MIT Sea Grant Quarterly Report

Gas Turbine Engine Could Boost Efficiency

Fuel costs alone can account for half the expenses of a commercial fishing boat's voyage. A more efficient engine would reduce these escalating costs and allow fishermen to catch more fish per trip or else to increase the profit. Considering that small marine engines represent a very limited market to prospective manufacturers, design changes should be simple and feasible; one option is to convert available engines.

David Gordon Wilson of the MIT Department of Mechanical Engineering suggests that variations of gas turbines installed in small marine craft, particularly fishing boats, could dramatically raise fuel efficiency compared to conventional diesel engines. "Our recent preliminary design studies have shown that engines converted from off-the-shelf engines should be able to improve on the fuel consumption of diesel engines by about 30 percent," estimates Wilson, when the ship is going from full load to 25 percent of its power. (The type of fishing determines whether the boat spends most of its time at full power on the way to a site, or operates at greatly reduced power in the fishing grounds. Most of the time the boats work under partial power.)

The gas turbine cycle, called a Brayton cycle, operates in steady flow with combustion at constant pressure. While larger gas turbines run more efficiently, the smallest ones manufactured with any commercial significance are several hundred horsepower — enough for a fishing boat.

Compression and expansion processes are more efficient in a gas turbine than in a diesel engine, even though diesel has the advantage of burning fuel at a higher temperature. For comparison, Wilson says that small automobile engines give a maximum efficiency of about 28 percent, compared to 20 to 24 percent with a spark ignition engine. Very large diesels such as 30,000 hp engines in ships reach 40 percent, with scores of 50 percent in experimental versions. Wilson predicts that the gas turbine will attain well over 55 percent peak efficiency, even in the size range appropriate for fishing vessels.

Not only would a Brayton cycle engine save an impressive percentage of fuel, says Wilson, but it would produce largely non-noxious exhaust. The output of nitrous oxides and particulates is very small compared to diesel engines. Wilson lists other strong points: "It's easy to get hot water or steam out of a gas turbine by putting on a waste heat boiler. It starts very rapidly. But the principal advantage for the fisherman is that it needs very little maintenance.

The turbine transfers energy to the compressor via a shaft in a simple gas turbine cycle. In a regenerative engine cycle, energy in the exhaust is transferred thermally using a heat exchanger. "A simple cycle operates best at very high pressure ratios — higher, in fact, than can be achieved because of mechanical constraints," explains Tom Wolf, a graduate student involved in the work. "However, the highly regenerative cycle which we're working on is optimized at a much lower pressure ratio, resulting in much lower working stresses." He claims that "highly regenerative" means about 95 percent or better heat exchange thermal efficiency. The low pressure ratio, highly regenerative cycle for small, high efficiency gas turbine engines looks like the most attractive mode of operation, says Wilson.

Using two gas turbines donated by the U.S. government for the MIT Sea Grant sponsored project, Wilson and Wolf plan to compare fuel consumption at different power levels with the manufacturers' estimates. Then they will dismantle the engine and convert it to work on the more desirable low pressure ratio cycle.

"Marked gains in off-design performance can be achieved by converting a simple-cycle engine to a low pressure ratio highly regenerated cycle," says Wilson. Engines with particular promise should be subject to a more detailed investigation of hardware modification.

Most existing gas turbine engines have been optimized for compactness or minimum weight, rather than for maximum thermal efficiency. They tend to

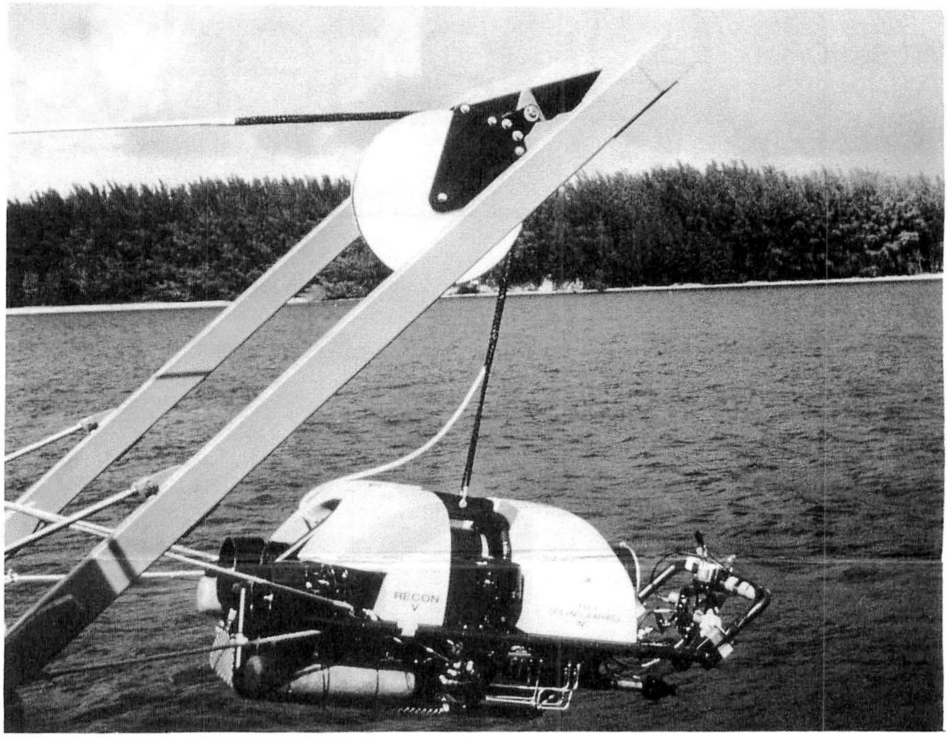
In this issue

either be simple cycle with a fairly high pressure ratio, or have a moderately effective regenerator with a compromise pressure ratio giving compactness and some improvement over the simple-cycle fuel consumption. The current design study modifies an engine of moderate pressure ratio to give a low pressure ratio and is fitted with a high-effectiveness regenerator.

Calculating off-design performance is generally an involved and tedious process. Wilson's group acquired a powerful, widely used computer program called NEPCOM which was written specifically for this purpose. Off-design performance is being simulated using NEPCOM II, and the reliability of the results has been checked by hand calculation.

Wilson admits that turbines tend to have problems with sea atmospheres. Salt melts in the combustion chamber, and then may stick onto the turbine blades. However, since they are smaller and lighter than diesels and can be mounted higher up in the ship rather than being buried in the engine room, gas turbines also tend to free up some cargo space.

"I think fishermen would use the gas turbine engine if it were demonstrated to them and if it were available at the right price," Wilson believes. Rather than make the engines from scratch for the limited fishing boat market, he suggests that a converter might like to buy new or used engines and modify them for the purpose by adding heat exchangers.



This tethered free-swimming submersible was recently made available to MIT by the Perry group of companies for underwater research.

Deep Sea Robots

Robots have recently moved into the factory, into the advertising business — even into the home. Now they are taking to the water, surveying the ocean floor and inspecting ocean structures and vessels. Robots are moving to the oceans with advances in offshore mining operations, scientific explorations, and military affairs. As these activities probe ever deeper into the sea, human safety and the cost of ensuring it becomes prohibitive, and the need for human replacements, robots, increases.

Unlike the traditional conception of robots, undersea robots look and act more like vehicles than like human beings. They are remotely operated vehicles (ROVs) powered and controlled through a cable (umbilical cord) tethered to a surface station or ship. There are three species of tethered ROVs: bottom crawlers, which maneuver on wheels or tractor treads on the ocean floor or on a structure; free swimming vehicles that glide through the water; and towed vehicles pulled by a surface ship, moving only forward or up and down by winch. Another class of ROVs is untethered (no umbilical cord), self-powered and -propelled, and controlled by acoustic commands or pre-programming.

At the control panels of these aquatic robots are people from three sectors, science, industry, and military. ROVs support scientific researchers with such tasks as inspecting underwater waste disposal sites, surveying the ocean floor, collecting samples and cores, and photographing. Military personnel use ROVs to search for and identify lost or sunken craft, monitor poison gas canisters, or survey bottom sites and cable routes, among other missions. But by far the most prevalent user of ROVs is industry, particularly offshore oil and gas companies. ROVs assist in all phases of the offshore oil and gas operation, from exploration and production to delivery. Traditionally, jobs done for the industry by ROVs have been performed by human divers, but divers are reaching their physiological limits as undersea tasks take them into deeper and more dangerous waters. ROV technology has not developed to the point where human divers can be replaced totally, in fact this goal is far off still and may never be fully achieved; some even doubt it should be. But ROVs can be equipped to help underwater in seven areas:

Inspection. The most popular use of ROVs is inspection. Closed-circuit TV cameras aboard the vehicle document the location and/or condition of undersea structures, detecting leaks, bent and broken members, etc.

Monitoring. TV cameras and depth sensors observe and measure operations in progress, such as grouting and installation of piles.

Survey. The vehicle is equipped with an echo-sounder, side-scan sonar, sub-bottom profiler, and/or TV camera for

MIT Sea Grant
Quarterly Report
Fall/Winter 1982

Editor: Elizabeth T. Harding
Program Director: C. Chryssostomidis

Articles by Lynne Newman and Debbie Levey

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, Building E38-302, Cambridge, MA 02139. Telephone (617) 253-3461.

mapping and sampling natural and human-made bottom features along pipeline routes or at sites for placement of structures.

Diver Safety/Support. ROVs usually are not specifically designed for accompanying divers, but they can photographically monitor the divers as they work in case of danger, direct them to the workplace, and provide light, tools, or a loading platform.

Search/Indentification. Using surveying equipment an ROV can locate and identify lost equipment or debris which might interfere with fishing.

Installation/Retrieval. Equipped with a manipulator arm an ROV can collect small artifacts, attach lift lines to recover debris and equipment, and bury cable by water jetting.

Cleaning. ROVs can be fitted with brushes and water jets for cleaning marine-fouled ship hulls and structures.

Use of ROVs is limited, however, because their ability to manipulate like the human arm and hand is primitive. Unless industry redesigns tasks to require a minimum of manipulative ability, something which seems unlikely to happen, or unless the technology of manipulators for ROVs improves, application of undersea vehicles will remain limited. MIT Sea Grant supports several projects aimed at solving the technical problems associated with underwater telemanipulation. The Naval Oceans Systems Center (NOSC) has incorporated results of Sea Grant research on computer control systems into a manipulator arm it has developed which has five joints, sufficient for most pick-and-place operations, and can lift a 14-pound load in salt water.

Recently a researcher at MIT Sea Grant designed and built a sensor that improves the touch sensitivity of a manipulator hand. A hand fitted with this sensor will have improved dexterity to perform simple maintenance and repair tasks. (*Quarterly Report*, Winter/Spring 1982)

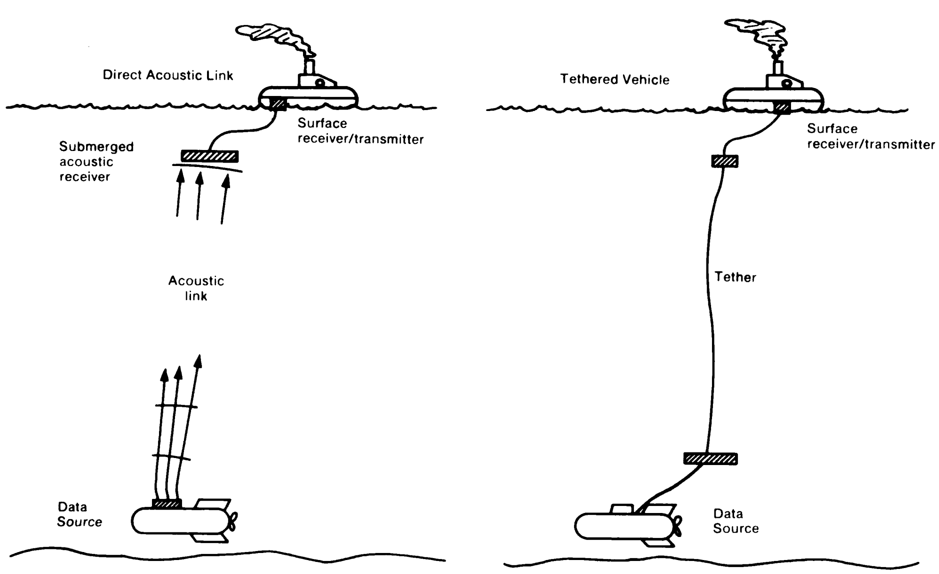
A further constraint on use of ROVs is complications with the umbilical cord connecting the vehicle to the surface station and providing power. Like a dog on a leash, the vehicle can become entangled in its umbilical cord, or the cord becomes entangled on bottom obstructions or mooring lines. Without this cable, however, power and control would be so restricted that manipulation or data-gathering might be extremely limited, even impossible. Some effective means of communicating through water without cables needs to be devised. Since a TV camera on the vehicle is the operator's "eye" for navigation, sensing methods independent of the cable also must be improved before the cable is eliminated.

The next generation of undersea robots will shed the troublesome umbilical, but much research is needed to prepare for this step. The U.S. Navy and the U.S. Geological Survey (USGS) are pioneering the technology for these independent systems. Increased use of microprocessors and fiber optics will contribute to more sophisticated control systems and command/control data processing. (*Quarterly Report*, Winter 1980) NOSC and the University of New Hampshire have built two prototype vehicles, EAVE EAST and EAVE WEST, to test untethered vehicle technology. The EAVE (Experimental Autonomous Vehicle Program) vehicles were developed for the USGS Outer Continental Shelf division. MIT Sea Grant has fashioned a sophisticated digital computer simulator of undersea vehicles in order to test control systems without having actually to build and install them in ROVs. (*Quarterly Report* Winter/Spring 1982) Untethered systems probably will be weaned on research assignments requiring less complex data gathering capabilities.

Even while this research progresses, though, the technology of tethered vehicles has yet to be perfected. For example, stronger, lighter, abrasion-proof cables need to be developed. Vehicle thrusters should provide more power for working against forceful currents and for maneuvering heavy loads. There is great opportunity for using ROVs to assist divers if vehicles would be designed specifically for the purpose. A method also should be devised for compensating for heaving of the surface support ship since the rocking disrupts TV monitoring and photography aboard the ROV. The Perry group of companies recently made available to MIT Sea Grant a tethered, free-swimming submersible for experimenting with advanced technologies for these vehicles.

Tethered commercial ROVs of the near future will be specialized vehicles developed by the oil and gas industry with advanced manipulation capabilities and special-purpose tool packages. Some such systems already have been built, for instance, a vehicle designed specifically for pipeline burial and one for maintenance of structures, with dedicated tool packages for installing and replacing specific parts. Specialization also is the trend in the deep-ocean mining industry.

Undersea robot technology has a long road to travel before its real contribution to industrial, military, and scientific deep-water operations is realized. But the pressing need for robots to do what humans cannot do safely or economically underwater will continue to spur research that paves the way.



MIT Sea Grant project is developing acoustic system for ROV communication.

MIT Summer Session Courses

The MIT Sea Grant College Program and MIT's Summer Session Office will sponsor several week-long courses at MIT this summer for engineers and professionals in ocean-related fields. The courses include: Corrosion: The Environmental Degradation of Materials (July 11-15); Seakeeping of Ships and Semi-Submersibles and the Dynamics of Oil Producing Systems (July 18-22); Design of High-Efficiency Gas Turbines (July 18-22); Combined Analytical and Experimental Methods for Solving Residual Stress Problems in Weldments (August 8-12). Brochures describing the courses in greater detail are available through the Sea Grant Communications Office.

Strengthening Ships for Ice Navigation

Guidelines for reinforcing ice transiting vessels vary with different regulatory bodies around the world. Recently two ships which followed the strictest rules, the Canadian Arctic Shipping Pollution Prevention Regulations, nevertheless suffered severe damage from ice.

While ships need substantial protection in ice-choked waters, costs from overdesigning can be formidable. For example, thickening the shell plating of a Coast Guard ice breaker by 0.125 in. (3.175 mm) might add around 90 tons and cost about $250,000.

To define strengthening criteria for navigating in ice, says Paul Xirouchakis of the MIT Department of Ocean Engineering, requires a structural design methodology to specify the scantlings (reinforced plate thicknesses) and spacings of various structural members. He is also examining the influence of ice properties and hull structural parameters on the response.

Strengthening requirements can be classified into first-yield, ultimate plastic, gross tearing and fatigue criteria. These categories must be prescribed for the primary, secondary and tertiary response structural levels. Referring to the deformation of the hull girder, the primary level includes the longitudinal and transverse strength. The secondary level considers the stiffened plating deformation with criteria for transverse frames and longitudinal stringers. The tertiary level involves the plating deformations.

The structural design method must also consider the prevailing sailing conditions: continuous motion in level ice, impacts from broken ice floes hitting the hull, hull striking against an unbroken ice edge (ramming), and compression of the hull in ice. The method must also give guidelines depending on the time of year, the geographic location, the assumed ice conditions, and the type of ship (ice breakers, cargo ships, tugboats).

Sea ice properties vary enormously depending on the size and orientation of ice grains, ice temperature, salinity, brine volume, strain rate and degree of confinement. Newly frozen smooth sheets create different problems than ragged multi-year deposits with ridges, rubble fields or fragmented ice covers. The ice failure modes — bending, buckling, crushing — also influence the maximum ice loading.

Many of the current regulations are based on work done in Finnish shipyards by B.M. Johansson, who selected the maximum displacement of the ship and the amount of installed horsepower as basic variables to describe the local ice loads on the structure. Xirouchakis explains, "The bigger and more powerful the ship is, the more you expect it to go into thicker ice where it would encounter higher loads." Separating the pressures where damage occurred from those which left ships unscathed, Johansson created guidelines for designing the vessels to withstand certain pressures.

Whether the ship escapes damage from ice depends on many more parameters besides the size of the vessel and the horsepower, says Xirouchakis, including the ship geometry, the type of ice and the vessel speed. "The model we're trying to develop takes into account the type of ice feature, the expected failure mode and the prevailing sailing conditions."

Xirouchakis describes ice failure as a very difficult problem because of the poorly understood behavior of ice, particularly at the higher strain rates. "In some cases we're interested in impact conditions, or moderately high strain rates. Also, we don't know much about the various failure mechanisms. Most probably there will be a mixture of buckling, bending and crushing."

Engineers commonly choose one of two approaches to determine the design pressure. They could study the force of the current or wind which drives the ice to make a model and find the pressure. Xirouchakis says the easier way is to take the maximum expected pressure, which involves asking what the maximum load is that a given ice field can sustain, or the maximum load that can possibly be applied to the structure. However, the number of parameters which affect ice properties complicates the second approach.

Besides trying to describe the ice load, understanding the ice strength and how it depends on parameters such as the rate of pressure application, Xirouchakis says, "All this has to be done in a simple way, or else people won't use it. We should be able to explain how it depends on the given ice feature." The work is done theoretically because of the immense difficulty of modeling real or synthetic ice, especially describing local ice load. However, theoretical predictions are compared with reported ice damage records.

Usually ships are fortified against ice by adding thicker plates and more stiffening directly above and below the water line. Xirouchakis feels a more integrated design is achieved by redesigning the whole vessel from the beginning as an ice transiting ship. For example, an ice transiting vessel might be designed up to a certain deck level with transverse framing to combat local ice loading. But the motion of an ice breaker which rides up on ice, slides back and rams up on the ice sheet again requires stiffening elements in the longitudinal and horizontal direction.

Robert Stortstrom, Geoffrey Abbott, and Esther Chi-Fang Chen have participated in the project, which is financed by MIT Sea Grant and the American Bureau of Shipping. Stortstrom and Xirouchakis showed how the scantlings, stiffening and spacing influence the strengthening mode when level ice compresses against the side of the vessel. Eventually the work should be compared to experimental evidence. The computer program to do plastic analysis, developed by Abbott, could be used as a design approach for the ultimate strength of the grillage in the side shell structure. Since classification societies and regulatory bodies need formulas in addition to computer models, Chen is working on analytical models which wil produce results to compare with Abbott's program predictions.

Attention Quarterly Report Subscribers

In the last issue, we announced an update of our mailing list and asked that you return a subscription card to let us know whether you wanted to continue receiving the *Quarterly Report*. If you haven't responded to that request, please return the card or drop us a note. The revised mailing lists will be used for our spring issue, to be published in June.

MIT Sea Grant

Abstracts

☐ 10th Annual Sea Grant Lecture: Biotechnology in the Marine Sciences

MITSG 82-2 40 pp. No charge.

Rita Colwell, Director of the University of Maryland Sea Grant College Program and a well-known microbiologist, delivered the 10th Annual Sea Grant Lecture as a keynote to a two-day seminar in Biotechnology and Genetic Engineering. Dr. Colwell's overview provides insights into the potential of applying these new sciences to aquaculture, marine pharmaceuticals and bioproducts, biofouling, and marine pollution control.

☐ Offshore Geotechnical Evaluation

MIT/Marine Industry Collegium
Opportunity Brief #27
MITSG 82-3 16 pp. $3.50

Important advances have been made in geotechnical analysis for designing offshore structures. Existing *in situ* testing procedures have been improved through extensive comparison and calibration of *in situ* tests. A "piezocone penetrometer" has been developed which provides simultaneous measurement of cone resistance and pore pressure. Variability of soil property estimates gathered by field measurement can be quantified and integrated into a comprehensive, quantitative analysis of the geotechnical risk in offshore structures.

☐ Directions for MIT Research in Unmanned Underwater Work Systems

MIT/Marine Industry Collegium
Opportunity Brief #29
MITSG 82-4 7 pp. $3.50

Research in controlling unmanned underwater work systems progresses with MIT Sea Grant support. Projects include vehicle simulation (a sophisticated simulator has been developed); manipulator systems (towards a working demonstration of a digitally driven, force-reflecting manipulator servo-system using brushless D.C. motors, and computer-graphic display aids for the operator of a remote work vehicle); relative motion of manipulator to work object (a demonstration system using a passive, lightweight six-degree-of-freedom arm has been completed); and touch sensing (using fiber optics).

☐ Dynamic Response of Marine Risers, Tension Legs, Cables and Moorings

MIT/Marine Industry Collegium
Opportunity Brief #30
MITSG 82-5 8 pp. $3.50

Major efforts are underway to obtain experimental data on the drag forces and dynamic response of riser-like systems subject to steady currents, and to steady currents and surface platform motion. Current investigations are concerned with drag coefficients found when the cylindrical system vibrates in response to vortex shedding forces; "in-line" alternating displacements; and alternating displacements perpendicular to the current flow. Field tests have been done in Castine, Maine and experiments performed on a scale model riser in a towing tank in Athens, Greece.

You may order one copy of these reports free of charge.

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.

Name ______________________ Title ______________________

Organization ______________________

Address ______________________

____

☐ Small Scale Tidal Power Plants, Part 1: Performance Part 2: Capital Cost

James A. Fay, Mark A. Smachlo
MITSG 82-9/10 30 pp. and 28 pp.
$5.00

Currently in Maine there is interest in considering an integrated system of small tidal power facilities in lieu of one large project. Without taking sides in the large versus small discussion, this two-part report develops a generic approach to the preliminary design and costing of a small-scale tidal power project. It provides information to help quantify technical performance and capital costs and discusses environmental effects.

☐ Cone Penetration and Engineering Properties of the Soft Orinoco Clay

Amr S. Azzouz, Mohsen M. Baligh, Charles C. Ladd
MITSG 82-11 53 pp. $5.00

Construction of an offshore platform design requires knowledge of sea floor soils: their ability to support gravity loads and to resist horizontal forces from waves, currents and seismic activities. This report discusses methods for identifying soil characteristics. The emphasis is on comparing the relative advantages of *in situ* versus conventional and "sophisticated" laboratory tests. Observations have been made at two widely separated borings in 40 m thick deposits of soft, plastic, Orinoco clay, a sediment found extensively offshore Venezuela.

☐ A Static Analysis Technique for Multi-Leg Cable-Buoy Systems

Ronald S. Harichandran, H. Max Irvine
MITSG 82-13 78 pp. $5.00

Surface moored buoys have been used for ocean marking, mooring, and navigation. Submerged buoys and their moorings used to support scientific instrumentation, such as current meters and sensors, must be controlled from moving in a dynamic ocean environment. Sea Grant research, described in this report, has explored static analysis as a method to be used for developing design procedures to properly locate anchor points on the seabed and to determine cable locations for multi-leg, cable-buoy systems.

☐ Marine-Related Research at MIT 1982

Barbara Steen-Elton, comp.
MITSG 82-14 52 pp. No charge.

Each year Sea Grant issues this directory to describe the range of marine-related projects at MIT. Short descriptions of research in progress pinpoint major objectives and list the names of the principal investigators. Indexes are by subject area and principal investigator.

☐ Sea Grant Publications for the Fishing Industry

Lynne M. Newman, ed.
MITSG 82-20 119 pp No charge.

This directory is a compilation of publications that have been written and produced from throughout the Sea Grant network for the fishing industry. The topics are organized under five major headings: Fish Harvesting; Fishing Vessel Design and Operation; Fish Handling, Preservation, and Processing; Fishing Economics and Management; Fish Ecology and Aquaculture. Prices and ordering information are included.
