CHAPTER 4: CARRIAGE OF BULK LIQUID GASES

A. GENERAL CONSIDERATIONS

1. Introduction

Like bulk liquid chemicals, bulk liquefied gases are evaluated for shipment according to their particular properties. The procedures outlined in MSM II F1 for evaluating new products and establishing minimum requirements are used. Liquefied gases have most of the same properties as liquid chemicals. Some gases, such as the alkanes (methane, ethane, propane, etc.), have flammability as their primary hazard. Others are nonflammable but highly toxic, such as chlorine and sulfur dioxide. Still others are corrosive, capable of polymerization, unstable, or are incompatible with common materials of construction. Some combinations of liquefied gases are incompatible; others require inhibition, as do liquid chemicals. Most gases carried in bulk are designated as "cargoes of particular hazard" in 33 CFR 126.10 because of their potential ability to cause damage over large areas.

2. Liquefaction Techniques

Economics dictate that when gases are carried in bulk, they be liquefied by compression, refrigeration, or both. Thus, they are carried in "unnatural" states, possessing tremendous amounts of potential energy. To contain them during carriage, the pressures or temperatures must be maintained. Under Coast Guard regulations, a cargo tank for gases must be able to withstand the vapor pressure of the cargo at 45°C or have reliquefaction equipment. The only exceptions to this rule are tanks that carry liquefied natural gas (LNG) (methane) or nitrogen.

> **NOTE:** Nitrogen is not currently carried as a cargo, but is carried as an inert gas.

Methane cannot be liquefied by pressure alone at temperatures above -82.2°C. Reliquefaction of methane is not currently practical on ships because very large refrigeration plants are required. Consequently, the boil-off vapors from LNG tanks are burned in the ship's boilers, in order to control temperature and pressure within the cargo tanks without venting to the atmosphere.

3. Determination of the Gaseous State

The breakpoint between liquids and gases for purposes of the regulations is somewhat arbitrary. In the past, the breakpoint has been a Reid vapor pressure (RVP) of 276 kilopascal (kPa) absolute (40 psia). However, when the International Maritime Organization (IMO) developed its Gas Code, certain products with RVP's below 276 kPa absolute were included. The Coast Guard regulations for gas ships now apply to cargoes with an RVP of 172 kPa absolute (25 psia) or higher. This figure includes the products that the IMO has included in its Gas Code. The IMO Code has also been amended to allow the carriage of seven high vapor pressure chemicals previously allowed only on chemical tankers: propylene oxide, isoprene, isopropylamine, diethyl ether, monoethylamine, vinylethyl ether, and vinylidene chloride. All of these have an RVP between 101 and 172 kPa absolute. Although these products do not meet the definition of a liquefied gas, they have been considered for carriage on gas ships. Special requirements for their carriage are similar to those for chemical carriers. U.S. gas ship regulations will be revised in the future to include these products.

4. Addressing the Carriage of LNG

Much public attention has been centered on the hazards of LNG. The Coast Guard has consequently published a guide entitled Liquefied Natural Gas and Liquefied Petroleum Gas - Views and Practices, Policy and Safety, Commandant Instruction (COMDTINST) M16616.4. Ports that handle LNG ships have published contingency plans concerning LNG incidents. Although concern about LNG hazards is justified, it should be remembered that most other liquefied gases are just as dangerous as LNG, some even more so.

B. NEW GAS SHIPS

1. Introduction

"New" gas ships are defined under the IMO Gas Code for New Ships and 46 CFR 154 as ships contracted after 31 October 1976, having a keel laid after 31 December 1976, or delivered after 30 June 1980. Any ship, regardless of its age, that meets the standards of this Code may be issued a Certificate of Fitness (COF).

2. Containment of Cargo

The major difference between a gas ship and an ordinary tanker is the cargo containment system. Due to a wealth of available information about containment systems in use (mostly about LNG tanks), this is not discussed in detail here. Briefly, there are six types of tanks used on gas carriers:

Integral Gravity Tanks

a. Integral Gravity Tanks. These are similar to conventional tanks on ordinary tankers. They cannot be used for cargoes carried below -10°C without special approval, and are generally not approved for pressures above 24.5 kPa gauge (3.55 psig). As a result, they are rarely encountered on gas ships.

Membrane Tanks

b. Membrane Tanks. As the name implies, these are very thin-walled tanks. They are not self-supporting and they must have a full secondary barrier, essentially another tank surrounding the primary barrier. The primary and secondary barriers and the insulation are all supported by the inner hull of the vessel. These tanks are capable of withstanding very low pressures only, internally and externally. They are used primarily for carriage of LNG.

Semi-Membrane Tanks

c. Semi-Membrane Tanks. These are similar to membrane tanks. However, they are self-supporting when empty, and thus may be built apart from the ship's hull and subsequently lowered into it. They have not been widely used.

Independent Tanks

d. Independent Tanks. There are three types of independent self-supporting tanks, or tanks that can be built outside the ship's hull. They do not form part of the ship's hull and are not essential to hull strength.

Type A

(1) Type A. These are prismatic-shaped tanks having internal or external stiffeners. They are required to have secondary barriers, and are very common on gas ships.

Type B

(2) Type B. These tanks are very much like pressure vessels, except that the weight, rather than the vapor pressure, of the cargo is the predominant design parameter. Thus, they do not fully meet the design criteria for pressure vessels. However, their rounded forms are easier to analyze than Type A tanks. As a result, they are required only to have a partial secondary barrier, which is essentially an extremely large drip pan. The primary example of this type is the large spherical tank aboard an LNG ship. These tanks are designed to withstand about 207 kPa gauge (30 psig), although in practice the safety relief valves are set to relieve at pressures below 69 kPa gauge (10 psig).

Type C

(3) Type C. True pressure vessels, these are very common in gas ships other than LNG carriers. They may or may not be refrigerated and insulated, and no secondary barrier is required.

---

3. Regulatory Safety Factors

All tank types except Type C independent tanks are heavily instrumented, with gas detection equipment in the hold and interbarrier spaces, temperature sensors, and pressure gauges. Hold spaces for tanks other than Types B and C must be inerted if the cargo is flammable. Hold spaces for Type B tanks or refrigerated Type C tanks may be filled with dry air (with a dew point of -45°C or lower); ships with Type B tanks must be capable of inerting the largest hold space rapidly if a leak is detected. 46 CFR 154 requires higher safety standards than does the IMO Gas Code, as outlined in the following subparagraphs:

Design of Type B and C Tanks

a. Design of Type B and C Tanks. Type B and C tanks must be designed with an allowable stress factor of A = 4.0. The Code makes provisions for indicating compliance with the U.S. standard by listing the allowable stress factors on the COF. U.S. and foreign vessels must meet this standard.

NOTE: The IMO Gas Code permits the use of an A = 3.0 factor for some materials.

Design Ambient Temperatures

b. Design Ambient Temperatures. Except for vessels with independent Type C tanks, the regulations require the use of lower ambient design temperatures than does the Code. The design temperatures must be shown on the COF. A foreign ship will not be issued a Letter of Compliance (LOC) if it has not met the U.S. standard.

Cargo Tank Pressure/Temperature Control

c. Cargo Tank Pressure/Temperature Control. As explained in chapter 26 of this volume, the regulations do not permit the options of the IMO Gas Code for controlling cargo temperature and pressure by periodic venting or operational restrictions on voyage length or locale. Commandant (G-MTH-1) verifies that Coast Guard requirements are met, based on special classification society certification.

Enhanced Steel Grades

d. Enhanced Steel Grades. Under 46 CFR 154, enhanced grades of steel are required for crack arresting purposes at the sheer strake, deck stringer, and bilge strake. The rules of some classification societies permit the construction of large LNG carriers with the entire outer shell made of Grade A steel. No strakes of material having enhanced notch toughness properties, to act as crack arresters, would be required. Because of possible crack initiation from a spill of cryogenic liquid, the Coast Guard requires enhanced grades of steel with enhanced crack arresting properties in the sheer strake, the deck stringer, and the bilge strake. This requirement must also be met for LOC gas ships (there is no indication of this on the COF). Commandant (G-MTH-1) verifies that crack arresting steels have been used before accepting an LOC application, by requiring appropriate classification society certification.

4. Relationship Between Regulations and the IMO Gas Code

General

a. General. Other than specifying operating requirements and the higher standards described above, the regulations follow the IMO Gas Code as closely as possible. In fact, the regulatory sections were numbered to correspond to the chapters of the Code (e.g., the regulations numbered 154.900 correspond to Chapter IX of the Code). Because of the similarity, a valid IMO COF issued under the Gas Code for New Ships is generally accepted by the Coast Guard as evidence of compliance with all of 46 CFR 154, other than the special standards listed in B.3 above. The regulations contain certain operating requirements in addition to those in the Code, namely Subpart E of 46 CFR 154. These are applicable to foreign vessels, except as indicated.

Certification of Compliance with Requirements

b. Certification of Compliance with Requirements. Since a U.S. gas ship that meets 46 CFR 154 requirements will also meet the requirements of the IMO Gas Code, the officer in charge, marine inspection (OCMI) may issue the vessel a COF; the information needed to complete the COF shall be supplied by the Marine Safety Center (MSC). It is not mandatory for a U.S. ship to have a COF, but the owner will probably request one. Liquefied gas ships are certificated under 46 CFR, Subchapter D (Tank Vessels), and endorsed to carry specific cargoes under 46 CFR 154 (Subchapter O). New gas ships may also be certificated to carry liquid chemicals under 46 CFR 153. They must, however, meet all requirements of Part 153 for such certification.

C. EXISTING GAS SHIPS

1. Criteria for Designation

Every gas ship that does not meet the "new" ship definition in 46 CFR 154 is an "existing" gas ship. It is recognized that many of the gas ships that will be active for the next several decades were under construction or already contracted for at the inception of the Gas Code for New Ships. Although the Gas Code does not strictly apply to these vessels, IMO urges all governments to apply the New Ship standards as far as reasonable and practicable, considering their stage of construction at the time of the Code's inception. This was done by IMO Resolution A.329(IX). These vessels are issued an IMO A.329(IX) Certificate, which indicates that they meet the Gas Code for New Ships, except for the items listed in an enclosure to the A.329 COF. For convenience and common reference, these vessels have been dubbed "A.329 ships." A second category of existing gas ships includes those that were in service at the time the IMO Gas Code was written. Major changes to these vessels were not envisioned or required, in view of the excellent safety record of gas ships. However, some upgrading of existing ships, particularly in firefighting equipment, has been required. IMO developed another code, the Existing Ship Code, to specifically address these ships. The required upgradings were included in this Code, and compliance was required on a 2 or 6 year schedule, depending upon the extent of modification necessary for each specific upgrade. Since the Existing Ship Code was adopted in 1975, all upgrades, including those with a 6-year lead time, are now in force.

2. Upgrading Standards

The first few LNG ships built for U.S. registry are in the "A.329" category, and are treated in accordance with Resolution A.329(IX). Their COF's carry a few endorsements listing areas not in compliance with the New Ship Code, Resolution A.328(IX). IMO Resolution A.329(IX) requires that these ships comply in full with the Existing Ship Code. The Coast Guard is not adopting the Existing Ship Code in full, since some of its standards are lower than those traditionally required under U.S. regulations and the LOC Program. However, existing gas ships may be required by a future revision to 46 CFR Part 154 to meet all the upgrading requirements specified by the Code. Additionally, the regulations, when amended, will detail the procedures and certification necessary for issuance and renewal of the LOC for existing vessels. It is envisioned that LOC vessels will be required to possess a COF prior to reissuance of an expired LOC. At the present time, 46 CFR 38 should be used as guidance for examinations of existing gas ships holding LOC's. In cases where a COF issued under the Code for Existing Ships was used in part by Commandant (G-MTH-1) for acceptance of a vessel, that Code should also be used for guidance during an LOC examination.

D. BARGES CARRYING LIQUEFIED GASES

1. Introduction

The regulations for barges carrying liquefied gases whose primary hazard is flammability (e.g., the alkanes and alkenes) are found in 46 CFR 38. Those for barges carrying liquefied gases with different or additional hazards are found in 46 CFR 151. The latter group includes ammonia, chlorine, butadiene, and vinyl chloride.

2. Chlorine Barges

Chlorine, which may not be carried on ships in the U.S., has been carried for many years in barges. Because of its extremely dangerous nature, barges carrying chlorine are handled somewhat differently than most gas barges. Existing barges, acceptance of which was grandfathered under 46 CFR 151, have had wing tanks installed to attain added flotation. These have been dubbed "Type 1-S" barges. Due to the unique operating procedures for chlorine transfer, the Commandant has allowed the quick-closing, remote-activated valves required by 46 CFR 151 to be kept ashore when not in use. This arrangement is possible because the chlorine industry, for the most part, uses standardized fittings so that fit-up is not a problem. The valves may be under the control of a tankerman located ashore, as no one is normally on the barge during transfer. If personnel are on the barge during transfer operations (but not during fit-up of hoses, etc.), at least one remote shutdown valve shall be on the barge.

3. LNG Barges

To date, only one LNG barge has been built; it is presently not in LNG service. LNG barge designs are unique since they can neither refrigerate the cargo nor contain the vapor pressure of the cargo at 45°C, as barges carrying other gases are required to do. To ensure that LNG vapors are not vented under normal conditions, LNG barges must contain the boil-off for twice the voyage length or 45 days, whichever is greater.

4. Liquefied Hydrogen and Oxygen Barges

Currently, liquefied hydrogen and liquefied oxygen have been shipped by the National Aeronautics and Space Administration (NASA) exclusively on barges operated as public vessels. No commercial barges have been approved to carry these cargoes.