International and U.S. Inland Navigation Rules and LNG Transport

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and LNG Transport

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Robert P. Garrett
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Study Abstract

This study was originated with the premise that there are failures and shortcomings of the existing navigation rules to adequately control and preserve the safe navigation of LNG vessels. The problems associated with the transportation of liquefied natural gas and how these problems relate to the International and U.S. Inland Rules of Navigation have been researched and investigated.

The methods which were utilized to prove the validity of the study's hypothesis, the existing rules of navigation do not provide adequate safeguards for vessels transporting the potentially dangerous cargo of liquefied natural gas, include: First, the dangers and potential dangers of LNG vessels that exist under the nowstanding rules are established. Second, the data of past accidents involving LNG vessels, to determine if these accidents resulted because of a failure or breakdown of the rules of navigation, was researched. Third, it was attempted to prove that these accidents could have been avoided by a more precise and coherent rule regarding LNG vessels. Finally, changes to the rules, as necessary, to preserve the safety of LNG transportation by ocean-going vessels are recommended.

Involved in the extensive research that was required by this study included; a research of publications dealing with the engineering and construction of LNG vessels, review of tests conducted by the U.S. Coast Guard and the U.S. Bureau of Mines.
dealing with the possible spill of LNG, establishment of the dangers of LNG, establishment of the U.S. Coast Guard Inland and International Rules of Navigation and how they relate to the safe navigation of LNG vessels, and recommendations for amendments and/or changes to the navigation rules to better ensure the safe navigation of LNG vessels.

The result and conclusions to this study deviate from the norm of this type of study in that the findings have proven to be inconclusive. The hypothesis, after much research, could not be proven due to the exemplary safety record of LNG vessels to date. The recommendations, however, for changes to the rules of the road were still made within this study in spite of this safety record because the dangers and potential for catastrophe of LNG vessels could be established and by instituting these recommendations as changes may prevent a pending catastrophe of cataclysmic proportions.
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Capacity of LNG ships
Since the early 1940's natural gas has been revealed as one of the most bountiful products of nature's chemistry. Thanks to rapid advances in science and technology, it has rapidly become an important and versatile fuel source. Exploration for natural gas has been met with great success in many areas of the world. Where natural gas has been discovered near large industrial complexes economical piping systems have been laid to transport the natural gas. The impact upon industry has been striking.

Much of the world's gas reserves, however, are located at considerable distances from the industrial complexes which are desirous to obtain this valuable resource. Over long distances the economic feasibility of transporting natural gas via pipeline deteriorates badly. For this reason, only a fraction of the world's natural gas resources is at present usefully consumed. This vast bulk is left to idle in the gas fields for lack of the possibility of developing large-scale local use on an economic basis. Or, as in the case of the gas associated with oil wells, it is flared, thus going to waste because, possibly, or the remoteness of the wells and lack of economic transportation.

The world's proven reserves of natural gas are put at over 700 million cubic feet.¹ In the United States natural gas provides about a third of the energy consumption, in the free world as a
whole (including the U.S.), natural gas accounts for 18 percent.\textsuperscript{2}

Transportation of natural gas to the industrial centers of the world by ship has opened the door on many economic advantages and many problems. In order for natural gas to be transported by vessel on the oceans of the world it has to be liquefied in order to become economically feasible to transport. Liquefying the gas is done by refrigeration to a level of minus 258°F, less than one six-hundredth of its gaseous volume. In this state its transport at atmospheric pressure in an insulated ship becomes a proposition.

The first shipment of LNG (liquefied natural gas) from Algeria to the United Kingdom in 1964 began the commercialization of a new industry. This advent opened up many problems to be contended with including the design of ships to transport this highly volatile and unstable cargo, the land storage of LNG, and the problem, which is the significance of this paper, the special navigation requirements which should accompany the transit of LNG vessels on the high seas of the world and coastal waters of the world, particularly the United States. As of this time there are no navigational rules of the road either international of U.S. inland which would incorporate LNG vessels into a rule of special circumstance. This is the purpose of this paper, to explore the world of LNG vessels and decide if, in fact, a special navigation rule should be made for LNG vessels and provide recommendations if warranted.

\textsuperscript{1} Wooler R.G. "Marine Transportation of LNG and Related Products,"

2. Ibid p 1.
Statement of the Problem

It is believed that there are failures and shortcomings of the existing navigation rules to adequately control and preserve the safe navigation of LNG vessels. The problems associated with the transportation of Liquefied natural gas and how these problems relate to the International and U.S. Inland Rules of Navigation will be investigated. The risk of potential accidents can be reduced by updating the rules of navigation to include as a rule of special circumstance vessels engaged in the transportation of LNG. Revisions and recommendations need to be made to the existing navigational rules to establish regulations and procedures for the identification and avoidance of LNG vessels when met on the waters of the world. The time has definitely come to include LNG vessels in a separate category in the navigational rules to preclude any kind of dangerous situation arising on the high seas or inland waters before a disastrous situation results and dictates the changing and amending of the rules.
Hypothesis

The risk of potential accidents can be reduced by updating the rules of navigation to include as a rule of special circumstance vessels engaged in the transportation of LNG. The existing International and U.S. Inland Rules of Navigation do not provide adequate safeguards for the vessels transporting the potentially dangerous cargo of liquefied natural gas; because the rules fail to provide identification for LNG vessels by ways of dayshapes, lights, and whistle signals which could signal to all other maritime vessels the nature of this special cargo and allow them extra room to maneuver. The rules also do not provide positive measures of protection for other vessels (other than LNG vessels) which may encounter LNG vessels on the high seas.

The basic question this paper will attempt to answer after a review of all the facts is - "Can adequate navigational rules and safeguards be enacted to ensure the safety of LNG transportation upon the high seas?"
Characteristics of LNG

LNG is a cold combustible liquid, (-258° F.), with a high vapor pressure, giving off a gas lighter than air at ambient conditions. Furthermore, this liquid has a low specific gravity (0.47) a very high dielectric strength, a low viscosity, a low surface tension, and a high latent heat. All of those properties have an effect on safe operating practices.

The Bureau of Mines offers the following concerning LNG transport:

1. First and foremost, LNG is a combustible liquid, but:
   a) when the combustible vapors are cold, they are enclosed in a visible cloud of condensed moisture, so the extent of the danger is apparent.
   b) when near ambient temperature, the gas will not accumulate in ground level layers but will rise, and openings at the top of the restricted places should therefore be provided so that it may escape.
   c) the radiation from an LNG fire is no more dangerous than that from a gasoline fire, and the same safety rules can be applied to both.
   d) the smaller the pool of burning LNG, the lower is the level of radiation from the fire.

2. The latent heat of vaporization is high. Every effort should, of course, be made to reduce vaporization if there is an open pool of LNG on fire because of the possibilities of conflagration. One must thus avoid:
   a) dis-
turbing the liquid, as this increases the surface area subjected to radiation from the flames; b) using a material which will encourage boiling. Water, with its high latent heat of freezing, must not be used against an LNG fire, except as a coolant.\(^3\)

3. LNG has a low viscosity and surface tension. The size of the methane molecule is very small so that liquid methane permeates easily through most substances, particularly through thin walls of plastics. Because of its high wetting power and its low viscosity, LNG will travel through fine cracks and, if trapped and warmed up, can generate very high pressures.

Because of its low surface tension, LNG must not touch the skin as it will cause serious burning, whereas liquid nitrogen, through colder, does not have the same effect.\(^4\)

4. It has a very high dielectric strength. LNG is a very poor conductor of electricity, and care should be taken to ground all equipment. However, like any other fuel, LNG requires oxygen to burn; carried or stored as a liquid near atmospheric pressure, it has no inherent potential energy.\(^5\)

5. LNG has a low specific gravity. The specific gravity of LNG is 0.47 as compared to water which is 1.0 or crude oil which is 0.8-0.9. The LNG cargo capacity is
volume-limited rather than weight-limited like a crude oil tanker. Thus the ships have a relatively lower draft and lower freeboard than a conventional tanker.\(^6\)

The properties of LNG are typically 97% methane (CH\(_4\)), with traces of nitrogen, carbon dioxide, ethane and propane. Liquefaction of the gas includes cleaning and refrigeration. At atmospheric pressure LNG liquefies at \(-161.5^\circ\text{C}\). Its volume is then \(1/600^{\text{th}}\) of the original gas volume at atmospheric pressure or about \(1/10^{\text{th}}\) the volume of high pressure pipeline gas. The density of methane is 0.415 when liquid at \(-164^\circ\text{C}\); it freezes at \(-183.2^\circ\text{C}\). Its flash-point is 538°C (1000°F), at atmospheric pressure. In the gas phase at \(-161.5^\circ\text{C}\), its boil-off density is about 45% greater than ambient air density. As methane warms to \(-114^\circ\text{C}\), its density equals that of air. At 0°C and 760mm pressure, the densities of methane and air are \(0.717\times10^{-3}\) and \(1.29\times10^{-3}\), respectively. Hence vaporized methane dissipates rapidly upwards as it warms to surrounding temperatures. Methane is an asphyxiant, although it is non-toxic and relatively non-reactive, except by burning.\(^7\)

Because of the nature of LNG, if a ship collision or grounding occurs, gas explosions, fires and drifting vapor-clouds from the LNG cargo could produce serious hazards to life within a few tens of kilometers of the accident site. Not to mention the probable complete destruction of the LNG vessels and any other vessel, if
any, involved in the accident.

2. Ibid.
3. Ibid.
4. Ibid.
5. Ibid.
Why is LNG Hazardous?

LNG behaves in an unpredictable way because of its unique and extreme properties: it is exceptionally cold, yet highly flammable; it is instantly transformable from a liquid to a gas, yet constantly changing in volume, density, and composition. Natural gas is composed of many different flammable constituents: methane, ethane, propane, butane, and others.

LNG is a thin and runny liquid that will spread out quickly, frothing and foaming, rapidly absorbing heat from the water and evaporating.

Most LNG research to date has been concentrated on water spills, since this is considered to be LNG’s greatest hazard. What would happen if the contents of a single cargo tank of an LNG supertanker were suddenly released at sea? Since such an accident has not yet occurred all existing knowledge is dependent upon small-scale tests which involve a few gallons to a few cubic meters of LNG and then the results are scaled-up. The finding from the most important of these tests are summarized in Figures 1 and 2.

As can be seen from the first table, there is not too much disagreement on the size of the initial vapor cloud. The liquid—all 25,000 cubic meters of it—will have evaporated within the space of a few minutes, and the gas cloud will be about half a mile in diameter, and between twenty-nine and forty-four feet
LNG clouds are dense, white, and infernally cold - white not because of the color of the LNG itself (which is colorless) but because its frosty temperature causes the water vapor in the air to condense into fog. Initially, the gas is about 250 times greater in volume than the spilled liquid, and about one and a half times heavier than air. It will roll out on the ground, like a carpet, eventually lengthening into a plume. Anyone caught at the center of the cloud will die of asphyxiation or freezing.\(^1\)

The plume will first become flammable in its downwind portions and around its edges; when the vapor mixes with air, at a ratio of 5-15 percent gas to air, it is ready to burn instantly. That part of the cloud closest to the original spill will tend to be too rich to burn; that at its leading edge will, over time, become too lean. But every portion of the cloud must pass through the flammable zone. In general, when there is an average concentration of about 10% gas to air, about half the cloud will be flammable.\(^2\)

It has been calculated that one cubic meter of LNG makes approximately 424,000 cubic feet of a highly combustible mixture of gas and air.\(^3\)

The distance downwind that an LNG plume would be flammable, as seen in Figure 2, is not so easily predictable. But be this as it may, one could only imagine that once within the thralls
Figure 1. Predictions of initial LNG vapor cloud size following instantaneous spill of 25,000 cubic meters of liquefied natural gas on water

<table>
<thead>
<tr>
<th>Source</th>
<th>Vapor cloud Radius (feet)</th>
<th>Vapor cloud Height (feet)</th>
<th>Evaporation Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raj/Kalelkar</td>
<td>1255</td>
<td>43</td>
<td>270</td>
</tr>
<tr>
<td>Fay</td>
<td>1417</td>
<td>34</td>
<td>316</td>
</tr>
<tr>
<td>Hoult (1)</td>
<td>3136</td>
<td>77</td>
<td>1390</td>
</tr>
<tr>
<td>Hoult (2)</td>
<td>1239</td>
<td>44</td>
<td>242</td>
</tr>
<tr>
<td>Otterman</td>
<td>1289</td>
<td>41</td>
<td>380</td>
</tr>
<tr>
<td>Muscari</td>
<td>1539</td>
<td>29</td>
<td>324</td>
</tr>
</tbody>
</table>

Notes: Raj/Kalkar estimate was published in the 1973 Fall Meeting, Western States Combustion Institute.

Hoult estimates were published in the Coast Guards’ Proceedings of Conference on LNG Importation and Safety (Boston, 1972).

Otterman estimate was published in "Cryogenics", August 1975.

Muscari estimate was cited by the Draft Environmental Impact Statement for Western LNG Terminal Associate’s California project (September 1976).

Source: U.S. Coast Guard (Department of Transportation), Predictability of LNG Vapor Dispersion from Catastrophic Spills into Water: An Assessment (Washington, D.C.: April, 1977), P.53.
Figure 2: Maximum extent of the flammable LNG plume following instantaneous spill of 25,000 cubic meters of liquefied natural gas on water.

<table>
<thead>
<tr>
<th>Model</th>
<th>&quot;Time-average&quot; vapor concentration of 5%</th>
<th>&quot;Time-average&quot; vapor concentration of 2.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Bureau of Mines</td>
<td>25.2 - 50.3</td>
<td>38.2 - 76.2</td>
</tr>
<tr>
<td>American Petroleum Institute</td>
<td>5.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Cabot Corporation</td>
<td>11.5</td>
<td>22.1</td>
</tr>
<tr>
<td>U.S. Coast Guard</td>
<td>16.3</td>
<td>24.4</td>
</tr>
<tr>
<td>Professor James Fay</td>
<td>28.0</td>
<td>47.2</td>
</tr>
<tr>
<td>U.S. Federal Power Commission</td>
<td>0.75</td>
<td>1.6</td>
</tr>
<tr>
<td>Science Applications, Inc.</td>
<td>1.2</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

Source: U.S. Coast Guard, op. cit., p. 24, 50, 80.
of an major collision involving an LNG vessel and the generation of a highly probable spark caused by collision would result in extremely violent explosion and conflagration destroying everything and everyone within the surrounding area whether it be upon the high seas or inside a much congested harbor.

The unpredictability of LNG was demonstrated, quite by accident, in the summer of 1972 at Staten Island, N.Y., when an official of Distrigas Corporation was proving publicly that LNG was not dangerous be dropping a burning cigarette into a dish of LNG which was immediately extinguished. But residents insisted he repeat the test outdoors. When he did "the vapors ignited instantly into a small fireball." Later, on February 10, 1973, that same facility on Staten Island was the scene of a violent gas blast and subsequent fire which killed 37 repairmen and 3 safety supervisors when the "empty" tank in which they were working exploded.

Taking into consideration the highly hazardous nature of LNG it can readily be seen why extra precautions need to be taken to ensure not only its safety but the safety of people involved in the LNG world or have any appreciation of its volatile nature.

A way in which some of the risks can be eliminated as in the case of LNG transport on the waters of the world is to distinguish these vessels from others of less dangerous cargo by enacting special rules of navigation in International and U.S. Inland waters before an accident of great scale takes place and the inadequacy of the rules of navigation are recognized by all by the resultant
loss of life and property.

1. Lee Niedringhaus Davis, "Frozen Fire, Where Will It Happen Next?," Friends of the Earth, 1979, p.27
2. Ibid
The LNG Vessel

The challenge of designing a successful LNG ship; one which can not only withstand all the pressures imposed on it by the carriage of LNG, but can also sail and handle well, and beat out all its competition on the market place; has attracted some of the most brilliant engineering minds in the business.

The typical LNG supertanker in use today can carry fully 125,000 cubic meters of liquefied gas. Such a ship carries enough LNG, when regasified, to heat 2.5 million homes on a 22°F day (-5.5°C), or to provide electricity for a city of 85,000 people for an entire year, and is over a thousand feet long - the length of three football fields. To carry that much energy in its gaseous state, according to the trade journal "Marine Engineering/Log", the ship would have to be 109 miles long, 1¾ miles across the beam, and have a draft of more than 4 miles.¹

LNG vessels must be specially made, being over a thousand feet long, with cargo tanks a hundred feet tall, and be fine tuned down to the smallest detail. Cargo tanks must be precision made taking into account expanding and contracting motions, without jamming, splitting, or cracking, as the ship is loaded and unloaded. The cargo tanks must be well insulated to prevent excess "boil-off" or evaporation during transportation. Some amount of the cargo LNG will boil off which in many cases is vented to the atmosphere.
or burned in ships' own propulsion plant.²

These LNG carriers are now seen on all oceans and waterways of the world and transport their cargo to most major parts of the world. At prices approaching $200 million apiece, they represent the most expensive non-military vessels operating today.³

With all the concern by environmentalists, in this era, it is imperative that these LNG vessels have every modern safety device and technique employed in their design. The result is a vessel which is safe in every way known to man leaving the only possible way left to ignite the LNG carried by one of these vessels would be from the result of a collision or a grounding which could cause structural damage, or in the event of a war, if one of these ships were to be torpedoed it would probably disappear in short order.

LNG Marine engineers must solve three specific problems peculiar to the carriage of liquefied natural gas. First, the ship's deck and hull must be protected from ever coming into contact with the cold liquid. As physicist Amory Lovins put it, if a ship suffered a massive LNG spill, "plate failure could propagate and cause an LNG carrier to unzip like a banana."⁴

Secondly, there is the problem of "boil-off". There is no way to eliminate this vaporization so it is necessary to vent the cargo tanks, and as previously stated it can be put to use in the ships own propulsion plant to augment the vessels consumption of fuel.
Third, since LNG is itself only two-fifths as dense as water, and since it is continuously vaporizing, liquefied gas is one of the most buoyant cargoes transported on the seas. LNG carriers ride usually high in the water, and are vulnerable to high winds and waves. "Free-Surface Effect" could also be a problem in tanks that are only partially filled and the sloshing motion which is created.

Tank construction for LNG carriers is the main variation in design for these vessels. There are three types of LNG carriers being built at this time; the membrane type, the conch tank type, and the spherical type.

The types of tanks used in these ships may be classified as follows:

- "Self-supporting tanks", "free-standing", or "independent tanks" as they are often called.
  These tanks do not form an integral part of the ship's hull, but are supported by structures independent of the hull. They must be of adequate strength to withstand the loads imposed by the cargo; may be prismatic (single-walled or double walled), spherical, or cylindrical in form.

- Membrane tank which contains the natural gas within a thin metallic liquid-tight lining completely supported by the structure of the
Figure 3

U.S. LNG Carrier Designs

Newport News’ LNGs are being built around the membrane-type tank.

Avondale and Sun Shipbuilding use the coast tank in their LNG construction.

General Dynamics’ LNGs use the distinctive spherical-type tanks.

Source: U.S. Naval Institute Proceedings, April 1977 p. 100
ship. There are two types available, one with a single metallic lining, the other with two linings separated by insulation.

-Semi-Membrane tank in which metallic lining is free of support at the corners.

All three types of tanks require a double hulled ship. The space between the two hulls is used for ballast. The cargo tanks are thus placed within holds formed by the inner hull and transverse bulkheads.

Looking at a typical LNG carrier such as the Artic Class 7 LNG carrier to obtain an idea concerning scale and capabilities, one sees the design characteristics as follows:

-Displacement: 145,000 tons

-Dimensions: 296m long, 46 m beam, 11m draft.

-LNG Cargo: 125,000 to 140,000 m$^3$ of LNG (weighing 52,000 to 58,000 tons).

-Speed: 22 knots maximum in open water, 16 knots cruising.

-Cargo containers: 6 prismatic tanks.

-Shaft HP: 150,000

-Crew: 45

-Fuels: Diesel and natural gas from boil-off. (Diesel fuel tanks carry up to 15,000 tons of diesel fuel.)

-Lubricating Oils: 550 tons

-Waste disposal: Sewage treatment and holding tanks.
FIG. 4 LNG ship cargo tank containment systems

FREE-STANDING SPHERICAL TANK SYSTEM

MEMBRANE TANK SYSTEM

Source: U.S. Congress, Office of Technology Assessment, Transportation of Liquefied Natural Gas (Washington, D.C., September, 1975), Figures 13, 15 (pp. 16-17), based on information from the U.S. Maritime Administration.
FIG. 5 Profiles of typical LNG ships.

**METHANE PRINCESS**
27,400 cubic meters

**DESCARTES**
50,000 cubic meters

**POLAR ALASKA**
71,500 cubic meters

**MEMBRANE TANK SHIP**
125,000 cubic meters

**SPHERICAL TANK SHIP**
125,000 cubic meters

Figure 6

Artic 7 LNG Carrier

ARCTIC CLASS 7 L.N.G. CARRIER
Dimensions (metres): 296x46x11
S.H.P.: 125,000

Source: LNG Transport in Parry Channel: Possible Environmental Hazards, Institute of Ocean Sciences, Patricia Bay, Sidney, B.C. 1979 p.6
LNG carriers must be thoroughly tested before they can be used and must pass strict inspections before they can be filled with liquefied gas. The rules for inspection, periodic surveys, ship building requirements, loading, materials to be used in construction, segregation, inerting, vapor relief, gas detection, insulation, and all other considerations for LNG vessels have been promulgated in the 1972 rules of American Bureau of Shipping, "Vessels Intended to Carry Liquefied Gases". Continuous research by the technical committees and experience gained in this field have kept these rules continually updated and beneficial.

The 1972 rules of American Bureau of Shipping however, do not provide for the safe steaming of these vessels in regard to the international and U.S. inland navigation rules and neither does the double hull construction of these ships provide strength against collisions and ramings. One can now begin to respect the LNG vessel and also begin to understand why the rules of navigation should be modified to safeguard these vessels and all other vessels from a possible LNG catastrophe caused by a collision at sea.

1. "Gotaas Larsen adds six 125,000 cubic meter LNG carriers to its shipping fleet," Marine Engineering/Log (September, 1976), p 64.
Accidents

LNG ships have only been in service a very short time and there have been no serious collisions to date. This does not preclude, however, the potential for a major collision and if a major collision can be avoided by the enactment of special rules of navigation for LNG vessels on the water of the world so much the better.

There have been, however, a few minor accidents that necessitate review to demonstrate the need for special rules of navigation for LNG vessels.

Minor collisions involving an LNG vessel include:

- November, 1974, Le Havre, France: LNG ship "Euclides" runs aground, damaging fourteen bottom plates, the propeller, and causing two shell fractures.¹

- 6 December 1974, Anvey Island, England: The coaster "Tower Princess", steaming way off course, strikes the LNG ship "Methane Progress" while it is tied up at the LNG jetty, tearing a three-foot gash in its stern. No LNG is spilled (the ship's cargo tanks were not located in that area), and no fire. The "Tower Princess" captain was reportedly asleep below when the accident happened.²

- July 1977, Bahrain: The LNG ship "LNG Challenger", lying at anchor at the unloading dock while cargo is being discharged, is struck by the "Lincolnshire", also a liquefied gas carrier. Damage done to the LNG ship's
starboard quarter, the way aft store, and the engine room. Permanent repairs are deferred to the owner's convenience.³

-14 August 1978, Singapore: LNG ship "Khannur" collides with the cargo ship "Hong Hwa" in the Straits of Singapore. No details of the damage are given.⁴

-26 August 1978, Bahrain: The Master of the "LNG Challenger" reports that at 2200 hours local time, his ship is struck by the floating crane "Magnus IX", which is in tow of the tug "Argus 7". The port anchor flukes are driven into the ship's shell. The "LNG Challenger" sustains two holes and a big dent on the port side.⁵

In a much more serious accident involving a Japanese vessel carrying related products—liquefied propane, butane, and naphta—the need for special rules of navigation can immediately be seen. Although in this case the vessel involved is not an LNG vessel there are many similarities in type of cargo and type of vessel and can be used to illustrate the point.

On 9 November 1974 in Tokyo bay the 80,000 cubic meter Japanese ship "Yuyo Maru" collided violently with the 11,000 ton Liberian cargo ship "Pacific Ares". The "Yuyo Maru" experienced a twenty-four meter long gash in her hull from which liquid naphta began to flow out and subsequently ignited, throwing flames 200 feet high into the air. Fire-fighting vessels had to keep back because of the intense heat generated in combustion and of fear of an explosion. Other tanks aboard the "Yuyo Maru"
are cooled at a distance. Thirty-three persons were killed and the "Yuyo Maru" continuing to burn had to be towed out to sea where it was ultimately sunk on November 27 and 28 by Japanese forces utilizing bombs, torpedoes, and rockets. 6

It cannot be determined from the review of these accidents that if, in fact, there were special rules of navigation in effect that they would have been avoided. It is submitted, however, that a rule in effect governing how close to an LNG vessel another vessel could approach and special concern given by a port when an LNG vessel enters their port could have eliminated all of these collisions. As in the case of Boston Harbor, all traffic is stopped and only the LNG vessel is in the harbor and is then able to utilize the entire waterway. Other U.S. Ports which do have regulations for the operation of LNG vessels within their harbors include New York, Los Angeles, Lake Charles, Port Arthur, Baltimore, New Orleans and Houston. Typical port regulations include; allowing LNG vessels to enter port only during certain daylight hours, only with certain tides, in several cases all other traffic is stopped in a channel and the channel is only opened for the LNG vessel, and all ports require strict inspection standards and a letter of compliance for LNG vessels. In no case, however, are any of the regulations standard operating procedure for all ports. Each port is ultimately responsible for their own regulations which they choose to enforce.
A wide-scale set of rules continue to be needed in international and U.S. inland waters for dealing with LNG vessels. The rules to be instituted should also include lights and dayshapes to be shown aboard LNG vessels to make them more readily identifiable.

2. Ibid
3. Ibid p.277
4. Ibid p.278
5. Ibid p.279
7. U.S. Coast Guard, "Operation/Emergency Plan, LNG, the Port of Lake Charles, La." 19 March 1980, Department of Transportation, U.S. Coast Guard.
Rules of Navigation and LNG vessels.

As transportation of LNG by water-borne vessel becomes more and more important and LNG itself increases as an important source of energy, the LNG fleet will also continue to grow. The importance of a new set of navigation rules both international and for U.S. inland waters becomes essential. This new rule to be recommended is required to ensure the safety of LNG vessels and all other vessels from the potential dangers of LNG which could result in the event of an accident such as a collision at sea.

The need for new regulations seems apparent, as it has been predicted that U.S. imports alone of LNG will reach 10 billion cubic feet a day by 1990. Ships will then be offloading at the rate of five a day, and there will be about 15 LNG carriers in U.S. ports at all times.¹

Due to the fact that there has been no major LNG collision which would necessitate the changing of the navigation rules it can be argued that the present Navigational Rules as published by the U.S. Coast Guard (CG-169) are doing an adequate job in dealing with LNG vessels. This is a very good point to overcome and the only argument against it is, without sounding like a prophet of doom, the potential for a catastrophic accident which can occur involving an LNG vessel. The hazards alone, as presented earlier in this paper, of LNG should necessitate LNG vessels be operated under special rules of navigation. At the present time there are no distinctions made for LNG vessels in navigation
rules.\textsuperscript{2}

For a vessel operating in international waters the international rules state: "Rule 7(a), Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist,"\textsuperscript{3}; and "Rule 8(a), Any action taken to avoid collision shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship."\textsuperscript{4} To many the coupling of these rules may seem sufficient to deal with any risk of collision that an LNG vessel may encounter. But, with special rules involved dictating a specified "Closest Point of Approach" (CPA) and identifying features such as lights and dayshapes required to be displayed by LNG vessels any kind of confusion or ambiguity caused may be eliminated. Ambiguity, for example, can be caused by the interpretation of "observance of good seamanship"; whereas, what may be considered acting with good seamanship to one master may be considered an abomination to another.

Likewise, in U.S. Inland Rules, there are many who consider Act 27 "The General Prudential Rule" the all encompassing "extra added protection" for any vessel requiring Special circumstances under the rules. The General Prudential Rules states: "In obeying and construing these rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances
Sources: "Rapport de la Sous-Commission H.I. 'G.N.L.,' 13th World Gas Conference" (London, 1976), pp. 64-66; Marine Engineering: lng. LXXXI (10), September, 1976, p. 44. Figures are for the delivery dates of the ships, compiled at the end of each year.
which may render a departure from the above rules necessary in order to avoid immediate danger." Again, it is believed that this rule is not adequate in providing protection for LNG vessels and other vessels on the seas from the imminent dangers imposed by the water-borne transfer of LNG. Modifications to the rules would alleviate any kind of confusion as to how to react to an LNG vessel when encountered.

Rules of Special Circumstance are not a new notion, there are many already in effect for other vessels requiring special consideration. Special consideration is usually handled by giving that vessel the right-of-way while requiring the vessel to display the proper lights and/or dayshapes necessary for proper identification. Vessels involved in special categories include:

- Aircraft carrier when launching or recovering aircraft.
- Sailing vessels when under power derived from sail.
- Towing vessels; for both the towed vessel and the towing vessel.
- Vessels engaged in trawling and fishing.
- Vessels conducting replenishment at sea while underway and alongside.
- Vessels engaged in dredging or underwater operations.
- Vessels constrained by their draft.
- Vessels engaged on pilotage duty.
Submarines operating on the surface. This is a very good example because of the special rule which requires submarines to show an amber rotating light producing 90 flashes per minute. Submarines are large deep draft vessels with limited maneuvering characteristics while they are on the surface.

Vessels engaged in minesweeping operations which are obviously required to be left a wide berth.

All of the above mentioned vessels are given special consideration because of the hazards they promote when met upon the waters of the earth. They have also been required to show certain lights and dayshapes in both international and U.S. inland waters so that other vessels will be able to identify them and take the appropriate actions necessary to avoid them. It is hereby submitted that LNG vessels are no less hazardous than those already heretofore described and that they also should have a required array of lights and dayshapes to display while underway and that they also require that other vessels movements with respect to them be done in a pre-arranged specified manner.

At the present time LNG vessels are required to show no identifying lights or dayshapes and have no special maneuvering requirements. This lack of special consideration fails to give LNG its much required respect as to the hazards involved, much less acknowledging that the hazards exist.
Many U.S. ports have taken the initiative, through the auspices of the U.S. Coast Guard, to regulate the movement of LNG in their harbors.

Lake Charles, La. is a case in point. Lake Charles employs strict regulations concerning LNG vessels including the following:

1. At least 72 hour advance notice of LNG vessel arrival.
2. All arriving LNG vessels must maintain a radio guard on channel 13 (156.65 MHz) and on channel 16 (156.8 MHz).
3. The LNG vessel must have its cryogenic sensing and indicating instrumentation in operation and in proper working condition.
4. The vessel shall have on board a cylinder of properly certified span gas for testing the gas detection system.
5. The vessel's agent must submit to the Coast Guard an application for a permit to handle explosives or other dangerous cargoes at least 24 hours in advance of the vessel's arrival. LNG may not be transported into the port unless the Coast Guard has approved the request and issued the permit.
6. Each foreign flag vessel concerned must be in possession of a valid Letter of Compliance issued by the Commandant U.S. Coast Guard for the carriage
change to the rules of the road is unnecessary because of the extent of the port regulations imposed upon LNG vessels in the United States. But, however, it is still contended that a change to the rules of the road establishing lights and dayshapes for LNG vessels would reduce the possibilities of an accident further and only seem to be a logical step when establishing regulations. Rules of the road, for LNG vessels, in international waters and in U.S. inland waters with the advent of 200 nautical mile coastal zones are extremely important and the fate of the LNG vessel should be considered.

1. "LNG-Still a Growth Industry", Marine Engineering/Log, November 1980, p.60
3. Ibid p.10.
4. Ibid p.10.
5. Ibid p.119.
6. Ibid p. 91.
Recommendations

Amendments must be made to the existing Navigation Rules of 1972 for both international and inland waters before an accident occurs that may have been avoided by the adoption of regulations for LNG vessels.

The accidents that were previously discussed involving LNG vessels may well have been avoided if the LNG vessels were required to display specific lights and dayshapes to enable them to be recognized for what they are and then having special maneuvering instructions for vessels meeting an LNG vessel.

The recommendations to be stated will require sponsorship from the U.S. Coast Guard in order to ensure their enactment. But, first, acknowledgement of the potential hazards of LNG in regard to a collision at sea must be fully realized and disseminated.

Recommendations are:

1. Establishment of a dayshape to be used in international and U.S. inland rules alike. The dayshape specified herewith would be 3 black diamond shapes in a vertical line displayed where best seen from the hours of sunrise to sunset. There is at this time no conflict in the present rules for the use of this dayshape.¹

2. Establishment of a light display for international and U.S. inland rules alike. The lights specified
herewith would be a green light over white light
over green light displayed in a vertical line on
the forward main mast of the vessel. The lights
would be 32 point all-around lights with a visibility
of 6 miles and would be displayed from sunset to
sunrise. There is at this time no conflict in the
present rules for the use of these lights. 2

3. For international waters a CPA (closest point of
approach) might be established. Wherewith, no
vessel may pass any closer to an LNG vessel than
3,000 yards ahead, 2,000 yards abeam, or 1,000 yards
astern for any reason except in an emergency situ-
ation and only then after informing the LNG
vessel via UHF communication channel 13 of its
intentions. Thus the 3-2-1 rule.

4. In U.S. inland waters all ports could be required
to institute a Vessel Traffic Scheme (VTS) or
Traffic Separation Scheme and monitor it by UHF
communications keeping all traffic apprised of the
situation. This would be more appropriate in inland
waters where recognition of a 3-2-1 rule would be
impossible. This would also set a standard through-
out U.S. ports and waterways which could regulate LNG
entry. Whereas, the actions taken by the Boston Port
Authority regarding LNG entry is only characteristic
to Boston and is not applicable to a port like Seattle, Wa. Thus a standard VTS system throughout the U.S. waterways is recommended. This would not only be beneficial to LNG vessels but to all other vessels as well. Since the establishment of a VTS system in Seattle in 1972 there has been no serious accidents in Puget Sound.

If followed these recommendations would benefit the entire shipping community in ensuring the safety of one more hazardous vessel on the seas— the LNG vessel.


2. Ibid.
Conclusions

As the transportation of LNG by waterborne carrier becomes more and more prominent in the shipping world the chances for a serious accident multiply at the same rate. The recommendations contained herein are timely and by positive action in incorporating these recommendations into the navigational rules of the road the safety record that LNG vessels have enjoyed could be continued.

The U.S. Coast Guard's work in LNG has been masterful to date ensuring that the regulations for vessel construction and shipboard safety are strictly adhered to. The Coast Guard coupled with the Bureau of Mines have been instrumental in investigating the dangers of LNG by conducting tests by the score. Through these countless efforts the transportation of LNG upon the waters of the world has been made almost completely "fool-proof"—except for one thing—the "fools" which are piloting many of the other vessels out there.

Without any method in which to be able to recognize an LNG vessel and its associated dangers it won't be long until one of these magnificently designed and constructed LNG vessels becomes involved in a collision at sea. When LNG comes in contact with other parts of two different vessels, which were not designed to come into contact with LNG, the LNG would freeze those metals, bodies, or other materials upon contact and would render them extremely fragile and as brittle as glass. Also the potential of an explosion of catastrophic proportions becomes imminent due
to the rapid evaporation of LNG into the immediate atmosphere and the ensuing spark which would ultimately be generated by the grinding of metal on metal by collision.

The area of the rules of the nautical road seems to be the only area which was not given consideration for LNG vessels by the U.S. Coast Guard, Bureau of Mines, the American Bureau of Shipping, and other cognizant agencies. This point could have very easily been missed by LNG researchers and regulators in the beginning of the development of this industry, but as the industry grows by virtue of the number of LNG vessels this problem can no longer be overlooked.

Prompt action should be taken in considering all recommendations for instituting changes to the rules of the road, both international and for U.S. inland waters, before a crisis develops resulting in loss of life and property dictating changes to the rules.

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10. The LNG vessel may enter and depart the harbor only during daylight hours and in periods of fair weather and good visibility.

11. While underway in the port area, LNG vessels must have the emergency steering position manned and ready for immediate operation. Communications between this position and the bridge must be maintained.

12. A minimum of three tugs, of not less than 300 horsepower each, will attend the needs of the vessel, acting as escort both inbound and outbound.

13. The Coast Guard, at their discretion, may close any channel and/or establish a sliding or fixed safety zone around an LNG vessel so as to prevent hazardous situations from arising with an inbound, outbound or moored LNG vessel. The authority to take these measures has been given under the Ports and Waterways Safety Act of 1972 as provided for in 33 CFR 160.39.7

The U.S. Coast Guard has done about everything it can to ensure the safety of LNG vessels within U.S. inland waters through strict regulations and procedures except to establish lights and dayshapes to identify these vessels. It may be argued that a
U.S. Coast Guard, "Operation/Emergency Plan, LNG, The Port of Lake Charles, La." 19 March 1980, Department of Transportation, U.S. Coast Guard.

