MIT Sea Grant
Fall/Winter 1985

Quarterly Report

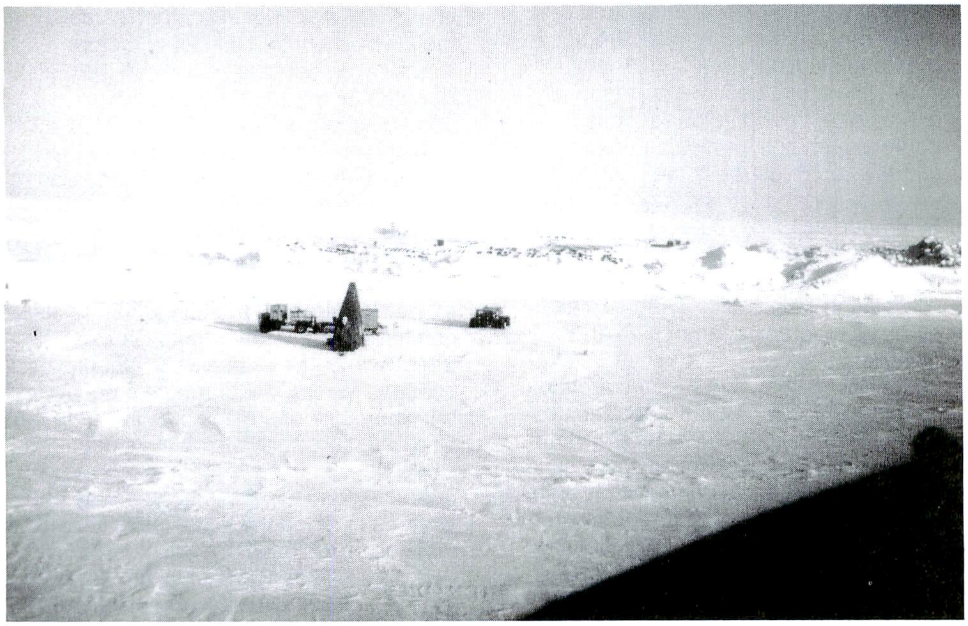

Figure 1. Researchers brave subzero temperatures to recover soil samples.

MIT Undertakes Major Arctic Research Effort

In 1983 MIT began a unique interdisciplinary research program to address simultaneously the manifold engineering unknowns associated with drilling in the Arctic. Initiated by a five-year grant from the Standard Oil Company of Ohio (Sohio), the new Center for Scientific Excellence in Offshore Engineering supports coordinated research to develop technology for evaluating various designs of Arctic offshore exploration and drilling platforms. The interdisciplinary project includes basic and applied research on Arctic ice, structures, soils, risk, and hydrodynamics.

Sohio's grant, shared by the MIT Departments of Civil and Ocean Engineering, is supervised by an advisory committee made up of representatives from MIT and Sohio. More than 10 faculty members are now participating, with projects including: ice and structural engineering, which encompasses the problems created for concrete and steel structures by ice floes and other environmental forces in Arctic areas; geotechnical engineering, involving the foundation stability for offshore structures; risk and reliability, which deals with forecasting the probability of success for new technological developments; and hydrodynamic modeling to help predict the effect of wind waves and ocean currents on the movement of ice floes.

"One of the great features of the Center," says Charles Ladd, the Center's director and MIT Professor of Civil Engineering, "is that we can stand back and look at developing procedures for long term solutions, not just tomorrow's immediate problems. It's unique to have people from so many different disciplines — ice, soil, structures, water — all working toward the same objective. All this will be brought together to hopefully yield an integrated approach to very difficult technical problems."

"The first priority," says Ladd, "is ice: how big is the ice mass and how fast will it be moving when it hits a structure? The second biggest problem is the tremendous uncertainty of how that ice mass will physically interact with a structure. Nobody has experience with structures designed for the magnitude of the horizontal loads imposed by ice. These loads are much larger than those from wave action during hurricanes." Complicating the research is the fact that most available data deals with freshwater ice, which has properties different from saltwater ice. The gravity structures likely to be deployed in the Arctic also are very different from Gulf of Mexico pile-supported platforms.

What lies underneath the ice and water introduces another set of formidable problems. Continues Ladd, "The soils or silts which overlie the permafrost behave quite differently from soils we've encountered in oceans throughout the rest of the world. It's hard to build a safe, economical structure when we don't know the strength of the soil by a factor of two or the ice load by a factor of 10, and these two are the most important design criteria."

The force of ice pushing against a structure impacts not only the structure, but also the underlying soil to which the stress is transmitted. Loaded vertically (e.g., with a heavy structure pressing downwards), Arctic silts can be relatively strong. But if a large ice mass shoves a platform sideways, shearing the soil layer on a horizontal surface, the same soil is much weaker.

This extreme horizontal ice loading, which can range from 50,000 to 200,000 tons, along with the unusual composition of offshore silts, is unique in the Arctic. It demands new procedures and equipment for determining soil strength. No longer are techniques developed for Gulf of Mexico soils, which many engineers currently use, adequate for these polar conditions.

In one of the Center's projects, supported by MIT Sea Grant, Professor Ladd and Dr. John Germaine, MIT Department of Civil Engineering, are examining Arctic soil samples in order to develop in situ and laboratory tools and techniques for determining soil strength. The project is an offshoot of recent Sea Grant research which has had a significant impact on geotechnical offshore engineering practice in the US and abroad.

Germaine spent a week in April 1984 on the ice around Mukluk Island, an artificial

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gravel island in Harrison Bay, Alaska, helping to gather soil samples. Sohio abandoned oil drilling at Mukluk after a dry hole, but it maintains instrumentation on the island to monitor ice movements, lateral deformations, settlements, pore pressures and temperature profiles.

Braving long hours of subzero temperatures, Germaine's group drilled through 7.5 ft of ice, 50 ft of water, and 25 ft of soil. Besides being arduous, sampling Arctic soil is also an expensive process. Obtaining an undisturbed soil sample can cost more than $10,000 per two-foot-long tube.

"We're trying to measure those properties of Arctic soils that are most relevant to foundations for gravity platforms," Germaine says. Samples examined so far are often layered with silts and clays. "We're especially looking at the strength when we change the direction of shearing. It's certainly the first time this has been done in Arctic soils." They are also X-raying the soil samples. "We see what we think are ice lenses that have developed in the material as it froze and thawed out," Germaine continues. These ice lenses are problematic in the process of gathering samples. If bringing the sample to the surface causes ice in the soil to melt, soil characteristics will be significantly altered. "We don't know what to do with these ice lenses yet," says Germaine.

Temperature effects on the engineering properties of soil are among the first experiments in the researchers' testing program, which they hope will run three to four years. Testing soil is a slow and laborious process, Germaine says. Having classified Arctic soils into two groups, silt-rich and clay-rich, they are running shear tests both to evaluate stability under the weight of the platform and during ice loadings.

While Ladd and Germaine progress in their understanding of soil characteristics, other engineers at the new Center for Scientific Excellence in Offshore Engineering are advancing knowledge about ice mechanics, structural engineering, hydrodynamic modeling, and other particular, but interrelated challenges to offshore drilling in the Arctic. ■

Arctic Conditions Challenge US Researchers

Oil wells first crept offshore in the early 1900s, originally erected on piers extending cautiously from beaches. By 1978, platforms reached down more than 1000 ft in the Gulf of Mexico to sunken oil fields. Around 770 offshore rigs of varied designs pump oil in waters around the world, ranging from the placid tropics to the turbulent North Sea.

Despite many decades of offshore experience, drilling in the Arctic is complicated by a formidable unknown factor—ice. Because of the uncertainty in ice behavior and forces, waters of 10 to 50 ft once again have become expensive exploratory zones. Scientists and industry professionals bemoan the lack of critical information about soils, ice forces and other vital facts needed to plan and construct platforms.

Yet the prospects of oil finds are too enticing to ignore. America's richest oil field at Prudhoe Bay on Alaska's North Slope singlehandedly supplies the nation with 18 percent of its domestic crude oil. While the field still holds over 9 billion barrels (bbl), or 1/3 of all US proven oil reserves, every day another 1.5 million bbls are drained out. In the Diapir field's 660,000 acres in the Beaufort Sea, one government estimate lists the chances of finding 2.3 billion bbl of oil at above 99 percent. The National Petroleum Council suggests that 28 percent of the total undiscovered oil and gas resources of the US lie under Arctic waters.

People who consider ice as a temporary winter nuisance may wonder why it presents such profound problems for the offshore industry. Its overwhelming presence in the Arctic makes necessary a whole new approach to platform design. Drilling costs in the Beaufort Sea run about $40 to $50 million per well, compared to an average of $1.5 to $3 million per well in the Gulf of Mexico. Like the nomadic wildlife and hunters in the far North, the ice can be in constant motion. "Sea ice is the most dynamic solid on the surface of the earth. The marginal ice zone (where some drilling will take place) generally is the most dynamic part of the sea ice cover, with ice velocities as great as 80 mi/day," says William J. Campbell of the USGS at University of Puget Sound.

Ice is generally characterized as first-year or multi-year. How much first-year ice develops during its initial winter depends on the heat sink capacity in the atmosphere, whether the area is insulated by snow, and whether the ice migrates or remains in place. In the relatively sheltered Cook Inlet in southern Alaska the ice might grow 18 to 24 in. before warmer weather sets in, while in the Beaufort Sea north of Alaska, 6 ft accumulations are typical.

Multi-year ice has survived more than one melt season. While some of the ice mass melts over the year, the remainder gains a new growth of ice the following season. Each additional year's growth will create ice which is more compact, less saline and stronger than first-year ice. It is common in the Beaufort and Chukchi Seas, but not the Bering Sea. Not only does the ice wander around the ocean, but it can also unpredictably plow onto the land and flatten everything in its path. During these ventures, called shore pile-ups, ice layers or blocks heap on top of each other along the coastline in jagged mounds occasionally 30 ft high. At other times, instead of accumulating in a pile the ice slides inland in a single sheet as far as 325 ft. This phenomenon, called ride-up, has pulverized boats, toppled trees, and occasionally crushed houses along with their unlucky inhabitants. So far, ride-ups haven't damaged any islands or structures built for oil exploration. However, pile-ups in Alaska in 1978 left ice rubble up to 23 ft high at a proposed exploratory drill site, and an abandoned steel building located 246 ft from the sea was damaged by ice ride-up in 1973.

Collisions between moving ice sheets form pressure ridges, which might shoot up to 150 ft of jagged ice chunks or sink to submerged ice barriers 200 ft deep. For the first year the underwater ice remains an unconsolidated heap of fragments and slush. In subsequent years the underwater part, called the multi-year pressure ridge, hardens into very strong, sound ice. Ben Gerwick, Jr., Professor of Civil Engineering at Berkeley and Arctic consultant, observed pressure ridges on a flight over

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the Chukchi Sea piled up in back of each other, about 200 ft apart, extending for hundreds of miles. "It's frightening to think of these huge ridges up to 100 ft deep, 300 ft wide and maybe half a mile long coming at an offshore structure. This type of ice exerts the greatest force on any structure and must be designed for, as we do for a 100-year storm."

Out in the open sea, ice sheets often progress several miles a day, while in shallow water the ice remains relatively stable once it freezes over for the year. "Even though the ice sheet moves very slowly, it and its ridges exert a tremendous force," stresses Gerwick. Wilford Weeks of the Cold Regions Research and Engineering Laboratory cites the experience of a group from his lab installing instruments in mid-March on a structure in the Canadian Arctic. In a typical losing battle with moving ice, the researchers "got all their instrumentation just about ready to hook up, and the ice took off and tore out all their cables."

This ice movement represents a very complex motion of the ocean currents beneath the ice and the winds above it. Whether the ocean currents or the winds dominate it depends on which are stronger at any particular time, as well as on the ice concentration. With much open water and loose ice, the ice will move around relatively quickly. But if the ice is packed in and subjected to large oceanic or atmospheric stresses, it buckles and forms pressure ridges.

In the Arctic the major design load comes from the ice, rather than the weight of the structure or wave forces. Yet there are very few published measurements of ice loads on structures. According to Charles Ladd, Professor of Civil Engineering at MIT, there is good reason to distrust ice behavior models. At present they do not take into account that ice is much colder at the outer surface than at the margin against the water, even though the strength of the ice varies with its temperature. The models also assume that ice has the same properties everywhere it hits a structure. To the contrary, ice will act stiff and have a high strength if it is loaded rapidly, while it will resist much less if the load is applied gradually. There are tremendous strain rate differences. When ice rams into a structure, only the ice right next to the structure will undergo a very fast rate of strain and act very brittle.

What lies underneath the ice and water introduces another set of formidable problems. Arctic soils or silts behave quite differently from soils encountered in oceans throughout the rest of the world. Building a safe, economical structure is hard without knowing the strength of the soil by a factor of two or the ice load by a factor of 10. In the soft soil zone area in the Beaufort Sea, Professor Ladd claims that he could show why any predicted soil strength could be either too high or too low by a factor of two. A safety factor of 1½ is usually picked for a design strength, making a factor of two uncertainty possibly unsafe. (On page 3 see "MIT Undertakes Major Arctic Research Effort.")

Besides coping with unpredictable ice, workers and materials in the Arctic are subject to extremities in weather, including temperatures which frequently drop below -35° F in winter. Windchill factors depress the temperature by another 20° or more. On the northeast coast of Alaska, fog persists at least 115 days per year. In the far north, weeks of midnight sun alternate with weeks of no sun. While temperatures out on the pack ice usually hover near freezing even in summer, the cold is also moderated by heat percolating up from the water through cracks in the ice. Usually people fly even short distances in the Arctic by helicopter, since the ice sheet terrain is ridged with piles of ice blocks and rubble several meters high. If the wind rises above 10 knots, drifting snow blots out visibility and the resulting white-out automatically postpones any work.

Like most Arctic researchers, William Sackinger of the Geophysical Institute at the University of Fairbanks has never directly encountered a polar bear but has heard stories from other workers and takes precautions. "We always have two or three people in our crew, and we always carry a 'polar bear protection device', which is the largest rifle we can buy." Some oil companies routinely hire an armed professional bear guard to avert any danger from bears or from startled novices dealing with firearms.

Scientists and engineers are gradually overcoming a whole range of obstacles the Arctic throws into the path of anyone working there. Especially in the last decade with support from industry and government the way is being smoothed for understanding the environment and working within its limits. ■

Oil Industry Trying Out Different Structures

Shallow water: Gravel islands. In both the Canadian and American sections of the Beaufort Sea, over 20 artificial islands have been built since the late 1970s from huge mounds of gravel dredged locally or else carried in by barge. Initially gravel islands were constructed at nearshore sites as shallow as 4 ft, but now they have edged out to about 60 ft deep in the moving ice pack north of the Canadian Mackenzie Delta.

Constructing a typical exploration island about 300 ft in diameter, located in 20 ft of water and rising 10 ft above the water line, consumes about 250,000 cubic yards of gravel. In 60 ft of water the gravel requirement increases tenfold. Where gravel is scarce, it might cost $60 million to $120 million to cart in enough material for a 60-ft island just to drill an exploratory well, which might prove dry. Should the tests actually discover oil, a production-sized island would need double the diameter, with further enormous gravel demands. Mukluk Island, the largest one to date, contains 1.25 million cubic yards of gravel, or enough to fill up the Empire State Building.

Caisson-retained islands. Caissons are huge concrete or steel rings placed on the seafloor to hold the gravel. While a plain gravel island with protective sandbags in 20 ft of water might require 800,000 cu yds. of fill, adding a reusable ring of steel caissons cuts down the fill to 150,000 cu yds. The steeply sloping caisson sides also lessen the amount of gravel erosion and delays caused by wave action during the island construction.

After the oil drilling finishes, the center core of sand can be dredged out, the cassions refloated and the structure carried to a new location. Caissons can be designed with ice deflectors to reduce threats of destructive ice ride-ups. However, their relatively steep sides make them more vulnerable to impact loadings from ice, and they also require a longer lead time to design and fabricate than a

Sea Grant Lecture and Seminar Announced for April 1985

The 1985 MIT Sea Grant Lecture/Seminar, April 17-19, will address "Ocean Disposal, Public Wastes: Technology and Policy for the Future." Fifteen experts will focus on long-term developments needed to make the oceans an acceptable and economically feasible option for disposing of large volume, public wastes including sewage, sludge, and dredge spoils. Sessions will be held on—

- Advanced Waste Treatment and Transport Systems
- Environmental Monitoring and Assessment Methodologies
- Economic and Institutional Issues
- Regional and National Projections for Waste Management

For more information and registration materials, contact Elizabeth Harding, MIT Sea Grant Program, 77 Massachusetts Ave., Cambridge, MA. (617) 253-7041.

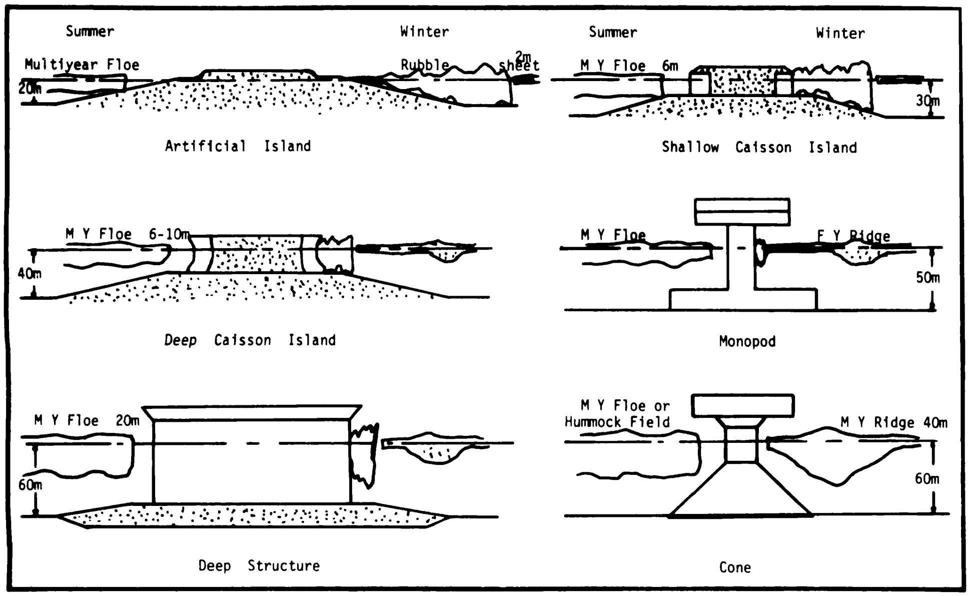

Figure 2. Typical ice conditions at structures in different water depths.

sandbag-fortified gravel island.

The first caisson island, Tarsiut ("nighthawk" in the Inuit language), was constructed for Dome Petroleum in 70 ft of water in 1981. Located in a transitional area between landfast ice and moving seasonal floes, it is subject to greater ice forces than more landward gravel islands. When another site a few km away proved to have more oil, Tarsiut became a research base to measure ice and other forces throughout the life of the island.

The experience gained at Tarsiut led to the Single Steel Drilling Caisson (SSDC), a modified tanker strengthened with 8000 tons of steel and 16,000 tons of structural concrete to deal with the ice forces. More versatile than caissons, the SSDC can be removed from a drilling site and set down on a new location within four days. It can also drill up to eight wells at one site, and can work through the winter season. In 1982, it became the first mobile drilling caisson to operate year-round in the Arctic.

Deepwater structures. Ice structures proposed for deeper water generally are intended to make ice fail in predictable ways rather than being designed to withstand all ice movements. Ideally a structure will force the ice to fail in tension and also will keep itself clean, so the breaking ice keeps additional ice from building up. These structure designs usually feature an enlarged base to intercept the ice well below the waterline. Some type of mobile conical configuration is usually proposed to force the ice to break upward by bending, rather than by the more destructive crushing mode. Exxon estimates costs for a cone drilling rig could range from $200 million to $500 million.

Both concrete and steel are being considered as the principal construction materials for Arctic structures, with the material most in favor dependent on market fluctuations. Steel bends better, but is more susceptible to local buckling and brittle fractures. Its much smoother surface can reduce the ice load better, says John Wang of Brian Watt Associates, a Houston consulting company. But concrete is better in resisting constant shear and its greater weight is an advantage in combating ice forces. To combine the best of both, he mentions a hybrid steel and concrete material being developed, with a steel skin covering a concrete infill.

Actual production structures would be built on the Pacific Northwest or in Japan and towed around Point Barrow to the Beaufort Sea in the two summer months between the retreat of the ice pack and the next freeze-up. With such a short time to get set up, equipment and facilities would have to be completed before the structure is towed.

The first mobile reusable gravity drilling structure will be the Concrete Island Drilling System (CIDS), a platform of stacked cellular concrete modules with a barge-mounted drilling rig perched on top. The interior concrete honeycomb forms a strong, durable structure capable of resisting cold temperatures and ice loads, while the steel mud base resting on the sea floor increases sliding resistance in areas with very poor soils. All components float, and the entire CIDS can be towed to a new location within two days. It can drill in water up to about 70 ft, and is being modified to accommodate depths of up to 150 ft.

After deploying the CIDS, Exxon plans to construct a spray ice barrier on three sides of the site. The barrier should act as a buffer between the structure and the moving ice sheet, absorbing impact forces and causing an advancing ice sheet to break into rubble outside the barrier. Much of the force of the moving ice would be transmitted through the grounded barrier into the seafloor, rather than to the structure.

Farther in the future, the Arctic Cone Exploratory Structure (ACES) is a prototype for mobile offshore drilling units in water depths of 50 to 110 ft (deeper than any current structures in the Beaufort Sea). Its base is prestressed lightweight concrete with steel decks. Brian Watt Associates is prime contractor for the design, which is sponsored by three oil companies and intended to cost $250 million. Another prestressed concrete drilling platform, the Sohio Arctic Mobile Structure, will rely on piles driven below the base to increase resistance to sliding in weak ocean bottom soils. Intended for water depths of 40 to 60 ft, its design features various sound baffles so that the installation would not affect migrating bowhead whales. ■

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Abstracts

New Issues

☐ Theoretical and Experimental Prediction of the Response of a Marine Riser Model - Report Series

C. Chryssostomidis
N.M. Patrikalakis
MITSG 83-2, 3, 4, 5, 6, 15, 18, 19, 20, 21, 22, 23
Complete set of 12 reports $200.00

A marine riser model, made up of an aluminum tube covered externally with a sealing material, has been developed. Each report in this 10-volume series describes the theoretical and experimental prediction of the response of a marine *riser model* subjected to specific excitation. Individual reports are available for $20 each. An order form with a complete list of titles will be sent on request.

☐ Case Studies of the MIT Oil Spill Model: Opportunity Brief #35

MIT Marine Industry Collegium
MITSG 84-2 20pp $4.00

A detailed description of the computer-based MIT Oil Spill Model and three applications are presented in this report. The model has been applied to examine the 1976 Argo Merchant oil spill and to help a Canadian petroleum company decide where to stockpile chemical dispersants in case of an offshore spill. The U.S. Navy Facilities Command is also using the model to analyze potential oil spill problems in the Port of Charleston, South Carolina.

☐ MIT Underwater Vehicle Research: Recent Advances and Future Programs: Opportunity Brief #36

MIT Marine Industry Collegium
MITSG 84-3 24pp $4.00

Gives brief descriptions of Sea Grant research in supervisory control for remotely operated systems, the effect of tethers on underwater vehicles, and an underwater welding system for remotely operated vehicles.

☐ Marine Corrosion and Biofouling: Opportunity Brief #37

MIT Marine Industry Collegium
MITSG 84-5 50pp $4.00

Eight marine materials scientists have coordinated their efforts to solve selected marine corrosion problems. Two broad problem areas were addressed: the relation between calcareous deposits and cathodic protection of structural steel, and the localized corrosion of aluminum and stainless alloys.

☐ Modeling of Coastal Processes: Circulation, Dispersion, and Waves: Opportunity Brief #38

MIT Marine Industry Collegium
MITSG 84-4 18pp $4.00

In the mid-1970s two computer models, CAFE and DISPER, dealing with circulation and dispersion in coastal environments, were developed by MIT Sea Grant. This report describes some substantial modifications in CAFE and DISPER that will enable users to model circulation at much lower cost.

☐ The Development of Fishing Trawl Testing Capabilities at NSRDC

Clifford A. Goudey
Craig A. Holberger
Center for Fisheries Engineering Research, Report 6
MITSG 84-10 6pp No charge

MIT Sea Grant has developed apparatus to allow the hydrodynamic testing of trawl nets at the Naval Ship Research and Development Center (NSRDC) in Bethesda, Maryland. This paper describes the test facilities and instrumentation used in the trawl tests. A list of the nets tested to date is provided along with examples of test results.

☐ **Development of Fully Automated and Integrated "Instamatic" Welding Systems for Marine Applications**

Koichi Masubuchi, et al
MITSG 84-11 61pp $5.00

Final report of a two-year research program to develop fully automated and integrated welding systems for marine applications. These systems package many welding operations, including feeding the electrode, manipulating the torch, etc., so that welding can be done by a person without welding skill.

☐ **Directory of MIT Sea Grant Program Publications**

v.1: 1970-1977, MITSG 78-6
v.2: 1978-1984, MITSG 84-16, with cumulative 1970-1984 indices
62pp No charge

Since 1970, the MIT Sea Grant Program has issued a variety of technical and advisory publications on marine-related research and the use of ocean resources. Ordering information, and author, subject/title, and numerical indexes are included in this directory. *(Circle the volume(s) you wish to order.)*

☐ **MIT Sea Grant Annual Report**

MITSG 84-18 40pp No charge

The annual report describes MIT Sea Grant projects ongoing in 1981-84. In addition to providing progress reports and an overview of the Program's research, public service, and education efforts, the report includes an institutional program summary that lists projects, principal investigators, sources of matching funds, and budgets.

☐ **Sea Grant Publications for the Fishing Industry, Revised**

Edited by Lynne Newman Lawson
MITSG 82-20 119pp $4.00

An updated compilation of publications written and produced by Sea Grant programs for the fishing industry. Topics are organized under five major headings: fish harvesting, vessel design and operation, handling and processing, economics and business, and ecology and aquaculture. Prices and ordering information included. (A supplement, Bibliography on Sea Food Processing and Marketing: publications and research in progress, 1983, 21pp. will be included upon request. No charge for single copies.)

☐ **MIT Summer Session 1985**

Brochure No charge

A preliminary brochure lists MIT special summer programs for professionals. 1985 programs range from "The MIT Executive Program in Financial Management" to "Physical Chemistry of Polymers." Of special note to Quarterly Report readers, Sea Grant is sponsoring ten marine-related courses: five in civil engineering, two in dispute resolution, two in materials science and engineering, and one in mechanical engineering. Detailed descriptions of the marine courses are available as well as the preliminary summer session brochure.

Biotechnology in the Marine Sciences: Proceedings of the 10th Annual MIT Sea Grant College Program Lecture and Seminar

Edited by Rita R. Colwell
E. Ray Pariser
Anthony J. Sinskey
MITSG 82-25 $40.00

The March 1982 MIT Sea Grant lecture and seminar responded to increasing interest in the application of biotechnology to solve marine problems and create new opportunities for using marine resources. Seminar papers cover four main topics: biotechnology in aquaculture, marine pharmaceuticals and bioproducts, marine biofouling, and marine pollution control. The lecture was presented by Rita R. Colwell, a noted marine microbiologist. *(Available only through John Wiley & Sons, 605 Third Avenue, New York, NY 10158)*

The City and the Sea - What We Need to Learn and Teach About Boston Harbor

Jay R. Kaufman, ed.
$2.50

Proceedings of a Massachusetts Bay Marine Studies Consortium symposium May 24, 1984. Four speakers approach the title question from different angles: James Hoyte, Mass. Secretary of Environmental Affairs; Steven Horowitz, counsel to the special master in the Boston Harbor pollution case; Les Kaufman, New England Aquarium Curator of Education; and James Kelso, businessman and investor. *Available through the Massachusetts Bay Marine Studies Consortium, P.O. Box 110, Cambridge, MA 02142.*

Journal Reprints

☐ Properties: Counter-Ion Activity in a Cationic Polyelectrolyte Solution

Carlos Kienzle-Sterzer
G. Bakis
Dolores Rodriguez-Sanchez
ChoKyun Rha
MITSG 84-13J 5pp No charge

The counterion transport properties, represented by the chloride ion activity coefficient in cationic polyelectrolyte solutions and the effect of polymer concentration and ionic strength of the media in non-dilute regime are examined in this article.

Reprinted from Polymer Bulletin, v.11, 1984, pp.185-190.

☐ Solution Properties of Chitosan: Chain Conformation

Carlos Kienzle-Sterzer
G. Bakis
Dolores Rodriguez-Sanchez
ChoKyun Rha
MITSG 84-14J No charge

Describes the hydrodynamic volume, chain stiffness and local conformational freedom of an isolated chitosan molecule, especially as influenced by the degree of ionization and counterion concentration in the media. Presented at the U.S./Japan Seminar on Chitin, Chitosan, and Related Enzymes, University of Delaware, April 24-27, 1984.

☐ The MIT Sea Grant Marine Industry Collegium: A Technology Transfer Partnership of Industry, Academia and Government

Dean A. Horn
Norman Doelling
MITSG 84-7J 4pp No charge

The authors describe how the MIT Sea Grant Marine Industry Collegium was implemented to transfer technology among industry, academia, and government. Two examples of ongoing successful technology transfer efforts are given. Reprinted from American Society of Mechanical Engineers. Winter annual meeting (1982) paper no.82-WA/TS-3.

Overstock

The reports listed below may be ordered without charge

☐ Crisis Science: Investigations in Response to the Argo Merchant Oil Spill

Andrew M. Pollack
Keith D. Stolzenbach
MITSG 78-8 328pp

Using the scientific investigation of the *Argo Merchant* oil spill on Nantucket Shoals in December 1976 as a reference point, this study analyzed the goals of scientific action following a spill. The scientific response is presented chronologically, and the scientific quality of the various endeavors evaluated.

☐ An Analysis of Longshore Currents and Associated Sediment Transport in the Surf Zone

David W. Ostendorf
Ole S. Madsen
MITSG 79-13 169pp

Three theoretical models - two current models and a sediment transport model are derived, calibrated and tested in this report.

☐ Superman: A System for Supervisory Manipulation and the Study of Human/Computer Interactions

Thurston L. Brooks and
Thomas B. Sheridan
MITSG 79-20 280pp

Mathematical principles are developed for spatial relationships between a remote teleoperator vehicle and its tasks. For the designer, a unified theoretical framework provides an overview of manipulator and processor selection factors, interface design considerations, control language attributes and implementation factors, and control philosophies.

☐ **An Assessment of Undersea Teleoperators**

Thomas N. Sofyanos
Thomas B. Sheridan
MITSG 80-11 315pp

Examines general purpose, remotely controlled work vehicles and discusses representative costs for offshore divers and manned and unmanned submersibles. The role of remotely operated vehicle systems in offshore installation inspection and development trends for teleoperator systems are evaluated.

☐ **Documentation of Four Ocean-Related Computer Program Modules**

Ronald W. Yeung
MITSG 76-18 70 pp

1. MCTRAJ - An offshore oil-spill trajectory-simulation program.
2. TI4TRAN - probabilistic wind transition matrices to be used by MCTRAJ and NEARSHORE.
3. NEARSHORE - nearshore oil-spill tracking-simulation program.
4. TWOFOIL - seeks the solution of the two-dimensional lifting flow about two symmetric bodies.

☐ **Waves and Wave Forces**

Jerome H. Milgram
MITSG 76-19 30 pp

Impact of waves and wave forces on offshore oil structures is considered, built on Hogben's 1974 comprehensive review paper on this topic.

☐ **Being Prepared for Future *Argo Merchants***

Jerome H. Milgram
MITSG 77-10 48 pp

Describes events of the *Argo Merchant* grounding related to pollution of the seas. A high seas oil clean-up system is suggested, based on current and projected capabilities for collecting large quantities of oil from offshore spills and for protecting land areas from oil so viscous that pumping is impractical.

☐ **Offshore Petroleum Engineering: A Bibliographic Guide to Publications and Information Sources**

Marjorie Chryssostomidis
MITSG 78-5 366pp

This report is organized to provide access to existing literature and to help the reader locate future information sources. Includes addresses of publishers and pertinent offshore engineering organizations.

Enclosed: $ ________

Please check off those publications you would like to order, and return this entire page—or a copy of it—to the Sea Grant Program, Massachusetts Institute of Technology, Building E38-302, Cambridge, MA 02139.

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