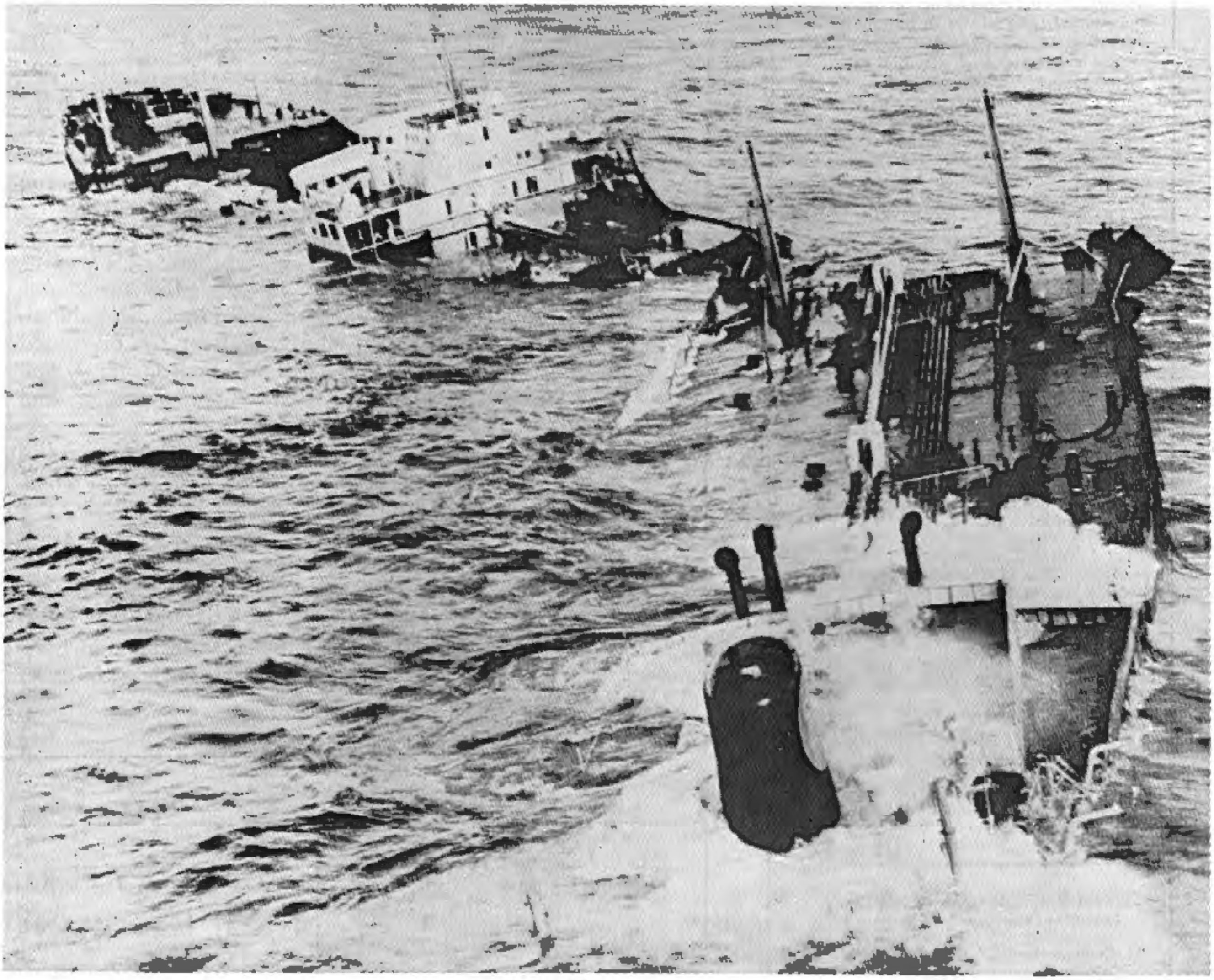
PROCEEDINGS

OF THE MARINE SAFETY COUNCIL



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PROCEEDINGS

OF THE MARINE SAFETY COUNCIL

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COVERS

Front: Ten years ago, on March 18, 1967, the supertanker *Torrey Canyon* grounded and broke up off Land's End, dumping thousands of tons of crude oil into the sea. The oil caused extensive damage on both sides of the English Channel, and focused worldwide attention on the need for preventing and minimizing the ill effects of such accidents.

The international approach to the problem of marine pollution has yielded significant developments over the past 25 years, as recounted in the article at page 94.

Back: The LNG carrier *Polar Alaska,* capacity 71,500 cubic meters, is one of the two vessels currently involved in U.S. export of LNG, trading between Alaska and Tokyo. Although the U.S. now exports more LNG than it imports, this situation is expected to change in the near future. The anticipated increase in LNG movement into U.S. ports is prompting a streogthening of Coast Guard safety standards for LNG carriers.

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maritime sidelights

PUBLIC HEARING

The Coast Guard will hold a public hearing June 21–23, at 9 a.m. in room 2230 of the Department of Transportation, Nassif Building, located at 400 Seventh Street SW. in Washington, D.C. The purpose of the hearing is to receive comments on the proposed regulations governing the qualifications of personnel involved in the handling and transportation of dangerous cargoes in bulk aboard ships and barges, and the proposed regulations governing the qualifications of the person in charge of oil transfer operations. These proposals, CGD 74–44 and CGD 74–44a, appeared in the April 25, 1977, edition of the "Federal Register."

SMILE

It is estimated that about 80 percent of the oil spilled into the oceans from maritime sources each year is the result, not of vessel casualties, but of deliberate shortcuts in such normal tanker operations as tank cleaning and deballasting. To avoid detection, the polluters often conduct their illegal activities under cover of darkness or inclement weather.

In recent weeks, the Coast Guard has begun operating a sophisticated sensor system to detect the illegal discharge of oil in nearly all types of weather, day or night. Installed aboard a Coast Guard C–130 aircraft, the Airborne Oil Surveillance System (AOSS) combines four sensors to spot pollution violators and provide evidence toward their prosecution.

The specially equipped aircraft is based at Elizabeth City, N.C., and conducts routine oil pollution surveillance patrols out to 50 miles along the East Coast.

The sensors include a side-looking radar and a passive microwave imager to locate and map oil spills within a 25-mile swath along the aircraft's path. An aerial reconnaissance camera and a multichannel line scanner provide clear images of oily discharges and identify suspected violators.

A computer-controlled console aboard the aircraft integrates the sensors with a position reference system, permitting on-the-spot interpretation of data and immediate enforcement response when a violation is detected.

The AOSS will also be used in fisheries surveillance, search and rescue, and ice patrol operations.

THE INSIDIOUS INJURY

An alarming number of eye injuries each year result from actinic radiation—flashburn. And as those who are familiar with the hazards of welding are aware, the injuries do not usually happen to the welder, but to his assistant or the assigned firewatch.

Why isn't the welder injured? He is schooled and skilled in his trade, one portion of which has to be good safety habits. In most cases, somewhere along life's trail, he has experienced a flashburn and does not want it to happen again.

Let's look at what happens when a welder strikes an arc with his equipment. Three types of radiation are produced:

(1) Ultraviolet, which, if the eye is exposed to it, will cause cumulative destructive changes in the cornea and lens;

(2) Visible radiation, which will cause eye strain and headache if the eye is exposed to it. If it is intense, the retina can be destroyed permanently; and

(3) Infrared, which radiates heat to the eye, causing discomfort.

All three types of radiation are highly reflective and the bulkheads in most compartments will reflect the radiation efficiently. Therefore, a person without eye protection may have his back to the welder or be a considerable distance away and still turn out to be the victim. The same condition can occur if eye protection does not fit properly.

The pain of flashburn appears up to 8 hours after the exposure, depending on the intensity and duration. The victim experiences diminished vision, along with seeing rings about lights. The pain is excruciating and there is a feeling of sand in the eyes. Usually both eyes are affected. Watering of the eyes is associated with a tremendous pain in bright light. In many cases where it is a first burn, the victim has an emotional upset caused by a fear of blindness.

Reported injury data also reveal that the majority of victims are young and inexperienced. The responsibility for the safety of these workers rests with the supervisor assigning them to the job. He must take the time to educate his work force on the seriousness of the hazards and on all aspects of sound safety procedures. The pain, loss of vision, and emotional upset resulting from flashburn should be made vivid to these workers. Welder's cover goggles with filter lenses must be provided and their use must be mandatory.

A pair of goggles, properly used, can keep a man on the job. There is no substitute for safety.

—*Adapted from* fathom, *spring 1977*

COMMITTEE TERMINATIONS

A review of Federal advisory committees by the Office of Management and Budget has resulted in the termination of two of the Coast Guard's Committees. The Towing Industry Advisory Committee and the National Offshore Operations Industry Advisory Committee will be discontinued as of June 1 and July 1, respectively.

LNG in U.S. Ports

By Lieutenant Commander Fred H. Halvorsen and Dr. Alan L. Schneider
Office of Merchant Marine Safety

The following is reprinted, by permission, from a paper presented at the OCEANS '76 combined conference of the Marine Technical Society and the Institute of Electrical and Electronics Engineers, Washington, D.C., September 13–15, 1976.

The Growing Need

Natural gas is second only to oil in providing energy for the country's needs and in many ways it is the preferred energy form because it is clean, low polluting, easy to handle, and inexpensive. These advantages have made it so popular that demand has outstripped supply, and significant curtailments among interruptable users have appeared in recent winters. For the past few years the amount of gas produced has exceeded new discoveries, and there is no reason to believe that this situation will soon be reversed. Some possible actions to reverse this trend include price deregulation, greater production of synthetic natural gas (syngas) from coal and oil, user conversion to other fuels, and importation. Price deregulation poses severe political difficulties and syngas from coal is expensive; shortages of water at likely conversion locations may preclude large production of gas. Syngas from oil is also expensive and would require additional oil imports. Conversion from gas to either oil or electricity would be very expensive for most users, and, for oil at least, would require more oil importation. Gas importation is possible from Mexico and Canada, but most of the world export sources lie overseas and can only be feasibly shipped in the form of liquefied natural gas (LNG) . . . .

If all of the present industry-proposed 1985 importation schemes were implemented, about 3 to 3.5 trillion cubic feet of gas per year (abbreviated TCF) would be imported. President Ford in his January 1976 energy message announced a 1 TCF target figure for 1985 LNG imports . . . . [The administration-appointed Energy Resources Council subsequently recommended an increase of that target to 2 TCF. How the new administration's energy policy will affect this figure is not yet clear, but, as the authors point out below, any revision of that target is unlikely to detract from their basic point in this section.—Ed.] This level of importation is still significant in that it represents about 3 percent of the country's predicted 1985 gas consumption and is equal to one loaded 125,000-cubic-meter carrier entering U.S. waters each day from overseas. This is in addition to El Paso's proposed Gravina Point, Alaska, to Southern California shipments which would involve about 1 TCF and one more ship arrival a day. The alternatives to LNG importation are not pleasant: By 1985 curtailments would reach many homes and high priority industrial users, with increased importation of oil and larger use of electricity as a result. Large-scale LNG importation seems certain, with only the volume being an issue of public policy.

Regulatory Authority

The Coast Guard is the primary Federal agency concerned with maritime safety and marine law enforcement. This concern encompasses not only vessels and operating personnel on the navigable waters, but also waterfront facilities, and persons and property adjacent to the waterways. Over the years the Congress has given the Coast Guard the authority to write and enforce regulations over most aspects of the marine environment. The tracing of the historical development of the Coast Guard's role in general maritime safety illustrates the President's and Congress' concerns for safety and the environment.

In 1838, after a series of steamboat boiler explosions and fires, the Congress passed legislation designed to protect passengers. Cargoes were not included, but the law provided for certain vessel inspections and required minimum firefighting capabilities aboard vessels. This was very significant because it was a recognition that leaving safety in the hands of the owners is not sufficient, that the owner's self-interest cannot by itself assure safety, and that an outside interest is required.

Although this 1838 law was amended several times, it was not until a fresh series of disasters occurred in 1852 that the problem of hazardous materials was addressed. The Steamboat Act of 1852 required licenses for the carriage of certain dangerous or flammable cargoes. Of course, the number and nature of the cargoes today is much removed from those of 1852, but the principle is the same—hazardous cargoes require special treatment. The part-time inspectors of the 1838 act were replaced by inspectors in the Steamboat Inspection Service, a recognition that an independent, professional body was necessary to safeguard the steamboat industry. This agency of the Federal Government eventually became the Coast Guard's Office of Merchant Marine Safety and the attendant Marine Inspection Offices in the field.

Yet the 1852 act applied to just a portion of the Nation's passenger vessel fleet. Legislation of 1871, 1897, and 1910 expanded the scope of the 1852 act to other types of vessels, because there was a need to protect all individuals involved and not just some passengers. But the emphasis was still not on the nature of the cargo but rather on the vessel and her crew. The Safety of Life at Sea Act of 1937 corrected this by providing for the regulation of tank vessels carrying bulk hazardous liquids. Ironically, it was not a marine disaster involving tank vessels, but accidents involving the passenger vessels *Morro Castle* and *Mohican* that precipitated this act.

Packaged cargoes were regulated by the Dangerous Cargo Act of 1940, and during the Second World War President Roosevelt placed the commercial vessel safety functions under Coast Guard authority where they have remained to this day.

The modern era of regulatory authority began with the Magnuson Act of 1950 which authorized the Coast Guard to issue rules for safeguarding vessels, waterways, and waterfront facilities from subversive activities. This authority, however, was limited only to those periods during which the President declared a national emergency. On October 20, 1950, during the Korean war, President Truman declared a national emergency based on the threat from subversive activities. The authority granted in this instance addressed issues beyond those subversive activities, however.

This somewhat awkward arrangement lasted until the Ports and Waterways Safety Act of 1972, which granted the Magnuson Act's powers independent of any declaration of a national emergency. Additionally, new areas of authority were established, including the prevention of damage or loss of merchant vessels and the protection of structures on, in, or immediately adjacent to the Nation's navigable waters. Environmental protection is also included in this authorization.

All of the above acts give the Coast Guard the power to write regulations to insure the safety of the port area. Briefly, these regulations cover the design and construction of vessels, the operations of vessels and shore terminals, the manning of vessels, the licensing of ships' officers, and the documentation of ships' crews. These regulations are enforced by local Coast Guard officials.

Regulations Specific to LNG

LNG is only one of a number of hazardous materials moved through and stored in the ports of this country. It is admittedly hazardous; however, it is certainly not the most dangerous material being handled, and the Coast Guard has not singled out LNG for specific regulatory control. Any hazardous material which possesses the same properties would be so regulated.

The Coast Guard has promulgated regulations for vessel design and construction, vessel manning standards, vessel operation, and requirements for routine inspections throughout the operating life of the vessel. Operating personnel must pass Coast Guard examinations prior to being licensed as officers or documented as crewmembers. All these regulations apply to all U.S.-flag vessels—whether passengers, container, or tank vessel. [In the Federal Register of October 4, 1976, the Coast Guard published a notice of proposed rulemaking on self-propelled vessels carrying bulk liquefied gases. These proposed regulations are based on the IMCO "Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk" (see PROCEEDINGS, vol. 33, No. 3). The final rules are expected to be issued later this spring.]

For vessels carrying hazardous materials such as LNG, the local Coast Guard Captain of the Port can require that the vessel submit to operating restrictions. These restrictions are locally published and may include the establishment of a moving security zone around the carrier, restrictions against night harbor operations, and prohibition of bunkering during cargo transfer operations. Other, more specialized requirements might include certain tidal restrictions, closing certain channels to LNG vessels, and specification of carrier escorts.

The number and nature of the cargoes today are much removed from those of 1852, but the principle is the same—hazardous cargoes require special treatment.

Proper siting of an LNG importation terminal is central to the safety of the facility, but the Coast Guard feels that the decision is best left to the local governmental authorities. However, once a site is proposed the local Coast Guard Captain of the Port must formulate a set of rules to insure the safety of the port area, and it is conceivable that the company involved will decide that these rules make that site uneconomic relative to other sites.

While the Coast Guard does not have comprehensive regulations for LNG terminals at present, it does regulate some aspects of the land terminal and is developing a set of rational standards with major assistance from the Chemical Transportation Industry Advisory Committee (CTIAC).

LNG Research and Development

To regulate the carriage of a commodity, the regulatory body must have a good understanding of the properties and hazards of that commodity. Perhaps if better information had been available about the chemical involved in the Cleveland LNG disaster of 1944, the catastrophe might have been avoided. The Cleveland LNG incident illustrated what can happen when a facility is built and operated without a true understanding of the properties of LNG—had the low-temperature embrittlement of low-nickel-content steel been known and the need for proper diking been understood, the loss of life might not have been as great. The principle of learning before approval is well known in such industries as ethical drugs and aircraft. The Coast Guard tends towards this procedure, and before seaborne commerce of LNG became significant, the Coast Guard embarked on an extensive study of LNG.

Before seaborne commerce of LNG became significant, the Coast Guard embarked on an extensive study of LNG.

As early as 1968 the Coast Guard contracted with the U.S. Bureau of Mines to carry out a study of LNG. Not only was this the Coast Guard's first LNG study, but it was the first study by anyone of the behavior of spills on water. Rather than attempting to answer a specific regulatory question, this project was intended to provide a basic understanding of the cargo. The Bureau of Mines began by measuring boiloff rates on water in an aquarium. Larger tests on a pond gave spill spread rates and downwind vapor concentrations. From this data an empirical model was derived capable of predicting the cryogen pool behavior and the dimensions of the flammable vapor cloud from both continuous and instantaneous releases of LNG.

Layering persists until the cloud dilutes below the lower flammable limit, meaning the cloud may travel long distances before becoming harmless.

There were two surprising findings from this study. First, it was generally felt that an ice layer would form under the cold liquid reducing the vaporization rate to a low level, and, second, that the vapors would quickly warm and would pose little hazard since they would dissipate. The Bureau of Mines reported that no coherent ice layer formed, although small pieces of ice did appear; also, little energy was transferred to the vapor cloud from the water or from radiant energy from the Sun. Virtually all the energy input into the cloud comes as a result of the mixing of air and gas, and, since the diluting air cools as the gas warms, the gas-air mixture is almost always denser than ambient air, causing layering. This layering persists until the cloud dilutes below the lower flammable limit, meaning that the cloud may travel long distances before becoming harmless. Additionally, the flameless explosion phenomenon and the cloud's high peak-to-average ratio was discovered.

A 1970 contract with the Bureau of Mines continued the effort in the area of the flameless explosion and vapor cloud burning. The flameless

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Dr. Alan L. Schneider *earned his Doctorate in chemical engineering in 1973 from the Massachusetts Institute of Technology. He has been working as a chemical engineer since 1974 with the Cargo and Hazardous Materials Division at Coast Guard Headquarters. As the Chief, Technical Support Section of the Hazard Evaluation Branch, he is concerned with liquefied natural gas, fire and explosion phenomena, and computer stimulation of cargo releases.*

explosion work was paralleled by other investigators resulting in a consensus that the phenomenon is not a significant hazard. The burning cloud work provided evidence that a flashback to the sources was probable. Finally, an elementary model of pool boiling was developed. This assumed that no more than 40 percent of the energy produced by the burning cloud could be radiated outwards, and gave an estimate of the minimum safe distance from a burning pool of LNG.

Together these studies form a part of the technical basis for the Coast Guard's LNG regulations. The research and development effort is continuing today at the Naval Weapons Center, China Lake, Calif. Here unconfined vapor clouds, including methane, are being tested for transitions from deflagration to detonation, in order to determine if detonation of a large unconfined vapor cloud is possible. There have been unconfined detonations involving liquefied petroleum gas (LPG), but no such detonations have occurred involving methane. One theory explaining this difference suggests that the carbon-carbon bonds present in LPG but not present in methane behave sufficiently differently from the carbon-hydrogen bonds. Therefore LPG can detonate in the unconfined state but methane cannot.

The major effort at China Lake is in igniting premixed clouds of flammable gases in air in 10- to 20-meter diameter thin-walled plastic hemispheres; both flame front accelerations and decelerations are being investigated. To investigate flame front accelerations a weak initiator is used to insure that the flame front starts out as a deflagration; to date, no cloud has detonated, including methane-air and ethylene oxide-air, and no significant accelerations have been noted. Some buoyancy and boundary layer effects have been observed, however.

Since structures capable of confining clouds are always present in inhabited areas, one question is whether a high energy ignition could lead to the detonation of an entire cloud; perhaps the portion of a cloud surrounding the initiator would detonate, but would the detonation propagate throughout the cloud without degrading to a deflagration, as evidenced by deceleration of the flame front? If this degrading or deceleration occurs, then an entire cloud probably cannot detonate. This would greatly mitigate the damage resulting from a high energy ignition source within a vapor cloud, and thereby reduce the hazards from an LNG spill.

The strong initiation of a cloud and flame front deceleration are both being studied at China Lake. Unconfined premixed clouds within a plastic hemisphere are ignited with a strong initiator—in this case, a high energy explosive. If detonation occurs, then it will be a conservative assumption to suggest that a cloud in the open will detonate when exposed to a strong ignition source. To measure decelerations high speed photography and pressure sensors will indicate flame front velocities and overpressures. Whether the maximum distance for deceleration (assuming it does occur) of 10 meters in the centrally ignited 10-meter-radius cloud is adequate for decelerations is unclear; in a mile-long cloud a good portion could detonate before deceleration becomes significant. Consistent decelerations occurring within 10 meters should prove that the detonation of a large cloud is not likely; contrarywise, if no decelerations are noted, then the involvement of at least a large portion of a cloud is likely.

There have been unconfined detonations of liquefied petroleum gas, but no such detonations have occurred with methane.

Along with the detonation tests, a series of LNG tests is scheduled at China Lake. These include shock tube tests, spills of LNG on water, ignition of vapor clouds, and measurements of thermal radiation energy fluxes. The spread of LNG on water will be measured to verify the Bureau of Mines results—surprisingly, spill spread rates have not been measured by others. Radiation from the burning pool on water and from the burning cloud has not been measured before and should prove rather helpful in determining separation distances for future construction.

In another effort, University Engineers has been contracted to investigate ways of mitigating the effects of an LNG spill. The effectiveness of several hazard mitigation techniques is being studied experimentally, including water spray on vapor dispersion, water spray on pool fire radiation, dry chemical on pool fires, dry chemical on obstructed fires (to simulate fires aboard ship), and water used to protect carbon steel from cryogenic damage. Additionally, the effects of training on the ability of firefighters will be quantified. While some of these tests have been at least partially performed with LNG land spills, this is the first time they have been done on water spills. In practice, University Engineers simulate spills on water by running water through pipes in a land pool of LNG. This gives a constant high boiloff rate corresponding to a continuous unconfined spill of LNG on water. This project should provide data on how best to fight fires of LNG spilled on water as well as LNG spilled aboard ship and, hopefully, will lead to development of better firefighting techniques.

In another related contract, University Engineers is preparing an analysis of the fire hazards and firefighting capabilities aboard LNG carriers. They are also developing a test program for determining the necessary resources for combating ship-board fires and the optimum way to use these resources.

One last project, by Operations Research, Inc., deals with LNG carrier crew qualifications. The principle is that while the Coast Guard can make the LNG vessel as safe as is economically feasible, there are still humans involved. An optimal set of training requirements is needed to reduce the hazard posed by human error; the possibilities of human error and the need for preventing it cannot be overstated.

An optimal set of training requirements is needed to reduce the hazard posed by human error.

Future LNG Research

The area of future Coast Guard LNG research and development efforts will be determined primarily by the results of ongoing work, the results of work done by other organizations, and the regulatory problems that develop over the years. These factors are not really predictable, but one significant issue has appeared. The desirability of testing with a truly large spill, from 1,000 up to 25,000 cubic meters of LNG, has been suggested by many. (Note that the largest instrumented spills to date are only of 10-cubic meters of LNG.) There are some problems with a very large spill—such a test would be difficult to design, run, interpret, and fund. Smaller scale spills may be appropriate, perhaps spills several times the volume of the largest spills to date. Even tests of this size would be very expensive, and there would need to be more technical justification than currently available in order to warrant the commitment of so large a portion of Coast Guard resources.

The Coast Guard research and development effort will continue in other directions with both LNG and many other hazardous materials. While the effort with LNG is extensive, the Coast Guard feels it now knows enough to regulate LNG properly. Additional work will expand and refine the information available.

Perhaps one of the most important contributions the Coast Guard has made in the area of LNG research has been the stimulus it has provided for others to work in this area. The American Petroleum Institute commissioned ESSO Research and Engineering Co. and two divisions of Shell Oil to study LNG, and several university projects have studied the material's interaction with water. The Coast Guard has monitored this research, in some cases witnessing experiments, and has included the results in the technical base upon which regulatinns are written.

Present LNG Movements

Currently very little LNG is being imported into the United States. Due to the ongoing shipment of the cryogen to Tokyo from Kenai, Alaska, the United States is actually a net exporter of LNG. Two major terminals are operational, and several are being built or planned.

The first American receiving terminal to open was Distrigas' Everett, Mass., facility. It has been receiving LNG recently from Arzew, Algeria, on a regular basis using the *Descartes*. This terminal is relatively small and wholesales both liquid and vapor. Distrigas is unusual in that it is neither a pipeline transmission company nor a gas distributor. The second operating terminal, Boston Gas, Dorchester, Mass., has received several shiploads of liquid on a spot basis, and also shipped LNG by barge to Providence, R.I., and New York. Terminals in Providence, Brooklyn, and Queens can receive barge shipments of LNG, and the now inactive TETCO terminal, owned by the Texas Eastern Transmission Co., was the site of the 1973 fatal explosion. Note that this was not an LNG accident but an industrial accident that occurred in the empty tank.

Three import terminals are under construction (Rossville, on Staten Island; Cove Point, Md.; and Savannah, Ga.) with all three well advanced. The Rossville terminal is close to being ready for operations with the major delaying factor being legal approval by the various regulatory bodies. Import terminals for which environmental impact statements or reports have been filed include the above plus Raccoon Island, N.J., and Oxnard, Point Conception, and Los Angeles/Long Beach, Calif. A similar study has been prepared for Nikiski, Alaska, a proposed loading terminal. Additional proposed terminals include another on Staten Island, one on the Delaware River in New Jersey, and one at Lake Charles, La. The only operating exporting facility in the United States is the aforementioned Kenai, Alaska, terminal.

There are only two trade routes currently in operation, Alaska to Japan and Algeria to Boston. The number of proposed routes is large, with the most likely being additional service from Algeria to the east coast and from Indonesia and Alaska to the west coast. Less definite sources of LNG for the west coast include Siberia, Iran, Equador, and the Persian Gulf States; also, sources of LNG for the east coast and/or gulf coast include Libya, Nigeria, and Venezuela. While few of these are likely to come to fruition in the next 10 to 15 years, the diversity of possible suppliers is great. Presently the only country exporting LNG to the United States is Algeria, with the *Descartes* delivering liquid to Everett. The Alaska-to-Japan route employs

Currently very little LNG is being imported .... The United States is actually a net exporter of LNG.

the *Polar Alaska* and the *Arctic Tokyo*.

Usually terminals and ships are scaled to the size of a trade contract; few ships are built on speculations or for the spot trade, which is quite different from the practice in the crude oil trade. Due to the need for many sophisticated carriers in a short period of time a number of shipyards are building carriers.

LNG Carriers

The vessels ordered follow a pattern. The 125,000-cubic-meter size is the current standard, at least for a few years, partly because prior to this size the largest vessels with significant operating experience were the 71,500-cubic-meter *Polar Alaska* and *Arctic Tokyo* ships, and partly because the 125,000-cubic-meter size is the maximum that can be handled in most east and gulf coast ports.

LNG carriers differ from conventional tankers in several ways, but most importantly, the cargo is very cold.

The margin between U.S. and foreign shipbuilding costs is falling and is at least partially made up by subsidies by the Maritime Administration; the ships are required by the terminal operators as rapidly as possible, so that the speed of construction becomes a major factor, and often several shipyards in different countries build ships for the same project. The receiving terminal owners either purchase or long-term charter vessels, or the exporting country may order the vessels involved. Finally, there is no clear preference as to cargo containment system.

The El Paso Natural Gas Co.'s ship orders reflect these generalities. They have ordered nine 125,000-cubic-meter ships from three shipyards, three each from Avondale, Newport News, and Chantiers de France, Dunkirk. These are dedicated to the Algeria-to-Cove Point and Algeria-to-Savannah routes. The owners apparently have no strong preferences among the various cargo containment systems, as each yard will use a different type. The ships are being built rapidly, with Avondale launching a ship every 6 months.

LNG carriers differ from conventional tankers in several ways, but most importantly, the cargo is very cold. Since natural gas at ambient conditions is above the critical point it must be refrigerated in order to be liquefied, and this is most economically done at one atmosphere and about −259°F. This requires materials that retain their ductility at low temperature such as 9 percent nickel steel, stainless steel, invar, and aluminum. The insulation must be effective, because reliquefaction equipment is too expensive to build aboard the ship. All boiloff is consumed in the boilers, and usually provides most of the energy needed for propulsion. Typically, boiloff is about 0.25 percent of capacity per day and, because the insulation is so efficient that the insulation is the limiting heat transfer step, this rate is independent of the tank ullage.

Since LNG has a low density (on the order of 0.4g/ml), the vessel design must maximize the cargo volume and so LNG carriers tend to ride high in the water relative to large crude carriers. Decks are high, and tanks usually extend above the deck level.

There are basically three types of cargo containment systems in use today, membrane, prismatic, and spherical. In the first the tank is integral with the ship's hull, with the hull supporting the tank. The tank has a primary barrier in contact with the cargo and a secondary barrier in contact with the hull, with insulation in between. This type maximizes the use of the ship's internal volume; in effect the cargo tank serves mainly to insulate the cargo from the ship's hull. The independent prismatic type tank is self-supporting but generally conforms to the shape of the hull. It also has a full secondary barrier, but is less volume-efficient than the membrane. In the spherical type, the tank is neither integral with the hull nor supported by the hull. This type is least efficient in its utilization of the underdeck volume, so the tanks extend far above the deck. Compensating is the reduction in the weight of metal and insulation used to form the tanks; this metal is relatively expensive and a sphere has the lowest surface-to-volume ratio of any shape.

A "Type II Hull" is required regardless of the cargo containment system, which means that certain levels of intact stability, damage stability, and cargo location requirements must be met. The damage requirements in particular were developed from empirical studies. This hull type in effect insures that the 125,000-cubic-meter LNG vessels remain afloat despite a hull opening anywhere along the hull.

These ships are also operated differently from conventional tankers. Vessel operations are heavily influenced by the extremely high costs—these are the most expensive non-military moving objects ever built by man for use on earth. Turnaround is rapid, and since cooldown takes time and warming/cooling cycles produce stresses that should be avoided if possible, the vessel is kept cool on its return voyage by cargo boiloff. Since LNG is such a clean and non-reactive material, tank cleaning is not needed. Time, temperature, and cleaning requirements preclude any different cargo on the return voyage. As remarked before, costs force the carrier

LNG vessels are the most expensive non-military moving objects ever built by man for use on earth.

(*Continued on page 97*)

Controlling Marine Pollution
The International Effort

By Commander Joel D. Sipes and Lieutenant (jg) Robert H. Warman

Office of Marine Environment and Systems

The following is the text of a presentation at the 1977 Oil Spill Conference held March 8–10 in New Orleans under the joint sponsorship of the American Petroleum Institute, the Environmental Protection Agency, and the Coast Guard.

Since its inception in 1959, IMCO, one of several specialized agencies of the U.N., has become the internationally accepted forum in which worldwide maritime problems (except those concerning rates and tariffs) are evaluated. IMCO provides the mechanism through which a great number of international agreements on safety and marine pollution have been achieved and amended as appropriate. As the name implies, IMCO has served as a consultative organization and does not have any direct regulatory responsibilities. International agreements, developed under the auspices of IMCO or for which IMCO now performs functions, can only enter into force by assent of the required number of governments acting through their individual legislative processes. Of the 22 international conventions for which IMCO is responsible, 12 directly or indirectly affect the transportation of crude oil or petroleum products carried in bulk by sea. It is interesting to note that early efforts to formulate international rules affecting vessel safety began in 1912 with the sinking of the *Titanic* and continued until 1948 when the basic charter of IMCO was elaborated.

The U.N. Maritime Conference on Safety of Life at Sea, 1948, in addition to amending the existing SOLAS Convention for the second time, recognized the need for one international forum to consider maritime questions. The 1948 Conference drafted the Convention on the Intergovernmental Maritime Consultative Organization, the basic charter of IMCO. The necessary ratifications of the IMCO Convention delayed its entry into force until 1958.

In 1954, representatives of several maritime countries met at an international conference in London to consider means to prevent pollution of the sea by oil. The result was the International Convention for the Prevention of Pollution of the Sea by Oil, 1954. This convention sets forth discharge limitations for tankers, as well as ships other than tankers, by establishing prohibited zones, generally within 50 miles of shore, where oil or oil mixtures cannot be deliberately discharged. Further, it requires the maintenance on board of an Oil Record Book in which entries are required regarding cargo tank cleaning, ballasting, or deballasting, and other such deliberate or accidental discharge of oil or oily mixtures. The convention entered into force internationally in 1958; the United States ratified in 1961.

The fourth International Conference on Safety of Life at Sea was held under IMCO sponsorship in 1960. The impetus for this meeting was the sinking of the *Andrea Doria*; the representatives present agreed to upgrade standards for stability, particularly in a damaged condition, and fire protection. The resulting 1960 SOLAS Convention was ratified by the United States in 1962 and entered into force internationally in 1965. Out of the same conference came the International Regulations for Preventing Collision at Sea, the most significant aspect being a special annex containing recommendations on the use of radar information as an aid to avoiding collisions. These regulations were proclaimed by the President of the United States in 1964 and subsequently entered into force internationally in 1965.

Under the auspicies of IMCO, delegates met in 1962 in London to consider amendments to the 1954 Oil Pollution Convention proposed by the United States, and to consider problems raised as the results of an IMCO survey of worldwide pollution. Several amendments were agreed, the most significant being aimed at establishment of reception facilities for oily wastes in port areas. The United States ratified the 1962 amendments in 1966. They entered into force early in 1967.

In 1966, an International Conference on Load Lines was convened under IMCO sponsorship to review the 1930 Load Line Convention. International agreement on minimum freeboard for ships on international voyages was achieved, an important contribution to the safety of life and property at sea. The 1966 Load Line Convention entered into force in 1968, having been ratified by the United States in 1967.

Disastrous fires on board the *Lakonia, Yarmouth Castle,* and *Viking Princess* set the international mechanism in motion again in 1966, once again to amend the SOLAS Convention by providing stricter fire protection standards [PROCEEDINGS, vol. 25, No. 5]. These amendments, ratified by the United States in 1967, have yet to be accepted by sufficient countries to bring them into force internationally. Since that time further amendments to the SOLAS Convention were agreed in 1967, 1968, 1969, 1971, and 1973.

In 1969, amendments to the 1954 OP Convention were agreed which will, in effect, provide discharge standards for all ocean waters for the first time. They will limit the instantaneous rates of discharge for vessels outside 50 miles and require that discharges made within 50 miles of land contain no more than 15 ppm of oil in water. The United States ratified the 1969 amendments in 1971, and they recently achieved sufficient ratifications to enter into force in January 1978.

Two international conferences were conducted under IMCO sponsorship in Brussels in 1969, in response to questions brought to light as a result of the *Torrey Canyon* incident. In the first instance the result is the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties. More familiarly known as the Intervention Convention, this agreement permits parties to act as necessary to "prevent, mitigate, or eliminate grave and imminent danger to their coastlines or related interests from pollution or threat of pollution of the seas by oil, following a maritime casualty or acts related to such casualty." The convention was ratified by the United States in 1971 and entered into force internationally in 1975. The United States invoked the Intervention Convention in the recent case of the *Argo Merchant*.

The second Brussels conference elaborated the International Convention on Civil Liability for Oil Pollution Damage. This is the first international effort to place certain liability on shipowners for pollution damage and cleanup costs resulting from oil spills. While the United States has not ratified this convention, it entered into force in 1975.

Stemming from a resolution of the 1969 Civil Liability Conference, the 1971 Compensation Fund Convention, also developed under IMCO auspices, establishes an international fund for the purpose of compensating victims of oil pollution where damage recovery is not possible under the Liability Convention. The two conventions are interrelated, with the Fund Convention designed to supplement the Liability Convention. The Fund Convention has not been ratified by sufficient countries to bring it into force. The United States has not ratified this convention; if the United States did ratify, the convention would enter into force 90 days thereafter.

Also in 1971 two amendments to the 1954 Oil Pollution Convention were agreed internationally. The first redefines the prohibited zones of the 1954 convention to include Australia's

Great Barrier Reef in order to protect that area from intentional oil discharges. The second specifies limits on cargo tank size of tankers in order to reduce the amount of oil outflow should an accident occur. Neither of these amendments has entered into force. The United States has yet to ratify them.

In 1972 the Collision Regulations were revised, taking into account technical and other developments since 1960, and drafted in the form of an international convention [PROCEEDINGS, vol. 30 Nos. 9–12, vol. 31 Nos. 1 and 2]. The increasing use of radar is recognized as well as development in the use of companion safety equipment. Certain of the provisions cover the conduct of ships in areas where traffic separation schemes exist. At present nearly 100 such schemes located in various areas of the world have been adopted by IMCO and recommended for observance. Although the United States has ratified this convention, domestic legislation implementing the convention has not been passed. It enters into force internationally in July 1977.

In 1973, delegations representing 71 nations met in London to negotiate a new International Convention for the Prevention of Pollution from Ships [PROCEEDINGS, vol. 31, Nos. 2 and 3]. This convention, when it enters into force, is intended to replace the 1954 convention as amended. While the 1973 convention contains the best features of the amended 1954 convention, it extends international controls to a broader range of oils and to other harmful substances such as chemicals. It broadly includes provisions which address not only operational discharges from ships but also ship design and construction standards. This convention has not yet been submitted to the Senate for advice and consent.

The 1973 Marine Pollution Conference also developed a protocol to extend the provisions of the Intervention Convention to include light oils and certain harmful substances other than oil. By these two measures first international recognition is given to the need to prevent pollution by substances other than oil. The 1973 Protocol has yet to enter into force. The United States has not ratified.

In 1974 the SOLAS Convention was once again amended to provide a faster procedure for adopting amendments and bringing them into force. These amendments were drafted in the form of a new SOLAS Convention in order to incorporate all amendments to the 1960 convention which had not entered into force.

The foregoing synopsis of conventions illustrates the success IMCO has enjoyed in pursuing its constitutional purposes. In order to attain this measure of success an organization must have representative membership from the total number of countries in the U.N. system, regional distribution among these countries, and varying levels of economic and technological development among them. With a current membership of 101 nations, of which nearly two-thirds are developing countries, and with all major shipowning States participating in its work, IMCO can readily be described as a truly international body.

The international community looks upon the conventions cited as a comprehensive "family" of conventions which go together to regulate and establish standards and practices in maritime safety, navigation, and the elimination of marine pollution. While the U.S. delegations have been in the forefront in developing each of these international treaties, at home the United States has demonstrated reluctance to adopt certain of them. For various reasons, the United States has ratified only 6 of the 12 conventions mentioned.

Due to the wide disparity in the dates of the various conventions and the time it took for them to enter into force, the average being 5 years, IMCO has been criticized as being slow and inclined toward foot dragging.

Only after considerable study and review of the provisions of a convention, and their implications, will a country, in accordance with its own

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Following graduation from the Coast Guard Academy in 1959 CDR Sipes served as assistant engineer on two Coast Guard vessels and in several assignments in the marine inspection field. In July he will assume duty as Commanding Officer, Marine Safety Office, Corpus Christi, Tex.

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After enlisting in 1967, Warman served in a variety of assignments including the Port Safety Station, New York. He received a Reserve commission in 1974 and since then has been assigned at Coast Guard Headquarters, part of that time as a duty officer in the National Response Center.

legal process, take on the international obligations entailed by acceptance and ratification. Then, for a convention to come into force, the necessary number of States specified by the convention must ratify it, in itself a lengthy procedure. There are conventions which require only a few State ratifications to bring them into force, while others may require not only a greater number of States but also that they represent ownership of a substantial percentage of the world's shipping. Finally, IMCO strives to maintain contact with member States to determine if problems exist which may impede ratification, and offers legal and technical assistance within the limits of its resources.

"Foot dragging and slow" are unfair accusations, for it is the actions of the member States themselves together with the requirements of the conventions which govern the speed of ratifications. ⚓

LNG in U.S. Ports

(*Continued from page 93*)

to be committed to a trade route. In many ways, then, both by design and operation LNG carriers are very different from more conventional vessels.

Casualty

No matter how perfect a system of regulation may be, no matter how well the vessel is built and the crew trained, the chance of an accident still is finite, though very small. Since the consequence of an accident is large, the public is concerned. As yet the Coast Guard does not use a formalized risk analysis system in which both probability and consequence are quantified and then multiplied to produce a numerical value of risk for comparison purposes with other of society's risks. Such a system is now under development, with LNG as well as many other hazardous cargoes. This generalized system is, however, several years away from completion. In the interim, a qualitative system of the worst credible scenario is employed. The following scenario is taken directly from the Coast Guard publication, "Liquefied Natural Gas, Views & Practices, Policy and Safety," CG–478, February 1, 1976.

Accident Scenario

If all preventative measures fail and a major collision does happen, the Coast Guard envisions the accident scenario as follows: The released cargo will probably ignite within a few seconds due to the frictional heating caused by the collision or by other nearby ignition sources. Great frictional heating is inevitable because a high energy collision is required to breach the cargo containment system of an LNG carrier. These vessels are designed so that no cargo will be released in low energy collisions . . . . Current vessel designs, materials, and construction methods strongly suggest that only one tank would be ruptured in a major collision. The largest cargo tanks are about 25,000 cubic meters and the largest vessels carry five such tanks. In view of American harbor depth limitations and current land terminal practices, the 125,000-cubic-meter (length 900 feet, beam 150 feet, depth 80 feet) LNG carrier is the current maximum size for use in this country although larger ships are projected.

To simplify the analysis of a single tank spill, the entire tank's contents are modeled as an instantaneous release. While this is unrealistic, it is a conservative approximation, leading to an overestimation of the hazards from such an event.

A fire from a 25,000-cubic-meter spill should last 10–15 minutes. In the unlikely circumstance that the spilled LNG did not immediately ignite due to frictional heating, the resulting LNG vapor cloud would drift downwind until an ignition source is reached. Ignition is likely to occur if the cloud passes over a ship or when the cloud starts to pass over inhabited land. Once ignited, that portion of the cloud with concentrations within the flammable limits will rapidly burn as a premixed flame but the overrich portion of the cloud will burn more slowly as a turbulent diffusion flame. If the pool of liquid has not yet completely vaporized, the flame will propagate to the pool and consume the vapors as they evolve, preventing the formation of another vapor cloud. Since LNG vapors hug the ground, a continuous path of vapor exists back to the pool as long as there is a pool.

Current evidence suggests that a transition from deflagration to detonation within the gas cloud without a strong initiator is impossible. Confirmation of this view is being sought in Coast Guard sponsored testing at the Naval Weapons Center, China Lake, Calif.

Unquestionably a major release of LNG must be avoided; vessel design and operational controls must be developed with this goal in mind.

Conclusion

The Coast Guard feels that LNG is a dangerous commodity, but not the most dangerous being shipped in bulk today. The safety of U.S. ports, and the people and property nearby, can only be assured by a good understanding of the material's behavior and by the proper regulation of vessel design and vessel operation. This fuel is needed and can be economically imported only by ship. The Coast Guard has an extensive LNG program ongoing, and feels that existing knowledge is sufficient for effectively regulating LNG transportation. The research and development effort is designed to refine and extend our knowledge of hazardous materials. ⚓

Nautical Queries

The following items are examples of questions which are included in the First Assistant Engineer and Towboat multiple choice examinations.

Engineer

1. The principal effects of free surface depend upon the volume of displacement of the vessel and the
   - A. dimensions of the liquid surface.
   - B. height of liquid in the tank.
   - C. amount of liquid in the tank.
   - D. weight of liquid in the tank.

2. If you were using a flame safety lamp in a compartment in which there was a lean concentration of explosive gases (below the explosive limit), the flame would
   - A. flare up brightly.
   - B. go out rapidly.
   - C. flare up and go out.
   - D. go out with a slight "pop".

3. A vessel which is subjected to "sagging"
   - A. has its bottom plating under tensile stress.
   - B. has its main deck under tensile stress.
   - C. is supported on a wave whose crest is amidships.
   - D. is said to be under a form of transverse bending.

4. A change of trim may be simply defined as
   - A. the change in difference between the drafts forward and aft.
   - B. the sum of free communication, free surface and pocketing.
   - C. the moment of inertia of the ship's waterline plane about athwartship axis.
   - D. rolling and listing.

5. The difference in water spray patterns between the high-velocity tip and low-velocity applicator is due to
   - A. the method of breaking up the water stream.
   - B. a difference in water pressure.
   - C. the type of fire being fought.
   - D. the length of the applicator used.

Towboat

1. A vessel on Inland waters that sounds three short blasts on the whistle is indicating the vessel's engines are going

   I. astern.

   II. full speed astern.
   - A. I only
   - B. II only
   - C. Either I or II
   - D. Neither I nor II

2. Blood flowing from a cut artery would appear
   - A. dark red with a steady flow.
   - B. bright red with a steady flow.
   - C. bright red and in spurts.
   - D. dark red and in spurts.

3. A vessel proceeding along the bank of a channel or canal has the tendency to
   - A. continue in line with the bank.
   - B. hug the bank.
   - C. sheer away from the bank.
   - D. increase speed.

4. Which statement(s) is (are) true concerning a "sea buoy" which marks the center of a channel entrance?

   I. It is marked with black and white vertical stripes.

   II. It may have either a red or green light.
   - A. I only
   - B. II only
   - C. Both I and II
   - D. Neither I or II

5. You are proceeding parallel to the coast. Lighthouse A is abeam to port, Lighthouse B is 40° off your port bow and both lighthouses are clearly displayed on your radar. What would result in the most reliable fix?
   - A. Range and bearing to A
   - B. Bearings to A and B
   - C. Ranges to A and B
   - D. Bearing to A and range to B

Answers

Engineer

1. A 2. A 3. A 4. A 5. A

Towboat

1. C 2. C 3. C 4. A 5. C

MERCHANT MARINE SAFETY PUBLICATIONS

The following publications of marine safety rules and regulations may be obtained from the nearest marine inspection office of the U.S. Coast Guard.* Because changes to the rules and regulations are made from time to time, these publications, between revisions, must be kept current by the individual consulting the latest applicable Federal Register. (Official changes to all Federal rules and regulations are published in the Federal Register, printed daily except Saturday, Sunday, and holidays.) The date of each Coast Guard publication in the table below is indicated in parentheses following its title. The dates of the Federal Registers affecting each publication are noted after the date of each edition.

The Federal Register will be furnished by mail to subscribers, free of postage, for $5.00 per month or $50 per year, payable in advance. The charge for individual copies is 75 cents for each issue, or 75 cents for each group of pages as actually bound. Remit check or money order, made payable to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

CG No.	TITLE OF PUBLICATION
*101	Specimen Examinations for Merchant Marine Deck Officers (Chief Mate and Master) (1–1–74).
101–1	Specimen Examinations for Merchant Marine Deck Officers (2d and 3d Mate) (5–1–75).
108	Rules and Regulations for Military Explosives and Hazardous Munitions (4–1–72). F.R. 7–21–72, 12–1–72, 6–18–75.
*115	Marine Engineering Regulations (6–1–73). F.R. 6–29–73, 3–8–74, 5–30–74, 6–25–74, 8–26–74, 11–14–74, 6–30–75, 9–13–76.
*123	Rules and Regulations for Tank Vessels (1–1–73). F.. 8–24–73, 10–3–73, 10–24–73, 2–28–74, 3–18–74, 5–30–74, 6–25–74, 1–15–75, 2–10–75, 4–16–75, 4–22–75, 5–20–75, 6–11–75, 8–20–75, 9–2–75, 10–14–75, 12–17–75, 1–21–76, 1–26–76, 2–2–76, 4–29–76, 9–30–76, 1–31–77.
169	Rules of the Road—International—Inland (8–1–72). F.R. 9–12–72, 3–29–74, 6–3–74, 11–27–74, 4–28–75, 10–22–75, 2–5–76, 3–1–76, 6–10–76, 3–31–77.
*172	Rules of the Road—Great Lakes (7–1–72). F.R. 10–6–72, 11–4–72, 1–16–73, 1–29–73, 5–8–73, 3–29–74, 6–3–74, 11–27–74, 4–16–75, 4–28–75, 10–22–75, 2–5–76, 1–13–77.
174	A Manual for the Safe Handling of Flammable and Combusible Liquids and Other Hazardous Products (9–1–76).
176	Load Line Regulations (2–1–71). F.R. 10–1–71, 5–10–73, 7–10–74, 10–14–75, 12–8–75, 1–8–76.
182	Specimen Examinations for Merchant Marine Engineer Licenses (Chief Engineer and First Assistant) (1–1–74).
182–1	Specimen Examinations for Merchant Marine Engineer Licenses (2d and 3d Assistant) (4–1–75).
184	Rules of the Road—Western Rivers (8–1–72). F.R. 9–12–72, 12–28–72, 3–8–74, 3–29–74, 6–3–74, 11–27–74, 4–16–75, 4–28–75, 10–22–75, 2–5–76, 3–1–76, 6–10–76.
*190	Equipment Lists (5–1–75). F.R. 5–7–75, 6–2–75, 6–25–75, 7–22–75, 7–24–75, 8–1–75, 8–20–75, 9–23–75, 10–8–75, 11–21–75, 12–11–75, 12–15–75, 2–5–76, 2–23–76, 3–18–76, 4–5–76, 5–6–76, 6–10–76, 6–21–76, 6–24–76, 9–2–76, 9–13–76, 9–16–76, 10–12–76, 11–1–76, 11–4–76, 11–11–76, 12–2–76, 12–23–76.
191	Rules and Regulations for Licensing and Certification of Merchant Marine Personnel (11–1–76), 3–3–77.
*200	Marine Investigation Regulations and Suspension and Revocation Proceedings (5–1–67). F.R. 3–30–68, 4–30–70, 10–20–70, 7–18–72, 4–24–73, 11–26–73, 12–17–73, 9–17–74, 3–27–75, 7–28–75, 8–20–75, 12–11–75, 5–6–76.
227	Laws Governing Marine Inspection (7–1–75).
239	Security of Vessels and Waterfront Facilities (5–1–74). F.R. 5–15–74, 5–24–74, 8–15–74, 9–5–74, 9–9–74, 12–3–74, 1–6–75, 1–29–75, 4–22–75, 7–2–75, 7–7–75, 7–24–75, 10–1–75, 10–8–75, 6–3–76, 9–27–76, 2–3–77, 3–31–77.
*257	Rules and Regulations for Cargo and Miscellaneous Vessels (4–1–73). F.R. 12–22–72, 6–28–73, 6–29–73, 8–1–73, 10–24–73, 12–5–73, 3–18–74, 5–30–74, 6–24–74, 1–15–75, 2–10–75, 8–20–75, 12–17–75, 4–29–76, 6–10–76, 8–5–76, 9–30–76, 1–31–77.
258	Rules and Regulations for Uninspected Vessels (5–1–70). F.R. 1–8–73, 3–2–73, 3–28–73, 1–25–74, 3–7–74.
*259	Electrical Engineering Regulations (6–1–71). F.R. 3–8–72, 3–9–72, 8–16–72, 8–24–73, 11–29–73, 4–22–75, 6–24–76.
268	Rules and Regulations for Manning of Vessels (12–1–73).
293	Miscellaneous Electrical Equipment List (7–2–73).
*320	Rules and Regulations for Artificial Islands and Fixed Structures on the Outer Continental Shelf (7–1–72). F.R. 7–8–72.
*323	Rules and Regulations for Small Passenger Vessels (Under 100 Gross Tons) (9–1–73). F.R. 1–25–74, 3–18–74, 9–20–74, 2–10–75, 12–17–75, 9–30–76, 1–31–77.
329	Fire Fighting Manual for Tank Vessels (1–1–74).
439	Bridge-to-Bridge Radiotelephone Communications (12–1–72). F.R. 12–28–72, 3–8–74, 5–5–75.
467	Specimen Examinations for Uninspected Towing Vessel Operators (10–1–74).

CHANGES PUBLISHED DURING MARCH 1977

CG–191, Federal Register of March 3.
CG–239, Federal Register of March 31.

*Due to budget constraints or major revision projects, publications marked with an asterisk are out of print. Most of these pamphlets reprint portions of Titles 33 and 46, Code of Federal Regulations, which are available from the Superintendent of Documents. Consult your local Marine Inspection Office for information on availability and prices.