MIT SEA GRANT
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Quarterly Report

Instamatic Technology to Improve Underwater Welds

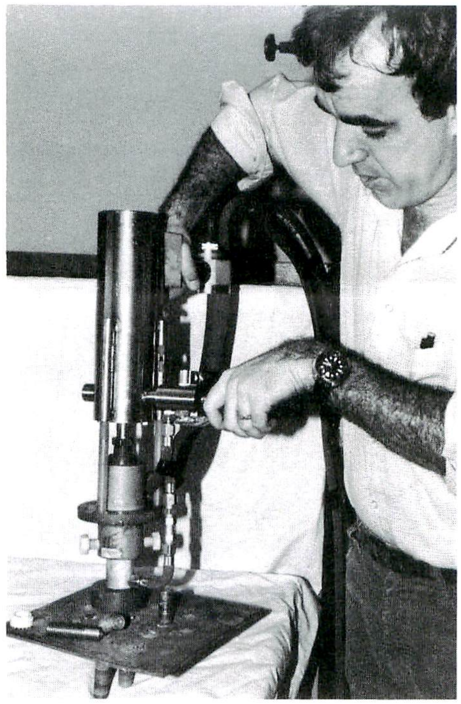
A recent trade magazine ad succinctly sums up the importance of good, reliable welds in offshore construction: *"If a Strong Wind can Sway a Skyscraper, Imagine what an Ocean Storm can do to a 60-Story Rig."* In fact, investigators suspect an inferior weld helped precipitate the collapse of the offshore platform, Alexander L. Kielland, during a North Sea storm in 1980; 123 men died in the catastrophe. Welding, even under ideal conditions, can be risky business.

Imagine welding offshore structure parts deep under the ocean. That is what Chris Von Alt, graduate student in MIT's Ocean Engineering Department, has been envisioning for the past year and a half. With Sea Grant support, Von Alt has designed and developed an arc stud welding gun for use either by an underwater telemanipulator or a diver without the exhorbitantly expensive hyperbaric chambers current methods require. An offshore operator can spend over a million dollars to outfit and deploy surface support equipment for one small repair job using a hyperbaric diving chamber.

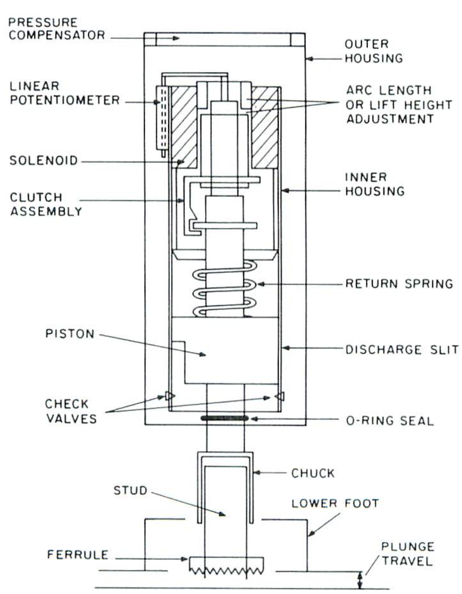
Even with all the expense, the impracticable ocean environment affords no guarantee of weld quality. Koichi Masubuchi, Principal Investigator of Sea Grant's underwater welding research, borrowed a concept from the evolution of camera technology to reduce the gamble of welding in remote and intricate surroundings. He pioneered the idea of "instamatic welding," packaging the various sub-tasks involved into an easy process that an inexperienced person – or a robot – can master. The welding research group works closely with Sea Grant's underwater telemanipulation research team, headed by Thomas Sheridan (see *Quarterly Report*, Fall/Winter 1982 and Winter/Spring 1982).

Von Alt incorporated the instamatic concept into the underwater stud welding gun. All an operator has to do is insert a stud and ferrule, position the gun, and pull the trigger to complete a weld.

The researcher's approach to building the arc stud welding gun was to use commercial dry welding technology and adapt it for underwater use. "Since the stud welding industry has been around for more than 40 years," Von Alt says, "I assumed



Graduate student Chris Vol Alt demonstrates a prototype of his underwater arc stud welding gun. Diagram shown below.



that the design of existing stud welding guns has been optimized." His tool has the capabilities of the most advanced commercial stud welding guns. A Nelson NS-20A model made available by the Nelson Stud Welding Division of TRW, Inc. is the basis for the new gun.

Problems welding guns don't encounter topside, but that need to be addressed underwater, are corrosion, water pressure, and brittle welds caused by excessively fast cooling of the molten metal. The underwater gun has a waterproof housing to isolate its inner mechanisms from seawater and prevent corrosion.

The waterproof housing is pressure-compensated so the force and speed with which the stud is plunged to the workpiece is not affected by ambient water pressure changes. Space between the inner and outer housings is filled with oil to pressure-compensate and further protect from humidity and salt penetration. Oil also lubricates the inner mechanisms and will help insulate against shock in case of an internal solenoid failure.

Cold seawater is not an environment conducive to quality welds. The molten metal cools too quickly, making the weld brittle. Expensive hyperbaric chambers have provided the required dry environment for welding, but rather than enclose operator (human or machine) and equipment in a bulky chamber, the new operation can take place in open water. When welding begins, pressurized gas jetting through a specially-designed assembly in the foot of the gun forces seawater from the immediate weld area.

A unique, Japanese-designed shield prevents the dispelled seawater from rushing back to the weld space. Constructed of layered stainless steel wire brush, the shield is a barrier with the flexibility to conform to surface deformities on the base metal. "Even though the base metal is still wet and there is still humidity, the effects of welding in a totally wet environment are minimized," Von Alt says.

Since welding is done from different positions, overhead, horizontal, or vertical, the force and speed at which the stud is

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plunged to the base metal must be variable. The hydraulic damping mechanism used to regulate the stud's return rate in commercial guns is too big for underwater use. The modified gun substitutes a newly-designed, lighter mechanism.

As the solenoid (electromagnet) lifts the stud into the gun for welding, oil from the outer chamber fills the inner chamber space created by the withdrawn stud. The speed and force of the returning stud are determined by the rate at which the oil can be displaced. A rotating piston regulates the size of the opening through which the oil exits.

Von Alt demonstrated a prototype of the new gun to some potential industry users. With their advice, he designed the current version, built by a local diving equipment manufacturer. Three other manufacturers, introduced to the gun through MIT Sea Grant's Marine Industry Collegium, are interested in building it commercially. Remote-controllability is an important selling feature.

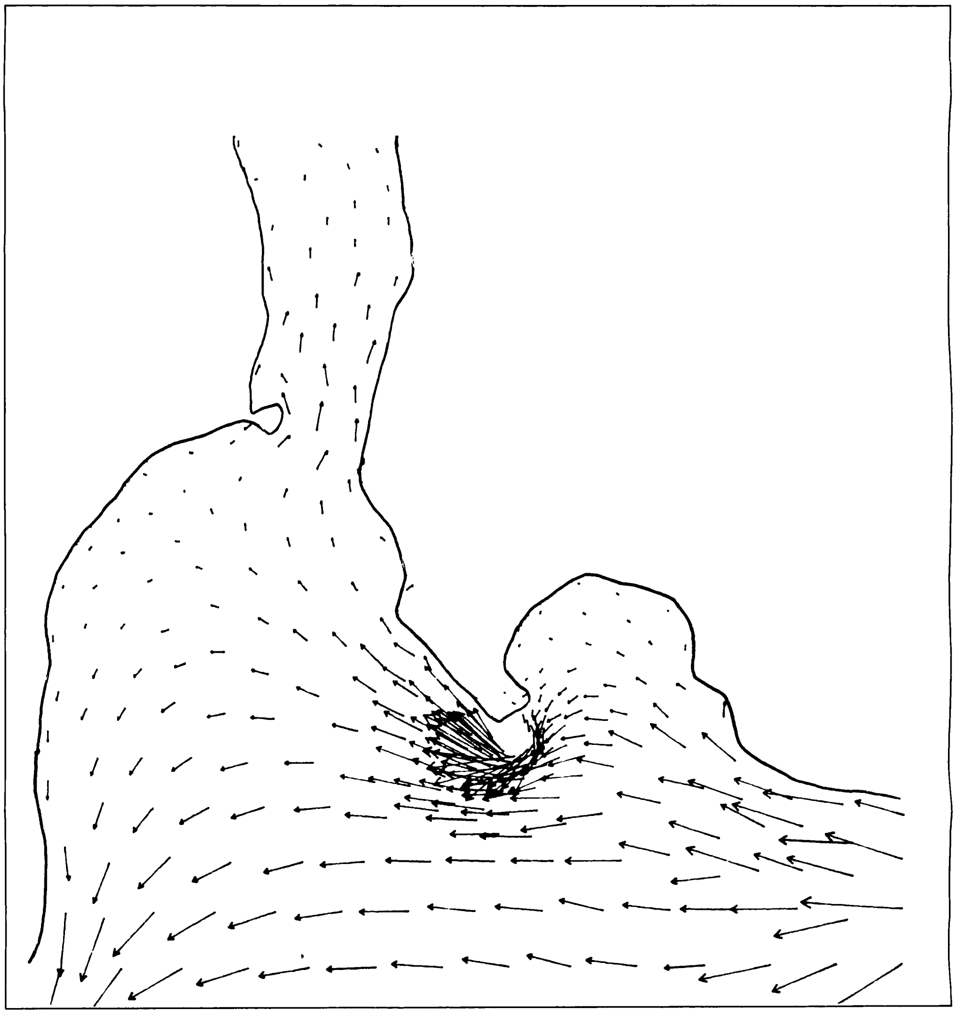
In spring, 1984, the gun will be tested in a pressure chamber at Perry Oceanographics Company, Florida. The following summer, actual performance will be evaluated on MIT Sea Grant's underwater vehicle at Woods Hole, Massachusetts. The Woods Hole experiment will be the first time a remotely-operated underwater weld has been performed. In lab tests at MIT the gun has worked well.

Von Alt is now designing a remote control system for evaluating welds, since it is impossible to achieve good welds consistently in the difficult ocean environment. The Kielland accident illustrates how disastrous a faulty weld can be. Currently, the gun's monitoring system records arc voltage and current and stud displacement. A microprocessor-based system would receive and correlate these data with a representation of a perfect weld made under identical conditions. The system can automatically adjust welding time until the actual data correspond with the model.

MIT Sea Grant, Kawasaki, Inc., and a consortium of small Japanese companies support the project. For more information: Koichi Masubuchi, 5-219, MIT, 77 Massachusetts Ave., Cambridge, MA 02139 (617)253-6820.

Tidal Model Developed for Craggy Coastlines.

Up and down the New England coastline there are many small, essentially closed tidal embayments which are ideal for small harbors and marinas. Coastal communities feel increasing pressure to develop these areas but are concerned with the environmental impact of low flushing rates and periodic dredging. Among the many natural processes which depend on the tidal and wind driven circulation in enclosed embayments are nutrient export from coastal marshes and the transport of red tide (paralytic shellfish poisoning) cysts. About a decade ago, MIT Sea Grant supported a study for calculating the circulation of materials in the 100-km wide Massachusetts Bay. Two widely used models resulted: CAFE, for water movement, and DISPER, for dispersion of dissolved substances. Because of the models' structure, they cost less to run for the main part of the Bay than for smaller semi-enclosed regions only 1 to 10 km across, the reason being that the same wave moving at the same speed across a much larger area can be tracked with fewer measurements.



Modeled water circulation at Millstone Nuclear Plant site showing strength of flood.

Editor: Elizabeth T. Harding
Program Director: C. Chryssostomidis
Writers: Lynne Newman Lawson, Debbie Levey, Elizabeth T. Harding

The MIT Sea Grant Quarterly Report reviews the Program's marine-related research, education, and advisory service activities at the Massachusetts Institute of Technology. Funding is provided by the National Oceanic and Atmospheric Administration through the Office of Sea Grant. Free subscriptions of the *Quarterly Report* are available on request from the MIT Sea Grant College Program, Guilding E38-302, Cambridge, MA 02139. Telephone (617)253-3461.

According to Keith Stolzenbach of the MIT Department of Civil Engineering CAFE and DISPER work very well when applied to fairly regular domains such as a large bay, but problems arise with the irregular boundaries and topography of craggy embayments. A time step model such as CAFE is extremely expensive because the small grid requires many, very closely spaced time measurements. A smaller region might require 10 to 100 more measurements than a large region, making CAFE and DISPER prohibitively expensive to run.

Professors Stolzenbach and John J. Connor, also of the Department of Civil Engineering, are adapting the models in the new project, named TEA (Tidal Embayment Analysis). They want to develop an alternate strategy for such computations based on frequency domain analysis, in which the frequency is known (e.g., the tidal period) while amplitude and peak variation can be calculated. In that case there are no requirements for small time steps imposed by small grid sizes. The proposed scheme uses frequency domain techniques to circumvent time step limitations and makes the necessary computations inexpensive enough to evaluate large numbers of alternative cases.

A linear version of the circulation model for TEA has been completed, and accepts input very similar to CAFE. The program computes water movement throughout a period of specified frequency for given values of tidal elevation changes and wind stress. For typical problems TEA runs up to 100 times faster than CAFE and has no difficulty handling small finite element grid sizes.

The new model will be applied to four case studies around Massachusetts Bay: a prospective marina, power generating plants in Massachusetts and Connecticut, and a pond by Cape Cod implicated as a source of red tide organisms. These case studies will compare computed circulation and dispersion with actual water movements inferred from available field data. In addition, the studies will provide an opportunity to systematically investigate the relative influence of natural forcing (wind, tide) and manmade activities (dredging, pipelines, etc.) on net circulation and flushing.

In the marina case study the flushing rate is crucial. Would bacterial contamination from shipboard wastes, and the oil and gas spilled during refuelling be trapped in the harbor and pollute it heavily, or would they be swept to sea, perhaps to taint shellfish flats on the way? Flushing rates were also considered in the small pond by Cape Cod, where spores linked with red tide outbreaks may move into the ocean.

Before computers became common laboratory accessories, Stolzenbach says that frequency domain techniques were the main methods for analyzing tidal problems because they were easier. Computers made it possible to work in the time domain (describing conditions at different times). For embayments, Stolzenbach says that time domain is too expensive but the "old fashioned" technique of frequency domain, proposed by co-principal investigator Conner, makes it feasible. While the technique is not new, Stolzenbach says that "in terms of implementing it in a practical domain, we think that probably nobody else is doing it at the state we're at." However, he adds that TEA still only solves linear problems while CAFE handles nonlinear, "so we can't match CAFE yet one for one."

If tides were a perfectly linear problem, water would move back and forth with no net motion and no flushing. Stolzenbach mentions, "The nonlinearities contribute to a net motion superimposed on the total motion. The effect of combined tides is for water that was in a semi-enclosed region to finally make its way out. A creeping slow motion is really the net difference of all the tidal movements."

TEA would be applicable in any semi-enclosed region with a well defined point where the tide enters and recedes. Since the model is meant for shallow water circu-

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Undergraduate Researchers at MIT

Hundreds of enthusiastic MIT undergraduate students would love to tackle a good research project. MIT UROP (Undergraduate Research Opportunities Program) gives them the chance. The unique program provides these creative learners opportunities to collaborate with MIT faculty actively engaged in research projects. Undergraduates can participate in every phase of research activity: proposal writing, establishing research protocol, experimenting, head scratching, analyzing results, presenting results orally and in writing, failing, and achieving. The majority of UROP students earn course credit for UROP projects; others earn a modest stipend. Many do it just for the tremendous experience it provides.

MIT Sea Grant participates in UROP by supporting undergrads interested in marine research. Each semester, Sea Grant invites UROP proposals and selects a number of winners. Two recent winning Sea Grant projects are described below.

A Novel Ship Propulsor

UROP student Bill Coney is an MIT senior majoring in Ocean Engineering. He is trying to solve an efficiency problem in ship propellors: propellors are designed for uniform water speed, but water speed inside a ship's wake is slower than the speed outside. Coney wants to convince the propellor that the ship isn't there by effectively eliminating the wake entering the propellor.

He proposes placing a small, trolling propulsor between the ship and its main propellor to boost water speed in the wake. He estimates that getting the most propellor thrust for the least energy could save thousands of dollars in fuel. Tests in a water tank using screens to create different wake configurations showed a two to six percent efficiency improvement using the second propellor. "Any measurable difference, even two percent, is significant when you consider the high cost of fuel and the amount ships use," Coney says.

By making water speed uniform, the auxiliary propellor also reduces noise, important to stealthy Navy ships, and cavitation on the main propellor, which slows the propellor down and ultimately damages it.

Heparin from Fish Wastes

Every year tons of fish viscera are thrown overboard when fishermen gut their catch at sea or on shore. These fish viscera contain heparin, a valuable clinical drug, whose uses range from the prevention of blood clots to the treatment of heart disease.

Biology students Nancy Walworth, a junior, and Aron Judkiewicz, a senior, are studying the possibilities of extracting heparin from fish wastes in commercial concentrations. They have taken the substance from flounder, scallop, cod, mussels, tautog, scup, and clam. The students have also used bio-assays to characterize the heparin's physio-chemical properties and compare them to those of commercially available heparin from pigs and cows.

Walworth and Judkiewicz have found heparin concentrations comparable to, and in some marine species higher than, amounts found in animals. Their extraction method, a combination of procedures developed through experimentation, is about 38 percent efficient. They hope to increase that efficiency by examining each step in the extraction process to see where heparin is being lost. Eventually they want to come up with a simple and practical extraction scheme that can be carried out, at least in part, on shipboard to minimize the volume of viscera hauled to shore.

lation problems, it doesn't take into account stratification and therefore wouldn't be appropriate for estuaries or other significantly stratified water.

Previously, most people have used tidal models to predict peak motion of tides so that they could anticipate how much to reinforce a bridge or pier. For the new work Stolzenbach says, "We're not so much interested in peak tidal velocity as in the long-term characteristics. Whenever we have a choice we are designing the technique to be good at long-term processes."

E. Eric Adams of the MIT Energy Laboratory is the third co-principal investigator, and students contributing to the project are Joannes Westerink and Antonio Baptista.

The work is supported by MIT Sea Grant and the MIT Energy Lab's Electric Utilities Program. For more information: Keith Stolzenbach, 48-321, MIT, 77 Massachusetts Ave., Cambridge, MA 02139 (617)253-6761

Sea Grant Announces Ten Undergraduate Research Awards

Ten undergraduates will take on a marine-related research challenge with Sea Grant support during the next semester, according to E.R. Pariser, Associate Director of Education. Their results, like all Sea Grant projects, will be documented in a final report which will be available through the Information Center.

Faruk Halil Bursal will analyze the kinematics and dynamics of a simple undersea manipulator arm to code a program that will yield realistic data for its behavior under user-imposed constraints. Eventually he will integrate the dynamics program with a graphics terminal to display resulting motions simultaneously as the equations are solved. (The faculty advisor is Professor Neville Hogan.)

To simulate conditions during a yacht race, John Cross will design, build and test a series of model keels to measure lift and drag over a range of water speeds and angles of attack. The data in this project will then be used to predict the performance of full-sized keels. (Professor Justin Kerwin)

Mark DeCew will adapt existing underwater photography and side-scan sonar equipment to collect light and sound images of marine wildlife. His specific target is the large aquatic species believed to reside in Loch Ness, Scotland. (Professor Harold Edgerton) As an alternative to the diesel engines now used in fishing boats, two students will help design highly efficient Brayton-cycle gas turbines John P. Deyst will consider where to position the engines, the arrangement of major subassemblies, and an analysis of the transmission options which could transfer power from the gas turbine engine to the propeller. Paul Shiu-ping Sheng will utilize computer techniques to analyze gas turbine engine performance, write a user's manual for the poorly documented Naval Engine Performance Computer Package, and simulate gas-turbine components on a computer. (Professor David G. Wilson) A mathematical model for distant shipping noise has been developed and analytical solutions interpreting ambient noise have been obtained. Andrew Gray will find mathematical results by performing calculations, evaluating numerical equations and plotting and analyzing functions. (Professor P.N. Mikhalevsky) Two students will work on marine risers, the structures that connect the bottom of drill ships to the oil heads. George A. Kriezis will predict the analytically dynamic response of a marine riser subjected to excitation from a uniform current. He will set up the mathematical model, solve the resulting differential equations numerically and compare results with available experimental data. While analyzing experimental data to derive the force that a marine riser experiences during drilling operations, Masakazu Mitsumata will set up a mathematical model and solve the resulting differential equations numerically. (Professor Chryssostomos Chryssostomidis) Catherine A. Smith will analyze ocean heat storage data, map the average storage values for all months, compute the differences and compare them against the known surface heating values. In the coming months she will create more large scale maps of the temperature at depth over the entire ocean during both El Nino and non-El Nino years. (Reginald Newell) Professor Michael Holick's full-scale Sea Grant project assesses the potential commercial feasibility of large-scale heparin extraction from tons of fish viscera that are normally discarded at sea. Mei Wang wants to evaluate additional species of fin and shellfish for biologically active heparin and experiment with the extraction procedure to maximize heparin yield while minimizing the time involved. This project complements the heparin research of Nancy Walworth and Aron Judkiewicz which we described in a previous story.

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Abstracts

☐ MIT Summer Session 1984

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A Preliminary announcement brochure lists MIT special summer programs for professional men and women to keep pace with developments in their fields. 1984 programs range from "Orientation for Executives Assigned Overseas in France or French-speaking Countries" to "Computer-Aided Multivariable Control System Design." Of special note to Quarterly Report readers, three marine-related courses are being sponsored by Sea Grant: "Design of High Efficiency Turbines," "Corrosion: The Environmental Degradation of Material," and "Recent Advances in Welding Technology." Sea Grant is holding a special one-week course, June 25-29, on Seakeeping of Ships and Deepwater Mooring and Riser Dynamics. The preliminary announcement and detailed course description of the marine courses are available through Sea Grant.

☐ Wastewater Management: Technical Alternatives and Regulatory Outlook

MIT/Marine Industry Collegium
Opportunity Brief #32
MITSG 83-9 21pp $3.50

Although ocean disposal of sewage sludge is against current national policy, new methods of ensuring protection of the marine environment and increasing its fertility could make ocean disposal not only acceptable but desirable in the future. At MIT progress has been made in two important technical areas related to wastewater management.

The first part of this report discusses research in the use of enzymes to precipitate phenols and related chemicals from industrial wastewater. The second section describes continued development in the electron irradiation process for treating municipal wastewaters. Finally, a discussion of new trends in financing water and wastewater projects in light of decreasing federal subsidies and strict regulation is presented.

☐ Application of Marine Acoustic Systems

MIT/Marine Industry Collegium
Opportunity Brief #33
MITSG 83-10 52 pp $5.00

This report examines three ocean applications of new and powerful communication technologies that were developed initially for application in other scientific disciplines. Ocean acoustic tomography, similar to the CAT (computer aided tomography) scan which uses x-rays for imaging parts of the body, deploys underwater sound waves to produce a picture of the inner ocean. The Digital Ocean Bottom Hydrophone (DOBH) is a self-contained instrument that can be left on the sea floor to collect acoustic and seismic data. The Digital Acoustic Telemetry System (DATS) applies modern communication techniques to communicate digital information from underwater vehicles or instruments without a cable.

☐ Enzymatic Removal of Hazardous Pollutants from Industrial Aqueous Effluents

Alexander Klibanov
MITSG 83-17 18 pp $3.50

A new method is described for the removal of phenols and aromatic amines from industrial wastewaters. It involves the treatment of wastewater with horseradish peroxidase and hydrogen peroxide. Phenols and aromatic amines are precipitated from water due to their enzymatic crosslinking. The peroxidase treatment has been successfully used to dephenolize samples of real industrial wastewater.

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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☐ Trawl Design Form

Clifford A. Goudey
MITSG 83-24 50 pp $8.00

Graph paper for use in the design of trawl nets. 11 x 16½″ sheets of 5mm, 60 degree grid lines, 157 meshes horizontal by 60 meshes vertical. Panels can be outlined, mesh for mesh, to ensure compatibility with adjoining panels and to minimize waste when cutting panels from stock. 50 sheets bound and punched.

☐ Trawl Detail Form

Clifford A. Goudey MITSG 83-25
50 pp $6.00

Similar to MITSG 83-24 above, but smaller sheets and slightly larger mesh size. 11″ x 8½″ sheets of 7mm, 60 degree grid lines, 65 meshes horizontal by 51 meshes vertical. Suitable for simpler net design or establishing local twine details of all nets. 50 sheets bound and punched.

☐ Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts

MITSG 83-30 124 pp $2.50

The Guide is an update of the 1979 edition. A concise directory of marine information sources has proven useful to individuals, local groups. and business organizations. This revised edition incorporates deletions, additions, and recommendations from people who have used the earlier editions and from the organizations listed. Each entry includes office hours, address, telephone numbers, and a description of the organization and its services. The Guide is cross-referenced and indexed.

☐ Marine Related Research Directory

Susan D. Stolz, comp.
MITSG 83-31 64pp No charge

This directory provides an overview of ocean and coastal research at MIT. Projects, researchers, and brief abstracts are organized by subject areas. These include: fisheries — food and drugs from the sea; marine biology; marine mineral resources; alternate marine energy sources; pollution control, including oil spills and waste disposal; oceanography, including chemistry, geology and physical oceanography; ocean engineering, acoustics, other instrumentation, underwater vehicles, and offshore structures; ship design and structures; shipping and transportation systems. Indexes by subject area and principal investigator help make this directory easy to use.