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June 9, 2011

VIA EMAIL ONLY

Ryan Albert, Ph.D., Environmental Scientist
U.S. Environmental Protection Agency
Office of Water
EPA EAST-Room 7329B Mail Code: 4203M
1200 Pennsylvania Ave., N.W.
Washington, DC 20460

Re: Lake Michigan Carferry Service: S.S. Badger: VGP and 2012

Dear Ryan:

Thank you (and your colleagues) for meeting with us regarding Lake Michigan Carferry Service's efforts to eliminate the coal ash discharge from the S.S. Badger by December 2012 as provided for in the Vessel General Permit. As we agreed, set forth below and attached are several items we offered to provide to EPA.

First, below is the contact information for those who attended the meeting. For purely technical (non environmental) engineering matters, the lead contact will be Chuck Cart, Senior Chief Engineer for the S.S. Badger. For all other matters you should reach out directly to Sharla Manglitz de Neyra, Vice President of Operations and General Counsel. You can contact me as a backup to Sharla.

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Second, we are attaching the report prepared by Great Lakes Environmental Center, and entitled "Evaluation of the Potential Ecological Impacts of Coal Ash Slurry Discharges from the S.S. Badger to the Open Waters of Lake Michigan." I assume you and Sean Ramach in Region 5 will distribute this as appropriate. This report, which was based on analyses of data and literature as well as engineering practices and calculations, includes findings demonstrating that the limited discharge of coal ash slurry from the S.S. Badger's operations does not and will not present any material harm to the environment as relates to turbidity and total suspended solids while we pursue technologically feasible, commercially available, and economically practicable alternatives that would eliminate the discharge.

Third, we are enclosing a set of slides that depict current concepts regarding the natural gas fuel system that is being evaluated as an alternative fuel source which would eliminate the need for coal and the resulting discharge of coal ash.

Fourth, set forth below is the current estimated time line for the technical engineers, DTE Energy and LMC, to design, manufacture, gain approval, and install a natural gas system to replace coal as fuel for the S.S. Badger. As we discussed at the meeting, we are working closely with DTE Energy, and the concept is still in its assessment and developmental stages. It appears to be a viable alternative in theory, but as our plans regarding the ash disposal system illustrated, there are no guarantees that it will, to a complete certainty, be technologically feasible, commercially available, or economically practicable, and it is very likely that this goal will not be reached by May 2013. Nonetheless, it is the option that we currently believe is most viable, and that makes sense from a business, environmental, technical, and commercial perspective and has the greatest chance of succeeding. Not only would it solve the ash discharge issues, but it would have collateral environmental benefits as well.

Our approach to the time line assumes four major phases: Design, Financing, Regulatory Approval, and Installation. In some cases steps within each phase can proceed simultaneously, while others must be sequential. For example, as we understand it, Coast Guard approval may occur both before installation (at the design stage) and after installation.

We are not sure we have fully anticipated how some steps may interrelate with others since this is a novel proposal. This is particularly true regarding regulatory approval processes and we want to work with the EPA and the Coast Guard to make sure we do not overlook anything. With those caveats, the suggested schedule is as follows:

Description of Step	**Estimated Completion Date or Time Period**
Complete internal designs in preparation for meeting with Coast Guard; this includes informal consultation with ABS, CG, and DTE Energy	July 2011
Begin process for seeking private and public financing: it is anticipated this will take 18-24 months depending on source of financing	July 2011 (begin)
Submit a concept description including basic technical aspects for open discussion with USCG (USCG responds within about 30 days	August 2011
Preliminary marine architectural engineering designs submitted to ABS/CG for review)	November 2011
ABS/CG Response to preliminary designs	February 2012
Submit detailed engineering drawings to the USCG Marine Safety Center (MSC) for review by MSC and CG	November 2012
EPA action permitting continued discharge of coal ash pending completion of fuel conversion process	February 2013
Formal CG/ABS review, responses and approval; Engineering drawings finalized	November 2013
Complete financing	November 2013
Select equipment and manufacturers	November 2013

Description of Step	Estimated Completion Date or Time Period
Begin design and construction of 15 CNG cylinders (11 for vessel and 4 on pier; assumes 24-32 months for completion)	November 2013
Badger and shoreside preparation/construction begins (includes below deck demolition, storage tank preparation and installation, deliver and installation of burners/controls)	November 2015
Badger and shoreside construction completed	May 2016
Final USCG certification of the vessel upon completion of the CNG installation would likely be conducted by the local USCG Sector Office. (Even if the vessel is classed by ABS, the USCG may also review the installation of the CNG system at the shipyard); sea trials	May/June 2016
Operation of system begins	**May/June 2016**

We did not include a specific time frame for the EPA process, other than to note that it would have to be in place prior to the opening of the 2013 season. We assume the form of that process (*e.g.*, permit vs compliance order) is something we would discuss with Region 5 next week. This would be pursued in the likely event that development, approval and installation of the system extend into and beyond the 2013 sailing season. In either event, we assume that process would run in parallel with the Coast Guard/ABS approval process.

The time line set out above is our best assessment at this time. It can be anticipated that a number of variables could either accelerate or delay this schedule, and it is likely that this could change over the next several months. As we indicated, we would and will work closely with you, Region 5, ABS and the Coast Guard as we proceed, and will keep you regularly and timely informed of conditions that would impact the suggested time frame.

We have information relating to the Coast Guard approval process that we discussed at the meeting as relates to the time line. Specifically, we inquired as to whether it will be necessary for the Coast Guard to first develop a new regulatory program addressing our proposed solution in order for it to approve a design for doing so. As a threshold, we have learned that a specific regulatory program containing substantive approval criteria is not always required to be promulgated before a single (and particularly first of its kind) system, such as ours, is approved by the Coast Guard. That is, the Coast Guard has the authority to approve such systems without first promulgating system-specific regulations.

The review process is, however, extremely detailed and robust, and so the time line for completing the fuel conversion process is difficult to estimate. From speaking with LCDR Bryson Spangler of the Coast Guard Headquarters Office of Design and Engineering Standards (CG-521), we learned that it is likely they will use the International Maritime Organization's 2009 *Interim Guidelines on Safety for Natural Gas-Fueled Engine Installations in Ships* (copy attached) as the basis for U.S.-flag requirements for CNG-fueled vessels until Coast Guard regulations on this subject are promulgated. He also provided us with the recently-issued May 2011 *ABS Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships* (copy attached). Both documents allow for below-deck storage of CNG, but require specific arrangements and extensive safety features for such an installation. The concept for, detailed engineering drawings for, and installation of a CNG fuel system on the S.S. Badger must each be reviewed and approved by the Coast Guard before the reconfigured vessel would be re-certified to carry passengers. Other Coast Guard officials who initially may be involved in this review and approval process include:

LCDR Bryson Spangler - USCG: CG-5211 Human Element and Ship Design Division, Bryson.T.Spangler@uscg.mil, (202) 372-1357

Mr. Tim Meyers - USCG: CG-5213 Systems Engineering Division, Timothy.E.Meyers@uscg.mil

Lt. Joe Morgans - USCG Marine Safety Center, Joseph.W.Morgans@uscg.mil, (202) 475-3440

Mr. James Fernie - LNG National Center of Expertise, James.D.Fernie@uscg.mil

As I mentioned to you on the phone, we are planning to meet with Sean Ramach (Permits Branch) and presumably others at Region 5 on June 16, 2011 at 3:00 PM Central Time at the EPA offices in Chicago. We have not set an agenda yet, and we intend to call Mr. Ramach once he has had a chance to review this letter. Of course, you and/or your staff are welcome to join in as you see fit. Because of the novel nature of our situation, we encourage as much coordination as is necessary both within EPA and with other experts, such as the Coast Guard and ABS. We are confident that if everyone involved is kept well informed, the S.S. Badger will be able to continue operating beyond 2012 while it pursues, and hopefully realizes this possible solution.

Finally, our goal remains to operate in an environmentally responsible manner while preserving the economic, cultural, and historic benefits that the S.S. Badger brings to the region. We look forward to continue working with you.

Sincerely,

Barry M. Hartman

Attachments:
1. *Evaluation of the Potential Ecological Impacts of Coal Ash Slurry Discharges from the S.S. Badger to the Open Waters of Lake Michigan*
2. Power Point Presentation
3. 2009 *Interim Guidelines on Safety for Natural Gas-Fueled Engine Installations of Ships*
4. May 2011 *ABS Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships*

cc: Sean Ramach w/attachments (via email only)
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Robert Manglitz
Sharla Manglitz de Neyra
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Evaluation of the Potential Ecological Impacts of Coal Ash Slurry Discharges from the S.S. Badger to the Open Waters of Lake Michigan

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June 3, 2011

1. INTRODUCTION

Great Lakes Environmental Center (GLEC) has prepared this report for the Lake Michigan Carferry Service to provide an interpretation and evaluation of the ecological impacts of turbidity and suspended solids associated with the coal ash slurry discharged from the S.S. Badger carferry to the open waters of Lake Michigan. Following a summary review of the information available to characterize this discharge, this report evaluates the possible ecological impacts of the discharge from a variety of perspectives:

- Potential dilution of effluents discharged from moving vessels;
- The relationship between turbidity and total suspended solids (TSS) concentration for coal ash;
- Effects of turbidity and suspended solids on freshwater aquatic life; and
- Sources of background turbidity and suspended solids, and particle deposition rates in Lake Michigan.

A summary and conclusions are offered in the final section of the report.

2. REVIEW OF COAL ASH DISCHARGES FROM THE S.S. BADGER

Available information to characterize the discharge of coal ash slurry from the S.S. Badger was provided in an October 27, 2008 letter to Duane Heaton of the Water Enforcement and Compliance Assurance Branch, Region 5, U.S. Environmental Protection Agency (EPA). Coal ash slurry is discharged from the S.S. Badger during about 2 ½ hours of the four-hour voyage across Lake Michigan, between the ports of Ludington, MI and Manitowoc, WI. According to the S.S. Badger’s Vessel General Permit, the discharge of coal ash slurry occurs when:

- the S.S. Badger is more than 5 nautical miles from shore,
- in water over 100 feet in depth, and
- while underway at a speed not less than 6 knots.

During 2008, on its last trip of the season (October 12) the amount of coal ash generated on one round-trip voyage was measured. To do so, the S.S. Badger retained all of the coal ash generated during a 12-hour period, which included one round trip from Ludington to Manitowoc. Upon returning to Ludington, the accumulated coal ash was removed from the carferry and weighed. Based on the quantity of ash generated (5,000 lbs.) as well as the amount of coal combusted (55,900 lbs.) during this trial, an ash generation rate of 8.94 percent was determined. Assuming that this ash generation rate applies for the entire 154 day season, the Lake Michigan Carferry Service estimated that the S.S. Badger generated (and discharged) 769.7 tons of coal ash in 2008.

For the 215 round-trip lake crossings over 137 days scheduled for 2011, the estimated ash discharge would be somewhat less, 537.5 tons.

During a single trip across the lake, 97,500 gallons of lake water are circulated aboard the S.S. Badger to convey and discharge 2,500 lbs of ash during a 150-minute active discharge period. Ash removal from the various accumulation points aboard the S.S. Badger (six boiler zones, three economizer boxes and dust collectors) is performed sequentially and manually, so the amount of coal ash being discharged varies over this 2 ½ hour period. Based upon information provided by Lake Michigan Carferry Service, the solids content of the coal ash slurry discharge is in the range of 2,500 milligrams per liter (mg/L) to 3,100 mg/L.

3. DILUTION OF EFFLUENT DISCHARGED FROM MOVING VESSELS

A literature review was conducted by GLEC to evaluate and characterize the rate of dilution of wastewater discharged from moving vessels. To date, few studies have been directed specifically at the dilution of vessel effluents, and limited research has been published on measurements and models of the dilution of discharges from offshore drilling platforms and cruise ships. Of these two sources, dilution of cruise ship discharges is more applicable to the coal ash slurry discharge associated with the S.S. Badger.

Discharges from cruise ships have been studied to assess the potential risk to the marine coastal environment resulting from cruise ship discharges, which include graywater[1] (water from accommodation sinks and showers, laundry and galleys) and blackwater[1] (wastewater generated from toilets and medical facilities). Several studies have reported the dilution of wastewater discharged from cruise ships while in transit, and results from those studies are summarized below.

The dilution achieved behind a moving self-propelled vessel has been estimated in a variety of ways. Colonell et al. (2000) modeled the near-field dilution and far-field dispersion of graywater discharge from a typical cruise ship. Although mathematical models exist for plume discharges and for ship wakes, Colonell et al. (2000) may have been the first to combine the two in order to create a practical model for calculating ships effluent dispersion in the environment.

As discussed in Colonell et al. (2000), a mixing zone model (CORMIX1[2]) was used to simulate the near-field dilution of graywater discharge, by treating it as an effluent discharged from a pipe

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[1] It should be noted that the S.S. Badger holds all graywater and blackwater, as well as oily bilge water, for disposal on shore.
[2] CORMIX1 is an EPA approved model designed for submerged discharges from a stationary outfall in a channel. Cruise ships are a nonstandard application of the model since CORMIX1 does not simulate the dynamics related to the ship's hull, displacement or propulsion system.

under the ship. CORMIX1 was used to predict the width of the effluent plume, and the depth of the plume was determined by a growing turbulent boundary layer along a flat surface (unlike the actual hull shape). CORMIX1 predictions of effluent dilution at a distance of 125 m from the discharge port, including the depth of the plume centerline, the minimum dilution, the maximum graywater concentration, and the half-width of the discharge plume were used as a basis for subsequent calculations of secondary dilution. Secondary dilution, promoted by turbulence generated by the ship itself, is due to the fluid boundary layer on the underside of the ship and the turbulent wakes generated by the ship's propellers (Colonell et al., 2000). Colonell et al. (2000) assumed that secondary dilution was equal to the flow through the rectangular plume cross-section of the ship, divided by the graywater discharge rate. This resulted in a conservative assumption (i.e. underestimate) of secondary dilution because it ignored any horizontal mixing of the effluent that might occur within the ship's boundary layer. Colonell et al. (2000) also assumed that the effluent plume did not intersect the cross-section of the propellers, so mixing by the propeller wake was not considered a significant component of the mixing process.

Colonell et al. (2000) determined that for a cruise ship traveling at 8 knots and discharging wastewater at a rate of 200 m^3/hr, initial (near-field) dilution of 2,500:1 (within about a minute) and far-field dilution of 25,000:1 (<5 days) were expected. Based on this model, EPA (2002) calculated that effluent discharges from cruise ships operating in Alaskan waters were expected to undergo initial dilution of approximately 40,000:1. Why the discharges predicted for Alaskan cruise ships were higher than the results presented by Colonell et al. (2000) was not stated by EPA, but may be related to the faster speed of the Alaskan cruise ships (15-19 knots). This is further discussed below.

A Scientific Advisory Panel (SAP) reporting to the Alaska Cruise Ship Initiative (Atkinson et al., 2001) commented that Colonell et al.'s (2008) approach underestimated the mixing process in the near-field, and was subject to the variations in the parameters used in the CORMIX1 model as well as the specific locations of the discharge pipes of each ship. They also noted that the plume that forms will undoubtedly be drawn into the propellers, and the dilution that occurs will be largely influenced by the propeller mixing and the returning displacement water from the ships' passage.

Further, the SAP (Atkinson et al., 2001) presented a simple approach to estimating dilution factors that was applicable to a variety of ships and locations of discharge ports. This approach addressed the three mixing processes that contribute to diluting a discharge from all propeller-driven ships including:

- turbulence from shear between the moving hull and the water,
- turbulence from the motion of the propellers, and
- turbulence from the hull across the full width of the ship.

The SAP (Atkinson et al., 2001) provided a simple estimate of the dilution of any substance discharged along the hull by assuming a well-mixed effluent over a vertical plane with an area that equals the width times the draft of the ship. Thus, a dilution factor can be calculated by comparing the rate the ship moves through a volume of water (cross section of ship times vessel speed) to the rate of effluent discharge:

Dilution = (ship width x ship draft x ship speed)/(volumetric discharge rate)

According to this equation, the dilution is proportional to ship speed and inversely proportional to the rate of effluent discharge. The SAP (Atkinson et al., 2001) considered dilution factors calculated by the formula above to be minimal estimates of the mixing of pollutants discharged from a propeller-driven ship within 15 minutes, pending further dilution studies. For the S.S. Badger, a dilution factor of 15,425:1 is calculated based on the SAP formula, as shown below:

$$(59.5 \text{ ft} \cdot 16 \text{ ft} \cdot 16 \text{ mi/hr} \cdot 5280/60)/(650 \text{ gal/min} \div 7.48) = 15{,}425$$

In addition, the EPA (2002) conducted a Cruise Ship Plume Tracking Survey to measure the dispersion of cruise ship wastewater discharges while in transit. The study found that discharges behind cruise ships moving at between 9 and 17 knots were diluted by a factor of between 200,000:1 and 640,000:1. These dilution factors were determined by measuring ambient concentrations of rhodamine dye discharged at known rates from four vessels. The measured dilutions were significantly higher than the dilution factors predicted by Colonell et al. (2000) or the SAP (Atkinson et al., 2001). The dye study results suggested that secondary dilution, including the mixing of the effluent that occurs when it passes through the propellers, is an important factor when considering the ambient concentrations of discharge effluents. According to EPA (2002), the effluent undergoes a dramatic and rapid dilution after mixing with ambient water in the propeller wash.

It is likely that the dilution of coal ash discharge behind the S.S. Badger is similar to the dilution measured for cruise ship wastewater discharges. This is based on the similarity of the S.S. Badger's speed (typical cruising speed is 15 - 17 miles per hour depending on wind and sea state) and the propeller configuration (2 screws, 14 ft. diameter) to those of the cruise ships studied by EPA (2002). However, it should also be recognized that the S.S. Badger is considerably smaller than the cruise ships studied by EPA (2002): the S.S. Badger's length (410 ft.) is less than half of the cruise ships, and its draft is shallower (16 vs. 25 ft.).

Accordingly, GLEC believes that it is most appropriate to consider a range of dilution factors for the S.S. Badger's coal ash slurry discharge. A lower-bound estimate of 15,425:1 is provided by the SAP (Atkinson et al., 2001) formula, while the most conservative of the dilution factors measured in the EPA (2002) Cruise Ship Plume Tracking Survey (200,000:1), represents a conservative upper bound.

Based on these dilution estimates, ambient concentrations of total suspended solids (TSS) can be calculated following the initial mixing of the coal ash slurry discharged by the S.S. Badger, as tabulated below:

Source	**Estimated Dilution factor**	**S.S. Badger TSS Discharge Concentration**	
		2,500 mg/L	3,100 mg/L
		Calculated Ambient TSS concentration	
SAP (Atkinson et al., 2001)	15,425	0.162 mg/L	0.201 mg/L
Cruise Ship Plume Tracking Survey (EPA, 2002)	200,000	0.013 mg/L	0.016 mg/L

Notes: mg/L – milligrams per liter

4. RELATIONSHIP BETWEEN TURBIDITY AND TOTAL SUSPENDED SOLIDS CONCENTRATION FOR COAL ASH

There are three primary ways in which solids or sediment are measured in the water column: turbidity, total suspended solids concentration, and water clarity (Bash et al., 2001). Although these three metrics measure different aspects of suspended sediments, they are often incorrectly used interchangeably in water quality monitoring and research papers. These measures are also frequently correlated with one another, although the strength of the correlations may vary widely between samples from different monitoring sites, between different watersheds, and for solids originating from different sources.

For example, the parent geological material in a basin, weathering rate, texture of sediment and soils produced through weathering and erodibility all have a great influence on the amount, texture, and behavior of fine sediments in streams and lakes (Everest et al., 1987 as cited in Bash et al., 2001). Turbidity and total suspended solids are defined as follows:

Turbidity is an optical property of water where suspended and dissolved materials such as silt, clay, finely divided organic and inorganic matter, chemicals, plankton, and other microscopic organisms cause light to be scattered rather than transmitted in straight lines. Measurements of turbidity have been developed to quickly estimate the amount of sediment within a sample of water and to describe the effect of suspended solids blocking the transmission of light through a body of water (Lloyd, 1987 as cited in Bash et al., 2001). Turbidity is usually measured in nephelometric turbidity units (NTU).

Total Suspended Solids represents the actual gravimetric measure of the mineral and organic particles suspended in a water sample. Fluctuating TSS levels in the water column may influence aquatic life from fish to phytoplankton (see Section 5).

While the discharge of coal ash slurry from the S.S. Badger has been quantified (Section 2 of this report) and TSS concentrations mixed in the wake of the car ferry were estimated based upon published dilution ratios (see Section 3), it is also necessary to relate these quantities to turbidity in order to evaluate the potential ecological impacts.

To some extent, how much light is scattered (i.e., turbidity) for a given amount of particulates is dependent upon properties of the particles such as their shape, color, and reflectivity. For this reason (and because heavier particles settle quickly and do not contribute to a turbidity reading), a correlation between turbidity and TSS is somewhat unique for each location or situation.

Schafran and Sellers (1991) measured turbidity and TSS of several samples of coal-ash laden wastewater from coal-fired boilers. Samples of wastewater containing fly ash and bottom ash were collected and yielded the following data:

Sample	**Turbidity (NTU)**	**TSS (mg/L)**	**Turbidity/TSS ratio**
Fly ash	204	515.3	0.40
Bottom ash	720	2,482.6	0.29

In addition, the relationships between turbidity and TSS were shown to be linear over a wide range of values for both fly ash and bottom ash (Schafran and Sellers, 1991). In general, the proportionality between turbidity and TSS measurements is maintained down to low values (e.g., <10 NTU and <10 mg/L). This was demonstrated for a number of industrial samples by Sadar (2011), and is also observed in many natural waters including the Laurentian Great Lakes (Lake Access, 2011).

Assuming that the turbidity/TSS ratios calculated above for the fly ash and bottom ash wastewater samples can be applied to the S.S. Badger's coal ash slurry discharge, then the following ambient turbidity values (following dilution in the ship's wake) can be calculated:

S.S. Badger, Estimated TSS Discharge Concentration	**Dilution factor**	**Turbidity/TSS ratio (Schafran and Sellers, 1991)**	
		0.40	0.29
		S.S. Badger Estimated Turbidity	
2,500 mg/L	Low	0.064 NTU	0.047 NTU
	High	0.005 NTU	0.004 NTU
3,100 mg/L	Low	0.080 NTU	0.058 NTU
	High	0.006 NTU	0.004 NTU

As can be seen from this table, the highest ambient turbidity calculated from the lower- and upper-bound dilution factors and the two turbidity/TSS ratios, is 0.080 NTU.

To provide some context for this level of turbidity, we note that EPA has published water quality criteria for turbidity [3], which include scientific assessments of the effects of turbidity on aquatic life. Although the States of Michigan and Wisconsin do not have water quality standards for turbidity, several other states have promulgated water quality standards for turbidity including:

State	**Turbidity standard (NTU)**	**Comments**
Louisiana	25, 50 or 150 NTU, or background plus 10 percent	Standard depends on the water body
Vermont	10 NTU or 25 NTU,	Standard depends on water body classification
Washington	5 NTU over background, or 10 percent increase	when background is 50 NTU or less when background is over 50 NTU

The upper-bound estimate of turbidity imparted by the S.S. Badger's coal ash slurry discharge (0.080 NTU) is far below the State water quality standards for turbidity that have been promulgated in Louisiana, Vermont, and Washington.

Turbidity standards are also used to ensure the quality of drinking water. In the United States, drinking water produced by treatment systems that use conventional or direct filtration methods cannot have turbidities higher than 1 NTU, and at least 95 percent of the drinking water samples collected in a month must have turbidities less than or equal to 0.3 NTU[4]. Many drinking water utilities strive to achieve turbidity levels as low as 0.1 NTU. Again, the upper-bound estimate of

[3] http://www.epa.gov/waterscience/criteria/library/goldbook.pdf
[4] http://water.epa.gov/drink/contaminants/index.cfm#3.

turbidity imparted by the S.S. Badger's coal ash slurry discharge (0.080 NTU) is much lower than the national standards for drinking water turbidity of 1 NTU and 0.3 NTU.

Finally, Figures 1 and 2 visually illustrate different levels of turbidity in water due to both algae and suspended sediment (Lake Access, 2011). Figure 1 shows filter discs prepared by filtering identical volumes of water from a lake, with their corresponding values of turbidity and chlorophyll. Figure 2 shows a second set of filters generated using nearshore water samples from an erodible area.

Figure 1. Filter Disc Photographs, Turbidity Due to Varying Concentrations of Algae

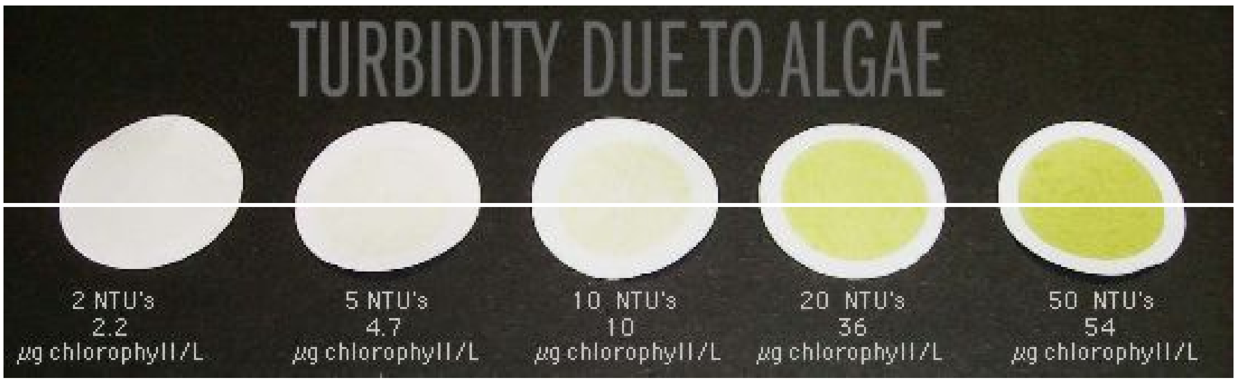


Figure 2. Filter Disc Photographs, Turbidity Due to Varying Concentrations of Suspended Sediment

Figure 3 shows water samples containing different levels of turbidity. Berry and Parkinson (2008) characterized a water sample measuring 5 NTU as being imperceptibly turbid. As mentioned previously, the highest ambient turbidity calculated for the S.S. Badger's coal ash slurry discharge using the lower- and upper-bound dilution factors and the two turbidity/TSS ratios, is 0.080 NTU, far below the value considered to be imperceptibly turbid (5 NTU; Berry and Parkinson, 2008).

Figure 3. Water Samples Containing Varying Concentrations of Turbidity

Turbidity standards of 5, 50, and 500 NTU

5. EFFECTS OF TURBIDITY AND SUSPENDED SOLIDS ON FRESHWATER AQUATIC LIFE

As mentioned previously, TSS and turbidity may influence aquatic life from fish to phytoplankton. At high TSS concentrations, suspended sediment causes a range of environmental effects, including benthic smothering and irritation of fish gills. Much of the impact of suspended sediment at lower concentrations is related to its light attenuation, which reduces visual range in water and light availability for photosynthesis.

The effects of TSS and turbidity on freshwater aquatic life have been studied extensively. With respect to TSS and turbidity, the lowest effects levels associated with freshwater aquatic life occur at concentrations far higher than those estimated for the S.S. Badger (0.201 mg/L and 0.080 NTU; see Section 4 of this report). Literature studies of the effects of TSS and turbidity on aquatic life are briefly summarized in the following text.

Bash et al. (2001) provide a review of the scientific literature on effects of turbidity and suspended solids on freshwater aquatic life with an emphasis on salmonid fishes, which are generally regarded to be highly sensitive to water quality. Suspended sediment is associated with negative effects on the spawning, growth, and reproduction of salmonids (Bash et al., 2001). Effects on salmonids will differ based on their developmental stage. Suspended sediments may affect salmonids by altering their physiology, behavior and habitat, all of which may lead to physiological stress and reduced survival rates. A sizable body of data has been gathered in North America focusing on the relationship between turbidity, total suspended sediments, and salmonid health.

Sigler et al. (1984)[5] identified a significant difference in growth rates between steelhead and coho in clear versus turbid water. As little as 25 NTUs of turbidity caused a reduction in fish growth. The implication of this finding is that fish subjected to turbidity in this experiment might experience increased probability of mortality in comparison to those fish experiencing normal growth. Sigler et al. (1984) also conducted tests to determine the point at which juvenile steelhead and coho subjected to continuous clay turbidities would emigrate from an area. Turbidities ranged from 57 to 265 NTUs. In tanks with mean turbidities of 167 NTUs or higher, no fish were found. Fish were found in tanks with lower turbidities (57 and 77 NTUs) at numbers near carrying capacity.

Newly emerged fry appear to be more susceptible to even moderate turbidities than are older fish. Turbidities in the 25-50 NTU range (equivalent to 125-175 mg/L of bentonite clay) reduced growth and caused more young coho salmon and steelhead to emigrate from laboratory streams than did clear water (Sigler et al., 1984). Juvenile salmonids tend to avoid streams that are chronically turbid, such as glacial streams or those disturbed by human activities (Lloyd et al., 1987), except when the fish have to traverse them along migration routes.

A mean avoidance of 25% was discovered for juvenile coho exposed to a 7,000 mg/L level of suspended sediment (Servizi and Martens, 1992). The authors estimated that the threshold for avoidance by juvenile coho in the vertical plane was 37 NTU. Berg (1982) found that juvenile coho exposed to a short-term pulse of 60 NTU left the water column and congregated at the bottom of an experimental tank. When the turbidity was reduced to 20 NTU, the fish returned to the water column. Bisson and Bilby (1982) subjected juvenile coho to experimentally elevated concentrations of suspended sediment. In their work, juveniles did not avoid moderate increases in turbidity when background levels were low. Significant avoidance, however, was observed at a level of 70 NTU.

Juvenile coho exposed to short-term sediment pulses exhibited altered territory structure and altered feeding behavior (Berg and Northcote, 1985). Normally, a dominant fish positioned upstream would consume the majority of the prey. During turbid phases, territories broke down,

[5] References in this section were cited in Bash et al., 2001.

and subordinate fish captured a greater proportion of the prey. This was most evident at 30 and 60 NTU.

Subsequent to a sediment pulse, a breakdown in social organization among juvenile coho in an artificial stream occurred (Berg, 1982). Territoriality appeared to cease during a short-term sediment pulse, possibly due to the inability of the fish to see the positions of their neighbors. Territory was reestablished when turbidity decreased to 20 NTU. Lateral displays, a territorial action performed by salmonids, were limited under the experimental conditions. Experiments conducted by Noggle (1978) within a turbid artificial stream and clear tributary illustrated avoidance by fish of their established territories.

The literature presents two major themes on the effect of turbidity on foraging. Many studies indicate that as visual feeders, the effectiveness of salmonids in obtaining food is reduced by turbidity at levels as low as 20 NTU (Berg, 1982). Other research indicates that some species of salmonids (juvenile coho, steelhead, and chinook) appear to prefer slightly to moderately turbid water for foraging, as reported in studies by Sigler et al. (1984) and Gregory (1988). This behavior may represent a trade-off between predation risk and bioenergetic demand and benefits of increased growth. While ability to forage in turbid water may be reduced, the reduction in predation risk may make it worthwhile to operate in partially turbid areas (Gregory and Northcote, 1993).

Berg (1982) showed a decrease in feeding ability by juvenile coho in response to short-term pulses of suspended sediment in a laboratory environment. At 0 NTU, 100% of the prey items offered to the fish were consumed, whereas at 60 NTU, only 35% of introduced prey were consumed. At a turbidity level of 10 NTU, fish were noted to frequently mis-strike prey items. A significant delay in the response of fish to introduced prey was noted at turbidities of 20 and 60 NTU. The acquisition of food resources in turbid waters may be reduced due to the effects of turbidity on behavior and vision.

As coho are visual feeders relying on drift, reduction in feeding ability may lead to depressed growth rates (Berg, 1982). Reid (1998) reported that published data suggest that feeding efficiency of juvenile coho salmon drops by 45% at a turbidity of 100 NTU. Additionally, prey behavior is also altered by TSS. Berg and Northcote (1985) showed a reduction in reaction distance by juvenile coho to adult brine shrimp after a sediment pulse (60-20 NTU) was introduced. Prey acquisition increased as the pulse dropped from 60 NTU to 20 NTU, but remained below levels occurring prior to the pulse.

Gregory and Northcote (1993) assessed the effects of turbidity on the foraging behavior of juvenile chinook in the laboratory. The reaction distance of the fish to planktonic adult *Artemia* prey was measured by examining the visual ability of the subjects. The foraging rate by juvenile salmonids for surface, planktonic and benthic prey was measured across a range of turbidity levels (<1, 18, 35, 70, 150, 370, 810 NTU). For all three prey types, foraging was reduced at higher turbidities. Foraging rates for surface and benthic prey were also reduced in clear water, with highest foraging rates attained at 35-150 NTU. The authors suggested that the increased feeding rate in turbid conditions may reflect reduced risk from predators.

Gardner (1981) showed reduced feeding rates for bluegills in turbid waters. Feeding rates in a 3 minute period declined from 14 prey per minute in clear water to 11, 10, and 7 per minute in pools of 60, 120, and 190 NTU. Gardner suggested that high (>50 NTU) levels of turbidity would reduce energy intake (through decreased feeding rates) thus reducing production of fish populations.

Vogel and Beauchamp (1999) quantified the reaction distance of adult lake trout (as predators) to rainbow trout and cutthroat as a function of light (0.17 – 261 lux[6]), prey size (55, 75, and 139 mm) and turbidity (0.09, 3.18, and 7.40 NTU). Reaction distances of adult lake trout to rainbow and cutthroat trout increased with increasing light (25 cm at .17 lux, to 100 cm at 17.8 lux). Reaction distance decreased as a decaying power function of turbidity. Vogel and Beauchamp (1999) used results to model prey detection capabilities of piscivores at varying depths and times of day in natural environments.

The response of *Daphnia*[7] to suspensions of several types of solids was reviewed by EIFAC (1965). The following results were reported:

Type of suspended solid	Harmful TSS concentration (mg/L)
Kaolinite	102
Montmorillonite	82
Charcoal	82
Pond sediment	1,458

Reproduction rate increased for *Daphnia* at lower rates of suspended sediment. McCabe and O'Brien (1983) determined that turbidity levels as low as 10 NTUs can cause significant declines in feeding rate, food assimilation, and reproductive potential of *Daphnia pulex*. Suspended sediment concentrations of 50-100 mg/L reduced algal carbon ingested by cladocerans to potential starvation levels. These zooplankton are an important food item for salmonid fishes.

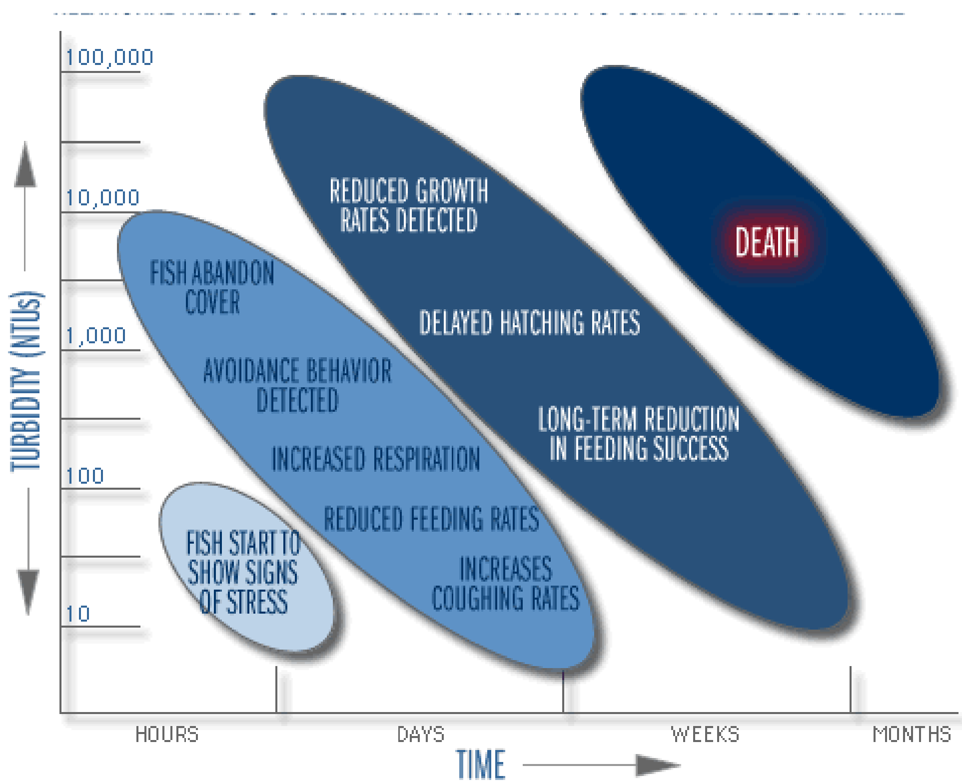
A 5 NTU increase in turbidity in a clear-water lake may reduce the productive volume of that lake by about 80% and a 25 NTU increase in a clear-water stream 0.5 m deep may reduce plant

[6] A measurement of light intensity measured with a light meter.
[7] *Daphnia* are small, planktonic crustaceans, between 0.2 and 5 mm in length, members of the order Cladocera.

production by approximately 50% (Lloyd et al., 1987). A 5 NTU increase in turbidity in a clear stream 0.5 m deep may reduce primary production by 13% or more, depending on stream depth.

Figure 4 summarizing the effects of turbidity exposure to freshwater fish is displayed below. As shown in this figure, as well as the literature review summarized above, adverse effects are not observed at turbidities below 5-10 NTU.

Figure 4. Relational Trends of Freshwater Activity to Turbidity Values and Time



Note: Figure adapted from: "Turbidity: A Water Quality Measure." Water Action Volunteers, Monitoring Factsheet Series. UW-Extension, Environmental Resources Center.

Given that the highest ambient turbidity calculated from the S.S. Badger's coal ash slurry discharge, the turbidity/TSS ratio, and the dilution factor in the previous sections is 0.080 NTU, it appears highly unlikely that the turbidity contributed by this discharge would have an adverse effect on aquatic life present in the Lake Michigan ecosystem.

6. SOURCES OF TURBIDITY, SUSPENDED SOLIDS AND PARTICLE DEPOSITION RATES IN THE LAKE MICHIGAN ECOSYSTEM

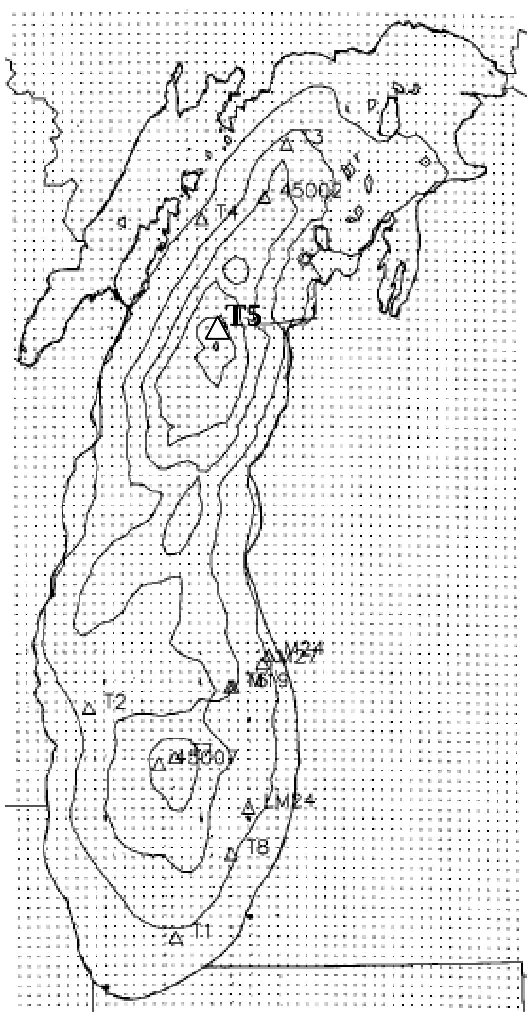
As shown in the previous sections, the turbidity associated with the S.S. Badger's coal ash slurry discharge is unlikely to cause harm to the aquatic life present in Lake Michigan. The significance of this discharge can be further evaluated by comparing it's magnitude to other known sources of turbidity and suspended solids to Lake Michigan. These include:

- Shoreline erosion, deposition and subsequent resuspension during storms;
- Autochthonous primary productivity;
- Calcium carbonate precipitation (whiting); and
- Tributary loading inputs.

Each of these turbidity-contributing processes has been well-studied and quantified in Lake Michigan, as reported in the scientific literature (e.g., Colman and Foster, 1994) and are briefly discussed in the following text.

To determine the overall rate of solids loading in the lake, Eadie (1997) measured the particle settling fluxes in southern Lake Michigan using sediment traps. During the stratified period (June-December), mass fluxes were low, less than 1 grams/meter^2/day (gm/m^2/d) near the lake surface. Higher fluxes (up to 15 gm/m^2/d) were measured below the thermocline, especially near the lake bottom due to sediment resuspension processes, and during the unstratified period. Solid deposition fluxes were also measured in a number of sediment traps at different locations in the lake during the 1994-95 Lake Michigan Mass Balance (LMMB, see Figure 5 below for trap locations). Trap T5 in the northern basin (midway between Sturgeon Bay, WI and Point Betsie, MI; 30 meter (m) trap depth; 260 m water depth) was the trap closest to the route of the S.S. Badger, and probably measured mass fluxes more representative of middle and northern Lake Michigan. During the stratified period (which includes the S.S. Badger's operating season), the average particle settling flux measured in trap T5 was 0.35 gm/m^2/d (personal communication, B. Eadie, NOAA Great Lakes Environmental Research Laboratory, December 12, 2002). The particle settling fluxes measured in sediment traps capture solids delivered to those locations in the lake from all of the sources listed above. Therefore, 0.35 gm/m^2/d was a measure of the total suspended solids loading delivered to the near surface waters of middle-northern Lake Michigan during the stratified period (Eadie, 1997).

Figure 5. Locations of sediment traps (triangle symbols) deployed during the Lake Michigan Mass Balance.



Fitzgerald and Gardner (1993) determined that the spring bloom of diatoms contributed 61 mmol/m^2/d of algal carbon over a 78 day period. Assuming an organic carbon content of 30%, this represents a solid mass flux of 2.44 gm/m^2/d. This flux may be higher than current values, given trends towards oligotrophication observed in Lake Michigan since the late 1990s. Evans et al. (2011) showed that spring silica concentrations (an indicator of decreasing growth of the dominant diatoms) have gradually increased in all basins of Lake Michigan between 1983 and 2008. These changes indicate the lake has undergone gradual oligotrophication coincident with and anticipated by nutrient management implementation. Slow declines in seasonal drawdown of silica (a proxy for seasonal phytoplankton production) also occurred, until recent years, when lake-wide responses were punctuated by abrupt decreases, putting them in the range of oligotrophic Lake Superior. The timing of these dramatic production drops is coincident with expansion of populations of invasive Dreissenid mussels, particularly quagga mussels, in each basin. Simply put, invasive quagga mussels have hastened the decline in diatom productivity in Lake Michigan, resulting in lower biotic particle fluxes and concentrations in the open lake waters.

With respect to the coal slurry discharge associated with the S.S. Badger, the loading of solids to Lake Michigan, measured as trap fluxes as described above, can be compared to the deposition of coal ash slurry solids from the S.S. Badger. This comparison must consider the variation of the S.S. Badger's course over the duration of the season, due to factors such as the direction and magnitude of wind and waves.

The Lake Michigan Carferry Service estimates that the S.S. Badger's course over a season may cover more than 1,000 mi^2. If the solids in the coal ash slurry discharge were deposited uniformly over this area, it would represent a solids flux of 0.0042 $gm/m^2/d$, about 1% of the deposition flux delivered to the near surface waters of northern Lake Michigan during the stratified period as measured by sediment traps (Eadie, 1997). If instead, the solids in the coal ash slurry discharge were deposited within a 1 mile wide "track" of the S.S. Badger across the lake, the solids flux would be 0.11 $gm/m^2/d$, still only about 30% of the deposition flux measured in sediment traps (Eadie, 1997).

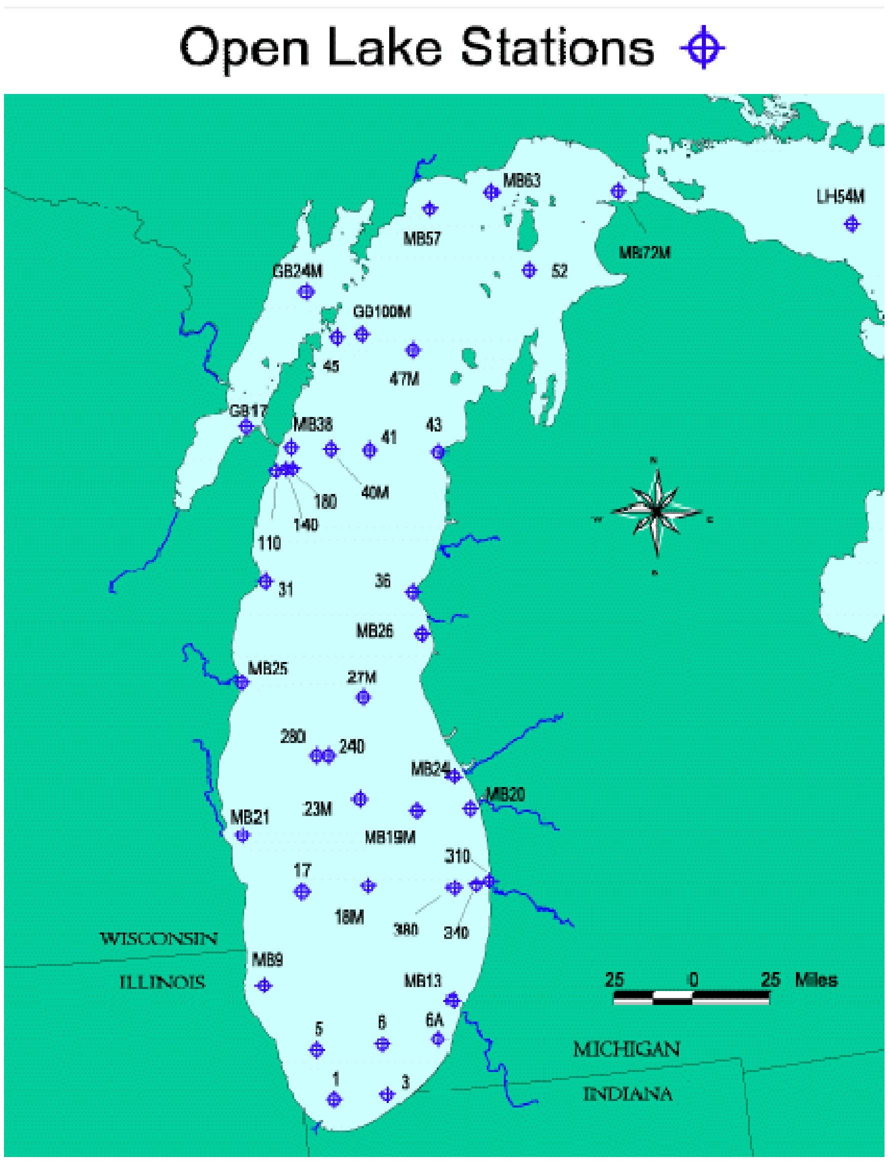
GLEC believes that these two estimates of solids flux represent lower and upper bounds on the mass loading of coal ash slurry solids from the S.S. Badger. In comparison to the near-surface solids mass fluxes measured in Lake Michigan during the unstratified period (5-15 $gm/m^2/d$) or even the stratified period (<1 $gm/m^2/d$), the solids fluxes attributable to the coal ash slurry discharge from the S.S. Badger are modest.

According to Dean, Shaefer and Armstrong (1993), TSS in the epilimnion of southern Lake Michigan varies from 0.4 to 1.4 mg/L, with higher values occurring during summer. Peak TSS concentrations are associated with the diatoms that bloom in May and June, contributing up to 0.7 mg/L of suspended solids, and calcite particles that precipitate in late August and September, contributing up to 1 mg/L.

To confirm these data and obtain values more representative of the waters navigated by the S.S. Badger, GLEC retrieved near surface TSS and turbidity data from LMMB stations MB26, 27M, 31 and 36 located near the S.S. Badger's route (see Figure 6 below). During the stratified period, the average and range of TSS and turbidity measured at each of these stations is tabulated below:

Station	TSS average (mg/L)	TSS range (mg/L)	Turbidity average (NTU)	Turbidity range (NTU)
MB26	1.14	0.93 – 1.53	0.54	0.32 – 0.75
27M	0.88	0.58 – 1.08	0.35	0.25 – 0.59
31	0.84	0.69 – 1.18	0.37	0.23 – 0.60
36	0.98	0.71 – 1.39	0.50	0.30 – 0.67

Figure 6. Locations of water quality monitoring stations sampled during the Lake Michigan Mass Balance.



By comparing these values to the upper-bound estimates of ambient TSS and turbidity contributed by the coal ash slurry discharge of the S.S. Badger, GLEC calculated that this discharge may locally increase TSS in Lake Michigan by 13 to 35% (average 21%), and turbidity by 11 to 35% (average 19%). The maximum ambient TSS and turbidity expected in the vicinity of the S.S. Badger, obtained by adding the highest values tabulated above to the upper-bound contributions expected from the S.S. Badger's discharge, are 1.73 mg/L and 0.83 NTU. These values are still well below concentrations associated with adverse effects to aquatic life that are discussed in Section 5. In addition, these estimated values are far below the State water quality standards for turbidity that have been promulgated in Louisiana, Vermont, and Washington, as previously discussed.

It should also be recognized that the maximum expected ambient TSS and turbidity values in the vicinity of the S.S. Badger, as presented above, presume a frame of reference moving at the speed of the carferry. At any given location in the lake, ambient TSS and turbidity elevated by the S.S. Badger's discharge will be a transient occurrence, because the solids in the coal ash slurry will be lost via settling through the water column following passage of the ship. Rates of settling for coal ash solids (fly ash and bottom ash) were reported by Kim et al. (1983). Settling rates were measured for fly ash from four power plants, each tested at different initial slurry concentrations. For the slurry concentrations closest to the S.S. Badger's coal ash slurry discharge concentration, the fly ash settling rates ranged from 0.143-0.299 ft/min (0.04360 – 0.0911 m/min). Bottom ash, in comparison, settled much faster; 2 minutes of settling removed 98% of the bottom ash from the experimental apparatus. By modeling the lake's epilimnion as a completely-mixed reactor, the rate of loss of coal ash slurry solids as a function of the settling velocity can be calculated:

$$\frac{dC}{dt} = -h\, v_s\, C$$

where:

C	=	coal ash slurry solids concentration (mg/L)
h	=	depth of epilimnion (10 m)
v_s	=	settling rate (m/s)

The solution to this equation is:

$$C(t) = C_o \exp\left(-v_s \frac{t}{h}\right)$$

where:

C_o = initial coal ash slurry solids concentration (mg/L)

According to this solution, the concentration of coal fly ash slurry solids will decrease by 50% in 1.27 to 2.65 hours, for high and low settling rates, respectively. Ninety percent concentration declines will occur in 4.21 to 8.80 hours. Since the slurry discharged by the S.S. Badger is a combination of fly ash and bottom ash (the latter which, according to Kim et al. (1983), settled much faster), the overall rate of decline in coal ash slurry solids will occur faster than the times calculated here.

7. SUMMARY AND CONCLUSIONS

This report was prepared to provide interpretation and evaluation of the ecological impacts of the suspended solids and turbidity associated with the coal ash slurry discharges from the S.S. Badger carferry to the open waters of Lake Michigan. Coal ash slurry is discharged during about 2 ½ hours of the S.S. Badger's four-hour voyage across Lake Michigan, between the ports of Ludington, MI and Manitowoc, WI. According to the Vessel General Permit, the discharge of ash slurry occurs when the S.S. Badger is more than 5 nautical miles from shore, in water over 100 feet in depth while underway at not less than 6 knots. The solids content of the coal ash slurry discharge is in the range of 2,500 mg/L to 3,100 mg/L.

A literature review was conducted to find the best available information to characterize the dilution of wastewater discharges from moving vessels. The dilution achieved behind a moving self-propelled vessel has been estimated in a variety of ways. For a cruise ship traveling at 8 knots and discharging wastewater at a rate of 200 m^3/hr, Colonell et al. (2000) calculated initial (near-field) dilution of 2,500:1 (within about a minute) and far-field dilution of 25,000:1 (<5 days) using the CORMIX1 model. Based on this same model, EPA (2002) calculated that effluent discharges from cruise ships operating in Alaskan waters were expected to undergo initial dilution of approximately 40,000:1.

A Scientific Advisory Panel (SAP) reporting to the Alaska Cruise Ship Initiative (Atkinson et al., 2001) presented a simple approach to estimating dilution factors that was applicable to a variety of ships and locations of discharge ports. A dilution factor can be calculated by comparing the rate the ship moves through a volume of water to the rate of the effluent discharge. For the S.S. Badger, a dilution factor of 15,425:1 was calculated based on the SAP formula (Atkinson et al., 2001). A Cruise Ship Plume Tracking Survey was conducted by EPA to measure the dispersion of cruise ship wastewater discharges while in transit. The study found that discharges behind cruise ships moving at between 9 and 17 knots were diluted by a factor of between 200,000:1 and 640,000:1.

Although it is likely that the dilution of coal ash discharge behind the S.S. Badger is similar to the dilution measured for cruise ship wastewater discharges, based on our review of the literature we believed that it was most appropriate to consider a range of dilution factors for the S.S. Badger's coal ash slurry discharge. A lower-bound estimate of 15,425:1 was provided by the SAP formula, while the most conservative of the dilution factors measured in the Cruise Ship Plume Tracking Survey, 200,000:1, represented a conservative an upper-bound estimate. Based on these estimates, ambient suspended solids concentrations of 0.013 to 0.201 mg/L were calculated following the initial mixing of coal ash slurry discharged by the S.S. Badger.

While the discharge of coal ash slurry from the S.S. Badger has been quantified and TSS concentrations diluted in Lake Michigan water have been estimated based upon dilution ratios, it was necessary to relate these quantities to turbidity in order to evaluate the potential ecological impacts. Turbidity/TSS ratios calculated using data from fly ash and bottom ash wastewater samples were applied to calculate ambient turbidity values (following dilution in the ship's wake) of 0.004 to 0.08 NTU. The upper-bound estimate of turbidity imparted by the S.S. Badger's coal ash slurry discharge (0.080 NTU) is much lower in comparison to water quality standards promulgated by several states, as well as in comparison to EPA's drinking water standard for turbidity.

A review of the scientific literature on effects of turbidity and suspended solids on freshwater aquatic life was also summarized. Adverse effects were not observed at turbidities below 5-10 NTU. Given that the highest ambient turbidity calculated from the S.S. Badger's coal ash slurry discharge, the turbidity/TSS ratio, and the dilution factor in the previous sections is 0.080 NTU, it appears very unlikely that the turbidity contributed by this discharge would have an adverse effect on the Lake Michigan ecosystem.

The significance of the S.S. Badger's coal ash slurry discharge was further evaluated by comparing it's magnitude to other known sources of turbidity and suspended solids in Lake Michigan. The overall rate of solids loading in the lake has been measured as particle settling fluxes in southern Lake Michigan using sediment traps (Eadie, 1997). If the solids in the coal ash slurry discharge were deposited uniformly over the 1,000 mi^2 area covered by the S.S. Badger's course over a season, it would represent a solids flux of 0.0042 $gm/m^2/d$, about 1% of the deposition flux delivered to the near surface waters of northern Lake Michigan during the stratified period as measured by sediment traps. If instead, the solids in the coal ash slurry discharge were deposited within a 1 mile wide "track" of the S.S. Badger across the lake, the solids flux would be 0.11 $gm/m^2/d$, still only about 30% of the deposition flux measured in sediment traps.

Near surface TSS and turbidity data from monitoring stations located near the S.S. Badger's route were also compared to the upper-bound estimates of ambient TSS and turbidity contributed by the coal ash slurry discharge of the S.S. Badger. It was calculated that this discharge may locally increase TSS in Lake Michigan by 13 to 35% (average 21%), and turbidity by 11 to 35% (average 19%). The maximum ambient TSS and turbidity expected in the vicinity of the S.S. Badger, obtained by adding the highest values tabulated above to the upper-bound contributions expected from the S.S. Badger's discharge, are 1.73 mg/L and 0.83 NTU. These values are still well below concentrations associated with adverse effects to aquatic life.

At any given location in the lake, ambient TSS and turbidity elevated by the S.S. Badger's discharge will be a transient occurrence, because the solids in the coal ash slurry will be lost via settling through the water column. According to this process, the concentration of coal fly ash slurry solids will decrease by 50% in 1.27 to 2.65 hours, for high and low settling rates, respectively. Ninety percent concentration declines will occur in 4.21 to 8.80 hours. Since the slurry discharged by the S.S. Badger is a combination of fly ash and bottom ash (the latter which, according to Kim et al., settled much faster), the overall rate of decline in coal ash slurry solids will occur faster than the times calculated here.

In summary, GLEC examined the possible impacts of the discharge of coal ash slurry from the S.S. Badger to Lake Michigan from a number of perspectives, and found no indication that the suspended solids or turbidity predicted to result from this discharge would be harmful to aquatic life. Although it was necessary to use data from a variety of sources to conduct this analysis, these data are believed to be reasonably representative. When variability or uncertainty in a particular parameter was encountered, calculations were repeated using upper- and lower- bound values. With regards to TSS and turbidity, more precise evaluation of the S.S. Badger's coal ash slurry discharge would require collection of site-specific data; however, such an effort appears unwarranted at this time given that the levels of suspended solids and turbidity associated with this discharge are well below values known to cause adverse effects to aquatic life present in the Lake Michigan ecosystem.

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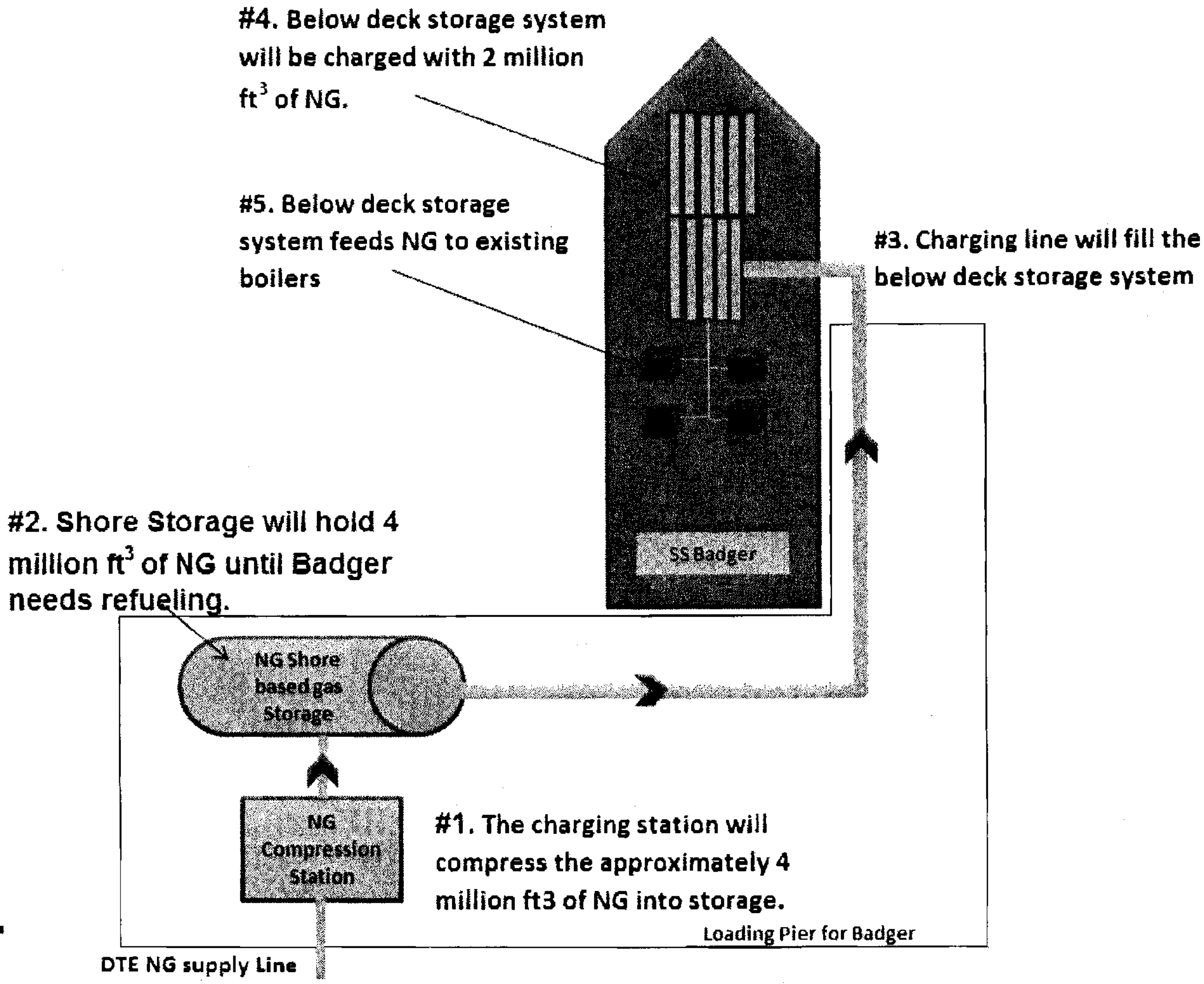
S.S. BADGER

Transition from Coal to Compressed Natural Gas for Boiler Fuel

Compressed Natural Gas Fuel System Schematic

S.S. BADGER
LAKE MICHIGAN CARFERRY



Natural Gas Conversion Project

S.S. BADGER

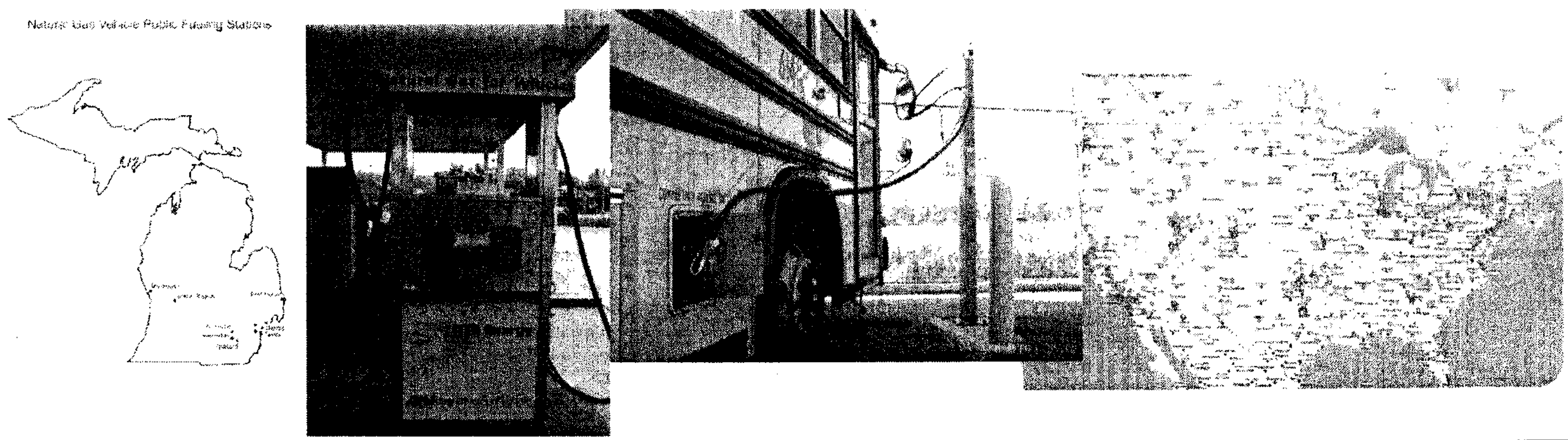
1. Preliminary Design, Economics and Funding Options.
    a. Boiler Retrofit from Coal Stoker to Natural Gas Burners and Controls.
    b. Shore Based Natural Gas Compressor and Storage System.
    c. Onboard Compressed Natural Gas Storage System (Below Deck).
2. U.S. Coast Guard Approval and Certification of Compressed Natural Gas Storage Below Deck (USCG and ABS).
3. Final Design, Contractor/Equipment Selection
4. Financing and Procurement
5. Below Deck Demolition/Site Preparation
6. Installation/Construction

Natural Gas Conversion

S.S. BADGER
LAKE MICHIGAN CARFERRY

1. **Boiler Retrofit From Coal to Natural Gas Burners.**
   - The conversion of the steam boilers from coal firing to natural gas firing does not appear to present any significant physical constraints or issues using land-based experience.

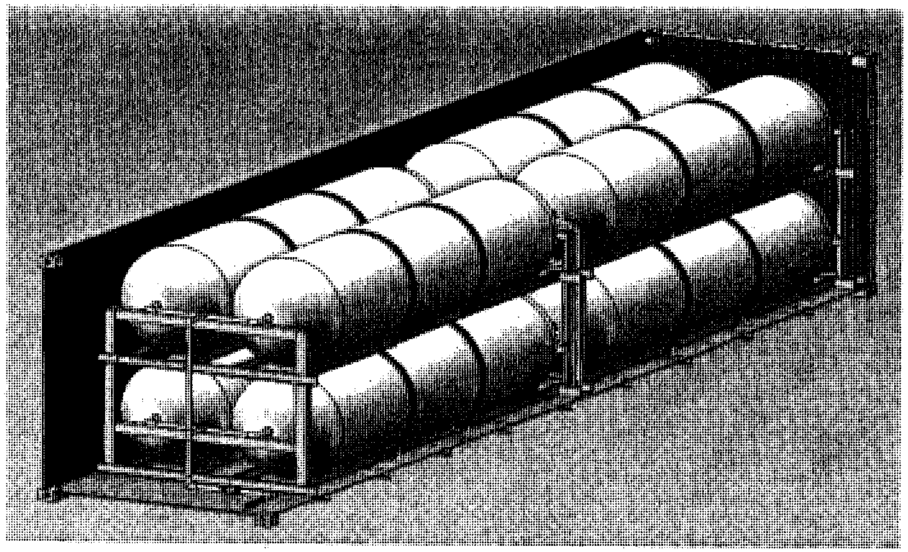
2. **Shore Based Natural Gas Compression and Storage.**
   - DTE owns and operates NG filling stations and pipeline compression throughout Michigan; The natural gas industry operates compression and CNG throughout North America.



Natural Gas Conversion - Challenges

S.S. BADGER
LAKE MICHIGAN CARFERRY

1. **On shore compressor and storage must accommodate cross lake service business schedule; less than 2-hour fill time during peak summer season.**
2. **Onboard compressed natural gas storage system below deck design and fit-out.**
3. **Regulatory approval and certification of compressed natural gas storage for maritime application below deck.**
4. **Project cost and financing/funding that supports operator's business plan**



- Example of a CNG container unit under evaluation
- Approximately 11 such containers required to operate the SS Badger storing 2 million cubic feet of Compressed Natural Gas at 2,600 Psig.
- There are currently no U.S. Regulations for the Storage of CNG Below Deck.
- U.S. Coast Guard approval may require will significant time and effort.

Natural Gas Conversion Experience LNG v. CNG

1. LNG is currently used to fuel some vessels
   - Example: Washington ferry
2. Limitations on use of LNG
   - Availability of CNG vs LNG in MI and WI
3. USCG-approved CNG fueled ferry operates in VA
4. Need USCG approval for below deck CNG storage
   - IMO and ABS guidelines allow this
5. ABS evaluation – Status
6. Process for USCG review and approval for SS Badger

Summary - Challenges

S.S. BADGER
LAKE MICHIGAN CARFERRY

1. Boiler retrofit from coal to natural gas burners.
   - Typical industrial boiler design, installation and implementation hurdles.
2. Shore based natural gas compression and storage system.
   - Design and operations must meet Ferry Operator's 1-2 hour time fill schedule requirements.
3. Onboard natural gas storage system below deck.
   - Design and installation challenging but not insurmountable.
4. Coast Guard approval of Compressed Natural Gas storage below deck.
   - Represents one of the primary challenges to complete the conversion to clean burning Compressed Natural Gas.
5. Project Funding
   - Project must maintain viability of ferry operations in order to maintain jobs, and benefit business and services within the local communities and states of Michigan and Wisconsin.

Project Benefits

S.S. BADGER
LAKE MICHIGAN CARFERRY

1. Eliminates use of coal in Lake Michigan cross lake operations
2. Could be the first ship in world to operate boilers on CNG.
3. Certification of the use of CNG below deck in maritime operations establishes further application of clean burning natural gas in the shipping industry.
4. Maintains the viability of an American business, maintains jobs, supporting services and businesses in hard hit recession regions of Michigan and Wisconsin.

ANNEX 11

RESOLUTION MSC.285(86)
(adopted on 1 June 2009)

INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Organization concerning the functions of the Committee,

NOTING that the International Convention for the Safety of Life at Sea, 1974 currently does not have any provisions for use of gas as fuel on ships other than gas carriers,

RECOGNIZING a need for the development of a code for gas-fuelled ships,

ACKNOWLEDGING that, in the interim, there is an urgent need to provide guidance to the Administrations on the gas-fuelled engine installations in ships,

HAVING CONSIDERED the Interim Guidelines prepared by the Sub-Committee on Bulk Liquids and Gases at its thirteenth session,

1. ADOPTS the Interim Guidelines on safety for natural gas-fuelled engine installations in ships, the text of which is set out in the Annex to the present resolution;

2. INVITES Governments to apply the Interim Guidelines to gas-fuelled ships other than those covered by the IGC Code;

3. URGES Member Governments and the industry to submit information, observations, comments and recommendations based on the practical experience gained through the application of these Interim Guidelines and submit relevant safety analysis on gas-fuelled installations;

4. AGREES to continue the work on the development of the International Code of Safety for Gas-fuelled Ships (IGF Code).

ANNEX

INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

Index

PREAMBLE

1 These Interim Guidelines have been developed to provide an international standard for ships, other than vessels covered by the IGC Code, with natural gas-fuelled engine installations.

2 The goal of these Interim Guidelines is to provide criteria for the arrangement and installation of machinery for propulsion and auxiliary purposes, using natural gas as fuel, which will have an equivalent level of integrity in terms of safety, reliability and dependability as that which can be achieved with a new and comparable conventional oil-fuelled main and auxiliary machinery.

3 To achieve this goal, the functional requirements described below are embodied in the relevant parts of these Interim Guidelines:

.1 Minimize hazardous areas as far as is practicable to reduce the potential risks that might affect the safety of the ship, personnel and equipment.

.2 Minimize equipment installed in hazardous areas to that required for operational purposes. Equipment installed in hazardous areas should be suitable and appropriately certified.

.3 Arrange hazardous areas to ensure pockets of gas cannot accumulate under normal and foreseeable failure conditions.

.4 Arrange propulsion and electrical power generating installation to be capable of sustained or restored operation in the event that a gas-fuelled essential service becomes inoperative.

.5 Provide ventilation to protect personnel from an oxygen deficient atmosphere in the event of a gas leakage.

.6 Minimize the number of ignition sources in hazardous spaces by design, arrangements and selection of suitable equipment.

.7 Arrange safe and suitable gas fuel storage and bunkering arrangements capable of taking on board and containing the gas fuel in the required state without leakage and overpressure.

.8 Provide gas piping systems, containment and overpressure relief arrangements that are of suitable design, construction and installation for their intended application.

.9 Design, construct, install, operate and protect gas-fuelled machinery, gas system and components to achieve safe and reliable operation consistent with that of oil-fuelled machinery.

.10 Arrange and locate gas storage tank rooms and machinery spaces such that a fire or explosion in either will not render the machinery/equipment in other compartments inoperable.

.11 Provide safe and reliable gas-fuel control engineering arrangements consistent with those of oil-fuelled machinery.

.12 Provide appropriate selection of certified equipment and materials that are suitable for use within gas systems.

.13 Provide gas detection systems suitable for the space concerned together with monitoring, alarm and shutdown arrangements.

.14 Provide protection against the potential effects of a gas-fuel explosion.

.15 Prevent explosion and hazardous consequences.

.16 Provide fire detection, protection and extinction measures appropriate to the hazards concerned.

.17 Provide a level of confidence in a gas-fuelled unit that is equivalent to that for an oil-fuelled unit.

.18 Ensure that commissioning, trials and maintenance of gas utilization machinery satisfy the goal in terms of reliability, availability and safety.

.19 Provide provision for procedures detailing the guidelines for safe routine and unscheduled inspection and maintenance.

.20 Provide operational safety through appropriate training and certification of crew.

.21 Provide for submission of technical documentation in order to permit an assessment of the compliance of the system and its components with the applicable rules and guidelines.

4 The Interim Guidelines address the safety of ships utilizing natural gas as fuel.

5 Natural gas (dry) is defined as gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).

6 The gas composition can vary depending on the source of natural gas and the processing of the gas. Typical composition in volume (%):

Methane (C_1)	94.0%
Ethane (C_2)	4.7%
Propane (C_3)	0.8%
Butane (C_4+)	0.2%
Nitrogen	0.3%
Density gas	0.73 kg/sm^3
Density liquid	0.45 kg/dm^3
Calorific value (low)	49.5 MJ/kg
Methane number	83

The gas may be stored and distributed as compressed natural gas (CNG) or liquefied natural gas (LNG).

CHAPTER 1

GENERAL

1.1 Application

1.1.1 These Interim Guidelines apply to internal combustion engine installations in ships using natural gas as fuel. The engines may use either a single fuel (gas) or dual fuel (gas and oil fuel), and the gas may be stored in gaseous or liquid state.

1.1.2 These Interim Guidelines should be applied in addition to the relevant provisions of the International Convention for the Safety of Life at Sea (SOLAS), 1974 and the Protocol of 1988 relating thereto, as amended.

1.1.3 The Interim Guidelines are applicable to new ships. Application to existing ships should be decided by the Administration to the extent it deems necessary.

1.2 Hazards

These Guidelines address the hazards related to the arrangements for the storage, distribution and use of natural gas as a fuel.

1.3 Definitions

For the purpose of these Guidelines, unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

1.3.1 *Accidents* mean uncontrolled events that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

1.3.2 *Certified safe type* means electrical equipment that is certified safe by a recognized body based on a recognized standard[1]. The certification of electrical equipment is to correspond to the category and group for methane gas.

1.3.3 *CNG* means compressed natural gas.

1.3.4 *Control stations* mean those spaces defined in SOLAS chapter II-2 and additionally for these Guidelines, the engine control room.

1.3.5 *Double block and bleed valve* means a set of three automatic valves located at the fuel supply to each of the gas engines.

1.3.6 *Dual fuel engines* mean engines that can burn natural gas and fuel oil oil fuel simultaneously or operate on oil fuel or gas only.

1.3.7 *Enclosed space* means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally[2].

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[1] Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

[2] See also definition in IEC 60092-502:1999.

1.3.8 *ESD* means emergency shutdown.

1.3.9 *Explosion* means a deflagration event of uncontrolled combustion.

1.3.10 *Explosion pressure relief* means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.

1.3.11 *Gas* means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

1.3.12 *Hazardous area* means an area in which an explosive gas atmosphere or a flammable gas (flashpoint below 60°C) is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Hazardous areas are divided into zones 0, 1 and 2 as defined below[3]:

.1 *Zone 0* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is present continuously or is present for long periods.

.2 *Zone 1* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is likely to occur in normal operation.

.3 *Zone 2* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.3.13 *Non-hazardous area* means an area which is not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

1.3.14 *High-pressure piping* means gas fuel piping with maximum working pressure greater than 10 bar.

1.3.15 *IEC* means the International Electrotechnical Commission.

1.3.16 *IGC Code* means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

1.3.17 *LEL* means the lower explosive limit.

1.3.18 *LNG* means liquefied natural gas (refer to 1.3.22).

1.3.19 *Main tank valve* means a remote operated valve on the gas outlet from a gas storage tank, located as close to the tank outlet point as possible.

1.3.20 *MARVS* means the maximum allowable relief valve setting of a gas tank.

1.3.21 *Master gas fuel valve* means an automatic valve in the gas supply line to each engine located outside the machinery space for gas-fuelled engines and as close to the gas heater (if fitted) as possible.

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[3] Refer also to the area classification specified in Sec. 2.5 of IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres.

1.3.22 *Natural gas* means a gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).

1.3.23 *Open deck* means a deck that is open on both ends, or is open on one end and equipped with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side panels or in the deck above.

1.3.24 *Organization* means the International Maritime Organization (IMO).

1.3.25 *Risk* means the expression of the danger that an undesired event represents to persons, to the environment or to material property. The risk is expressed by the probability and consequences of an accident.

1.3.26 *Recognized standards* means applicable international or national standards acceptable to the Administration or standards laid down and maintained by an organization which complies with the standards adopted by the Organization and which is recognized by the Administration.

1.3.27 *Safety management system* means the international safety management system as described in the ISM Code.

1.3.28 *Second barrier* means a technical measure which prevents the occurrence of a hazard if the first barrier fails, e.g., second housing of a tank protecting the surroundings from the effect of tank leaks.

1.3.29 *Semi-enclosed space* means a space limited by decks and or bulkheads in such manner that the natural conditions of ventilation are notably different from those obtained on open deck[4].

1.3.30 *Single gas fuel engine* means a power generating engine capable of operating on gas-only, and not able to switch over to oil fuel operation.

1.3.31 *SOLAS Convention* means the International Convention for the Safety of Life at Sea, 1974, as amended.

1.3.32 *Source of release* means any valve, detachable pipe joint, pipe packing, compressor or pump seal in the gas fuel system.

1.3.33 *Tank room* means the gastight space surrounding the bunker tank, containing all tank connections and all tank valves.

1.4 Survey requirements

1.4.1 Surveys should be performed and certificates issued in accordance with the provisions of SOLAS 1974, as modified by its 1988 Protocol and as amended, chapter 1, part B, regulation 6 or 7, as applicable[5].

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4 Refer also to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

5 Refer to the Revised survey guidelines under the harmonized system of survey and certification (resolution A.997(25)).

CHAPTER 2

SHIP ARRANGEMENTS AND SYSTEM DESIGN

2.1 General

2.1.1 For any new or altered concept or configuration a risk analysis should be conducted in order to ensure that any risks arising from the use of gas-fuelled engines affecting the structural strength and the integrity of the ship are addressed. Consideration should be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure.

2.1.2 The risks should be analysed using acceptable and recognized risk analysis techniques and loss of function, component damage, fire, explosion and electric shock should as a minimum be considered. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks, and the means by which they are mitigated, should be included in the operating manual.

2.1.3 An explosion in any space containing open gas sources should not:

.1 cause damage to any space other than that in which the incident occurs;

.2 disrupt the proper functioning of other zones;

.3 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

.4 damage work areas or accommodation in such a way that people who stay in such areas under normal operating conditions are injured;

.5 disrupt the proper functioning of control stations and switchboard rooms for necessary power distribution;

.6 damage life-saving equipment or associated launching arrangements;

.7 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space; or

.8 affect other areas in the vessel in such a way that chain reactions involving, *inter alia*, cargo, gas and bunker oil may arise.

2.2 Material requirements

2.2.1 Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with gas should be in accordance with IGC Code, chapter 6, Materials of construction. For CNG tanks, the use of materials not covered by the IGC Code may be specially considered by the Administration.

2.2.2 Materials for piping system for liquefied gases should comply with the requirements of the IGC Code, section 6.2. Some relaxation may, however, be permitted in the quality of the material of open-ended vent piping, provided the temperature of the gas at atmospheric pressure is -55°C or higher, and provided no liquid discharge to the vent piping can occur. Materials should in general be in accordance with recognized standards.

2.2.3 Materials having a melting point below 925°C should not be used for piping outside the gas tanks except for short lengths of pipes attached to the gas tanks, in which case the low melting point materials should be wrapped in class A-60 insulation.

2.3 Location and separation of spaces

2.3.1 The arrangement and location of spaces

The arrangement and location of spaces for gas fuel storage, distribution and use should be such that the number and extent of hazardous areas is kept to a minimum.

2.3.2 Gas compressor room

2.3.2.1 Compressor rooms, if arranged, should be located above freeboard deck, unless those rooms are arranged and fitted in accordance with the requirements of these Guidelines for tank rooms.

2.3.2.2 If compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration should be of gastight type.

2.3.3 Machinery spaces containing gas-fuelled engines

2.3.3.1 When more than one machinery space is required for gas-fuelled engines and these spaces are separated by a single bulkhead, the arrangements should be such that the effects of a gas explosion in either space can be contained or vented without affecting the integrity of the adjacent space and equipment within that space.

2.3.3.2 ESD-protected machinery spaces for gas-fuelled engines should have as simple a geometrical shape as possible.

2.3.4 Tank rooms

2.3.4.1 Tank room boundaries including access doors should be gastight.

2.3.4.2 The tank room should not be located adjacent to machinery spaces of category A. If the separation is by means of a cofferdam the separation should be at least 900 mm and insulation to class A-60 should be fitted on the engine-room side.

2.4 Arrangement of entrances and other openings

2.4.1 Direct access through doors, gastight or otherwise, should generally not be permitted from a gas-safe space to a gas-dangerous space. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided.

2.4.2 If the compressor room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided.

2.4.3 The tank room entrance should be arranged with a sill height of at least 300 mm.

2.4.4 Access to the tank room should as far as practicable be independent and direct from open deck. If the tank room is only partially covering the tank, this requirement should also apply to the room surrounding the tank and where the opening to the tank room is located. Where a separate access from deck is not practicable, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided. The access trunk should be fitted with separate ventilation. It should not be possible to have unauthorized access to the tank room during normal operation of the gas system.

2.4.5 If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances should be arranged with self-closing doors. An audible and visual alarm should be provided at a permanent manned location. Alarm should be given if the door is open continuously for more than 1 min. As an alternative, an arrangement with two self-closing doors in series may be acceptable.

2.5 General pipe design

2.5.1 The requirements of this section apply to gas piping. The Administration may accept relaxation from these requirements for gas piping inside gas tanks and open-ended piping after special consideration, such as risk assessment.

2.5.2 Gas piping should be protected against mechanical damage and the piping should be capable of assimilating thermal expansion without developing substantial tension.

2.5.3 The piping system should be joined by welding with a minimum of flange connections. Gaskets should be protected against blow-out.

2.5.4 The wall thickness of pipes should not be less than:

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}} \text{ (mm)}$$

where:

t_0 = theoretical thickness
t_0 = $pD/(20Ke + p)$

where:

p = design pressure (bar), refer to 2.5.5.

D = outside diameter (mm).

K = allowable stress (N/mm^2), refer to 2.5.6.

e = efficiency factor equal to 1 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases an efficiency factor value depending on the manufacturing process may be determined by the Administration.

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not give, b should be:

$$b = \frac{Dt_0}{2.5r} \text{ (mm)}$$

with:

r = mean radius of the bend (mm).

c = corrosion allowance (mm). If corrosion allowance or erosion is expected, the wall thickness of the piping should be increased over that required by other design requirements. This allowance should be consistent with the expected life of the piping.

a = negative manufacturing tolerance for thickness (%).

The minimum wall thickness should be in accordance with recognized standards.

2.5.5 The greater of the following design conditions should be used for piping, piping system and components as appropriate:

.1 for systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Administration (refer to IGC Code, paragraph 4.2.6.2), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

.2 the MARVS of the gas tanks and gas processing systems; or

.3 the pressure setting of the associated pump or compressor discharge relief valve if of sufficient capacity; or

.4 the maximum total discharge or loading head of the gas piping system; or

.5 the relief valve setting on a pipeline system if of sufficient capacity; or

.6 a pressure of 10 bar except for open-ended lines where it is not to be less than 5 bar.

2.5.6 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 2.5.4 should be the lower of the following values:

$$\frac{R_m}{A} \text{ or } \frac{R_e}{B}$$

where:

R_m = specified minimum tensile strength at room temperature (N/mm²).

R_e = specified lower minimum yield stress or 0.2% proof stress at room temperature (N/mm²).

A = 2.7.

B = 1.8.

For pipes made of materials other than steel, the allowable stress should be considered by the Administration.

2.5.7 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipe due to superimposed loads from supports, ship deflection or other causes, the wall thickness should be increased over that required by 2.5.4 or, if this is impractical or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

2.5.8 Gas piping systems should have sufficient constructive strength. For high pressure gas piping systems this should be confirmed by carrying out stress analysis and taking into account:

.1 stresses due to the weight of the piping system;

.2 acceleration loads when significant; and

.3 internal pressure and loads induced by hog and sag of the ship.

2.5.9 Flanges, valves, fittings, etc., should be in accordance with recognized standards taking into account the design pressure defined in 2.5.5. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 2.5.5 may be accepted.

2.5.10 All valves and expansion joints used in high pressure gas systems should be of an approved type.

2.5.11 The following types of connections may be considered for direct connection of pipe lengths (without flanges):

.1 Butt welded joints with complete penetration at the root may be used in all applications. For design temperature below -10°C, butt welds should be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 10 bar and design temperatures -10°C or lower, backing rings should be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions satisfactory to the Administration, should only be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.

.3 Screwed couplings should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

2.5.12 Flanges should be of the welding neck, slip-on or socket welding type. For all piping (except open-ended lines), the following apply:

.1 For design temperatures < -55°C only welding neck flanges should be used.

.2 For design temperatures < -10°C slip-on flanges should not be used in nominal sizes above 100 mm and socket welding flanges should not be used in nominal sizes above 50 mm.

2.5.13 Piping connections other than those mentioned above may be accepted upon consideration in each case.

2.5.14 Postweld heat treatment should be required for all butt welds of pipes made with carbon, carbon-manganese and low-alloy steels. The Administration may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

2.5.15 When the design temperature is -110°C or lower, a complete stress analysis for each branch of the piping system should be submitted. This analysis should take into account all stresses due to weight of pipes with cargo (including acceleration if significant), internal pressure, thermal contraction and loads induced by movements of the ship. For temperatures above -110°C, a stress analysis may be required by the Administration. In any case, consideration should be given to thermal stresses, even if calculations need not be submitted. The analysis should be carried out according to a recognized code of practice.

2.5.16 Gas pipes should not be located less than 760 mm from the ship's side.

2.5.17 Gas piping should not be led through other machinery spaces. Alternatively, double gas piping may be approved, provided the danger of mechanical damage is negligible, the gas piping has no discharge sources and the room is equipped with a gas alarm.

2.5.18 An arrangement for purging gas bunkering lines and supply lines (only up to the double block and bleed valves if these are located close to the engine) with nitrogen should be provided.

2.5.19 The gas piping system should be installed with sufficient flexibility. Arrangement for provision of the necessary flexibility should be demonstrated to maintain the integrity of the piping system in all foreseen service situations.

2.5.20 Gas pipes should be colour marked based on a recognized standard[6].

[6] Refer to EN ISO 14726:2008 Ships and marine technology – Identification colours for the content of piping systems.

2.5.21 If the fuel gas contains heavier components that may condense in the system, knock out drums or equivalent means for safely removing the liquid should be fitted.

2.5.22 All pipelines and components which may be isolated containing liquid gas should be provided with relief valves.

2.5.23 Where tanks or piping are separated from the ship's structure by thermal isolation, provision should be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections should be electrically bonded.

2.6 System configuration

2.6.1 *Alternative system configurations*

2.6.1.1 Two alternative system configurations may be accepted:

.1 *Gas safe machinery spaces*: Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

.2 *ESD-protected machinery spaces*: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery is to be automatically executed while equipment or machinery in use or active during these conditions are to be of a certified safe type.

2.6.2 *Gas safe machinery spaces*

2.6.2.1 All gas supply piping within machinery space boundaries should be enclosed in a gastight enclosure, i.e. double wall piping or ducting.

2.6.2.2 In case of leakage in a gas supply pipe making shutdown of the gas supply necessary, a secondary independent fuel supply should be available. Alternatively, in the case of multi-engine installations, independent and separate gas supply systems for each engine or group of engines may be accepted.

2.6.2.3 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.6.3 *ESD-protected machinery spaces*

2.6.3.1 Gas supply piping within machinery spaces may be accepted without a gastight external enclosure on the following conditions:

.1 Engines for generating propulsion power and electric power should be located in two or more machinery spaces not having any common boundaries unless it can be documented that the common boundary can withstand an explosion in one of the rooms. Distribution of engines between the different machinery spaces should be such that in the case of shutdown of fuel supply to any one machinery space it is possible to maintain at least 40% of the propulsion power plus normal electrical power supply for sea-going services. Incinerators, inert gas generators or other oil fired boilers should not be located within an ESD-protected machinery space.

.2 The gas machinery, tank and valve installation spaces should contain only a minimum of such necessary equipment, components and systems as are required to ensure that any piece of equipment in each individual space maintains its principal function.

.3 Pressure in gas supply lines within machinery spaces should be less than 10 bar, e.g., this concept can only be used for low pressure systems.

.4 A gas detection system arranged to automatically shutdown the gas supply (also oil fuel supply if dual fuel) and disconnect all non-explosion protected equipment or installations should be fitted, as outlined in 5.5 and 5.6.

2.6.3.2 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.7 Gas supply system in gas machinery spaces

2.7.1 Gas supply system for gas safe machinery spaces

2.7.1.1 Gas supply lines passing through enclosed spaces should be completely enclosed by a double pipe or duct. This double pipe or duct should fulfil one of the following:

.1 the gas piping should be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system should be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

.2 the gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct should be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors should comply with the required explosion protection in the installation area. The ventilation outlet should be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited.

2.7.1.2 The connecting of gas piping and ducting to the gas injection valves should be so as to provide complete coverage by the ducting. The arrangement should facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting should be required also for gas pipes on the engine itself, and all the way until gas is injected into the chamber.[7]

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[7] If gas is supplied into the air inlet on a low pressure engine, double ducting may be omitted on the air inlet pipe on the condition that a gas detector is fitted above the engine.

2.7.1.3 For high-pressure piping the design pressure of the ducting should be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure and is given by the following expression:

$$p^{*} = p_0 \left(\frac{2}{k+1} \right)^{\frac{k}{k-1}}$$

where:

p_0 = maximum working pressure of the inner pipe

k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat

k = 1.31 for CH_4

The tangential membrane stress of a straight pipe should not exceed the tensile strength divided by 1.5 ($R_m/1.5$) when subjected to the above pressures. The pressure ratings of all other piping components should reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports should then be submitted.

2.7.1.4 For low pressure piping the duct should be dimensioned for a design pressure not less than the maximum working pressure of the gas pipes. The duct should also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

2.7.1.5 The arrangement and installation of the high-pressure gas piping should provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of the main engine, without running the risk of fatigue problems. The length and configuration of the branch lines are important factors in this regard.

2.7.2 *Gas supply system for ESD-protected machinery spaces*

2.7.2.1 The pressure in the gas supply system should not exceed 10 bar.

2.7.2.2 The gas supply lines should have a design pressure not less than 10 bar.

2.8 Gas fuel storage

2.8.1 *Liquefied gas storage tanks*

2.8.1.1 The storage tank used for liquefied gas should be an independent tank designed in accordance with the IGC Code, chapter 4.

2.8.1.2 Pipe connections to the tank should normally be mounted above the highest liquid level in the tanks. However, connections below the highest liquid level may be accepted after special consideration by the Administration.

2.8.1.3 Pressure relief valves as required in the IGC Code chapter 8 should be fitted.

2.8.1.4 The outlet from the pressure relief valves should normally be located at least B/3 or 6 m, whichever is greater, above the weather deck and 6 m above the working area and gangways, where B is the greatest moulded breadth of the ship in metres. The outlets should normally be located at least 10 m from the nearest:

.1 air intake, air outlet or opening to accommodation, service and control spaces, or other gas safe spaces; and

.2 exhaust outlet from machinery or from furnace installation.

2.8.1.5 Storage tanks for liquid gas should not be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in the IGC Code, paragraph 15.1.4. A filling limit curve for actual filling temperatures should be prepared from the formula given in the IGC Code, paragraph 15.1.2. However, when the tank insulation and tank location makes the probability very small for the tank contents to be heated up due to external fire, special considerations may be made to allow a higher filling limit than calculated using the reference temperature, but never above 95%.

2.8.1.6 Means that are not dependent on the gas machinery system should be provided whereby liquid gas in the storage tanks can be emptied.

2.8.1.7 It should be possible to empty, purge gas and vent bunker tanks with gas piping systems. Procedures should be prepared for this. Inerting should be performed with, for instance, nitrogen, CO_2 or argon prior to venting to avoid an explosion hazardous atmosphere in tanks and gas pipes.

2.8.2 ***Compressed gas storage tanks***

2.8.2.1 The storage tanks to be used for compressed gas should be certified and approved by the Administration.

2.8.2.2 Tanks for compressed gas should be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 2.8.1.4.

2.8.3 ***Storage on open deck***

2.8.3.1 Both gases of the compressed and the liquefied type may be accepted stored on open deck.

2.8.3.2 The storage tanks or tank batteries should be located at least B/5 from the ship's side. For ships other than passenger ships a tank location closer than B/5 but not less than 760 mm from the ship's side may be accepted.

2.8.3.3 The gas storage tanks or tank batteries and equipment should be located to assure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

2.8.3.4 Tanks for liquid gas with a connection below the highest liquid level (see 2.8.1.2) should be fitted with drip trays below the tank which should be of sufficient capacity to contain the volume which could escape in the event of a pipe connection failure. The material of the drip tray should be stainless steel, and there should be efficient separation or isolation so that the hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid gas.

2.8.4 ***Storage in enclosed spaces***

2.8.4.1 Gas in a liquid state may be stored in enclosed spaces, with a maximum acceptable working pressure of 10 bar. Storage of compressed gas in enclosed spaces and location of gas tanks with a higher pressure than 10 bar in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Administration provided the following is fulfilled in addition to 2.8.4.3:

.1 adequate means are provided to depressurize the tank in case of a fire which can affect the tank; and

.2 all surfaces within the tank room are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

.3 a fixed fire-extinguishing system is installed in the tank room.

2.8.4.2 The gas storage tank(s) should be placed as close as possible to the centreline:

.1 minimum, the lesser of B/5 and 11.5 m from the ship side;

.2 minimum, the lesser of B/15 and 2 m from the bottom plating;

.3 not less than 760 mm from the shell plating.

For ships other than passenger ships and multi-hulls, a tank location closer than B/5 from the ship side may be accepted.

2.8.4.3 The storage tank and associated valves and piping should be located in a space designed to act as a second barrier, in case of liquid or compressed gas leakage. The material of the bulkheads of this space should have the same design temperature as the gas tank, and the space should be designed to withstand the maximum pressure build-up. Alternatively, pressure relief venting to a safe location (mast) can be provided. The space should be capable of containing leakage, and is to be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of leakage of the liquid or compressed gas. This second barrier space is in other parts of these Guidelines called "tank room". When the tank is double walled and the outer tank shell is made of cold resistant material, a tank room could be arranged as a box fully welded to the outer shell of the tank, covering all tank connections and valves, but not necessarily all of the outer tank shell.

2.8.4.4 The tank room may be accepted as the outer shell of a stainless steel vacuum insulated tank in combination with a stainless steel box welded to the outer shell, containing all tank pipe connections, valves, piping, etc. In this case the requirements for ventilation and gas detection should be made applicable to the box, but not to the double barrier of the tank.

2.8.4.5 Bilge suctions from the tank room, if provided, should not be connected to the bilge system for the rest of the ship.

2.9 Fuel bunkering system and distribution system outside machinery spaces

2.9.1 *Fuel bunkering station*

2.9.1.1 The bunkering station should be so located that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration. The bunkering station should be physically separated or structurally shielded from accommodation, cargo/working deck and control stations. Connections and piping should be so positioned and arranged that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge.

2.9.1.2 Drip trays should be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays should be made of stainless steel, and should be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted for bunkering operations. The surrounding hull or deck structures should not be exposed to unacceptable cooling, in case of leakage of liquid gas. For compressed gas bunkering stations, low temperature steel shielding should be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.

2.9.1.3 Control of the bunkering should be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level should be monitored. Overfill alarm and automatic shutdown should also be indicated at this location.

2.9.2 *Bunkering system*

2.9.2.1 The bunkering system should be so arranged that no gas is discharged to air during filling of storage tanks.

2.9.2.2 A manually-operated stop valve and a remote operated shutdown valve in series, or a combined manually-operated and remote valve should be fitted in every bunkering line close to the shore connecting point. It should be possible to release the remote-operated valve in the control location for bunkering operations and or another safe location.

2.9.2.3 If the ventilation in the ducting around the gas bunkering lines stops, an audible and visual alarm should be provided at bunkering control location.

2.9.2.4 If gas is detected in the ducting around the bunkering lines an audible and visual alarm should be provided at the bunkering control location.

2.9.2.5 Means should be provided for draining the liquid from the bunkering pipes at bunkering completion.

2.9.2.6 Bunkering lines should be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes should be gas free.

2.9.3 *Distribution outside of machinery spaces*

2.9.3.1 Gas fuel piping should not be led through accommodation spaces, service spaces or control stations.

2.9.3.2 Where gas pipes pass through enclosed spaces in the ship, they should be enclosed in a duct. This duct should be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in 5.5 should be provided.

2.9.3.3 The duct should be dimensioned according to 2.7.1.3 and 2.7.1.4.

2.9.3.4 The ventilation inlet for the duct should always be located in open air, away from ignition sources.

2.9.3.5 Gas pipes located in open air should be so located that they are not likely to be damaged by accidental mechanical impact.

2.9.3.6 High-pressure gas lines outside the machinery spaces containing gas-fuelled engines should be installed and protected so as to minimize the risk of injury to personnel in case of rupture.

2.10 Ventilation system

2.10.1 ***General***

2.10.1.1 Any ducting used for the ventilation of hazardous spaces should be separate from that used for the ventilation of non-hazardous spaces. The ventilation should function at all temperature conditions the ship will be operating in. Electric fan motors should not be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

2.10.1.2 Design of ventilation fans serving spaces containing gas sources should fulfil the following:

.1 Electric motors driving fans should comply with the required explosion protection in the installation area. Ventilation fans should not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, should be of non-sparking construction defined as:

  .1 impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

  .2 impellers and housings of non-ferrous metals;

  .3 impellers and housing of austenitic stainless steel;

  .4 impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

  .5 any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

.2 In no case should the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

.4 The installation on board of the ventilation units should be such as to ensure the safe bonding to the hull of the units themselves.

2.10.1.3 Any loss of the required ventilating capacity should give an audible and visual alarm at a permanently manned location.

2.10.1.4 Required ventilation systems to avoid any gas accumulation should consist of independent fans, each of sufficient capacity, unless otherwise specified in these Guidelines.

2.10.1.5 Air inlets for hazardous enclosed spaces should be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct should have over-pressure relative to this space, unless mechanical integrity and gastightness of the duct will ensure that gases will not leak into it.

2.10.1.6 Air outlets from non-hazardous spaces should be located outside hazardous areas.

2.10.1.7 Air outlets from hazardous enclosed spaces should be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

2.10.1.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

2.10.1.9 Non-hazardous spaces with opening to a hazardous area should be arranged with an air-lock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation should be arranged according to the following requirements:

.1 During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it should be required to:

.1 proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and

.2 pressurize the space.

.2 Operation of the overpressure ventilation should be monitored.

.3 In the event of failure of the overpressure ventilation:

.1 an audible and visual alarm should be given at a manned location; and

.2 if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations according to a recognized standard[8].

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[8] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, table 5.

2.10.2 ***Tank room***

2.10.2.1 The tank room for gas storage should be provided with an effective mechanical forced ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations should be demonstrated by a safety analysis.

2.10.2.2 Approved automatic fail-safe fire dampers should be fitted in the ventilation trunk for tank room.

2.10.3 ***Machinery spaces containing gas-fuelled engines***

2.10.3.1 The ventilation system for machinery spaces containing gas-fuelled engines should be independent of all other ventilation systems.

2.10.3.2 ESD-protected machinery spaces should have ventilation with a capacity of at least 30 air changes per hour. The ventilation system should ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces is ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

2.10.3.3 The number and power of the ventilation fans should be such that the capacity is not reduced by more than 50% of the total ventilation capacity, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

2.10.4 ***Pump and compressor rooms***

2.10.4.1 Pump and compressor rooms should be fitted with effective mechanical ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour.

2.10.4.2 The number and power of the ventilation fans should be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

2.10.4.3 Ventilation systems for pump and compressor rooms should be in operation when pumps or compressors are working.

2.10.4.4 When the space is dependent on ventilation for its area classification, the following should apply:

.1 During initial start-up, and after loss of ventilation, the space should be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in absence of ventilation. Warning notices to this effect should be placed in an easily visible position near the control stand.

.2 Operation of the ventilation should be monitored.

.3 In the event of failure of ventilation, the following should apply:

.1 an audible and visual alarm should be given at a manned location;

.2 immediate action should be taken to restore ventilation; and

.3 electrical installations should be disconnected[9] if ventilation cannot be restored for an extended period. The disconnection should be made outside the hazardous areas, and be protected against unauthorized reconnection, e.g., by lockable switches.

CHAPTER 3

FIRE SAFETY

3.1 General

3.1.1 The requirements in this chapter are additional to those given in SOLAS chapter II-2.

3.1.2 A compressor room should be regarded as a machinery space of category A for fire protections purposes.

3.2 Fire protection

3.2.1 Tanks or tank batteries located above deck should be shielded with class A-60 insulation towards accommodation, service stations, cargo spaces and machinery spaces.

3.2.2 The tank room boundaries and ventilation trunks to such spaces below the bulkhead deck should be constructed to class A-60. However, where the room is adjacent to tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces, the insulation standard may be reduced to class A-0.

3.2.3 The fire and mechanical protection of gas pipes lead through ro-ro spaces on open deck should be subject to special consideration by the Administration depending on the use and expected pressure in the pipes. Gas pipes lead through ro-ro spaces on open deck should be provided with guards or bollards to prevent vehicle collision damage.

3.2.4 The bunkering station should be separated by class A-60 divisions towards other spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

3.2.5 When more than one machinery space is required and these spaces are separated by a single bulkhead, the bulkhead should be class A-60.

3.2.6 A compressor room in a ship not subject to the IGC Code should be regarded as a machinery space of category A for fire insulation requirements.

9 Intrinsically safe equipment suitable for zone 0 is not required to be switched off. Certified flameproof lighting may have a separate switch-off circuit.

3.3 Fire extinction

3.3.1 *Fire main*

3.3.1.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure is sufficient to operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

3.3.1.2 When the storage tank is located on open deck, isolating valves should be fitted in the fire main in order to isolate damage sections of the main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section of water.

3.3.2 *Water spray systems*

3.3.2.1 A water spray system should be fitted for cooling and fire prevention and to cover exposed parts of gas storage tank located above deck.

3.3.2.2 The system should be designed to cover all areas as specified above with an application rate of 10 *l*/min/m^2 for horizontal projected surfaces and 4 *l*/min/m^2 for vertical surfaces.

3.3.2.3 For the purpose of isolating damage sections, stop valves should be fitted at least every 40 m or the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

3.3.2.4 The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

3.3.2.5 A connection to the ship's fire main through a stop valve should be provided.

3.3.2.6 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system should be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

3.3.2.7 The nozzles should be of an approved full bore type and they should be arranged to ensure an effective distribution of water throughout the space being protected.

3.3.2.8 An equivalent system to the water spray system may be fitted provided it has been tested for its on-deck cooling capability to the satisfaction of the Administration.

3.3.3 *Dry chemical powder fire-extinguishing system*

3.3.3.1 In the bunkering station area a permanently installed dry chemical powder extinguishing system should cover all possible leak points. The capacity should be at least 3.5 kg/s for a minimum of 45 s discharges. The system should be arranged for easy manual release from a safe location outside the protected area.

3.3.3.2 One portable dry powder extinguisher of at least 5 kg capacity should be located near the bunkering station.

3.4 Fire detection and alarm system

3.4.1 *Detection*

3.4.1.1 An approved fixed fire detection system should be provided for the tank room and the ventilation trunk for tank room below deck.

3.4.1.2 Smoke detectors alone should not be considered sufficient for rapid fire detection.

3.4.1.3 Where the fire detection system does not include means of remotely identifying each detector individually, the detectors should be arranged on separate loops.

3.4.2 *Alarms and safety actions*

3.4.2.1 Required safety actions at fire detection in the machinery space containing gas-fuelled engines and tank room are given in table 1 of chapter V. In addition, the ventilation should stop automatically and fire dampers are to close.

CHAPTER 4

ELECTRICAL SYSTEMS

4.1 General

4.1.1 The provisions of this chapter should be applied in conjunction with applicable electrical requirements of part D of SOLAS chapter II-1.

4.1.2 Hazardous areas on open deck and other spaces not defined in this chapter should be decided based on a recognized standard[10]. The electrical equipment fitted within hazardous areas should be according to the same standard.

4.1.3 Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard[11].

4.1.4 Electrical equipment fitted in an ESD-protected machinery space should fulfil the following:

.1 In addition to fire and hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans should be certified safe for hazardous area zone 1.

.2 All electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 should be automatically disconnected, if gas concentrations above 20% LEL is detected on two detectors in the space containing gas-fuelled engines.

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[10] Refer to IEC standard 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.

[11] The type of equipment and installation requirements should comply with IEC standard 60092-502: IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features and IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.

4.1.5 There should be an equalization connection between the bunker supplier and the bunkering station on the ship when a flammable gas/liquid is transferred.

4.1.6 Cable penetrations should satisfy the requirements regulating the dispersion of gas.

4.2 Area classification

4.2.1 *General*

4.2.1.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

4.2.1.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2[12]. See also 4.3 below.

4.2.1.3 Area classification of a space may be dependent on ventilation[13].

4.2.1.4 A space with opening to an adjacent hazardous area on open deck, may be made into a less hazardous or non-hazardous space, by means of overpressure. Requirements to such pressurization are given in 2.10.

4.2.1.5 Ventilation ducts should have the same area classification as the ventilated space.

4.3 Definition of hazardous area zones

4.3.1 *Hazardous area zone 0*

This zone includes:

.1 the interiors of gas tanks, any pipework of pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas.[14]

4.3.2 *Hazardous area zone 1*

This zone includes:

.1 tank room;

.2 gas compressor room arranged with ventilation according to 2.10.4;

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[12] Refer to standards IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

[13] Refer to standard IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features for tankers, table 1.

[14] Instrumentation and electrical apparatus in contact with the gas or liquid gas should be of a type suitable for zone 0. Temperature sensors installed in thermo wells, and pressure sensors without additional separating chamber should be of intrinsically safe type Ex-ia.

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet[15], bunker manifold valve, other gas valve, gas pipe flange, gas pump-room ventilation outlets and gas tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of gas compressor and pump room entrances, gas pump and compressor room ventilation inlets and other openings into zone 1 spaces;

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3m beyond these, up to a height of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing gas are located, e.g., ducts around gas pipes, semi-enclosed bunkering stations; and

.7 the ESD-protected machinery space is considered as non-hazardous area during normal operation, but changes to zone 1 in the event of gas leakage.

4.3.3 *Hazardous area zone 2*

This zone includes:

.1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1[16].

CHAPTER 5

CONTROL, MONITORING AND SAFETY SYSTEMS

5.1 General

5.1.1 A local reading pressure gauge should be fitted between the stop valve and the connection to shore at each bunker pipe.

5.1.2 Pressure gauges should be fitted to gas pump discharge lines and to the bunkering lines.

5.1.3 A bilge well in each tank room surrounding an independent liquid gas storage tank should be provided with both a level indicator and a temperature sensor. Alarm should be given at high level in bilge well. Low temperature indication should lead to automatic closing of main tank valve.

5.2 Gas tank monitoring

5.2.1 Gas tanks should be monitored and protected against overfilling as required in the IGC Code, sections 13.2 and 13.3.

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[15] Such areas are, for example, all areas within 3 m of gas tank hatches, ullage openings or sounding pipes for gas tanks located on open deck and gas vapour outlets.

[16] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features or IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas, according to the area classification., as applicable if not otherwise specified in this standard.

5.2.2 Each tank should be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the tank. In addition, high-pressure alarm, and if vacuum protection is required, low pressure alarm should be provided on the bridge. The alarms should be activated before the set pressures of the safety valves are reached.

5.3 Gas compressor monitoring

Gas compressors should be fitted with audible and visual alarms both on the bridge and in the engine-room. As a minimum the alarms should be in relation to low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

5.4 Gas engine monitoring

5.4.1 Additional to the instrumentation provided in accordance with SOLAS chapter II-1, Part C, indicators should be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

.1 operation of the engine in case of gas-only engines; or

.2 operation and mode of operation of the engine in the case of dual fuel engines.

5.4.2 Auxiliary systems where gas may leak directly into the system medium (lubricating oil, cooling water) should be equipped with appropriate gas extraction measures fitted directly after the outlet from the engine in order to prevent gas dispersion. The gas extracted from auxiliary systems media should be vented to a safe location in the open.

5.5 Gas detection

5.5.1 Permanently installed gas detectors should be fitted in the tank room, in all ducts around gas pipes, in machinery spaces of the ESD-protected type, compressor rooms and other enclosed spaces containing gas piping or other gas equipment without ducting. In each ESD-protected machinery space, two independent gas detector systems should be required.

5.5.2 The number of detectors in each space should be considered taking size, layout and ventilation of the space into account.

5.5.3 The detection equipment should be located where gas may accumulate and/or in the ventilation outlets. Gas dispersal analysis or a physical smoke test should be used to find the best arrangement.

5.5.4 An audible and visible alarm should be activated before the vapour concentration reaches 20% of the lower explosion limit (LEL). For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% LEL. The protective system should be activated at a LEL of 40%.

5.5.5 Audible and visible alarms from the gas detection equipment should be located on the bridge and in the engine control room.

5.5.6 Gas detection for gas pipe ducts and machinery spaces containing gas-fuelled engines should be continuous without delay.

5.6 Safety functions of gas supply systems

5.6.1 Each gas storage tank should be provided with a tank valve capable of being remote operated and should be located as close to the tank outlet as possible.

5.6.2 The main gas supply line to each engine or set of engines should be equipped with a manually operated stop valve and an automatically operated "master gas fuel valve" coupled in series or a combined manually and automatically operated valve. The valves should be situated in the part of the piping that is outside machinery space containing gas-fuelled engines, and placed as near as possible to the installation for heating the gas, if fitted. The master gas-fuel valve should automatically cut off the gas supply as given in table 1.

5.6.2.1 The automatic master gas fuel valve should be operable from a reasonable number of places in the machinery space containing gas-fuelled engines, from a suitable location outside the space and from the bridge.

5.6.3 Each gas consuming equipment should be provided with a set of "double block and bleed" valves. These valves should be arranged as outlined in .1 or .2 (respectively shown as alternatives 1 and 2 in figure 1) so that when automatic shutdown is initiated as given in table 1, this will cause the two gas fuel valves that are in series to close automatically and the ventilation valve to open automatically and:

.1 two of these valves should be in series in the gas fuel pipe to the gas consuming equipment. The third valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or

.2 the function of one of the valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

5.6.3.1 The two block valves should be of the fail-to-close type, while the ventilation valve should be fail-to-open.

5.6.3.2 The double block and bleed valves should also be used for normal stop of the engine.

5.6.4 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve should be ventilated, if reverse flow from the engine to the pipe must be assumed.

5.6.5 There should be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.

5.6.6 For one-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined. Examples for the high-pressure system are shown in figures 1 and 2.

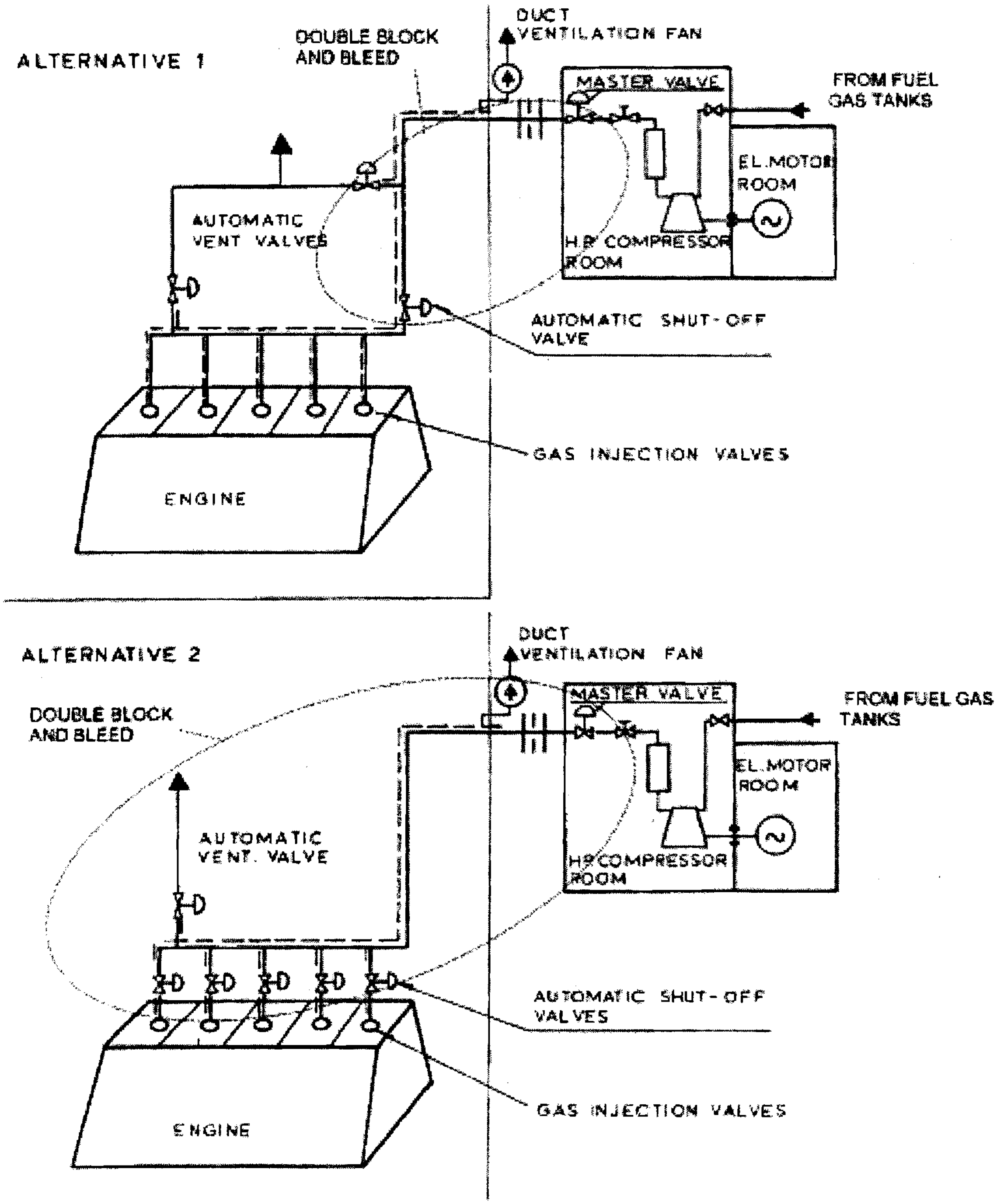

Figure 1

Alternative supply valve arrangements for high-pressure installations (single engine or separate master valve arrangement)

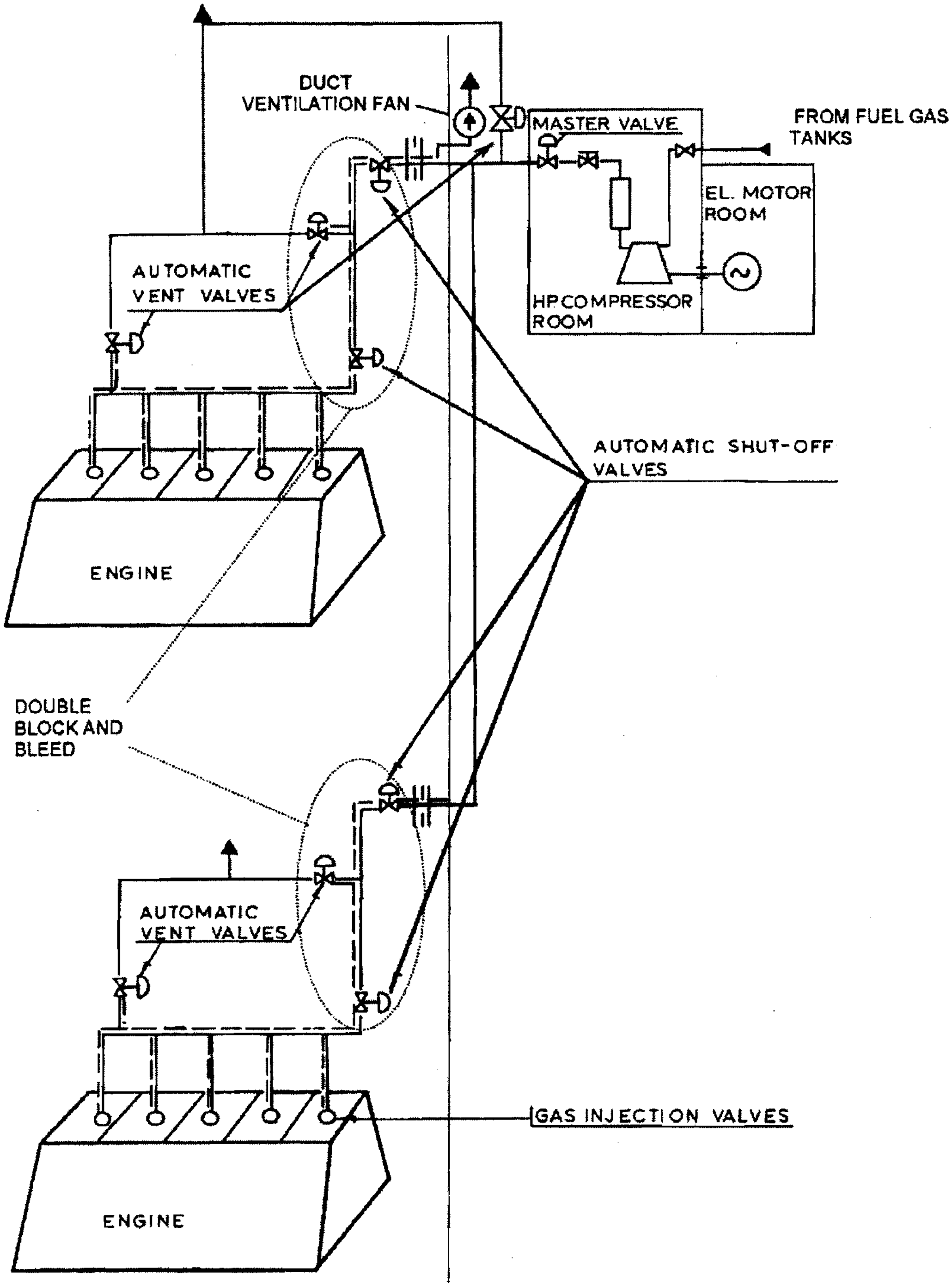

Figure 2

Alternative supply valve arrangements for high-pressure installations (multi-engine installation)

5.6.7 The total loss of ventilation in a machinery space for a single fuelled gas system should, additionally to what is given in table 1, lead to one of the following actions:

.1 *For a gas electric propulsion system with more than one machinery space*: Another engine should start. When the second engine is connected to bus-bar, the first engine should be shutdown automatically.

.2 *For a direct propulsion system with more than one machinery space*: The engine in the room with defect ventilation should be manually shutdown, if at least 40% propulsion power is still available after such a shutdown.

If only one machinery space for gas-fuelled engines is fitted and ventilation in one of the enclosed ducts around the gas pipes is lost, the master gas fuel and double block and bleed valves in that supply line should close automatically provided the other gas supply unit is ready to deliver.

5.6.8 If the gas supply is shut off due to activation of an automatic valve, the gas supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the gas supply lines.

5.6.9 If a gas leak leading to a gas supply shutdown occurs, the gas fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.

5.6.10 A signboard should be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the gas pipes, should not be done when the engine(s) is running on gas.

Table 1 – Monitoring of gas supply system to engines

Parameter	Alarm	Automatic shutdown of main tank valve	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comment
Gas detection in tank room above 20% LEL	X			
Gas detection on two detectors [1] in tank room above 40% LEL	X	X		
Fire detection in tank room	X	X		
Bilge well high level tank room	X			
Bilge well low temperature in tank room	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines above 20% LEL	X			
Gas detection on two detectors [1] in duct between tank and machinery space containing gas-fuelled engines above 40% LEL	X	X [2]		
Gas detection in compressor room above 20% LEL	X			
Gas detection on two detectors[1] in compressor room above 40% LEL	X	X [2]		

Parameter	**Alarm**	**Automatic shutdown of main tank valve**	**Automatic shutdown of gas supply to machinery space containing gas-fuelled engines**	**Comment**
Gas detection in duct inside machinery space containing gas-fuelled engines above 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors[1)] in duct inside machinery space containing gas-fuelled engines above 40% LEL	X		X [3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in machinery space containing gas-fuelled engines above 20% LEL	X			Gas detection only required for ESD protected machinery space
Gas detection on two detectors[1)] in machinery space containing gas-fuelled engines above 40% LEL	X		X	Gas detection only required for ESD protected machinery space containing gas-fuelled engines. It should also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines [6)]	X		X [2) 4)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines [6)]	X		X [3) 4)]	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in machinery space containing gas-fuelled engines	X		X	ESD protected machinery space containing gas-fuelled engines only
Fire detection in machinery space containing gas-fuelled engines	X		X	
Abnormal gas pressure in gas supply pipe	X		X [4)]	
Failure of valve control actuating medium	X		X[5)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X[5)]	
Emergency shutdown of engine manually released	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self monitoring type the installation of a single gas detector can be permitted.
2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.
3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.
4) This parameter is not to lead to shutdown of gas supply for single fuel gas engines, only for dual fuel engines.
5) Only double block and bleed valves to close.
6) If the duct is protected by inert gas (see 2.7.1) then loss of inert gas overpressure is to lead to the same actions as given in this table.

CHAPTER 6

COMPRESSORS AND GAS ENGINES

6.1 Gas compressors

6.1.1 The fuel gas compressor should be fitted with accessories and instrumentation necessary for efficient and reliable function.

6.1.2 The gas compressor and fuel gas supply should be arranged for manual remote emergency stop from the following locations:

.1 cargo control room (relevant for cargo ships only);
.2 navigation bridge;
.3 engine control room; and
.4 fire control station.

6.2 Gas engine design general

6.2.1 The last gas valve prior to the gas engine should be controlled by the engine control system or by the engine gas demand.

All gas engine components, gas engine systems and gas engine subsystems should be designed to:

.1 exclude any explosion at all possible situations; or

.2 to allow explosions without detrimental effect and to discharge to a safe location. The explosion event should not interrupt the safe operation of the engine unless other safety measures allow the shutdown of the affected engine.

6.2.1.1 When gas is supplied in a mixture with air through a common manifold, sufficient flame arrestors should be installed before each cylinder head. The mixture inlet system should be designed to withstand explosions of mixture by means of:

.1 explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed in a way that it discharges to a safe location; or

.2 documentation demonstrating that the mixture inlet system has sufficient strength to contain the worst case explosion.

6.2.1.2 The exhaust system should be designed to withstand explosions of unburned mixture by means of:

.1 explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed such that they discharge to a safe location; or

.2 documentation showing that the exhaust system has sufficient strength to contain the worst case explosion.

6.2.1.3 The crankcase of gas engines should be provided with:

.1 crankcase explosion relief valves of a suitable type with sufficient relief area. The relief valves should be installed in way of each crank throw and should be arranged or provided with means to ensure that discharge from them is so directed as to minimize the possibility of injury to personnel. Refer to SOLAS regulations II-1/27 and 47.2; or

.2 documentation showing that the crankcase has sufficient strength to contain the worst case explosion.

6.2.1.4 It should be ensured that the explosion of unburned mixture within the exhaust system or the crankcase or the explosion of mixture within the mixture inlet is allowed without detrimental effect.

6.2.2 The design of piping on gas engines should follow the requirements in chapter 2.6 "System configuration" and chapter 2.7 "Gas supply system in gas machinery spaces".

6.2.3 The combustion of the gas mixture should be monitored. This can be achieved by monitoring of the exhaust gas or combustion chamber temperature.

6.2.4 The exhaust pipes of gas-fuelled engines should not be connected to the exhaust pipes of other engines or systems.

6.3 Requirements dual fuel engines

6.3.1 Start and normal stop should be on oil fuel only. Gas injection should not be possible without a corresponding pilot oil injection. The amount of pilot fuel fed to each cylinder should be sufficient to ensure a positive ignition of the gas mixture.

6.3.2 In case of shut-off of the gas fuel supply, the engines should be capable of continuous operation by oil fuel only.

6.3.3 Changeover to and from gas fuel operation should only be possible at a power level and under conditions where it can be done with acceptable reliability as demonstrated through testing. On power reduction the changeover to oil fuel is to be automatic. The changeover process itself from and to gas operation should be automatic. Manual interruption should be possible in all cases.

6.3.4 On normal stop as well as emergency shutdown, gas fuel supply should be shut off not later than simultaneously with the oil fuel. It should not be possible to shut off the supply pilot fuel without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

6.4 Requirements gas-only engines

6.4.1 The starting sequence should be such that fuel gas is not admitted to the cylinders until ignition is activated and the engine has reached an engine and application specific minimum rotational speed.

6.4.2 If ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve the gas supply valve should be automatically shut off and the starting sequence terminated. It should be ensured by any mean that any unburned gas mixture is flushed away from the exhaust system.

6.4.3 On normal stop as well as emergency shutdown, gas fuel supply should be shut off not later than simultaneously with the ignition. It should not be possible to shut off the ignition without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

6.4.4 For constant speed engines the shut down sequence should be such that the engine gas supply valve closes at idle speed and that the ignition system is kept active until the engine is down to standstill.

CHAPTER 7

MANUFACTURE, WORKMANSHIP AND TESTING

7.1 General

The manufacture, testing, inspection and documentation should be in accordance with recognized standards and the specific requirements given in these Guidelines.

7.2 Gas tanks

Tests related to welding and tank testing should be in accordance with the IGC Code, sections 4.10 and 4.11.

7.3 Gas piping systems

7.3.1 The requirements for testing should apply to gas piping inside and outside the gas tanks. However, relaxation from these requirements may be accepted for piping inside gas tanks and open-ended piping.

7.3.2 Welding procedure tests should be required for gas piping and should be similar to those required for gas tanks in the IGC Code, paragraph 6.3.3. Unless otherwise especially agreed with the Administration, the test requirements should be in accordance with 7.3.3 below.

7.3.3 Test requirements:

.1 Tensile tests: Generally, tensile strength should not be less than the specified minimum tensile strength for the appropriate parent materials. The Administration may also require that the transverse weld tensile strength should not be less than the specified tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture should be reported for information.

.2 Bend tests: No fracture should be acceptable after a 180° bend over a former of a diameter four times the thickness of the test piece, unless otherwise specially required or agreed with the Administration.

.3 Charpy V-notch impact tests: Charpy tests should be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (*E*), should be no less than 27 J. The weld metal requirements for sub-size specimens and singe energy values should be in accordance with the IGC Code paragraph 6.1.4. The results of fusion line and heat affected zone impact tests should show a minimum average energy (*E*) in accordance with the transverse or longitudinal requirements of the base material, whichever applicable, and for sub-size specimens, the minimum average energy (*E*) should be in accordance with the IGC Code, paragraph 6.1.4. If the material thickness does not permit machining either full-sized or standard sub-size specimens, the testing procedure and acceptance standards should be in accordance with recognized standards.

Impact testing is not required for piping with thickness less than 6 mm.

7.3.4 In addition to normal controls before and during the welding and to the visual inspection of the finished welds, the following tests should be required:

.1 For butt welded joints for piping systems with design temperatures lower than -10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, 100% radiographic testing should be required.

.2 When such butt welded joints of piping sections are made by automatic welding processes in the pipe fabrication shop, upon special approval, the extent of radiographic inspection may be progressively reduced but in no case to less than 10% of the joints. If defects are revealed the extent of examination should be increased to 100% and shall include inspection of previously accepted welds. This special approval should only be granted if well-documented quality assurance procedures and records are available to enable the Administration to assess the ability of the manufacturer to produce satisfactory welds consistently.

.3 For other butt welded joints of pipes, spot radiographic tests or other non-destructive tests should be carried out at the discretion of the Administration depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes should be radiographed.

Butt welded joints of high-pressure gas pipes and gas supply pipes in ESD-protected machinery spaces should be subjected to 100% radiographic testing.

The radiographs should be assessed according to a recognized standard[17].

7.3.5 After assembly, all gas piping should be subjected to a hydrostatic test to at least 1.5 times the design pressure. However, when piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board should be hydrostatically tested to at least 1.5 times the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing methods should be submitted for approval.

7.3.6 After assembly on board, each gas piping system should be subjected to a leak test using air, halides or other suitable medium.

7.3.7 All gas piping systems including valves, fittings and associated equipment for handling gas should be tested under normal operating condition before set into normal operation.

[17] Refer to ISO 5817:2003, Arc-welded joints in steel – Guidance on quality levels for imperfections, and should at least meet the requirements for quality level B.

7.4 Ducting

If the gas piping duct contains high-pressure pipes the ducting should be pressure tested to at least 10 bar.

7.5 Valves

Each size and each type of valve intended to be used at a working temperature below -55°C should be prototype tested as follows. It should be subjected to a tightness test at the minimum design temperature or lower and to a pressure not lower than the design pressure for the valves. During the test, the good operation of the valve should be ascertained.

7.6 Expansion bellows

7.6.1 The following prototype tests should be performed on each type of expansion bellows intended for use in gas piping, primarily on those used outside the gas tank:

.1 An overpressure test. A type element of the bellows, not pre-compressed, should be pressure tested to a pressure not less than 5 times the design pressure without bursting. The duration of the test should not be less than 5 min.

.2 A pressure test on a type expansion joint complete with all the accessories (flanges, stays, articulations, etc.) at twice the design pressure at the extreme displacement conditions recommended by the manufacturer. No permanent deformations should be allowed. Depending on materials the test may be required to be performed at the minimum design temperature.

.3 A cyclic test (thermal movements). The test should be performed on a complete expansion joint, which is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. Testing at room temperature, when conservative, is permitted.

.4 A cyclic fatigue test (ship deformation). The test should be performed on a complete expansion joint, without internal pressure, by simulating the bellow movement corresponding to a compensated pipe length for at least 2×10^6 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

7.6.2 The Administration may waive performance of the tests specified in 7.6.1, provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 1 bar, this documentation should include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

CHAPTER 8

OPERATIONAL AND TRAINING REQUIREMENTS

8.1 Operational requirement

8.1.1 The whole operational crew of a gas-fuelled cargo and a passenger ship should have necessary training in gas-related safety, operation and maintenance prior to the commencement of work on board.

8.1.2 Additionally, crew members with a direct responsibility for the operation of gas-related equipment on board should receive special training. The company should document that the personnel have acquired the necessary knowledge and that this knowledge is maintained at all times.

8.1.3 Gas-related emergency exercises should be conducted at regular intervals. Safety and response systems for the handling of defined hazards and accidents should be reviewed and tested.

8.1.4 A training manual should be developed and a training programme and exercises should be specially designed for each individual vessel and its gas installations.

8.2 Gas-related training

8.2.1 *Training in general*

The training on gas-fuelled ships is divided into the following categories:

.1 category A: Basic training for the basic safety crew;
.2 category B: Supplementary training for deck officers; and
.3 category C: Supplementary training for engineer officers.

8.2.1.1 *Category A training*

.1 The goal of the category A training should provide the basic safety crew with a basic understanding of the gas in question as a fuel, the technical properties of liquid and compressed gas, explosion limits, ignition sources, risk reducing and consequence reducing measures, and the rules and procedures that must be followed during normal operation and in emergency situations.

.2 The general basic training required for the basic safety crew is based on the assumption that the crew does not have any prior knowledge of gas, gas engines and gas systems. The instructors should include one or more of the suppliers of the technical gas equipment or gas systems, alternatively other specialists with in-depth knowledge of the gas in question and the technical gas systems that are installed on board.

.3 The training should consist of both theoretical and practical exercises that involve gas and the relevant systems, as well as personal protection while handling liquid and compressed gas. Practical extinguishing of gas fires should form part of the training, and should take place at an approved safety centre.

8.2.1.2 *Categories B and C training*

.1 Deck and engineer officers should have gas training beyond the general basic training. Category B and category C training should be divided technically between deck and engineer officers. The company's training manager and the master should determine what comes under deck operations and what comes under engineering.

.2 Those ordinary crew members who are to participate in the actual bunkering work, as well as gas purging, or are to perform work on gas engines or gas installations, etc., should participate in all or parts of the training for category B/C. The company and the master are responsible for arranging such training based on an evaluation of the concerned crew member's job instructions/area of responsibility on board.

.3 The instructors used for such supplementary training should be the same as outlined for category A.

.4 All gas-related systems on board should be reviewed. The ship's maintenance manual, gas supply system manual and manual for electrical equipment in explosion hazardous spaces and zones should be used as a basis for this part of the training.

.5 This regulation should be regularly reviewed by the company and onboard senior management team as part of the SMS system. Risk analysis should be emphasized, and any risk analysis and sub-analyses performed should be available to course participants during training.

.6 If the ship's own crew will be performing technical maintenance of gas equipment, the training for this type of work should be documented.

.7 The master and the chief engineer officer should give the basic safety crew on board their final clearance prior to the entry into service of the ship. The clearance document should only apply to gas-related training, and it should be signed by both the master/chief engineer officer and the course participant. The clearance document for gas-related training may be integrated in the ship's general training programme, but it should be clearly evident what is regarded as gas-related training and what is regarded as other training.

.8 The training requirements related to the gas system should be evaluated in the same manner as other training requirements on board at least once a year. The training plan should be evaluated at regular intervals.

8.3 Maintenance

8.3.1 A special maintenance manual should be prepared for the gas supply system on board.

8.3.2 The manual should include maintenance procedures for all technical gas-related installations, and should comply with the recommendations of the suppliers of the equipment. The intervals for, and the extent of, the replacement/approval of gas valves should be established. The maintenance procedure should specify who is qualified to carry out maintenance.

8.3.3 A special maintenance manual should be prepared for electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces should be performed in accordance with a recognized standard.[18]

8.3.4 Any personnel that should carry out inspections and maintenance of electrical installations in explosion hazardous spaces should be qualified pursuant to IEC 60079-17, item 4.2.

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[18] Refer to IEC 60079-17:2007 Explosive atmospheres – Part 17: Electrical installations inspection and maintenance.

ABS

FOUNDED 1862

GUIDE FOR

PROPULSION AND AUXILIARY SYSTEMS FOR GAS FUELED SHIPS

MAY 2011

American Bureau of Shipping
Incorporated by Act of Legislature of the State of New York 1862

Foreword

In recent years, medium speed dual fuel diesel engines have been chosen to power a number of new LNG carriers in preference to the traditional steam turbine powered propulsion plant arrangements. This has improved operational efficiency and reduced engine room space requirements. Furthermore dual fuel and single fuel engines have been successfully installed and operated in a number of offshore support vessel and ferry applications.

It is envisaged that the effect of increasingly stricter air emissions legislation implemented through IMO Annex VI and other local air quality controls, together with favorable financial conditions for the use of natural gas instead of liquid fuel oil as a bunker fuel, will see an increasing number of dual fuel diesel engine and single gas fuel engine applications to LNG carriers and other vessel types in the future.

In some cases, dependent on the bunker fuel storage configuration and the selected propulsion and power generation arrangement, there may be a need to also install a gas combustion unit or alternative system to dispose of excess boil-off gas.

Accordingly, this Guide has been developed in order to provide guidance for the design and construction of the aforementioned propulsion prime mover arrangements, auxiliary power generation arrangements and associated systems for gas fueled ships and may be applied to all types of vessel, other than those covered by the IMO IGC Code, that utilize natural gas as fuel.

For LNG carrier requirements see the ABS *Guide for Propulsion Systems for LNG Carriers*.

The requirements in this Guide have been developed in consideration of IMO Resolution MSC.285(86) *Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships* which was adopted 1 June 2009 and the IMO *International Code of Safety for Gas-Fuelled Ships* (IGF Code), which at the time of the issuance of this Guide is under development, and are consistent with the requirements and principles of the IMO IGC Code.

Where the requirements of the Guide are proposed to be used to comply with IMO Resolution MSC.285(86), or the to be developed IMO IGF Code, such application is subject to approval by the Flag Administration prior to issuance of Certificate of Fitness on behalf of the Flag Administration by ABS.

The applicable edition of the ABS *Rules for Building and Classing Steel Vessels* is to be used in association with this Guide.

This Guide becomes effective 25 May 2011.

We welcome your feedback. Comments or suggestions can be sent electronically to rdd@eagle.org.

GUIDE FOR

PROPULSION AND AUXILIARY SYSTEMS FOR GAS FUELED SHIPS

CONTENTS

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SECTION 1 General

1 Scope and Application

This Guide has been developed to provide guidance for the design, construction, and survey of vessels utilizing gas as a fuel. The Guide is focused on systems and arrangements provided for the safe use of gas for propulsion and auxiliary systems. The Guide is for application to gas fueled ship types other than those falling under the scope of the IGC Code and associated ABS requirements for *Vessels Intended to Carry Liquefied Gases in Bulk* under Part 5C, Chapter 8 of the ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*. The prime movers may use either a single fuel (gas) or dual fuel (gas and fuel oil) and the gas may be stored and distributed as Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG). The use of other fuel types will be subject to special consideration.

The use of natural gas as fuel in ships other than LNG carriers is not covered by international conventions. However, the installations will still be subject to approval by the Flag Administrations. The *Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships* (hereinafter referred to as *Interim Guidelines*) were adopted by International Maritime Organization (IMO) Resolution MSC.285(86) on 1 June 2009 which invites governments to apply the *Interim Guidelines* to gas fueled ships other than those covered by the IGC Code.

Where appropriate, this Guide has been aligned with the aforementioned *Interim Guidelines*.

This Guide is to be applied to both new construction and existing vessel conversions, regardless of size, utilizing natural gas as fuel.

2 Objectives

The objective of this Guide is to provide criteria for the arrangements, construction, installation and operation of machinery, equipment and systems for vessels operating with natural gas as fuel in order to minimize risks to the vessel, crew and environment. Detailed requirements are provided in each of the Sections of this Guide to achieve this objective in accordance with the following key requirements:

- Gas fuel storage systems are to be designed in accordance with Chapter 4 of the IGC Code, as incorporated by Section 5C-8-4 of the *Steel Vessel Rules*, and as applicable the ABS *Guide for Vessels Intended to Carry Compressed Natural Gases in Bulk (CNG Guide)*.
- Gas fuel storage tank pressure, temperature and filling limits are to be maintained within the design limits of the storage tank at all times.
- Means are to be provided to evacuate, purge and gas free the gas fuel storage tank.
- Gas fuel storage tanks are to be located in a protected location.
- Gas fuel storage spaces, bunkering stations, fuel gas preparation spaces and machinery spaces containing gas utilization equipment are to be located and arranged such that the consequences of any release of gas will be minimized while providing safe access for operation and inspection.
- Gas fuel supply piping, systems and arrangements are to provide safe handling of gas fuel liquid and vapor under all operating conditions. Means are to be provided to inert and gas free piping and systems.
- Gas fuel utilization equipment and machinery is to be designed and arranged for the safe consumption of natural gas as fuel.
- Automation, instrumentation, monitoring and control systems are to be provided to enable safe carriage, conditioning and utilization of natural gas.

- The vessel and systems are to be arranged with sufficient redundancy so as to provide continuity of electrical and propulsion power in the event of an automatic safety shut down of fuel gas supply.
- Explosion protection and fire protection, detection and extinguishing arrangements and systems are to be provided to protect the vessel and crew from possible hazards associated with using natural gas as fuel.

3 Definitions

3.1 Block and Bleed Valve

Block and Bleed Valve means a set of two valves located in series to the fuel supply to each of the gas utilization units with a third valve that vents that portion of the gas fuel piping that is between the two valves in series. See also 5/3.1ii) of this Guide. This set of valves is referred to as "Double Block and Bleed" by the *Interim Guidelines*.

3.2 BOG Utilization System

A *BOG (boil-off gas) Utilization System* is an arrangement of BOG consumers (e.g., gas combustion unit, re- Liquefaction units, dual fuel auxiliary generator) including piping systems, electrical systems, control and safety systems, which may be used for controlling gas fuel storage tank pressure and maintaining it below the maximum allowable relief valve setting.

3.3 Certified Safe Type

Certified Safe Type means electrical equipment that is certified safe by a competent, independent testing laboratory based on a recognized standard. The certification of electrical equipment is to be suitable for the category and group for methane gas. See also 4-8-3/13 of the *Steel Vessel Rules*.

3.4 CNG

CNG means compressed natural gas.

3.5 Dual Fuel Diesel Engine

Dual Fuel Diesel Engine is a diesel engine that can burn natural gas as fuel simultaneously with liquid (pilot) fuel and also have the capability of running on liquid fuel only.

3.6 Dual Fuel Propulsion or Auxiliary Gas Turbine

Dual Fuel Gas Turbine, Propulsion or Auxiliary is a gas turbine using natural gas as fuel and also having the capability of running on liquid fuel.

3.7 Enclosed Space

Enclosed Space means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally. See also 4-8-4/27 of the *Steel Vessel Rules*.

3.8 Fuel Containment System

Fuel Containment System is the arrangement for containment of fuel including, as applicable, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the hold space.

The spaces around the fuel storage tank are defined as:

3.8.1 Hold Space

Hold Space is the space enclosed by the ship's structure in which a fuel containment system is located.

3.8.2 Interbarrier Space

Interbarrier Space is the space between a primary and secondary barrier, whether or not completely or partially occupied by insulation or other material.

3.8.3 Tank Connection Space

Tank Connection Space is a gas tight space surrounding the parts of the fuel tank containing all tank connections and tank valves.

3.9 Gas Combustion Unit (or Thermal Oxidizer)

A *Gas Combustion Unit (or Thermal Oxidizer)* is a system used for controlling the pressure in the LNG bunker tanks by burning the excess boil-off gas from the tanks inside an enclosed combustion chamber under controlled and safe conditions.

3.10 Hazardous Area

Hazardous Area means an area in which an explosive gas atmosphere is, or may be expected to be, present in quantities such as to require special precautions for the construction, installation and use of equipment. See also 4-1-1/1.9.4 and 4-8-4/27 of the *Steel Vessel Rules* and Subsection 2/8 of this Guide.

Hazardous areas are divided into zones 0, 1 and 2 as defined below:

3.10.1 Zone 0

Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods or frequently.

3.10.2 Zone 1

Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation occasionally.

3.10.3 Zone 2

Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

3.11 Non-Hazardous Area

Non-hazardous Area means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment.

3.12 High Pressure Piping

High Pressure Piping means gas fuel piping with a maximum working pressure greater than 10 bar.

3.13 IGC Code

IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

3.14 LEL

LEL means the lower explosive limit.

3.15 LNG

LNG means liquefied natural gas.

3.16 Main Tank Valve

Main Tank Valve means a remote operated shut-off valve on the gas supply line from a gas storage tank, located as close to the tank outlet as possible. See also 2/6.2.3 of this Guide.

3.17 MARVS

MARVS means maximum allowable relief valve setting.

3.18 Master Gas Valve

Master Gas Valve means an automatic gas shut-off valve in the gas supply line to each individual gas utilization unit and which is located outside the machinery space of the gas utilization unit. See also 2/6.2.1 of this Guide.

3.19 Natural Gas

Natural Gas (dry) is defined as gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane). The gas composition can vary depending on the source of natural gas and the processing of the gas. Typical composition in volume %:

Methane (C_1)	94.0%
Ethane (C_2)	4.7%
Propane (C_3)	0.8%
Butane (C_4+)	0.2%
Nitrogen	0.3%

Density gas	0.73 kg/Sm^3
Density liquid	0.45 kg/dm^3
Calorific value (low)	49.5 MJ/kg
Methane number83	

The gas may be stored and distributed as CNG or LNG.

3.20 Normal Boil-off Gas Rate (NBOR)

For the purposes of this Guide, the *Normal Boil-off Rate* is the specified BOR in the shipbuilding or manufacturer contract, conforming to the design boil-off rate at the upper ambient design temperatures as specified in 5C-8-7/1.2 of the *Steel Vessel Rules.*

3.21 Primary Barrier

Primary Barrier is the inner element designed to contain the fuel when the fuel containment system includes two boundaries.

3.22 Recognized Standard

A *Recognized Standard* is an international or national standard acceptable to ABS.

3.23 Re-Liquefaction Unit

A *Re-liquefaction Unit* is a system used for taking the boil-off gas from bunker tanks and condensing it in a refrigeration system. LNG is then returned to the tanks. A typical re-liquefaction plant will comprise an electric motor-driven boil-off gas compressor, cryogenic heat exchangers, pre-coolers, separator, nitrogen storage tanks, an LNG transfer system, electric-driven refrigeration compressors/expanders with interstage coolers, a discharge cooler and associated control systems.

3.24 Rules

Rules means the applicable edition of the ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules).*

3.25 Secondary Barrier

Secondary Barrier is the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of LNG through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level.

3.26 Single Gas Fuel Engine

Single Gas Fuel Engine is an engine capable of operating on gas fuel only.

4 Classification Notations

4.1 Gas Fueled Ship

Where a vessel is arranged to burn natural gas as fuel for propulsion or auxiliary purposes the requirements for gas fuel storage, fuel bunkering systems, fuel gas preparation rooms and fuel gas supply system arrangements are to be designed, constructed and tested in accordance with Sections 2, 3, 4, and 5 of this Guide. The **GFS** notation may be assigned in association with one or more of the following additional notations (e.g., **GFS(DFD, GCU)**).

4.2 Re-Liquefaction Unit

Where a Re-Liquefaction Unit is designed, constructed and tested in accordance with Section 2 and Section 6 of this Guide, the **RELIQ** notation may be assigned.

4.3 Gas Combustion Unit

Where a Gas Combustion Unit is designed, constructed and tested in accordance with Section 2 and Section 7 of this Guide, the **GCU** notation may be assigned.

4.4 Dual Fuel Diesel Engine Power Plant

Where a dual fuel diesel engine power plant is designed, constructed and tested in accordance with Section 2 and Section 8 of this Guide, the **DFD** notation may be assigned.

4.5 Single Gas Fuel Engine Power Plant

Where a single gas fuel engine power plant is designed, constructed and tested in accordance with Section 2 and Section 8 of this Guide, the **SGF** notation may be assigned.

4.6 Dual Fuel Gas Turbine Power Plant

Where a dual fuel gas turbine power plant is designed, constructed and tested in accordance with Section 2 and Section 9 of this Guide, the **DFGT** notation may be assigned.

5 Materials of Construction

Materials in general are to comply with the requirements of the ABS *Rules for Materials and Welding (Part 2)*.

Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with cryogenic liquids or gases are to be in compliance with Section 5C-8-6 of the *Steel Vessel Rules*.

For CNG tanks, the use of alternative materials not covered by Section 5C-8-6 of the *Steel Vessel Rules* may be accepted provided such materials are approved in connection with the design and that they are verified or tested by a Surveyor, as applicable, as complying with the approved specifications. For further guidance on CNG tanks, see the *CNG Guide*.

6 Operating and Maintenance Instruction Manuals

Detailed instruction manuals are to be provided onboard, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the use of gas as a fuel.

The manuals are to include, but not be limited to, the regular test and maintenance procedures for the gas detection systems, safety shut-off systems and the integrity of backup systems.

In addition there is further guidance regarding the contents of the operating and maintenance manuals in each of the individual sections of this Guide such as the gas fuel storage, fuel bunkering and fuel gas supply systems. Reference is to be made to the requirements in each section of this Guide. Inspection and maintenance of certified safe electrical equipment is to be in accordance with the applicable requirements of Section 9 and 10 of IEC 60092-502.

7 Alternatives

Equipment, components, and systems for which there are specific requirements in this Guide, or its associated references, may incorporate alternative arrangements or comply with the requirements of alternative recognized standards, in lieu of the requirements in this Guide. This, however, is subject to such alternative arrangements or standards being determined by ABS as being not less effective than the overall safety and strength requirements of this Guide or associated references. Where applicable, requirements may be imposed by ABS in addition to those contained in the alternative arrangements or standards so that the intent of this Guide is met. In all cases, the equipment, component or system is subject to design review, survey during construction, tests and trials, as applicable, by ABS for purposes of verification of its compliance with the alternative arrangements or standards. The verification process is to be to the extent as intended by this Guide.

Where these alternative or equivalent equipment, components and systems are intended to be used in lieu of the requirements of IMO Resolution MSC.285(86), or the to be developed IMO IGF Code, such application is subject to approval by the Flag Administration prior to issuance of a Certificate of Fitness on behalf of the Flag Administration by ABS.

8 Certification

Design review, survey, testing, and the issuance of reports or certificates constitute the certification of machinery, equipment and systems; see also 4-1-1/3 of the *Steel Vessel Rules*. There is guidance on the certification requirements for machinery, equipment and systems in each of the applicable individual sections of this Guide. The applicable edition of the *Steel Vessel Rules* is to be used in association with the subject Guide.

SECTION 2 Ship Arrangements and System Design

1 General

1.1 Application

The requirements specified in this Section provide general guidance on ship arrangements and system design. There are further requirements contained in each of the individual Sections of this Guide such as the gas fuel storage, fuel bunkering and fuel gas supply systems. Reference is to be made to the requirements in each Section.

1.2 Plans and Data to be Submitted

Plans and specifications covering the ship arrangements are to be submitted, in addition to the requirements contained in each of the individual sections and are, as applicable, to include:

- Ship safety concept including propulsion and auxiliary arrangement requirements detailed under 2/5.1 of this Guide
- General arrangement
- Gas fuel storage arrangements
- Fuel bunkering station arrangements
- Hazardous area classification plan
- Vent mast and venting arrangements

2 Location and Separation of Spaces

2.1 General

The arrangement and location of spaces containing potential sources of fuel liquid and vapor release directly into the space are to be such that an explosion in such spaces will not cause damage to any space other than that in which the incident occurs nor render the machinery or equipment in other spaces inoperable. Such incidents should also not cause damage that would under normal operating conditions, injure people in work areas, accommodation, service spaces, or control stations.

2.2 Gas Storage Tanks

2.2.1 Gas Storage Tanks – Storage on Open Deck

i) Gas storage tanks of the compressed (CNG) or the liquefied (LNG) type stored above deck level may be accepted.

ii) The gas storage tanks are to be located at least *B*/5 from the ship's side. For ships other than passenger ships a tank location closer than *B*/5 but nowhere less than 800 mm from the ship's side may be accepted. See also 2/2.2.2iii) of this Guide for alternative acceptance criteria.

iii) The gas storage tanks and equipment are to be located so as to facilitate sufficient natural ventilation, in order to prevent accumulation of escaped gas.

iv) LNG storage tanks with a connection below the highest liquid level, (see 3/3iii) of this Guide) are to be fitted with drip trays below the connections which are to be of sufficient capacity to contain the volume which could escape in the event of a leakage from pipe connection. The material of the drip tray is to be stainless steel, and there is to be efficient separation or isolation so that the hull or deck structures are not subjected to low temperatures below the allowable design temperature of the material, in case of leakage of LNG.

The drip trays located below the tank connections and other sources of vapor release on the tanks are to be located not less than 3 m from entrances, air inlets and openings to accommodation spaces, services spaces, cargo spaces, machinery spaces and control stations.

v) Gas storage tanks located above deck are to be shielded with class A-60 insulation towards accommodation, service spaces, cargo spaces, machinery spaces and control stations.

2.2.2 Gas Storage Tanks – Storage in Enclosed Spaces

i) LNG fuel may be stored in enclosed spaces, with a maximum allowable working pressure of 10 bar.

ii) Storage of compressed gas in enclosed spaces is to be in accordance with the *CNG Guide*.

The location of compressed gas storage tanks with a design pressure greater than 10 bar in enclosed spaces would be acceptable, provided the following is fulfilled in addition to 2/2.2.2iv) of this Guide:

a) Adequate means are to be provided to depressurize the tank in case of fire which could affect the tank; and

b) All surfaces within such enclosed spaces are to be provided with suitable thermal protection against any high pressure gas leakage and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

c) A fixed fire extinguishing system is installed in such enclosed spaces; and

d) Means are to be provided to relieve pressure resulting from a catastrophic failure of the containment system so that hull structural integrity can be maintained.

iii) Gas storage tanks are to be located as close as possible to the ship centerline and:

a) Minimum, the lesser of $B/5$ and 11.5 m from the ship side measured inboard from the ship's side at right angles to the centerline at the level of the summer load line; and

b) Minimum, the lesser of $B/15$ and 2 m from the bottom plating; and nowhere to be less than 800 mm from the shell plating..

c) Gas storage tanks for ships other than passenger vessels, or where gas storage tanks are not located adjacent to accommodation, service or control stations, may be located closer than $B/5$ from the ship side provided the following criteria is applied:

d) Minimum, the lesser of $B/15$ and 2 m from the bottom plating; and

e) Nowhere less than d, where d is as follows:

1. For storage tanks $V \leq 1{,}000\ \text{m}^3$ $\quad d = 0.8$ m
2. For $1{,}000\ \text{m}^3 \leq V \leq 5{,}000\ \text{m}^3$ $\quad d = 0.75 + V \times 0.20/4{,}000$ m
3. For $5{,}000\ \text{m}^3 \leq V \leq 30{,}000\ \text{m}^3$ $\quad d = 0.8 + V/25{,}000$ m

Where V corresponds to 100% of the gross design volume of the individual storage tank at 20°C, including domes and appendages and d is measured at any cross section at a right angle from the molded line of the outer shell.

iv) Gas storage tanks located in enclosed spaces are to be arranged in accordance with the fuel containment and secondary barrier principles of the IGC Code Chapter 4, as incorporated by Section 5C-8-4 of the *Steel Vessel Rules*. Arrangements are to be such that the effects of any release of gas or liquid are mitigated while providing safe access for operation and inspection.

All tank connections, fittings, flanges and associated valves are to be located on the open deck except that for Type C independent tanks, such connections may be located in a gas tight space. This tank connection space is to be arranged to safely contain any leakage from the tank connections, without this leakage spreading to other spaces, or leading to hazardous incidents. Tank connection space boundaries including access doors are to be gastight.

The material of this space which may come into contact with liquid or gaseous fuel is to have the same minimum design temperature as the gas storage tank, and the space is to be designed to withstand the maximum pressure build up. Alternatively, pressure relief venting to a safe location (mast) may be provided.

The space is to be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of leakage of the liquid or compressed gas. Calculations in accordance with 5C-8-4/8.2 of the *Steel Vessel Rules* are to be undertaken so that the temperature of the hull structure cannot fall below the allowable design temperature for the material.

v) Where LNG is carried in a storage tank requiring a complete or partial secondary barrier (storage tanks other than Type C) hold spaces are to be segregated from the sea by a double hull space.

vi) Bilge systems installed in areas where gas fuel may be present due to leakage from the storage or piping systems are not to be connected to the bilge system for the rest of the ship.

A bilge well in each gas containing system surrounding an independent liquid gas storage tank is to be provided with both a level indicator and a temperature sensor. An alarm is to be provided to indicate a high liquid level in the bilge well. The temperature sensor low temperature indication is to lead to automatic closing of the main tank valve.

vii) Fuel containment systems are not to be located adjacent to category A machinery spaces. Separation is to be by means of a cofferdam, the separation is to be at least 900 mm.

However, a hold space containing a Type C fuel storage tank with no connections to the tank inside the hold space may be separated from a category A machinery space by a single gas tight class A-60 bulkhead.

viii) Tank connection spaces and ventilation trunks to such spaces below the bulkhead deck are to be constructed to class A-60.

2.3 Access in way of Gas Storage Tanks

i) Where access is required for inspection between the gas storage tank surface (flat or curved), and structural elements (such as deck beams, stiffeners, frames, girders, etc.), the distance between that surface and the free edge of the structural elements is to be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted (e.g., deck, bulkhead or shell) is to be at least 450 mm for a curved tank surface or 600 mm for a flat tank surface. See also 5C-8-3/5.2.1, 5C-8-3/5.2.3 and 5C-8-3/5.2.4 of the *Steel Vessel Rules*.

ii) Where access is not practical between the surface to be inspected and any structural elements, the distance between the free edge of the structural element and the surface to be inspected is to be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger. See also 5C-8-3/5.2.2 of the *Steel Vessel Rules*.

iii) Where applicable the minimum distance between the plane surfaces of a bunker tank sump and adjacent double bottom structure in way of a suction well is not to be less than 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is to be at least 380 mm. If there is no suction well, the distance between the bunker tank sump and the inner bottom is not to be less than 50 mm. See also 5C-8-3/5.2.5 of the *Steel Vessel Rules*.

2.4 Fuel Bunkering Station

i) The bunkering station(s) and manifold(s) are to be located on the open deck so that sufficient natural ventilation is provided. Alternatively closed or semi-enclosed bunkering stations may be approved subject to the provision of effective mechanical ventilation.

The bunkering station is to be physically separated or structurally shielded from adjacent normally manned areas such as accommodation, cargo/working deck and control stations. Particular consideration is to be made to the provision of adequate structural protection where vessel cargo handling operations increase the risk of mechanical impact damage. Connections and piping are to be positioned and arranged so that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge.

ii) In case of leakage of LNG the surrounding hull or deck structures are not to be exposed to low temperatures below the allowable design temperature of the material. Accordingly drip trays are to be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays are to be made of stainless steel and the drainage arrangements may be temporarily fitted for bunkering operations. Where the leakage containment arrangements are such that damage to the hull structure from accidental spillage of LNG during bunkering operations cannot be precluded, additional measures such as a low-pressure water curtain, are to be fitted under the bunkering station to provide for additional protection of the hull steel and the ship's side structure.

For compressed gas bunkering stations, low temperature steel shielding is to be provided as necessary to prevent possible cold jet impingement on the hull structure.

iii) Bunkering stations are to be shielded with class A-60 insulation towards other spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation may be reduced to A-0 class.

2.5 Gas Compressor and Fuel Preparation Rooms

i) Compressor and fuel preparation rooms are to be in compliance with 5C-8-3/3 of the *Steel Vessel Rules*. Compressor or fuel preparation rooms may be located below the open deck provided the arrangements are in accordance with the applicable requirements of 2/2.2.2, 2/3.3, and Subsection 3/6 of this Guide. Particular consideration is to be made to the provision of adequate structural protection where vessel cargo handling operations increase the risk of mechanical impact damage.

ii) Gas compressor or fuel preparation rooms are to be treated as if they were category A machinery spaces for the purposes of fire protection.

2.6 Machinery Spaces Containing Gas Utilization Units

i) When more than one machinery space is required for gas fueled engines (see 2/5.4 of this Guide) and these spaces are separated by a single bulkhead, in order to maintain continuity of power, the arrangements are to be such that the effects of a gas explosion in either space can be contained or vented without affecting the integrity of the adjacent space and equipment within that space.

ii) When more than one machinery space is required (see 2/5.4 of this Guide) and these spaces are separated by a single bulkhead, the bulkhead is to be class A-60.

iii) Machinery spaces in which gas fuel is utilized are to be fitted with a mechanical ventilation system and are to be arranged in such a way as to prevent the formation of dead spaces. The ventilation system is to be independent of all other ventilation systems.

iv) The number and power of the ventilation fans should be such that if one fan, or a group of fans with common circuit from the main switchboard or emergency switchboard, are out of service the capacity of the remaining ventilation fan(s) is not to be less than 100% of the total required.

v) Permanently installed gas detectors complying with the requirements of Subsection 5/8 of this Guide are to be fitted in these spaces, particularly in the zones where air circulation is reduced.

vi) Machinery spaces applying the single wall fuel gas piping concept for gas fueled engines detailed under 2/5.4 of this Guide are to be as simple a geometrical shape as possible and be as small in volume as practicable, without compromising maintainability, in order to facilitate effective ventilation and gas detection. See also Subsection 8/2 of this Guide.

3 Arrangement of Entrances and Other Openings

3.1 General

i) Direct access through doors, gastight or otherwise, from a hazardous area classified as zone 0 or zone 1 to a non-hazardous area is generally not permitted. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of 5C-8-3/6.2 through 5C-8-3/6.7 of the *Steel Vessel Rules* is to be provided.

ii) Access to a single wall fuel gas piping concept machinery space is to be by self-closing gastight doors. An audible and visual alarm is to be provided at a permanent manned location. Alarm is to be given if the door is open continuously for more than 60 seconds. As an alternative, an arrangement with two self-closing doors in series may be acceptable. See also 8/2.5 of this Guide.

3.2 Gas Compressor and Fuel Preparation Rooms

If the compressor or fuel preparation room is located below deck, the room is, as far as practicable, to have an independent access direct from the open deck. Where a separate access from the open deck is not practicable, an air lock which complies with the requirements of 5C-8-3/6.2 through 5C-8-3/6.7 of the *Steel Vessel Rules* is to be provided.

3.3 Gas Storage Tanks and Fuel Containment Systems

i) Access to the tank connection space is, as far as practicable, to be independent and direct from the open deck. If the tank connection space is only partially covering the tank, this requirement is also to apply to the space surrounding the tank and where the opening to the tank is located. Where a separate access from the open deck is not practicable, an air lock which complies with the requirements of 5C-8-3/6.2 through 5C-8-3/6.7 of the *Steel Vessel Rules* is to be provided. The access trunk is to be fitted with separate ventilation. The dimensions of horizontal and vertical openings are to be in accordance with 5C-8-3/5.3.1.2 and 5C-8-3/5.3.1.3 of the *Steel Vessel Rules*. Arrangements are to be such that it is not possible to have unauthorized access to the tank connection space during normal operation of the gas system.

ii) Inspection openings in accordance with 4-4-1/17.3 of the *Steel Vessel Rules* are to be provided for Type C gas fuel storage tanks. Where applicable, circular access openings are not to have diameters less than 600 mm, as per 5C-8-3/5.3.3 of the *Steel Vessel Rules*. Consideration will be given to alternative arrangements which can be shown to provide for an equivalent degree of internal inspection.

iii) For independent tanks operating with inerted interbarrier spaces, access arrangements are to be such that unintended entry by personnel is to be prevented. If access to such spaces is not from the open deck, sealing arrangements are to prevent leakage of inert gas to adjacent spaces.

4 Gas Pipe Design and Arrangements

4.1 General

i) Gas piping is to comply with 5C-8-5/2.1.2, 5C-8-5/2.1.4, 5C-8-5/2.1.6, 5C-8-5/2.2.1, 5C-8-5/2.3.2, 5C-8-5/2.4.1 through 5C-8-5/4, 5C-8-5/2.5, 5C-8-5/4.2 through 5C-8-5/4, and 5C-8-5/4.6.2 of the *Steel Vessel Rules*.

ii) Gas pipes are not to be located less than 800 mm from the ship's side. Where necessary, low temperature piping is to be thermally isolated from the adjacent hull structure to prevent the temperature of the hull from falling below the design temperature of the hull material.

iii) The piping system is to be of welded construction and flange joints are to be kept to a minimum. Gaskets are to be protected against blow-out. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections or pump seals, protection for the hull beneath is to be provided.

iv) The gas piping system is to be installed with sufficient flexibility to accommodate the oscillating movements that may be applicable without risk of fatigue failure. Arrangement for provision of the necessary flexibility is to be demonstrated to maintain the integrity of the piping system in normally foreseen service situations.

v) An arrangement for purging gas bunkering lines and supply lines with nitrogen is to be provided.

vi) If the fuel gas contains heavier components that may condense in the system, a vapor-liquid separator or equivalent means for safely removing the liquid is to be fitted.

vii) Gas piping is to be protected against mechanical damage.

viii) Gas pipes are to be color marked based on a recognized standard.

4.2 High Pressure Gas Piping

i) The arrangement and installation of high pressure gas piping is to provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of the main engine, without running the risk of fatigue problems. The length and configuration of the branch lines are important factors in this regard.

ii) High pressure gas piping systems are to have sufficient constructive strength which is to be confirmed by carrying out stress analysis taking into account the stresses due to the weight of the piping system including acceleration load when significant, internal pressure and loads induced by hog and sag of the ship.

iii) All valves and expansion joints used in high pressure gas fuel supply lines are to be of an approved type.

iv) Joints on the entire length of high pressure gas fuel supply lines are to be butt-welded joints with full penetration and are to be fully radiographed, except where specially approved.

v) Pipe joints other than welded joints at the specially approved locations identified under 2/4.2iv) of this Guide are to comply with recognized standards or may be accepted subject to specific approval on a case by case basis.

vi) For all butt-welded joints of high pressure gas fuel supply lines, post-weld heat treatment is to be performed dependant on the type of material.

vii) High pressure installations are to be provided with means for rapid detection of a rupture in the gas supply line. When rupture is detected, a valve is to automatically close. This valve is to be located outside but as close as possible to the machinery space; it can be a separate valve or combined with other functions such as the master gas valve. Acceptable means of detection are:

a) An orifice or flow fuse detecting excess flow and located close to the point of entry to the machinery space;

b) A combined excess flow detector with automatic shut off valve located as close as possible to the point of entry to the machinery space;

c) A low pressure detector located close to the engine inlet connection.

4.3 Distribution Outside of Machinery Spaces

Gas piping is not to be led through other machinery or enclosed spaces. Alternatively, double wall fuel gas piping may be approved, provided the danger of mechanical damage is considered negligible, the gas piping has no discharge sources and the space is equipped with a gas detection alarm. See also Subsection 5/4 of this Guide.

5 System Configuration

5.1 General

i) The propulsion and auxiliary arrangements and fuel supply systems are to be arranged so that in the case of emergency shutdown of the fuel gas supply the propulsion and maneuvering capability, together with power for essential services, can be maintained. Under such a condition the remaining power is to be sufficient to provide for a speed of at least 7 knots or half of the design speed, whichever is the lesser.

ii) Automatic means are to be provided to stop the supply of natural gas into an area or space where a gas release has been detected.

iii) Means are to be provided to control the pressure and temperature of the fuel gas delivered to each gas utilization unit.

5.2 Alternative System Configurations

Two alternative system configurations may be accepted:

i) *Double Wall Fuel Gas Piping Concept.* Arrangements in machinery spaces are such that the spaces are considered non-hazardous under all conditions, normal as well as abnormal conditions. This concept is in accordance with the principles of the IGC Code, which relies on encased gas fuel pipes and a ventilation duct or hood over the potential sources of leakage.

ii) *Single Wall Fuel Gas Piping Concept.* This concept may only be applied to machinery spaces containing dual fuel or single fuel engines using low pressure, 10 bar (10.2 kgf/cm^2, 145 psi) or less, fuel gas supply systems. The entire engine compartment is to contain only the engine(s) and minimum necessary equipment. The machinery space, or engine compartment, is to be as small in volume as practicable without compromising maintainability, in order to facilitate effective ventilation and gas detection. By the adoption of redundant ventilation systems, gas detection and associated safety systems, the engine compartment arranged under this concept is considered equivalent to the IGC Code concept referenced by 2/5.2i) of this Guide.

5.3 Double Wall Fuel Gas Piping Concept

Where the double wall fuel gas piping concept is applied, the engine room arrangement is to comply with the applicable requirements of 2/2.6 of this Guide and gas fuel supply and safety systems are to be in compliance with Section 5 of this Guide.

5.4 Single Wall Fuel Gas Piping Concept

Where the single wall fuel gas piping concept is applied, the engine room arrangement is to comply with Subsection 8/2 of this Guide and the fuel supply and safety systems are to be in compliance with Section 5 of this Guide.

In order to maintain propulsion capability in case a single wall fuel gas piping engine compartment is shut down, propulsion engines and necessary equipment are to be located in at least two separate compartments. These compartments are not to have common boundaries unless it can be documented that the common boundary can withstand an explosion in one of the compartments. As per 2/5.2ii) of this Guide, the engine compartment is to contain only the engine(s) and minimum necessary equipment.

6 Gas Utilization

6.1 Utilization or Disposal of Boil-off Gas

Unless the entire bunker tank system is designed to withstand the full gauge vapor pressure of the gas under conditions of the upper ambient design temperatures, as specified in 5C-8-7/1.2 of the *Steel Vessel Rules*, means are to be provided to maintain the tank pressure below the MARVS by safely utilizing or disposing of the natural LNG boil-off at all times, including while in port, while maneuvering or standing by, as per Section 5C-8-7 of the *Steel Vessel Rules*. Systems and arrangements that may be used for this purpose may include one or any combination of the following:

i) A dual fuel diesel engine plant for propulsion and power generation

ii) A single gas fuel engine plant for propulsion and power generation

iii) A gas turbine plant for propulsion and power generation

iv) A re-liquefaction system

v) A gas combustion unit

vi) Other approved BOG utilization units, such as an auxiliary steam boiler capable of burning boil-off vapors

vii) Gas fuel storage tank pressure accumulation whereby the bunker tank fuel is allowed to warm up and increase in pressure. The tank insulation or tank design pressure is to be sufficient to maintain tank pressure below the MARVS and for the tank not to become liquid full for a period of 15 days under all tank fill conditions.

The aggregate capacity of the means provided for BOG utilization/disposal is to be not less than the normal boil-off rate (NBOR).

6.2 Supply of Fuel Gas and BOG to Utilization Units

6.2.1 Master Gas Valve

The gas supply to each gas utilization unit as specified in 2/6.1 of this Guide, located outside the gas storage area is to be through its own individual gas shut-off valve arranged for automatic closure if leakage of gas is detected, or loss of ventilation for the duct or casing or loss of pressurization of the double wall gas fuel piping occurs.

In addition, there are safety features required in each of the individual Sections of this Guide for protection of the equipment defined in these Sections, such as the re-liquefaction plant, gas combustion unit, dual fuel diesel engines, single gas fuel engines, gas turbine and associated installation. These safety features will require each individual gas shut-off valve to close under emergency or fault conditions. Reference is to be made to these requirements in each Section.

The master gas shut-off valve for each gas utilization unit required above is to be located outside the space containing the gas utilization unit but it need not be located in the gas storage area. However, if it is located in an enclosed space such as a gas valve unit room, that space is to be protected against gas leakage by another automatic shutdown valve arranged for closure in accordance with 5C-8-16/3.7 of the *Steel Vessel Rules*.

6.2.2 Automatic Purge

Arrangements are to be provided such that upon closure of the master gas valve the piping between the valve and the gas utilization unit will be automatically purged with inert gas.

6.2.3 Main Tank Valve

In addition to the individual master gas valve(s) fitted to each gas utilization unit, a main tank valve is also to be fitted in those instances where there is a connection below the highest liquid level or a pressurized fuel outlet. The main tank valve is to be located on the outlet from the gas fuel storage tank as close to the tank outlet as possible. Where applicable this main tank valve is to be arranged to automatically close as required by Section 3, Table 1 of this Guide.

6.2.4 Pressure Surge Protection

Where there is a risk of a pressure surge in a pipeline caused by an instantaneous closure of the gas shut-off valve or shutdown of gas utilization unit (e.g., in the pipe downstream of the compressor), the piping system is to be designed to withstand a surge of gas pressure.

7 Ventilation Systems – General

i) Any ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces. Ventilation ducting arrangements are to be of a gas tight construction. The ventilation is to function at all temperature conditions the ship will be operating in. Electric fan motors are not to be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

ii) Design of ventilation fans serving spaces containing gas sources are to fulfill the following:

a) Electric motors driving fans are to comply with the required explosion protection in the installation area. Ventilation fans are not to produce a source of vapor ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, are to be of non-sparking construction defined as:

i) Impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

ii) Impellers and housings of non-ferrous metals;

iii) Impellers and housings of austenitic stainless steel;

iv) Impellers of aluminum alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

v) Any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

b) In no case is the radial air gap between the impeller and the casing to be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

c) Any combination of an aluminum or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and is not to be used in these places.

d) The ventilation units are to be safely bonded to the hull structure.

iii) Any loss of the required ventilating capacity is to give an audible and visual alarm at a normally manned location.

iv) Air inlets for hazardous enclosed spaces are to be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to have over-pressure relative to this space, unless mechanical integrity and gas-tightness of the duct is such to prevent gases from leaking into it.

v) Air outlets from non-hazardous spaces are to be located outside hazardous areas.

vi) Air outlets from hazardous enclosed spaces are to be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

vii) The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

viii) Ventilation ducts are to have the same area classification as the ventilated space.

In addition there are specific ventilation requirements in each individual Section of this Guide, reference is to be made to the requirements in each section.

8 Electrical Systems

8.1 General

i) The electrical requirements in this Subsection and in each individual Section of this Guide are to be applied in conjunction with the requirements of Part D of SOLAS Chapter II-1 and Chapter 8 of Part 4 of the *Steel Vessel Rules*.

ii) Electrical equipment and wiring is in general not to be installed in hazardous areas unless essential for operational purposes.

iii) Hazardous areas on open deck and other spaces not defined under 2/8.3 of this Guide are to be determined based on a recognized standard (e.g., IEC 60092-502 or IEC 60079-10-1). Installed electrical equipment is to be of a certified safe type based on that standard.

iv) Cable penetrations are to satisfy the requirements regulating the dispersion of gas.

v) An inspection and maintenance manual is to be prepared for electrical equipment that is installed in explosion hazardous spaces and areas in accordance with Section 9 and 10 of IEC 60092-502.

8.2 Area Classification

i) Hazardous areas are spaces where flammable or explosive gases, vapors or dust are normally present, or likely to be present. Hazardous areas are to be classified based on the likelihood of presence and the concentration and type of flammable atmosphere, as well as in terms of the extent of the space.

Area classification is a method of analyzing and classifying the areas where these explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical equipment able to be operated safely in the defined areas.

In order to facilitate the selection of the appropriate electrical equipment and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2 in accordance with recognized standard IEC publication 60079-10-1.

ii) Area classification of a space may be dependent on ventilation. A space with opening to an adjacent hazardous area on open deck, may be made into a less hazardous or non-hazardous space, by means of overpressure.

8.3 Hazardous Area Zones

8.3.1 Hazardous Area Zone 0

Hazardous Area Zone 0 includes:

i) The interiors of gas tanks, any pipework of pressure relief or other venting systems for gas tanks, pipes and equipment containing gas.

8.3.2 Hazardous Area Zone 1

Hazardous Area Zone 1 includes:

i) Fuel containment system spaces (except spaces containing Type C fuel storage tanks with no connections to the tank in the space, which are considered zone 2);

ii) Gas compressor or fuel preparation room with ventilation arranged according to Subsection 5/7 of this Guide;

iii) Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapor outlet, bunker manifold valve, other gas valve, gas pipe flange, gas pump-room ventilation outlets and gas tank openings for pressure release provided to permit the flow of small volumes of gas or vapor mixtures caused by thermal variation;

iv) Areas on open deck or semi-enclosed spaces on deck, within 1.5 m of gas compressor, gas pump or fuel preparation room entrances, gas compressor, gas pump or fuel preparation room ventilation inlets and other openings into zone 1 spaces;

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v) Areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck; and

vi) Enclosed or semi-enclosed spaces in which pipes containing gas are located (e.g., ducts around gas pipes, semi-enclosed bunker stations).

8.3.3 Hazardous Area Zone 2

Hazardous Area Zone 2 includes:

i) Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

SECTION 3 Gas Fuel Storage

1 General

i) The gas fuel storage tank is to be sufficiently protected against external damage caused by collision, grounding, fire or other probable operational damage. Arrangements are to be in accordance with 2/2.1 and 2/2.2 of this Guide.

ii) For single fuel installations (gas only), the fuel storage is to be divided between two or more tanks of approximately equal size. The tanks are to be located in separate compartments.

1.1 Plans and Data to be Submitted

Plans and specifications covering the gas fuel storage arrangements with all of the accessories are to be submitted and are, as applicable, to include:

- General arrangement of the gas storage tank(s) and as applicable hold space/gas fuel storage room, including location of the gas detectors, electrical equipment and lighting
- Detailed drawings of the gas storage tank, supports and stays, secondary barrier and insulation
- Material specifications for tanks, valves and associated components
- Weld procedures, stress relieving and non-destructive testing plans
- Specifications of design loads and structural analyses for the gas storage tank(s) together with complete stress analysis as applicable
- Calculation of gas storage tank relief valve capacity including back pressure
- Filling limit curve as referenced by 3/3vi) of this Guide
- Tank pressure accumulation calculation as referenced by 2/6.1vii) of this Guide
- Fuel gas storage tank thermal isolation calculation as referenced by 2/2.2.2iv) of this Guide
- Ventilation or inert gas arrangements for the hold space/gas fuel storage room
- Fixed gas detection and alarm systems, and associated shut-off and shutdown systems
- Gas fuel piping systems including details of piping and associated components, design pressures, temperatures and insulation where applicable
- Gas compressors
- Gas heaters
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the hold space/gas fuel storage room
- Electric bonding (earthing) arrangement
- Emergency shutdown arrangements
- Operating and maintenance instruction manuals (see 3/3vi), 3/3viii) and Subsection 3/2 of this Guide)
- Forced and natural boil-off gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials.

2 Storage Tank Operation

In accordance with Subsection 1/6 of this Guide detailed instruction manuals are to be provided onboard, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the use of gas as a fuel.

The storage tank operation aspects of the manuals are to include, but not be limited to, the instructions for pumping bunker fuel, stripping tanks, inerting, warming up/cooling down procedures and venting.

The manuals are to be submitted for review solely to verify the presence of all the information required by this Section.

3 LNG Storage Tanks

i) The storage tank used for liquefied gas is to be an independent tank Type A, B or C designed in accordance with Section 5C-8-4 of the *Steel Vessel Rules*. Membrane tanks designed in accordance with Section 5C-8-4 of the *Steel Vessel Rules* may be accepted subject to satisfactory sloshing analysis under all tank fill conditions. The testing relating to welding and tank testing is to be in accordance with 5C-8-4/10 and 5C-8-4/11 of the *Steel Vessel Rules*.

ii) For storage tanks requiring a full or partial secondary barrier, the secondary barrier is to be capable of containing the determined leakage for a period of time as agreed based on the proposed means to dispose of same but in no case less than 15 days.

iii) Pipe connections to the tank are normally to be mounted above the highest liquid level in the tanks. However, connections below the highest liquid level may be accepted for Type C independent tanks where such connections are located in a gas tight space; see also 2/2.2.2iv) and Subsection 3/6 of this Guide.

iv) Pressure relief valves as required in Section 5C-8-8 of the *Steel Vessel Rules* are to be fitted.

v) The outlet from the pressure relief valves is normally to be located at least $B/3$ or 6 m, whichever is greater, above the weather deck and 6 m above the working area and gangways, where B is the greatest molded breadth of the ship in meters. The outlets are normally to be located at least 10 m from the nearest:

   a) Air intake, air outlet or opening to accommodation, service or control spaces, or other non-hazardous spaces; and

   b) Exhaust outlet from machinery or from furnace installation.

vi) Storage tanks for liquid gas are not to be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in 5C-8-15/1.4 of the *Steel Vessel Rules*. A filling limit curve for actual filling temperatures should be prepared from the formula given in 5C-8-15/1.2 of the *Steel Vessel Rules*. However, when the tank insulation and tank location makes the probability very small for the tank contents to be heated up due to external fire, special considerations may be made to allow a higher filling limit than calculated using the reference temperature.

vii) Means that are not dependent on the gas machinery system are to be provided whereby liquid gas in the storage tanks can be emptied.

viii) It is to be possible to empty, purge gas and aerate bunker tanks with permanently fitted gas piping systems. Procedures shall be prepared for this in accordance with Section 5C-8-9 of the *Steel Vessel Rules*. Dependant on the particular vessel type it may be that permanent piping arrangements are installed but the intention is for operations to be undertaken by a service vessel. Such arrangements will be subject to special consideration on a case-by-case basis.

4 CNG Storage Tanks

i) The storage tanks used for compressed gas are to be designed in accordance with the *CNG Guide*.

ii) Tanks for compressed gas are to be fitted with pressure relief valves with a set point below the design pressure of the tank and with the outlet located as required in 3/3v) of this Guide.

5 Gas Storage Tank Monitoring

i) Gas storage tanks are to be monitored and protected against overfilling as required by 5C-8-13/2 and 5C-8-13/3 of the *Steel Vessel Rules*.

ii) Each tank is to be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The manometers and indicators are to be clearly marked with the highest and lowest pressure permitted in the tank. In addition, high-pressure alarm, and if vacuum protection is required, low pressure alarm are to be provided on the bridge. The alarms are to be activated before the set pressures of the safety valves are reached.

iii) Each tank is to be provided with at least two devices for indicating temperature, one placed at the bottom of the tank and the second near the top of the tank, below the highest allowable liquid level. The lowest temperature for which the tank has been designed is to be clearly indicated on the tank itself, or by means of a sign on or near the temperature indicating devices.

The temperature indicating devices are to be capable of providing temperature indication across the expected operating temperature range of the tanks.

Where thermowells are fitted they are to be designed so that failure will not occur due to fatigue in normal service.

iv) For storage tanks requiring a full or partial secondary barrier, means are to be provided to detect leakage from the primary barrier.

v) The monitoring and safety shutdowns for gas storage tanks and gas fuel storage rooms are to be in accordance with Section 3, Table 1 of this Guide.

6 Gas Fuel Storage Room and Tank Connection Space

6.1 General

The requirements of 3/6.2 through 3/6.4 of this Guide are applicable to Type C tanks with connections below the highest liquid level. Where the tank connection space is only partially covering the tank these requirements are also to apply to the gas fuel storage room surrounding the tank and where the opening to the tank is located.

6.2 Ventilation

i) The tank connection space located below deck is to be provided with an effective mechanical forced ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour.

ii) Approved automatic fail-safe fire dampers are to be fitted in the ventilation trunk for the tank connection space. In the event of fire detection the ventilation should stop and the fire dampers should close automatically.

6.3 Gas Detection

i) Permanently installed gas detectors are to be fitted in the tank connection space.

ii) Audible and visible alarms from the gas detection equipment are to be located on the bridge and in the control room.

iii) Tank connection space gas detection is to be continuous without delay.

6.4 Fire Detection

i) An approved fixed fire detection system is to be provided for the tank connection space and the ventilation trunk for the tank connection space below deck.

ii) Smoke detectors alone are not to be considered sufficient for rapid fire detection.

iii) Where the fire detection system does not include means of remotely identifying each detector individually, the detectors are to be arranged on separate loops.

6.5 Alternative Arrangements

Inert gas or dry air filling of the hold or void spaces surrounding gas storage tanks, as an alternative means of providing a non combustible environment in accordance with IGC Code principles, may be accepted. Such arrangements are to be in accordance with the applicable environmental control, ventilation and gas detection requirements of Sections 5C-8-9, 5C-8-12, and 5C-8-13, respectively, of the *Steel Vessel Rules*.

7 Fire Extinguishing Systems

7.1 General

i) The requirements for gas fuel storage fire extinguishing systems given in this Subsection are to be regarded as additional to the requirements of SOLAS Chapter II-2.

7.2 Fire Main

i) The water spray system required below may be part of the fire main system provided that the required fire pump capacity and pressure are sufficient for operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

ii) When the storage tank is located on open deck, isolating valves are to be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main is not to deprive the fire line ahead of the isolated section from the supply of water.

7.3 Water Spray Systems

i) A water spray system is to be fitted for cooling and fire prevention and to cover exposed parts of storage tanks located above deck.

ii) The system is to be designed to cover all areas as specified above with an application rate of 10 liters/min/m^2 for horizontal projected surfaces and 4 liters/min/m^2 for vertical surfaces.

iii) For the purpose of isolating damaged sections, stop valves are to be fitted or the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

iv) The capacity of the water spray pump is to be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above.

v) A connection to the ship's fire main through a stop valve is to be provided.

vi) Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system are to be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

vii) The nozzles are to be of an approved full bore type and they are to be arranged to provide an effective distribution of water throughout the space being protected.

viii) An equivalent system to the above detailed water spray system may be accepted by special consideration and subject to satisfactory demonstration of its on deck cooling capability.

8 Surveys during Construction

8.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of gas storage tanks and associated systems onboard the vessel. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

8.2 Surveys at Manufacturer's Facility

Construction and testing of gas storage tanks, valves, pumps and associated piping is to be in accordance with 5C-8-4/10, 5C-8-4/11, 5C-8-5/3, 5C-8-5/4, and 5C-8-6/3 of the *Steel Vessel Rules*, as applicable.

Certification of the complete gas storage tank and associated systems cannot be accepted based only on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*.

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair gas storage tanks or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules*.

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

8.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the gas storage tank, gas fuel storage room and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by 5C-8-5/5 of the *Steel Vessel Rules*.

ii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 of the *Steel Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The gas storage tank and gas fuel storage room operation systems are to be checked for proper operation in accordance with the ABS approved installation test procedure.

8.4 Surveys During Trials

During the initial gas trials, the gas storage tank and associated systems are to be confirmed for satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the ABS approved testing procedure during gas trials.

TABLE 1
Monitoring and Safety System Functions for Gas Fuel Storage Tanks and Gas Fuel Storage Rooms

Monitored Parameters	*Alarm*	*Automatic Shutdown of the Main Tank Valve*
High or low liquid level in gas fuel storage tank	X	
High or low pressure in gas fuel storage tank	X	
High or low temperature in gas fuel storage tank	X	
Gas detection in tank connection space above 20% LEL (1)	X	
Gas detection in tank connection space above 40% LEL (1)	X	X
Fire detection in tank connection space (1, 2)	X	X
Bilge well high level in gas fuel storage room	X	
Bilge well low temperature in gas fuel storage room	X	X

Notes:

1 Where the tank connection space is only partially covering the tank these requirements are also to apply to the gas fuel storage room, see 3/6.1 of this Guide.

2 Ventilation is to be stopped and fire dampers closed automatically, see 3/6.2ii) of this Guide.

TABLE 2
Certification of Gas Fuel Storage Tanks and Gas Fuel Storage Rooms

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
MD	*Manufacturer's Documentation* – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*MD*	*DR*	*MT*	*MS*	*FS*
LNG/CNG tanks		X	X	X	X
LNG pumps		X			X
Pump motors (rated at 100 kW and over)		X			X
Main tank valve and associated piping		X (1)	X	X	X
Pressure relief valves and associated piping		X (1)	X	X	X
Fuel gas piping system in tank connection space and gas fuel storage room, as applicable		X	X	X	X
Fuel gas piping ventilation system		X (1)			
Ventilation system and fire dampers in tank connection space and gas fuel storage room, as applicable		X			X
Hold space inert gas system		X			X
Gas storage pressure vessels (2)					
Tank monitoring system		X			X
Fire detection system		X			X
Fire extinguishing system		X			X
Gas detection system		X			X
Automatic shutdown system		X			X

Notes:

1 Design verification only.

2 See Appendix 1, Table 1 of this Guide.

SECTION 4 Fuel Bunkering System

1 General

At the time of issuance of this Guide fuel bunkering operations for non gas carrier LNG powered vessels have typically been undertaken by a truck to ship or on-shore storage terminal to ship system. Considerable effort is underway within the marine industry to develop ship to ship procedures and it is anticipated that international requirements may be developed in the usual manner in due course to cover these bunkering aspects.

The purpose of this Section is to define the on-board requirements for fuel bunkering systems to enable safe and effective transfer of LNG or CNG from the bunker supplier (ship/truck/terminal) to the vessel gas storage system.

It is understood that the on-board bunkering system would typically comprise a bunkering station located on either side of the vessel. Each station would have provision for one bunkering line and one return line together with nitrogen purging facility, associated relief/safety valves and control station. The LNG or CNG is led by piping from the bunker station to the gas storage tank(s). Consideration is to be given to relevant aspects of related standards such as ISO 28460, EN 1473, EN 1474, etc.

2 Plans and Data to be Submitted

Plans and specifications covering the gas fuel bunkering system with all of the accessories are to be submitted and are, as applicable, to include:

- General arrangement of the gas fuel bunkering system including location of the gas detectors, electrical equipment and lighting
- Detailed drawings of the bunkering station, manifolds, valves, couplings and control stations
- Gas fuel piping systems including details of piping and associated components, design pressures, temperatures and insulation where applicable
- Material specifications for manifolds, valves and associated components
- Weld procedures, stress relieving and non-destructive testing plans
- Ventilation system
- Fixed gas detection and alarm systems, and associated shut-off and shutdown systems
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the bunkering and control stations
- Electric bonding (earthing) arrangement
- Emergency shutdown (ESD) arrangements and ESD flow chart
- Operating and maintenance instruction manuals
- Testing procedures during sea/gas trials

3 Fuel Bunkering Operation

In accordance with Subsections 1/6 and 3/2 of this Guide detailed instruction manuals are to be provided onboard, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the use of gas as a fuel.

The fuel bunkering operation aspects of the manuals are to include, but not be limited to, the instructions for connecting, inerting, warming up/cooling down, pumping bunker, draining, purging, disconnecting, emergency shutdown procedures and emergency ship to ship transfer.

The manuals are to be submitted for review solely to verify the presence of all the information required by this Section.

4 Fuel Bunkering Station

Fuel bunkering station arrangements are to be in accordance with 2/2.4 of this Guide.

5 Fuel Bunkering System

5.1 General

i) The bunkering system is to be arranged so that no gas is discharged to air during the gas storage tank filling operations.

ii) A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve, are to be fitted in every bunkering line close to the bunker supplier connecting point. It is to be possible to release the remote operated valve in the control location for bunkering operations and/or another safe location.

iii) Means are to be provided for draining the liquid from the bunkering pipes at bunkering completion.

iv) Bunkering lines are to be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes are to be gas free.

5.2 Fuel Bunkering Manifolds

i) The bunker manifold(s) are to be arranged for one or more bunkering lines. Filters are to be fitted to prevent the transfer of foreign objects. Connections for LNG vapor return lines are to be provided. The return line is typically used to return evaporated gas to the bunker supplier and may, subject to transfer arrangements, be used to balance delivering and receiving tank pressures.

ii) Manifold connections not being used for bunker transfer operations are to be blanked with blank flanges rated for the design pressure of the pipeline system.

iii) Arrangements are to be provided for making an emergency shutdown connection to the bunker supplier at each bunker station/manifold.

iv) There is to be an equipotential bonding connection between the bunker supplier and the bunkering station on the ship when flammable gas/liquid is being transferred.

5.3 Fuel Bunker Piping

Fuel bunker piping arrangements between the bunkering manifold and the gas storage tank are to be in accordance with the requirements of Subsection 2/4 of this Guide.

5.4 Emergency Shutdown System

i) An emergency shutdown system is to be fitted to stop bunker flow in the event of an emergency. The design of the ESD system is to avoid the potential generation of surge pressures within bunker transfer pipe work.

ii) The ESD system is to be activated by the manual and automatic inputs listed in Section 4, Table 1 of this Guide. Any additional inputs should only be included in the ESD system if it can be shown their inclusion does not reduce the integrity and reliability of the system overall.

iii) A functional flow chart of the ESD system and related systems is to be provided in the fuel bunkering control station and on the bridge.

iv) One ESD valve is to be provided at each manifold connection. The ESD valve may also be the remote operated valve required by 4/5.1ii) of this Guide.

v) ESD valves are to be remotely operated, be of the fail closed type (closed on loss of actuating power), are to be capable of local manual closure and have positive indication of the actual valve position.

vi) ESD valves in liquid piping systems are to close fully and smoothly under all service conditions within 30 seconds of actuation. Information about the closure time of the valves and their operating characteristics is to be available onboard, and the closing time is to be verifiable and reproducible.

vii) The closing time of the valve referred to in 4/5.4vi) (i.e., time from shutdown signal initiation to complete valve closure) is not to be greater than:

$$\frac{3600 \cdot U}{LR} \text{ seconds}$$

where:

U = ullage volume at operating signal level, in m^3

LR = maximum loading rate agreed between ship and bunker supplier, in m^3/h

The loading rate is to be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm, the ship and the bunker supplier piping systems where relevant.

6 Control and Monitoring

i) Control of bunkering is to be possible from a safe location in regard to bunkering operations. At this location the tank pressure and tank level are to be monitored. Overfill alarm and automatic shutdown are also to be indicated at this location.

ii) A local reading pressure gauge is to be fitted between the stop valve and the connection to the bunker supplier at each bunker pipe.

iii) Pressure gauges are to be fitted to gas pump discharge lines and to the bunkering lines.

iv) An independent ESD system in accordance with 4/5.4 of this Guide is to be operational during bunker operations and is to be controllable from both the bunker supplier and the receiving ship to enable a safe shut down in the event of an emergency during bunker delivery. The ESD actions are to be coordinated.

v) As a minimum, the ESD system is to be capable of manual operation by a single control on the bridge, the safe control position required by 4/6i) of this Guide and at least two strategic positions around the bunker loading area.

The monitoring and safety shutdowns for the fuel bunkering system are to be in accordance with Section 4, Table 1 of this Guide.

7 Ventilation System

i) Where gas bunkering lines pass through enclosed spaces they are to be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct is to be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour.

ii) The duct should be dimensioned according to 5/3.2iii) or 5/3.2iv) of this Guide.

iii) The ventilation inlet for the duct is to always be located in open air, away from ignition sources.

iv) The fan motors are to be placed outside the ventilated pipe or duct.

v) The ventilation outlet is to be covered by a protection screen and placed in a position where no gas-air mixture may be ignited.

vi) The ventilation is to always be in operation during bunkering operations.

vii) If the ventilation in the ducting around the gas bunkering lines stops, an audible and visual alarm is to be provided at the bunkering control location.

8 Gas Detection

i) Enclosed or semi enclosed bunker stations are to be fitted with permanently installed gas detectors.

ii) Audible and visible alarms from the gas detection equipment are to be located on the bridge and in the bunker control room.

iii) Fuel bunkering gas detection is to be continuous without delay.

iv) If gas is detected in the ducting around the bunkering lines an audible and visual alarm is to be provided at the bunkering control location.

9 Fire Detection and Extinguishing Systems

i) An approved fixed fire detection system is to be provided for the gas fuel bunkering station.

ii) Smoke detectors alone are not to be considered sufficient for rapid fire detection.

iii) Where the fire detection system does not include means of remotely identifying each detector individually, the detectors are to be arranged on separate loops

iv) In the bunkering station area a permanently installed dry chemical powder extinguishing system is to cover all possible leak points. The capacity is to deliver a rate of discharge of not less than 3.5 kg/s for a minimum of 45 seconds. The system is to be arranged for easy manual release from a safe location outside the protected area.

v) One portable dry powder extinguisher of at least 5 kg capacity is to be located near the bunkering station

10 Surveys During Construction

10.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of fuel bunkering components, piping and associated systems onboard the vessel. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

10.2 Surveys at Manufacturer's Facility

Construction and testing of fuel bunkering components and associated piping is to be in accordance with 5C-8-5/3, 5C-8-5/4 and 5C-8-6/3 of the *Steel Vessel Rules*, as applicable.

Certification of the complete fuel bunkering system cannot be accepted based only on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*.

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair gas storage tanks or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules*.

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

10.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the gas fuel bunkering components, piping and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by 5C-8-5/5 of the *Steel Vessel Rules*.

ii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 of the *Steel Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The fuel bunkering systems are to be checked for proper operation in accordance with the ABS approved installation test procedure.

10.4 Surveys During Trials

During the initial gas trials, the gas fuel bunkering components and associated systems are to be confirmed for satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the ABS approved testing procedure during gas trials.

TABLE 1
Monitoring and Safety System Functions for Fuel Bunkering Systems

Monitored Parameters	*Alarm*	*Automatic Shutdown of the Manifold ESD Valves* (1)
Gas detection at enclosed or semi enclosed bunker station above 20% LEL	X	
Gas detection at enclosed or semi enclosed bunker station above 40% LEL	X	X
Fire detection at bunker station	X	X
Fire detection in gas fuel storage room, compressor room or fuel preparation rooms	X	X
Loss of ventilation in ducting around the gas bunkering lines	X	
Gas detection in ducting around gas bunkering lines above 20% LEL	X	
Gas detection in ducting around gas bunkering lines above 40% LEL	X	X
High level in gas storage tank	X	X
High pressure in gas storage tank	X	X
Manual ESD shutdowns	X	X
Manual or automatic ESD signal from bunker supplier	X	X
Loss of ESD valve motive power (2)	X	X

Notes:

1 ESD signal and automatic activation of the ESD valves on the bunker receiving ship to activate automatic shutdown of the ESD valves and supply pumps at the bunker supplier.

2 ESD valves are to be of fail closed type as per 4/5.4 v) of this Guide.

TABLE 2
Certification of Fuel Bunkering Systems

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
MD	*Manufacturer's Documentation* – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*MD*	*DR*	*MT*	*MS*	*FS*
Bunker manifolds		X	X	X	X
Manifold valves, ESD valves and associated piping		X (1)	X	X	X
Fuel gas bunker piping system		X	X	X	X
Fuel gas bunker piping ventilation system		X (1)			
Monitoring system		X			X
Fire detection system		X			X
Fire extinguishing system		X			X
Gas detection system		X			X
Automatic shutdown system		X			X

Notes:

1 Design verification only.

SECTION 5 Fuel Gas Supply System

1 General

The requirements specified in this Section are intended to cover the fuel gas supply arrangements and systems installed on board to deliver natural gas from the gas fuel storage tank to the prime movers and gas utilization units. Installed arrangements and systems will vary from vessel type to vessel type and from prime mover to prime mover and hence may for example include compressor rooms, process skids or cryogenic fuel preparation rooms, etc. Dependent on the specific arrangements reference may also need to be made to the requirements for re-liquefaction components and systems given under Section 6 of this Guide.

1.1 Warning Notices

i) If the gas supply is shut off due to activation of an automatic valve, the gas supply is not to be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect is to be placed at the operating station for the shut-off valves in the gas supply lines.

ii) If a gas leak leading to a gas supply shutdown occurs, the gas fuel supply is not to be operated until the leak has been found and dealt with. Instructions to this effect are to be placed in a prominent position in the machinery space.

iii) A visible notice is to be permanently fitted in the machinery space containing gas fueled engines stating that heavy lifting around the gas engine, implying danger of damage to the gas pipes, is not to be undertaken when the engines are running on gas.

1.2 Plans and Data to be Submitted

Plans and specifications covering the fuel gas supply arrangements with accessories are to be submitted and are, as applicable, to include:

- General arrangement of the fuel gas supply room including location of the gas detectors, electrical equipment and lighting
- Material specifications for compressors, pumps, evaporators, vaporizers, condensers, coolers, heaters, valves and associated components
- Ventilation systems for the fuel gas supply room
- Fixed gas detection and alarm systems, and associated shut-off and shutdown systems
- Gas fuel piping systems including details of piping and associated components, design pressures, temperatures and insulation where applicable
- Weld procedures, stress relieving and non-destructive testing plans
- Gas compressors
- Vaporizers/Heaters
- Pressure vessels
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the fuel gas supply room
- Electric bonding (earthing) arrangement

- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the fuel gas supply system (see 5/6.1ii) of this Guide)
- Emergency shutdown arrangements
- Operating and maintenance instruction manuals
- Forced and natural boil-off gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials.

2 Fuel Gas Supply System Operation

In accordance with Subsections 1/6, 3/2, and 4/3 of this Guide detailed instruction manuals are to be provided onboard, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the use of gas as a fuel. The manuals are to include maintenance procedures for all technical gas-related installations, and are to comply with the recommendations of the suppliers of the equipment. The intervals for and the extent of the overhaul or replacement/approval of gas valves are to be established. The maintenance procedure is to specify who is qualified to carry out maintenance.

The fuel gas supply operation aspects of the manuals are to include, but not be limited to, the instructions for BOG management, LNG pumping, vaporization, warming up/cooling down, gas compression and emergency shutdown procedures.

The manuals are to be submitted for review solely to verify the presence of the information required by this Section.

3 Gas Supply Systems in Machinery Spaces

3.1 General

i) The main gas supply line to each engine or set of engines is to be equipped with a manually operated stop valve and an automatically operated gas valve (master gas valve) coupled in series or a combined manually and automatically operated valve. The valves are to be situated in the part of the piping that is outside the machinery space containing the gas fueled engines. The master gas valve is to automatically cut off the gas supply as per Section 5, Table 2 of this Guide.

The master gas valve is to be operable from at least two separate locations in the machinery space containing gas fueled engines, from a suitable location outside the space and from the navigation bridge.

ii) Each natural gas utilization unit is to be provided with a set of three automatic valves. Two of these valves are to be in series in the gas fuel pipe to the gas utilization unit. The third valve is to be in a pipe that vents to a safe location in the open air, or to an alternative acceptable location to safely dispose of the gas, that portion of the gas fuel piping that is between the two valves in series.

These valves are to be arranged so that when automatic shutdown is initiated as per Section 5, Table 2 of this Guide, this will cause the two gas fuel valves that are in series to close automatically and the ventilation valve to open automatically.

Alternatively, the function of one of the valves in series and the ventilation valve may be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

The three shut off valves are to be arranged for manual reset either locally or remotely. Where remote reset is fitted, the control system is to be arranged such that the natural gas utilization unit cannot be made operational in gas mode until the abnormal conditions that caused the shut-off of the valves initially have been resolved and safe operation can be resumed.

The two block valves are to be of the fail-to-close type, while the ventilation valve is to be fail-to-open.

The block and bleed valves are also to be used for normal stop of the engine.

iii) Provision is to be made for inerting and gas-freeing the gas fuel piping system. An automatic purge is to be activated upon automatic closure of the master gas valve. Arrangements are to be such that a ventilation valve will ventilate the gas fuel piping between the master gas valve and the block and bleed valve. Discharges are to be led to a safe location in the open air. See also 2/6.2.2 of this Guide.

For high pressure systems the system is to be arranged so that the gas fuel pipe between the master gas valve and the gas injection valves is automatically purged with inert gas when the master gas valve is closed.

For normal stop of engine on high pressure systems the gas piping between the block and bleed valve and gas injection valves are to be automatically vented.

iv) There is to be one manually operated shutdown valve in the gas supply to each engine to provide safe isolation during maintenance of the engine.

v) For single engine installations and multi-engine installations where a separate master gas valve is provided for each engine the master gas valve and the block and bleed valve functions may be combined.

3.2 Gas Supply System for Double Wall Fuel Gas Piping Concept

i) Gas supply lines passing through enclosed spaces are to comply with Subsection 2/4 of this Guide and are to be completely enclosed by a double pipe or duct. This double pipe or duct is to fulfill one of the following:

a) The gas piping is to be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes is to be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes.

Construction and strength of the outer pipes are to be in accordance with 5C-8-5/2 of the *Steel Vessel Rules*; or

b) The gas fuel piping is to be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct is to be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. The fan motors are to be placed outside the ventilated pipe or duct. The ventilation outlet is to be covered by a protection screen and placed in a position where no gas-air mixture may be ignited. The ventilation inlet may be from a non-hazardous machinery space. The ventilation is always to be in operation when there is fuel in the fuel gas supply piping. The applicable master gas valve is to automatically close if the required air flow is not established and maintained by the ventilation system.

The number of flanged joints in protective pipes or ducts is to be minimized and joints are to be gas tight. The materials, construction and strength of protection pipes or ducts and mechanical ventilation systems are to be durable against bursting and rapid expansion of high pressure gas in the event of a gas pipe rupture. The air intakes of the mechanical ventilation system are to be provided with non-return devices effective for gas fuel leaks. However, if a gas detector is fitted at the air intakes, the non-return devices can be dispensed with.

ii) The connecting of gas piping and ducting to the gas injection valves is to be arranged so as to provide complete coverage by the ducting. The arrangements are to facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is to be required also for the gas pipes on the engine itself, all the way until gas is injected into the combustion chamber.

iii) For high pressure piping the design of the ducting is to be taken as the higher of the following:

a) The maximum built up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space; or

b) Local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure and is given by the following expression:

$$p^* = p_o\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where:

p_o = maximum working pressure of the pipe

k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat

k = 1.31 for CH_4

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests may be used. Test reports are then to be submitted.

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1.5 when subjected to the above pressures. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes.

iv) Ducting for high pressure piping is to be pressure tested to at least 10 bar.

v) For low pressure piping the duct is to be dimensioned for a design pressure not less than the maximum working pressure of the gas pipes.

vi) Permanently installed gas detectors complying with the requirements of Subsection 5/8 of this Guide are to be fitted in all ducts around gas pipes applying the ventilated duct arrangement of 5/3.2i)b) of this Guide.

vii) Electrical equipment located in the double wall pipe or duct specified in 5/3.2i) of this Guide is to be of the certified safe type.

3.3 Gas Supply System for Single Wall Fuel Gas Piping Concept

i) As per 2/5.2ii) of this Guide, the pressure in the gas supply system is not to exceed 10 bar. The gas supply lines are to have a design pressure not less than 10 bar and are to comply with the requirements of 2/4.1 of this Guide.

ii) Means are to be provided for rapid detection and automatic shut off of the gas supply in the event of a rupture in the gas supply line to a single wall fuel gas piping compartment. Arrangements are to be in accordance with 2/4.2vii) of this Guide.

iii) Arrangement of single wall fuel gas piping compartments to be in accordance with Subsection 8/2 of this Guide.

4 Gas Distribution Outside of Machinery Spaces

i) Gas fuel piping is not to be led through accommodation spaces, service spaces or control stations.

ii) Where gas pipes pass through enclosed spaces in the ship, they are to be enclosed in a duct. This duct is to be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as per Subsection 5/8 of this Guide is to be provided. See also 2/4.3 of this Guide.

iii) The duct is to be dimensioned according to 5/3.2iii) or 5/3.2v) of this Guide.

iv) The ventilation inlet for the duct is to always be located in open air, away from ignition sources.

v) Gas pipes located in open air are to be located so that they are not likely to be damaged by accidental mechanical impact.

The fire and mechanical protection of gas pipes that lead through ro-ro spaces on open deck is to be subject to special consideration depending on the use and expected pressure in the pipes. Gas pipes that lead through ro-ro spaces on open deck are to be provided with mechanical protection to prevent vehicle collision damage.

vi) Gas fuel piping outside the machinery spaces containing gas fueled engines is to be installed and protected so as to minimize the risk of injury to personnel in case of rupture.

5 Fuel Gas Preparation Equipment

5.1 General

i) In addition to the requirements given under this Section there may, dependent on the arrangement of the specific fuel gas supply system, be further applicable component requirements under Section 6 of this Guide. Reference is therefore also to be made to the requirements under that section.

ii) Fuel gas preparation systems are to be designed to provide a reliable source of fuel gas supply to the prime movers for propulsion and power generation, primarily by means of certification of critical components and providing redundancy in the system, so that propulsion and manoeuvring of the vessel may still be possible in the event of a single failure in the system.

iii) The transient response characteristics of the fuel gas supply and control systems are to be such that transient variations in fuel gas demand would not cause unintended shutdown of the fuel gas supply system.

5.2 Vaporizers/Heaters

i) Heat exchangers used for heating or vaporizing fuel gas are to be designed, constructed and certified in accordance with Section 4-4-1 of the *Steel Vessel Rules*. For the requirements for re-liquefaction cryogenic heat exchangers see 6/3.4 of this Guide.

ii) For pressure and temperature measurements and controls, see Section 5, Table 1 of this Guide.

iii) Arrangements are to be provided to prevent in-operation freezing of the intermediate heat exchange mediums containing products with higher freezing points than LNG, such as Ethylene Glycol, by establishing adequate flow prior to establishing flow of LNG to the heat exchanger/vaporizer or by some other equivalent control strategy.

iv) Where the auxiliary heat exchange circuits are likely to contain gas in abnormal conditions as a result of a component failure (refer to FMEA), they are to be arranged with gas detection in the header tank. Alarm is to be given when the presence of gas is detected. Vent pipes are to be independent and to be led to a non-hazardous area.

5.3 LNG Pumps

i) LNG pumps used in fuel gas supply systems are to be entirely independent of all other pumps.

ii) Material used in the design of the LNG pumps is to be in accordance with 5C-8-6/1.3 of the *Steel Vessel Rules.*

5.4 Fuel Gas Compressors

i) The gas compressors for pressurizing the boil-off or vaporized gas are to be designed in accordance with Section 4-4-1 and 5C-8-16/4 of the *Steel Vessel Rules.*

ii) Fuel gas compressors are to be fitted with accessories and instrumentation necessary for efficient and reliable function.

iii) The fuel gas compressor and fuel gas supply are to be arranged for manual remote emergency stop from the following locations:

a) Cargo control room (relevant for cargo ships only);

b) Navigation bridge;

c) Engine control room; and

d) Fire control station.

iv) High pressure gas compressors are to be approved and certified by ABS.

v) Where pumps or compressors are driven by shafting passing through a bulkhead or deck, gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal are to be fitted in way of the bulkhead. Temperature sensing devices are to be provided for bulkhead shaft glands, bearings and casings for pumps or compressors located in the pump or compressor room. High temperature audible and visual alarms are to be provided at a normally manned control station.

5.5 Ancillary Systems

Where cooling/heating mediums are required in fuel gas supply or ancillary systems, the supply is to be arranged as follows:

i) A minimum of two pumps are to be provided, one of which is to be exclusively provided for this duty.

ii) Where seawater is used, each pump is to have at least two sea suction lines, where practicable leading from sea chests, one port and one starboard.

6 Instrumentation and Safety Systems

6.1 General

i) The control system for the fuel gas supply system may be connected to an integrated control system or be a stand-alone system.

ii) An analysis is to be carried out for the fuel gas supply system identifying component criticality.

iii) The overall system design is to be based on single-fault criteria. The system is to be designed such that a single fault of a component will not lead to serious consequences.

6.2 Control and Monitoring System

i) Automatic control, alarm and safety functions are to be provided so that operations remain within preset parameters for all gas storage tank filling and gas demand conditions.

ii) The temperature and pressures in the fuel gas supply system are to be controlled as follows:

a) A control and monitoring system is to be provided in the control room.

b) The design of the control system is to be such as to ensure identification of faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-1/9 of the *Steel Vessel Rules*, as applicable.

c) Indications of parameters necessary for the safe and effective operation of the process are to be provided, as per Section 5, Tables 1 and 2 of this Guide.

d) The computer-based control systems are to comply with the applicable requirements of Section 4-9-6 of the *Steel Vessel Rules.*

e) The electronic control equipment is to be performance tested in the presence of the Surveyor or by a recognized testing laboratory, in accordance with the criteria of 4-9-7/Tables 9 and 10 of the *Steel Vessel Rules*.

iii) The gas compressor control and monitoring system is to include anti surge protection.

iv) Gas compressors are to be fitted with audible and visual alarms both on the bridge and at the control station. As a minimum the alarms are to be in relation to low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

v) LNG pumps are to be fitted with audible and visual alarms both on the bridge and at the control station. As a minimum the alarms are to indicate low LNG discharge pressure, high LNG inlet temperature, high LNG discharge pressure and LNG pump operation.

6.3 Safety Shutdown System

An independent shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

i) Means are to be provided to indicate the parameters causing shutdown.

ii) Upon activation of the safety shutdown system, alarms are to be given at the normal control position and at the local control position.

iii) In the event where shutdown by the safety shutdown system is activated the restart should not occur automatically, unless after the system is reset.

Monitoring and safety shutdowns are to be in accordance with Section 5, Tables 1 and 2 of this Guide.

7 Ventilation System

i) Pump, compressor and fuel preparation rooms are to be fitted with an effective mechanical ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour.

ii) The number and power of the ventilation fans should be such that if one fan, or a group of fans with common circuit from the main switchboard or emergency switchboard, are out of service the capacity of the remaining ventilation fan(s) is not to be less than 100% of the total required.

iii) Operating manual required by Subsection 1/5 is to indicate that ventilation systems for pump, compressor and fuel preparation rooms are to be in operation when pumps or compressors are working.

8 Gas Detection

i) Permanently installed gas detectors are to be fitted in pump, compressor and fuel preparation rooms.

ii) Audible and visible alarms from the gas detection equipment are to be located on the bridge and in the control room(s).

iii) Pump, compressor and fuel preparation room gas detection is to be continuous without delay.

9 Fire Protection and Fire Extinguishing System

Fuel gas supply pump, compressor and fuel preparation rooms are to be provided with fire detection, protection and extinguishing systems complying with the requirements of Part 4, Chapter 7 and Section 5C-8-11/5.1 of the *Steel Vessel Rules* and SOLAS Chapter II-2.

10 Surveys During Construction

10.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of fuel gas supply components and associated systems onboard the vessel. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

10.2 Surveys at Manufacturer's Facility

Construction and testing of fuel gas supply components and associated piping is to be in accordance with the applicable parts of 5C-8-4/10, 5C-8-4/11, 5C-8-5/3, 5C-8-5/4 and 5C-8-6/3 of the *Steel Vessel Rules*.

Certification of the complete fuel gas supply system cannot be accepted based only on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*.

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair gas storage tanks or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules*.

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

10.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the fuel gas supply components and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by 5C-8-5/5 of the *Steel Vessel Rules*.

ii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 of the *Steel Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The fuel gas supply systems are to be checked for proper operation in accordance with the ABS approved installation test procedure.

10.4 Surveys During Trials

During the initial gas trials, the fuel gas supply components and associated systems are to be confirmed for satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the ABS approved testing procedure during gas trials.

TABLE 1
Instrumentation and Alarms in Centralized Control Stations for the Fuel Gas Supply System

Item			*Display*	*Alarm Activated*	*Automatic Shut Down*
BOG Compressor	Driving motors (2)		Running	Stop	
	LO Temperature			High	
	LO Pressure			Low	
	Sealing gas pressure, if applicable			Low	
	Control air pressure loss, if applicable			Failed	X
	Suction line	Pressure	X	High/Low	X (High-High)
		Temperature	X	High	X (High-High)
	Discharge line	Pressure	X	High/Low	X (Low-Low)
		Temperature	X	High/Low	X (High-High)
LNG Pumps	Driving motors (2)		Running	Stop	
	Inlet	Temperature	X	High/Low	X (High-High)
	Discharge line	Pressure	X	High/Low	X (High-High)
Recondenser/Suction Drum	Temperature		X		
	Level low		X	Low	X (Low-Low)
	Level high		X	High	X (High-High)
	Pressure high		X	High	X (High-High)
Vaporizer/Heater	LNG Inlet	Temperature	X	High/Low	X (High-High)
	LNG Discharge line	Pressure	X	High/Low	X (High-High)
		Temperature	X	High/Low	X (High-High)
Heating circuit for LNG Vaporizer/ Heaters	Tank fluid level		X	High/Low	X (Low-Low)
	Gas detection in tank (1)		X	X	
	Pump driving motor		Running	Stop	
	Pump discharge line	Pressure	X	High/Low	X (Low-Low)
	Electric heater		Running	Stop	
	Inlet	Temperature	X	High/Low	X (Low-Low)
Control System	Control power supply			Failed	
	Emergency Shutdown			X	

Notes:

1 See 5/5.2iv) of this Guide.

2 See 5/5.4v) of this Guide for gland, bearing and casing temperature monitoring, as applicable.

TABLE 2
Monitoring and Safety System Functions for Fuel Gas Supply Systems

Monitored Parameters	*Alarm*	*Automatic Shutdown of the Main Tank Valve*	*Automatic Shut-off of the Master Gas Fuel Valve and Automatic Activation of the Block and Bleed Valves*
Gas detection in duct between tank and machinery space containing gas fueled prime movers above 20% LEL	X		
Gas detection in duct between tank and machinery space containing gas fueled prime movers above 40% LEL	X	X(1)	
Gas detection in compressor, pump or fuel preparation room above 20% LEL	X		
Gas detection in compressor, pump or fuel preparation room above 40% LEL	X	X(1)	
Gas detection in duct inside machinery space containing gas fueled prime movers above 30% LEL	X		
Gas detection in duct inside machinery space containing gas fueled prime movers above 40% LEL	X		X(2)
Gas detection in machinery space containing gas fueled prime movers above 20% LEL	X		
Gas detection in machinery space containing gas fueled prime movers above 40% LEL	X		X(3)
Loss of ventilation in duct between tank and machinery space containing gas fueled prime movers (4)	X		X(1)
Loss of ventilation in duct inside machinery space containing gas fueled prime movers (4)	X		X(2)
Loss of ventilation in machinery space containing gas fueled prime movers (6)	X		X
Fire detection in machinery space containing gas fueled prime movers	X		X
Abnormal pressures in the gas fuel supply line	X		X
Failure of valve control actuating medium	X		X(5)
Automatic shutdown of engine (engine failure)	X		X(5)
Emergency shutdown of engine manually released	X		X

Notes:

1 If the tank is supplying gas to more than one prime mover and the different supply pipes are completely separated and fitted in separate ducts and with the master gas valves fitted outside of the duct, only the master gas valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

2 If the gas is supplied to more than one prime mover and the different supply pipes are completely separated and fitted in separate ducts and with the master gas valves fitted outside of the duct and outside of the machinery space containing gas fueled prime movers, only the master gas valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

3 When a gas leakage is detected in a gas fueled prime mover machinery space and before the gas concentration detected reaches 60% of the LEL, all the electrical equipment inside the machinery space, other than certified safe type, is to be automatically isolated from its electrical supply and all the engines in that machinery space are to be shutdown.

4 If the duct is protected by inert gas (see 5/3.2i)a) of this Guide) then loss of inert gas overpressure is to lead to the same actions as given in this table.

5 Only block and bleed valves to close.

6 Single wall fuel gas piping machinery spaces only.

TABLE 3
Certification of Fuel Gas Supply Systems

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
MD	*Manufacturer's Documentation* – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment (1)	*MD*	*DR*	*MT*	*MS*	*FS*
BOG compressors		X	X		X
LNG pumps		X	X		X
Pump and compressor motors (rated at 100 kW and over)		X			X
Condensers (2)		X	X		X
Vaporizers/Heaters (2)		X		X	X
Heat exchangers (2)		X		X	X
Cryogenic valves and associated piping		X(3)	X	X	X
Fuel gas supply piping		X	X	X	X
Fuel gas piping ventilation system		X(3)			
Pump room, compressor room, fuel preparation room ventilation system		X			X
Control system		X			X
Fire detection system		X			X
Fire extinguishing system		X			X
Gas detection systems		X			X
Automatic shutdown and safety system		X			X

Notes:

1 As applicable

2 See Appendix 1, Table 1 of this Guide.

3 Design verification only

SECTION 6 Re-liquefaction Unit

1 General

It is understood that re-liquefaction systems are likely to be mainly installed on LNG carriers. However for non-LNG carriers there may be instances where re-liquefaction systems are utilized as a secondary means of controlling bunker tank pressure so that, as per 2/6.1 of this Guide, the tank pressure is maintained below the MARVS at all times or that re-liquefaction forms a part of the fuel gas supply system process. Accordingly, and as per Subsection 5/1 of this Guide, aspects of the requirements contained within this Section may, as applicable, be applied to fuel gas supply systems.

The re-liquefaction system typically comprises:

i) Vapor BOG/LNG (condensate) circuit, which is vapor from the bunker tank(s) and LNG return to the bunker tank(s).

ii) Refrigeration circuit for cooling down and re-liquefying the boil-off vapor.

1.1 Capacity

i) The capacity of the re-liquefaction unit is to be based on the requirements of 2/6.1 of this Guide.

ii) The re-liquefaction unit is to be capable of operating satisfactorily with a reduced rate of boil-off gas.

1.2 LNG Return to Bunker Tanks

i) The re-liquefaction system is to be arranged such that the LNG returned to bunker tanks can be distributed in such a way so as not to cause the liquid level in any bunker tank to exceed that permitted by 3/3vi) of this Guide.

ii) Where it is proposed that LNG from the re-liquefaction system is returned without the use of a pump, by way of a gravity return or pressure return system, pressure drop calculations for the as-fitted system are to be submitted. The calculations are to consider ship motion and fluid motion inside the bunker tanks. If no motion data is available from model test for dynamic design of inclination for propulsion and auxiliary machinery in 4-1-1/Table 7 of the *Steel Vessel Rules* may be used.

1.3 Plans and Data to be Submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted (see 4-1-1/5 of the *Steel Vessel Rules)* and are to include:

- General arrangement of re-liquefaction unit compartment, as applicable, including location of the gas detectors, electrical equipment and lighting
- Ventilation systems for re-liquefaction unit compartment
- Fixed gas detection and alarm systems, and associated shut off and shutdown systems
- Gas fuel piping systems including details of pipes and associated components, design pressures and temperatures
- Gas compressors
- Gas heaters
- Gas storage pressure vessels
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

- Details of all electrical equipment in the re-liquefaction unit compartment
- Electric bonding (earthing) arrangement
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the re-liquefaction unit (see 6/4.1ii) of this Guide)
- Emergency shutdown arrangements (see Section 6, Table 1 of this Guide)
- Forced boil-off gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials.

2 Vapor (BOG)/LNG Circuit

2.1 BOG Compressors

i) Compressors for pressurizing the boil-off gas in the re-liquefaction system are to be independent of all other gas duties.

ii) The compressors are to be designed in accordance with 5C-8-16/4.2 of the *Steel Vessel Rules*, except that the compressors are to be capable of being stopped locally and remotely from the control room and from the bridge.

iii) For pressure and temperature measurement and control, see Section 6, Table 1 of this Guide.

2.2 LNG Pumps

i) Where LNG pumps are used for the return of LNG to the bunker tank(s), these pumps are to be entirely independent of all other pumps.

ii) Material used in the design of the LNG pumps is to be in accordance with 5C-8-6/1.3 of the *Steel Vessel Rules.*

2.3 Separation of Impurities

Impurities in the boil-off gas, as well as nitrogen, may be separated prior to the return of LNG from the re-liquefaction plant to the bunker tank(s). The separation of impurities may be through a separator or by other approved means. Details of the separation system are to be submitted.

3 Refrigeration System

3.1 General

Refrigeration systems are to be provided with environmentally acceptable refrigerants. The use of ozone depleting refrigerants and those refrigerants contributing to the global warming potential (ODP and GWP), as defined by the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, as amended, is not acceptable.

3.2 Refrigerants

i) Refrigerants other than those referred to in 6-2-6/3.1.6 of the *Steel Vessel Rules*, may be used, provided they are considered to be adequate for use in shipboard applications in accordance with national or international standards, international treaties adopted by the government(s) and the Flag States or other similar legislation laid down by the Flag State. Details, such as the chemical properties, toxicity and flammability, together with the supporting data, are to be submitted for review.

ii) The refrigerant capacities are to be as follows:

- Where nitrogen is used as the refrigerant supplied by the vessel's nitrogen generation system, there is to be a minimum of two independent units fitted, so that with any one unit inoperative, 100% of the required capacity will be available.
- Where a cascade system is fitted, there is to be a sufficient capacity of the refrigerant onboard to recharge the system once.

iii) Where a cascade system is used requiring onboard storage of refrigerant, the refrigeration system is to be fitted with a receiver capable of holding the complete charge of the refrigerating units. Where each refrigeration unit is fitted with an individual receiver, the capacity is to be sufficient to hold the charge of that unit.

iv) In the case of nitrogen, part of the charge may be discharged/vented to the atmosphere.

3.3 Compressors/Expanders

i) Air-cooled compressors are to be designed for an air temperature of at least 45°C (113°F). Water-cooled compressors are to be designed for a water temperature of at least 32°C (90°F).

ii) Compressor vibration resulting from gas pressure pulses and inertia forces is to be taken into account in the compressor design and mounting arrangement. Acceptable mounting arrangements include resilient rubber mounts or springs.

iii) Material for housings, rotors and rotor casings is to be in accordance with the applicable requirements of 6-2-6/7 of the *Steel Vessel Rules*. The compressor casing design is to be suitable for the maximum design pressure of the high pressure side of the system.

iv) For instrumentation, monitoring and control system for the compressors, see Section 6, Table 1 of this Guide.

3.4 Cryogenic Heat Exchangers and Cold Box

i) The heat exchangers are to be designed, constructed and certified in accordance with Section 4-4-1 of the *Steel Vessel Rules.* If nitrogen refrigeration compressors are to be located in non-hazardous spaces to mitigate the risks of boil-off gas returning to the refrigeration compressors through the refrigerant system, the pressure in the refrigerant circuit is to be maintained greater than the pressure in the boil-off gas circuit at all times.

ii) Piping inside the cold box is to be of all-welded construction. Where flanged connections are essential, details indicating the necessity for this connection are to be submitted for approval on a case-by-case basis.

iii) For pressure and temperature measurements and controls, see Section 6, Table 1 of this Guide.

iv) Where the heat exchanger is enclosed in a cold box, the following requirements apply:

a0 The cold box is to be designed to withstand nitrogen purge pressures likely to be encountered in service and is to be fitted with pressure and vacuum relief devices to prevent over- and under pressurization.

b) To prevent overpressuring of the cold box by leaking nitrogen or BOG/LNG, a safety relief valve is to be provided. The vent from the cold box safety relief valve is to be led to the weather.

c) Means of detecting boil-off gas leakage within the cold box is to be provided. The detection system is to give an audible and visual alarm at the cargo control station and the bridge upon detection of gas leakage.

d) Where the cold box is insulated, means are to be provided for continuous purging of the insulation spaces with nitrogen or other suitable inert gas.

4 Instrumentation and Safety Systems

4.1 General

i) The control system for the re-liquefaction unit may be connected to an integrated control system or may be a standalone system.

ii) An analysis is to be carried out for the re-liquefaction unit identifying component criticality.

iii) The overall system design is to be based on single-fault criteria. The system is to be designed such that a single fault of a component will not lead to serious consequences.

4.2 Control and Monitoring System

i) Automatic control, alarm and safety functions are to be provided to prevent operations exceeding preset parameters under specified conditions.

ii) The temperature and pressures in the re-liquefaction unit are to be controlled as follows:

a) A control and monitoring system is to be provided in the control room. Additionally, a motor control panel is to be provided in the vicinity of the boil-off gas compressor and the refrigeration compressor motors.

b) The design of the control system is to be such as to identify faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-1/9 of the *Steel Vessel Rules*, as applicable.

c) Indications of parameters necessary for the safe and effective operation of the process are to be provided, as per Section 6, Table 1 of this Guide.

d) All electrical control systems are to have two means of power supply and each is to be individually monitored for faults.

e) All computer-based control systems are to comply with the applicable requirements of Section 4-9-6 of the *Steel Vessel Rules.*

f) All electronic control equipment is to be performance tested in the presence of the Surveyor or by a recognized testing laboratory, in accordance with the criteria of 4-9-7/Tables 9 and 10 of the *Steel Vessel Rules*.

iii) The gas compressor control and monitoring system is to include anti surge protection.

4.3 Safety Shutdown System

An independent shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

i) Means are to be provided to indicate the parameters causing shutdown.

ii) Upon activation of the safety shutdown system, alarms are to be given at the normal control position and at the local control position.

iii) In the event where shutdown by the safety shutdown system is activated the restart should not occur automatically, unless after the system is reset.

iv) The safety shutdown system is to be supplied by two sources of power.

v) Means are to be provided to evacuate LNG remaining in the system after a shutdown.

Safety shutdowns are to be in accordance with Section 6, Table 1 of this Guide.

5 Electrical System

The electrical systems intended for the re-liquefaction unit are to be designed, constructed, tested, certified and installed in accordance with the requirements of this Subsection and Part 4, Chapter 8 and Section 5C-8-10 of the *Steel Vessel Rules*, as applicable.

5.1 Motor Controllers

Means are to be provided to shutdown the compressor from outside the space of the compressor room.

6 Location and Installation

Re-liquefaction units and components are to be located in a space which, dependant on installation arrangements, is to meet the requirements for gas fuel storage, compressor or fuel preparation rooms detailed under Sections 2, 3 and 5 of this Guide.

7 Gas Detection System

The machinery spaces containing the refrigeration equipment are to be fitted with a low oxygen level detection system.

Where the refrigerant being used is considered to be toxic, an alarm system is to be fitted to detect refrigerant concentration exceeding the time-weighted average to which personnel may be repeatedly exposed in the space.

8 Ancillary Systems

Where cooling water is required in refrigeration systems, the cooling water supply is to be as follows:

i) A minimum of two pumps are to be provided, one of which is to be exclusively provided for this duty.

ii) Where seawater is used, each pump is to have at least two sea suction lines, where practicable leading from sea chests, one port and one starboard.

9 Fire Extinguishing Systems

The machinery space containing re-liquefaction equipment is to be provided with fire extinguishing arrangements complying with 5C-8-11/5.1 of the *Steel Vessel Rules.*

10 Surveys during Construction

10.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of re-liquefaction units onboard. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

10.2 Surveys at Manufacturer's Facility

See Section 6, Table 2 of this Guide for certification requirements of re-liquefaction units. Survey requirements for equipment components and packaged units at the manufacturer's facility are summarized in relevant sections of applicable Rules/Guides.

Certification of the complete re-liquefaction unit cannot be accepted based only on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with the ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*.

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair re-liquefaction units or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules*.

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

10.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the re-liquefaction unit and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by the *Steel Vessel Rules*. Pressure tests conducted on Class I piping (see 4-6-1/Table 1 of the *Steel Vessel Rules*) systems should preferably be recorded on test charts for the duration of their tests.

ii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 of the Steel Vessel Rules and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves installed on the unit are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The re-liquefaction unit is to be checked for proper operation in accordance with the ABS approved installation test procedure.

10.4 Surveys During Trials

During the initial gas trials, the re-liquefaction unit is to be confirmed for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the ABS approved testing procedure during gas trials.

TABLE 1
Instrumentation and Alarms in Centralized Control Stations for the Re-liquefaction Unit

Item			*Display*	*Alarm Activated*	*Automatic Shut Down*
BOG Compressor	Flow rate		X	Low	X (Low-Low)
	Driving motors		Running	Stop	
	LO temperature			High	
	LO Pressure			Low	
	Separator level, if fitted		X	High	
	Suction line	Pressure	X	High/Low	X (High-High)
		Temperature	X	High	X (High-High)
	Discharge line	Pressure	X	Low	X (Low-Low)
		Temperature	X	High/Low	X (High-High)
	Gas Detection in cold box			X (30% LEL)	X (60% LEL)
	Cryogenic heat exchanger inlet temperature		X	High	X (High-High)
Refrigerating Compressor	Lubricating oil temperature		X	High	X (High-High)
	Driving motors		Running	Stop	
	Inlet	Pressure	X	Low	X (Low-Low)
		Temperature	X	High/Low	X (High-High)
	Discharge line	Pressure	X	High	X (High-High)
		Temperature	X	High/Low	
	Seal gas pressure		X	Low	X (Low-Low)
	Seal gas leakage expander pressure		X	High	X (High-High)

TABLE 2
Certification of Re-Liquefaction Units

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
MD	*Manufacturer's Documentation* – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*MD*	*DR*	*MT*	*MS*	*FS*
BOG compressors		X	X		X
LNG pumps		X	X		X
Pump and compressor motors (rated at 100 kW and over)		X			X
LNG separators (where fitted)		X	X		X
Refrigerant compressors/expanders		X			X
Cryogenic heat exchanger/cold box (1)		X	X	X	X
Refrigerant/Sea water coolers (1)		X		X	X
Refrigerant accumulators (1)		X		X	X
LNG return to bunker tank piping system		X	X		X
Re-Liquefaction control system		X			X
Gas detection system		X			X
Automatic shutdown and safety system		X			X

Notes:

1 See Appendix 1, Table 1 of this Guide.

SECTION 7 Gas Combustion Units/Thermal Oxidizers

1 General

It is understood that Gas Combustion Unit (GCU) plant is likely to be mainly installed on LNG carriers. However, for non-LNG carriers there may be instances where a GCU is utilized as a secondary means of controlling bunker tank pressure so that, as per 2/6.1 of this Guide, the tank pressure is maintained below the MARVS at all times. Accordingly, as applicable, the GCU is to be available for disposal of boil-off gas that cannot be otherwise utilized during all modes of operations satisfying the requirements of 2/6.1 of this Guide.

A gas combustion unit system will generally contain the following major components:

i) Boil-off gas compressors

ii) Heaters

iii) Automatic master gas valve (see 2/6.2.1 of this Guide) and associated pipe work

iv) Pipe work in way of the safe areas where the GCU is located

v) Gas valve enclosure and venting of the enclosure/hood

vi) Gas burner unit including oil pilot burner and burner management system

vii) Combustion chamber and associated refractory

viii) Forced draft fans, and where fitted, dilution fans

ix) Exhaust trunk from the GCU

1.1 Capacity

i) The capacity of the GCU system is to be based on the requirements of 2/6.1 of this Guide.

ii) The GCU unit is to be capable of operating satisfactorily with a reduced rate of boil-off gas.

iii) The GCU is to be designed to function safely during inerting and purging modes of operations if it is intended that the unit consume the gas displaced from the bunker tanks during these operations.

iv) Documentation to show the control system operational capability over the entire range of operations envisaged is to be submitted.

v) Where the GCU is intended to be used under a free flow mode, design features such as pipe sizing, electrical ignition system and oil pilot burner will be subject to special consideration.

1.2 Plans and Data to be Submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted (see 4-1-1/5 of the *Steel Vessel Rules)* and are to include:

- General arrangement of the GCU compartment, including location of the gas detectors, electrical equipment and lighting
- Ventilation system for the GCU compartment
- Fixed gas detection and alarm systems, and associated shut-off and shutdown systems
- Gas fuel piping systems including details of piping and associated components, design pressures and temperatures
- Burner management system

- Gas compressors
- Gas heaters
- Gas storage pressure vessels
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the GCU compartment
- Electric bonding (earthing) arrangement
- Emergency shutdown arrangements (see Subsection 7/10 of this Guide)
- Forced boil-off gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials.

2 Vapor (BOG) Circuit

2.1 Compressors

Compressors intended to be used for sending the boil-off gas to the GCU may be also used for other duties.

The compressors are to be designed in accordance with 5C-8-16/4.2 of the *Steel Vessel Rules*, except that the compressors are to be capable of being stopped locally and remotely from the control room and from the bridge.

For pressure and temperature measurement and control, see Section 7, Table 1 of this Guide.

2.2 Heaters

The heaters are to be designed, constructed and certified in accordance with Section 4-4-1 of the *Steel Vessel Rules.*

2.3 Gas Fuel Supply to GCU

Gas fuel piping is not to pass through accommodation spaces, service spaces or control stations. Gas fuel piping may pass through or extend into other spaces, provided the arrangements fulfill one of the following:

i) Gas fuel supply piping is to be installed to comply with 5C-8-16/3 of the *Steel Vessel Rules.*

ii) Alternatively, where the fuel gas supply piping system is a single wall design and the associated valves including the burner gas fuel connection at the GCU are located inside a gas tight compartment inside an engine room or other non-hazardous spaces, the arrangements are to be as follows:

a) The pressure in the fuel gas supply line is not to exceed 10 bar (10.2 kgf/cm^2, 145 psi).

b) The pipes are to be of all-welded construction with flange connections only at connections to equipment.

c) This compartment is to have access to the open deck. Where this is not possible, entrance and exits to this compartment from a non-hazardous space are to be through a self-closing gas-tight door.

d) The compartment is to be fitted with a mechanical exhaust ventilation system complying with Subsection 7/8 of this Guide.

e) The compartment is to be fitted with a gas detection system complying with Subsection 7/9 of this Guide.

f) The gas supply pipes are to incorporate a block and bleed valve arrangement and comply with the purging requirements, as referred to in 5C-8-16/3.6 of the *Steel Vessel Rules* and 5/3.1ii) of this Guide.

g) The alarms and shutdowns are to comply with Section 7, Table 1 and Subsection 7/10 of this Guide, respectively.

3 Gas Burner Unit and Burner Management System

i) The gas burner management control philosophy for all modes of operation is to be submitted. This should be accompanied by a safety analysis identifying the modes of failures and shutdown and startup sequences of the system.

ii) Where free flow of BOG to the GCU is intended, the GCU control system is to be designed to safely manage such mode of operation.

iii) Gas nozzles should be fitted in such a way that gas fuel is ignited by the flame of the oil pilot burner described in Subsection 7/4 of this Guide or by an electrical ignition system.

iv) The gas burner is to be fitted with a flame scanner. The flame scanner is to be dual scanners or a scanner of the self-checking type. The flame scanner control should provide for a trial-by-ignition period of not more than ten (10) seconds, during which time gas fuel may be supplied to establish a flame. If the flame is not established within ten (10) seconds, the gas fuel supply to the burner is to be immediately shut off automatically. In the case of flame failure, shut-off is to be achieved within four (4) seconds following flame extinguishment. In the case of failure of the flame scanner, the gas fuel is to be shut off automatically.

v) After flame extinguishment, the gas burner supply piping and combustion chamber is to undergo the purge sequences required by 5C-8-16/5.4 and 5C-8-16/5.6 of the *Steel Vessel Rules.*

vi) The burner management system is to be arranged such that the gas burner cannot be ignited until forced draft and dilution air fan flow is established.

vii) The gas burner unit is to have the capability of automatic operation with manual local controls.

A manually operated shut-off valve is to be fitted on the pipe of each gas burner.

4 Oil Pilot Burner/Electrical Ignition System

Each gas fuel burner unit is to be fitted with an oil pilot burner and/or electrical igniter. The arrangements of the piping system, storage and heating of the fuel for the oil pilot burner are to be in accordance with the applicable requirements of 4-6-4/13 and 4-6-6/7 of the *Steel Vessel Rules.*

The oil pilot burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. The shut-off is to be achieved within six (6) seconds following flame extinguishment. In the case of failure of the flame scanner, the fuel to the oil pilot burner is to be shut off automatically.

5 Forced Draft Fans and Dilution Fans

There is to be a minimum of two forced draft fans for each gas combustion unit. Each fan is to be sized such that the total capacity is not less than 100% of the total capacity required to support the full rated capacity of the GCU with one fan kept in reserve. Forced draft fan motors are to be located in a non-hazardous space. Where operational or structural requirements are such as to make it impossible to install the motors in the non-hazardous space, the following certified safe type motors are to be provided:

- Increased safety type with flameproof enclosure; or
- Pressurized type

There is to be a minimum of two dilution fans provided. Each dilution fan is to be sized such that the total capacity is not less than 100% of the total capacity required to support the full rated capacity of the GCU with one dilution fan kept in reserve. Means are to be provided for measuring and monitoring of air flow in the forced draft and the dilution air flow streams on the discharge side.

6 Combustion Chamber and Associated Refractory

i) The combustion chamber walls are to be protected with insulated fire bricks/refractory and/or a cooling system. Hot surfaces likely to come in contact with the crew during operation are to be suitably guarded or insulated.

ii) The combustion chamber and the refractory are to be designed so that in the event of failure of the dilution fans, the temperature of the casing, or the outer casing where double casing is fitted, does not exceed 230°C (446°F).

iii) Where the casing of the combustion chambers is required to be cooled due to temperature limitation of the material used, this may be achieved by dilution fans, as per Subsection 7/5 of this Guide. Alternative means of cooling will be considered subject to approval of the details.

iv) The design is to take into consideration the expected frequency of operation of the GCU and possible vibrations.

v) The design of the combustion chamber is to be such that the flame length always remains within the extent of the gas combustion unit under all modes of operation.

vi) The combustion chamber is to be of suitable form such as not to present pockets where gas may accumulate.

7 Exhaust Gas Piping

i) Exhaust gas temperature at the discharge from the GCU is not to exceed 535°C (995°F) during any operating mode.

ii) The requirements of 4-6-5/11 of the *Steel Vessel Rules* for exhaust gas piping of internal combustion engines apply.

8 Ventilation

Ventilation arrangements are to comply with 5C-8-16/3 of the *Steel Vessel Rules*, except that where the gas fuel supply pipe is a single wall design, as described in 7/2.3ii) of this Guide, the ventilation of the spaces containing the gas combustion unit is to be in accordance with the following requirements:

i) The gas combustion unit compartment is to be fitted with a mechanical ventilation system having a capacity of at least thirty (30) air changes per hour based on the gross volume of the compartment. The ventilation system is to be provided with at least two fans. Each fan is to be sized such that the total capacity is not less than 100% of the total capacity required with one fan kept in reserve.

ii) Ventilation ducting is to be situated in the gas combustion unit compartment in such a manner as to provide immediate evacuation of the leaked gas from the entire compartment without the possibility of pockets of gas remaining in isolated corners. Either a gas dispersion analysis or a physical smoke test under all possible operating modes is to be conducted in order to prove that the inlets in the ducting are strategically positioned for the effective removal of the leaked gas from the compartment.

iii) The ventilation system in the gas combustion unit compartment is to be separate from those intended for other spaces. The ventilation inlet and discharge are to be respectively from and to a non-hazardous area.

iv) The ventilation fans are to be of non-sparking construction (see 5C-8-12/1.9 of the *Steel Vessel Rules*) and electric motors for these fans are to be located outside of the airflow stream.

9 Gas Detection

Gas detection arrangements are to comply with 5C-8-16/3 of the *Steel Vessel Rules*, except that where the gas fuel supply pipe is a single wall design as described in 7/2.3ii) of this Guide, the gas detection arrangements are to be in accordance with the following requirements:

i) There are to be at least two independent fixed gas detection systems in the gas combustion unit compartment for continuous monitoring of the presence of leaked gas.

ii) Each gas detection system is to be of the self-monitoring type.

iii) In the case that a detection system fault is detected by the self-monitoring functions, the output of the detection system is to be automatically disconnected such that the detector fault will not cause false emergency shutdown.

iv) Each gas detection system is to be so arranged that it provides functional redundancy when either one of the systems fails.

v) Gas detection equipment is to be so designed that it may be readily tested.

Placement of the detectors is critical to the effectiveness of the gas detection. The exact location of the gas detectors is to be determined taking into consideration the sensitivity of gas detectors under the prevailing airflow. Arrangements will be subject to approval for each application based upon the gas dispersion analysis or the physical smoke test.

When the GCU is fitted with a double casing, care is to be exercised to preclude the possibility of gases leaking into and being trapped in pockets of the outer casing. Gas detection probes within the casing and explosion-relief doors on the outer casing are to be provided.

10 Automatic Shutdown System

The monitoring and safety system functions for the GCU gas fuel supply systems are to be provided in accordance with Section 7, Table 1 of this Guide. The alarms are to be provided at the GCU control station. In addition, a summary alarm is to be provided at the navigation bridge. Shutdown arrangements are to comply with 5C-8-16/3 of the *Steel Vessel Rules*, except that where the gas fuel supply pipe is a single wall design as described in 7/2.3ii) of this Guide, the shutdown arrangements are to be as follows:

i) In the event of leakage of gas in the compartment, an alarm is to be given when the gas concentration within the compartment reaches 30% of LEL by volume.

ii) If the gas concentration in the compartment continues to rise to 60% of LEL by volume, the master gas valve is to close automatically, the block and bleed valves are to operate and all non-certified electrical equipment within the compartment is to be isolated from their electrical supply. The ventilation fans are to continue operating until the gas concentration in the compartment has reached a safe level for entry.

iii) In the event of ventilation system failure in the compartment (see Subsection 7/8 of this Guide), an alarm is to be given in the control center and on the bridge, the entire gas combustion unit is to shut down and the gas shut-off valve is to close automatically.

11 Fire Extinguishing System

The compartment described in 7/2.3ii) of this Guide is to be provided with a fixed fire extinguishing system complying with 4-7-2/1.1.1 of the *Steel Vessel Rules.*

12 Surveys During Construction

12.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of gas combustion units onboard. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

12.2 Surveys at Manufacturer's Facility

See Section 7, Table 2 of this Guide for the ABS certification requirements for gas combustion units. Survey requirements for equipment components and packaged units at the manufacturer's facility are summarized in relevant sections of the applicable Rules/Guides.

Certification of the complete gas combustion unit cannot be accepted based only on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*.

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair gas combustion units or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or screwed ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules*.

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

12.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the gas combustion unit and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by the *Steel Vessel Rules*. Pressure tests conducted on Class I piping (see 4-6-1/Table 1 of the *Steel Vessel Rules*) systems should preferably be recorded on test charts for the duration of their tests.

ii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 of the *Steel Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves installed on the unit are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The gas combustion unit is to be checked for proper operation in accordance with the ABS approved installation test procedure.

12.4 Surveys During Trials

During the initial gas trials, the gas combustion unit is to be confirmed for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with the ABS approved testing procedure during gas trials.

TABLE 1
Instrumentation and Alarms in Centralized Control Stations for the GCU

Item		*Display*	*Alarm*	*Automatic Shutdown*
Gas valves enclosure	Gas detection		30% LEL	60% LEL
	BOG flow rate	X	Low	X (Low-Low)
	BOG temperature	X	Low	
	Ventilation fan	Running	Stopped	X (failure)
Gas valve train	LD Compressor pressure	X	High	X (High-High)
	Discharge line temperature	X	High/Low	X (High-High)
Oxidizing Unit and burner casing	Combustion Fan	Running	Stopped/standby auto start	
	Dilution fan	Running	Stopped/standby auto start	
	Flame scanner		X	Failed
	Burner flame		X	Failed
	Furnace temperature	X	High	
	Fire or high temperature in flue gas section	X	High	X (High-High)
	Gas fuel pressure		Low	X (Low-Low)
	Gas fuel temperature		High/Low	X (HH/LL)
Burner Management and Control System	Control power supply		Failed	
	Emergency Shutdown		X	

TABLE 2
Certification of Gas Combustion Units

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
MD	*Manufacturer's Documentation* – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*MD*	*DR*	*MT*	*MS*	*FS*
Gas burner unit including oil pilot burner	X				
Burner management system		X			X
Combustion chamber and associated refractory	X				
Forced draft fans and dilution fans	X				
Exhaust trunk	X				
Combustion chamber cooling water pumps	X				X
Gas detection system		X			X
Automatic shutdown and safety system		X			X

SECTION 8 Dual Fuel Diesel and Single Gas Fuel Engines

1 General

1.1 Condition

The requirements specified in this Section are additional to all other relevant requirements of the *Steel Vessel Rules*.

1.2 Application

1.2.1 General

The requirements of this Section are applicable to dual fuel diesel engines and single gas fuel engines. Low pressure gas engines may apply the double wall or single wall fuel gas piping concept detailed under Subsections 2/5 and 5/3 of this Guide. The engine compartment arrangements for the single wall fuel gas piping concept detailed under Subsection 8/2 of this Guide may only be applied to dual fuel or single gas fuel engines with low pressure, (10 bar or less) fuel gas supply systems. Dual fuel or single gas fuel engines with high pressure gas supply systems are to apply the double wall fuel gas supply concept.

Machinery spaces applying the double wall fuel gas piping concept are to be arranged in accordance with 2/2.6 of this Guide and fuel gas supply and safety systems are to be arranged in accordance with Section 5 of this Guide.

1.2.2 Gas Valve Unit (GVU) Room

Where the GVU is located in a dedicated compartment, the safety principles and arrangements of that compartment (i.e., the forced ventilation, gas detection and automatic gas supply shut-off arrangements) are to be the same as those required for an engine compartment applying the single wall fuel gas piping concept detailed in 8/2.2 through to 8/2.7 of this Guide.

1.3 Plans and Data to be Submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted (see 4-1-1/5 of the *Steel Vessel Rules)* and are to include:

- General arrangement of engine compartment(s), including location of the gas detectors, electrical equipment and lighting
- Ventilation system for engine compartment(s)
- Fixed gas detection and alarm systems, and associated shut-off and shutdown systems
- Gas fuel piping system including details of pipes and associated components, design pressures and temperatures
- Gas compressors
- Gas heaters
- Gas storage pressure vessels
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of the electrical equipment in the engine compartment(s)
- Electric bonding (earthing) arrangement

- Arrangement and details of crankcase protection (see 8/3.3 of this Guide)
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the dual fuel diesel or single gas fuel engines (see 8/3.4 of this Guide) for each engine type
- Arrangement of explosion protection for air inlet manifolds and for exhaust manifolds including design basis and size calculations (see 8/3.2.4 and 8/3.5.1 of this Guide)
- Emergency shutdown arrangements
- Operating and maintenance instruction manuals
- Forced boil-off or LNG vaporization gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials

2 Arrangement of Engine Compartments with Single Wall Fuel Gas Piping

2.1 General

The propulsion and auxiliary arrangements for single wall fuel gas piping engine compartments are to comply with Subsection 2/5 of this Guide. Fuel gas supply arrangements are to comply with Section 5 of this Guide.

2.2 Ventilation

2.2.1 Capacity

Each single wall fuel gas piping engine compartment is to be fitted with at least two mechanical ventilation fans with a total capacity of at least 30 air changes per hour based on the gross volume of the compartment, without taking into consideration the combustion air required for the engine(s) in the compartment.

If one fan is out of service, the capacity of the remaining ventilation fan(s) is to be not less than 100% of the total required.

2.2.2 Ducting

Ventilation ducting is to be situated in the single wall fuel gas piping engine compartment in such a manner that immediate evacuation of the leaked gas from the entire compartment occurs without the possibility of pockets of gas remaining in isolated corners.

Either a gas dispersion analysis or a physical smoke test under the possible operating modes is to be conducted in order to prove that the inlets in the ducting are strategically positioned for the effective removal of the leaked gas from the compartment.

2.2.3 System Requirements

The ventilation system in each single wall fuel gas piping engine compartment is to be separated from those intended for other spaces including other single wall fuel gas piping engine compartments.

The ventilation inlet and discharge are to be respectively from and to a non-hazardous area.

The ventilation fans are to be of non-sparking construction (see 5C-8-12/1.9 of the *Steel Vessel Rules*) and electric motors for these fans are to be located outside of the airflow stream.

The ventilation system is to be always in operation when there is gas fuel in the piping while in normal operation, as well as in purging operation prior to maintenance works.

2.3 Gas Detection

2.3.1 System Requirements

There are to be at least two independent fixed gas detection systems in each single wall fuel gas piping engine compartment for continuous monitoring of the presence of leaked gas.

Each gas detection system is to comply with the following requirements:

i) Gas detection system is to be of the self-monitoring type.

ii) In the case that a detection system fault is detected by the self-monitoring functions, the output of the detection system is to be automatically disconnected such that the detector fault will not cause false emergency shutdown as per Subsection 8/4 of this Guide.

iii) The gas detection system is to be so arranged that it provides functional redundancy when either one of the systems fails.

iv) The gas detection equipment is to be so designed that it may be readily tested.

The gas detection system is always to be in operation when there is gas fuel in the piping while in normal operation, as well as in purging operation prior to maintenance works.

2.3.2 Installation

Placement of the detectors is critical to the effectiveness of the gas detection system.

The exact location of the gas detectors is to be determined taking into consideration the sensitivity of gas detectors under the prevailing airflow.

Arrangements will be subject to approval for each application based upon the gas dispersion analysis or the physical smoke test, as required by 8/2.2.2 of this Guide.

2.3.3 Periodic Maintenance and Testing

The gas detection systems and the associated emergency shutdown systems are to be tested and maintained to verify their reliability during working conditions and are to be recalibrated at regular intervals in accordance with the manufacturer's recommendations given in the maintenance and instruction manual.

Tests and maintenance procedures are to be documented and kept onboard for the crews' use (see Subsection 1/6 of this Guide).

Records of the maintenance and the testing are to be maintained onboard. The records will be subject to ABS Annual Survey (see Subsection 8/5 of this Guide).

2.4 Electrical Equipment

Electrical equipment, which may create an electrical spark, such as magnetic contactors, circuit breakers, motor starters, switchboards, slip rings or commutators, is to be located outside of the single wall fuel gas piping compartment.

Electrical equipment in the single wall fuel gas piping engine compartment, which is intended to be operational after the engines have been shut down due to a gas leakage, is to be of the certified safe type.

2.5 Access and Means of Escape

The access to the single wall fuel gas piping engine compartment is to be provided with a self-closing gastight door with alarm that would be initiated when the door remains open for more than 60 seconds.

Two means of escape are to be provided for machinery spaces of category A, as required by SOLAS 1974, as amended.

2.6 Fire Protection and Fire Extinguishing System

Fire protection and extinguishing systems are to comply with the requirements of Part 4, Chapter 7, and Section 5C-8-11 of the *Steel Vessel Rules* and SOLAS Chapter II-2.

2.7 Explosion Protection

Arrangements are to be such that effects of an explosion in a single wall fuel gas piping engine compartment can be contained or vented and will not cause damage to any space other than that in which the incident occurs nor render machinery or equipment in other spaces inoperable.

3 Dual Fuel Diesel and Single Gas Fuel Engines

3.1 General

i) The requirements of this Subsection are applicable to all gas fueled engines. The requirements may be applied to dual fuel diesel and single gas fuel engines operating according to the lean burn Otto cycle with pilot injection or spark ignition, dual fuel diesel and single gas fuel engines where the gas is mixed with air before the turbocharger (so called 'Pre-mixed engines') and dual fuel engines operating high pressure direct injection gas systems. Additional requirements specific to dual fuel diesel, single gas fuel and 'Pre-mixed' gas engines are given under 8/3.8 through 8/3.10 of this Guide.

ii) Gas fueled engines are to be capable of operating with possible variations of the Methane Number and Heat Value and the extent of those permitted variations are to be declared by the manufacturer and detailed in the operation and maintenance manuals required by Subsection 1/6 of this Guide.

iii) Gas engine components or systems containing or likely to contain gas are to be designed to the following general principles:

a) It should be demonstrated that there is no risk of explosion; or

b) The consequences of a possible explosion are acceptable and can be contained without any detrimental effect by either the inherent strength of the component or by safety pressure relief mechanisms. Discharges from safety devices are to be led to a non-hazardous area in the open air, or to an alternative acceptable location to safely dispose of the gas, through a flame arrester. The explosion event is not to interrupt the safe operation of the engine unless other safety measures allow the shutdown of the affected engine.

iv) The transient response characteristics of dual fuel and single fuel gas engines are to be appropriate for the intended application. Dual fuel diesel engines (gas mode) and single gas fuel engines driving generators are to meet the transient response requirements of 4-2-1/7.5 of the *Steel Vessel Rules,* however consideration may be given to the use of alternative performance criteria such as ISO 8528 where appropriately matched with the vessel power management system.

3.2 Gas Fuel and Air Supply

3.2.1 Gas Fuel Supply

Fuel gas piping, arrangements and fuel gas supply systems are to be in compliance with Subsections 2/4, 2/5, and 5/3 of this Guide; additional requirements for high pressure piping systems are given under 2/4.2, 5/3.1iii), 5/3.2i), and 5/3.2iii) of this Guide.

3.2.2 Starting Air

Where air is introduced directly into the cylinders for starting purposes, the starting air branch pipes to each cylinder are to be provided with flame arresters.

3.2.3 Air Intakes

Where air intakes are located inside the engine compartment, these are to be situated as far apart as practicable from the gas fuel supply pipe such that, in the event of a gas leak, the risk of the gas entering the intake is minimized.

Engine air intakes located outside the engine compartment are to be lead from a non-hazardous area at least 1.5 m away from the boundaries of any hazardous area.

3.2.4 Air Inlet Manifolds

An explosion relief valve or other appropriate protection against explosion is to be provided on the air inlet manifolds.

Protective devices that require dismantling or replacement prior to continued engine operation are not to be installed on single engine main propulsion installations.

The arrangement and location of the protection devices is to be such as to minimize the dangers to personnel and equipment from operation of the protective device.

Alternatively, documentation may be submitted for consideration showing that the system has sufficient strength to withstand a worst-case explosion, or that the assumed possible gas explosion in the air inlet manifold is not a plausible scenario due to the inherent design characteristics.

3.3 Protection of Crankcase

3.3.1 Explosion Relief Valves

The explosion relief valves are to be in accordance with 4-2-1/7.1 of the *Steel Vessel Rules*. High pressure dual fuel engines are to be fitted with explosion relief valves in way of each crank throw.

3.3.2 Ventilation

To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

The crankcase is to be continuously vented and arrangements are to be made so that any blow-by gas may readily reach the vent. However fresh air ventilation of the crankcase, and any arrangement which could produce a flow of external air within the crankcase, is not permitted.

Crankcase ventilation pipes are to be as small as practicable, in accordance with manufacturers recommendations, to minimise the inrush of air after a crankcase explosion. If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes for instance), the vacuum in the crankcase is not to exceed 2.5×10^{-4} N/mm^2 (2.5 mbar).

The outlet of the vent line is to be led to a non-hazardous area in the open air, or to an alternative acceptable location to safely dispose of the gas, through a flame arrester.

3.3.3 Inerting

A means is to be provided for inerting and aerating the crankcase before opening the crankcase doors for maintenance.

The crankcase is to be fitted with a gas sampling connection in order to allow the measurement of the gas concentration by portable gas detection equipment.

3.3.4 Instrumentation

Instrumentation installed inside the crankcase is to be of the certified safe type.

The crankcase is to be protected by an oil mist detector.

3.3.5 Warning Notice

The warning notice required by 4-2-1/7.13.1 of the *Steel Vessel Rules* is to include a caution that the crankcase is not to be opened until adequate precautions have been taken to determine that no gas remains trapped in the crankcase.

3.4 Protection against Explosion

In addition to the requirements in 4-2-1/7 of the *Steel Vessel Rules,* a Failure Modes and Effects Analysis (FMEA) is to be carried out by the engine manufacturer in order to determine necessary additional means of safeguards to address the hazard associated with the use of gas as a fuel.

The analysis is to identify all plausible scenarios of gas leakage and the resulting possible explosion. Then the analysis is to identify necessary means to control the identified explosion hazards.

The FMEA is to be submitted to ABS for approval.

3.5 Engine Exhaust System

3.5.1 Explosion Protection

Explosion relief valves or other appropriate protection against explosion, such as burst discs of an approved type, are to be provided on the exhaust manifolds.

Protective devices that require dismantling or replacement prior to continued engine operation are not to be installed on single engine main propulsion installations.

The arrangement and location of the protective devices is to minimize the dangers to personnel and equipment from operation of the protective device.

Alternatively, documentation showing that the system has sufficient strength to withstand a worst-case explosion may be submitted for consideration.

3.5.2 Installation

The exhaust gas pipes from dual fuel diesel or single gas fuel engines are not to be connected to the exhaust pipes of other engines or systems.

Installation arrangements are to have the exhaust pipes sloped upwards after the turbocharger in order to avoid formation of gas pockets.

3.5.3 Purging

A manual purging connection is to be provided.

In the event that a single gas fuel engine stops or a dual fuel engine stops during the gas fuel mode of operation, the exhaust system is to be purged for a sufficient time, to discharge the gas that may be present. The purge time is to be based on a minimum of four air changes of the volume of the exhaust system.

3.6 Auxiliary System Venting

Auxiliary system circuits, such as cooling water or dry/wet sump lubricating oil systems, that are likely to contain gas in normal conditions or abnormal conditions as a result of a component failure (refer to FMEA) are to be arranged in accordance with the following requirements:

i) Auxiliary system circuits are to be arranged to avoid cross connection between engine systems and to avoid the migration of gas to non-hazardous areas;

ii) Vent pipes are to be independent and to be led to a safe location external to the machinery space and to be fitted with a flame arrester.

3.7 Control and Monitoring Systems

i) The last gas valve prior to the dual fuel diesel or single gas fuel engine is to be controlled by the engine control system.

Where additional features such as hydraulic control circuits or sealing systems form part of the systems for safe operation of the gas valves and engine, the loss of actuating medium in these systems is to cause automatic shutdown of the fuel gas supply system.

ii) The combustion of the in-cylinder gas mixture is to be monitored on an individual cylinder basis; this can be achieved by the use of exhaust gas or combustion chamber temperature monitoring, cylinder combustion pressure and for Otto cycle engines by the use of knock sensors.

iii) Indicators are to be provided at the engine control station, navigation bridge and maneuvering platform to indicate the mode (i.e., gas or diesel) and operation of dual fuel diesel engines and to indicate operation in the case of single gas fuel engines.

iv) Unless the FMEA proves otherwise, the monitoring and safety system functions for the dual fuel diesel or single gas fuel engines are to be provided in accordance with Section 8, Table 1 of this Guide and for the engine fuel gas supply systems in accordance with Section 5, Table 2 of this Guide, as applicable.

v) The alarms required by Section 8, Table 1 are to be provided at the engine control station. In addition, a summary alarm is to be provided at the navigation bridge.

3.8 Dual Fuel Diesel Engines

i) Dual fuel diesel engines are to be of the compression-ignition, dual fuel type arranged to use either oil fuel or gas fuel for the main fuel charge and with pilot oil fuel for ignition. The amount of pilot oil fuel fed to each cylinder is to be sufficient to provide a positive ignition of the gas mixture. Gas injection is not to be possible without a corresponding pilot oil injection or controlled ignition of the main fuel charge.

ii) The engines are to be arranged for easy changeover to either fuel; rapid (emergency) changeover is only required from gas fuel to diesel fuel mode. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to propulsion or power supply.

iii) Changeover to and from gas fuel operation is only to be possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing. On power reduction the changeover to oil fuel is to be automatic. The changeover process itself to and from gas operation is to be automatic but manually activated shutdown is to be possible in all cases.

iv) Only oil fuel is to be used when starting the engine and prior to a normal stop. On normal stop as well as emergency shutdown, gas fuel supply is to be shut off not later than simultaneously with the oil fuel. It is not to be possible to shut off the supply pilot fuel without first, or simultaneously, closing the gas supply to each cylinder or to the complete engine. In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.9 Single Gas Fuel Engines

i) Single gas fuel engines are to be arranged with in-cylinder pre-chamber and high voltage spark ignition or micro-pilot oil fuel injection for ignition of the main gas fuel charge.

ii) The starting sequence is to be such that fuel gas is not admitted to the cylinders until spark ignition or micro-pilot ignition systems are activated and the engine has reached an engine and application specific minimum rotational speed.

iii) If spark ignition or micro-pilot has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve, the gas supply valve is to be automatically shut-off and the starting sequence terminated. Any unburned gas mixture is to be cleared from the exhaust system.

iv) On normal stop as well as emergency shutdown, the gas fuel supply is to be shut off not later than simultaneously with the spark ignition or micro-pilot. It is not to be possible to shut off the ignition systems without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

v) The shut down sequence is to be such that the engine gas supply valve closes at idle speed and that the spark ignition or micro-pilot system is kept active until the engine is at standstill.

3.10 'Pre-Mixed' Gas Fuel Engines

i) For gas fueled engine types where the gas is mixed with air before the turbocharger (so called 'Pre-mixed system'), the engine components containing the gas/air mixture, such as inlet manifold, turbo-charger, charge air cooler, etc., are to be considered as parts of the fuel gas supply system.

Such engine types are to be installed in a machinery space complying with the requirements for single wall gas fuel piping detailed under Subsection 8/2 of this Guide. Alternative arrangements may be considered on a case by case basis.

ii) In addition to the requirements for engine component pressure tests given under 4-2-1/Table 2 of the *Steel Vessel Rules*, engine components containing gas/air mixtures during normal operation such as inlet manifolds, charge air coolers, charge air cooler casings, turbocharger compressor casings, etc., are to be pressure tested at 1.5 times the maximum working pressure of the component. These tests are to be carried out by the manufacturer whose certificate of test will be acceptable.

4 Emergency Shutdown

4.1 Automatic Shut Off of Gas Fuel Supply

The monitoring and safety system functions for gas fuel supply systems are to be provided in accordance with Section 5, Table 2 of this Guide.

4.2 Emergency Shutdown of the Engine Compartment

When a gas leakage is detected in a dual fuel diesel or single gas fuel engine compartment, and before the gas concentration detected reaches 60% of the LEL, all the electrical equipment inside the compartment, other than certified safe type, is to be automatically isolated from its electrical supply and all the engines in that compartment are to be shut down. See Section 5, Table 2 of this Guide.

4.3 Power Management

Where dual fuel diesel or single gas fuel engines are used for electric propulsion power generation, a power management system is to be provided to safeguard the power supply system from overloading, which may occur due to the sudden shutdown of an engine compartment.

5 Surveys During Construction

5.1 General

This Subsection pertains to surveys during fabrication at manufacturer's facility and installation and testing of dual fuel diesel engines and single gas fuel engines onboard gas fueled ships. For surveys at the manufacturer's facility, the scope of the Survey will be confined to only those items that are supplied by the manufacturer.

5.2 Surveys at Manufacturer's Facility

See Section 8, Table 2 of this Guide for the ABS certification requirements for dual fuel diesel engines and single gas fuel engines. Survey requirements for equipment components and packaged units at the manufacturer's facility are summarized in relevant sections of applicable Rules/Guides.

Certification of complete dual fuel diesel engines and single gas fuel engines cannot be accepted based only on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1).*

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair dual fuel diesel engines or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules.*

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

5.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the dual fuel diesel engines or single gas fuel engines and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by the *Steel Vessel Rules*. Pressure tests conducted on Class I piping (see 4-6-1/Table 1 of the *Steel Vessel Rules*) systems should preferably be recorded on test charts for the duration of their tests.

ii) Electrical wiring and connections are to be in accordance with Part 4 of the *Steel Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves installed on the unit are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The dual fuel diesel engine or single gas fuel engine is to be checked for proper operation in accordance with the ABS approved installation test procedure.

5.4 Surveys During Trials

During the initial gas trials, the dual fuel diesel engine or single gas fuel engine is to be confirmed for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with ABS approved testing procedure during sea/gas trials. The dual fuel diesel engine or single gas fuel engine is to be run whilst the vessel is underway at sea and the propulsion system operating over its full range of power.

TABLE 1
Monitoring and Safety System Functions for Dual Fuel Diesel and Single Gas Fuel Engines

Monitored Parameters	*Alarm*	*Automatic Activation of the Block and Bleed Valves*	*Automatic Switching Over to Oil Fuel Mode* [(1)]	*Engine Shutdown*
Gas fuel supply systems – malfunction	X	X	X	
Pilot oil fuel injection or spark ignition systems – malfunction	X	X	X	
Exhaust gas after each cylinder, temperature – high	X	X	X	
Exhaust gas after each cylinder, deviation from average, temperature – high	X	X	X	
Cylinder pressure or ignition – failure, including misfire and knocking	X	X	X	
Oil mist in crankcase, mist concentration	X	X		X
Engine stops – any cause	X	X		
Failure of the control-actuating medium of the block and bleed valves	X	X	X	
Failure of the control-actuating medium of the gas valves, as applicable	X	X	X	
Failure of the gas valve oil sealing system, as applicable	X	X	X	

Notes:

1 Duel Fuel Diesel engines only

TABLE 2
Certification of Dual Fuel Diesel and Single Gas Fuel Engines

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
MD	*Manufacturer's Documentation* – Manufacturer should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*MD*	*DR*	*MT*	*MS*	*FS*
Gas valve enclosure		X			X
Gas storage pressure vessels (1)					
Fuel gas piping system in engine room incl. block and bleed valves		X			X
Dual fuel diesel or single gas fuel engine (3)		X	X	X	X
Crankcase, inlet manifold and exhaust manifold explosion protection systems (3)					X
Engine compartment ventilation system		X(2)			
Fuel gas piping ventilation system		X(2)			
Control system		X			X
Engine compartment fire detection system		X			X
Engine compartment fire extinguishing system		X			X
Engine compartment explosion protection arrangements		X			X
Gas detection system		X			X
Automatic shutdown and safety systems		X			X

Notes:

1 See Appendix 1, Table 1 of this Guide.

2 Design verification only.

3 See Section 4-2-1 of the *Steel Vessel Rules*. See also additional requirements for 'Pre-mixed' gas engine components under 8/3.10ii) of this Guide.

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SECTION 9 Dual Fuel Gas Turbine Propulsion System

1 General

1.1 Application

The requirements in this Section are applicable to natural gas and liquid fuel propulsion gas turbine and piping systems based on the following concepts:

i) The dual fuel gas turbine is fitted in a gas-tight enclosure to minimize the risk associated with gas leakage, fire and any other hazards associated with the use of gas and oil fuel.

ii) The entire gas turbine enclosure is to encase the gas turbine(s) and, as a minimum, the associated equipment necessary for starting and continuous operation. Even though the internal space of the enclosure will contain the high pressure gas supply line, integrity is achieved by the required ventilation system, gas detection systems and associated safety shutdown systems, as well as the fire protection and firefighting systems which are equivalent to a localized protected space, as per Chapter II-2 of SOLAS 1974 as amended. Because this enclosure is considered to encase the entire gas turbine with all the necessary additional protection required by the IGC code and Section 5C-8-16 of the *Steel Vessel Rules*.

iii) Dual fuel gas turbines intended for use as prime movers for propulsion (mechanical drive or generator drive), electric power generation and auxiliary services equipment are to be designed, constructed, tested, certified and installed in accordance with the requirements of this Section, in addition to the *Rules*.

iv) Piping systems serving gas turbine engines, such as fuel oil, gas fuel, lubricating oil, starting air/hydraulic and exhaust gas systems, are to be in compliance with Sections 4-6-5 and 5C-8-16 of the *Steel Vessel Rules*.

v) Gas turbine(s) used for propulsion are to be designed to enable maneuvering from stop to full ahead and vice-versa without a delay using either gas or liquid fuel. When changeover of fuel is activated during all modes of operation, this should be smooth, without interruptions to the power, as far as practicable.

2 Arrangement of Dual Fuel Gas Turbines

2.1 General

The dual fuel gas turbine power plant arrangement may consist of the dual fuel gas turbine as the prime mover driving rotating equipment, such as generator(s), a gearbox, couplings and propulsion shafting, together with associated equipment that may include; a starter, governor and fuel control, enclosure, piping, and auxiliary systems and exhaust gas/waste heat recovery boilers and instrumentation, monitoring and control systems.

2.1.1

Where the dual fuel gas turbine prime mover and the minimum associated equipment necessary for its operation are fitted in an enclosure, this enclosure is to be of minimum size, as far as practicable without compromising the accessibility, maintainability and operability. This enclosure is to be provided with effective ventilation and gas detection systems.

3 General

3.1 Gas Turbine Propulsion System

i) Both liquid fuel and boil-off gas may be used simultaneously.

ii) Gas turbines are to be capable of operation with a range of gas composition mixtures reflective of that likely to be encountered during service.

4 Plans and Data to be Submitted

In addition to the plans and particulars required as per 4-2-3/1.5 of the *Steel Vessel Rules*, the following plans and particulars for dual fuel applications are also to be submitted:

- General arrangements showing location of the power plant and individual items of machinery, such as the gas turbine units(s), exhaust gas boilers, turbo generators(s), diesel generators and other associated equipment (such as the gas combustion units(s), re-liquefaction plant and the gas supply line to the consumers)
- General arrangement of the gas turbine engine enclosure, including location of the gas detectors, electrical equipment, lighting and ventilation, etc.
- Gas fuel manifold arrangement and details, including design pressure and temperatures, operational schematics, material specifications and bill of materials
- Enclosure, including size and dimensions, gas tightness, entrance and exits and other openings, such as ventilation intakes and outlets
- Ventilation systems details, including inlet cooling air calculations for the enclosure
- Fixed gas detection and alarm systems, and associated shut-off and shutdown systems
- Gas fuel piping systems, including details of pipes and associated components, design pressures and temperatures, operational schematics, flange/joints loadings, material specifications and bill of materials
- Gas compressors, with details such as type, size, mechanical components, materials used and details of alarms, indication, shutdown and control system.
- Mist separators
- Vaporizers
- Heat exchangers, including BOG heaters, BOG coolers, etc.
- Pressure vessels, including recovery tanks, etc.
- Descriptions and schematic diagrams for control and monitoring systems, including set points for abnormal conditions together with control logic for the entire power plant and individual items in the systems.
- Details of the electrical equipment in the turbine engine enclosure
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the dual fuel gas turbine
- Electric bonding (earthing) arrangement
- Emergency shutdown arrangements (see 9/13.3 of this Guide)
- Operating and maintenance instructions manuals
- Schematic diagram showing gas and fuel supply lines from the source to the consumers for the entire power plant system
- Forced boil-off and LNG vaporization gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials

5 Materials of Construction

i) Materials entering into the construction of gas turbine engine propulsion systems are to comply with the requirements of Chapter 3 of the ABS *Rules for Materials and Welding (Part 2)* and 4-2-3/3 and 5C-8-6/2 of the *Steel Vessel Rules*.

ii) Materials subjected to low temperatures are to comply with the requirements of Sections 2-3-2 and 2-3-13 of the ABS *Rules for Materials and Welding (Part 2)*.

6 Dual Fuel Propulsion Gas Turbines

6.1 General

i) Gas turbines as components are to comply with the requirements of Section 4-2-3 and 5C-8-16/8 of the *Steel Vessel Rules*.

ii) The dual fuel gas turbine is to be fitted within an acoustic gas-tight enclosure providing effective gas detection, fire protection, ventilation and cooling, as per the requirements given in this Section. Alternatively, the gas turbines may be located in a space containing other machinery, provided that the installation arrangements of the gas turbine are in compliance with 9/2.1.2 of this Guide.

iii) The design of the gas fuel manifold and nozzles is to provide complete venting upon shutdown to prevent gas leakage and fire, unless the manufacturer demonstrates to the satisfaction of ABS by experience with similar installations or test data that the gas manifold evacuation is not necessary

iv) The design of the gas turbine is also to provide positive means of evacuating all unburned gas from the combustor, turbine and exhaust collector.

6.2 Gas Fuel Manifold

i) The gas fuel manifold fitted on the engine is to be designed for the maximum design pressure, temperatures, thermal growth, dominant resonances and vibrations that may be experienced after installation.

ii) The installation arrangements of the gas fuel manifold, piping and pipe fittings, joints, etc., are to provide the necessary flexibility to accommodate the oscillating movements of the engine without risk of fatigue failure in the piping connections to the engine.

iii) The gas fuel manifold and piping configuration is to be approved and certified by ABS as per the engine manufacturer's design.

iv) All metallic gas fuel manifold/lines are to be of corrosion resistant steel.

v) All mechanical joints are to be of welded type, as far as practicable, and designed to prevent accidental leakage onto hot engine parts and any other source of ignition. Shielding or other means are to be provided to prevent this.

vi) Non-welded connections will be subject to special consideration.

6.3 Gas Fuel Control Valves

i) Actuation is to be from the machinery control room, both at local and remote locations. Where the source of power to the actuator is electrical, the electrical source should be from the emergency power supply or provided with a backup power supply. All shut-off valves are to close rapidly and completely. All shut-off valves are to be of fail-safe type.

ii) All internal elements of the gas fuel system are to be resistant to corrosion.

7 Gas Turbine Enclosure

7.1 General

i) The gas turbine is to be resiliently or rigidly mounted to a structural foundation within an acoustically and thermally insulated enclosure.

ii) The enclosure design is to maintain all components within their safe working temperature under expected operating conditions to minimize the risk of fire from sources of ignition such as hot spots. This is to prevent damage by heat to the adjacent components by providing effective fire prevention, ventilation and cooling.

7.2 Construction

i) Unless the fuel gas piping up to the gas turbine inlet is of double wall design and in full compliance with Section 5C-8-16 of the *Steel Vessel Rules*, the enclosure is to be gas-tight.

ii) The enclosure is to be of steel construction and designed for removal of major components, such as the generator, reduction gear (where fitted) or gas turbine. The manufacturer is to identify maintenance access envelopes for removal of the above major components.

iii) The enclosure is to maintain structural integrity with the access panels removed.

iv) The enclosure is to be arranged such that if the removal of the access panels and doors while the turbine may be operating causes an unsafe condition, then the access panels and doors are to be provided with interlocks or other means to automatically secure the turbine prior to removal of the access panel.

v) The enclosure, including enclosure cooling ducting, is to be designed as airtight, as required by 9/7.2i) of this Guide, and capable of withstanding the pulsation pressure that emanates from the gas turbine during operation.

vi) The enclosure is to be sized to allow for maximum deflection of the mounted equipment without the equipment striking the enclosure.

vii) Where one enclosure serves two gas turbines, an internal wall is to be provided.

viii) Where a gas turbine is located inside a gas-tight acoustic enclosure, the internal space of the enclosure is considered to be a Category A machinery space, hence, the separation of this space from the adjoining spaces and fire protection of this space is to be in accordance with the applicable requirements in the *Steel Vessel Rules* and SOLAS 1974, as amended.

ix) Each enclosure is to form a gas-tight seal at all piping, ducting and electrical connections that penetrate the enclosure walls.

x) A suitable means of inspection such as a glass inspection window or a CCTV system is to be installed in the enclosure such that it is possible for operators to observe the engine and its major components, including gearbox accessories, intake, piping and instrumentation, during operation looking for evidence of fluid leakage, fire, smoke or other abnormal operating conditions without entering the enclosure.

xi) The inspection windows may be installed in the enclosure access doors where the door location meets the internal viewing requirements. Where the enclosure is considered a category A machinery space, the windows are to be of the same fire rating as the bulkhead in which they are installed.

xii) Interior lighting is to be provided in the enclosure to allow a clear view of all components from the inspection windows. Enclosure access doors are to be provided in locations that will allow maintenance personnel easy access to both sides of all major components within the enclosure. Access to the air intake of the engine is to be provided.

xiii) The enclosure is to be sound and thermally insulated.

xiv) Thermal and acoustic insulating material is to be provided with protection to minimize the possibility of absorption of oils, grease and moisture.

xv) Protective metal guards are to be provided to avoid wear or puncture of exposed insulated areas subject to mechanical abrasion.

xvi) A temperature sensor is to be placed inside and adjacent to each gas turbine engine compartment entry to indicate compartment internal temperature.

xvii) A placard stating necessary safety precautions to be taken by personnel is to be provided at the engine space access if entrance to the engine compartment is required after gas turbine engine shutdown.

xviii) A hazard label is to be placed on or adjacent to each access to the enclosure and internal to the enclosure, located so as to be visible upon entry, and is to provide appropriate personnel warnings.

xix) Each base and enclosure is to be provided with floor drains to prevent the accumulation of fluids. The floor drains are to be situated to negate any effect of base and enclosure installation rake on drainage. Fluid drains are to be arranged so as to prevent migration of fluids to the gas turbine exhaust area and hot section.

xx) Means are to be provided for drainage of the enclosure space in a safe manner. Where an enclosure is fitted with a water-based fire protection system, a fixed permanently installed bilge system for the enclosure is to be provided.

8 Enclosure Air Intakes and Exhaust System

8.1 General

i) The design and arrangement of the system is to minimize pressure drop and back pressure, turbulence, noise and ingestion of water or spray.

ii) The systems are to be designed and supported to prevent stress loading of the flexible connections and expansion joints.

iii) The design is to also minimize the transfer of vibration to the supporting structure and withstand stresses induced by weight, thermal expansion, engine vibration, working of the vessel and pressure thrust caused by the exhaust gas and intake air.

iv) The perforated plate interior surface of the exhaust ducts is to be held in place using retainer clips welded to the duct structure.

v) All systems are to be designed to withstand dynamic forces encountered by motion of the vessel at sea, as specified in 4-1-1/7.9 and 4-1-1/Table 7 of the *Steel Vessel Rules*.

vi) All sections of systems exposed to the weather are to be self-supporting without any wire, rope, etc.

vii) Air intake and exhaust ducting is to be of welded construction as far as practicable and is to be in accordance with the requirements of Sections 2-4-2 and 2-4-4 of the ABS *Rules for Materials and Welding (Part 2)*.

viii) Cover plates for maintenance and access openings are to be bolted on and are to have handles or other means to facilitate their removal. All cover plates are to open outwards.

ix) Flexible metal hoses or expansion joints of an approved type are to be used at the engine air intakes, as well as at the exhaust outlets and elsewhere, as required for flexibility. The flexible joints are to be provided with internal flow liners. The method of connecting these flexible metal hoses or expansion joints to the gas turbines is to be in accordance with builders' and manufacturers' recommendations.

x) Adjustments for misalignment through the use of expansion joints are not permitted.

xi) Provisions are to be made to allow for differences in expansion between the stack and the uptakes.

xii) Uptakes are to be fitted with expansion joints to allow for thermal expansion and to prevent overstressing of the uptake plating and vessel structure.

xiii) The systems, including air filters, moisture separators, intake silencers, exhaust mufflers, water traps and valves, are not to impose a pressure drop or back pressure which will exceed the acceptable values as specified in the engine specifications.

xiv) The internal surface of ducting is to be as smooth as practicable. Strengthening members are to be on the external surface of the duct.

xv) Where ducts are large enough to permit entry of personnel for inspection and maintenance access, they are to be provided with removable cover plates and grab rods or access hatch.

xvi) Gas passages are to be free of internal obstruction, except that grab rods and ladder rungs are to be installed for inspection and maintenance.

xvii) Ducts too small to permit entry of personnel are to be provided with openings and removable cover plates at the ends of horizontally installed sections for cleanout.

xviii) The systems are to be provided with drains at the low points. Collected drainage is to be led overboard, if environmentally safe and possible, or connected to a drain system.

xix) The intakes, cooling air and exhaust duct openings are to be located above the waterline and positioned to minimize the probability of raw water entering the air inlet, cooling air and exhaust systems. These are also to be located to minimize the probability of sea spray being entrained in the air flow and carried into air inlets and cooling ducts.

xx) Air intake, cooling air and exhaust ducts are to be positioned and designed to minimize the probability that exhaust gases from any engine or any other source are drawn into the air inlet or cooling air duct of gas turbine.

xxi) The exhaust gases outlet from the gas turbine are to be clear of any ventilation system inlets.

8.2 Combustion Air Intake System

8.2.1 General

i) The air intake system is to consist of all devices from the weather to the front face of the gas turbine, and is to be in accordance with the requirements of this Section and 4-2-3/11.3 and 5C-8-16/10.3 of the *Steel Vessel Rules*.

ii) The engine manufacturer is to provide the following performance requirements for compressor inlet airflow:

- Inlet pressure loss (max.), in mm (inches) of H_2O
- Air compressor inlet flow distortion (max.), in percent. Alternatively, manufacturer is to approve the design of the aerodynamics of intake.
- Air compressor pre-swirl angle (max.), in degrees
- Air compressor counter-swirl angle (max.), in degrees
- Total pressure fluctuation (max.), in mm (inches) of H_2O
- Turbulence (max.) in percent, where turbulence is defined as the root mean square of the fluctuating pressure level between 0.5 and 700 Hz as measured by a fast response pressure transducer divided by the steady state (average) total pressure

iii) Each unit of installed equipment requiring combustion air is to have a separately ducted air system from the weather directly to the gas turbine.

iv) Combustion air shall be ducted from the weather, through a separator system, directly to each propulsion gas turbine.

v) The design is to be such that the pressure drop in the gas turbine combustion air intake does not exceed that specified by the engine manufacturer.

vi) Gas turbine intake systems are to be designed to withstand compressor surging, as specified by the gas turbine manufacturer.

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vii) Ducting material for the gas turbine combustion air intake systems is to be corrosion-resistant alloys or stainless steel.

viii) Fasteners inside duct assemblies exposed to the weather are to be corrosion resistant and to be of material that will prevent a galvanic reaction with the surrounding material.

ix) A moisture separator, as described below, is to be installed, unless another effective arrangement is approved. The moisture separator elements are to have separation efficiency, as required by the gas turbine engine manufacturers. The elements are to be readily accessible for inspection and easily removed manually for cleaning or replacement.

x) Each gas turbine engine intake is to consist of louvers or vanes, moisture separator water wash manifold (if applicable to the moisture separator type).

The following items are also to be provided:

- Moisture separator panels, differential pressure safety system to activate alarms and open blow-in doors, intake support structure, drainage and discharge ducting.
- The piping, wiring and fittings associated with the above are to be provided.

xi) Moisture separator filters are to be provided and are to be accessible for inspection and removal.

xii) The moisture separator is to have the capability of being cleaned, both manually or by the moisture separator waterwash system.

xiii) Filter materials are to be fire resistant and of a consistent material density throughout. Removable moisture separator filters are to be enclosed in a rigid, self–contained frame fabricated of corrosion resisting alloys or stainless steel.

xiv) The moisture separator filter assemblies are to meet or exceed the salt efficiency requirements as specified by the gas turbine manufacturer.

xv) A fresh water connection for cleaning the separator filter is to be provided to reduce the pressure drop across the filter.

xvi) Differential pressure indicators for each intake system are to be provided.

xvii) The intake system is to withstand compressor surging, as specified by the engine manufacturer.

xviii) Splitters and turning vanes are to be provided as necessary to meet the engine manufacturer's performance requirements for compressor inlet flow as specified.

xix) Fasteners on the internal side of the intake system, such as nuts and bolts, are to be secured with some type of locking device, such as lock wire or self-locking nuts, so as not to become adrift.

xx) The intake system is to be fitted with protective foreign object damage (FOD) screens to prevent entrance of foreign objects. The screens are not to impede or limit the blow-in panels from operating.

8.2.2 Anti-icing Systems

i) When the intake system is to include an anti-icing system that allows the gas turbine to operate during cold weather conditions, the gas turbine manufacturer's requirements governing airflow temperature distortion, distribution and rate of change is to be complied with in the design of the system that introduces thermal energy into the intake.

ii) The cold weather protection system for the intake and its filtration system is to provide sufficient thermal energy to prevent ice and snow accumulation from occurring across the face of, and within, any weather opening protected by devices such as louvers or the intake's filtration system, so as to preclude pressure drop growth.

iii) In addition, any filter drain troughs or drainage related mechanisms are to be heated so that these devices continue to function as intended during cold weather operations.

iv) Temperature and humidity sensors and ice detection sensors are to be provided for anti-icing control and to indicate an alarm condition in the machinery control system. These sensors are to be installed near the weather entry to the gas turbine intakes, to indicate the condition of the air entering. In addition, a temperature and humidity sensor is to be located near the intake bellmouth to the gas turbine.

The temperature and humidity sensors are to indicate icing conditions whenever ambient temperature is below 5°C (41°F) and the relative humidity is above 70 percent. The temperature and humidity sensors are to be capable of providing continuous temperature and humidity readings.

8.3 Exhaust System

8.3.1 General

i) Each gas turbine unit is to have a separate exhaust system which ducts the gases to the weather directly or through a waste heat recovery boiler.

ii) The exhaust gas outlets are to be located where the exhaust gases will not contaminate ventilation or combustion air intakes, interfere with the vessel's crew, impinge on vessel equipment, or create a fire or explosion hazard. These are to be designed to discharge gases clear of the vessel to the maximum extent practicable.

iii) Exhaust systems are not to run through accommodations or other spaces where such may affect habitability. Where it is necessary to run the exhaust system through these spaces, adequate insulation is to be provided and flanged joints are not to be installed in such spaces. The piping and ducting are to be of all-welded construction.

8.3.2 Gas Turbines

i) Gas turbine exhaust systems are to comply with the requirements of 4-6-5/11.5, 4-6-5/11.11, and 5C-8-16/14 of the *Steel Vessel Rules.*

ii) The dual fuel gas turbine is to be fitted within an acoustic gas-tight enclosure providing effective gas detection, fire protection, ventilation, and cooling, as per the requirements given in this Section. Alternatively, the gas turbines may be located in a space containing other machinery, provided that the installation arrangements of the gas turbine are in compliance with 9/2.1.2 of this Guide.

iii) The gas fuel manifold and nozzles are to be designed to provide complete venting upon shutdown to prevent gas leakage and fire, unless the manufacture satisfactorily demonstrates by satisfactory experience with similar installations or test data that the gas manifold evacuating is not necessary.

iv) The design of the gas turbine is to provide positive means of evacuating all unburned gas from the combustor, turbine, and exhaust collector.

v) Gas turbine fuel oil piping system is to comply with the requirements of 4-6-5/3.7 of the *Steel Vessel Rules* except that gas fuel piping within the enclosure need not be jacketed or shielded.

9 Gas Turbine Enclosure Ventilation

9.1 General

In general, the ventilation systems are to comply with the requirements of 4-1-1/7.13, 5C-8-16/2, and 5C-8-16/15 of the *Steel Vessel Rules.*

9.2 System Requirements

i) Enclosures or spaces containing turbines using gas or fuel are to be fitted with mechanical exhaust ventilation such that the pressure in the space containing the gas turbine remains negative relative to the pressure in the adjoining spaces while the turbines are operating on the gas mode.

ii) The ventilation fans are to be of non-sparking construction (see 5C-8-12/1.9 of the *Steel Vessel Rules*) and electric motors for these fans are to be located outside of the airflow stream.

iii) The ventilation system is to be designed in order provide effective air circulation and cooling as specified by the turbine manufacturer but is not to be less than 30 air changes per hour based on the volume of the space.

iv) The ventilation system is to be always in operation when the gas turbine is in the gas mode as well as during purging operations prior to maintenance. The gas shut-off valve referred to in 2/6.2.1 of this Guide is to close automatically if the required air flow is not established and maintained by the exhaust ventilation systems.

v) The ventilation system is to be designed in such a way as to prevent the formation of dead spaces, specifically in the vicinity of electrical equipment, hot surfaces or other potential source of ignition.

vi) The ventilation system is to be entirely separate from all other ventilation systems.

vii) The gas turbine enclosure cooling and ventilation air is to be provided from the weather, unless otherwise approved as per the design.

viii) The inlet cooling and ventilation air calculations or modeling analysis are to be performed and submitted for approval to demonstrate and verify that adequate ventilation capacity is provided for the gas turbine enclosure.

10 Fire and Gas Detection

10.1 Gas Detection System Requirements

i) There are to be at least two independent fixed gas detection systems in each dual fuel turbine enclosure for continuous monitoring of the presence of leaked gas.

ii) Each gas detection system is to comply with the following requirements:

a) Each gas detection system is to be of the self-monitoring type.

b) In the case that a detection system fault is detected by the self-monitoring functions, the output of the detection system is to be automatically disconnected such that the detector fault will not cause false emergency shutdown.

c) Each gas detection system is to be so arranged that it provides functional redundancy when either one of the systems fails.

d) Gas detection equipment is to be so designed that it may be readily tested.

e) The gas detection system is to cover all areas of the enclosure or machinery space, where gas is likely to accumulate or where air circulation may be reduced.

f) Failure of the gas detection system is to cause the gas turbine(s) to changeover to liquid fuel and shutdown all gas fuel sources to the gas turbine engine automatically.

iii) The gas detection system is always to be in operation when there is gas fuel in the piping system while in normal operation, as well as during purging operations prior to maintenance works.

iv) The gas detection system is to be interfaced with the emergency shutdown system as specified in 9/10.2 and 9/10.3 of this Guide.

10.2 Gas Detection Set Point

i) Gas detection system is to be arranged such that at 10% of LEL in the space containing the gas turbine, the gas supply is to be immediately stopped by closing the automatic gas shut-off valve as in 2/6.2.1 of this Guide and the gas turbine is to be automatically changed over to liquid fuel. An audible and visual alarm is to sound to indicate this fault.

ii) If the gas concentration inside the space containing the gas turbine reaches 20% of LEL, then all the fuel supplies to the gas turbine are to be shut off and the space containing gas turbine is to be electrically isolated such that all sources of vapor ignition are removed.

iii) An alternative level of gas concentration to that specified in 9/10.2ii) above may be considered based on gas dissipation study inside the enclosure.

10.3 Installation

Placement of the detectors is critical to the effectiveness of the gas detection system.

The exact location of the gas detectors is to be determined taking into consideration the sensitivity of gas detectors under the prevailing airflow.

Arrangements will be subject to approval for each application based upon a gas dispersion analysis or physical smoke test.

10.4 Periodic Maintenance and Testing

The gas detection systems and the associated emergency shutdown systems are to be tested and maintained to verify their reliability and are to be recalibrated at regular intervals in accordance with the manufacturer's recommendations.

Tests and maintenance procedures are to be documented and kept onboard for the crews' use.

11 Fire Protection and Fire Extinguishing System

11.1 General

Fire protection and extinguishing systems are to comply with the requirements of Part 4, Chapter 7, and Section 5C-8-11 of the *Steel Vessel Rules*, SOLAS Chapter II-2 and the following requirements:

11.2 Fixed Fire Extinguishing Systems

Spaces containing internal combustion machinery, including dual fuel turbines are to comply with 4-7-2/1.3 of the *Steel Vessel Rules*.

11.3 Portable Foam Applicators, Dry Material and Portable Fire Extinguishers

These are to be in compliance with 4-7-2/1.1.2, 4-7-2/1.1.3, 4-7-2/1.1.4, and the Table specified in Section 4-7-2 of the *Steel Vessel Rules*.

11.4 Fixed Local Application Firefighting Systems

Machinery spaces of Category A above 500 m^3 (17,657 ft^3) in volume are to be provided with an additional water mist system, complying with the requirements specified in 4-7-2/1.11.2 of the *Steel Vessel Rules*.

11.5 Fire Detection System Requirements

The fire detection system is to comply with the following requirements:

i) Fire protection arrangements for the one or more gas turbine enclosures or machinery spaces are to be integrated with, and capable of, activation individually or at the same time as, those covering the main machinery spaces.

ii) A fire detection in the gas turbine enclosure is to shut down gas or liquid fuel supply into the enclosure.

12 Piping and Auxiliary Systems

12.1 General

i) Piping systems serving the gas turbine, such as gas fuel, liquid fuel, lubricating oil, starting air/ hydraulic and exhaust gas systems are to be in compliance with 4-2-3/9, 4-6-5/3, 4-6-5/5, 4-6-5/7, 4-6-5/9, 4-6-5/11.11, 5C-8-5/2 through 5C-8-5/5, and Sections 5C-8-6 and 5C-8-16 of the *Steel Vessel Rules*.

ii) Pipe fabrication, joining details and test requirements are to comply with Sections 2-3-12 and 2-3-13 of the ABS *Rules for Materials and Welding (Part 2)* and Sections 5C-8-5 and 5C-8-6 of the *Steel Vessel Rules*.

iii) Gas fuel piping is not to pass through accommodation spaces, service spaces or control stations.

iv) All equipment (heaters, compressors, filters, etc.) for making-up the gas for its use as fuel, the related storage tanks and associated piping is to comply with the requirements in Section 5C-8-5 and 5C-8-16/4 of the *Steel Vessel Rules*.

12.2 Gas Fuel Supply Piping System to Gas Turbine

i) High pressure gas supply lines up to the gas turbine or spaces containing the gas turbine are to be of all-welded construction and adequately protected against impact through falling objects, etc.

ii) Gas fuel piping may pass through or extend into other spaces outside the dual fuel gas turbine enclosure or machinery space, provided they fulfill the requirements of 5C-8-16/3.1 of the *Steel Vessel Rules*.

iii) All gas lines are to be capable of being vented and subsequently purged with nitrogen. All nitrogen connections to gas lines with pressures greater than that of the nitrogen purge system are to employ a double block and vent valve arrangement to mitigate the risk of contamination and overpressurizing the nitrogen system.

iv) Where reverse flow of gas supply from gas turbine is possible, a check valve with reverse flow protection is to be provided. This check valve is to be located as close to the gas turbine as practical.

v) If a gas leak occurs, the gas fuel supply should not be restored to that enclosure or machinery space until the leak has been found and repaired.

12.3 Block and Bleed Valve Arrangement

The block and bleed arrangements are to comply with 5C-8-16/3.6 of the *Steel Vessel Rules.*

12.4 Gas Shut-off Valve

i) A gas shut-off valve for the gas turbine enclosure is to be arranged so as to close automatically in accordance with 9/13.3 of this Guide

ii) After closure of the master gas valve, the block and bleed valve as per 9/12.3 of this Guide is to activate.

12.5 Gas Compressor

i) The gas compressors for pressurizing the boil-off gas for the propulsion system are to be designed in accordance with Section 4-4-1 and 5C-8-16/4 of the *Steel Vessel Rules.*

ii) High pressure gas compressors are to be approved and certified by ABS.

12.6 Pressure Vessels, Heat Exchangers and Coolers

Pressure vessels, including storage tanks, separators, vaporizers, heat exchangers, and coolers, etc., are to be designed in accordance with Sections 4-4-1, 5C-8-16, and 5C-8-16/5 of the *Steel Vessel Rules.*

12.7 Exhaust Gas Boilers

i) Exhaust gas boilers are to comply with the requirements of Section 4-4-1 of the *Steel Vessel Rules*.

ii) Where the exhaust gas boiler is arranged to burn fuel gas, it is to comply with the requirements of 5C-8-16/5 of the *Steel Vessel Rules*.

12.8 In-duct Burner

i) In-duct burners using gas and/or liquid fuels are to comply with the requirements of Section 4-4-1 of the *Steel Vessel Rules*.

ii) They are to be arranged such that the fired section of the ducting can be cleared of combustible vapors and provided with suitable charge of air to support safe and efficient combustion prior to operation.

13 Electrical, Automation, Instrumentation and Control Systems

13.1 General

i) Electrical equipment for the dual fuel turbine gas propulsion system is to comply with the applicable requirements of Part 4, Chapter 8 (in particular Section 4-8-3) and Section 5C-8-10 of the *Steel Vessel Rules.*

ii) The instrumentation, monitoring and control systems for gas turbine engines are to comply with the applicable requirements of Part 4, Chapter 9 (in particular Section 4-9-7) and 5C-8-16/17 of the *Steel Vessel Rules*, and all associated electrical systems are to comply with the requirements of Section 5C-8-10 of the *Steel Vessel Rules.*

13.2 Electrical Equipment

i) Electrical equipment which may create an electrical spark, such as magnetic contactors, circuit breakers, motor starters, switchboards, slip rings or commutators, is to be located outside of the dual fuel gas turbine engine enclosure or machinery space containing the gas turbine unless fuel gas piping is in full compliance with Section 5C-8-16 of the *Steel Vessel Rules.*

ii) All electronic and electrical equipment in the dual fuel gas turbine enclosure, which is intended to be operational after the dual fuel turbine engines have been shut down due to leakage is to be of certified safe type.

13.3 Alarm and Shutdown System

13.3.1 Automatic Shut-off of Gas Turbine and Fuel Supply

i) The monitoring and safety system functions for dual fuel gas turbine and gas fuel supply systems are to be provided in accordance with Section 4-2-3, 5C-8-16/12.3, and 5C-8-16/17 of the *Steel Vessel Rules,* and Section 9, Table 1 of this Guide.

Means are to be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply is to be shut down.

ii) An alarm(s) is to be provided at the engine control station. In addition, a summary alarm(s) is to be provided at the navigation bridge.

14 Surveys During Construction

14.1 General

This Subsection pertains to surveys during fabrication at manufacturer's facility and installation and testing of dual fuel gas turbines onboard. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

14.2 Surveys at Manufacturer's Facility

See Section 9, Table 2 of this Guide for the certification requirements for dual fuel gas turbines. Survey requirements for equipment components and packaged units at the manufacturer's facility are summarized in relevant sections of applicable Rules/Guides.

Certification of complete dual fuel gas turbines cannot be accepted based only on the ABS Type Approval Program, and therefore Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1).*

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules or this Guide, the manufactured/assembled system components will be verified to be satisfactorily in compliance with a recognized standard. Surveyor's attendance is required typically for the following purposes:

i) To confirm that the facility to manufacture, fabricate or repair dual fuel gas turbines or its components do have and maintain a quality-control program effectively covering design, procurement, manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.

iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Witness of material testing where required by the *Steel Vessel Rules*.

iv) To survey final weldments.

v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.

vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication procedures.

vii) To witness testing of subassemblies and completed units as called for in the fabrication procedures.

viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.

ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during prefabrication meeting.

14.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the dual fuel gas turbine and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested, as required by the Rules. Pressure tests conducted on Class I piping (see 4-6-1/Table 1 of the *Steel Vessel Rules*) systems should preferably be recorded on test charts for the duration of their tests.

ii) Electrical wiring and connections are to be in accordance with Part 4 of the *Steel Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves installed on the unit are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) The dual fuel gas turbine is to be checked for proper operation in accordance with the ABS approved installation test procedure.

14.4 Surveys During Trials

During the initial gas trials, the dual fuel gas turbine is to be confirmed for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted in accordance with ABS approved testing procedure during sea/gas trials. The dual fuel gas turbine is to be run whilst the vessel is underway at sea and the propulsion system operating over its full range of power.

TABLE 1
Monitoring and Safety System Functions for Dual Fuel Gas Turbine Engines and Supply Systems

Monitored Parameters	*Alarm*	*Automatic Shut-off of the Individual Master Gas Valve and Automatic Activation of the Block and Bleed Valves*	*Automatic Switching over to Oil Fuel Mode*	*Enclosure/ Mach. Space Shutdown (see 9/13.3.1)*
Gas Turbine High Exhaust Temperature – High	X			
Gas Turbine High Exhaust Temperature – High-High		X		
Gas Turbine Bearing metal chip detector	X			
Gas compressors low lube oil level	X			
Gas fuel leakage detection at 5% LFL or lower	X	X	X	
Incorrect combustion	X	X	X	
Loss of ventilation for the gas turbine engine space	X	X	X	
Low pressures in the gas fuel supply line	X	X	X	
Failure of the control-actuating medium of the master/ESD gas fuel valve	X	X	X	
Failure of gas detection system	X	X	X	
Loss of airflow in the space between gas fuel pipe and ventilated pipe or duct, as specified in 9/9.2, if fitted	X	X	X	
Fire detection in the turbine engine space	X	X		X
Gas fuel leakage detection before 10% LEL	X	X		X
Vibration – High	X			
Vibration – High-High		X		

TABLE 2
Certification of Dual Fuel Gas Turbines

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*, IMO IGC Code and other IMO requirements. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*, the IGC Code and other IMO requirements. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
VD	*Vendor Documentation* – Vendor should supply documentation as evidence that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*VD*	*DR*	*MT*	*MS*	*FS*
BOG compressors		X			X
BOG heaters (1)		X			X
Master gas fuel valve and associated piping		X (2)	X		X
Gas storage pressure vessels (1)					
Gas valve enclosure	X				
Fuel gas piping system in engine room incl. block and bleed valves		X	X		X
Fuel gas piping ventilation system		X			
Gas fuel manifold		X	X		X
Gas turbine enclosure ventilation system		X			
Gas turbine enclosure fire fighting system		X			
Dual fuel gas turbine (3)		X		X	X
Gas turbine combustion air supply ducting		X (2)			
Gas turbine exhaust system		X (2)			
Gas detection system		X			X
Gas turbine combustion control system		X			X
Automatic shutdown and safety system		X			X

Notes:

1 See Appendix 1, Table 1 of this Guide.

2 Design verification only.

3 See Section 4-2-1 of the *Steel Vessel Rules*.

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SECTION 10 Surveys After Construction and Maintenance of Class

1 General

This Section pertains to periodical surveys after construction for the equipment described in Sections 1 to 9 of this Guide.

1.1 Definitions

For definitions related to the surveys of equipment covered by this Guide, see Section 1 of this Guide and 7-1-1/3 of the ABS *Rules for Survey After Construction (Part 7).*

1.2 Damage, Failure and Repair

1.2.1 Examination and Repair

Damage, failure, deterioration or repair of gas utilization systems and associated components, which affects or may affect classification, is to be submitted by the Owners or their representatives for examination by a Surveyor at first opportunity. All repairs found necessary by the Surveyor are to be carried out to the Surveyor's satisfaction. Where repairs are planned in advance to be carried out, a complete repair procedure including the extent of proposed repair and the need for Surveyor's attendance is to be submitted to and agreed upon by ABS reasonably in advance.

Note: The above applies also to repairs during voyage. See Appendix 7-A-2 of the ABS *Rules for Survey After Construction (Part 7).*

The above is not intended to include maintenance and overhaul in accordance with the manufacturer's recommended procedures and established marine practice and which does not require ABS approval. However, any repair as a result of such maintenance and overhauls which affects or may affect classification is to be noted in records maintained on the vessel and readily available to the attending Surveyor, when required.

Material, components and equipment used in the course of a repair for which the Guide/Rules require vendor certification are to be provided with the required certificates/reports.

When a piece of machinery, piping or process equipment suffers a premature or unexpected failure and is subsequently repaired or replaced without Surveyor attendance, details of the failure, including damaged parts, where practicable, are to be retained onboard and presented to the attending Surveyor during the next scheduled visit. Alternatively, the part(s) may be landed ashore for further examination and testing, as required. If failures noted above are deemed to be a result of inadequate or inappropriate maintenance, the maintenance and inspection plan is to be amended and resubmitted for approval.

1.2.2 Suspension of Classification

Failure to submit a damage, failure, deterioration or repair governed by 10/1.2.1 of this Guide to a Surveyor for examination at first opportunity, or failure to notify ABS in advance of the repairs contemplated by 10/1.2.1 of this Guide, may result in suspension of the vessel's classification from the date of arrival at the first port of call after the initial damage, failure, deterioration or repair until such time as the damage, failure or deterioration is repaired to the Surveyor's satisfaction, or the repair is redone or evidence submitted to satisfy the Surveyor that the repair was properly carried out.

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1.3 Modifications

When it is intended to carry out any modifications to the gas utilization system and associated components, which may affect classification, including substitutions of material differing from that originally installed, the details of such modifications are to be submitted for review. If ABS determines that the modification will affect classification, the affected system or component to be modified will be subject to the review, testing and survey requirements in accordance with this Guide.

2 Survey Intervals

2.1 Annual Survey

An Annual Survey of a gas fueled ship and installed classed systems covered by this Guide is to be carried out within three (3) months before or after each annual anniversary date of the crediting of the previous Special Periodical Survey or original construction date. For gas fueled ships on Continuous Survey, all Continuous Survey requirements for those parts (items) due are generally to be completed each year. The Annual Survey will not be credited and the Certificate of Classification will not be endorsed unless Continuous Survey items that are due or overdue at the time of the Annual Survey are either completed or granted an extension.

2.2 Intermediate Survey

An Intermediate Survey of a gas fueled ship is to be carried out either at or between the second and third Annual Survey after Special Periodical Survey No. 1 and subsequent Special Periodical Surveys.

2.3 Special Periodical Survey

A Special Periodical Survey is to be completed within five years after the date of build or after the crediting date of the previous Special Periodical Survey. The fifth Annual Survey must be credited as a requirement of the Special Periodical Survey. The interval between Special Periodical Surveys may be reduced by the Committee.

The Special Periodical Survey may be commenced at the fourth Annual Survey and be continued with completion by the fifth anniversary date. Where the Special Periodical Survey is commenced prior to the fourth Annual Survey, the entire survey is to be completed within fifteen (15) months if such work is to be credited to the Special Periodical Survey.

A Special Periodical Survey will be credited as of the completion date of the survey but not later than five years from date of build or from the date recorded for the previous Special Periodical Survey. If the Special Periodical Survey is completed within three (3) months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date. Special consideration may be given to Special Periodical Survey requirements in unusual cases. Consideration may be given for extensions of Rule-required Special Periodical Surveys under exceptional circumstances.

2.4 Continuous Survey Program

At the request of the Owner, and upon approval of the proposed arrangements, a system of Continuous Surveys may be undertaken, whereby the Special Periodical Survey requirements are carried out in regular rotation to complete all of the requirements of the particular Special Periodical Survey within a five-year period. The proposed arrangements are to provide for survey of approximately 20% of the total number of survey items during each year of the five-year period. Reasonable alternate arrangements may be considered as recommended by the manufacturer.

Generally each part (item) surveyed becomes due again for survey approximately five (5) years from the date of the survey and the due parts (items) are generally to be completed each year. For Continuous Surveys, a suitable notation will be entered in the *Record* and the date of the completion of the cycle published.

ABS may withdraw its approval for Continuous Survey if the Surveyor's recommendations are not complied with.

2.5 Survey Based upon Preventative Maintenance Techniques

A properly conducted approved program of preventative-maintenance/condition-monitoring plan may be credited as satisfying the requirements of Special Continuous Survey. This plan must be in accordance with Appendix 7-A-14 "Guide for Survey Based on Preventative Maintenance Techniques" of the ABS *Rules for Survey After Construction (Part 7)*.

3 Surveys

3.1 Annual surveys

3.1.1 General

The following should be carried out during each Annual Survey of the Gas Fuel Storage, Fuel Bunkering System, Fuel Gas Supply System and GAS Utilization Systems unless all the requirements of Subsection 10/4 of this Guide are complied with:

i) *General.* The logbooks are to be examined with regard to correct functioning of the fuel gas detection systems, fuel gas supply/gas systems, etc. The hours per day of the prime movers, re-liquefaction plant, GCU, as applicable, or the boil-off rate are to be considered together with historical gas detection records.

ii) *Operating and Maintenance Instruction Manual.* The approved instructions and manuals covering the operations, safety and maintenance requirements and occupational health hazards relevant to gas fuel storage, fuel bunkering, fuel gas supply, gas utilization units and associated systems and use of gas as fuel, are to be confirmed as being aboard the vessel.

iii) *Instrumentation and Safety Systems.* Gas detection equipment in all compartments containing gas fuel storage, fuel bunkering, fuel gas supply or gas utilization equipment or components or associated systems, including indicators and alarms, is to be confirmed in satisfactory operating conditions. Verification of installed interlocks in the gas detection system is to be verified in working condition. Any piping of the gas detection system is to be visually examined for corrosion and damage and the integrity of the line between suction points and analyzing units is to be confirmed as far as possible. Recalibration of the gas detection systems should be verified in accordance with the manufacturers' recommendations.

iv) *Fuel Gas Handling Piping and Machinery.* All piping, hoses, emergency shut-down valves, remote operating valves, machinery and equipment for gas fuel storage, fuel bunkering, fuel gas supply and gas utilization such as venting, compressing, refrigerating, liquefying, heating, cooling or otherwise handling the liquefied gas or vapor is to be examined, as far as possible. Stopping of pumps and compressors upon emergency shut-down of the system is to be confirmed.

v) *Ventilating System.* Examination of the ventilation system is to be made for all spaces containing gas fuel storage, fuel bunkering, fuel gas supply and gas utilization units or components or associated systems, including air locks, pump rooms, compressor rooms, fuel preparation rooms, gas valve rooms, control rooms and spaces containing gas burning equipment. All required portable ventilating equipment is to be examined. Provision of spares for mechanical ventilation fans recommended by manufacturer is to be confirmed. Where alarms, such as differential pressure and loss of pressure alarms, are fitted, these should be operationally tested as far as practicable.

vi) *Drip Trays.* Portable and fixed drip trays and insulation for the protection of the deck in the event of gas leakage are to be examined

vii) *Sealing Arrangements.* Sealing arrangements in way of openings and bulkhead penetrations for the gas fuel system are to be examined

viii) *Fire Protection and Fire Extinguishing Equipment.* The required fire protection and fire extinguishing system contained in areas and spaces where gas fuel storage, fuel bunkering, fuel gas supply and gas utilization units are fitted are to be examined and operationally tested, in so far as practicable.

ix) *Electrical Equipment.* Electrical equipment in gas-dangerous spaces or zones is to be examined for continued suitability for their intended service and installation area.

x) *Electrical Bonding.* Electrical bonding arrangements, including bonding straps where fitted, of the piping systems for gas utilization systems located within bunker tanks, ballast tanks, pipe tunnels, cofferdams and void spaces bounding bunker tanks are to be examined.

3.1.2 Gas Fueled Ship (GFS)

The following are to be examined, so far as applicable during each Annual Survey. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated:

3.1.2(a) Gas Fuel Storage

i) External examination of the bunker tanks and secondary barrier or gas fuel storage room.

ii) External examination of main tank and relief valves.

iii) Testing of tank monitoring system.

iv) Examination and testing of installed bilge alarms and means of drainage of the compartment.

v) Testing of the remote and local closing of the installed Main Tank Valve.

3.1.2(b) Fuel Bunkering System

i) Examination of all bunker stations and the fuel bunkering system during working condition.

ii) External examination of bunker manifolds.

iii) External examination of manifold valves and manifold ESD valves.

iv) Testing of fuel bunkering control, monitoring and shut-down systems as far as practicable, or verification of set-points in accordance with approved test program.

v) Testing of bunker lines inert and gas freeing system.

3.1.2(c) Fuel Gas Supply System

i) The fuel gas supply system during working condition.

ii) External examination of all pressure vessels, heat exchangers, pumps, compressors, filters etc. for making-up the gas for its use as fuel in the system.

iii) External examination of relief valves, if fitted.

iv) Location of applicable warning notices.

v) Where double wall fuel gas piping is provided, means for detecting any leakage should be tested.

vi) The fuel gas supply system component spares as recommended by the manufacturer.

vii) Testing of control, monitoring and shut-down systems as far as practicable, or verification of set-points in accordance with approved test program.

3.1.3 Re-Liquefaction Plant (RELIQ)

The following are to be examined, during each Annual Survey so far as applicable. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated:

i) The plant during working condition.

ii) External examination of all pressure vessels in the system

iii) External examination of relief valves, if fitted.

iv) The re-liquefaction/refrigeration plant spare gears as recommended by the manufacturer.

v) Testing of control, monitoring and shut-down systems as far as practicable, or verification of set-points in accordance with approved test program.

vi) Examination and testing of installed bilge alarms and means of drainage of the compartment.

3.1.4 Gas Combustion Unit (GCU)

The following are to be examined, so far as applicable during each Annual Survey:

i) The Gas Burning Unit during working condition.

ii) External examination of all pressure vessels in the system.

iii) Testing of burner management control system, and flame scanner and installed interlocks.

iv) External examination of the combustion chamber and associated refractory

v) External examination of exhaust gas piping/ducts.

vi) Testing of the remote and local closing of the installed Master Tank Valve and Master Gas Valve for the GCU compartment.

3.1.5 Dual Fuel Diesel Engine Power Plant (DFD)

In addition to the Annual Survey requirements for liquid fuel diesel engines, the following are to be examined, during each Annual Survey so far as applicable. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated:

i) External examination of any pressure vessels, heat exchangers, compressors, filters etc. for making-up the gas for its use as fuel.

ii) Operational test, as far as practicable of the power management system for the emergency shutdown of the dual fuel engine compartments and testing of the automatic shut-off of gas fuel supply.

iii) Where double wall fuel gas piping is provided, means for detecting any leakage should be tested.

iv) Verification of redundancy and testing of gas detection system in engine rooms together with any interlocks.

v) Testing of alarm for the access doors to the engine rooms.

vi) Testing of the remote and local closing of the installed Main Tank Valve and Master Gas Valve for each engine compartment.

3.1.6 Single Gas Fuel Engine Power Plant (SGF)

In addition to the Annual Survey requirements for liquid fuel diesel engines, the following are to be examined, during each Annual Survey so far as applicable. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated:

i) External examination of any pressure vessels, heat exchangers, compressors, filters etc. for making-up the gas for its use as fuel.

ii) Operational test, as far as practicable of the power management system for the emergency shutdown of the single fuel engine compartments and testing of the automatic shut-off of gas fuel supply.

iii) Where double wall fuel gas piping is provided, means for detecting any leakage should be tested.

iv) Verification of redundancy and testing of gas detection system in engine rooms together with any interlocks.

v) Testing of alarm for the access doors to the engine rooms.

vi) Testing of the remote and local closing of the installed Main Tank Valve and Master Gas Valve for each engine compartment.

3.1.7 Dual Fuel Gas Turbine Power Plant (DFGT)

Gas turbines are to be opened and maintained in accordance with manufacturer's recommendations, as appropriate for the actual applicable operating conditions

Owners are to submit for approval maintenance schedules for the type of gas turbine in service, specifying proposed intervals for combustion checks, hot-gas-path examinations and major examinations, see also Subsection 9/4 of this Guide. Upon approval, the schedules will become part of the Special Periodical Survey – Machinery records; see 10/2.4 and 10/2.5 of this Guide.

At each Annual Survey, the attending Surveyor should examine, as far as applicable, the following:

i) Verify compliance with the approved maintenance schedule and manufacturers recommendations, taken into consideration the "in-service" records for the unit and applicable hours of running time for each type of fuel.

ii) Structural examination of the gas turbine enclosure and foundation.

iii) Verify satisfactory operation of any fitted interlocks on the gas enclosure.

iv) Verify air-tightness of the gas turbine enclosure or its capability of maintaining a negative pressure inside the enclosure by means of testing of installed alarms if fitted.

v) Examination and testing of installed gas turbine enclosure ventilation and associated alarms.

vi) External examination of gas turbine enclosure air intakes, combustion air intake and exhaust system and fitted dampers.

vii) Testing of the remote and local closing of the installed Main Tank Valve and Master Gas Valve for each dual fuel gas turbine.

viii) Testing of the control system for the gas turbine and associated alarms, change over and shutdown functions.

3.2 Intermediate Surveys

In addition to the applicable requirements contained in 10/3.1 of this Guide, the Intermediate Survey is to be carried out in accordance with 7-3-2/3.15.1 of the ABS *Rules for Survey After Construction (Part 7)*. Intermediate Survey of gas fuel storage, fuel bunkering, fuel gas supply and gas utilization equipment should be in accordance with 7-3-2/3.15.1 of the ABS *Rules for Survey After Construction (Part 7)* in addition to the Annual Survey requirements contained in 10/3.1.1 of this Guide.

3.3 Special Periodical Survey

In addition to the items covered by the Annual Survey, listed in 10/3.1.1 of this Guide, the Special Survey of the gas fuel storage, fuel bunkering, fuel gas supply and gas utilization units and equipment is also to include the following:

i) *Fuel Gas Handling and Piping Material.* All piping, machinery and equipment for gas fuel storage, fuel bunkering, fuel gas supply and gas utilization, such as venting, compressing, refrigerating, liquefying, heating storing, burning or otherwise handling the liquefied gas or vapor and liquid nitrogen installations are to be examined including removal of insulation and opening for examination, as deemed necessary. Where deemed suspect, a hydrostatic test to 1.25 times the Maximum Allowable Relief Valve Setting (MARVS) for the pipeline is to be carried out. After reassembly, the complete piping is to be tested for leaks. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the Surveyor may accept alternative testing fluids or alternative means of testing.

ii) *Fuel Gas Valves.* All emergency shut-down valves, check valves, block and bleed valves, master gas valves, remote operating valves in the gas fuel storage, fuel bunkering, fuel gas supply and gas utilization piping systems are to be inspected and proven operable. The pressure relief valves are to be function-tested. A random selection of valves is to be opened for examination and adjusted as necessary.

iii) *Pressure Vessels.* Internal examination and thickness measurement of the fitted pressure vessels in the fuel gas storage, fuel gas supply and gas utilization units as deemed necessary by the Surveyor.

iv) *Electrical Equipment.* Examination and testing of electrical equipment. This examination is to include the physical condition of electrical cables and supports, intrinsically safe, explosion proof, or increased safety features of electrical equipment, functional testing of pressurized equipment and associated alarms, testing systems for de-energizing electrical equipment which is not certified for use in gas-hazardous areas, and insulation resistance readings of circuits. Where a proper record of testing is maintained, consideration may be given to accepting recent readings.

v) *Gas Combustion Unit.* Internal examination of the gas combustion unit, combustion chamber and associated refractory.

vi) *Gas Turbines.* For dual fuel gas turbine units in continuous service, at least one hot-gas-path examination is to be scheduled each survey cycle and is to include an examination of turbine rotors, fixed blading, combustors, inlet casings (including demisters and filters), exhaust casing (including regenerator), air control valves and protective apparatus.

Other parts of the dual fuel gas turbine and associated equipment, as may be deemed necessary by the attending Surveyor, are to be opened up for examination

Where units are arranged such that the unit is removed from the vessel in accordance with the approved plans and the maker's recommendations, and dismantled at another facility, the internal examination may be carried out at the facility in the presence of the Surveyor. Upon reassembly/ reinstallation, all fuel lines, lube oil piping, the unit itself and exhaust system are to be checked under full speed and its range of operational conditions for leakage.

4 Alternative Surveys

ABS is at all times ready to consider alternative survey arrangements which can be shown, through either satisfactory service experience or a systematic analysis based on sound engineering principles, to meet the overall safety, serviceability and standards of the *Steel Vessel Rules* and this Guide. Alternative to requirements particularly contained in Subsection 10/3 of this Guide, an In-Service Inspection Plan (ISIP) may be developed by the Owner and submitted to the Assistant Chief Surveyor's office for review. Stamped copy of the ISIP placed onboard the gas fueled ship is to be referenced during all of the scheduled surveys.

4.1 Inspection Plan

The ISIP is to utilize the technical information available in the Operating and Maintenance Instruction Manuals that have been reviewed by ABS. The ISIP may contain, but not be limited to the following:

- Maintenance records for gas fuel storage, fuel bunkering, fuel gas supply and gas utilization equipment.
- Operational Procedures of all gas fuel storage, fuel bunkering, fuel gas supply and gas utilization equipment.
- Details of the Continuous Survey Program.
- Details of any Preventative Maintenance Program including manufacturer recommendations for overhaul and condition monitoring.
- Records of any Risk Based evaluations.
- Details of maintenance agreements with sub-contractors.

A note in the vessel's record will denote the approved survey plan and associated alternative survey requirements.

4.2 Application

Based on the information contained in the ISIP and any possible review of records of sister vessels in the same fleet, ABS may consider special arrangements such as alternative survey techniques and/or frequency of surveys, provided this is not less effective. These arrangements may also require the approval of the flag Administration, in which case this must be included in the approved ISIP. A note in the vessel's record will denote the approved survey plan and associated alternative survey requirements contained. The ISIP will no longer be valid if the vessel is sold or otherwise changes owner or management.

APPENDIX 1 Certification of Pressure Vessels

TABLE 1
Certification of Pressure Vessels

This Table has been prepared for guidance only and annotated to agree with the *Steel Vessel Rules*. The list is not to be considered exhaustive; should additional equipment not listed be fitted onboard, same will be subject to special consideration for compliance with the *Steel Vessel Rules*. This list is not to be considered as substitutive or integrative of the content of the *Steel Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Steel Vessel Rules* and regulations, the latter are to be considered applicable.

Code	*Explanation*
VD	*Vendor Documentation* – Vendor should supply documentation that the material or the equipment complies with an acceptable standard (e.g., standard tests reports, ex certification, etc.).
DR	*Design Review* – Design review required.
MT	*Material Testing* – Material testing is to be witnessed by the Surveyor.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

	Equipment	*VD*	*DR*	*MT*	*MS*	*FS*
1	Containers for liquid whose pressure exceeds 41.4 bar or temperature exceeds 204°C or temperatures below –55°C.		X	X	X	X
2	Containers for vapor or gas whose pressure exceeds 41.4 bar or temperature exceeds 371°C.		X	X	X	X
3	Containers with pressure over 6.9 bar up to 41.4 bar, (with I.D. > 150 mm).		X (3)		X	X
4	Containers for other liquids whose pressure is over 1 bar up to 6.9 bar, with internal volume exceeding 0.14 m^3 and temperature exceeding 149°C.		X		X	X
5	Containers for steam, gas or vapors whose pressure is over 1 bar up to 6.9 bar, with internal volume exceeding 0.14 m^3 and temperature exceeding 149°C.		X		X	X
6	Containers not covered by 1 through 5 above.	X				
7	All fired heaters not covered by 1 and 2 above with maximum allowable pressure above 1.0 bar.		X		X	X
8	Dearating heaters, condensers, fuel oil heaters, feed water heaters, evaporators and feed water filters not covered by 1 through 4 and installed between the pumps and the boilers.	X				

Notes:

1 If not tested and not stamped by an independent agency authorized by Flag Administrations.

2 Where not in compliance with a recognized Standard, refer to 4-6-7/3.5.5 of the *Steel Vessel Rules*.

3 Diameter limitation not applicable to hydraulic accumulators. Refer to 4-6-7/3.5.4 of the *Steel Vessel Rules*.