with cooperative agreements between the United States, Peru, and Chile. Atmospheric and oceanic measurements from the buoys are reported via the Geostationary Operational Environmental Satellite (GOES) and distributed over the Global Telecommunications System (GTS).

NDBC arranged for the special deployment of two 3-meter buoys to support the 2-month Genesis of Atlantic Lows Experiment (GALE) in early 1986. The dense GALE observation network across the Carolinas and adjacent marine area also included two established NDBC ocean stations in the Atlantic and several NDBC coastal sites. In addition to their usual complement of instruments, the 3-meter buoys and the coastal site at Diamond Shoals, North Carolina, were equipped with experimental relative humidity sensors, and were set up to transmit data twice each hour.

COASTAL-MARINE AUTOMATED NETWORK

In the late 1970s, NWS recognized that more coastal observations were needed. At about the same time, however, most of the traditional headland and offshore sites, primarily USCG Light Stations, were becoming automated, so that the number of available manual observations was decreasing. As a result, the Coastal-Marine Automated Network (C-MAN) was begun in 1981. The first C-MAN headland site was established in late 1982. By the time the initial phase of the C-MAN program was completed in May 1986, the program had grown to a total of 38 fixed headland sites, 8 Large Navigational Buoys (LNB) and one Exposed Location Buoy (ELB) (Figure 1). An additional temporary land station at Settlement Point, Grand

Bahama Island, supports the Subtropical Atmospheric Climate Study (STACS). NWS has determined a total C-MAN requirement of 127 land stations, which will be installed as resources permit.

Selection of all C-MAN sites is based on the need to improve coastal and marine forecasts, watches, and warnings. Site selection criteria include the physical accessibility, availability of power and phone communications, electromagnetic and radio frequency interference, maintenance and support requirements, sensor exposure, and placement of the antenna. The desire is for site placement and sensor exposure that best represent the nearby marine environment (Figure 4).

To take automated, self-timed, weather observations, NDBC developed the Data Acquisition Control and Telemetry (DACT) electronics system. The DACT takes observations at regular intervals, processes and formats the data internally, then transmits them at predetermined times—usually each hour—to the GOES via an ultrahigh frequency (UHF) communications link. Where telephone service is available, the system can also report data through telephone interrogation.

C-MAN observations are formatted at the DACT into a modified form of the surface synoptic code. The data are transmitted via GOES through the National Environmental Satellite, Data, and Information Service (NESDIS) to NMC, which processes the observations before dissemination to the field through the various communications networks.

All C-MAN sites measure air temperature, atmospheric pressure, wind direction and speed, and peak wind gust. The DACT was originally designed to be easily expandable, so dew point, precipitation, water level, and wave meaurements have been added to the observations at some sites. More new sensors will be installed after successful field tests and evaluation. Preliminary testing of visibility sensors is under way, with the hope that a prototype system can be tested by late 1987. Coastal wave measurements began this summer at Grand Isle, Louisiana, using a Waverider-type buoy to report to a nearby C-MAN station; and a laser wave sensor is being tested at Chesapeake Light Station, Virginia. Finally, rain gauges and relative humidity sensors are being installed and will be tested at selected sites through the next year.

The U.S. Coast Guard has operated and maintained LNBs in the coastal waters for several years to make navigation and shipping safer. Cooperation between NDBC and the Coast Guard led to instrumentation of LNBs with meteorological and wave-measuring systems. Smaller and less expensive ELBs are now being tested to see if they can operate satisfactorily as navigation aids and make environmental measurements. Tests during the late 1970s demonstrated this to be feasible because of improved microcomputers, like DACT units, and improved satellite communications. However, because ELBs are considerably smaller (2.9-meter diameter, 11.4-meter height), and since they are not designed to follow the surface of the water, their motion and stability are markedly different from buoys designed to take environmental measurements. The smaller size also presents servicing problems, since crew members must clamber aboard the buoy to prepare it to be hoisted on board the ship (Figure 5). Field tests comparing ELB and LNB measurements are being performed this summer off the coast of California at St. Georges Reef, and at the mouth of the Columbia River to ensure averaging techniques and algorithms are valid.

Figure 4. The C-MAN Sites Are Sometimes Very Remote, such as Five Finger Light Station, Alaska.

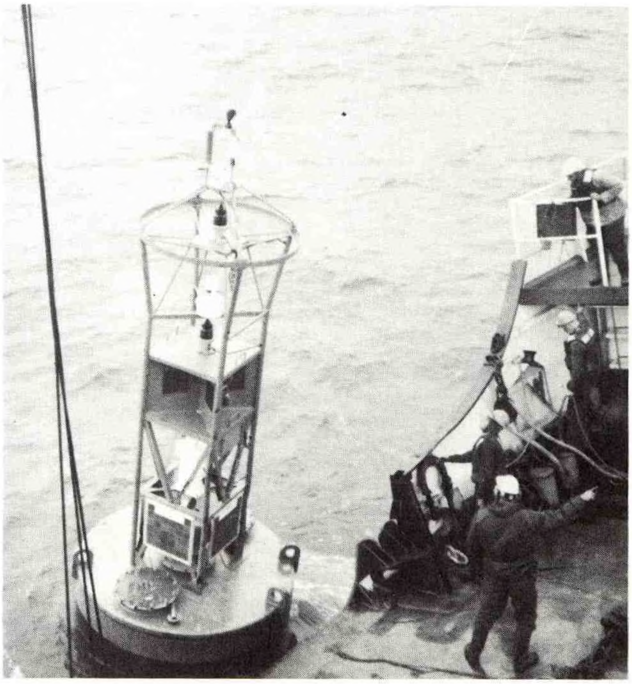

Figure 5. U.S. Coast Guard Exposed Location Buoy Being Prepared for Servicing.

DRIFTING BUOYS

The NDBC drifting buoy program is a far-reaching effort with a significant domestic and international role. It is the focus of the United States' drifting buoy development and operations. Accordingly, NDBC was a major participant in developing the National Operations Plan for Drifting Data Buoys, the first document to provide a framework to all aspects of the United States' drifting buoy program, from specifications and development to data usage and archiving. Drifting buoys have been deployed on behalf of the National Hurricane Center (NHC), the Minerals Management Service, the U.S. Navy, the U.S. Coast Guard, and other agencies. At this writing, NDBC has about 80 drifting buoys deployed that provide information to organizations around the world for use in analysis, forecasting, and research. Development and deployment of buoys in support of other government agencies and international research programs are other facets of the NDBC drifting buoy program. The drifting buoy program is also involved in the advancement of all aspects of drifting buoy technology, and the critical issue of near-real-time quality control.

Perhaps the most glamorous operational program has been in support of NHC. In 1984, drifting buoys were deployed by aircraft for the first time into the path of Hurricane Josephine. The eye of Hurricane Josephine passed directly over one of the buoys, and there was excellent agreement between measurements from the buoy and weather reconnaissance aircraft (Reference 3). During the 1985 hurricane season, Air Force C141 aircraft deployed a half dozen buoys in the western Atlantic and the eastern Pacific near Hawaii to help monitor meteorological conditions after the imaging capability of

GOES East was lost. In the same year, Tropical Storm Danny passed within 83 km of both a moored and a drifting buoy in the western Gulf of Mexico. Measurements from the drifting buoy were in good agreement with those from the moored buoy, following correction to the wind speed to account for the 1-meter anemometer height of the drifter (Figure 6). Support to NHC is continuing in 1986. A small network of drifting buoys is planned east of the Caribbean Sea to help monitor cyclonic systems in the Atlantic, and a small number may be deployed in the Gulf of Mexico if storms threaten the Gulf Coast.

NDBC is developing and procuring a Waves Air-Sea Interaction Drifter (WASID) buoy. Besides measuring air temperature, wind speed, atmospheric pressure, and subsurface temperature to a depth of 600 meters, the WASID buoys will also be capable of providing significant wave height, period, and nondirectional wave spectra data.

Several private companies are now developing miniature drifting buoys (minibuoys). NDBC will conduct a comprehensive testing program to evaluate the performance of these systems. The minibuoys would be deployed by aircraft, but would be less expensive than conventional drifters and have a life span on the order of 90 to 120 days.

NDBC is the lead agency for drifting buoys in the TOGA research program, a 10-year study of global climatic variations and the El Nino Southern Oscillation phenomenon. An earlier program during 1978 and 1979, the First GARP Global Experiment (FGGE), had demonstrated the potential of measuring and transmitting drifting buoy data from remote areas to users in near-real time. It also demonstrated that successful deployment of a large array of drifting buoys was possible. TOGA is a natural extension of FGGE. For the TOGA experiment, NDBC has been given the task of procuring the United States' buoys, and planning and arranging for their deployment in remote areas from the Southern Pacific and Indian Oceans to near Antarctica. The United States will provide some 40 to 50 drifters per year to TOGA through 1995. So far, over 90 percent of the buoys deployed for TOGA have remained operational for more than 6 months.

Drifting buoy technology has been applied in the development of a Local User Terminal (LUT). NDBC is the lead procurement activity for the system, which allows acquisition of drifting buoy meteorological and oceanographic data in real time directly from NOAA polar-orbiting satellites. The LUT can be shipped from place to place as needed and can be set up in less than 1 hour. Data processing and distribution will be controlled locally or remotely by the operator. Data from the drifting buoys reach the LUT directly by very high frequency (VHF) downlink from the satellite, rather than through the path normally travelled from buoy to user via Service Argos (Reference 4). By accessing data directly, the LUT can receive data immediately from any satellite Data Collection Platform (DCP) within about 2600 km of the LUT location, and eliminate the time delay of several hours that occurs with the Argos system. This capability will be a genuine asset to drifting buoy users in data-sparse, remote areas, or in any application where timeliness is critical.

The practicality of portable LUTs had been threatened by a proposal to eliminate both the 136.77- and 137.77-megahertz (MHz) VHF downlinks on future NOAA polar-orbiting satellites. NDBC was a leader in the struggle to retain at least one VHF downlink. As a result, not only will the 137.77-MHz downlink channel be retained, but a second will be established in the 137-MHz range. The proposal to eliminate the frequencies was based in part on earlier agreements that will re-allocate the 136.77-MHz frequency to aircraft mobile services in 1990. Had the VHF capability been eliminated, satellite downlinks would have been on S-band frequencies, requiring much larger ground antenna systems and receiving equipment nearly ten times as expensive as current LUTs. This would have made it economically and physically impractical for many potential users of drifting buoy data to obtain measurements in real time. Because the VHF downlink will be retained, growth of portable LUT usage is likely to continue in the coming years.

In an effort to ensure that data quality remains high, an agreement has been proposed to Service Argos for NDBC to quality control all data from North-American-sponsored drifting buoys that report through the Argos system. This will require NDBC to upgrade its computer center. A technical workshop sponsored by NDBC in July 1986 brought together a number of U.S. and Canadian researchers and operational managers of environmental data for the purpose of defining the best approach to ensuring high-quality drifting buoy data. Other NDBC efforts through the International Cooperation Panel on

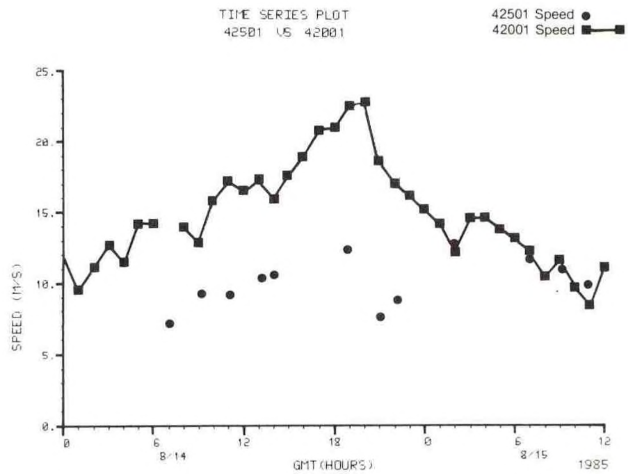

Figure 6. Time Series Plot of Wind Speeds Measured by Moored Buoy 42001 (25.9°N, 89.7°W) and Nearby Drifter 42501 During Tropical Storm Danny. Drifting Buoy Observations Are Not Available Every Hour, Due to Data Transmission Limitations of Polar-Orbiting Satellites. (Courtesy D. Gilhousen)

Drifting Buoys are aimed at developing international standards and procedures to ensure that only the best possible drifting buoy data reach the users.

PAYLOAD DEVELOPMENT

Data from remote areas are most useful when measurements are dependable and accurate, and when the transmission system is reliable and durable. The electronic payloads aboard NDBC systems that collect, process, and transmit data via satellite, vary considerably in design and complexity. Drifting buoy payloads, whose messages are routed via polar-orbiting satellites, are expendable and typically require low power to operate. They have quickly matured into low-cost systems and now require only minimal developmental efforts. Moored buoy and C-MAN payloads, however, measure more parameters, are more complex systems, and have a longer design life. They require more power and must function under the discipline of reporting in real time via GOES. Because they operate from remote stations, high reliability is imperative. These payloads have evolved through several generations since the first data buoy was deployed in 1971. The latest version under development is the Value Engineered Environmental Payload (VEEP) (Reference 5).

The VEEP will have the same capabilities as the DACT, with equal or greater reliability, but at a much lower cost. Savings will be realized by using an equally dependable but less expensive grade of computer microchip, modernized circuitry, and commercial, off-the-shelf hardware. The VEEP will be used on all moored buoy and C-MAN systems, with present electronic payloads eventually being phased out. Essentially the same data will be measured, processed, and transmitted, but the procedure will be more efficient and faster. The VEEP will require almost no power about 40 percent of the time, during those periods when the system is inactive, and should allow longer deployment periods. This new payload is being tested this year.

WAVE MEASUREMENT PROGRAM

The wave measurement program at NDBC began in the mid-1970s when a system was developed to measure nondirectional wave spectra. Research and development since that time have improved the quality and amount of nondirectional wave information that can be processed, and systems are now capable of measuring extensively directional wave spectra. There are several wave measurement projects under way that are advancing the capability even further.

Changes in wave spectral analysis methods in the VEEP, referred to earlier, will require development of a new nondirectional wave-measuring system. Depending upon whether it is mounted aboard a buoy or a fixed platform, the system will use a suitable wave-measuring sensor to observe nondirectional wave spectra. Although the data produced will be essentially the same, the new payload will be more modern and cost less.

In the C-MAN program, various experiments are being planned and conducted to evaluate methods for making nondirectional wave measurements at fixed sites. The choice may well turn out to be influenced predominantly by site-specific constraints. Candidate approaches include pressure sensors, lasers, and the use of buoys with line-of-sight radio telemetry.

Along similar lines, preliminary work has begun at NDBC to develop a Local Wave Monitoring System (LWMS). Such a system would be deployed near the coast in shallow areas, where sea states can become critical to life, safety, or property (e.g., shallow areas adjacent to shipping channels where operations become hazardous when waves suddenly build due to distant weather systems). This system would differ from the C-MAN configuration in that it would include a direct link from the wave sensor to nearby users on shore. This will allow instantaneous readouts of sea states in rapidly changing situations. Although a wave-measuring buoy is foreseen as the most likely sensor, the LWMS might also use lasers, wavestaffs, or submerged pressure sensors.

A system to add nondirectional wave measurement capability to drifting buoys is under development in the WASID buoy. These drifters will measure and process wave spectra for transmission via the NOAA polar-orbiting satellites. There may be fewer spectral bands reported than with the VEEP system, however, due to message length limitations of the Argos system.

NDBC efforts at routinely producing directional wave spectra from moored buoys began in April 1984 during a cooperative study with the U.S. Army Corps of Engineers. A 10-meter discus buoy was fitted with a directional wave measurement device and stationed in the Pacific Ocean about 185 km southwest of Los Angeles, California. This 18-month program provided the data to investigate the relationship between deep-water and shallow-water directional wave spectra. Excellent hourly wave data were produced and archived at the National Oceanographic Data Center.

A newer, improved directional wave system was refitted aboard the same hull, and the buoy was redeployed in January 1986 approximately 40 km south of the Naval Civil Engineering Laboratory (NCEL) in Port Hueneme, California. Data from this buoy are being used to support a Motion Measurement Experiment being conducted by NCEL. NDBC anticipates equipping some of the 3-meter buoys with this type of directional wave-measuring system during 1986-87 in support of other Defense Department programs.

PROJECTS UNDER DEVELOPMENT

Because of earlier successes in planning, developing, and engineering marine data acquisition systems, NDBC expertise has recently been extended to systems that have potential application over land as well as water. One such program, the Automated Surface Observing System (ASOS), is in place; and for another, the Wind Profiler Demonstration Program, the necessary hardware is now being engineered and procured.

NWS embarked on the ASOS program in 1981 to automate meteorological observations at principal NWS airport locations. This will reduce the time-consuming work of manually taking weather observations, allowing the staff to redirect its time to other services. The automated system will use calibrated instruments and algorithms to take regular measurements and allow more frequent surface observations during rapidly changing weather situations.

NDBC prepared the specifications and acquired the first 14 ASOS systems for the demonstration phase. A mini-network of six ASOS sites has been established in Kansas to evaluate the concept, improve the system performance, and assess how well observers and users will accept the system. Four more systems are to be used to evaluate performance in semitropical, coastal, and northern climates. The Federal Aviation Administration (FAA) will also evaluate the system to determine whether their requirements can be met.

The ASOS site layout consists of three zones (i.e., Center Field, Touchdown, and Operations Building). In the Center Field zone, measurements are made of wind, temperature, dew point, precipitation, freezing rain, lightning, and present weather. At the Touchdown Zone, cloud height and visibility are measured. Barometric pressure is measured in the Operations Building. The data are collected from Data Collection Packages in the various zones, transmitted to the Acquisition and Control Unit (ACU) in the Operations Office, and processed automatically. The observer can make corrections manually, if required. The ACU then reports the data automatically by landline on the NWS Automation of Field Operations and Services (AFOS) communications network hourly, or when special weather events occur. Data are available to local personnel via two video display terminals, which allow presentation of current conditions or historical data from archival memory. Remote users can access the same data via telephone modem. Earliest test results have generally been positive. System failures have been less than expected, and suggestions for sensor improvements have been made. Following the tests and necessary modifications, NWS expects to begin procuring the production systems late this year.

Wind profiler development is the result of experiments in the mid-1970s that showed active radar techniques might be used to measure wind velocities into the upper atmosphere. In subsequent work, the Wave Propagation Laboratory (WPL) at Boulder, Colorado, successfully demonstrated that radar can measure vertical wind profiles accurately, automatically, continuously, and with high resolution. NDBC and WPL entered into a cooperative agreement to transfer the WPL technology to systems developed by commercial industry. NDBC is providing system engineering specifications and procurement management for the development of field evaluation systems. The program aims to determine operational and engineering requirements for a nationwide wind profiler system; to develop and refine forecast procedures and techniques using profilers in conjunction with rawinsondes, satellite Visible and Infrared Atmospheric Sounders (VAS), and the Next-Generation Radar (NEXRAD); and to satisfy research needs.

The initial wind profiler demonstration program will be conducted in the Midwest and Plains states and will consist of a network of 30 radars, to be in place by 1988 and to be operated for a period of 5 years. Each 405-MHz pulsed Doppler radar will use an electronically steerable phased-array antenna to measure wind velocities in 36 narrow vertical increments from the ground to the tropopause. The system is based on current state-of-the-art radar technology, so that cost and development risk are minimized.

NDBC recently awarded the contract for the prototype wind profiler system. The demonstration program will provide essential data for the Storm Scale Operational and Research Meteorology (STORM) program. Subsequently, data will flow to the NWS to be integrated into their forecasting scheme, and to the FAA for their use. The preliminary target date for full deployment of an operational wind profiler network is in the early to mid-1990s.

THE OUTLOOK AT NDBC

Since it was established, NDBC has improved its automated environmental monitoring systems and has expanded its coverage from the oceans to the coastlines. New efforts are laying the groundwork to reach onto land areas where manual observations are becoming physically or economically impractical.

Observations from NDBC systems are used in all aspects of operations and research. Users rely on them because of the Center's history of sound technical planning, thorough development, logistical support, and rigorous quality control of data. The Center intends to play a significant role in both land and marine observation systems well into the next century to ensure that the Nation is equipped with the most cost-effective and accurate data acquisition networks for weather analysis, forecasting, and environmental research.

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THE DESIGN OF A WAVE-DIRECTIONAL MEASURING BUOY SYSTEMS.

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ABSTRACT

A convenient buoy system is developed to observe the ocean wave characteristics which has small and light spherical body and power saving devices. The buoy can measure the wave height, wave direction, power spectra and sea surface temperature. The observed data were collected by ARGOS system via satellite NOAA. Especially, the wave direction is measured by sensing the horizontal and vertical components of acceleration induced by the wave motion making use of the triaxial orthogonal accelerometer mounted on a gimbal submarged in a vessel filled with the viscous oil.

Two sets of the experimental buoy were produced and tested in 1984 and 1985. The first buoy had operated for 70 days on Kumanonada area off the Kii Peninsula and the open sea east off the Nojimazaki. The second buoy had operated more than 120 days on the sea south off the Shikoku Island. During the test period, several times the drifting buoys recorded successfully extraordinarily high waves with height more than 10m. And the reported wave directions agree well with the wave directions shown in the "Ocean Wave Chart".

In this paper, we describe the buoy mainly the performance of measuring wave direction, and conclude the usefulness of the buoy to detect the wave direction.

INTRODUCTION

The principle of wave direction sensing buoy may be classified into two types, that is, a slope following type and an orbital following type.

Disk-shaped buoy[1],[2], ship-shaped buoy[3] and Cloverleaf buoy[4] are all the wave slope following buoy. These slope-following type buoy is likely to have the risk of capsizing during severe weather conditions. To avoid the disaster, the buoy must be large enough and the disk-shaped buoy of NDBO has a diameter of 12m, when it is used in severe sites[5].

The ENDECO Wave Track buoy[6] is an orbital following buoy and its shape is spherical with a diameter of 0.3m. The buoy senses to the subsurface velocity gradient induced by the orbital water particle motion which attenuates with depth.

For the sake of observing the wave directional spectrum, all of the above mentioned buoys record the heaves, east-west and north-south slopes of the body. So, the gyroscope is needed so as to measure the slope components exactly, resulting in high cost and large power consumption.

Based on these considerations, following drifting buoy is developed. The shape of the buoy is designed as spherical form in order to prevent from capsizing. As the sensor for measuring the wave direction, the triaxial orthogonal accelerometer mounted on the gimbal is used because of the power saving.

The motion of the buoy mainly follows the slope of water surface and also affected by the orbital motion of water particles. However, the gimbal can approximately follow the slope of water, because the direction of acceleration subjected to the gimbal is perpendicular to the water surface. The difference of the direction between gimbal and the water slope produces horizontal acceleration, which is proportional to the acceleration induced by the wave orbital motions.

The configuration of the buoy, communication system, elements of observation and the observational data recorded extraordinarily high waves were already reported in a previous paper[7]. So, in this paper, the outline of the drifting buoy systems and the response of the accelerometer mounted on the gimbal are described.

OUTLINE OF DRIFTING BUOY SYSTEM

The appearance and internal construction of the drifting buoy are shown in Fig.1. The buoy has a spherical body made of aluminum with a diameter of 95cm and weight of 160kg. Four damper fins are installed at the bottom of the body to prevent the body from turning round. A protec-

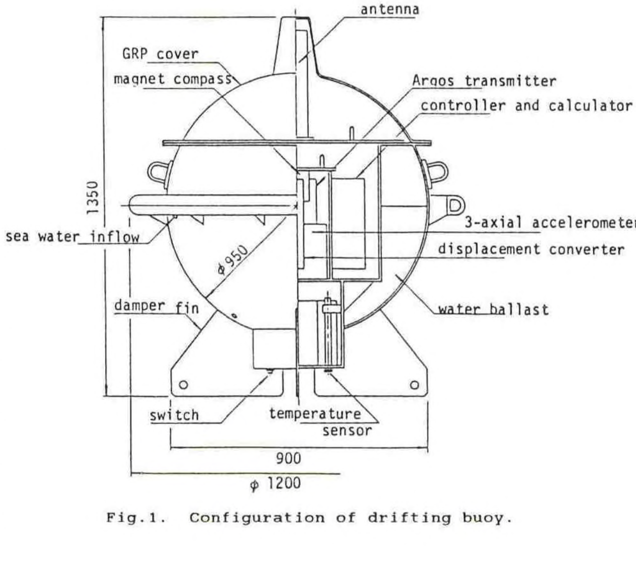

Fig.1. Configuration of drifting buoy.

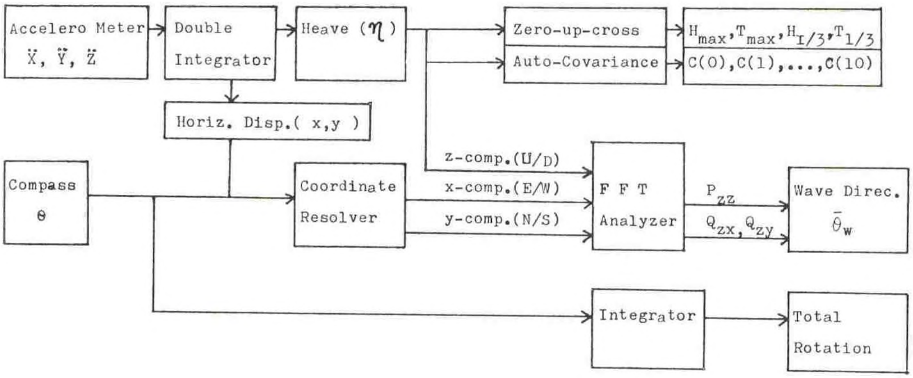

Fig.2. Schematic block-diagram of the wave data analyzing.

tion belt winded around the broadside reduces the pitch/roll motion of the body. A triaxial accelerometer mounted on a gimbal is placed near the center of gravity on the vertical axis of the buoy. A thermometer, which measures the water temperature of sea surface, is attached at the bottom of the buoy.

The block-diagram of the wave data analyzing scheme is shown in Fig.2. The raw data of the accelerations $\ddot{x}$, $\ddot{y}$ and $\ddot{z}$-comp., which are measured by the triaxial accelerometer, are converted into the displacement x, y, z-comp. by making use of the double integrator. The maximum wave (Hmax,Tmax), significant wave (H1/3,T1/3) and the auto-covariances C(0), C(1), ,,, C(10) are obtained by analyzing the z-comp. of the displacement, which means heave. With the off-line handing, the power spectra of waves may be given by the values of the auto-covariance by means of AR-method at the land.

Using the azimuth angle θ, the horizontal displacements, i.e. x-comp. and y-comp. are resolved into E/W-comp.(X) and S/N-comp.(Y) of the displacement. After the quadrature spectrum Qzy and Qzx are obtained by the F.F.T. analysis, the wave directions of the component waves, whose energy density has peaks with high-level energy, are given by the following equation.

$$\bar{\theta}_w = \tan^{-1}(\theta_{zy}/\theta_{zx}) \qquad \cdots\cdots\cdots\cdots (1)$$

Above mentioned data processing and analysis are carried out making use of the converter, controller and calculator which are installed in the buoy (see Fig.1). These analyzed data such as wave heights, wave directions, water temperature are collected by ARGOS system via satellite NOAA at the transmitted time.

RESPONSE OF THE GIMBAL

The triaxial accelerometer is supported on a gimbal installed in the buoy. In general, the gimbal follows the slope of the water surface, because the direction of the acceleration supported on the gimbal is always perpendicular to the water surface. In this case, based on the linear theory of the infinitesimal waves, the horizontal component of the acceleration induced by the wave motion is canceled out with that of the acceleration of gravity.

Then the motion of the gimbal is delayed from the water slope by the more viscous oil than usually used, which is contained in the gimbal. Hence, the difference of the slope between gimbal and the water surface produces horizontal acceleration, which is proportional to the acceleration induced by the wave orbital motions.

Now we discuss on the response of the gimbal which is suspended in viscous oil. It is considered that the motion of the gimbal, which is induced by a wave, may be replaced by that of a pendulum as shown in Fig.3. A pendulum is suspended in a vessel, is filled with viscous oil, and oscillates around the axis of the gimbal, with the same angle (θ) as that of the surface slope. Under these conditions, the motion of the pendulum is given by the equation [8],

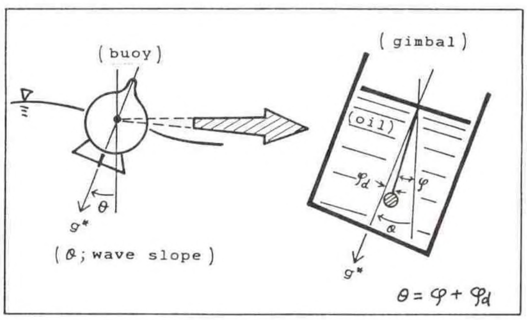

Fig.3. Rough sketch of the motion of a gimbal. The motion of the gimbal is regarded as that of a pendulum. The pendulum is contained in a vessel filled with viscous oil.

$$ml\ddot{\varphi} - C_0\rho l L^3\ddot{\varphi}_d - C_2\rho l^2 L^2\dot{\varphi}_d|\dot{\varphi}_d| - C_3\mu l L\dot{\varphi}_d - C_4 g\dot{\varphi}_d/|\dot{\varphi}_d| - (m + C_5)g^*\sin\varphi_d = 0 \quad \cdots (2)$$

In the equation, each term is as follows.

$ml\ddot{\varphi}$; inertia force of momentum

$C_0\rho l L^3\ddot{\varphi}_d$; added inertia force of momentum

$C_2\rho l^2 L^2\dot{\varphi}_d|\dot{\varphi}_d|$; restoring force which is proportional to the square of velocity

$C_3\mu l L\dot{\varphi}_d$; restoring force which is proportional to the velocity

$C_4 g \dot{\varphi}_d/|\dot{\varphi}_d|$; restoring force owing to the friction of the axis of the gimbal

$(m+C_5)g^* \sin\varphi_d$; restoring force of g^* and that the bending elastic force of a lead

Where g^* means the apparent gravitational acceleration which acts always perpendicular to the slope of water surface, l the length of the pendulum, L the representative length of the gimbal submerged within the oil, μ the viscosity of oil and C_0 ,C_2 ,,C_5 mean the restoring-force coefficient.

Giving these constants for the buoy, the response curve of the gimbal is obtained in Fig.4. It is found that the amplification factor $\ddot{X}out/\ddot{X}in$ decreases almost proportional to the square of the period and also decreases slightly associated with the increase of viscosity. It is seen that the phase angle decreases rapidly as the viscosity diminished from 2000cs to 100cs. So the phase angle is kept in the range smaller than 5 degree for the viscosity of 100~200cs.

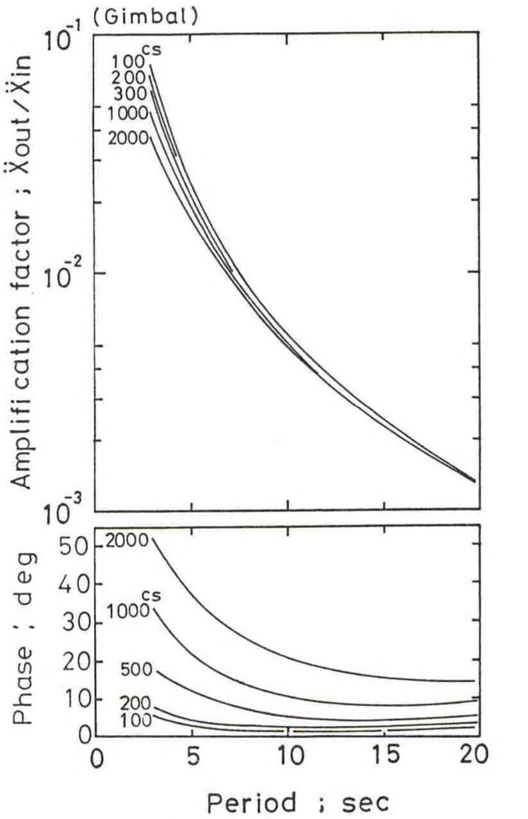

Fig.4. Response curves of the gimbal. In the figuer, the value of 100, 200, 300, 1000 and 2000cs means the coefficient of viscosity, respectively.

CALIBRATIONS

The response curve of the gimbal obtained by eqn.(2), is calibrated by the Water Track Simulator shown in Fig.5. This apparatus is capable to simulate the orbital motion of a water particle. The typical experimental data obtained are plotted in Fig.6 together with the theoretical curve in case of μ= 200cs. In this figure, the experimental values agree fairly well with the theoretical results.

The wave directions measured by the triaxial accelerometer, mounted on the gimbal, are also calibrated making use of the Wave Track Simulator. In the experiments, wave height is set to 1m, and wave period is changed in 5 steps from 4.1 second to 12.0 second, that is, T=4.1, 6.2, 8.2, 10.0, 12.0sec, H=1m. The results are shown in Fig.7, in which the measured wave directions agree well with the directions simulated by the Wave Track Simulator for the period less than 6.2sec. The range corresponds to the range of wave steepness H/L>0.017, because the wave height is set to 1m in the experiments. For the period longer than 10 seconds, the accuracy of the measurement is not satisfactory because the amplification factor $\ddot{X}out/\ddot{X}in$ decreases rapidly according as the increase in wave period as mentioned in Fig.4.

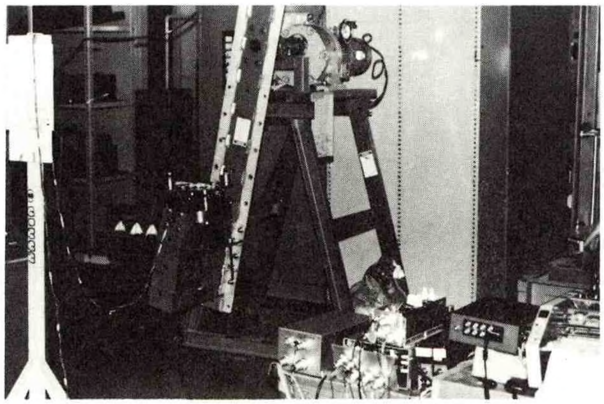

Fig.5. Photograph of the Wave Track Simulator. A gimbal is attached on a rotating arm, which rotates in a vertical plane with an arbitrary period.

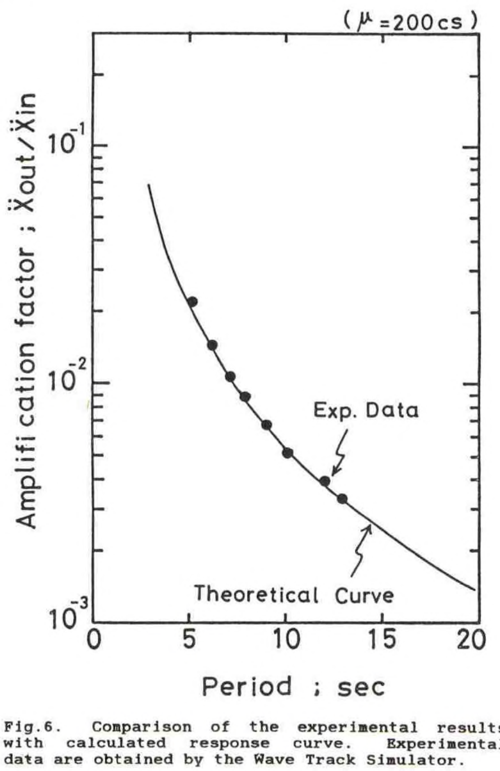

Fig.6. Comparison of the experimental results with calculated response curve. Experimental data are obtained by the Wave Track Simulator.

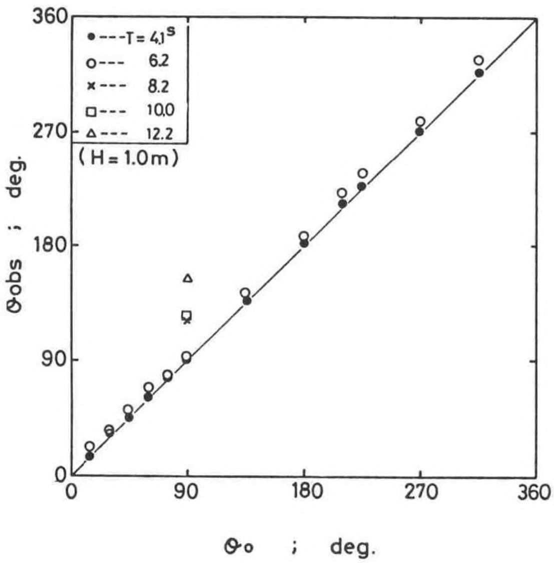

Fig.7. Calibration of the wave direction using the Wave Track Simulator.

CONCLUDING REMARKS

The drifting buoy, in which a triaxial orthogonal accelerometer mounted on a gimbal, is developed for the sake of measuring wave heights and directions. With the theoretical discussions and the experimental results using the Wave Track Simulator, it is confirmed that the wave direction can be measured with satisfactory accuracy if the steepness (H/L) is greater than about 0.017. According to the field experiments of the drifting buoy performed in 1984 and 1985, the wave directions reported from the buoy agree well with the wave directions shown in the "Ocean Wave Charts", which are analyzed by the J.M.A. when the wave steepness is larger than 0.015 [9]. In case of the steepness less than 0.015, the agreement is rather vague but not so bad to lose the practical worth.

The buoy measures wave direction conveniently in addition to the wave height and period on the open ocean. On the coastal area also, wave directional information is needed in the field of coastal engineering and monitoring of ocean pollusion. But drifting buoys are not practical and moored system is desired on the coastal area. And we are conducting the development of mooring technique for the small wave buoy.

This researches and newly-designed buoy projects have been supported by a Grant in Aid for the Japan Shipbuilding Promotion Foundation. These projects have been carried by a joint project of the Japan Weather Association and Toyo Communication Equipment Co.Ltd., and conducted by the members of the research and development committee (chairman ; Dr.Takeo Koyama) and that of a promotion committee (chairman ; Dr.Kohei Ohtsu). The authors' grateful thanks are due to all the members of the committies, and thanks are also due to other related many persons for generous assistances in facilitating the project.

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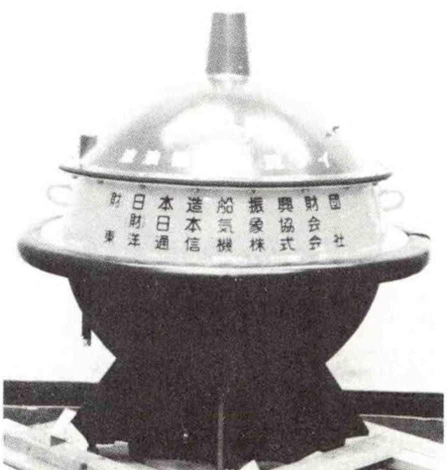

A photograph of the drifting buoy.

SURFACE DRIFT MODELING IN A BAY BASED ON CURRENT AND WIND DATA

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abstract

A trial for predicting the route of drifting objects in a bay is introduced. A semi-empirical method is used for calculating current speed. In that, wind effect and tidal residual current are estimated from the observed data, where the coefficients are determined in regression analysis.

1. Introduction

Recently, the coastal area of the sea has been becoming a field for human activities for various purposes. As a result, the number of the marine disasters are also increasing. In such cases, prediction of th route of the drifting objects are important for rescue purposes. In the Hydrographic Department of the Maritime Safety Agency, the system for prediction of such drifting routes is under development. Two bays were chosen as test sites (Fig.1). There are two primary sources of element which affect the drifting route, that is, direct effect of the wind and current effect. In this report, current prediction method for the system is described.

2. Modeling of current

Currents are classified basicaly into two parts, periodical and non-periodical. The former is essentially a tidal current, while the latter are composed of several elements. such as wind-induced current, density current, tidal residual current etc. For the purpose of predicting the drifting route, the latter is rather impotant, because the tidal current does not contribute to the transport of the objects in a long term.

The currents are expressed as;

$$v_i(t) = v_{0i}(t) + \sum_{n=1}^{4} f_n V_{ni} \cos(\sigma_n t - \kappa_{ni} + V_{0n} + u_n)$$

(i=1, 2, northward and eastward) —— (1)

The first term shows a slow varying non-periodical term, and the second term shows tidal current. Four major constituents of tidal currents are used in the above expression (M_2, S_2, K_1, O_1). Coefficients for tidal currents can be determined from field observation data.

The first term may be expressed as;

$$V_{0i}(t) = d_i V_c^L(t) + \sum (a_{n\tau i} W_{Nn\tau} + b_{n\tau i} W_{En\tau}) + u_{ei}(t) \quad \text{—(2)}$$

The first term in (2) shows a tidal residual current($V_c(t)$ is a velocity of tidal current.). The second term represents an effect of wind. $W_{Nn\tau}$ and $W_{En\tau}$ are northward and eastward component of the wind at the time $t=-n\tau$. $n\tau$ takes the values of 0, 12, 24, 48, which means the wind up to the two-day earlier time affects the current at the time $t=0$. $a_{n\tau i}$ and $b_{n\tau i}$ are coefficients which can be determined from the field data by least square method. $u_{ei}(t)$ is other unknown element, which is neglected in Tokyo Bay case.

3. Direct effect of wind

The direct effect of wind is estimated as follows. The relative velocity of the objects to the water is expressed as:

$$V_r = K \sqrt{B/A}\ U_{10}$$

where U_{10} is a wind speed at 10 m above the sea surface. A is a section of the object above the sea surface and B a section below the sea surface.

4. The result in the Tokyo Bay

The mesh size is one minute. Tidal constants are prepared by the interpolation on the observed data. Long term current observation data at several locations are used for determining the wind effect coefficients($a_{n\tau i}$, $b_{n\tau i}$, in (2)). In order to make a comparison, a drift experiment was conducted. A drum was put at sea and traced for a day. Fig. 2 is the result of the drift experiment and the predicted drift route.

5. The result in Mikawa Bay

A similar method is applied to the Mikawa Bay. Mesh size is one-minute by one minute. In the case of Mikawa Bay, u_{ei} in formula (2) is handled as an unknown constant in regresssion analysis. The computed current for Aug 29 1985 is shown in Fig.3. The comparison between the computed drift route and a field test is shown in Fig.4.

6. Problems and future study

The study showed rather good result, but in Mikawa Bay where the depth is very shallow (about 20m), density current is rather big and produces an error.

A study is now undertaken at the coastal area which is open to the deep ocean, where a branch of ocean current makes a big effect. Sea level data at coast and island stations are considered to be a good measure for inferencing the ocean current.

Fig.1. The locations of selected two Days

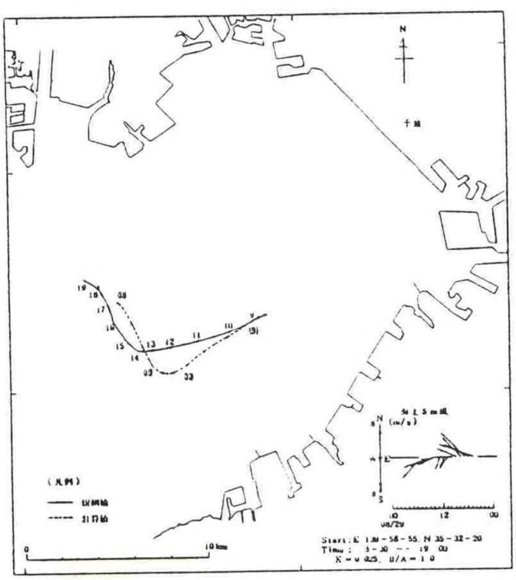

Fig.2 The result in Tokyo Bay
solid : observed
dashed : predicted

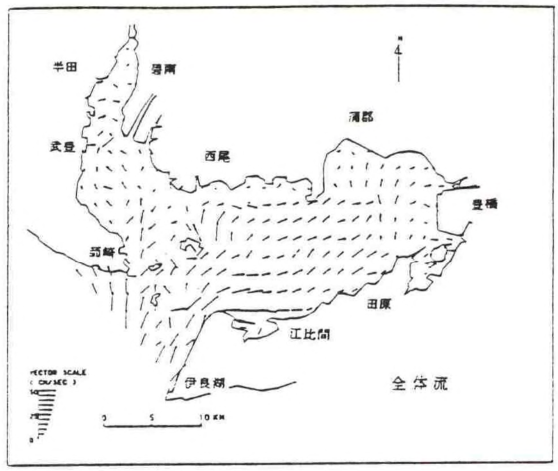

Fig.3 Computed current for the day Aug 29. 1985 at 4p.m local time

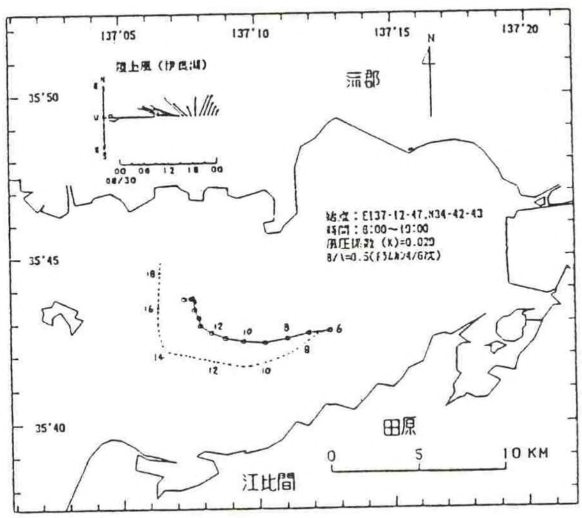

Fig.4 The result in Mikawa Bay
solid : observed
dashed : predicted

METEOROLOGICAL AND OCEANOGRAPHIC SERVICES FOR ALASKAN ARCTIC AREAS

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ABSTRACT

The National Research Council has recently completed a study of meteorological and oceanographic services for the arctic seas and seasonally sea-ice covered areas of Alaska. This project, which was requested by the National Oceanic and Atmospheric Agency and was conducted by the Committee on Arctic Integrated Ocean Information Systems under the auspices of the Marine Board, identifies and assesses the user needs for data and information, both real-time and archived. The study also assesses the available technology and practices employed to respond to user needs. The technology of interest includes sensing, data processing and interpretation, transportation, and dissemination. Deficiencies in the information systems and processes are identified along with recommendations to improve systems and resolve problems.

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) is faced with expensive and sometimes difficult technical choices in providing environmental data and information services to remote and sparsely settled arctic marine and coastal areas. To assist in its planning for the enhancement of present services and future improvements, NOAA requested that the National Research Council (NRC) conduct a study, under the auspices of the Marine Board, to identify the major user needs and to assess the technical means of responding to these needs. The Committee of Arctic Integrated Ocean Information Systems was appointed to conduct this assessment and published its report in September 1986.

This report, NOAA Information Services for Arctic Marine Operations: An Assessment of Needs and Technology, addresses the special needs for oceanographic and meteorological data and information services for Alaska's arctic and subarctic ocean areas. These oceanic regions are rich in fisheries resources--about 40 percent of the total U.S. allowable catch --and have long-term potential for oil and gas development--possibly over half of the U.S. Outer Continental Shelf resources.

The needs of arctic marine users addressed by the study were broadly perceived to be for those services that enhance productivity and safety. NOAA arctic activities include weather forecasts and storm warnings; environmental satellite operations, data archiving, and data dissemination and exchange; and management of fishery resources. Users of data and services include federal (primarily NOAA, U.S. Navy, U.S. Coast Guard, and Minerals Management Service), state, and local governments; industry (oil and gas, fishing, mining, and maritime); research organizations; and the local coastal population. The availability of these data services are of interest to both domestic and international marine and fishing operators, including Japanese maritime and fishing enterprises.

Many of the issues confronting NOAA with regard to environmental services supporting operations and research in U.S. arctic and subarctic marine areas are also concerns common to the entire nation: making optimum use of the government's present and pending investment in meteorological satellite systems, integrating data processing to use the special capabilities of the major agencies that provide environmental data (e.g., Navy, Air Force, and NOAA), providing adequate validation of satellite data, integrating both earth-based and satellite data, and determining what long-term data should be acquired and archived.

What makes these concerns special, in the arctic and subarctic context, are the environmental conditions which are characterized by:

- winter darkness, fog, and summer clouds, which often occlude visual observation and high-resolution satellite-borne sensors;
- ice movement, which can threaten coastal communities and facilities, endanger fishing operations, and halt or hinder seasonal shipping;
- arctic lows and rapidly developing storms, which are seldom detectable in their early development from satellite observations; few commercial vessels transit these areas

even in the open water season, and no other surface-based sensors exist to provide data for real-time forecasting;

• rich fisheries and an abundance of marine mammals, which occupy the subarctic Bering Sea and northern Gulf of Alaska; as prey and predators, both fish and mammals are intricately related in fisheries management policy as well as in protection of threatened or important sea life;

• expensive and often difficult accessibility to arctic areas for research and for taking ground measurements to validate satellite data.

NOAA SERVICES: ASSESSMENT AND RECOMMENDATIONS

In general, NOAA's products and services satisfy current government and industry needs. However, there are deficiencies in forecasting and data dissemination systems, and problems are expected in the future as new satellites come on line. The most critical need is that of planning for the processing and utilization of the huge volumes of data that will be acquired by satellites scheduled to be launched in the next decade (see Table 1).

As discussed below, the common problems of lack of basic data and poor access to data affect three general areas: forecasting, data management, and fisheries management.

1. **Oceanographic and Meteorological Forecasting** Improvements are needed in forecasting and warning capability concerning small-scale severe weather, rapidly developing low-pressure systems, and tsunamis. Since there is little commercial ship traffic in the eastern Bering Sea, the opportunities to obtain meteorological observations from ships are minimal and irregular. Except for one buoy in the Bering Sea (Navarin Basin), there are no continuous sea-surface weather observation buoys. The report recommends increasing frequency and density of ocean and weather observations by encouraging more reporting by fishing vessels (foreign and domestic), using automated shipboard reporting units (e.g., "black boxes"); and using ocean data buoys.

The validity of existing numerical models used for environmental forecasting north of the Aleutian Islands is questionable; the models in use for operational forecasting were designed for mid-latitudes, not high latitudes. Models need to be developed to account for arctic parameters.

Real-time capability in monitoring and forecasting ice edge and ice cover movement is not adequate for maritime and many fishing operations. Ice movement is tracked by satellite, with some aerial reconnaissance of critical areas. The two principal platforms used are NASA's NIMBUS-7 scanning multichannel microwave radiometer (SMMR) and NOAA's advanced very high resolution radiometer (AVHRR). The SMMR has low resolution (25 km) but can see through cloud cover; AVHRR has very high resolution (1.1 km) but cannot penetrate clouds. The lack of digital processing capability has resulted in underutilization of SMMR data for strategic ice monitoring.

Synthetic aperture radar (SAR) data from the European Space Agency Remote Sensing Satellite (ERS-1), scheduled to be launched in 1990, will provide both high resolution (25-40 m) and cloud penetration capability. The SAR sensors ERS-1 and other new satellites have an extremely high data acquisition rate, which precludes on-board image processing. U.S. access to ERS-1's SAR data is dependent on establishing a receiving station at Fairbanks, which NASA plans to construct. However, the SAR data are to be processed for research use, and it is not clear whether these data will be available on a real-time basis for operations and forecasting. The report recommends that NOAA execute the necessary interagency planning to add this real-time capability.

2. **Data Management** Image processing must be combined with satellite and in situ numerical data to provide for optimum use of current and future satellites. Extracting numerical information from images (both SAR and AVHRR produce images) is difficult and is limited by lack of multifrequency systems. At present, no single microwave sensor is operational; the first will be the special sensor microwave imager (SSM/I) in late 1986. The report recommends that funds and programs be directed to obtaining surface-based and airborne measurements to validate satellite

TABLE 1 Approved/Planned Polar-Orbiting Satellite Missions

Country	Mission/ Type	Main Sensors	Orbit (Altitude)/ Maximum Latitude	Launch Dates	Comments
United States	NOAA-Series/ operational	AVHRR, AMSU, HIRS	854 km/sun-synchronous	1985-1993	
	DMSP operational	SSMI/I SSM/T	837 km/86° N sun-synchronous	1986-1993	
	NROSS-1 operational	Radar altimeter scatter-ometer, SSM/I, LFMR	830 km/sun-synchronous	1989-1990	
	GEOSAT operational	Radar altimeter	800 km/72° N	1985	
Europe	ERS-1 research	SAR, wind scatter-ometer, radar altimeter	780 km/82° N sun-synchronous	1990	
	ERS-2 operational	SAR Wind scatter-ometer radar altimeter		1992	Proposed
Canada	RADARSAT research	SAR, scatter-ometer, AVHRR	1001 km/76° N sun-synchronous (SAR)	1990	Phase B
Japan	MOS-1	MESSR, VTIR, MSR	909 km/82° N sun-synchronous	1987	
	JERS-1	SAR, VNIR	570 km/sun-synchronous	1991	
France	SPOT-1		832 km/82° N sun-synchronous	1986	Launched

NOTES:
AVHRR: advanced very high resolution radiometer
AMSU: advanced microwave sounding unit
HIRS: high-resolution infrared radiation sounder
SSMI/I: special sensor microwave/imager
SSM/T: special sensor microwave/temperature
LFMR: low frequency microwave radiometer
SAR: synthetic aperture radar
MESSR: multispectral electonic self-scanning radiometer
VTIR: visible and thermal radiometer
MSR: microwave scanning radiometer
VNIR: visible and near infrared radiometer

sensor data and the algorithms used in processing them. Further, the committee recommends that NOAA operational and research elements develop appropriate hardware and software systems to combine satellite and surface-based data to optimize current and future sensor capabilities.

In assessing data-processing systems, the report notes that accessibility of archival and new data presents immediate difficulties to users and is expected to be further complicated in the future by the archival needs of more sophisticated satellite systems. Currently, users often must contact different archive centers or operations (see Table 2) to obtain data that may be archived separately by source (sensor platform), discipline, or type (e.g., climate, ice). The archiving of historical data is not integrated. The report recommends upgrading data processing and dissemination systems for future and archival data, and developing systems to integrate satellite and surface-based data.

Despite initial planning, the NRC's committee expresses concern that the Department of Defense/NOAA Shared Processing Program for data from the Defense Meteorological Satellite Program (DMSP) and NOAA polar orbiters, and from the Navy Remote Sensing System in 1990, will not meet its full-capability target date of 1988. NOAA's participation in this program as essential to optimum utilization of satellite capabilities and to improved ice, sea-surface, and meteorological forecasting and analysis, and recommends a firm long-term commitment to the program. It is recommended that routine exchange of data among the three Centers of Expertise (NOAA, Navy, Air Force) designated in the program be fully automated.

3. **Fisheries Management** NOAA accumulates an analyzes economic information from the fishing industry to ascertain the benefit of fisheries location, as required by the Fishery Conservation and Management Act of 1976. The report concludes, however, that information needed to assess fish stocks and determine allocations to various fishing gear groups is too limited. Collection and validation of catch data and continuation of the domestic observer program cannot be adequately accomplished under present funding. Budgets will be further depleted by loss of fees due to reduced foreign fishing activity.

Short- to medium-range transport and water column structure prediction models are needed for fishery management and development. Lack of focused arctic environmental studies and limited time-series data have proved to be a major hindrance to development of models. Sea-surface thermal analyses, which have been conducted in other regions, are lacking for the eastern Bering Sea and northern Gulf of Alaska. Oceanographic research to establish key baseline data is inadequate. Improved fisheries data collection systems be developed for domestic fisheries in U.S. arctic and subarctic waters.

CONCLUSION

It is recognized that most of the deficiencies cited in the report have been identified by NOAA. Planning and budgets requests now include specific project initiations, interagency coordination, and actions within NOAA itself to resolve or anticipate the needs for optimum use of present and planned capabilities and facilities for acquiring and processing environmental data.

TABLE 2 Data Archiving Centers - NOAA, National Environmental Satellite Data and Information Services (NESDIS)

All of the NESDIS centers contain arctic environmental data. In most cases there are no exclusively arctic data sets, since the observations are collected for international or national programs. The following are the NESDIS data archive centers:

- National Climate Data Center (NCDC) Hourly and daily reports on surface and upper-air weather variables, atmospheric properties, and derived data are archived together with derived climatic statistics. They are available on magnetic tape, diskette hard copy, or microfiche.

  The Satellite Data Services Division (SDSD) of NCDC archives raw and summarizes digital remote-sensing data, photographic products, and certain analysis products from the NOAA polar orbiters, which provide twice-daily coverage for the arctic region.

- National Geophysical Data Center (NGDC) This center, located in Boulder, Colorado, manages data on marine geology and geophysics, including tsunamis, bathymetry, and marine minerals. Closely linked with NGDC is the National Snow and Ice Data Center (and WDC-A for Glaciology), operated under contract from NOAA/NESDIS through the Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder. This center archives hard copy and digital data on sea ice, snow cover, glaciers, and ground ice. It also archives imagery from the Defense Meteorological Satellite Program (DMSP) for SDSD.

- National Oceanographic Data Center (NODC) Data on physical and chemical ocean properties (temperature, salinity, dissolved oxygen, and nutrients) together with data from the U.S. Outer Continental Shelf, including Alaska, are held at NODC. Additionally, there are data sets on plankton, fish, and shellfish resources and marine pollutants.

- National Environmental Data Referral Service (NEDRES) The Assessment and Information Services of NESDIS operates NEDRES to identify, locate, and catalog environmental data sets. Its data base is a public information service that can be accessed through commercial data communication networks. An inventory of arctic data holdings in NESDIS centers will be available in 1986.

- Climate Analysis Center Products derived from NMC analyses are retained by the Climate Analysis Center (CAC) of NMC. These are gridded data, and are primarily of interest to researchers.

Microwave radiometric observations of sea ice
-Observation of fundamental microwave emissive properties of sea ice-

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Astract

This work is concerned with observation of sea ice for identifying its fundamental microwave emissive properties. The final purpose of this work is application of microwave radiometry to sea ice observations for the prediction of its distribution, growth and degradation and drifting. Observations were made at Mombetsu on Okhotsk Cost in Hokkaido in 1985 - 6. This report compares the typical microwave emissive properties among sea water, sea ice and snow cover on sea ice, characterizing their own microwave emissive properties.

Background of sea ice observation

Recently human being has gained activities in oceanic approach even in sea ice areas such as the Polar Seas, etc., mainly because of exploitation of underwater resources such as petroleum and partly because of transportations, traffics, fisheries, scientific researches (geophysics, meteorology, geology, biology, oceanograpgy, etc.) and so on.

Japan has been much related to sea ice areas, since she has supplied many drilling rigs there and had joint project of subbottom petroleum exploitation with China in Bo Hai (Gulf of Chihli), where the surface is frozen in winter. Japan herself has sea ice area in Hokkaido in the Sea of Okhotsk, which begins freezing in northern coastal zones of lower salinity in early winter and is finally frozen up to 80 % of the whole area. In the next early year, breaking of sea ice plate occurs and broken sea ices go down south toward Okhotsk Coast of Hokkaido, staying there for three to four months. Therefore sea ice blocks up the way in the sea, and their activities are completely suspended in winter season there. Since the most people live on harbor, fisheries and maritime public works. Sea ice also brings abnormally lower atmospheric temperatures, leading to unseasonable weather. Photo.1 shows typical sea ices in the Sea of Okhotsk, observed from aircraft.

For above reasons, sea ice technology has become one of the most important ocean

technologies in Japan too. Seasat-I has already revealed that microwave radiometry, in which microwave radiation spontaneously emitted from objectives is observed, is also of much effect for sea ice observation, inspite of its too short life of only three months. Authors have studied the fundamental microwave emissive properties of sea ice, which may be applied to sea ice observations at various levels from the surface up to satellite levels in the future.

Purposes of this work

The purposes of our studies are summarized as follows :

(1) Identification of dependences of fundamental microwave emissive properties of sea water, sea ice and snow cover on sea ice on frequency, incidence angle, polarization type and physical and chemical properties of these objectives.
(2) Comparison of emissive properties among sea water, sea ice and snow cover.
(3) Studies on interaction mechanisms of frictional forces between sea ice and wind, leading to sea ice drifting.
(4) Proposal of optimal conditions for

microwave radiometric observation of sea ice area.

Observations and data processings

Microwave emission from sea ice is dependent on so many parameters, such as the physical and chemical properties of sea ice, e.g. temperature, salinity, porosity, surface state and shape, etc. and observational conditions like frequency, incidence angle, polarization type. Observed parameters are listed below :

* Microwave emissions
* Sea ice and snow surface temperatures
* Salinity of sea ice
* Wind speed and direction
* Relative humidity
* Air temperature
* Cloud amount

Microwave radiometric observations were made at Mombetsu on Okhotsk Coast, Hokkaido (see Fig.1) in winter in 1985 - 6. Photo.2 shows two microwave radiometer sets observing sea ice from the deck of a truck.

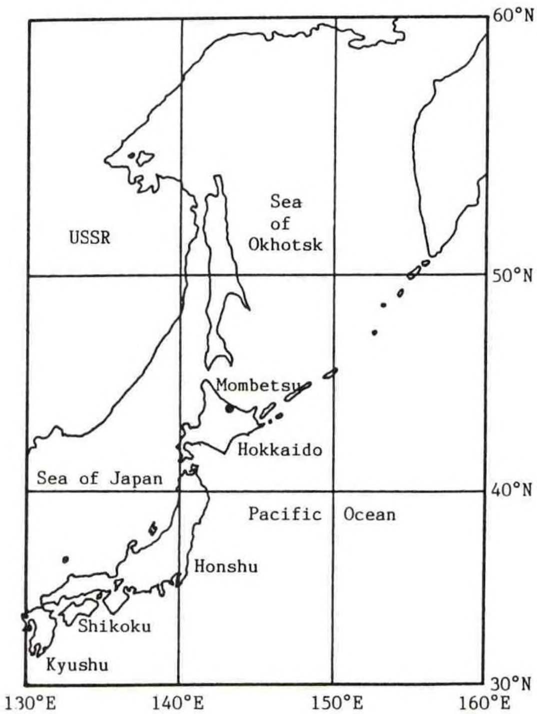
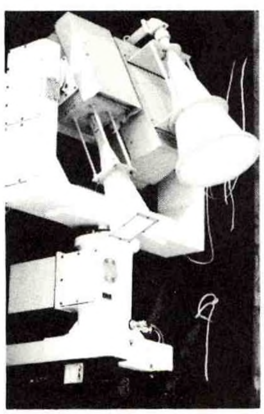
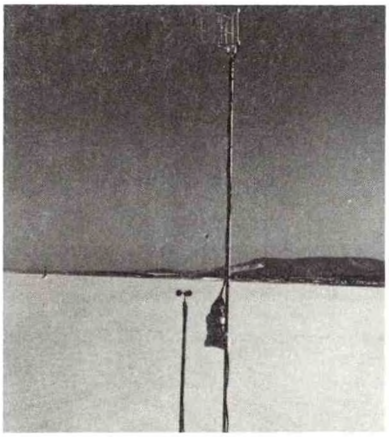


Fig.1

Radiometers are auto-zero-balancing receivers furnished with a Dicke type horn antenna of high directivity of 9° and 10° beam widths in E- and H-planes respectively. Photo.3 shows wind speed observation with a sonic anemometer. Wind measrements were made at 7 m height above the sea level and wind data was automatically sampled and stored in cassette tapes. Microwave emissions at 6.7 and 18.6 GHz were observed for the snow cover on the sea ice at first, then the cover was taken off over the area of 30 m in width and 70 m in length for sea ice observations. The sea ice is a fixed plate originally frozen in Mombetsu harbor, and has flat surface and thickness of 40 to 50 cm. Snow cover also has flat surface and thickness of 10 cm. Microwave observations were made in co-polarization between 6.7 and 18.6 GHz. The sea ice and snow observations were made in angular range of incidence from 20° to 70°, and the sky observations, in the zenith angle range from 0° to 90°, i.e., from the zenith to the horizon. The sky observation, prerequisite for applying correction of its reflected component in the retrieval of microwave emissions inherently emitted from sea ice or snow, immediately followed each sea ice or snow observation. Sea ice was sampled at 22 points over footprint of antenna's main lobe for salinity measurements. Microwave emissions observed at both frequencies were frequency translated to signals of 100 MHz intermediate frequency, transmitted to signal processings, sampled with a personal computer PC 8001 MK-II of Nippon Electrics Corp. through GPIB (general purpose interface bus) interface and stored in floppy discs. This data was transfered to a computer VAX-11/780 of Digital Equipment Corp. for analyses. Sea ice salinity is from 2.67 to 4.59 ‰. Two microwave radiometers are calibrated between 30 - 300 K with signals from a standard low temperature noise generator. Then the emissive properties of sea surface, snow and atmosphere are disussed in terms of brightness temperature (i.e. microwave temperature). Their brightness temperatures are derived from comparison of radiometer's output and calibration data. The highest and the lowest air temperatures during observations were -8 and -17°C respectively. High frequency unit of both radimoeters are so highly sensitive to temperature variation that the temperature inside the housing of high frequency unit was monotored with six thermosensors and controlled thermostatically with built-in heaters. In data processings no corrections for the reflection of the sky radiation are made yet. The reflectivities of the sea ice and the snow are not high at both frequencies except for larger incidence angles and further the sky radiations at both frequencies are less intense so that their contributions to the observed





brightness temperatures of the sea ice and the snow might be negligible.

Results and discussions

Figs.2 through 5 show a portion of our results. Figs.2 and 3 compare the observed brightness temperatures of snow cover (—o—, —●—) and the theoretically predicted ones of sea water at 0°C (———) in both vertical and horizontal polarizations at 6.7 and 18.6 GHz respectively. The snow and the sea water show drastically large differences in brightness temperatures. The water has a marked incidence angle dependnce but does not the snow. No marked differences are also noticeable for the snow between 6.7 and 18.6 GHz in both polarizations.

Figs.4 and 5 show the same comparisons between the sea ice and the water. The sea ice

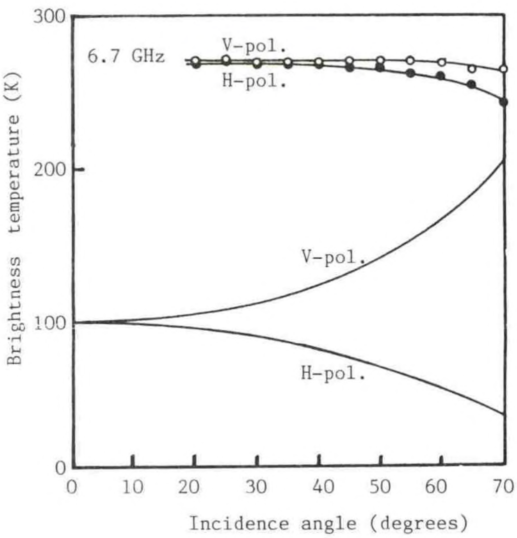


Fig.2

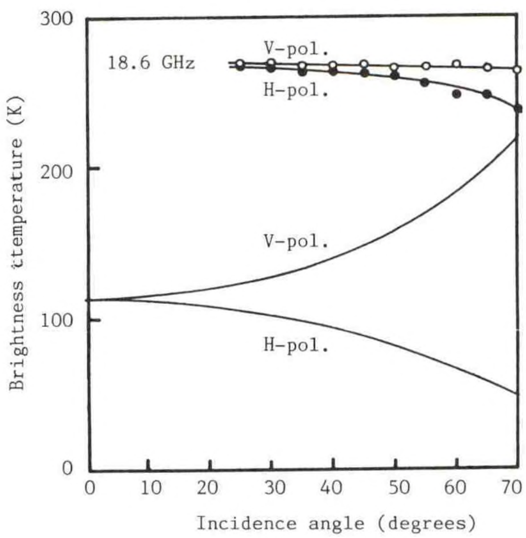


Fig.3

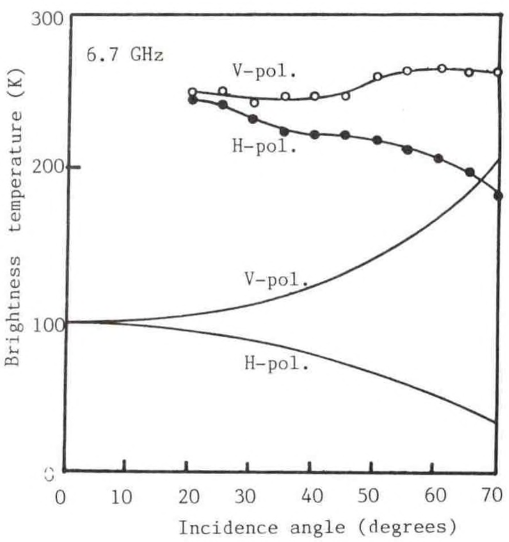


Fig.4

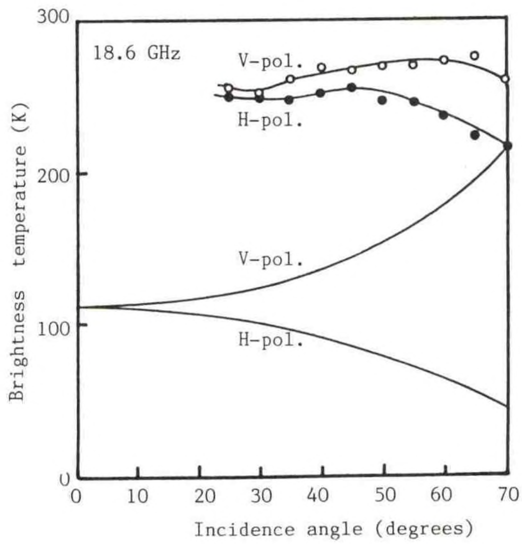


Fig.5

also shows much higher brightness temperature than the water. Both polarizations show incidence angle dependence at both frequencies, however the differences in brightness temperature between polarizations are larger at 6.7 GHz than 18.6 GHz and at higher incidence angle at both frequencies.

Comparisons between Fis.2 and 4 and between Fgs.3 and 5 show that snow and sea ice are quite different from water in microwave emissive characteristics, since they have lower salinity of the order of one tenth or less, comparing with sea water. Sea ice and snow may be considerably transparent for microwave, then internal emission will be also contributable to the observed emissions. For this reason, it's very difficult to estimate the microwave emissivity, i.e. the reflectivity too, leading to difficulty in estimations of the reflected sky radiation.

Conclusion

Sea ice and snow shows typical emissive characteristics and much higher brightness temperatures. Also they show typical dependences on frequency, incidence angle, polarization type and salinity, then the further experiments and detailed analyses will enable us to observe their distributions, growth and degradation, drifting, and physical and chemical properties.

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REFERENCE REPORTS

DESIGNING RELIABILITY INTO SYSTEMS

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Early decisions made during the concept-definition phase of a device, as well as the design phase, seriously impact the costs of long-term operation and production. A system designed for reliable operation saves many times its production cost by cutting the "downtime" of major operations. Reliability and sustainability are vital to operations carried out in a severe marine environment that often require expensive, integrated operations underwater, plus the coordination of offshore platforms, support ships, and numerous personnel.

The theme of this conference is "Designing for Intervention." This is, intervention into the sea to perform useful functions in support to important offshore objectives. A crucial element of design is the discipline necessary to provide reliable, producible, sustainable products that meet functional, technical, environmental, and operational requirements at reasonable costs. We have a major initiative to apply practical product assurance methods to each of our programs to assist in achieving these goals. Many of these procedures may be directly applicable to your own development projects. A "product assurance program" must be devised as an integral portion of each new design project:

To be effective, a product assurance program identifies and describes those program elements such as reliability, maintainability, quality assurance, design assurance, system safety assurance configuration management, and integrated logistic support. All of these factors pertain when planning development projects. The product assurance program also provides the project manager with guidelines for all phases of engineering development, production, and in-service operation. The primary objective of a product assurance program is to ensure, through an integrated and systematic approach, that the manufactured product will achieve a level of quality consistent with operational requirement and specifications. An environmental testing program that responds to the environmental specifications should be included as part of the product assurance plan. When those manufactured products include systems and equipment intended for eventual offshore use, it is important to have effective product assurance planning and implementation.

The elements of the product assurance plan may be applied selectively to everything from small devices to large systems, their design and development, manufacture, test, evaluation, maintenance, overhaul, and repair. The plan is also applicable to a variety of engineering support efforts encompassing components, materials, processes, and computer software. The extent to which the individual elements apply will depend entirely upon the nature and complexity of the program, and the intended use of its products.

Here are some examples of the flexibility of a good product assurance program. The HYDRAULIC SNOOPY, Figure 1, was constructed in 1969 to provide an initial concept of a very small, lightweight, remotely operated undersea observation vehicle.

Figure 1

Since this was a one time only technology validation device with no intention for long term operation or production, very little of the product assurance elements were applied - just some careful component selection and some pre-assembly and system testing prior to operation. Based on the successful demonstration of the HYDRAULIC SNOOPY, and its follow-on, ELECTRIC SNOOPY, a request was received from the Naval Facilities

Command to develop a vehicle to support their diving engineers. The resultant NAVFAC SNOOPY, Figure 2, was also one of a kind,

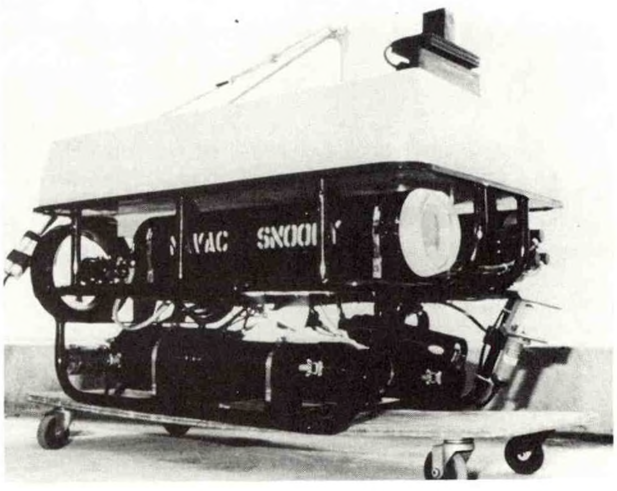

Figure 2

but it required the application of many product assurance elements since it was intended for extended operational use. Based on experience with the observational capabilities of the SNOOPYs and the work capabilities of Cable controlled Underwater Recovery Vehicles (CURVs), a request was then received to develop an undersea vehicle that could classify and neutralize mines. The vehicle would be installed on two classes of new construction mine countermeasure ships. The resultant Mine Neutralization Vehicle (MNV), Figure 3,

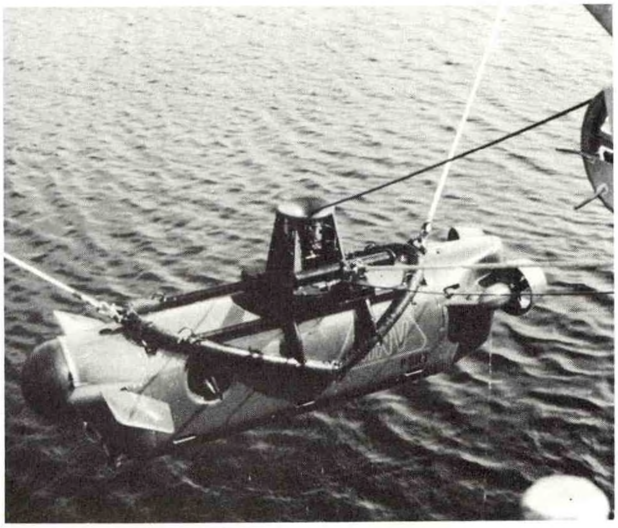

Figure 3

is now being produced in quantity, and will be operated and maintained for extended periods of time by Navy personnel. This program required the full application of all of the elements of the product assurance plan. The following discusses some of the elements and notes when it may be advantageous to apply them.

RELIABILITY AND MAINTAINABILITY (R&M) can be defined as "the continuing analysis and monitoring of system/equipment design, operation and maintenance, through its life cycle, in order to assure satisfactory performance under required conditions, for the required period of time." A basic procedure that initiates the implementation of this product assurance element is R&M modeling with R&M block diagrams of the product throughout various stages of assembly or module replacement level which are prepared and updated in the design evolution. Related mathematical equations or programs are developed to exercise the model for predicting, apportioning, and estimating R&M values that will be used to establish design criteria. Each block will include item identification in consonance with the design phase; the current estimated reliability and maintainability; and the apportioned R&M goal for that specific element. The modeling effort will consider such things as Failure Mode Effect and Criticality Analysis (FME-CA), and Logistics Support Analysis (LSA)> Quantitative R&M requirements will apportioned, R&M predictions inserted, the effects of parts de-rating defined, and FME-CA performed to identify the key components that determine system operability. Stress analysis is another important part of R&M. This includes electrical, mechanical, and thermal prestressing of all components to determine de-rating conditions and to validate their de-rating conditions and to validate their ability to properly function to the design criteria. Sneak circuit analysis is expensive due to software costs and should be performed on only selected circuits. This analysis will investigate sneak paths, sneak timing, sneak levels, and sneak indicators that may exist in the design. Latent paths that degrade system performance below specification requirements can then be corrected. And finally, worst case analysis will be performed to examine the effects on both mechanical and electrical performance characteristics when components are at their tolerance limits, and to consider cumulative tolerance build up, and its effect on performance.

THE QUALITY ASSURANCE element is defined as "the planned and systematic technical direction and surveillance of producers, their material, components controls, manufacturing processes, and their inspection and test practices to ensure the delivery of systems/equipments is of acceptable quality as defined by the system/equipment drawings and specifications." In order to provide a competent quality assurance program, monitoring and inspection techniques will be developed and scrupulously followed including certified calibration of inspection tools and adequate documentation of plans and results. These procedures will be applied to component procurement as well as to component manufacture. Quality discrepancy/failure reports will be collected, analyzed, and used for corrective actions.

Software, as well as hardware, must be subject to a well-discipline quality assurance program with careful verification and validation testing conducted on all segments.

DESIGN ASSURANCE is defined as "the technical direction and monitoring of the system/equipment design documentation process to assure that the design appears to be reliable and producible, and that the engineering drawings and specifications are complete in their disclosure of the design, and contain appropriate product assurance requirements." The intent of the design assurance requirements during the design phase is to ensure that RM&Q is designed into the product. This is accomplished through actions such as establishing and designing to mission oriented RM&Q quantitative requirements; defining and analyzing according to mission profile; system designing for operational availability; allocating mean time to repair (MTTR) requirements; implementing design standards to control stress; performing analysis to design out or reduce the probability of failure modes; using R&M predictions to identify weak areas of the design and assess maturity; and designing test and quality assurance methods to verify the design.

SYSTEM SAFETY ASSURANCE is defined as the "continuing analysis and monitoring of system/equipment design, operation, and maintenance to assure that the optimum degree of safety is attained within the constraints of operational effectiveness, time, and cost." Persons with operational experience and a background of safety will work closely with the designers to ascertain that the safety objectives are met. The individual system of equipment must be analyzed from the standpoint of the totality of the operations in which it is utilized; the adequacy of the documentation (technical manuals, etc.); and expected degree of training and expertise of the operators. Special emphasis will be placed on highlighting potential hazards and emergency procedures to respond to dangerous conditions.

CONFIGURATION MANAGEMENT is a discipline applying administrative direction and surveillance to: (1 identify and document the functional and physical characteristics of a configuration item; (2) control changes to those characteristics; and (3) record and report the change, process, and implementation status. The purpose of configuration management is to prevent engineering anarchy and to permit the orderly development, recording, reproduction, an support of a system. Configuration management is intended to control configuration changes, not to prevent them. The formalities of configuration control should not inhibit the accomplishment of necessary changes or force bypassing of the change control procedures. Effective control procedures are meant to eliminate the nice, but not necessary changes that keep designs in a state of turmoil; lead to litigation; and unnecessarily burden the logistic support system and training program. Configuration control should not become so strict and burdensome as to arrest or inhibit the design maturation process. Change will always be necessary to enhance design attributes such as reliability, maintainability, and producibility; to correct latent design deficiencies discovered by ongoing tests and production acceptance tests; to embrace applicable new technology; and to accommodate changing requirements. As long as changes are carefully controlled and accounted for in the management system, they can significantly enhance the utility of the system.

INTEGRATED LOGISTICS SUPPORT (ILS) is a product assurance technique for designing the support concurrent with the system design so the ILS options and trade offs can be considered before a design is frozen, and while the optimum balance of logistics support elements can be achieved. The principal ILS elements include: maintenance planning, manpower and personnel, supply support, support equipment, technical data, training and training and training support, computer resources support, facilities, packaging, handling, storage, transportation, and design interface. Integration is the key to good support planning. The Integrated Logistics Support Plan (ILSP) provides a framework for organizing and managing the resources and activities which will culminate in efficient, cost effective support for the system under development. The ILSP reduces uncertainty in support planning, ensures compatibility of resources, and diminishes the duplication of effort. The elements of ILS are planned simultaneously during the development phases of a program. The maintenance plan is the lead document because the concept of maintaining the system affects the planning of all other elements. For example, technical manuals must be consistent with the levels of repair defined in the maintenance plan, and training schedules for maintenance personnel must be coordinated in order that correct number of skilled personnel are available when the system is introduced into the field.

Finally, there must be the means to monitor the progress and accomplishments of the product assurance plan. This is accomplished through testing and design reviews.

TEST PLANNING FOLLOWED BY TESTING provide the proof of achieved reliability/maintainability and, conversely, the uncovering of deficient areas of design. The designer should gather the appropriate data for reliability purposes during both the development and the testing stages. Measures such as accept/reject criteria, the definition of a failure, and instrumentation and data requirements should be established. The designer should also supply information which in dictates the types of tests to specify, test equipment required for the test, acceptable limits of operation, and type of test report required. Testing should be performed on the environmental stresses listed in individual equipment specifications. These inputs allow the test and evaluation group to develop a satisfactory reliability test plan.

DESIGN REVIEWS, both formal and informal, provide the necessary interaction between designers, project managers, sponsors, and users that permit an insight into the designer's ideas and allow an appraisal of his or her approach, progress, and problems. Design reviews provide the designer with a more precise understanding of the user's requirements and problems, and of whether or not the design approach will fulfill the reliability needs of the user. Formal design reviews usually consist of a preliminary design review held during the preliminary design of the equipment; a critical design review usually held 30 days prior to formal design release; and final design review.

Throughout the planning and implementation of product assurance plans, we must always remember that software deliverables must be treated to the same regimen as hardware. In today's systems, software accounts for more than one-half the design effort, the production cost, and any resultant integration problems. Good, definitive, software design aids, documentation procedures, methods of quality control, and configuration management have already been developed and they should be applied. rigorous testing should also be emphasized for both software and hardware. There should be acceptance testing upon delivery of all purchased components and subassemblies; efficient quality inspection and testing of components and subassemblies upon completion of fabrication; and thorough testing upon completion of production.

The application of a well thought out product assurance plan with its requisite monitoring system, and supported by adequate testing, will provide a high probability of meeting the ultimate goal of reliable, sustainable equipment delivered to the field at an affordable price.

THE OCEAN ENGINEERING CHALLENGE OF PROJECT DUMAND

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INTRODUCTION

The Deep Underwater Muon and Neutrino Detection (DUMAND) Project is directed at the use of the ocean as a very large detector for cosmic-ray muons and neutrinos. The project has been active since 1975, and summer workshops have been held in which concepts for the use, design, and construction of such a detector have been developed.

DUMAND was originally considered as a billion-ton detector - one cubic kilometer of ocean water, at a depth of 5 km - to reduce cosmic-ray background. It will detect muons and neutrinos from extraterrestrial sources via the Cerenkov light produced in interactions of these particles with nuclei. The array is powered by a submarine cable from shore, which also carries data back to shore.

Since this project proposes to develop, install, and operate the largest array of instrumentation ever envisioned for the deep sea, if it should proceed, it would be a major force in rapidly advancing the state-of-the-art in ocean engineering. The components required and the techniques for deployment are at the very edge of current capabilities, but based on studies conducted to date they appear completely feasible.

Besides providing a unique instrument for basic scientific research, the implementation of the DUMAND Project would result in the ocean-engineering equipment and expertise needed to solve many other difficult undersea problems.

SCIENTIFIC GOALS (From paper by Dr. Vincent Peterson, University of Hawaii)

The concept of DUMAND has a long history. It became more than just an idea in the mid-1970's when several active deep underground experimenters (F. Reines, S. Miyake, M. A. Markov, et al.) took action to explore the advantages of using water as a target-detector for very high energy neutrino interactions. Since muons provide the neutrino's charged-current signature, DUMAND is designed to detect the Cerenkov radiation from ultra-relativistic muons. Thus it can also be used for cosmic ray spectrum studies. Occasional short-term summer workshops (1974-1978) at Seattle, Honolulu, and San Diego led to the concept of an array of water Cerenkov counters and/or acoustic detectors within a cubic kilometer volume of sea water at great depths. Such an array would provide an immense neutrino detector and investigate neutrino interactions at energies above accelerator capabilities.

Initial scientific goals included neutrino astronomy (search for point sources), cosmic ray muon physics (energy spectrum, multiple muons), and very high energy neutrino interactions (search for new particles). More recently it has been realized the DUMAND could be an excellent magnetic monopole detector.

Figure 1 is a sketch of the DUMAND concept. The detector in the deep ocean is well-shielded from low energy muons. High energy muons from various sources (atmosphere-produced mesons, extra-terrestrial diffuse and point sources) penetrate from above; neutrinos from the same sources arrive from all directions.

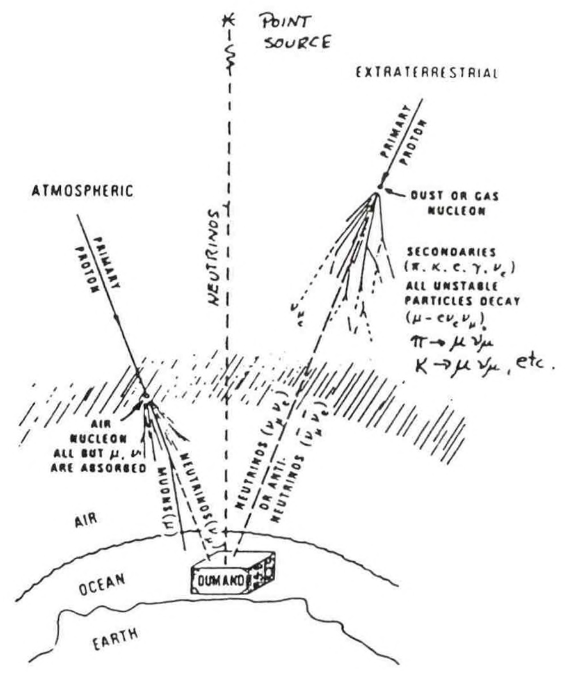

Figure 1
Concept of DUMAND

Cost estimates of instrumenting the 10^9 ton detector mass with optical detectors proved discouraging, namely $100 million or more. The less expensive technique of detecting neutrino interactions from the accompanying acoustic pulses was shown to have a threshold too high (10^{17} eV) for adequate statistics. Hence, by 1979 it was decided that the DUMAND concept needed a thorough feasibility study, involving measurements of critical parameters. The interest of key physicists at Hawaii, chosen as the best site for DUMAND, plus local support for the project, led to formation of the Hawaii DUMAND Center at the University of Hawaii in early 1980 to assume the task of conducting the feasibility study.

One of the first results of the feasibility study was to establish priority of goals: neutrino astronomy was chosen as the primary goal, due to its intrinsic astrophysical interest. Cosmic ray muon physics, a search for monopoles, and neutrino oscillations are secondary goals. One advantage of viewing DUMAND as a neutrino telescope is that the "target volume" is not limited to the instrumented water volume, but encompasses all matter whose muons can reach the detector. Measuring muon energy (a difficult problem in DUMAND) is much less important to neutrino astronomy than measuring the direction of each muon. A detailed calculation of the minimum instrumented detector volume required for neutrino astronomy of known point sources was made.) This resulted in the present dimension of 500 m x 250 m x 250 m (3.2 x 10^7 tons of water) and an array of 756 optical detectors. It also has reduced the estimated fabrication and deployment cost for the DUMAND array to about $15 million.

The feasibility study (1980-1982) was conducted by a collaboration which included physicists from Hawaii, Irvin, Tokyo, Purdue, Wisconsin, CalTech, Scripps, Vanderbilt, Bern, and Kiel, thus involving seven USA groups and three groups from other countries. Much progress has been made in developing prototype optical modules, measuring site characteristics, designing electronics and fiber optics system, and detailing an overall system. Several ocean operations were undertaken to test prototypes and the successes (and failures) provided valuable experience in the interdisciplinary techniques required by DUMAND. The net result of the study was to produce an official proposal to the Department of Energy (DOE), "High Energy Physics" in the USA, which was acted upon favorably in April 1983 for Stage I (the Short Prototype String construction and operation). At the completion of Stage I, DUMAND will again be reviewed.

SITE CONSIDERATIONS

Hawaii is the preferred DUMAND site due to the accessibility of deep, clear water close to land (volcanic island). Other factors are the existence of programs in ocean science and high energy physics at the University of Hawaii, plus the active interest of neutrino physicists residing in Honolulu. Even before 1980 several important determinations of site parameters (e.g., water transparency, ocean currents, biofouling, seabed properties) were made by ocean experts from the Hawaiian Institute of Geophysics and the Scripps Institute of Oceanography. High clarity of water (30 meters mean attenuation distance in the blue-green), and low values of deep ocean currents (less than 10 cm/sec) were very encouraging. Biofouling is believed to be absent in the very cold (<4° C) water at great depths. Optical background, from K-40 radioactivity and bioluminescence, has been the subject of several extended investigations since 1980. If major turbulence occurs, stimulated bioluminescence can produce serious optical backgrounds. Very recent results on NON-stimulated bioluminescence yield levels comparable to, or less than, K-40 background, when measured with a bottom-tethered detector typical of a DUMAND optical module. Such low backgrounds are easily discriminated against.

DESCRIPTION OF THE ARRAY

Figure 2 is a sketch of the planned DUMAND array: six rows of six strings, each string containing 21 optical and three acoustical modules. The strings are spaced 50 meters apart; the modules on a string are 25 meters apart. Most high energy neutrino interactions (outside or inside the array) will produce a muon track which passes through the array in a straight line. The Cerenkov light produces "hits" in several to many modules. Interactions inside the array will also produce Cerenkov light (and acoustic signals) from the hadronic cascade.

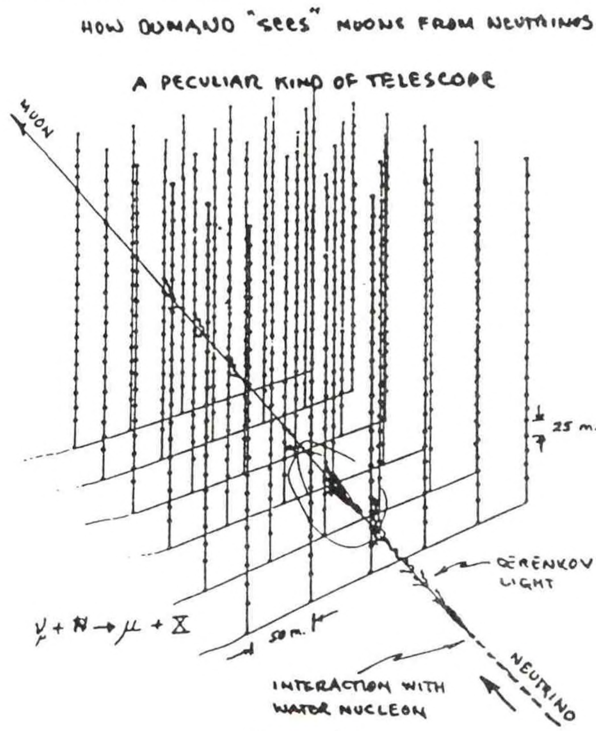

Figure 2
DUMAND Array

The most important parameter of the

"telescope" is the angular resolution of the muon direction, which varies with muon energy and direction over the range 15 to 45 mrads. This is adequate to resolve point sources of neutrinos above 1 TeV, with a signal/noise ratio S/N ≥10, if the neutrino intensity exceeds 10^{-10} neutrinos/cm^2/second at the detector. Neutrinos sources of this strength (e.g., Cygnus X-3) are expected based upon recent measurements of TeV gamma-ray fluxes and the expected ratio of neutrinos/gammas escaping from such point sources. A plot of proton luminosity versus distance for candidate neutrino sources is displayed in Figure 3. The slanting solid line represents DUMAND's threshold for detection, namely 10 events per year (with less than one background event).

The array of strings will be bottom-tethered about 100 meters above the ocean floor in an abyssal plain about 40 km west of the island of Hawaii, near Keahole Point, as shown in Figure 4. Each row would be connected to shore by a separate electro-optic cable, which provides power, data transmission, and control signals. Low-loss fiber optics in the 40 km cables does not require repeaters between the "string-bottom controllers" at the base of each string and the shore-based computer. The shore station at Keahole Point, a state-owned installation originally developed for OTEC and other energy projects, is being made available to DUMAND.

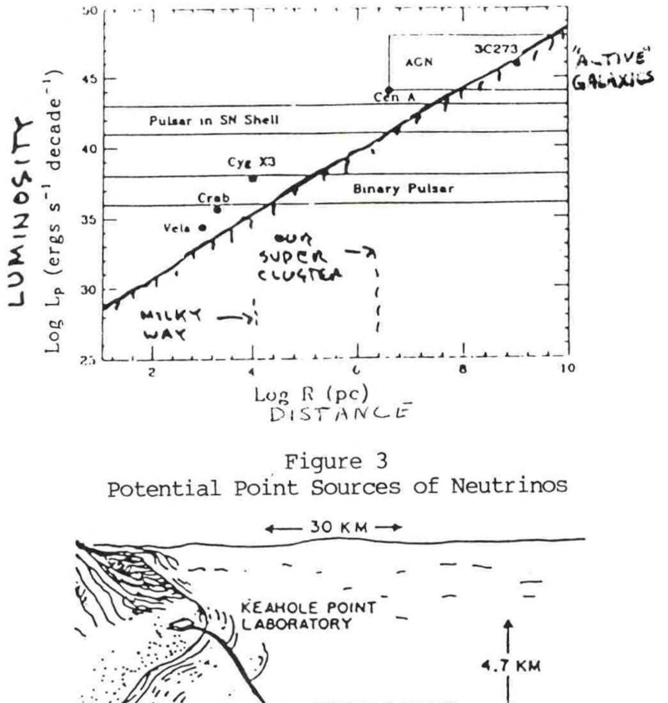

Figure 3
Potential Point Sources of Neutrinos

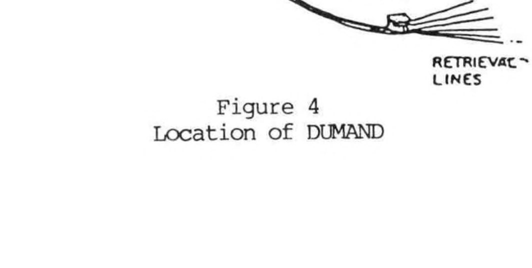

Figure 4
Location of DUMAND

THE OPTICAL MODULE

One of the major goals of the feasibility study has been to develop a Cerenkov detector module of rugged construction, high sensitivity, and time resolution which will operate reliably in the deep ocean for long periods of time. The present choice is a large (16-inch diameter) Hamamatsu photomultiplier with hemispherical photocathode mounted inside a glass pressure-sphere ("Benthos sphere"). The electronics for control and readout of the PMT are mounted inside the sphere, as shown in Figure 5. The resulting

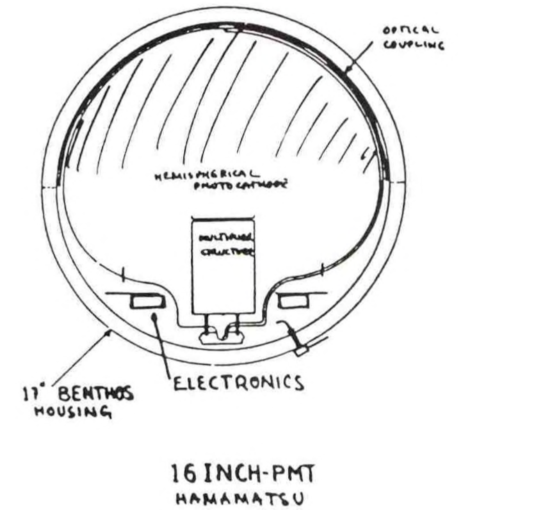

Figure 5
DUMAND Optical Module

Cerenkov detector accepts photons from all angles, although the backward direction is partially obscured; the measured angular response is $S(0) = 0.6 + 0.4 \cos \theta$. Monte Carlo simulations show that the angular response of the array of 756 photomodules show less variation with muon direction, especially if the tube orientations are alternated.

A minimum ionizing muon traversing the array will emit about 20,000 photons per meter in the blue-green wavelength band. The average muon traversing the array will trigger eight PMTs along its path. PMT pulse time (±10 ns) of the hits, and position location of the PMTs (to ± 20 cm), make it possible to reconstruct the trajectory and determine the direction of the muon.

The electronics package contained within each pressure sphere includes a microprocessor, PMT power supply, fiber optic transmitter and receiver, pulse height and timing digitizer, and control circuits.

The complete prototype module is now operational in Hawaii, and eight modules were assembled for the short prototype string (SPS) test in 1985. A 6-km length of armored electro-optic cable is now being fabricated for a later SPS test, and a longer (40-km) cable is planned with six fibers.

THE SHORT PROTOTYPE STRING (SPS) COSMIC RAY MUON TEST

Development of the DUMAND array is envisaged in stages: one string, then three strings (TRIAD) anchored at the points of a 50-meter equilateral triangle, then one row of six strings, then six rows of six strings (the array). Stage I consists of a SPS which, embodies all the technical elements of DUMAND but is expected to detect mainly atmospheric muons. The spacing between modules is deliberately made small (5 meters) so that the SPS will accept a large solid angle. The goal is to demonstrate rejection of background and isolation of the muon signal cleanly enough to measure the angular distribution and absolute flux of cosmic ray muons with precision limited by statistics. The effective area of the SPS depends upon thresholds required to reduce background but adequate statistics should be obtained in a deployment of only 10 days.

SCHEDULE

The initial deployment of the SPS occurred in November 1985. Results of this preliminary test are being incorporated in design changes for a next SPS test in the summer of 1986. Design of the TRIAD is planned for spring and summer of 1986 with fabrication in late 1986 and early 1987, and deployment in the summer of 1987. The deployment of a full row, with even spacing between strings, is a more complex oceanographic operation. Deployment of the full array of six rows is even more difficult, but the use of a semi-submerged Small Water-plane Area Twin Hull (SWATH) ship of great stability and maneuverability will make the problem tractable. The goal is to have the full array in place by late 1988 or mid-1989.

ENGINEERING CONSIDERATIONS

Since this project proposes to develop, install and operate the largest array of instrumentation ever envisioned for the deep sea, there is a synergistic effect between the Deep Ocean Engineering Community and the DUMAND Project. They need the most advanced deep ocean technology and at-sea experience and the Deep Ocean Engineering Community can profit from advances in technology and experience required by DUMAND. The following are some specific items to be covered by DUMAND that are of special interest.

a. For Ocean Engineering:

(1) Definition and development of components for a very large array of sensors for installation in deep water; including such items as:

(a) Fiber optic cables

(b) Fiber optic and electrical underwater connectors

(c) Optical and acoustic sensors

(d) Precise position monitoring

(e) In-situ signal processing

(f) Power supplies and distribution

(g) Pressure tolerant electronics (PTE) applied throughout

(h) Special materials

(i) Lightweight structural frameworks

(j) Special anchoring

(2) Development of installation procedures for very large arrays into deep water.

(3) In-situ processing of large quantities of data, to reduce bandwidth for cable economies.

(4) Development of unmanned vehicle expertise for inspection and repair of sensors and cabling systems in deep water.

(5) Installation and maintenance of deep sea cables.

(6) Investigation of structural response in long undersea sensor strings.

(7) Access to advanced undersea ideas of others working in the field, who will propose techniques for installing very large objects into the sea.

b. For biological effects:

(1) Determination of the nature of deep biota.

(2) Measure optical emanations from deep sea organisms, and the response of optical sensors to these natural background noises.

(3) Determine the details of background signals versus nuclear particle related Cerenkov flashes.

(4) Potential for fouling of optical sensors, and means to clean them.

c. For site studies:

(1) Obtain detailed physical survey of the site in deep water near Hawaii.

(2) A better understanding of soil interaction in specific areas in reference to stirring, clouding, and settling as related to installation techniques and optical data gathering over long periods of time.

d. During operations:

(1) A better understanding of basic

SWATH Ships: State of the Art for Predicting Lifetime Maximum Loads and Fatigue Loads

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ABSTRACT

Small waterplane area twin hull (SWATH) ships offer improved seakeeping and increased operational effectiveness. For this reason they have stimulated considerable interest within the U.S. Navy. As with any structure, SWATH design requires a knowledge of the expected loads. Both model test and analytical load characterization data have been obtained. Statistical analysis methods have been applied to this data to obtain lifetime maximum and fatigue loads. These methods have also been used to generate a simple equation for estimating lifetime maximum loads. Statistical analysis of monohulls indicates that U.S. Navy ships are designed to about two-thirds of their predicted lifetime maximum bending moments. Design stresses are about two-thirds of yield. History shows this approach to be sound. This information suggests SWATH ships can be designed similarly.

BACKGROUND

Small waterplane area twin hull ships have generated serious interest in the U. S. Navy because they offer improved seakeeping and increased operational effectiveness. One of the challenges in developing this ship concept has been that of generating loads for structural design. The governing primary loads (acting on the total hull structure) are wave generated forces which tend to alternately push the submerged hulls toward each other and pry them away from each other (Figure 1). The problem has been to develop a fairly accurate, yet reasonably utilitarian methodology for obtaining the lifetime maximum and cyclic distribution of these loads.

In the U. S. Navy, design primary loads are obtained for conventional ships by statically balancing the ship on a wave of length equal to the ship's length, and height proportional to the square root of the ship's length. Changes in vertical buoyancy forces produce the governing primary loading, and these can be calculated readily and with sufficient accuracy. The adequacy of this approach has been verified by thousands of ship-years of operations. For SWATHs, the loads of concern are generated by wave reflection and refraction and are laterally applied. These phenomena are not readily simulated by static balance approaches, and attempts to do so produce results which do not agree with experimentally obtained results. Therefore, a different approach must be taken.

APPROACH

Physical model tests are of great value for obtaining primary loads data. However, physical model simulation of a ship's lifetime operating experience is prohibitively expensive. So, too, is conducting a full range of physical model parametric investigations in order to develop empirical relationships for primary loads as a function of ship geometry. On the other hand, purely analytical approaches without experimental substantiation leave considerable doubt as to the validity of the results. Therefore, it was decided to develop a combined experimental and analytical approach, employing the best features of each. The following path was taken:

(1) develop model test data processing methods which could be used to produce lifetime maximum and fatigue load predictions for any particular SWATH ship of interest

(2) apply these approaches to monohull ships to determine the relationship between lifetime maximum and design bending moments

(3) conduct parametric studies using analytical models to relate primary loads to SWATH ship geometry.

The essence of this approach is statistical analysis, and the key parameter is the unit response curve. This curve gives the ratio of primary load to wave height as a function of wave frequency (or length). Squaring the ordinates of the unit response curve produces what is known as the response amplitude operator, or RAO.

STATISTICAL ANALYSIS

A valuable statistical representation of a sea condition (time history of wave elevation) is the wave spectrum. This representation gives the wave energy as a function of wave frequency. The product of a wave spectrum and a response amplitude operator (square of response per unit wave height) is a response spectrum. The area enclosed under a spectrum is a statistical quantity which indicates the magnitude of the input (wave height) or response (primary load). If the spectrum is narrow, the enclosed area is sufficient to define the probability density function for the amplitude distribution of the original time history. Also, if the duration of the original time history is known, the probability density can be used to define the histogram of amplitude distribution. The histogram provides the number of cyclic excursions between amplitude bands. Figure 2 illustrates this discussion.

For ship primary loads the response amplitude operator is a function of the ship's geometric properties, its heading relative to the waves and, to a lesser degree, its speed. A ship's operating mode is defined by its heading, speed and the sea condition. Strictly speaking, the ship can experience an infinite number of operating modes in its lifetime. To make a statistical approach tractable, one may consider the entire set of operating modes as a block with axes corresponding to speed, heading, and sea condition (see Figure 3). This block can be subdivided into sub-blocks of incremental values. Each sub-block can be represented by its mid-range values. The sea condition can be further subdivided as to the form of the wave spectrum, corresponding to rising seas, fully developed seas, falling seas, mixed sea and swell, etc. The six parameter spectrum formulation devised by Ochi (references 1, 2) has been used in this development.

The probability of being within a particular incremental operating mode is the product of the individual probabilities of being within the incremental ranges of each parameter (wave height, spectral shape, relative heading and ship speed). The total time spent in a particular incremental mode is the product of the probability of being in that mode and the total operating life of the ship. Each incremental mode will result in a particular response (loading) spectrum, probability density function of response, and response histogram. The total number of response cycles for each incremental operating mode is the product of the time spent in that mode and the average (modal) frequency of the response spectrum. A summation of all of the individual histograms results in a histogram of cyclic response (loading) amplitudes for the entire ship life. This is the fatigue load spectrum. The maximum value found in the lifetime histogram is the expected maximum lifetime load.

STATISTICAL RESULTS

The statistical methods described above were applied to a dozen naval monohulls. It was found that the design bending moment is, on the average, two-thirds of of the lifetime maximum value for twenty years of operations in the North Atlantic, assuming operations during one hundred and eighty days per year. Also, lifetime maximum stresses were found to be close to yield, or about one and one half times the design values. Therefore, it is reasonable to design SWATH ships to two-thirds of expected lifetime maximum primary loads, at design stresses presently in use. An interesting finding of the statistical analysis is that lifetime maximum loads can occur in sea conditions less than maximum expected conditions. The reason for this is that more operating hours are spent in less than maximum expected sea conditions, and probable maximum values grow somewhat with increasing exposure time at each incremental operating mode. This result is illustrated in Figure 4.

SIMPLIFIED LOAD EQUATION FOR SWATH

In order to develop a simple equation for estimating the lifetime maximum and design primary loads for SWATH ships, an analytical parametric study was undertaken. The work of Curphey and Lee (reference 3) was used to evaluate the effects on primary loads of variations in particular ship dimensions and properties. Response amplitude operators were obtained for these variations. Then statistical analyses were performed to determine the effects on lifetime maximum loads. It was found that the parameters which most significantly affect primary load are ship displacement, draft, and strut length. The data generated in this study, together with model test data, were used to formulate a simple semi-empirical equation for expected lifetime maximum primary loads for SWATH ships. It was found that this equation agrees with statistical values obtained from model test response amplitude operators to within a standard deviation of error of eleven percent.

A general equation for the primary load is given in reference 4. For SWATH ships with one strut per side, a simplified expression for lifetime maximum load is:

F(max) = Displacement x D x T x L, where

D = 1.55 - 0.75tanh(Displacement(tons)/11,000)

T = 0.532 x draft/d

L = -0.725 + 2.99tanh("length"/24d)

d = one-third power of displacement(tons)

"length" = (strut + submerged hull length)/2

The ship geometric bounds of applicability for this equation are presented in reference 4.

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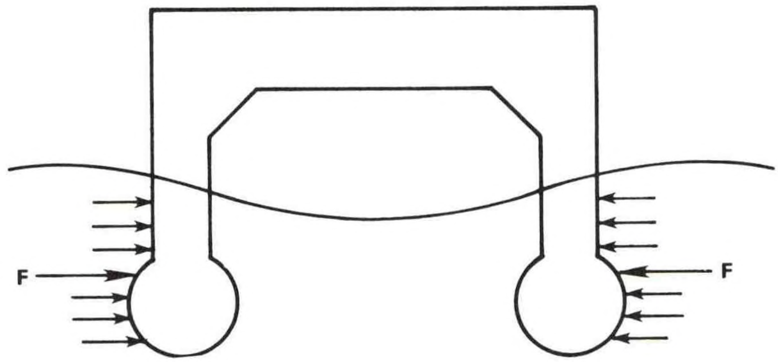

Figure 1 - SWATH PRIMARY LOAD

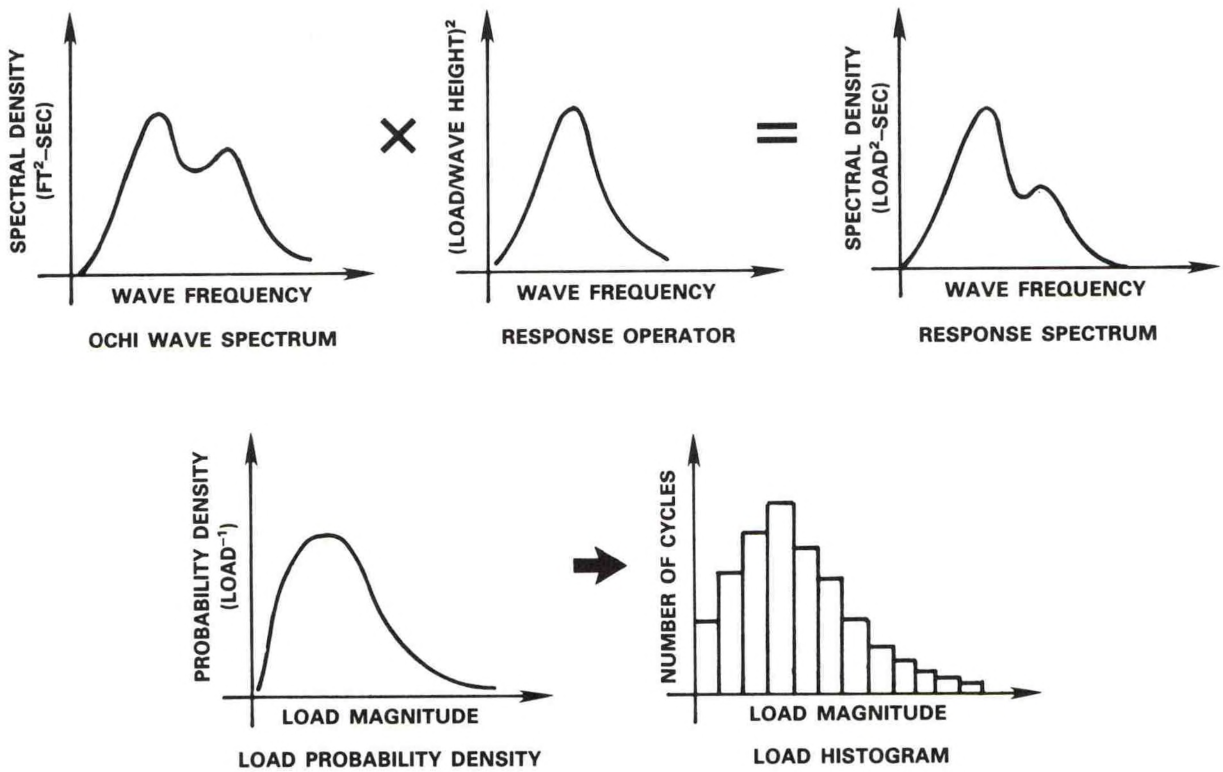

Figure 2 - STATISTICAL DATA PROCESSING

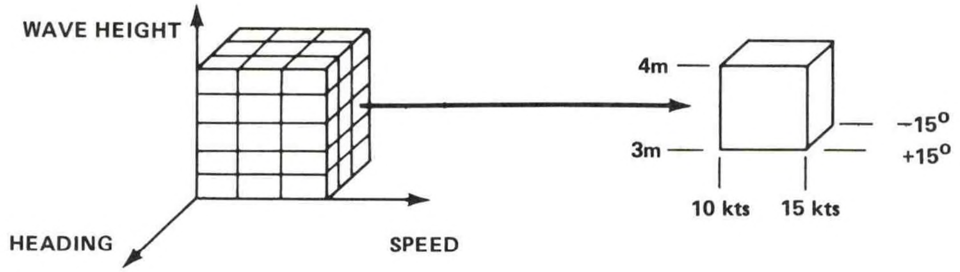

Figure 3 – SCHEMATIC OF INCREMENTAL OPERATING MODE

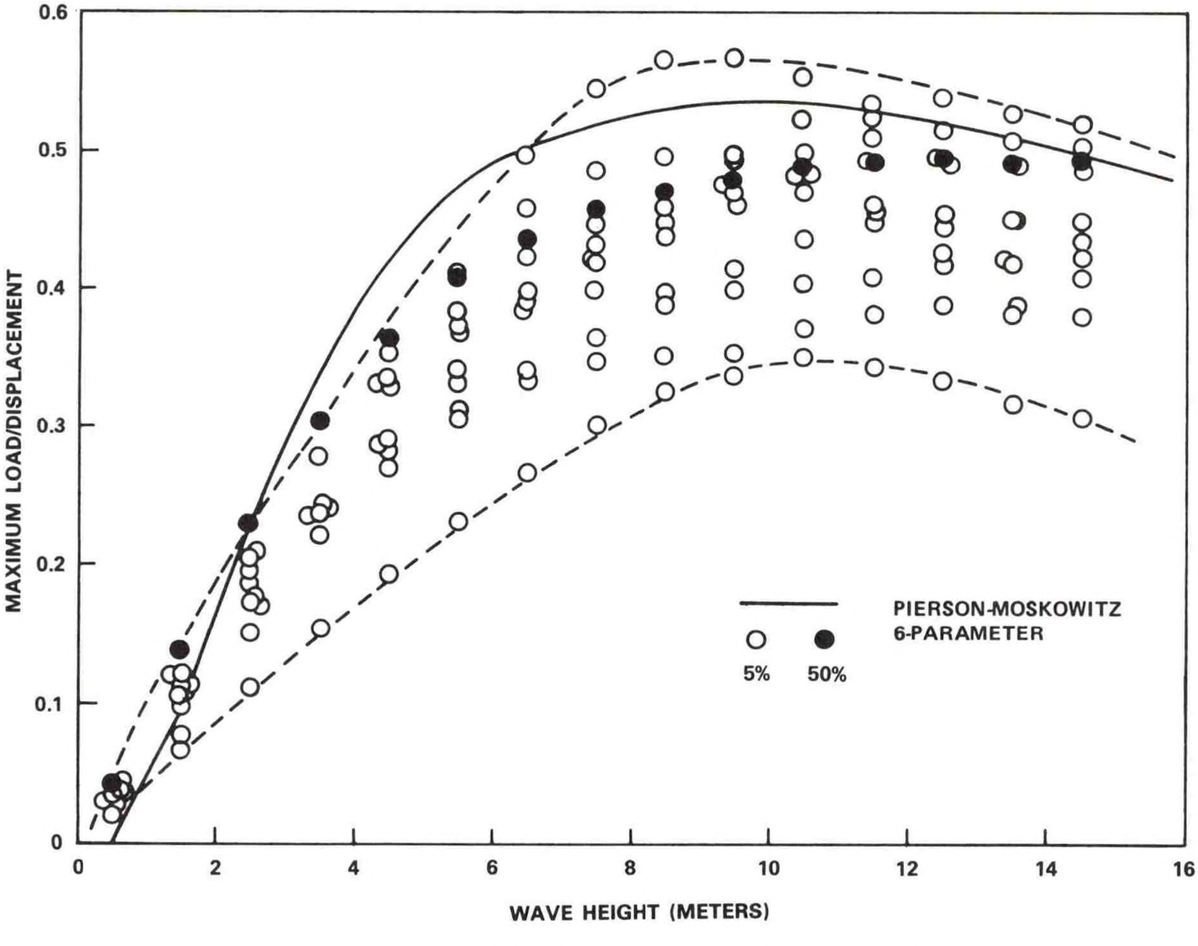

Figure 4 – LIFETIME MAXIMUM LOAD V. SEA CONDITION

TECHNICAL CONSIDERATIONS IN THE DESIGN OF AN OFFSHORE PATROL BOAT

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UNITED STATES COAST GUARD

ABSTRACT

The U.S. Coast Guard currently operates twenty two 95 ft Cape Class and fifty three 82 ft Point Class multi-mission patrol boats (WPB). The WPB's, suffering from old age and over utilization, are rapidly approaching the end of their useful service life. The first WPB entered service in 1953 and is now 32 years old. This paper presents the U.S. Coast Guard WPB replacement conceptual design and highlights the general design approach and technical considerations used to develop the design.

BACKGROUND

The U.S. Coast Guard fleet of multi mission patrol boats (WPB) are scheduled for replacement within the next few years. A number of options are under consideration including advanced and conventional craft. This paper describes the Coast Guard's conventional design which is distinguished by the fact that it utilizes modern well proven design practices and avoids technologies which have not been adequately demonstrated. General design objectives include mission effectiveness, enhanced seakeeping, improved habitability, fuel efficiency, and reliability with respect to maximizing available operational time. Maximizing survivability and personnel safety were also important design objectives.

The primary mission capabilities include:

Enforcement of Laws and Treaties (ELT)

provide a deterrent against smuggling, illegal entry of aliens and fisheries violations and have the ability to intercept suspect vessels, conduct boardings, and make necessary seizures.

Search and Rescue (SAR)

render assistance including rescue of personnel in the water, dewatering, firefighting, assisting grounded vessels, and towing disabled vessels.

Defense Operations (DO)

quickly adapt to wartime tasking in in-shore undersea warfare, protection of offshore assets, coastal surveillance, interdiction and mine countermeasures, and Maritime Defense Zone (MDZ) responsibilities.

The performance requirements are:

Maximum speed:	30 knots (minimum)
Range:	1680 nautical miles
	24 hrs at 30 knots
	96 hrs at 10 knots
Endurance:	5 days
Environment:	10 ft seas (operational)
	25 ft. seas (survival)
Accommodations:	2 Officers
	14 Enlisted,
Appendage Draft:	8 feet (maximum)
Towing:	500 tons
Small Boat:	Rigid Hull Inflatable

HULL FORM DEVELOPMENT

Initial hull form selection studies were conducted seeking the best combination of resistance and seakeeping characteristics for the mission requirements. Minimum resistance was sought at the maximum continuous speed in an effort to reduce the propulsion engine size and total fuel capacity requirement. Hull form optimization at the low speed loitering condition was a second priority since it represents a comparatively small percentage of the estimated fuel load.

The initial weight and arrangement studies clearly show that the vessel operates between the semi-displacement and planing regime at the maximum continuous speed requirement. Assessments of round bilge and hard chine full-scale and series model data indicate lower resistance characteristics for the hard chine type form. At higher speed the resistance advantage of the hard chine form is more evident. Typical resistance characteristics for efficient hard chine forms are shown for various slenderness ratios in Figure 1. At the estimated design Volume Froude Number, it can be seen that slenderness ratio has an important effect on resistance with increased slenderness ratio providing decreased resistance.

High slenderness ratio also has significant advantages with respect to seakeeping characteristics and speed loss in a seaway. Narrow beam and high deadrise are particularly important in reducing vertical acceleration. The minimum beam is however limited by stability requirements, engine room access, and other arrangement considerations. The double chine hull form was selected since it provides an effective means to resolve these conflicting requirements.

The narrow, lower chine beam has the effect of reducing impact acceleration and favors lower resistance. The upper chine, on the other hand, provides the wider beam necessary for stability and arrangement requirements. The effectiveness of this configuration is generally considered to be dependent on the ability of the flow to separate from the lower chine. The double chine form has been successfully utilized on a number of designs. The first and most notable application was the U.S. Navy's Coastal Patrol and Interdiction Craft (CPIC) developed in the mid 1970's. A general discussion of the hull form development is provided in Reference 1. A more recent embodiment of the double chine form is described in Reference 2. The double chine form developed for the concept design is shown in Figure 2. The principal hull dimensions are listed in Table I.

PERFORMANCE CHARACTERISTICS

1:9 scale model tests were conducted to evaluate calm water resistance and seakeeping characteristics. The range of displacements and longitudinal center of gravity (LCG) positions are based on the design weight estimate and include the lightship (110 tons), half load (135) and full load (160). The LCG was varied over a range of conditions from 36 percent of the length on waterline (39.6 feet forward of station 10) to 42 percent (46.2 feet forward of station 10). The effective horsepower results are shown in Figure 3. These results show that the 39 percent LCG (42.9 feet forward of station 10) is the optimum position for high speed running. The change in running trim, as measured form the static waterline is shown in figure 4. The trim relative to the mean buttock is 0.2 degrees higher to compensate for static trim.

Limited seakeeping tests were conducted. Tests included measurement of vertical accelerations, pitch and heave in irregular seas. They were made at the bow and center of gravity for sea state 3 at twenty eight knots and for sea state 5 at fifteen and twenty knots. The results are shown in Table II. In an effort to make some determination about the effectiveness of the concept design hull form, a comparison was made to data presented by Blount and Hankley in Reference 3. The reference reports full scale and model data for two craft; a conventional hard chine form and double chine form. The body plans are presented in the reference.

Table III compares vertical accelerations at the bow and center of gravity on the basis of Volume Froude Number and wave height to beam ratio. Because of varying test conditions, the wave height to beam ratio was corrected to the concept design model conditions by linear extrapolation. The basis for the correction is the linear relationship between acceleration and wave height to beam ratio identified in Reference 4.

On the basis of the comparison it can be seen that the concept design provides an improvement over the single chine craft but does not perform as well as the Navy double chine craft. This is attributable to differences in hull geometry such as length to beam ratio. For example, the Navy double chine form has a particularly high length to beam ratio compared to the concept design. Further when comparing the data it should be noted that the model data over predicts the full scale performance. This has been noted in other model/full scale comparisons. Consequently, full scale accelerations of the concept design are expected to be lower than the model data indicates.

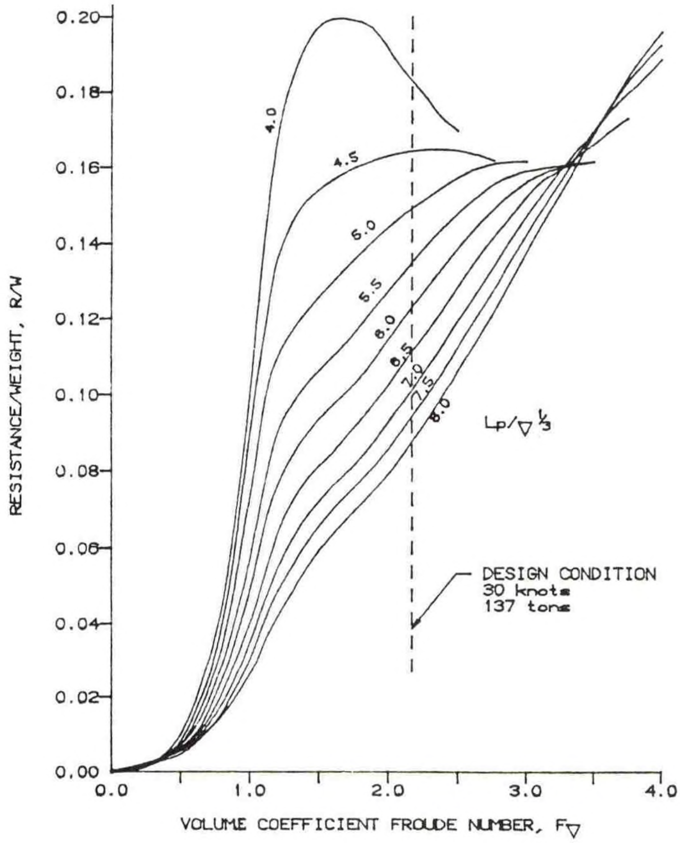

Figure 1

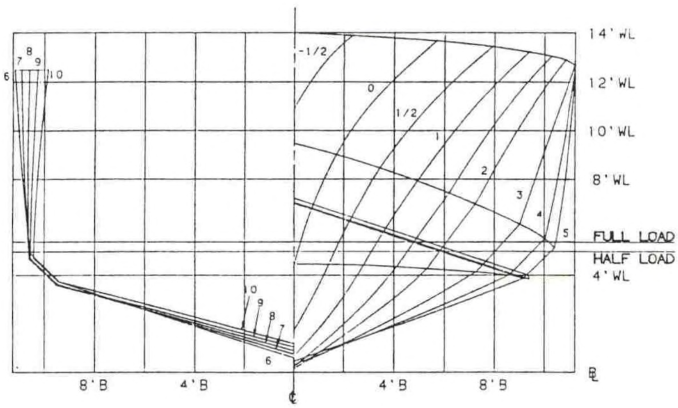

Figure 2

Table I

Principal Characteristics of Conceptual Design

Length, overall	118.8 ft.
Length, design waterline	110.0 ft.
Displacement, full load	157.0 l.t.
Displacement, half load	137.0 l.t.
Beam, maximum overall	22.5 ft.
Beam, upper chine, midships	20.8 ft.
Beam, lower chine, midships	18.3 ft.
Beam, upper chine, maximum, sta 8	21.2 ft.
Beam, lower chine, maximum, sta 8	19.0 ft.
Freeboard, forward	8.2 ft.
Freeboard, transom	7.0 ft.
Depth	12.0 ft.
Draft, appendage, full load	8.3 ft.
Draft, appendage, half load	7.9 ft.
Draft, molded, half load	5.0 ft.
Maximum Continuous Speed, half load	30 knots (minimum)
Maximum Speed, half load	Classified
Economic Speed - 2 Shafts @ 570 BHP	12 knots
Fuel Consumption, Continuous Speed	244 GPH
Fuel Consumption, Economic Speed	40 GPH
Endurance	5 days
Range, 24 hours - 30 knots plus 96 hours - 12 Kts	1,872 NM
Fuel Capacity	9,850 gal.
Potable Water Capacity	1,200 gal.
Water Maker Capacity, per day	400 gal.
Accommodation, crew	16
Accommodation, spare	2

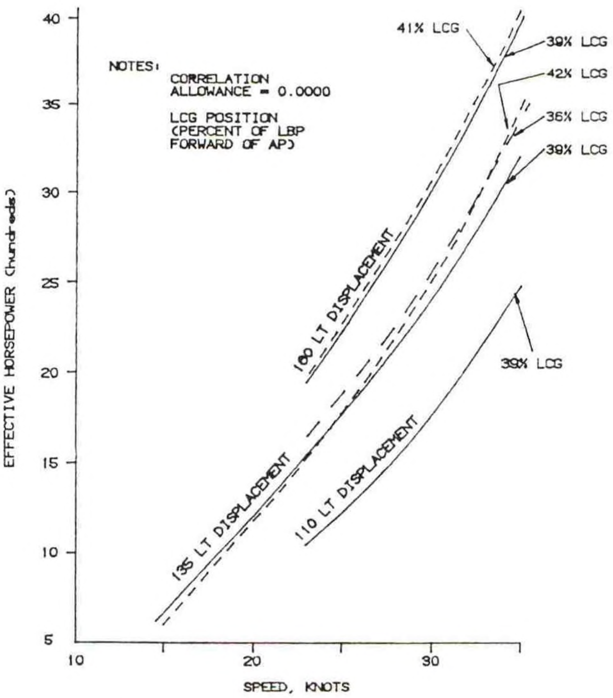

Figure 3

ARRANGEMENTS

The profile and arrangement drawings are shown in Figure 5 and Figure 6. The arrangements were based upon a number of considerations including operational requirements, habitability, producibility, and access for personnel and equipment maintenance. In so far as possible, the spaces were arranged to limit personnel exposure to noise/vibration, to minimize the effects of vessel motions on the crew, and to provide convenient personnel access to all spaces and decks. The arrangement of the aft deck was primarily influenced by requirements for small boat handling, towing, and engine removal.

The midship location is considered most favorable for berthing and messing in that the vessel motions will be comparatively low, especially during loitering. As shown on the drawings, these spaces are relatively quiet since the galley and stores attenuate noise, and the berthing is outside the normal flow of personnel. Arrangements with forepeak berthing or messing/berthing aft of the engine room were not considered since the forepeak is subject to extreme vertical accelerations, and the aft location has high ambient noise and vibration levels. The aft location also restricts below deck access to the forward spaces.

Galley and stores are adjacent to the engine room bulkhead to limit piping and electrical runs for the galley equipment and to assist in sound deadening of the forward spaces. Also, the adverse effect of vessel motions are minimized. The galley is separated from the messing area by a joiner bulkhead to further limit noise and provide separate heating and cooling zones. A counter top opening to the messing area is provided for serving.

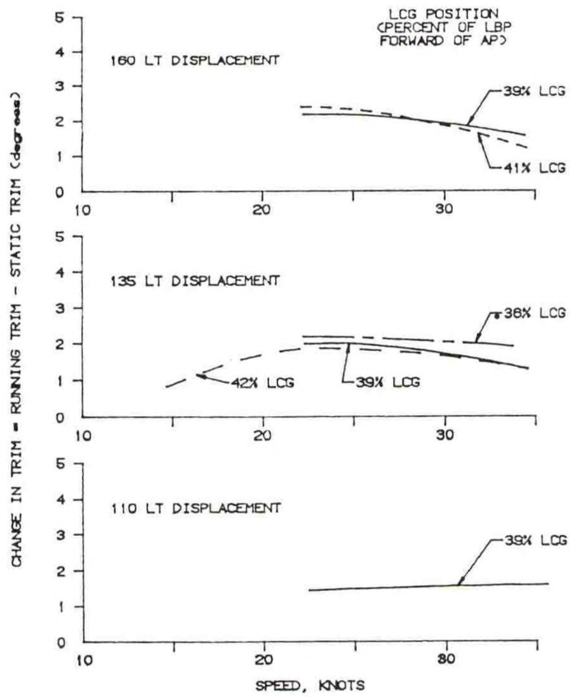

Figure 4

The bridge arrangement includes open and enclosed steering stations. The open bridge affords optimum day and night visibility and promotes full awareness of the sea and weather conditions. It also permits direct voice communication for all deck evolutions including small boat operations and towing. The open bridge instrumentation and electronic outfit is necessarily limited to the essentials because of potential weather damage. The enclosed bridge has full engine instrumentation/alarms, complete electronic navigational capability including a full-sized chart table, and extensive communication suite inside a secure space. Aft visibility is provided through the weather door to the open bridge and aft facing pilothouse windows on the port side and centerline.

Access to the open and enclosed stations is through the athwartship passage, bridge wing doors, and deckhouse ladder. The arrangement specifically avoids personnel traffic through the bridge areas (i.e. access to the lower accommodations and galley) and thus limits potential distractions. Elevated wings surrounding the enclosed bridge permit direct access to the foredeck and side shell to facilitate alongside maneuvering operations and small boat handling. The wing structure also acts as breakwater to limit water on deck and to protect the house from damage. It should be noted that the height of both the open and enclosed bridge is limited to avoid excessive wind heel, and to reduce the adverse effect of low speed roll motions

Table II

USCG WPB SEAKEEPING TEST RESULTS

IRREGULAR WAVES, FULL SCALE

135 LT, 39% LCG, Ky =0.247LBP

	Average of 1/3 Highest			Average of 1/10 Highest		
Sea State	3	5	5	3	5	5
Speed (kts)	28	20	15	28	20	15
Wave Height (ft) Double Amplitude	2.77	10.5	10.4	3.53	13.4	13.3
Pitch (deg) Single Amplitude	1.50	9.24	8.86	1.92	11.8	11.3
Heave (ft) Single Amplitude	1.30	4.81	4.88	1.66	6.13	6.22
Bow Accel. (g) Single Amplitude	0.487	1.56	1.05	0.766	2.45	1.65
C.G. Accel. (g) Single Amplitude	0.271	0.596	0.506	0.426	0.937	0.795

The flush aft deck arrangement maximizes the available space and consequently greatly improves operations for a number of deck evolutions including small boat launch and recovery, towing, at-sea personnel transfer, military retrofit, and the storage and deployment of deck cargo. The small boat, as shown, is a 5.4 meter rigid hull inflatable. It is located close to the deckhouse to afford protection against sea and weather.

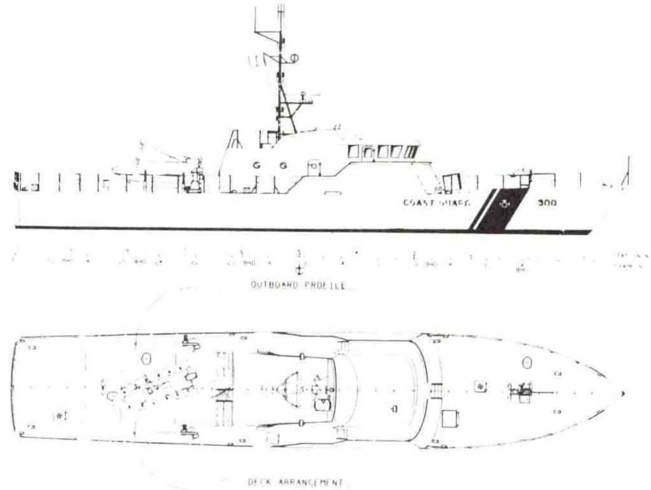

Figure 5

The forward location also permits a favorable tow bitt location. Two davits are provided for port and starboard launch capability and redundancy in the event of a failure. The small boat is rotated from the centerline position so that the davit can be used to handle the spare outboard motor stored on the after deckhouse bulkhead.

MACHINERY

The propulsion configuration is a conventional, in-line shaft arrangement. In keeping with Coast Guard design practice, the main engine, diesel generator, and other major components were selected based on conservative ratings to insure maximum reliability and maintainability. In particular, the main propulsion engine was selected based on continuous duty rating. Several engines are available which are capable of meeting the minimum power requirements within the existing space and weight limitations.

Where practical, machinery is located to facilitate maintenance, removal and to improve survivability in the event of vessel casualty. Machinery removal is an important arrangement consideration since overhauls and repairs will be performed at shore-based facilities. Inoperable machinery (e.g. main engine, diesel generator, etc.) will be removed from the vessel and replaced with inventoried spares to reduce vessel downtime. Onboard maintenance will be limited to routine, short duration tasks. In line with this approach, a design goal is to remove and replace a complete main engine in six hours.

The combustion air is drawn directly from the engine space. This is done to reduce moisture ingestion and to reduce the fan size required to cool the engine space. It is recognized that this may result in a slight loss of engine efficiency because of increased intake temperature. This may require reevaluation as the design progresses. It should be noted that the intakes are inboard facing and located well above the deck level to reduce moisture ingestion and improve the downflood angle.

The exhaust system is a conventional, underwater system and was selected for a number of reasons; including reduced airborne and structure-borne noise, improved aft visibility (i.e. no vertical stacks), lower weight and center of gravity, low visual and infrared exhaust signature, and improved interior and exterior arrangements. Exhaust cooling is provided by the raw water discharged from the engine heat exchanger. The system is comprised of a low power, above water exhaust, and a separate, high power underwater exhaust. The low power exhaust is run through the transom to reduce the presence of gases on deck during loitering and alongside while deploying or recovering the small boat. The diesel generator also exhausts through the transom for similar reasons. The underwater high power exhaust exits the side shell (between the upper and lower chine) to limit exhaust back pressure which is a critical factor for turbocharged engines.

STABILITY AND SURVIVABILITY

The concept design is in accordance with U.S. Navy intact and damage stability criteria for wind heel, turning, personnel crowding, icing and lifting weights over the side. It also meets two compartment floodable length requirements. A separate towing stability analysis was conducted. Both Navy criteria and floodable length requirements have been adjusted to include an additional 10 ton weight reservation located on the main deck at the longitudinal center of gravity. As it now stands, the concept design is in excess of the Navy requirements and a slight reduction in waterplane may be expected as the design progresses.

Several design features are incorporated to improve survivability. For example, the engine room watertight doors are located above the damaged engine room waterline to prevent progressive flooding. Where practical, electric equipment and cables are also positioned above the damaged compartment waterline. Similarly,

Table III

VERTICAL ACCELERATION COMPARISON

g's, 1/10th highest
head seas

	USCG WPB	CRAFT I	CRAFT II
Hull type	--- Double	Chine ---	Single Chine
	Vol Fr No. = 1.46	$H_{L_3}/B = 0.55$	
Bow accel., model test	2.45	2.90	4.28
full scale	--	2.60	2.44
CG accel., model test	0.94	0.69	1.22
full scale	---	0.53	0.76
	Vol Fr No. = 2.04	$H_{1/3}/B = 0.15$	
Bow accel., model test	0.77	1.04	1.75
full scale	--	0.79	0.71
CG accel., model test	0.43	0.25	0.58
full scale	--	0.17	0.29

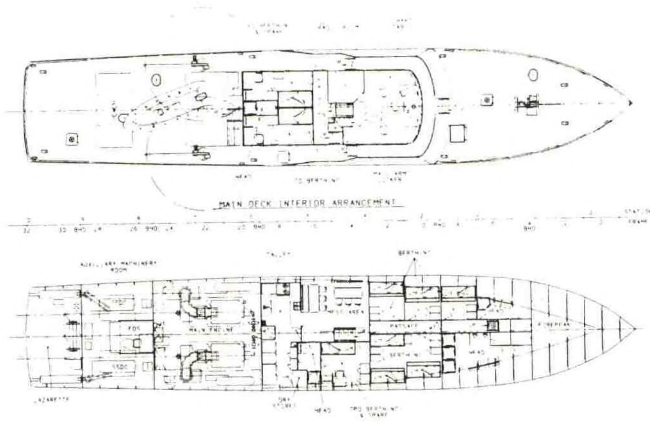

Figure 6

vertical axis electric pumps are used where practical to elevate the motor above the flooded waterline.

The generators are located outside the engine room to improve survivability in the event of a main engine fire and/or flooding. If the generator compartment should flood (one compartment), generators will remain operable since they are located above the flooded waterline. As a further measure, the fire pumps are located outside the engine room to reduce their vulnerability in the event of fire or flooding. One pump is located in the generator compartment and the other forward of the engine room.

The magazine flooding is accomplished through the fire main. As shown on the inboard profile, the magazine is located on centerline, below the waterline, for maximum safety. In the event of a failure of the firemain, the space can be flooded by gravity at a slower rate.

ACKNOWLEDGMENTS

The authors would like to extend their appreciation to the many people who contributed their ideas, comments and encouragement. Special appreciation goes to Mr. Jeff Curtis for his outstanding work in the preparation of the design drawings, his patience and persistence throughout the innumerable arrangement tradeoff studies and his astuteness in making all the pieces fit together.

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ADVANCED PROPULSORS

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ABSTRACT

Full scale trials were performed with a United States Coast Guard 41 Foot Utility Boat (41' UTB) retrofitted with a set of asymmetrical pre-swirl vanes. These vanes, positioned ahead of the propeller, increased overall propulsive efficiency by 10 to 12 percent. Data collected from the trials is compared with baseline propulsion data obtained from the 41' UTB without pre-swirl vanes.

INTRODUCTION

Marine propellers can be inefficient in converting engine power into craft forward speed. Propellers on small commercial vessels, pleasure craft, and patrol boats typically operate in the 0.50 to 0.60 efficiency range with 0.55 used as a rule of thumb. The wasted energy can be seen on many vessels as the frothing white jet of rotating water leaving the propeller and extending far aft of the vessel. If it were possible to recapture or minimize this energy loss, propulsive efficiency would increase significantly.

RECAPTURING ROTATIONAL KINETIC ENERGY

The energy losses in the jet of fluid that one sees can be catagorized into two components: axial kinetic energy loss, and rotational kinetic energy loss. One method of minimizing both of these components is to increase the diameter of the propeller while decreasing it's RPM. However, almost without exception this is impossible on small craft due to limitations on available gearbox ratios and tip clearance constraints. Another way to conserve energy is to reduce rotational kinetic energy losses only. This can be done with the use of stationary pre-swirl vanes located immediately ahead of the propeller. These vanes function by inducing a rotation or swirl into the flow of the propeller which is equal (ideally) but opposite in direction to that induced by the propeller. The net result is a cancellation of the rotational fluid velocities behind the propeller and an increase in propulsive efficiency. Recognizing the energy saving potential of pre-swirl vanes, the USCG began a program to develop this technology.

During the Fall of 1985, a set of asymmetrical pre-swirl vanes (designed by the Pennsylvania State University/Applied Research Laboratory and manufactured by LIPS Propellers of Chesapeake Virginia), Figure 1, were retrofitted to a 41' UTB, and full scale trials performed by the Naval Sea Combat Engineering Station in Norfolk, Virginia. Characteristics

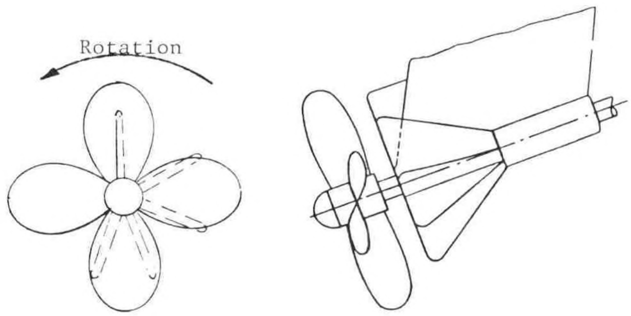


Figure - 1 Asymmetrical Pre-Swirl Vane Installation on USCG 41 Foot UTB

of the 41' UTB are listed in Table 1, and instrumentation aboard for the trials is listed in Table 2. Shaft horsepower, thrust, and RPM data taken from the port propulsor during the trials, and faired using a fourth degree polynomial least squares regression method, are presented in APPENDIX A. Table 3 contains data interpolated from the fourth degree polynomials which are multiplied by a factor of 2.0 to account for the starboard propulsor. The ratio of SHP_s/SHP_p shown in Table 3 and graphed in Figure 2 is equivalent to the ratio of propulsive efficiencies, $_p/_s$, for the craft. At ten knots the increase in propulsive efficiency is approximately twelve percent while at twenty knots the increase is ten percent.

NOMENCLATURE

$SHP_{p,\ s}$	Shaft Horsepower; subscripts s and p signify stock and pre-swirl, respectively
n	revolutions per second
r	blade section radius
$\vec{v}_{boat}$	boat velocity
α, β	blade section angle of attack
$\eta_{p,\ s}$	propulsive efficiency

TABLE I

41' UTB CHARACTERISTICS

Displacement	28,000 lbs.
Length, Overall	40.3 feet
Beam	13.5 feet
Draft, Navigation	4.0 feet
Power	Two engines; each 320 HP at 2600 RPM.
Reduction Gear	2:1 Reduction
Propellers	26-Inch Diameter; 28-Inch Pitch; 0.731 Blade Area Ratio.; 4 blades
Speed (Maximum)	23.0 Knots

TABLE II

INSTRUMENTATION

1. Thrust-Torque-RPM meter, port shaft.
2. Torque - RPM meter, starboard shaft.
3. Turbine fuel flow meters on supply and return lines, both engines.
4. Tri-axial accelerometer on hull above port propeller.
5. Humphrey Vertical Gyro
6. Pitch (Bubble) Inclinometer.
7. Electronic counters for visual display of data.
8. Electronic tape recorder for storage of data.

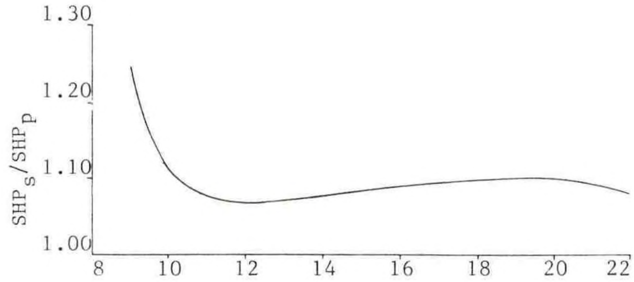


Figure - 2 Ratio of SHP_s/SHP_p Versus Speed for the 41 Foot UTB

The difference in thrust required to propel the craft with and without pre-swirl vanes at a given speed, Table 3, indicates to first order the increase in craft drag caused by the vanes. One would expect to find a defin increase in thrust over the whole speed range of the 41' UTB equipped with pre-swirl vanes; however, this does not appear to be the case. Between 14 and 16 knots, no differential in thrust was detected. One explanation for this may be as follows: with the use of pre-swirl vanes the force perpendicular to an inclined shaft (see discussion below on inclined shafts) is reduced. Since the perpendicular force has a vector component directed aft, a reduction in this force may offset the increased drag caused by the vanes.

INCLINED SHAFTS AND ASYMMETRICAL VANES

In addition to increasing propulsive efficiency, the pre-swirl vanes are unique in another way: the vanes are spaced about the shaft centerline in an asymmetrical pattern, Figure 1. The asymmetrical design counter swirls the incoming flow to the propellers over a prescribed portion of the propeller disk only, and results in the elimination of unsteady forces and cavitation problems related to the inclination of the propeller shaft, APPENDIX B. Data gathered from the 41' UTB

TABLE III

TRIALS DATA FOR 41' UTB

SPEED (kts)	SHP_s (hp)	SHP_p (hp)	$\frac{SHP_s}{SHP_p}$	$THRUST_s$ (lbs)	$THRUST_p$ (lbs)	RPM_s	RPM_p
9.0	110.58	87.62	1.26	1988	1984	630	579
10.0	173.14	154.32	1.12	2718	2824	730	686
12.0	273.06	254.16	1.07	3680	3789	865	822
14.0	348.58	323.46	1.08	4188	4212	947	896
16.0	411.02	376.86	1.09	4449	4450	1011	950
18.0	471.68	428.96	1.10	4617	4703	1078	1008
20.0	541.88	494.38	1.10	4790	5011	1157	1082
22.0	632.96	587.74	1.08	5009	5258	1249	1167

equipped with pre-swirl vanes indicates a large reduction in the magnitude of longitudinal accelerations over that of the non-equipped boat. This will result in increased crew comfort, and reduced wear and tear on equipment, bearings, and machinery.

IN THE FUTURE

Current plans call for further full scale trials (tentatively to be held in the Fall of 1986) on the 41' UTB equipped with pre-swirl vanes. The object of these trials will be to maximize the energy saving potential of the pre-swirl vanes and stock propeller combination. After these tests, an operational evaluation over a lengthy period of time is planned and then a potential retrofit to the United States Coast Guard's fleet of 41' UTB's. Additional future applications for these vanes include the following: cavitation control at the propeller hub as well as on the blade sections; protection of the propeller from debris in the water; reduction in horsepower requirements on new ship and boat designs; operating draft reductions (a smaller diameter, more highly loaded propeller can be designed to operate with the pre-swirl vanes); and, protection for swimmers when used as a propeller guard. The possibilities are numerous and we have yet to harness the axial kinetic energy loss that one sees in the frothing wake of the propeller.

APPENDIX A

FAIRED TRIALS DATA

Figures 3 through 5 contain measured or actual data taken from instrumentation on the port propulsor of the 41' UTB. This data was faired using a fourth degree polynomial, least squares regression method.

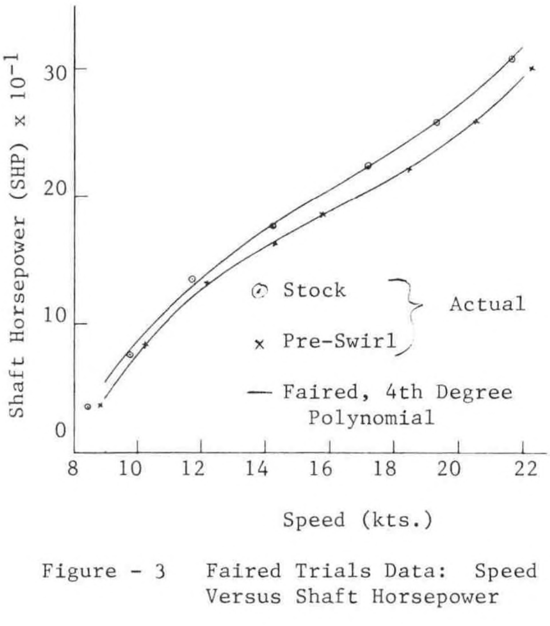


Figure - 3 Faired Trials Data: Speed Versus Shaft Horsepower

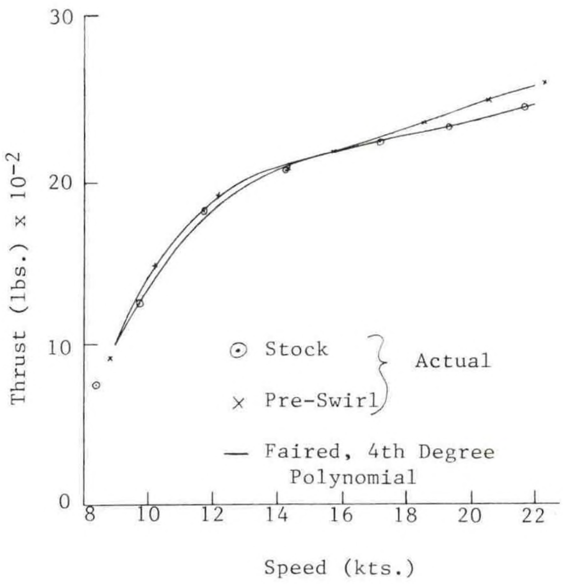


Figure - 4 Faired Trials Data: Speed Versus Thrust

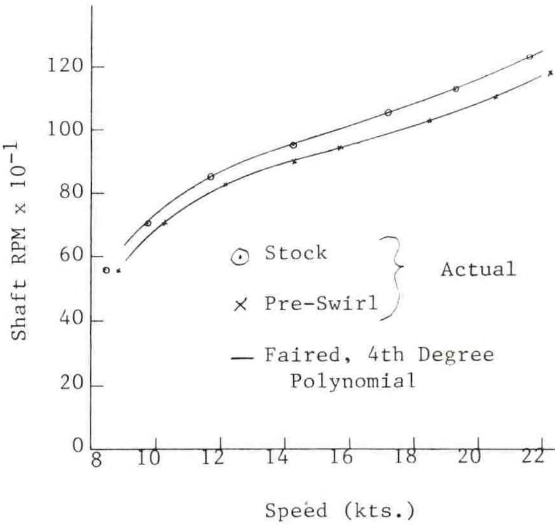
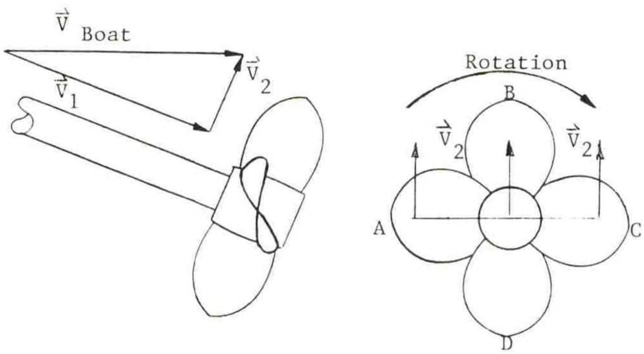


Figure - 5 Faired Trials Data: Speed Versus Shaft RPM

APPENDIX B

FORCES RESULTING FROM A PROPELLER OPERATING ON AN INCLINED SHAFT

Figure 6 shows how the blade sections experience a variation in angle of attack as the propeller rotates on an inclined shaft. The variation of angle of attack causes steady and unsteady forces to occur in addition to the propeller thrusting force. Of particular note is the force perpendicular to the shaft, figure 7, which has a component directed aft. The cancellation or reduction of this component by



Velocity Vectors for Blade Sections at Points C and A

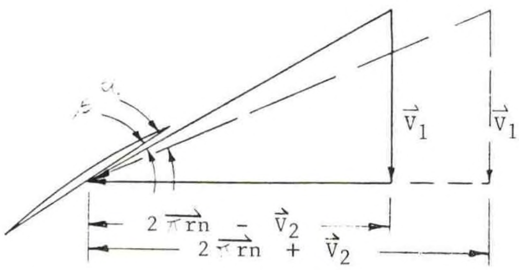


Figure - 6 Variation in Blade Section Angle of Attack Due to Inclination of the Shaft.

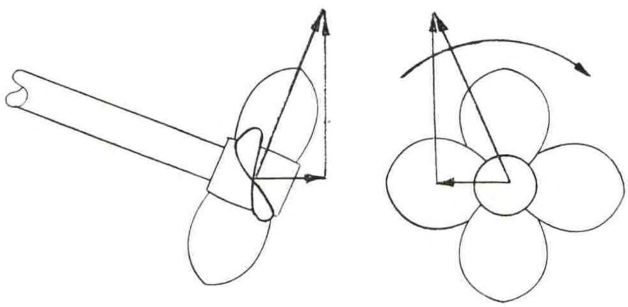


Figure - 7 Force Perpendicular to an Inclined Propeller Shaft

the pre-swirl vanes may offset to some extent the increase in drag caused by the vanes. As the inclination of the shaft goes to zero, the steady and unsteady forces associated with the inclination also go to zero. The unsteady forces are transmitted by the shaft to the hull and machinery where they can cause damage, noise, and vibrations. The perpendicular shaft force on a single screw ship causes the stern to swing away from the intended course creating a need for constant rudder correction. While this correction is small it does result in an additional drag and a reduction in propulsive efficiency.

AUTOMATED AIDS TO NAVIGATION POSITIONING SYSTEM

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ABSTRACT

The Automated Aid Positioning System (AAPS) was developed to automate the methods the Coast Guard now uses to position buoys. The objective of this computer-based system is to provide our buoy positioning fleet with Loran-C based routine navigation information and multiple input maneuvering information during buoy positioning operations. AAPS also automates the record keeping task associated with positioning buoys.

The information gathered while setting buoys is the same with or without AAPS. AAPS allows the information to be processed instantly and made available to assist the conning officer while maneuvering to set buoys. AAPS constructs a positioning grid and an error plot within seconds after the buoy is set. Should this plot show the buoy is off station, the ship can reposition it while still alongside. AAPS then automatically produces the required Aid Positioning Record (APR) from the fix data that was stored while setting the buoy.

INTRODUCTION

AAPS was developed by Johns Hopkins University's Applied Physics Laboratory (APL) for the United States Coast Guard's Office of Research and Development. The Coast Guard wanted to automate the tedious methods now used to position buoys. The AAPS has two modes of operation—the Loran-C based PILOT mode and the survey sextant or Loran-C based POSITIONING mode.

In the PILOT mode, AAPS provides the Aids-to-Navigation fleet with real-time routine navigation information during transits between work areas. In the POSITIONING mode, it provides maneuvering information during buoy positioning operations, calculates how accurately the aid was position, and automatically constructs the required positioning reports.

TEXT

The system is composed of a Hewlett Packard 9836C computer; three C. Plath survey sextants, modified by Teledyne-Gurley to produce a digital output; the ship's gyro compass; the ship's Loran-C receiver; a printer; an interface chassis; and remote display screens. The sensors have direct inputs to the computer. Ranges and bearings to objects obtained by the radar or any other means can be entered through the keyboard. To use AAPS the operator selects a task from a list of menus. The system operator must be trained in the aid positioning procedures used by the Coast Guard before this system will be useful. An AAPS tutorial program is provided with the system to acquaint the system operator with the software.

Buoys are positioned in two phases—maneuvering to set the buoy and determining the real world position after it is set. In the POSITIONING mode, AAPS provides assistance to the tender during both phases. The great majority of buoys are positioned based on horizontal sextant angles between fixed land-based objects. The sextant angles are electronically transmitted to the computer with a trigger on the sextant. This allows the sextant operator to keep the objects aligned continuously during the maneuvering process. Alternate methods of positioning buoys include Loran-C and/or range and bearing fixes. The method used for a particular buoy is dictated by the information available in the area. Figure 1 is a typical arrangement of objects (A, B, and C) and the buoy's desired position (P). The line of positions (LOPs) to determine P would be established by angles APB and CPB. AAPS allows as many as three Loran-C time differences (TD) and nine sextant angles and/or ranges and bearings to be included in the LOPs used to determine the most probable position (MPP) of the buoy. Three LOPs are required to position a buoy.

Before the AAPS can lend the tender a hand in working buoys, it must be loaded with Pre-Computation data that consists of the latitude and longitude of the buoy's assigned position (AP); the accuracy classification (AC) of the buoy's position; the latitude and longitude of the surveyed objects; the ranges and bearings from the AP of the surveyed objects; and the preferred sextant angle pairs of the objects. Just prior to working a buoy the aid file is entered into AAPS. Next the survey sextants are calibrated in a routine manner, then the error is automatically accounted for after it is entered into AAPS. Any observer offsets are also entered and accounted for automatically. (An "Offset" is the distance and bearing between the buoy and the sextant operator.)

Prior to coming alongside the buoy for a position check, additional information is required to provide a more accurate graphic display. This includes the side of the tender from which the buoy will be worked, whether or not the buoy is at short stay, the buoy's chain length, the depth of water where the buoy is set, the approximate range and bearing of the buoy's offset due to wind and current, estimated current velocity and direction, estimated wind velocity and direction, and

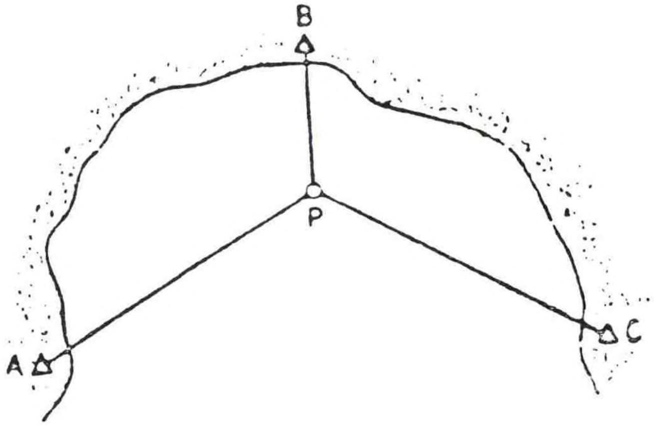

Fig. 1 - Relative arrangement of objects

any known Loran-C biases.

Once the required data are in AAPS, the conning officer can monitor the tender's approach to the buoy's AP on the remote display located next to the conning station. He is provided a polar grid and a real-time plot of the ship's movement. Figure 2 shows the polar grid displayed during the approach. The tender's position relative to the AP is marked by an arrow. The tip of the arrow coincides with the buoy port of the tender. The alignment of the arrow is a function of the ship's head input from the gyro compass. If the ship's head were due north, the arrow on the polar grid would be vertical and pointing up. The present ship's position is marked in red with past positions marked in yellow. The position is updated anytime a new value for the LOPs is entered by the sextant operators. After eight updates the screen is cleared and a new history is started.

The scale of the grid is displayed on the screen along with the distance the tender is from the AP. This distance is displayed as Delta North, Delta East and range, bearing. The scale may be zoomed in or out using the special function keys. With this automatic position plot, the conning officer has continuous real-time information that he may use to determine

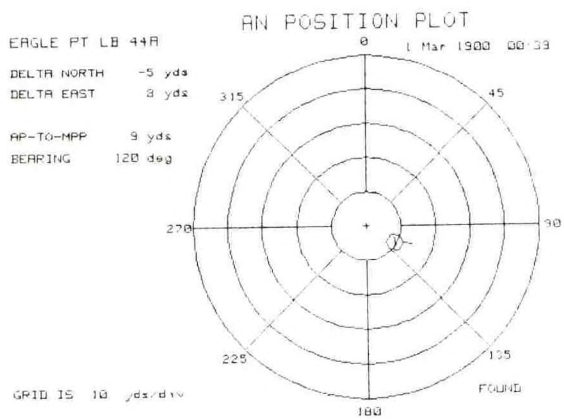

Fig. 2 - Polar Positioning Grid

how the wind and current are affecting the tender's position relative to the AP. He may then adjust his approach techniques to reduce his maneuvering time. In the past, these plots were hand-plotted from angles read visually and passed to the Quartermaster verbally. The old process was relatively slow and prone to many errors.

After maneuvering into position for setting the buoy, AAPS allows the tender to check the position in relation to the required accuracy classification. An error plot (Figure 3) may be displayed to check if this location would place the buoy on-station. If it were not on-station, the conning officer would be required to continue maneuvering to get closer to the AP. The error plot is a rectangular grid with the AP at the origin. The MPP is marked by a small cross at the center of an Error Ellipse (EE). The error ellipse is enclosed by the Buoy Station Dimension Circle (BSDC) and that is enclosed by the Accuracy Classification Circle (ACC).

The three LOPs required to fix a position rarely intersect at a single point. Due to the many inherent errors in the positioning process, the intersection is usually a small triangle. The center of this triangle corrected for observer offsets will be the MPP. The size of this triangle along with the geometry of the objects with respect to the AP affects the size and orientation of the EE. The BSDC is the area in which the buoy can travel about its moorings. It is a function of chain length, chain size, water depth, buoy body size, and the forces (wind and current) acting on the body. The BSDC limits depend on the size of the EE. The ACC is the area in which the mariner can expect to see the buoy 90% of the time. It is a function of the geographic area of the buoy, the amount of traffic in the area, and the type of cargo aboard that traffic. If the Buoy Station Diameter Circle is wholly contained within the Accuracy Classification Circle, the buoy is on-station.

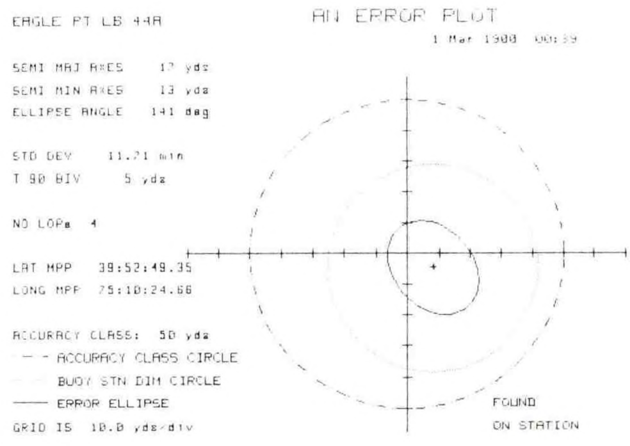

Fig. 3 - Rectangular Error Plot

All the information the conning officer needs to decide where to set the buoy is provided to him graphically before he lets go of the buoy's sinker. The error plot may be updated with each round of angles. Once the buoy is set and checked, the tender is required to submit an AID POSITIONING RECORD (APR) to the district office. AAPS produces the filled out form (Figure 4) using the data stored during the positioning process. The error plot may also be printed and retained in the aid file. The APR form generated by AAPS is identical to the manually-prepared form now in use.

In the PILOT mode, AAPS provides continuous piloting information relative to Loran-C waypoints (WPs). The hyperbolic Loran-C coordinate system is converted by AAPS to a rectangular coordinate system about once a minute. Three Loran-C LOPs are used to fix the tender's position when the data are available; otherwise, AAPS will perform a two LOP solution. If the fix is within the area of the displayed chart, the tenders position will be automatically plotted on the chart. Alphanumeric information is also displayed on the remote displays.

Up to fifty waypoints can be stored in a file on the chart disk. These WPs may be arranged in sequence to provide a route. A maximum of 10 routes of 30 WPs each can be defined. When a route has been selected, AAPS provides the distance along the trackline from or to a selected WP. It will also calculate the perpendicular distance off the trackline. It is not necessary to specify a route or WP to use the chart graphics. The tender's position will be displayed on the chart if the Loran-C TDs are located within the area of the chart.

The Coast Guard has two prototype systems under evaluation aboard USCGC RED OAK in Gloucester City, New Jersey and USCGC COWSLIP in Portsmouth, Virginia. The crew became proficient with the system in less than two weeks. The training provided by the APL developers consisted of a few days of on-scene instruction and the tutorial disk provided with the system. The Office of Research and Development is producing three more prototype systems that will be installed on different types of buoy positioning vessels through out the United States. The Office of Navigation intends to place an Automated Aid Positioning System on about 63 tenders and 56 buoy boats. The Coast Guard's future plans include developing performance specifications for procurement of the system; incorporating additional sensor inputs such as Global Positioning System (GPS), differential precision Loran-C, depth finders, and magnetic compass. We hope to have the specifications completed and the procurement started by September 1987.

```
DEPT. OF TRANS.   |
U.S. COAST GUARD  |            AID POSITIONING RECORD
CG-5216 (04-82)   |
 AID NAME: EAGLE PT LB 44A                        | UNIT: USCGC RED OAK
 AID POSITION:   LAT.   39.5249500         LONG.   75.1025000
 LLNR/P:          | CHART:              | ED:       | TARGET AREA:  50  YDS        HOR
        OBJECTS DEAL    | INDEX |  ARC    | UNCORRECTED ANGLES|OBSERVER
                        |  ANGLES | ERROR | ON|OFF|  FOUND   |   SET   |
 TANK PIER 7            |         | 47:58.00  |   |          | 47:45.90|  0:00.00
 KOCH GREEN STACK       |         |       |   |   |          |         |
 TNK MOMOUTH            |         |130:05.70  |   |          |129:50.40|  0:00.00
 KOCH GREEN STACK       |         |       |   |   |          |         |
 TANK PIER 7            |         | 82:07.70  |   |          | 82:27.80|  0:00.00
 TNK MOMOUTH            |         |       |   |   |          |         |
 TORCH TEXACO EAGLE PT  |         | 50:57.03  |   |          | 51:03.50|  0:00.00
                        |         |       |   |   |          |      KOCH GREEN
                      |
      DEPTH                       GYRO BEARINGS/RADAR RANGES                      |
   ___ SOUNDING POLE  |                                  |        CORRECTED READI
   ___ LEADLINE       |             OBJECT       |     FOUND      |       SET     |
OBSERVED DEPTH |  0.0|                                 |          |         |
DRAFT (+)      |     |                                 |          |         |
UNCOR. DEPTH   |     |                                 |          |         |
TIDE CORRECTION |    |                                 |          |         |
DATUM          |     |                                 |          |         |    |
       MISCELLANEOUS                     |  LORAN-C:        PRIMARY         BACKUP
DATE:  1 Mar 1900  TIME SET:  00:39    |REF. POINT      |
SHIP HEADING     |        95.0     T   |RATE            |          |
EST. BEARING/RANGE|   15  R   14  YDS  |REF. READINGS   |          |
AID AT SHORT STAY |   x  YES      NO   |DELTA TD        |          |
ESTIMATED WIND    |   0.0 T   0.0 KTS  |IDEAL READINGS  |          |
ESTIMATED CURRENT |   0.0 T   0.0 KTS  |  FOUND TD'S    | 27361.250     43385.660
LENGTH OF MOORING |               FT   |  SET  TD'S     |          |0.000
   MPP: LAT. 039:52:49.35      LONG. 075:10:24.66
   AP to MPF:           9 YDS     120 T
   DELTA NORTH:        -5 YDS   DELTA EAST:          8 YDS
   STD DEV:         11.71 MIN   T 90 BIV:            5 YDS
   SEMI MAJ AXES:      17 YDS   SEMI MIN AXES:      13 YDS
   ELLIPSE ANGLE:     141 DEG
   AID OFFSET:          0 DEG        0 YDS
 SIGNATURE                       | DATE    | SIGNATURE (CO/OINC)          | DATE
                                 |         |                         FOR DISTRICT
 CHECKED BY                        | DATE
                                   |                      READVERTISE/NEW GRID
 MOST PROBABLE POSITION                             | AP TO MPP
  LAT.                  LONG.                      |            T            YDS
 COMMENTS:                                 | MAX. WATCH CIRCLE:              YDS
                                           |      ON STATION        OFF STATION
 DATE RETURNED TO UNIT | DATE RESUBMITTED    | RECHECKED BY               | DATE
                       |                     |                            |
```

Fig. 4 - Computer Generated APR.

U.S. COAST GUARD VESSEL TRAFFIC SERVICES

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ABSTRACT:

Vessel Traffic Services have been operated in the U.S. by the Coast Guard since 1972. VTSs in New York, New Orleans, Houston/Galveston, San Francisco, Puget Sound and Prince William Sound have made significant contributions to vessel safety in those ports.

BACKGROUND:

In the early morning of January 8, 1971, two tankers approached the Golden Gate Bridge in San Francisco Bay. Heavy fog limited visibility to only a few yards. Unable to contact each other by radio, the vessels collided under the bridge, severely damaging both, spilling 800,000 gallons of oil into the Bay. This disaster subsequently led Congress to pass both the Bridge-to-Bridge Radiotelephone Act and the Ports and Waterways Safety Act.

The Bridge-to Bridge-Radiotelephone Act, passed in 1972, requires all vessels 300 gross tons or more, as well as certain categories of smaller vessels, to carry a VHF radio on the bridge. These vessels are required to maintain a listening watch on the specified bridge-to-bridge channel when operating in U. S. waters, and when necessary, transmit and confirm their intentions to other vessels operating in the area.

The Coast Guard was authorized by the Ports and Waterways Safety Act of 1972 (PWSA), and later by the Port and Tanker Safety Act of 1978 (PTSA), to operate Vessel Traffic Services in ports with congested vessel traffic. In response to the PWSA, the Coast Guard conducted a VTS Analysis of Port Needs Study in 1973. Twenty-two major ports and waterways were examined in order to establish a relative ranking of the need for a VTS in each of those ports. The ports were selected for study on the basis of tonnage of cargo handled, number of vessel transits, and number of vessels involved in collisions, rammings, and groundings over a four year period. The study analyzed each port's casualty data, traffic patterns, congestion, anticipated growth, and potential for catastrophic casualties. The analysis then determined the effectiveness a VTS would have on preventing vessel casualties in that specific port.

Based on this study, San Francisco, Puget Sound, Houston/Galveston, New Orleans, and New York were selected for establishment of a VTS. VTS Prince William Sound, mandated by the Trans-Alaska Pipeline Act of 1973, is the only VTS not established under the authority of the PWSA.

Once established, a VTS is intended to assist in the safe and orderly flow of traffic into, and out of, a port or waterway. To do this, the VTS can inform, advise, or direct the waterway user. At the information level, the VTS seeks to increase the quality and timeliness of navigational information that a user needs to navigate his vessel safely. Locations and intentions of other vessels, aids to navigation outages, hazards to navigation, weather reports or other navigation information are passed to participating vessels. At the advisory level the VTS alerts the participants to potential conflict situations, such as a vessel obstructing a channel, and recommends a course of action to avoid those conflicts. In most cases, the Master will voluntarily act on the VTS recommendation. Ninety-nine percent of all communications between the VTS and the participant are at the information or advisory levels.

The service provided by U.S. VTSs gives a Master information necessary for safe navigation in congested or hazardous port areas. In rare cases, when this information is ignored and a vessel proceeds in a unsafe manner the VTS may intervene by issuing "direction", either under the authority of the

Captain of the Port, or under VTS regulations where implemented. Failure to follow the direction of the VTS would subject the Master to the possibility of administrative hearings and civil or criminal penalties.

It is the affirmed and long standing policy of the U.S. Coast Guard that the Master is ultimately responsible for the safe navigation of his vessel. The Master must remain in effective control and must make the final decision on whether to consider information, advice, or direction from the VTS. In the event of a collision or grounding, a court of law or administrative hearings would determine whether the Master properly used the information or advice Provided by the VTS, or properly followed its direction if given.

Each VTS includes a Vessel Traffic Center (VTC) manned, at least at the present time, by Coast Guard officers and petty officers with extensive seagoing experience. A Vessel Movement Reporting System (VMRS) is critical to the effective operation of each VTS. The VMRS uses various assigned VHF-FM channels for communicating with vessels in the VTS operating area. By managing the VMRS, and monitoring other VHF frequencies in the area, the VTS can insure each vessel is aware of the presence and intentions of vessels around them. The VMRS also allows a vessel participating in a VTS to drop its required guard on the VHF distress frequency, channel 16. With the exception of VTS New Orleans, each VTS also uses radar, closed circuit television, or a combination of this equipment to provide surveillance of critical areas.

VTS SAN FRANCISCO:

VTS San Francisco was commissioned in August 1972. Seven officers and nineteen petty officers are presently assigned. The system uses a voluntary VMRS on Channel 13 and two radar sites for surveillance. The VTC, located on Yerba Buena Island, monitors vessel traffic in San Francisco Bay and its offshore approaches, and assists vessels proceeding to the ports of Stockton and Sacramento. In spite of the voluntary nature of the VTS, some ninety-nine percent of all port users participate in the system. The VTS recently prevented a disaster which would have destroyed the Richmond - San Rafael Bridge, crowded with afternoon traffic. A large offshore drilling rig dragged anchor in high winds, and was being driven out of control towards the bridge. The VTS, seeing this on their radars, called for tug assistance and stopped the rig yards before collision.

VTS PUGET SOUND:

VTS Puget Sound, operational since September 1972, covers the Eastern end of the Strait of Juan de Fuca, Rosario Strait, Admiralty Inlet, and Puget Sound south to Olympia. The VTS is staffed with eight officers and fifty-five petty officers. System components include a mandatory VMRS on Channel 14, a Traffic Separation Scheme and ten radar sites providing surveillance of most of the VTS area. A Joint Canadian/U.S. traffic separation scheme was instituted in the Strait of Juan de Fuca in March 1975, revised in 1981, and formally adopted by the International Maritime Organization (IMO) on 1 January 1982.

An international agreement between Canada and the U.S. for cooperative traffic management in the Strait of Juan de Fuca region was signed on 19 December 1979. Upon implementation of the regulations, expected early in 1987, active U.S. - Canadian vessel traffic management will cover the entire Straits of Juan de Fuca, the Strait of Georgia, and the San Juan Islands, in addition to the present VTS area. A vessel will then transit from one zone to the next with no discernible procedural differences in Canadian and U.S. operations other than VHF-frequencies.

VTS HOUSTON/GALVESTON:

VTS Houston/Galveston went on the air in February 1975. A voluntary VMRS, low light level television, radar surveillance, and computer tracking is used to assist vessel traffic through the VTS area. User participation averages over ninety-nine percent of the ship channel users.

The Houston/Galveston VTC is located in Galena Park, Texas, on the Houston Ship Channel. Staffed by eight officers and thirty-seven petty officers, the VTS area encompasses 70 miles of narrow, congested, and dangerous waterways from Galveston to Houston, including side channels into Texas City, Bayport, and the Intracoastal Waterway. In September 1982, the VTS area was divided into two sectors, using Channel 11 above Baytown Bend and Channel 12 below Baytown Bend.

VTS NEW ORLEANS:

VTS New Orleans, established in October 1977, is a voluntary VMRS with computer assisted tracking. The VTS area covers the Mississippi River between the mouth and Baton Rouge, as well as the Mississippi River-Gulf Outlet (MRGO). The area is divided into four sectors using Channels 11, 12, and 14. Channel 67 is used as the Bridge-to-Bridge frequency in the VTS New Orleans area to alleviate congestion on Channel 13.

VTS New Orleans operations have been suspended twice. In July of 1980, New Orleans was "off air" for ten days due to budgetary constraints. Operations, however, were restored by Congressional mandate. In March 1982, operations were again suspended due to budgetary constraints. Later that year, Congress restored funding for and directed the continued operation of VTS New Orleans. Operations were restored in Sectors 3 and 4 in September 1982, Sector 2 in April 1983, and in the MRGO in July 1983. Sector 1 operations were restored on 1 December 1983, thereby again achieving full VTS operations.

VTS PRINCE WILLIAM SOUND:

VTS Prince William Sound, mandated by law under the Trans-Alaska Pipeline Act, was placed in operation in July, 1977. The VTC, located in Valdez, Alaska, is manned by five officers and seven petty officers, and uses a mandatory VMRS on Channel 13, seven communications sites, and two radar sites.

VTS NEW YORK:

VTS New York was scheduled to become operational in July, 1978. Due to equipment installation problems and budgetary constraints, the VTS was placed in a caretaker status until those problems were resolved. In May 1981, as the revised implementation plans were being finalized, the ferry American Legion and the container ship Hoegh Orchid collided in the Upper Bay in May 1981. A subsequent National Transportation Safety Board investigation recommended the Coast Guard establish a fully operational VTS for traffic coordination near the ferry routes between Staten Island and Manhattan. With resolution of the equipment problems the VTS was reestablished in March 1984. The seven officers and twenty-four petty officers assigned began arriving soon after, with training well underway by mid-September. On January 1, 1985, VTS New York became fully operational.

The original plans for VTS New York included a five-sector VMRS covering Ambrose Channel, the East River, Hudson River, the Kills, Newark Bay, and the Upper Bay. The area of operation under the revised plan was reduced to one sector to concentrate on the ferry routes, covering the Upper Bay, Kill Van Kull, and the lower portion of Newark Bay.

The VTC, located on Governors Island, uses Channel 14 as the primary VTS frequency, with Channel 12 available for anchorage management. In addition to the voluntary VMRS, the Center uses two radar sites and six closed circuit televisions sites to monitor and assist vessel movements. The VTS has already prevented one disaster - a collision involving a fully loaded ferry. In an almost carbon copy repeat of the American Legion - Hoegh Orchid incident the ferry Lehman, with 3500 passengers onboard and the tanker Anagel Hope came within yards of colliding in dense fog - only intervention by the VTS avoided tragedy.

FUTURE OUTLOOK:

The opening of VTS New York is expected to be the last U.S. Coast Guard operated VTS placed in operation in the foreseeable future. Any changes in the VTS program will be concentrated in efforts to reduce operating costs and refining our present operations. Based on 1982 data, four of the five largest ports in the U.S. are now located in areas covered by a VTS. During that year, fifty-four percent of all waterborne commerce in the U.S. moved under the watchful guidance of a VTS. Over 832,000 transits and 52 million passengers move annually thru these areas. The Coast Guard fully intends to continue its operation of the existing six VTSs, subject to budgetary constraints, as significant reductions in collisions, rammings and groundings are evident in those VTS ports where the existing data base is adequate for analysis.

A major cost reduction project in replacing existing VTS radar has just been completed. The radar systems in VTSs Prince William Sound, San Francisco, and Houston/Galveston have been replaced with standard Coast Guard radars. The VTS consoles installed at these centers provide an automatic tracking capability, greatly enhancing our watchstanders effectiveness. Since these systems for the most part will be maintained by Coast Guard personnel, annual savings of $347,000 is expected in reduced maintenance costs.

We are now converting 55 military positions in the VTS program to civil service positions. While there is little, if any, cost savings anticipated, lower personnel turnover should reduce the time required for training new personnel, and gradually increase the level of watchstander expertise.

As VTS equipment is replaced, new technology is looked at closely in an effort to achieve cost reductions and operational enhancements. Significant future savings are expected in data transmission through the use of narrow band microwave, video compression techniques, optical fiber cables, and high grade telephone lines. Use of integrated display systems will reduce watchstander strain, provide them with accurate traffic summaries, and enable reduction of VHF transmission time while greatly improving the accuracy of the information passed.

As previously stated, VTS New Orleans is the only U.S. VTS presently without surveillance. A Congressionally mandated study completed in 1981 for the Coast Guard by Louisiana State University on the needs for communications and electronic surveillance of the Lower Mississippi River concluded that electronic surveillance in that area is necessary.

Included in the FY-85 and FY-86 budgets is a total of $6.4 million to install four radars, seven closed circuit televisions, fifteen microwave relay systems, and an associated data processing system. The project should be started in the next year, with completion expected sometime during 1989.

Vessel Traffic Services have been proven time and time again on a worldwide basis to reduce vessel casualties and ease congestion in port areas. Over 130 VTS's are now in operation, with many more in the planning stages. The International Maritime Organization recently adopted guidelines for Vessel Traffic Services. The COST-301 Project, an extensive study on VTS sponsored by the European Economic Commission, is expected to form the basis for cooperation between European VTS systems. VTS is obviously here to stay.

R & D on robot application techniques to shipbuilding

Technology Division, Maritime Technology and
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The progress in mechanization and application of automation in the shipbuilding 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 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 light-labor-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 such of shipbuilding featured by its small lot production in large diversification, radical 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 an advanced nations.

Item	Brief description of target	Significance of development	Development target	Major R & D items	Examples of related materials
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.	Of shipbuilding processes, the automation technique up to the stage of steel plate cutting process has made a considerable development including those application techniques in shipbuilding practice. However, automation techniques for bending process, assembly process, cleaning, polishing and painting processes following the plate cutting process involve a great deal of technical problems, and thus have so far demonstrated no appreciable degree of progress. In the case of building ordinary ships, the volume of man-hours for these processes shares as high as 60% of the total work volume of shipbuilding where almost dirty work and dangerous work are also included. In this connection, it is	(1) Press processing robots capable of completing the designed form of press object by accurately estimating the spring back amount in the course of bending process with a press machine (2) Assembly processing robots capable of setting the heavy items such as steel plates at their correct position and attitude automatically in the course of position fixing	(1) a) Theoretical method of calculation for determining the amount of spring back in the bending process b) Approximation for the above c) Large three-dimensional coordinates measuring instrument (2) a) Pattern recognition method b) Heavy object transfer and attitude control system	o High accuracy sensors (visual, pressure-sensible, weight-sensible, color-sensible and temperature-sensible features) o Laser o VLSI

Item	Brief description of target	Significance of development	Development target	Major R & D items	Examples of related materials
Shipbuilding robots (cont'd)		extremely important to promote the development of shipbuilding robots as the applied teqhniques of industrial robots which have been the subjects of enthusiastic R & D activities in a wide variety of areas in recent years and due to introduction of such techniques for the improvements of productivity and working environment. Further, it is expected by automation that product quality and reliability may improve shapely, such as reduction in welding faults and upgrading in machining accuracy.	(3) Welding robots capable of carrying out automatic welding of thick steel plates within a complex hull structure. In some cases, they carry out welding while running by their own self-running features. (4) Cleaning, polishing and painting robots applicable to services for large and complex hull structure (5) An interim target has been set at 40% reduction of shipbuilding man-hours.	(3) a) Self-diagnostic type welding follow-up system b) Transfer system within complex and narrow hull structure c) Down-sizing of welding machine (4) a) Cleaning and polishing procedures b) Transfer system within complex and narrow hull structure	

EFFECTIVE MANNING ARRANGEMENTS MEETING THE NEEDS OF TECHNOLOGICAL INNOVATIONS IN SHIPS

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Abstract

'Modernization of Seafaring System' in a project which has been promoted through concerted efforts by the Government, the experts of learning and scholars, and labour and management. The project has been progressed through experiments on board modernized ocean going ships to establish advanced seafaring system under the Committee for the Modernization of Seafaring System along with the path drawn under the 'Hypothetical Image of Seafarer'.
The experiments of Stage A completed with the results of 18 manning standards, and Stage B, with 16 manning standards.
The experiments will be stepped up to Stage C in this summer using highly automated ships.

Outlins of experiments and effective manning arrangements

In the quest of the most desirable seafaring system including the qualifications of seafarers and manning arrangements meeting the ever advancing technological innovations in ships, a project called the "Modernization of Seafaring System" has been promoted in Japan through an integrated cooperation by labour, management and the government, also the experts of learning and scholars.

What is lying in the background of the positive stimulus given to the need for reviewing the existing seafaring system may be identified in the recent striking development of technological innovations in ships and the changing circumstances of economy, in a variety, surrounding the ocean-going shipping of our country.

On the technological innovations, labour-saving in the main engine and related auxiliaries as typically represented by the so-called M-zero ships featuring an extensive unmanned machinery operation to begin with, and also, labour-saving and automation in the equipment and machinery having relevance to navigation, cargo operation and communications are vigorously being pursued.

While on the other hand, the decline in the international competitiveness of Japanese-flag ships due to sharp increase in their shipping costs has caused the greater reliance on ships of foreign charter. In association therewith, the number of Japanese seafarers employed in Japanese merchant fleet has been on the steady decrease.

The objectives of modernization of the existing seafaring system are to establish a new shipboard working system meeting the mounting technological innovations in ships which enables them to execute their duties with positive enthusiasm in utili:'ng their excellent knowlege and skills sufficiently under comfortable shipboard working envitonments; and thereby increase the weight of Japanese-flag ships served by Japanese seafarers amidst the scene of international shipping business with eventual consolidation of conditions necessary to build up a firm ground for their stable employment situation.

The project of modernization of seafaring system has been making its materialized progress centring around the Committee for the Modernization of Seafaring System organized in April 1979 by labour, management and the government, also the experts of learning and scholars, whereby proposals for the new system of qualifications of seafarers and ships' manning arrangements have been drawn up in the form of a report and the feasibility and reasonability of the proposals have been proved through experiments conducted on board real ships.

The basic concepts of the modernization of seafaring system held by the Committee for the Modernization of Seafaring System are to disintegrate the outmoded organizational framework featuring the sectionalism on the seniority basis such as deck department officers and ratings, engine department engineers and ratings, and to strengthen the linkage between different departments by mutually undertaking the duties centring on the watchkeeping of different departments, and also to intensify the linkage between ships' officers and ratings within the same department by distributing part of the officers' duties to ratings for eventual formation of a new system of shipboard work.

In order to implement experiments efficiently, the Committee drew up in May 1980 an interim target to guide the experiments "Hypothetical Image of Seafarer in the Future" representing the image conceived at that time. This comprises a hypothetical image of seafarer in the future as a target (Fig. 1) and another hypothetical image of seafarer in the transitional process in the premature stage of approach thereto (Fig. 2).

It was decided to proceed experiments under the Committee for the Modernization of Seafaring System along with the path drawn under hypothetical image of seafarers in the transitional process, and Stage A experiments were started with 14 highly automated M-zero ships as from February 1981. In these experiments, attempts were made to introduce 6 dual purpose crew in place of the system of deck department ratings and engine department ratings. As for ships' officers, third officer and third engineer under the traditional system were replaced with watch officers who serve both navigational and engineering watchkeeping duties with a resultant complement of 18 men.

On receiving a report from the Committee in October 1981 stating that satisfactory results on Stage A experiments were obtained, consolidations for legal measures reflecting the results of Stage A experiments were made in May 1982. The contents of such measures established include: standards for installations and equipment on board modernized ships of Stage A (Modernized ships Type 1), the system of watch officers which are ships' officers of a new type to be employed in the modernized ships and the system of dual purpose crew in replacement of the traditional deck and engine ratings, and the manning standards for modernized ships Type 1. Further, the system of education of seafarers has also undergone changes whereby education and training of watch officers and dual purpose crew were started at the national institutions of education in fiscal 1983.

Stage B experiments were launched in August 1982 onboard highly sophisticated ships equipped with automatic collision avoidance system and other advanced systems. In Stage B, experiments were conducted in the first hand to form a system of watch officers so that second officers and second engineers can assume watchkeeping duties of departments different from their own, thence experiments with a reduced manning arrangement of 17 men, i.e., one watch officer less, and experiments were further modified to those with a complement of 16 men, i.e., one steward less. On the other hand, Stage A experiments of greater comprehension were made to prove the reasonability of the new system of shipboard work with a variety of diverse ships in a total number of 145.

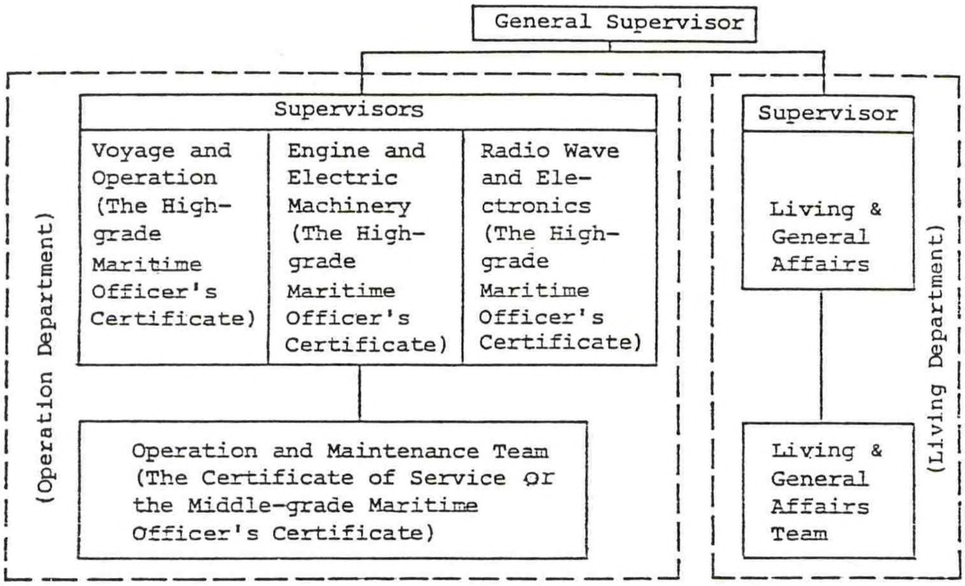
In consequence of various investigations and evaluations of the results of Stage B experiments by the Committee for the Modernization of Seafaring System, the adequacy of the new seafaring system simulated in the experiment has been verified. Agreeably with the above results, consolidations of legal measures corresponding to the results and achievements of Stage B experiments were made. The contents of such measures include: standards for installations and equipment on board modernized ships of Stage B (Modernized ships Type 2), the manning standards to modify the conventional officers and engineers of the second and third classes into three watch officers. On the system of shipboard work at Stage A, it has come to a decision that the experimental framework imposed by the Committee for the Modernization of Seafaring System was to be disintegrated for realizing its wide application to practical uses.

As of May 1986, the number of ships being operated under the new seafaring system of 18-crew is 146 and that of 16-crew is 15. These 161 of modernized ships share 15% of the total number of large ocean-going Japanese-flag ships.

It is stated that the Committee for the Modernization of Seafaring System will carry on its work, and the schedule of experiments dictates that the attempt of Stage C experiments will be launched in this summer or thereabout through the use of still more modernized ships equipped with a system capable of having bridge control of the engine toward due realization of the most advanced seafaring system, i.e., the third stage of modernization of seafaring system.

Fig. 1

Hypothetical Image of Seafarer in the Future



a) The General Supervisor

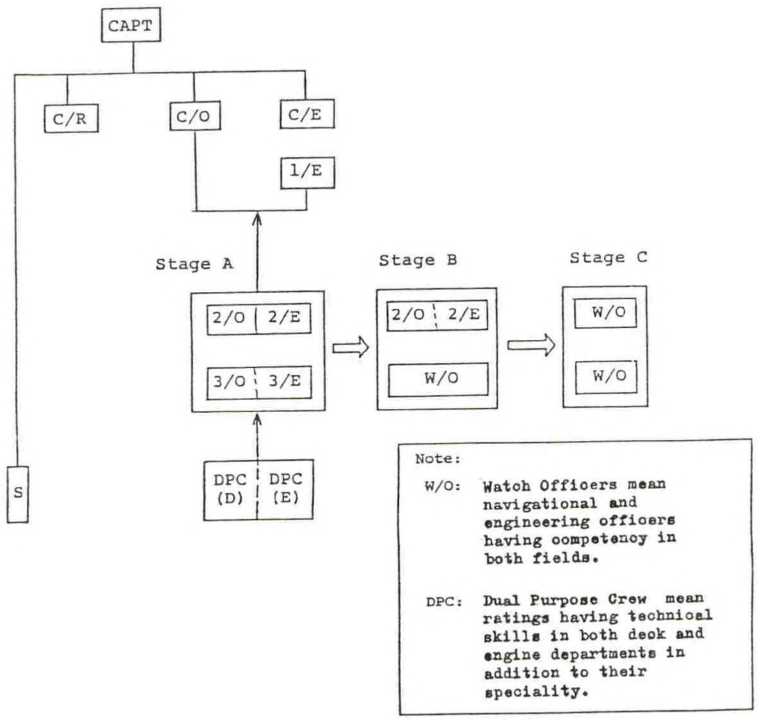
He corresponds to the present captain to the post of which supervisors of the operation department provided with experience, competency and insight will promote.

b) **The supervisors of the operation department**

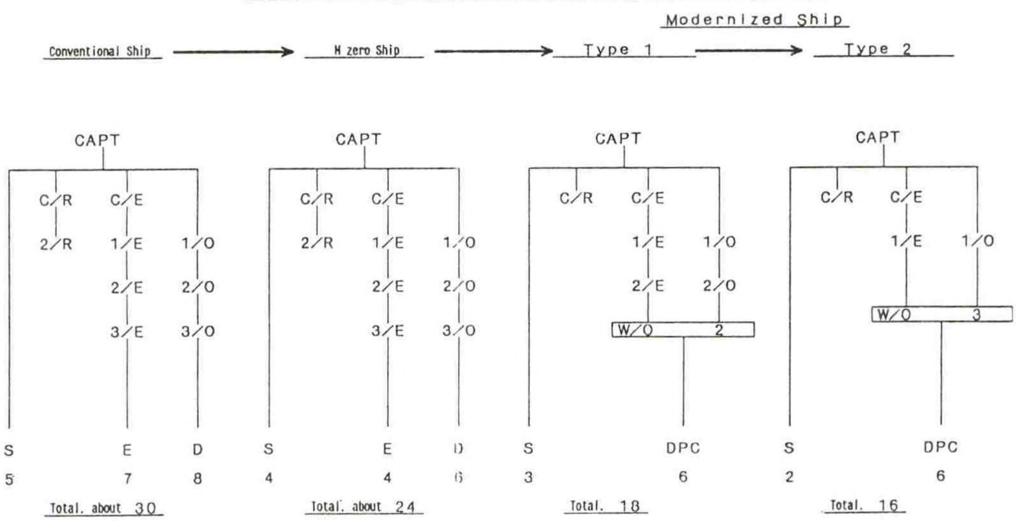
As techniques needed for the operation of vessels are divided into some special fields, supervisors are selected from each of those fields as the experts in respective fields. (one from each field)

Fig. 2

Hypothetical Image of Seafarer in Transitional Process



TRANSITION OF COMPLEMENT



Forwarding Plan of Ocean Development

The Liaison Conference of Ministries Related to Ocean Development

This plan is composed of an introduction and three parts of texts (contains five chapters and materials).

The Introduction (chapter 1) gives an outline of the importance of ocean development and the plan.

Part I, containing chapters 2-4, discusses the Japanese Government's forwarding plan of ocean development. Chapter 2 clarifies nine development targets related to science and technology for the plan and makes a comparison between the targets. It gives a general view of subjects that must be implemented in order to begin accomplishing the targets. The targets were adopted from a report submitted by the Ocean Development Council of Japan.

An outline of programs for each subject and experience of Japanese ministries related to ocean development in 1985 is described in chapter 3. Chapter 4 reports on research by related agencies.

Part II, comprised solely of chapter 5, clarifies the outline of each work's total plan and the 1985 program about ocean development.

Part III provides materials. Since ocean development covers a wide field of studey and involves alot of technology, materials are useful in showing the general view of ocean development. Therefore, related materials will be provided as much as possible in this forwarding plan. The program for 1985 includes a list of government facilities, such as ships, automatic marine observation units, testing tanks, artificial satellites, etc. Also, a chronological table of ocean development is provided.

A BRIEF OVERVIEW OF JODC'S ACTIVITIES

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INTRODUCTION

The Japan Oceanographic Data Center(JODC), established in 1965 under the International Oceanographic Data Exchange(IODE) system of the IOC, operates as an administrative component of the Japanese Hydrographic Department, Maritime Safety Agency. Since its establishment, the JODC has accepted internally its resposibilities for the marine data bank of Japan in collecting, processing and archiving the marine data acquired through various arrangement from marine research institutes, universities and other organizations. The JODC also has been providing the marine community with the data which supports research and development in marine engineering, ocean resource development, theoretical oceanography, etc..

In order to facilitate data flow internationally, the JODC operates as RNODCs for IGOSS, WESTPAC and MARPOLMON as well as one of NODCs through world-wide data exchange system promoted by the IOC.

JODC'S MAJOR ACTIVITIES

1. Collecting and archiving of Marine Data & Information

Marine physical, chemical, geological, geophysical and meteorological data are collected from various institutes and agencies listed below. In order to make these data available on request to secondary users, the JODC holds them primarily in computer-readable form. Table 1 summarizes JODC's data holdings on magnetic tapes.

Principal Organizations:
- Environmental Agency
- Defence Agency
- Japan Marine Science & Technology Center
- Marine/Fishery Research Inst. of Universities
- Maritime Safety Agency
- Japan Meteorological Agency
- Port Construction Bureau
- Fisheries Research Laboratories
- Geographical Survey Institute
- Geological survey of Japan
- Local Fisheries Research Laboratories

2. Data Products and Services

The JODC offers some kinds of inventory information, products and services for most of the data it manages. Requests from all users may be submitted by letter, telephone or visit to the JODC.

(1) Data Inventory Information

The JODC presents free of charge such as geographic data distribution, counts of observations by month or season and list of cruises. Figure 1 is an example of station count plot.

(2) Data Products

The JODC provides the data in a form and in a medium which allows the user to further process the data for his purposes. There is an increment of requests demanding the data on floppy disk due to recent popularizing of microcomputer. The data on MT/FD are available on a cost of MT/FD to the users who contribute oceanographic data. In addition to the simple MT copies, data in JODC's data sets can be provided to users in the forms of computer-generated data summaries, statistical process and graphic plots.

(3) Publications

The JODC produces following publications which are available free of charge.

JODC News: Biannual publications informing the latest data products, services & activities in the JODC, and providing general marine information at home and abroad

Data Catalog: Serial publications describing JODC's data holdings & their formats and Report of Observations/Samples Collected by Oceanographic Programmes(ROSCOP) of Japanese marine research institutes or laboratories

Atlas and Map: Publications of statistical map and marine environmental atlas resulting from summaries or analyses of the data

Data Report: Publications describing all the data produced by such specific marine research programme as 'The Cooperative Study of Kuroshio and Adjacent Waters' and 'Kuroshio Exploitation and Utilization Research'

Technical Guide: Publications introducing international data exchange system & format and data handling

(4) Referral Services

The JODC acts as a referral agency for oceanographic data/information. Marine Information Section established within the JODC in 1984 assists domestic users in locating or obtaining marine data/information held by every organizations in Japan.

3. International Cooperation and Data Exchange

The JODC serves as the Japanese focal point for data exchange activities conducted within the purview of the Working Committee on IODE of IOC, and collects and promulgates on a regular basis such inventories as Declared National Programmes, ROSCOPs and Planned Oceanographic Cruise of Japanese marine research organizations, and is also responsible for the submission of Japanese oceanographic data to the World Data Center A & B according to international agreements.

In addition, the JODC has functioned as the RNODCs in support of the WESTPAC Research Programme and the Integrated Global Ocean Station System, and as a temporary RNODC for the Marine Pollution Monitoring Programme. Figure 2 shows the data flow and management diagrams in each of the RNODCs.

A number of bilateral exchange agreements exist between Japan and other countries. As a result of these agreements, the JODC exchanges the data with the U.S.A., Canada, France and China.

FIGURE 1. STATION COUNT PLOT FOR XBT

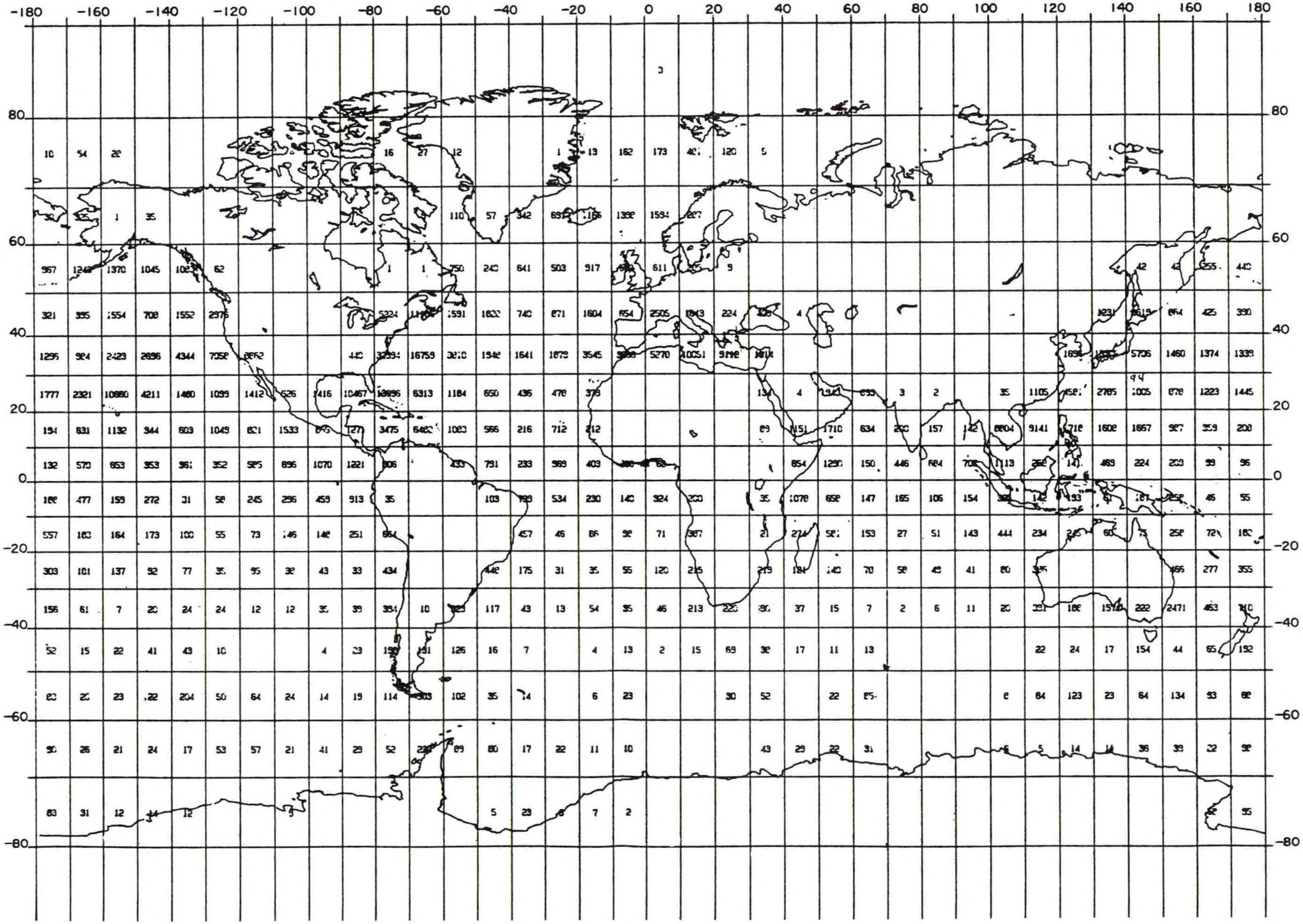

FIGURE 2. DATA FLOW AND MANAGEMENT DIAGRAM

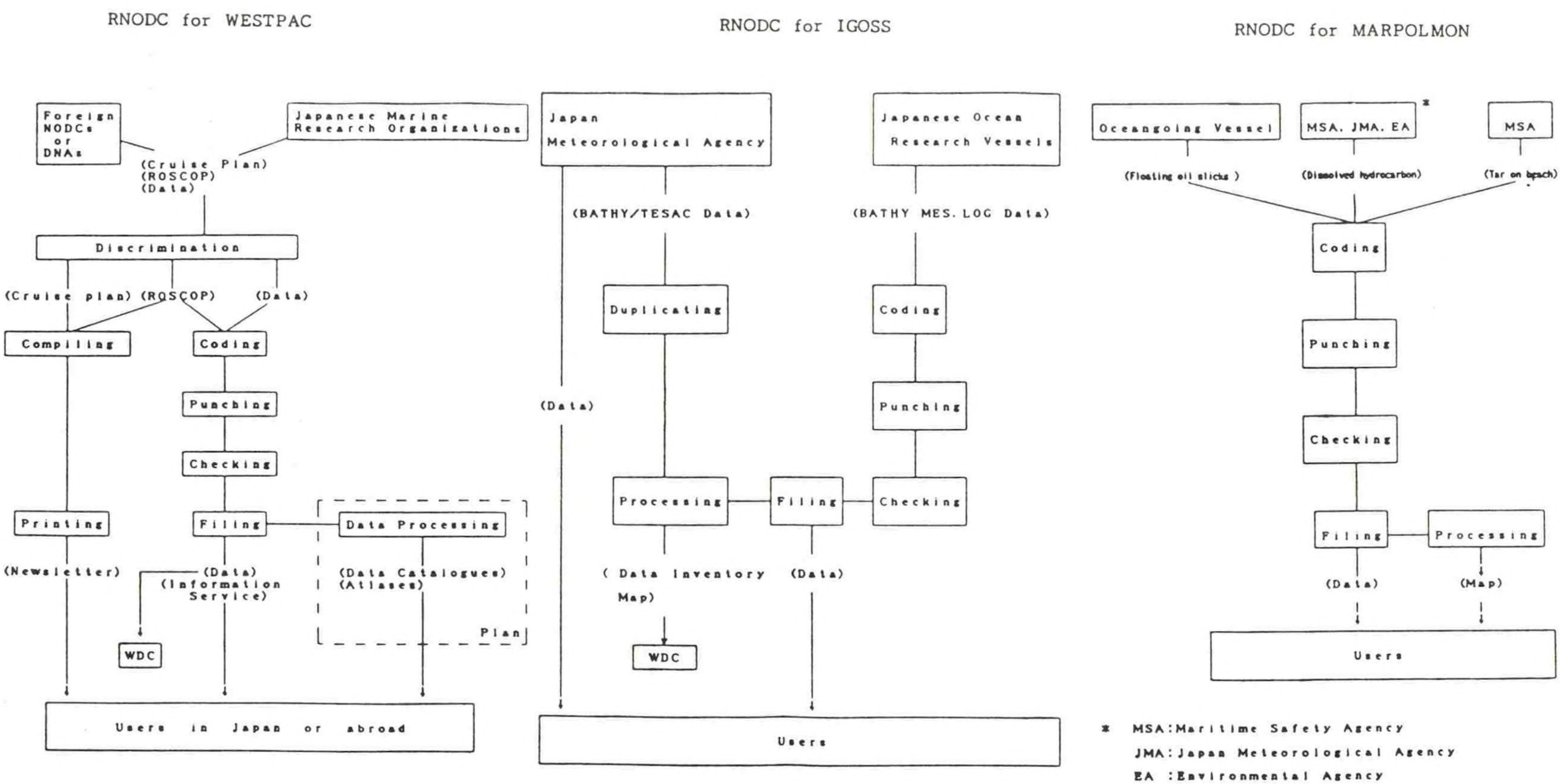

TABLE 1. DATA SETS IN JODC

Kind of Data	Approximate Amount in Thousands	Geographic Coverage
Oceanographic serial Station	335.2	Worldwide Ocean
MBT	1,071.8	Worldwide Ocean
XBT	380.2	Worldwide Ocean
DBT	9.4	Adjacent Seas of Japan
STD	0.7	Adjacent Seas of Japan
Current(drift)	2,018.5	Worldwide Ocean
Current(GEK)	160.6	Adjacent Seas of Japan
BATHY/TESAC	111.3	Worldwide Ocean
Pollution	2.8	Western Pacific
Oil Pollution	116.7	Worldwide Ocean
Tidal Current	14.2	Adjacent Seas of Japan
Tide	1.7	Japanese Coastal Waters
Tidal Constants	4.4	Worldwide Ocean
Surface Temperature	5,147.4	Worldwide Ocean
Marine Meteorology	3,617.3	Adjacent Seas of Japan
Wave(observed)	97.0	Adjacent Seas of Japan
Bathymetry	1,303.4	Western Pacific
Sediments	223.9	Adjacent Seas of Japan
Magnetism	1,205.8	Western Pacific
Gravity	874.2	Western Pacific
Heat Flow	6.6	Western Pacific

ADVANCES IN PORT AND HARBOUR OPERATION

----- UTILIZATION OF OCEANOGRAPHIC AND METEOROLOGICAL INFORMATION -----

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ABSTRACT

A unified system of oceanographic and meteorological information for ports and harbours has not yet been established in Japan. At present, the data observed by the various organizations are independently collected and then independently utilized by port authorities, shipping companies, forwarding agents, navigation vessels, etc. according to their respective purposes.

This paper comprises a brief outline of the institutional structure for the operation and management of ports and harbours in Japan followed by an outline of the present conditions of the collection and utilization of oceanographic and meteorological data for port design and construction, for navigation, and for cargo handling.

1. OUTLINE OF INSTITUTIONAL STRUCTURES FOR THE MANAGEMENT AND OPERATION OF PORTS AND HARBOURS IN JAPAN

In Japan, ports and harbours play a major role in the economy, there are a large number of organizations concerned with the management and operations of Japanese ports. The various organizations have various functions, and the interrelations among these organizations are quite complicated.

In Japan, individual ports and harbours are generally managed by local port authorities. Technically, there are independent bodies, but in fact most of them actually functions as administrative units of local governmental bodies at the municipal or the prefectural level. These individual port authorities are responsible of the regular operations of the individual ports.

However, these port authorities are supported by various agencies of the central government. Furthermore, although the individual port authorities generally function as self-supporting entities, major construction works are usually subsidized by the central government based on set percentages for various ports and port works as established by law.

Certain port functions are undertaken by the local offices of national agencies at the individual ports. For example, the regulation of navigation to ensure safety, customs procedures and quarantine are carried out by local offices of the Maritime Safety Agency, the Ministry of Finance and the Ministry of Welfare, respectively.

As for the mooring facilities and the cargo handling and storage facilities at the individual ports and harbours, some of these are owned by the individual port authorities and operated by these bodies in the public interest. There are also certain private facilities for exclusive use which are constructed the private sector with the permission of the port bodies. Furthermore, there are some facilities which are constructed by the port terminal cooperations but then leased to the private sector for exclusive use.

In summary, there are a large number of governmental, semi-governmental and private organizations concerned with the operation and management of ports and harbours in Japan. The interreactions among these organizations are quite complicated.

2. OBSERVATION AND COLLECTION SYSTEM FOR OCEANOGRAPHIC AND METEOROLOGICAL INFORMATION IN JAPAN

In Japan, oceanographic and meteorological data are observed over wide areas by the Meteorological Agency, the Maritime Safety Agency and the Ports and Harbours Bureau of the Ministry of Transport as outlined below.

(1) The Meteorological Agency

Air pressure, wind speed and other basic data are measured over the earth and sea and in the upper atmosphere throughout Japan by the Meteorological Agency. This Agency also conducts wave observations along Japanese coasts in cooperation with the Ports and Harbours Bureau of the Ministry of Transport. Based on the various data collected by the agency, meteorological and hydrographic conditions are grasped and future conditions are predicted. These data and forecasts are made available to interested parties through general meteorological reports.

(2) The Maritime Safety Agency

This Agency regularly observes tides and coastal currents at numerous locations throughout the nation. The Maritime Safety Agency also observes ocean currents along coastal areas by means of observation and patrol vessels and air crafts. The Maritime Safety Agency reports the results of its observations as well as the observation data and forecasts of the Meteorological Agency to maritime vessels on a regular basis.

(3) Ports and Harbours Bureau of the Ministry of Transport.

The Ports and harbours Bureau of the Ministry of Transport regularly observes wave height and direction in coastal areas at numerous locations throughout Japan. Particularly, the Bureau attempts to predict the hydrographic conditions at ports and harbours throughout the country based on the observation data reported by the Meteorological Agency. The Bureau also regularly observes weather and tide at certain locations.

(4) Others

Local port authorities generally carry out regular observations of the hydrographic conditions at thair own ports. Futhermore, various observations are also carried out by the private sector, particularly the owners of port facilities and firms involved with the construction of port facilities.

3. UTILIZATION OF OCEANOGRAPHIC AND METEOROLOGICAL DATA

The oceanographic and meteorological data described above are used by various organizations for the design and construction of ports and harbours, for navigation and for cargo handling as detailed below.

(1) Utilization of Oceanographic and Meteorological Information for the Design of Ports and harbours

Port facilities are generally planned based on meteorological and hydrographic conditions, projected demand and other socioeconomic and natural conditions including soil conditions and the present and future functions of the port. The layout of entire ports as well as the structural type and design of individual port facilities are highly dependent on meteorological and hydrographic data including data concerning air temperature, rainfall, winds, tides, waves, currents, and drift and tidal waves.

Port structures have a lifetime of several decades, and port development projects are normally planned based on long-term observations data. Actual data over a period of 20 to 30 years are usually used. However, when empirical wave data are not available, it is often necessary to utilize various simulation models to predict the level of calmness within the harbours and alongside the proposed mooring facilities. These simulations take into account the refraction and diffraction of waves, and can be used to determine the optimal arrangement of the necessary facilities.

In Japan, port structures are designed in accordance with the Technical Standard for the Facilities for Ports and Harbours, a national standard set by the Ministry of Transport in order the ensure the safety of ports and harbours. These standards are set in terms of threshold values. For example, the wave height limit for cargo handling is 30cm inside basins and 50-70cm at other areas. For Japanese mooring facilities, the wave height must be below 50-70cm, 90-95% of the time. The standard tractive force on mooring poles is based on a wind speed of 25-30m/s for straight poles and 15m/s for curved poles.

(2) Utilization of Oceanographic and Meteorological Information for the Construction of Ports and Harbours

The coastal areas of Japan are exposed to severe winds and waves throughout the year due to typoon in fall, prevailing winds and waves in winter, the depression known as the Taiwan Booze in early spring, and so forth. Thus meteorological and hydrographic conditions greatly affect port construction works, and accurate data are necessary for planning the construction schedule and determining the best construction process.

In addition to data provided by the Meteorological Agency, construction firms also record local data themselves to monitor changing conditions at the site. Construction work is suspended when appropriate based on the local conditions. The data are also used to determine appropriate mooring methods and anchoring or shelter locations for the construction vessels.

In the planning stage, the data are used to estimate the number of workable days for the various construction works. During the actual construction, 3 day predictions, one week predictions and special predictions are made, forecasting essencial meteorological and hydrographic conditions for the construction works. These forecasts are usually entrusted to special consulting firms. The one week predictions are used to set the construction schedule each week, but may be modified as appropriate. Special predictions are performed as necessary, especially when a sudden change of conditions significantly affects the construction works.

(3) Utilization of Oceanographic and Meteorologocal Data for Navigation

The oceanographic and meteorological information obtained by shipping companies and navigation agents through common weather reports, from the Meteorological Agency, and from other reports provided by private sector firms are transmitted to individual vessels. Combining this information with the data obtained at the vessels location, the captain makes various judgements concerning the navigation of his vessel.

The Maritime Safety Agency regularly reports weather conditions to navigating vessels via satellite. These broadcasts include data observed by various local bodies concerning wind direction, wind speed, weather conditions, visibility, waves, swell, etc. at capes, ports and harbours located all over Japan is broadcast to navigating vessels via 8 shipping communications signal stations located at major ports. These stations also broadcast other conditions relating to navigation such as information about the amount of traffic, and other information related to course control. Furthermore, these stations also broadcast specific information in response to requests from individual vessels.

Generally, the severest oceanographic and meteorological phenomena in Japanese ports and harbours occurr during typhoons. In this season, advice for refuge is given by the Maritime Safety Agency. Typhoon committee at respective ports and harbours (which include representative of Maritime Safety Agency, port authorities, shipping companies and forwarding agents) also confer and advice certain vessels to take refuge when appropriate. Thus the refuge conditions such as wind speed, type of vessel, etc. are specified at individual ports and harbours according to the course and speed of the typhoons, and therefore are not always the same. At present, the method and the location for refuge are usually left to the captain's judgement. However, in response to request for presentation of such information from individual vessels advice is given. These have been taken freely at major ports and harbours in Japan. They are not mandated by law. However, they have proved to be really effective up to now.

(4) Utilization of Oceanographic and Meteorological Data for Cargo Handling

Oceanographic and meteorological informations are also important for cargo handling operations. Cargo handling operations must be suspended under adverse conditions ; the handling agents generally decide themselves when cargo handling works must be suspended. The judgements are made based on general meteorological reports provided by the Meteorological Agency and local data concerning the conditions at the site.

It seemed that the standard limit of the wave height for cargo handling is about 30cm for basins, 50-70cm for quay walls and 1.0-1.5m for the mooring facilities for large-size tankers.

The limitation of cargo handling operations due to wind varies with the size of the vessels, the kind of cargo and the kind of cargo handling machines. However, the limit of wind speed is usually 14-16m/s based on a questionnaire.

When the wind speed is too high, cargo handling operations become dangerous or impossible. The cargo may scatter. The crab sways and it becomes difficult for the cargo to pass through the hatch and the cellguide. Slinging work becomes difficult, freight fall off the pallets, and it becomes difficult to operate the cranes. Accordingly, large cranes usually equipped with an air speedometer located at the top of the crane with an indicator gauge inside the cab. Thus, the operator can monitor the wind speed and suspend operations when appropriate.

Some cargo handling operations are sometimes suspended due to the rain, as there are certain cargoes.

Overall, oceanographic and meteorological conditions are crucial to the smooth progress of cargo handling operations, and good data are very important for planning and supervising cargo handling.

CONCLUSION

This paper presents a summary of the present conditions of the collection and the utilization of oceanographic and meteorological data in Japan related to ports and harbours. I regret that this is somewhat different from the information recently requested by the U.S. side. Nevertheless, I hope that this will be of some use, and will help the reader to gain a better understanding of the current situation in Japan.

In Japan, particularly in the field of the design and management of ports and harbours, we are making an effort to deal effectively with the new "information society". We would like to further research the collection and utilization of oceanographic and meteorological data in the future. We would greatly appriciate it if you could provide us with information about the present situation in the U.S.

Development of the Operational Wave Forecast Model in Coastal Area

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Abstract: This paper describes a numerical prediction model developed for the operational coastal wave forecast.

An ocean wave model was already developed based on the linear spectral concept by I. Isozaki and T. Uji in 1973 and has been used successfully in the North Pacific wave forecast since March 1977 in the Japan Meteorological Agency, Tokyo (JMA). Succeedingly, a coastal wave forecast model was developed and has been used for operational work since March 1983. The model consists of coarse mesh wave model (381 km spacing between adjacent grids), fine mesh wave model (127 km) and coastal wave model (10 km). The first two models are similar to the previous ocean wave model. In the coastal wave model, wind waves and swell are calculated independently and combined to make wave information at every grid point in coastal areas.

Wind wave and swell calculated by means of the significant wave method and spectral method respectively. Post analysis rerealed that the results of the model prediction technique agrees fairly well with the actual observations. The coastal wave information is now broadcast by land-line facsimile as two charts, one is the analysis chart and the other the 24 hours prognostic chart.

1. Introduction

Disasters at sea have been caused by innumerably different severe meteorological and marine situations. These disasters still continue to occur in spite of our increased knowledge about the sea state.

Accordingly, accurate and precise sea surface information, supplied routinely, is badly needed for the safety and economic efficiency of the marine industry.

In the JMA, the ocean wave information service covering the western North Pacific was started in 1972. At that time manual analysis of actual sea conditions making use of meteorological and maritime reports from ships was carried out and was broadcast by radio facsimiles as the ocean wave analysis chart covering the western North Pacific.

In 1977, numerical prediction model of ocean wave conditions was introduced, and an ocean wave forecast chart covering the same region as in the analysis chart was broadcast by radio facsimile.

These two charts are broadcast once a day continuously since 1977.

Recently economic activity has increased in the coastal region and requests for wave forecasts in the region have gradually risen. These requests have originated from a wide variety of organizations involved with ocean development, ships operating in the coastal areas, fisheries and tourist organizations.

We, in collaboration with the Meteorological Research Institute (MRI), have developed a coastal wave model. The calculated products by the model are translated into coastal wave chart and two kinds of information (Analysis and Forecast) are broadcast every day since March 1983 using land-line communication system.

In this report we introduce an outline of the ocean wave model, the coastal wave model, the operational procedures of the model and an evaluation of the performance using real time data. ("Wind wave" is used here as a general term for waves which are growing under a local wind. "Wave" means both of wind wave and swell.)

2. Ocean wave model

An ocean wave model was developed by ISOZAKI and UJI (1973, 1974) and has been operationally used by the JMA for wave forecast. The model consisted of two parts, a numerical model of marine surface winds which is established by using an operational numerical weather forecast system, and a numerical model of ocean waves by means of the known relationships between winds and waves.

2.1 Numerical model of marine surface winds

To know the surface wind field is very important because of its significant influence on the change of sea conditions. The field is now inferred mainly by surface wind reports from merchant ships.

Accordingly, vast data scarce areas exist over the ocean because of the limited distribution of ship routes. Many investigations have verified the usefulness of satellite derived low level wind data but these data are not yet used operationally.

It is necessary to obtain marine surface winds over the analysis area before carrying out the numerical wave analysis and wave forecast. BLACKADAR (1965) and CARDONE (1969) proposed a method of marine surface wind estimation. ISOZAKI and UJI (1974) used this method and constructed a computation scheme for the routine wave operations of the JMA. It is a two layer baroclinic non-neutral method and produces surface winds and friction velocities. As seen in Fig. 1, the atmospheric surface boundary layer is assumed

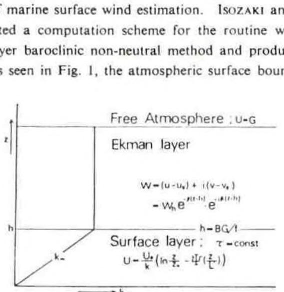

Fig. 1. Model of atmospheric boundary layer.

to be separated into two regions: the surface layer and the Ekman layer. In the surface layer, the Coriolis parameter is neglected, the turbulent transfer coefficient for momentum (K_m) increase almost linearly with height, and the wind stress is constant. The vertical wind profile is as follows;

$$U_z=\frac{u_*}{k}\left[\ln\frac{z}{z_0}-\psi\left(\frac{z}{L'}\right)\right] \tag{2.1}$$

where U_z is the wind speed at the height z, u_* the friction velocity, k the Karman constant, z_0 the roughness parameter, L' the modified Monin-Obukhov's stability length, and $\psi(z/L')$ the correction term with respect to the atmospheric stability.

The height of the surface layer h is given by Blackadar's formulation;

$$h=B_0G/f \tag{2.2}$$

where B_0 is the constant, G the gradient wind, and f the Coriolis parameter.

It is assumed in the Ekman layer that K_m is constant, the wind stress decreases with height and the vertical wind distribution is assumed to be specified by Ekman's solution. We represent the components of $\vec{U}$ and $\vec{G}$ as (u, v) and (u_g, v_g) respectively, and the deviation of $\vec{U}$ from $\vec{G}$ as follows;

$$\vec{W}=(u-u_g)+i(v-v_g) \tag{2.3}$$

then the solution is

$$\vec{W}=W_h e^{-\beta(z-h)}e^{i\beta(z-h)} \tag{2.4}$$

where W_h is the W at the height h, and;

$$\beta=\sqrt{f/2K_m} \tag{2.5}$$

We assume boundary condition as follows;

$$\left.\begin{array}{lll}\vec{U}=0 & \text{at} & z=z_0\\ \vec{U}=\vec{G} & \text{at} & z=\infty\\ \vec{U},\ \dfrac{\partial\vec{U}}{\partial z},\ \vec{\tau} & \multicolumn{2}{l}{\text{are continuous through } z=h}\end{array}\right\} \tag{2.6}$$

where $\vec{U}$, $\vec{G}$ and $\vec{\tau}$ are the vectors of wind, gradient wind and wind stress respectively and these are represented by complex variable form.

Using these results, Equation (2.1) can describe completely the profile of the wind in the surface layer.

2.2 Numerical model of ocean waves

The numerical computation of wave conditions is performed by means of a spectral wave model developed by ISOZAKI and UJI (1973). The model is based on the two-dimensional spectral concept of ocean waves and contains five energy transfer processes. These are the linear and exponential wave growths, wave breaking, frictional dissipation and the effect of opposing winds.

The fundamental equations are represented as follows according to the each stage of the sea state.

$$\left.\begin{array}{ll}\dfrac{\partial S}{\partial t}=-C_g\cdot\nabla S+(\mathrm{A}+\mathrm{B}S)\left\{1-\left(\dfrac{S}{S_\infty}\right)^2\right\}\Gamma(\theta') & \theta'\leq 90^\circ,\ S\leq S_\infty\\ \dfrac{\partial S}{\partial t}=-C_g\cdot\nabla S-\mathrm{D}f^4S & \theta'\leq 90^\circ,\ S>S_\infty\\ \dfrac{\partial S}{\partial t}=-C_g\cdot\nabla S-\{\mathrm{B}\Gamma(\theta')+\mathrm{D}f^4\}S & \theta'>90^\circ\end{array}\right\} \tag{2.7}$$

where the first equation is for the growing stage, the second for the decaying stage and the third for the opposite wind. And where S is the two-dimensional energy spectrum, C_g the group velocity of the wave component, A and B the linear and exponential growth rates respectively, θ' the angle between direction of wind and wave propagation, $\Gamma(\theta')$ the angular distribution of two-dimensional spectral density, D the numerical constant which represents the energy dissipation, and S_∞ the fully developed spectrum. As the rates of wave growth A and B the empirical formula of Inoue (1967) are used for expedience. $\Gamma(\theta')$ is replaced by the rule of $\cos^2\theta$. The fully developed spectrum S_∞ is assumed to be given by the function described by PIERSON and MOSKOWITZ (1964): that is;

$$S_\infty(\omega)=\frac{\alpha g^2}{\omega^5}e^{-\beta\left(\frac{g}{U\omega}\right)^4} \tag{2.8}$$

where α and β are the numerical constant, ω the angular frequency, and g the gravitational acceleration.

3. Coastal wave model

It has been confirmed that the comparatively accurate description of the wave situation in the oceans adjacent to coastal regions are obtained by means of the above-mentioned ocean wave model. But a detailed description of the wave conditions in a coastal region is more difficult to obtain for a number of reasons: Japan is surrounded by sea on all sides and the shape of coastal line is complicated; and the total length is approximately 30,000 km.

To compute the wave spectra for all coastal regions would therefore consume a vast amount of computer resources because the computation needs very fine grid size and small time step. Another problem is that we cannot obtain marine surface wind data which is acculate and of sufficient spatial density to justify the computation of such a fine resolution model. In these circumstances, some simplified model is sought for operational coastal wave forecasting.

After some considerations, we developed a model for the coastal waves prediction in which wind waves and swell are computed separately. For the estimation of wind waves and swell we use the characteristic significant wave method and the spectral method respectively.

The grid interval of 10 km was chosen as a compromise between good coastline-shape resolution and computer capability. Only deep water waves are treated as the grid interval of 10 km does not allow for accurate treatment of shallow water waves.

3.1 Computation of swell

(a) The table of dissipating ratio: $c(\mathbf{X}, \theta)$

The wave energy which is generated over the outer ocean and enters the coastal area is transformed and dissipated by islands, peninsula and cape. The dissipation at a selected point depends only on the direction of the intruding propagation energy. So we can define a dissipating ratio $c(\mathbf{X}, \theta)$ as the ratio of the wave energy at a selected point in the coastal region versus the energy incomming through the outer boundary. We calculated and tabulated them previously for routine operation.

We use the second equation of (2.7) for calculation of the dissipating ratio table, i.e.;

$$\frac{\partial S}{\partial t} = -C_g \cdot \nabla S - Df^4 S \tag{3.1}$$

where $S(\mathbf{X}, t, f, \theta)$ is the two-dimensional energy spectrum defined as a function of position $\mathbf{X}$, time t, frequency f and traveling direction θ. Other variables are the same as before.

Before applying the coastal wave forecast model a coastal area was selected and a 42 by by 32-grid point array (10 km spacing between adjacent points) is arranged over this area.

At first, the wave energy at all sea points is set to zero. Next, constant energy at a given direction is supplied continuously from the outer boundary, and the energy propagation is calculated by integrating equation (3.1).

The adopted energy spectrum has a peak at 10 seconds, based on the assumption that this value is generally representative of the wave period from the outer ocean. The computation is discontinued when the energy levels of all grid points reach saturation. In this way the dissipating ratio is obtained as the value of grid energy divided by the boundary energy.

Using directional energy distribution of $\cos^2\theta$ law, we can remake this ratio to the dissipating rate of wave height. As an example, Fig. 2 shows the contour map of dissipating rate of wave height. In this map dotted areas indicate land.

(b) Swell estimation

Fig. 3 shows a conception of the swell calculation. Arrows marked on the outer boundary express the direction of wave energy which propagates from boundary to the grid point X. $S(\mathbf{X}, \theta, f)$ shows the two dimensional energy spectrum which is defined as a function of position X, traveling direction θ and frequency f. It is assumed that S is given as follows;

$$S(\mathbf{X}, \theta, f) = c(\mathbf{X}, \theta)\, S(\mathbf{X}_0, \theta, f) \tag{3.2}$$

where $c(\mathbf{X}, \theta)$ is the dissipating ratio of energy in direction θ and position X, and $S(\mathbf{X}_0, \theta, f)$ is the spectral component at position $\mathbf{X}_0$ on the outer boundary of calculating area, and which is supplied from the calculation over the outer ocean. Total spectral density $E(\mathbf{X})$ at position X is expressed as follows;

$$E(\mathbf{X}) = \iint S(\mathbf{X}, \theta, f)\, df\, d\theta \tag{3.3}$$

We convert $S(\mathbf{X}, \theta, f)$ to three simplified parameters of swell as follows. Significant wave height is computed from spectral density as follows;

$$H_S = 2.83\sqrt{E} \tag{3.4}$$

As a parameter which represents period, we selected the period at which the one dimensional

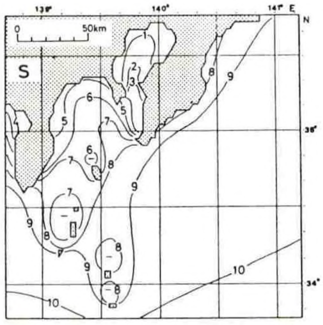

Fig. 2. An example of dissipating rate of wave height. (propagating direction; S)

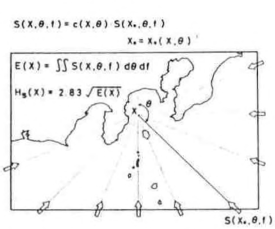

Fig. 3. A concept of the swell calculation.

spectral energy density is maximum. As a wave direction at a point X, we choose the direction in which energy is most concentrated. In this way, wave height, period and wave direction of swell over each grid point in a computation area are given.

3.2 Computation of wind waves

(a) Assumption of a marine surface wind

Before computing wind waves in coastal areas, it is necessary to estimate the local marine surface wind blowing over the domain.

1) We use wind data from the meteorological model which is 12 layer, fine mesh (127 km grid interval) limited area model. Initially approximate values of marine surface wind (u', v') at a point are defined as follows;

$$\left.\begin{aligned} u' &= \sum_{k=1}^{m} w_k u_k / \sum w_k \\ v' &= \sum_{k=1}^{m} w_k v_k / \sum w_k \end{aligned}\right\} \tag{3.5}$$

where u_k, v_k (k=1, .., m) are the wind components of fine mesh grid, m the number of grid point and w_k the weighting functions.

2) We use wind data from land station near the shore, and a second set of approximate values of marine surface wind (u'', v'') are defined as follows;

$$\left.\begin{aligned} u'' &= \Big(\sum_{k=1}^{m} w_k u_k + \sum_{l=1}^{n} w_l u_l\Big) / \Big(\sum w_k + \sum w_l\Big) \\ v'' &= \Big(\sum_{k=1}^{m} w_k v_k + \sum_{l=1}^{n} w_l v_l\Big) / \Big(\sum w_k + \sum w_l\Big) \end{aligned}\right\} \tag{3.6}$$

where u_l, v_l (l=1,.., n) are the wind components of each land observation. n the number of stations and w_l the weighting functions. We deal with several points with m and n.

Finally, wind direction at a point is calculated from the values of u'' and v'', and wind speed is calculated by;

$$V = (w_0 V'' + w_1 V') / (w_0 + w_1) \tag{3.7}$$

where

$$w_0 = \sum_{k=1}^{m} w_k + \sum_{l=1}^{n} w_l$$

$$w_1 = \min(1.0,\ V'')$$

$$V' = \sqrt{u'^2 + v'^2}$$

$$V'' = \sqrt{u''^2 + v''^2}$$

In this way, we estimate marine surface wind at all grid points in the coastal area.

(b) The effective fetch and estimation of wind wave.

Wave generation is limited by the wind fetch which varies largely due to the influence of the coast line configuration such as islands, peninsulas and capes.

So the objective determination of the wind fetch is required for the wave calculation, and we introduce an "effective fetch" F_e shown in Fig. 4. The effective fetch at a point for a wind direction θ is defined as;

$$F_e(\theta) = \sum_i F_i \cos^2\theta_i / \sum \cos\theta_i \tag{3.8}$$

where F_i is the distance between the point and the coast line at an angle of θ_i from the wind direction. The summation on the right hand side of the equation is done over an angle of 45 degrees of both sides of the wind direction. The length of an effective fetch is determined and previously stored in the computer memory for each grid points and wind directions. Fig. 5 shows an example of an effective fetch contour map.

For the calculation of wave generation on each grid points over the coastal area by the

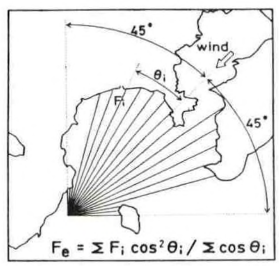

Fig. 4. A concept of an "Effective Fetch" calculation.

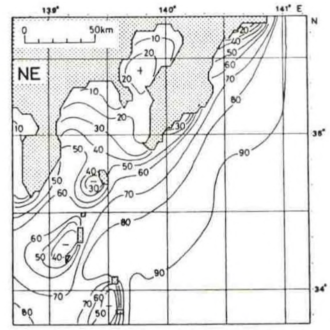

Fig. 5. An example of an effective fetch contour map. (wind direction; NE)

use of above determined wind data and effective fetch, Willson's formula (Willson, 1965) is adopted, that is;

$$\frac{gH_w}{V^2} = 0.30\left[1 - \left\{1 + 0.004\left(\frac{gF_e}{V^2}\right)^{1/2}\right\}^{-2}\right] \tag{3.9}$$

where H_w is the significant wave height, V the wind speed (m/sec), g the acceleration of gravity (m/sec²) and F_e the effective fetch (meter).

The direction of wind wave is that of the marine surface wind, and the period of the wave is computed by the equation of WILLSON (1965) as follows;

$$\frac{gT_w}{2\pi V}=1.37\left[1-\left\{1+0.008\left(\frac{gF_e}{V^2}\right)^{1/3}\right\}^{-5}\right] \tag{3.10}$$

where T_w is the significant period of wind wave. In this way wave height, period and wave direction of wind wave over each grid point are computed.

3.3 Wave estimation for coastal areas

We have described the derivation of swell information in section 3.1 and of wind wave information in section 3.2. Final wave information at a grid point is defined as follows;

(1) Wave height is assumed as combined wave height by using the following equation;

$$H=\sqrt{H_w^2+H_s^2} \tag{3.11}$$

(2) The predominant wave period is given by the period of the higher wave between wind wave and swell, that is

$$T=\begin{cases} T_s & (\text{in case of } H_s \geq H_w) \\ T_w & (\text{in case of } H_s < H_w) \end{cases} \tag{3.12}$$

where T_s is the period of swell and T_w is that of wind wave.

(3) The predominant wave direction is given by the direction of the higher wave between wind wave and swell, that is

$$D=\begin{cases} D_s & (\text{in case of } H_s \geq H_w) \\ D_w & (\text{in case of } H_s < H_w) \end{cases} \tag{3.13}$$

where D_s is the direction of swell and D_w is that of wind wave.

4. Operational implementation of wave forecasts in the JMA

The numerical model in the JMA consists of three steps which are connected from a large grid size to a smaller one. These are, as it were, nesting model. The first step uses a coarse mesh (grid interval is 381 km at 60 degrees north latitude), the second a fine mesh (grid interval is 127 km at 60 degrees north latitude), and the last is the estimation of waves for coastal seas of Japan (the grid interval is 10 km at a representative point in the computation area).

4.1 Operation for coarse mesh

In this step the ocean wave model described in sections 2.1 and 2.2 is used for numerical estimation of sea waves. Pressure and temperature just above sea level supplied by atmospheric model called 12-layer hemispheric spectral model are used to compute the gradient wind.

The energy spectrum of sea waves consist of 22 frequency components from 0.04 Hz to 0.25 Hz with 0.01 Hz-interval and of 16 direction components in step of 22.5 degrees. The area of computation are the western North Pacific, Japan Sea, East China Sea and a part of South China Sea shown as A in Fig. 6. The grid size for computation consists of 36 by

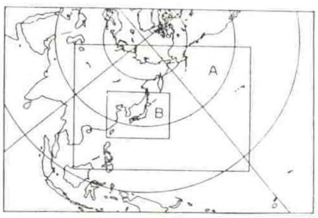

Fig. 6. Calculation area of coarse mesh (region; A) and fine mesh (region; B)

27 grid points and computations are made only at grid points located over the sea. When a grid point is covered by sea ice, the grid point is considered as a land point. The time step interval for calculation is 6 hours and two versions are run. The first is a 24 hour hindcast version and the wave energy spectrum of the last step is used as the initial condition of the forecast version and stored as an initial condition for the next day's hindcast computation. In this version, sea level pressure and air temperature are supplied from the objective analysis and prediction by the atmospheric model. The next is 36 hours forecast version in which the initial condition is prepared by the first version and the meteorological conditions are from the prediction by the atmospheric model.

The energy spectra include various information on the wave condition and are very useful in the precise description of the sea state. But a large number of information are not always convenient to describe the general features of the sea state. So, the results of the model computations are summarized into simplified parameters such as wave height, period and wave direction using the same methods described in section 3.1(b).

Significant wave height is computed from spectral densities as follows;

$$H_{1/3}=2.83\sqrt{E} \tag{4.1}$$

where $$E=\iint S(\theta, f)\,df\,d\theta$$

The prevailing period is defined as the period of the one-dimensional spectral peak and the wave direction as the direction in which most energy is concentrated.

Fig. 7 shows flow of operational numerical wave model in the JMA. The ocean wave information produced using the procedure are broadcast by radio facsimile as the wave analysis chart and the wave forecast chart (24 hours prognostic chart) over the western North Pacific. Examples of the products are shown in Fig. 8 and Fig. 9.

Fig. 8 is the wave analysis chart at 00Z, Sep. 24, 1983 made by the model calculation and ship observations. Fig. 9 is the 24 hr-forecasting chart made at 00Z, Sep. 23, 1983. Comparison of both figures shows reasonable agreement between prediction and observation.

Because of the relatively long time step and coarse resolution of the atmospheric model,

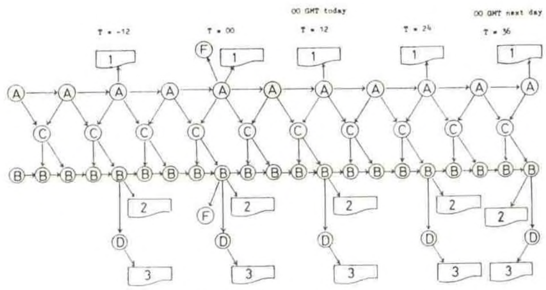

Fig. 7. Calculation flow of wave model in the JMA.

A; Calculation of coarse mesh model over the western North Pacific
B; Calculation of fine mesh model over the adjacent sea of Japan
C; Interpolation
D; Calculation of coastal model around Japan
F; Data for next day's calculation
1; Print-Out of products of the western North Pacific
2; Print-Out of products of the adjacent sea of Japan
3; Print-Out of products of the coastal sea of Japan
where 1, 2, 3 & D are made every 6 hours

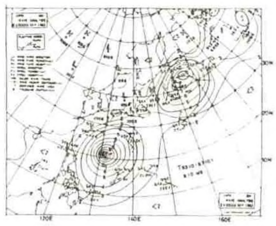

Fig. 8

Fig. 9

Fig. 8. Wave analysis chart over the western North Pacific.
Fig. 9. Wave forecast chart over the western North Pacific.

the ocean wave model is not capable of predicting very high waves generated in typhoons and rapidly developing lows. Manual corrections are made empirically based on the sea situation, ship observations and the forecast chart of surface pressure.

If a typhoon structure is predicted by means of Fujita's formula (FUJITA, 1962), objective correction of waves in typhoon area can be made in our ocean wave model (UJI, 1975).

4.2 Operation for fine mesh

The method which estimates the sea conditions for the fine mesh is based on the spectral method similar to that of the coarse mesh procedure.

A calculation area is divided into 37 by 31 grid points, the area of computation is shown as B in Fig. 6. The time step interval is 3 hours and the sea level pressure and the air temperature just above sea level are prepared from the atmospheric model (12-layer fine mesh limited area model) as the basic external data for wind calculations.

Computational conditions on the outer boundary are provided by the spatial and temporal interpolation of the products from the coarse mesh model taking one half the time step and one third the grid interval.

4.3 Operation for coastal waves

Fig. 10 shows the general flow chart of the operational coastal wave model mentioned in section 3. The table of the dissipating ratio for wave energy and the table of the effective fetch are stored on a disk and are refered to as they are needed. In the estimation of the sea surface winds in coastal areas, winds of land stations are used only in the hindcast version and winds from the atmospheric model are used at any time. Calculations are carried out

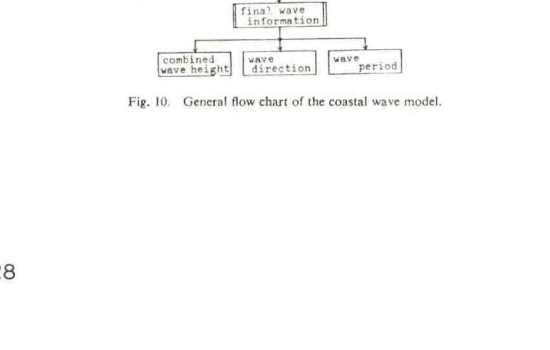

Fig. 10. General flow chart of the coastal wave model.

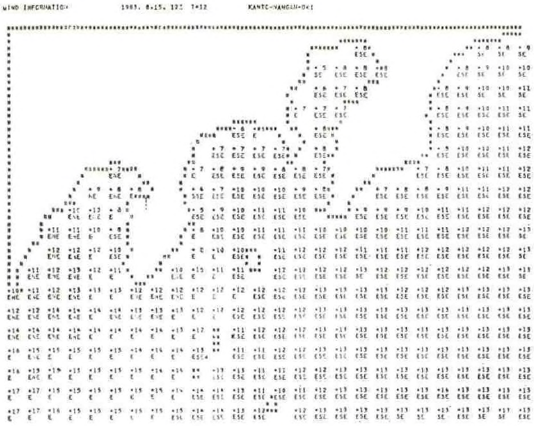

Fig. 11. An example of sea surface wind informations of coastal area. '+' mark shows a grid point (interval of each grid is 10 km), group of numerals (upper) and alphabets (lower) wind speed and direction respectively.

for about 12 coastal areas around Japan which include imptorant ports and harbors. Each coastal area is divided into 42 by 32 grid points with the grid interval of 10 km. As shown in Fig. 7, the coastal wave model forecast system output some list every 6 hours interval and the following are produced for coastal areas:

1) Sea surface wind (direction and speed) information. Examples are shown in Fig. 11.
2) Wave information (significant wave height, prevailing wave period and direction) which are shown in Fig. 12 as example.
3) Time sequence for every 6 hours of wave and wind data at about 120 points.
4) Machine drawn chart of significant wave height for all coastal areas.

Fig. 13 shows an example of the analysis chart of the coastal sea area prepared routinely by the JMA for broadcast. Configuration of the forecast chart of the coastal sea areas is the same as the analysis chart except for the data of coastal wave-recorders. These charts are transmitted to local meteorological offices by land-line telecommunication system (not by radio facsimile) once a day.

Fig. 12. An example of wave informations of a coastal area. Group of alphabets and numerals show significant wave height (upper), wave direction (middle) and wave period (lower). Grid interval of this map is 20 km and group of same numbers shows contour line of wave height.

When forecasters of a local meteorological office formulates forecasts and warnings for weather and waves in the coastal areas, these staff would then refer to the wave analysis and forecast charts to increase the accuracy of their results.

5. Evaluation

5.1 Wind and wave caused by Typhoon

Among severe meteorological situations, typhoon is considered as one of the most severe meteorological phenomena affecting the safety and economy of ships. Thus it is very important to make an acculate prediction of the distribution of wave conditions in a typhoon area. As an example we compared our model estimation with the observations which was made when Typhoon 8013 Orchid passed through west of Japan from south to north on 11, Sept. 1980. Fig. 14 shows the track of Typoon 8013 Orchid.

Fig. 15 shows the time variation of wind speed and significant wave height of the ocean data buoy (25.67N, 135.92E) and hindcast data of our fine mesh wave model respectively. In the process of computation of fine mesh wave model the typhoon correction model was applied.

Variation of wind speed by the model estimation agrees well with the buoy observations. The prediction of wave height also agrees reasonably well with the observations, however it has systematic descrepancies, that is slower growth and decay than the observations and lower estimation of wave height during the most severe wave conditions. The descrepancies may be due to the smoothing effect of finite time step and grid interval which are used in the prediction equation. The 127 km-grid interval and 3 hours-time step are not sufficient to represent the complicated meteorological and maritime conditions near a typhoon center.

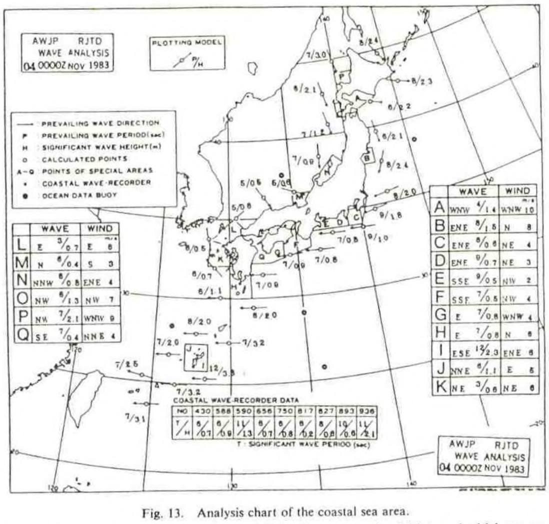

Fig. 13. Analysis chart of the coastal sea area.

Fig. 16 shows the time variation of wind of an observation point and a grid near the point by coastal wave model throughout the typhoon passage. The observation point is Shionomisaki Observatory (see Fig. 14) which is located at the southern tip of Kii-Peninsula. Based on our experience wind speed estimated by our fine mesh model has a higher value

Fig. 14. Track of the Typhoon 8013 Orchid from 7 to 11 Sep. 1980.

than that actually observed near the coast, because our fine mesh model does not incorporate topographical effects in the wind estimation.

The winds used in the coastal wave prediction are estimated by the spatial interpolation method with the wind of the fine mesh model and land observations by eq. (3.7).

Overestimated wind speed values during the typhoon passage are shown in Fig. 16 (lower). Before and after this period estimated wind speeds agree fairly well with the observations. As shown in the upper part of Fig. 16 almost all estimations of the wind direction generally coincide with observations. The accuracy of the wind direction is very vital in the determination of the effective fetch which is one of the major parameters of the coastal wave estimation.

5.2 Comparison with coastal wave observation

The JMA has spread the network of coastal wave-recorders since 1977 and is now routinely operating 10 stations as shown in Fig. 17. The coastal wave-recorders are the ultrasonic type and set at a depth of about 50 meters off the respective coast. The records are taken at 0.5 second-interval over 20 minutes every three hours, and statistics of wave height and wave period are calculated routinely.

We evaluated the coastal wave model by comparing the estimated values of the significant wave height with the observation from the above mentioned coastal wave recorders. The comparison was made after a year routine operation from March 1983 to February 1984, and the results are shown in Table 1.

In this table, the upper four stations are located on the coast of the Japan Sea and the lower five stations are on the Pacific coast (see Fig. 17). T=12 and T=36 represent the results of 12 hours predictions and 36 hours predictions respectively.

Observed annual means of the significant wave height are lower than that of the model prediction, but the discrepancy is not so large.

In our coastal wave model, wind waves over the coastal area are assumed to be saturated with respect to the wind direction, and the wave heights are determined by the effective fetch and wind speed because of the narrowness of the coastal area. This may at times result in the overestimation of the wave height.

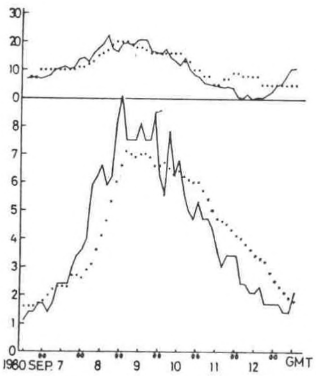

Fig. 15. Time valuation of wind speed (upper) and significant wave height (lower). Full line; the ocean data buoy (25.67N, 135.92E) and dotted line; hindcast data of the model. Period; 6 to 13 Sep. 1980.

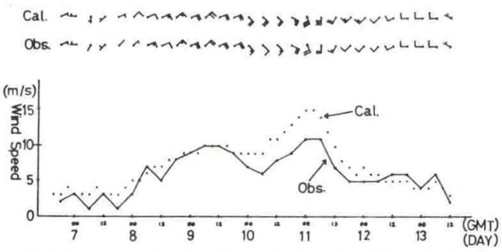

Fig. 16. Valuation of winds at the Shionomisaki Observatory (Wakayama Prefecture and the hindcast data of the model. Upper shows wind direction and lower wind speed. Period; 7 to 13 Sep. 1980.

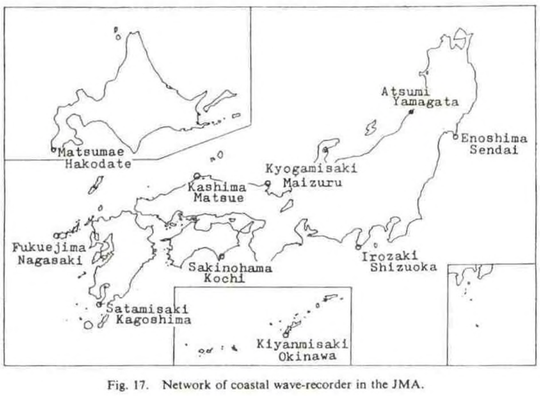

Fig. 17. Network of coastal wave-recorder in the JMA.

Table 1. Comparison of significant wave height between coastal wave-recorder and model output from Mar. in 1983 to Feb. in 1984.

STATION	T = 12							T = 36						
	n	Mean		σ		γ	RMS	n	Mean		σ		γ	RMS
		Obs.	Cal.	Obs.	Cal.				Obs.	Cal.	Obs.	Cal.		
Matsumae	355	0.97	1.21	0.76	0.79	0.84	0.42	354	0.97	1.53	0.76	0.98	0.82	0.43
Atsumi	358	1.19	1.23	1.09	0.91	0.89	0.49	357	1.19	1.48	1.10	1.09	0.86	0.55
Kyogamisaki	359	1.12	1.29	0.95	0.93	0.91	0.39	358	1.12	1.50	0.95	1.08	0.87	0.47
Fukuejima	359	1.15	1.31	0.83	0.87	0.84	0.45	358	1.15	1.40	0.83	0.95	0.75	0.55
Enoshima	363	1.32	1.42	0.78	0.66	0.75	0.51	362	1.32	1.43	0.78	0.77	0.71	0.54
Irozaki	356	1.27	1.32	0.76	0.85	0.72	0.53	355	1.27	1.44	0.76	0.89	0.74	0.51
Sakinohama	352	0.91	1.06	0.61	0.82	0.69	0.44	351	0.91	1.08	0.61	0.90	0.69	0.44
Satamisaki	353	0.79	1.11	0.48	0.64	0.71	0.34	352	0.79	1.22	0.48	0.69	0.64	0.37
Kiyanmisaki	319	0.95	1.65	0.53	1.03	0.69	0.39	318	0.95	1.64	0.53	0.87	0.69	0.39

where (n) is data amount, (σ) standard deviation, (γ) correlation coefficient, RMS root mean square error, Obs. observation value of a coastal wave-recorder, Cal. model output.

As for the correlation coecffiient in Table 1, the predictions have rather higher correlation to the observations at the stations on the Japan Sea coast than on the Pacific coast. The reason is that the Japan Sea is a closed basin and the effect of swell on the coastal waves can be well defined but in the Pacific the swell effect can only be roughly estimated because of its wideness. Seasonal characteristics of the present evaluations, which are not shown in Table 1 however, are that the correlations at the Japan Sea coast are higher in the cold season due to the prevailing northwest winter monsoon than during the warm season. On the other hand, the reverse is the case at the Pacific coast during the southerly summer wind season.

6. Concluding remarks

The numerical wave prediction model which has been used in the JMA since 1983 consists of a coarse mesh model, a fine mesh model and a coastal wave model. The coarse mesh model and the fine mesh model are almost the same as the ocean wave model which has been used routinely for the western North Pacific in the JMA since 1977. In the coastal wave model, wind waves and swell are calculated separately and computed thereafter. These models are used successfully through the last two years, but some revision are planned as follows,

1) Extension of wave forecasting period in the ocean.
   24 hour predictions are made at present, but 4 days or one week predictions are desired in the field of ship routing and coastal engineering.
2) Extension of wave analysis and forecast areas in the coastal wave prediction.
   At present the results of analysis and forecast are presented on the representative point in each of 12 selected sea area. It is now deemed necessary that the wave distribution be presented over the selected coastal areas, and the selected area should be extended to cover all of the Japanese coast.
3) Introduction of new ocean wave model.
   In our ocean wave model which is used since 1977, a linear spectral wave model is adopted. Based on the recent theoretical and experimental studies of wind wave generation, the linear spectral model will be replaced by a coupled discrete mode which was developed at the MRI (Uji, 1983).
4) Improvement of wind analysis method.
   Wind estimation at present depends on the pressure and temperature of the atmospheric model. By incorporating ship observations, we hope to have better forecast accuracy in the wind estimation.

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