INTERNATIONAL MARITIME ORGANIZATION

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SUB-COMMITTEE ON CARRIAGE OF CARGOES AND CONTAINERS 9th session Agenda item 10	CCC 9/10/2 26 June 2023 Original: ENGLISH Pre-session public release: ☒

UNIFIED INTERPRETATION OF PROVISIONS OF IMO SAFETY, SECURITY, AND ENVIRONMENT-RELATED CONVENTIONS

Draft unified interpretations of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

Submitted by IACS

SUMMARY

Executive summary:	This document proposes draft unified interpretations in relation to sections 4.23.1.1, 4.23.1.2, 4.23.2.5, 4.23.4, 4.23.3.1, 4.23.3.2, 5.2.2.1, 5.12.4, 5.12.3.1, 8.1, 9.4.4, 16.3.4, 17.1 and 17.4 of the IGC Code, contained in annex 1. Should the Sub-Committee choose to amend the IGC Code instead of issuing interpretations, annex 2 contains draft amendments to the IGC Code (i.e. incorporating same UIs into the IGC Code) for the consideration of the Sub-Committee as part of the current work on the Revision of the IGC Code under agenda item 4 of CCC 9.
Strategic direction, if applicable:	7
Output:	7.1
Action to be taken:	61
Related documents:	None

Introduction

1 The *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*, as amended by resolution MSC.370(93) (hereafter referred to as the "IGC Code"), provides revised international standards for the design and construction of ships carrying liquefied gases in bulk.

2 IACS members, acting as recognized organizations, have discussed the implementation of the requirements of the IGC Code and concluded that some requirements need further clarification in order to facilitate their universal and uniform implementation as discussed below.

Discussion

A Unified interpretation of paragraphs 5.2.2.1 and 9.4.4 of the IGC Code clarifying interconnections between inert gas and nitrogen systems and cargo or gas fuel systems containing product liquid or vapours

3 Paragraph 5.2.2.1 of the IGC Code requires that systems containing cargo liquid or vapours shall be segregated from other piping systems except for the period of time when such connection is required for ongoing operation. Further, paragraph 9.4.4 of the IGC Code requires that, when not in use, the inert gas system shall be made separate from the cargo system in the cargo area.

4 Paragraph 1.2.47 of the IGC Code defines "separate systems" as "those cargo piping and vent systems that are not permanently connected to each other".

5 Both the IGC Code (paragraph 9.4.4) and the FSS Code (paragraph 2.2.3.1.1 of chapter 15) address the necessity to have arrangements to prevent back flow of cargo vapours into the inert gas system.

6 Due to specifics of operation, the fuel gas supply system shall be periodically inerted in a section of the pipe between the gas fuel isolating valve (required by paragraph 16.4.5 of the IGC Code) and the gas fuel consumer. It requires a permanent connection between the inert gas (nitrogen) and the gas fuel supply system segment.

7 As the same product is carried in the cargo system and in the gas fuel system when such cargo is used as fuel, the equivalent level of safety and risk mitigation measures will be required for both the cargo and gas fuel system. Double block and bleed valves arrangement as described in paragraph 2.2.3.1.2 of chapter 15 of the FSS Code is adopted as equivalent to physical segregation of systems since it excludes the risk that a single failure in such an arrangement will lead to an accident.

8 Considering that the risk of cargo liquid or vapour backflow to inert gas or nitrogen system equally affects connection to cargo and gas fuel system when such systems are kept under pressure, IACS considers that the requirements in paragraphs 5.2.2.1 and 9.4.4 of the IGC Code address both the cargo and gas fuel system. As the connection of the inert gas (nitrogen) line to the gas fuel system requires automated operation and thus is physically permanent, an equivalence to physical segregation of the systems arrangement shall be required in this position. IACS opines that existing and proven in service double block and bleed valves arrangement as described in the FSS Code would meet the purpose of segregation.

9 It is understood that the provisions for inerting of the remaining segment of the gas fuel piping located outside cargo area between the master gas valve and the gas consumer isolation valves, as addressed in paragraph 16.4.1.2 of the IGC Code, may be arranged by alternatively permanent or temporary (non-permanent) connection.

10 Non-permanent connections with means of physical segregation such as removable spool pieces or elbows, when used, do not require additional arrangement to those described in paragraph 9.4.4 of the IGC Code (two non-return valves or equivalent devices and, in addition, a removable spool piece) installed in the inert gas header.

11 In order to clarify the issues discussed in paragraph 3 to 10 above, IACS proposes a draft unified interpretation of paragraphs 5.2.2.1 and 9.4.4 of the IGC Code, as set out in section A of annex 1 to this document.

12 In addition, noting the ongoing work in the Sub-Committee on the revision of the IGC Code, section A of annex 2 to this document contains the corresponding draft amendments of paragraphs 5.2.2.1 and 16.4.1 of the IGC Code, should the Sub-Committee decide to favour the route of amending the IGC Code rather than approving a unified interpretation.

B Unified interpretation of paragraphs 8.1 and 16.3.4 of the IGC Code regarding separation between fuel gas and cargo containment vent systems

13 The proposed unified interpretation aims to clarify the implications of requirements of paragraph 8.1 in relation to paragraph 16.3.4 of the IGC Code, as explained below.

14 Paragraph 8.1 of the IGC Code reads as follows:

> "8.1 ... Pressure control systems specified in chapter 7 shall be independent of the pressure relief systems."

15 Paragraph 16.3.4 of the IGC Code reads as follows:

> "16.3.4 All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space...".

16 Thermal oxidation, where the boil-off vapours are utilized as fuel for shipboard use, forms part of cargo pressure control. Due to that, IACS considers that all piping arrangements for vents and bleed lines which may contain or be contaminated by gas fuel (including a vent mast) serving the fuel gas system from the engine-room need to be maintained independent from the vent system of cargo containment. The purpose of that arrangement is to prevent the flow of venting vapour from cargo area to the gas-safe engine-room space.

17 Considering paragraphs 14 to 16, IACS opines that an interpretation is necessary in order to provide a clarification which would ensure and prevent any possible cross contamination of cargoes vapours from the vent systems to the engine-room via any connection between the cargo and fuel vent systems.

18 In order to ensure the safe application of the arrangements for the vents from cargo and fuel systems, IACS proposes a unified interpretation of paragraphs 8.1 and 16.3.4 of the IGC Code in relation to the vent systems from fuel systems and cargo containment as set out in section B of annex 1 to this document.

19 In addition, noting the ongoing work in the Sub-Committee on the revision of the IGC Code, section B of annex 2 to this document contains the corresponding draft amendment to paragraph 16.3.4 of the IGC Code, should the Sub-Committee decide to favour the route of amending the IGC Code rather than approving a unified interpretation.

C Unified interpretation of paragraphs 17.1 and 17.4 of the IGC Code regarding refrigeration systems for the carriage of certain products

20 IACS proposes a unified interpretation of paragraphs 17.1 and 17.4 of the IGC Code to clarify that requirements in paragraph 17.4 pertaining to refrigeration systems, listed in column "i" of chapter 19 of the IGC Code, are applicable only when a refrigeration system is fitted and should not be interpreted as requiring one to be fitted.

21 Chapter 19 of the IGC Code summarizes minimum requirements for different cargoes; "Special requirements (column i)" in the explanatory notes to that summary states:

> "When specific reference is made to chapters 14 and/or 17, these requirements shall be additional to the requirements in any other column.".

22 Paragraph 17.1 of the IGC Code states:

> "17.1 General
>
> The requirements of this chapter are applicable where reference thereto is made in column "i" in the table of chapter 19. These requirements are additional to the general requirements of the Code."

23 The title of paragraph 17.4 of IGC Code reads:

> "17.4 Refrigeration systems".

24 Considering the above two references, IACS opines that requirements listed in "Special requirements (column i)" should apply for the carriage of specific cargo listed in table of chapter 19 of the IGC Code, and in order to load certain cargoes against which paragraph 17.4 of the IGC Code appears in column "i" in table of chapter 19 of the IGC Code, a refrigeration system should be installed.

25 For example, for cargo "propylene oxide", the following requirements pointing at the presence of the refrigeration system are stated:

.1 column "i" of table of chapter 19 of the IGC Code lists the reference to the following paragraph 17.4.1 of the IGC Code:

"17.4.1 Only the indirect system described in 7.3.1.2 shall be used", where the referenced paragraph 7.3.1.2 of the IGC Code states:

"7.3.1.2 an indirect system, where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed;"; and

.2 column "o" of table of chapter 17 of the IBC Code lists the reference to the following paragraph 15.14 of the IBC Code:

"15.14.1 For a cargo referenced in column o in the table of chapter 17 to this section, a mechanical refrigeration system shall be provided unless the cargo system is designed to withstand the vapour pressure of the cargo at 45°C."

26 However, normally there is no refrigeration system on ships constructed to transport Mixed C4 Cargoes (a pressure accumulation method is applied to control the cargo pressure/temperature). From the below paragraph 7.1.1 of the IGC Code, IACS understands that any suitable pressure and temperature control method listed therein is acceptable:

> "7.1.1 With the exception of tanks designed to withstand full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, cargo tanks' pressure and temperature shall be maintained at all times within their design range by either one, or a combination of, the following methods:
>
> .1 reliquefaction of cargo vapours

.2 thermal oxidation of vapours;

.3 pressure accumulation; and

.4 liquid cargo cooling."

27 Based on the above references, IACS considers that the requirements of paragraph 17.4 of the IGC Code on refrigeration systems should apply only to ships fitted with a refrigeration system. Therefore, the appearance of the reference to paragraph 17.4 of the IGC Code in the "Special requirements (column i)" of table of chapter 19 of the IGC Code should not be interpreted as requiring installation of a refrigeration system.

28 In order to avoid possible misunderstanding, IACS proposes a unified interpretation of paragraphs 17.1 and 17.4 of the IGC Code on refrigeration systems as set out in section C of annex 1 to this document.

29 In addition, noting the ongoing work in the Sub-Committee on the revision of the IGC Code, section C of annex 2 to this document contains the corresponding draft amendment to paragraph 17.4 of the IGC Code, should the Sub-Committee decide to favour the route of amending the IGC Code rather than approving a unified interpretation.

D0 Unified interpretation of paragraph 4.23.3.1 of the IGC Code

30 Paragraph 4.23.3.1 of the IGC Code gives the allowable stresses for the plastic deformation of a type C tank. IACS prepared draft interpretation to reflect the application of the finite element (FE) method used for type C tank strength check which is currently used by the industry. The draft interpretation provides the permissible stresses in way of supports and stiffener rings of type C cargo tanks as well as other highly loaded locations not fully covered by prescriptive requirements.

31 It defines the assumption for making the beam model of the stiffening ring and mentions the buckling strength check of the stiffening ring.

32 IACS notes that the strength utilization of 0.57 x tensile strength and 0.85 x yield strength was defined before the stiffening rings, as the shell element applied to FE analysis is often used and the factors are based on C-Mn steel only. Analyses required today are almost always based on FE analysis with shell elements or solid elements and with other steel types. Paragraphs 1 and 2 of the draft unified interpretation reflect current practices.

D1 Unified interpretation of "finite element analysis of type C cargo tanks" of paragraph 4.23.3.1 of the IGC Code

33 IACS has prepared a draft unified interpretation on "finite element analysis of type C cargo tanks" for the FE application of the type C tank which also applies to the stiffening rings of the type C tanks.

34 Paragraph 4.23.3.1 of the IGC Code gives the allowable stresses for the plastic deformation of a type C tank as below:

"4.23.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5f$
$\sigma_L + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$,

where:

σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;
σ_g = equivalent secondary stress; and
f = the lesser of R_m /A or R_e /B,

with R_m and R_e as defined in 4.18.1.3. With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in 4.28.3 are referred. The values A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least the following minimum values:

	Nickel steels and carbon-manganese steels	**Austenitic steels**	**Aluminium alloys**
A	3	3.5	4
B	1.5	1.5	1.5

"

35 IACS notes that recently, the FE method in application in the independent type C tank has been widely used by the industry on the analysis of independent type C tanks. However, there might be some misunderstanding or inappropriate ways to apply the strength criteria for FE given in paragraph 4.23.3.1 of the IGC Code.

36 The proposed unified interpretation clarifies the following technical points for the application of FE analysis on type C tanks using the seven stress checking criteria regarding "plastic deformation" in paragraph 4.23.3.1 of the IGC Code:

.1 general requirements, e.g. the scope and location of application, the FE analysis procedure given in the IGC Code and the recognized standards (such as ASME Boiler and Pressure Vessel Code, section VIII, Division 2 or other equivalents which is acceptable to the classification society/recognized organization), the relationship between the prescriptive requirements and FE analysis application, etc.; and

.2 more detailed interpretation regarding the seven stress criteria of "plastic deformation".

D2 Unified interpretation of paragraph 4.23.3.2 of the IGC Code on "buckling assessment of type C cargo tanks"

37 Paragraph 4.23.3.2 of the IGC Code gives the buckling criteria of a type C tank as follows:

> "4.23.3.2 Buckling criteria shall be as follows: the thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length."

38 IACS notes that paragraph 4.23.3.2 of the IGC Code only states that buckling strength assessment should be evaluated by an accepted pressure vessel buckling theory, and there are no detailed requirements specified in the IGC Code. Accordingly, each classification society/recognized organization has performed the buckling strength assessment by different recognized standards and different results can be obtained.

39 To address the buckling strength check, IACS has prepared a draft unified interpretation of paragraph 4.23.3.2 of the IGC Code on "buckling assessment of type C cargo tanks" both for the type C tank and the stiffening rings.

40 This draft unified interpretation clarifies the following technical points for buckling assessment on type C tanks:

.1 general requirements, e.g. acceptance of recognized standard, net scantling approach, consideration of lateral buckling of stiffening rings, application for novel configuration tanks, and alternative method by non-linear FE analysis; and

.2 detailed buckling strength requirement regarding cylindrical and spherical shell, and stiffening rings.

D3 Unified interpretation of paragraphs 4.23.1.1, 4.23.1.2, 4.23.2.5 and 4.23.4 of the IGC Code

41 IACS considers that some of the requirements concerning safety factors and the maximum allowable cumulative fatigue damage ratio on the fatigue assessment of a type C tank need further clarification in order to facilitate their global and uniform implementation.

42 Paragraphs 4.23.1.1, 4.23.1.2, 4.23.2.5 and 4.23.4 of the IGC Code set out general conditions and requirements of fracture mechanics, crack propagation and fatigue assessment for a type C tank. IACS is of the opinion that these paragraphs in the IGC Code are unclear about the safety level of type C tanks. Consistent safety principles for fracture mechanics indicated in these paragraphs should be applied to crack propagation and fatigue assessment for type C tanks.

43 In order to clarify the issues discussed in paragraph 30 to 42 above, IACS proposes draft unified interpretations of the IGC Code, as set out in sections D0, D1, D2 and D3 of annex 1 to this document.

44 Should the Sub-Committee decide to favour the route of amending the IGC Code rather than approving unified interpretations as proposed in paragraphs 30 to 42, IACS has prepared corresponding draft amendments to the IGC Code addressing the issues raised in those paragraphs, as contained in sections D0, D1, D2 and D3 of annex 2 to this document.

E Draft amendments to MSC.1/Circ.1625 on unified interpretation of paragraph 5.12.3.1 of the IGC Code

45 Paragraph 5.12.3.1 of the IGC Code states:

> "5.12.3.1 Cargo piping systems shall be provided with a thermal insulation system as required to minimize heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces.".

46 Paragraph 6.2 of MSC.1/Circ.1625 provides examples of piping that do not necessarily require thermal insulation from the standpoint of personnel protection as follows:

> "**6 Cargo piping insulation (paragraph 5.12.3.1)**
>
> 6.1 The expression "a thermal insulation system as required to minimize heat leak into the cargo during transfer operations" means that properties of the piping insulation should be taken into consideration when calculating the heat balance of the containment system and capacity of the pressure/temperature control system.
>
> 6.2 The expression "cargo piping systems shall be provided with a thermal insulation system as required ... to protect personnel from direct contact with cold surfaces" means that surfaces of cargo piping systems with which personnel are likely to have contact under normal conditions should be protected by a thermal insulation, with the exception of the following examples:
>
> .1 surfaces of cargo piping systems which are protected by physical screening measures to prevent such direct contact;
>
> .2 surfaces of manual valves having extended spindles that protect the operator from the cargo temperature; and
>
> .3 surfaces of cargo piping systems whose design temperature (to be determined from inner fluid temperature) is above minus 10°C."

47 For ships carrying liquefied gas in bulk, a design solution has been recently introduced by the shipbuilding industry to prevent accidents in which personnel come in contact with cold surfaces; that design proposes installation of permanent walkways called "flying passage" or "catwalk" or by installing cargo piping at a distance from walkways taking into account ergonomic standards, such as ASTM C1696-15 Industrial Thermal Insulation Systems.

48 In applying the IGC Code and MSC.1/Circ.1625 to that design, IACS members have received a proposal from the industry suggesting that thermal insulation is not necessarily required on the surface of such pipes, because personnel do not directly touch the cargo piping under normal conditions in the cases mentioned above, as well as in the examples provided in paragraphs 6.2.1 to 6.2.3 of MSC.1/Circ.1625. IACS agrees with the suggestion as the provision proposed for paragraph 6.2.4, as shown in annex 1 section E of this document, is respected on recent ship designs and arrangements on board.

49 In addition to the above, for the purposes of paragraph 5.12.3.1 of the IGC Code, IACS is of the opinion that the requirements for thermal insulation should apply not only to pipes but also to process pressure vessels as well, and it should be clarified that the term "cargo piping systems" in paragraph 5.12.3.1 of the IGC Code includes process pressure vessels.

50 In order to facilitate universal and uniform implementation, IACS proposes an amendment to MSC.1/Circ.1625 on unified interpretation of paragraph 5.12.3.1 of the IGC Code as set out in section E of annex 1 to this document.

51 Noting the ongoing work in the Sub-Committee on the revision of the IGC Code, section E of annex 2 to this document contains the corresponding draft amendment to the IGC Code, should the Sub-Committee decide to favour the amendment of the IGC Code route.

F Unified interpretation of paragraph 5.12.4 of the IGC Code regarding corrosion of cargo piping in the presence of a salt-laden atmosphere on exposed deck

52 Paragraph 5.12.4 of the IGC Code reads:

> "5.12.4 Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt-laden atmosphere, adequate measures to avoid this occurring shall be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection."

53 Table 6.4 of the IGC Code indicates that austenitic steels, such as types 304 and 304L, maybe used for cargo and process piping for design temperatures below 0°C and down to -165°C.

54 During surveys of gas ships in service, IACS members' surveyors have reported several pitting corrosion issues of deck piping such as the one shown in the below photo. Such pitting corrosion is leading to gas leakages, increasing methane and other harmful gases fugitive emissions and flammability and toxicity hazards and risks.

Figure 1 – Example of pitting on cargo piping

55 Pitting and other corrosion occurs mostly on pipes fitted on exposed deck; it is industry's best practice to fabricate those pipes using material with enhanced properties against corrosion, such as austenitic steel 316, 316L instead of 304/304L which, in the presence of salt-laden atmosphere on open deck, accelerate further pitting corrosion rates and increase the susceptibility to chloride stress corrosion cracking.

56 IACS understands that although the hard synthetic cover for the insulation may be efficient at the initial stage of the life of the ship, the cover deteriorates with the normal use at sea, under heat and sun light and, therefore, it cannot be considered as a suitable adequate measure for the life of the ship to avoid corrosion of the piping located on exposed open deck.

57 Furthermore, the use of material 304/304L is generally not permitted in exposed marine environments for other maritime industries because of its lower pitting corrosion resistance number (PREN) ~19 vs material 316L which has PREN ~24 (reference is made to international standards such as ISO 21457 and Norsok M-001, Table 10).

58 Based on the above evidence and references, IACS considers that the requirements of paragraph 5.12.4 of the IGC Code need to be interpreted and/or amended to take into consideration the potential of pitting corrosion and chloride stress corrosion cracking which would lead to methane and other harmful gases emissions, flammability and toxicity hazards.

59 In order to avoid possible misunderstanding, IACS proposes a unified interpretation of paragraph 5.12.4 of the IGC Code on cargo piping located on exposed open deck as set out in section F of annex 1 to this document.

60 Noting the ongoing work in the Sub-Committee on the revision of the IGC Code, section F of annex 2 to this document contains the corresponding draft amendment to the IGC Code, should the Sub-Committee decide to favour the amendment of the IGC Code route.

Action requested of the Sub-Committee

61 The Sub-Committee is invited to consider the foregoing and in particular:

.1 proposals in paragraphs 11, 18, 28, 43, 50 and 59 related to the draft unified interpretations in annex 1 of this document; or

.2 proposals for corresponding amendments of the IGC Code contained in annex 2 of this document as explained in paragraphs 12, 19, 29, 44, 51, and 60 above; and

.3 take action, as appropriate.

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ANNEX 1

DRAFT UNIFIED INTERPRETATIONS OF THE IGC CODE

A Draft unified interpretation of paragraphs 5.2.2.1 and 9.4.4 of the IGC Code

Paragraphs 5.2.2.1 and 9.4.4 of the IGC Code read:

"5.1 General

5.1.1 The requirements of this chapter shall apply to products and process piping, including vapour piping, gas fuel piping and vent lines of safety valves or similar piping. Auxiliary piping systems not containing cargo are exempt from the general requirements of this chapter.

5.2 System requirements

5.2.2 Arrangements: general

5.2.2.1 Any piping system that may contain cargo liquid or vapour shall:

.1 be segregated from other piping systems, except where interconnections are required for cargo related operations such as purging, gas freeing or inerting. The requirements of 9.4.4 shall be taken into account with regard to preventing back-flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections;";

"9.4 Inerting

9.4.4 Arrangements to prevent the backflow of cargo vapour into the inert gas system that are suitable for the cargo carried shall be provided. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves or equivalent devices and, in addition, a removable spool piece shall be fitted in the inert gas main in the cargo area. When not in use, the inert gas system shall be made separate from the cargo system in the cargo area except for connections to the hold spaces or inter-barrier spaces."

Chapter 15 of the FSS Code reads:

"2.2.3.1.1 At least two non-return devices shall be fitted in order to prevent the return of vapour and liquid to the inert gas plant, or to any gas-safe spaces.

2.2.3.1.2 The first non-return device shall be a deck seal of the wet, semi-wet, or dry type or a double-block and bleed arrangement. Two shut-off valves in series with a venting valve in between, may be accepted provided:

.1 the operation of the valve is automatically executed. Signal(s) for opening/closing is (are) to be taken from the process directly, e.g. inert gas flow or differential pressure; and

.2 alarm for faulty operation of the valves is provided, e.g. the operation status of "blower stop" and "supply valve(s) open" is an alarm condition.

2.2.3.1.3 The second non-return device shall be a non-return valve or equivalent capable of preventing the return of vapours and liquids and fitted between the deck water seal (or equivalent device) and the first connection from the inert gas main to a cargo tank. It shall be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the first connection to the cargo tanks to isolate the deck water seal, or equivalent device, from the inert gas main to the cargo tanks."

Interpretation

1 The risk of cargo liquid or vapour backflow to inert gas or nitrogen system equally affects connection to cargo and gas fuel system when such systems are kept under pressure. The expression in paragraph 5.2.2.1 of the IGC Code "any systems containing cargo liquid or vapours" should be understood to address both the cargo system and the gas fuel system.

2 Connections between the inert gas/nitrogen system and the mentioned two systems, when not in use, should be segregated with removable spool pieces and blanks. Where permanent connections are required for automated purging of lines, arrangement to prevent back flow of cargo vapours or liquid into the inert gas distribution system should be provided with due regard to properties of product and system design criteria (temperature, pressure and physical state of fluid) and should meet the requirements of paragraph 2.2.3.1 of chapter 15 of the FSS Code.

3 Double-block and bleed valves arrangement for automatic operation should meet the requirements of paragraph 2.2.3.1.2.1 of chapter 15 of the FSS Code.

B Draft unified interpretation of paragraphs 8.1 and 16.3.4 of the IGC Code regarding separation between fuel gas and cargo containment vent systems

Paragraph 8.1 of the IGC reads as follows:

"8.1 ... Pressure control systems specified in chapter 7 shall be independent of the pressure relief systems."

Paragraph 16.3.4 of the IGC reads as follows:

"16.3.4 All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space...".

Interpretation

As thermal oxidation where the boil-off vapours are utilized as fuel for shipboard use is part of cargo pressure control, all piping arrangements for vents and bleed lines that may contain or be contaminated by gas fuel, including any vent mast, for the fuel gas system from spaces containing gas consumers should be maintained independent from the vent system for cargo containment to prevent flow of venting vapour from cargo area to the space containing the gas consumer.

C Draft unified interpretation of paragraphs 17.4 of the IGC Code on refrigeration systems

Paragraph 17.1 of the IGC Code states:

"17.1 General

The requirements of this chapter are applicable where reference thereto is made in column "i" in the table of chapter 19. These requirements are additional to the general requirements of the Code."

Paragraph 17.4 of the IGC Code states:

"17.4 Refrigeration systems

17.4.1 Only the indirect system described in 7.3.1.2 shall be used.

17.4.2 For a ship engaged in the carriage of products that readily form dangerous peroxides, recondensed cargo shall not be allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:

.1 using the indirect system described in 7.3.1.2, with the condenser inside the cargo tank; or

.2 using the direct system or combined system described in 7.3.1.1 and .3 respectively, or the indirect system described in 7.3.1.2 with the condenser outside the cargo tank and designing the condensate system to avoid any places in which liquid could collect and be retained. Where this is impossible, inhibited liquid shall be added upstream of such a place.

17.4.3 If the ship is to consecutively carry products as specified in 17.4.2 with a ballast passage between, all uninhibited liquid shall be removed prior to the ballast voyage. If a second cargo is to be carried between such consecutive cargoes, the reliquefication system shall be thoroughly drained and purged before loading the second cargo. Purging shall be carried out using either inert gas or vapour from the second cargo, if compatible. Practical steps shall be taken to ensure that polymers or peroxides do not accumulate in the cargo system."

Interpretation

The special requirements in relation to paragraphs 17.4.1, 17.4.2 and 17.4.3 of the IGC Code listed under column "i" in table of chapter 19 of the IGC Code should be applicable only when a refrigeration system is required or used to maintain the cargo tank pressure and temperature within design limits of the containment system and/or carriage requirements of the cargo indicated on the Certificate of Fitness.

D0 Draft unified interpretation of paragraph 4.23.3.1 of the IGC Code

Permissible stresses of the stiffening ring of type C cargo tanks using FE method

Paragraph 4.23.3.1 of the IGC Code reads:

"4.23.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5f$
$\sigma_L + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$,

where:

σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;
σ_g = equivalent secondary stress; and
f = the lesser of Rm /A or Re /B,

with R_m and R_e as defined in 4.18.1.3. With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in 4.28.3 are referred. The values A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least the following minimum values:

	Nickel steels and carbon-manganese steels	**Austenitic steels**	**Aluminium alloys**
A	3	3.5	4
B	1.5	1.5	1.5

"

Interpretation

1 Calculated stresses using FE method in stiffening rings

The calculated stresses of the stiffening ring of type C cargo tanks using finite element method should be performed according to the unified interpretation on "finite element analysis of type C cargo tanks".

2 Permissible stresses of stiffening rings modelled by finite element methods

The strength of stiffening rings of type C cargo tanks should be checked. The permissible stresses of the stiffening ring should not exceed that of the tank body defined in the unified interpretation on "finite element analysis of type C cargo tanks".

3 For calculation of reaction forces at the supports, the following factors should be taken into account:

.1 elasticity of support material of wood or similar material; and

.2 change in contact surface between tank and support, and of the relevant reactions, due to:

.1 thermal shrinkage of tank; and

.2 elastic deformations of tank and support material.

The final distribution of the reaction forces at the supports should not show any tensile forces.

D1 Draft unified interpretation on "finite element analysis of type C cargo tanks"

Paragraph 4.23.3.1 of the IGC Code reads:

"4.23.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5f$
$\sigma_L + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$,

where:

σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;
σ_g = equivalent secondary stress; and
f = the lesser of Rm /A or Re /B,

with R_m and R_e as defined in 4.18.1.3. With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in 4.28.3 are referred. The values A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least the following minimum values:

	Nickel steels and carbon-manganese steels	**Austenitic steels**	**Aluminium alloys**
A	3	3.5	4
B	1.5	1.5	1.5

"

Interpretation

1 General

1.1 The allowable stresses described in paragraph of 4.23.3.1 of the IGC Code should be applicable for the finite element analysis of the type C cargo tanks.

1.2 As a supplement to the prescriptive requirements, the finite element analysis of the type C cargo tanks may be carried out for the following cases:

.1 locations where a structural strength cannot be assessed by the prescriptive requirements, e.g. structural discontinuities in way of tank support, Y connection of bi-lobe and multi-lobe tank, etc.; and

.2 tanks of novel design or configuration.

1.3 The procedure for finite element analysis should be in accordance with the recognized standards such as ASME Boiler and Pressure Vessel Code, section VIII, Division 2 or other equivalent which is acceptable to the recognized organization / classification society provided the maximum strength utilizations in paragraph 4.23.3.1 of the IGC Code should be complied with.

1.4 The IACS Recommendation 174 could be applied as a guidance.

1.5 The scantling defined by the prescriptive requirements on a type C tank of the IGC Code should not be reduced by any form of alternative calculations using finite element analysis.

2 Allowable stresses for finite element analysis

2.1 In general, finite element models composed of 2D shell element or solid 3D element should be considered acceptable for stress calculation.

2.2 The application of allowable stresses for linear finite element analysis of a type C tank body using 2D shell element or solid 3D element should be as given in table 1.

Table 1 Application of allowable stresses for finite element analysis of a type C tank body using the FE 2D shell element or solid 3D element

The IGC Code criterion	Application for FE 2D shell element or 3D element	
	Finite Element Results Check	Locations where check should be applied
$\sigma_m \leq f$	$\sigma_{e\_membrane} \leq f$ 1)	[A] Areas remote from structural discontinuities
$\sigma_L \leq 1.5f$	$\sigma_{e\_membrane} \leq 1.5f$ 1)	[B] Area in way of structural discontinuities
$\sigma_b \leq 1.5f$	$\sigma_{e\_surface} \leq 1.5f$ 1)	[C] Any area([A] or [B]) where bending stresses exist
$\sigma_L + \sigma_b \leq 1.5f$	$\sigma_{e\_surface} \leq 1.5f$ 1)	See [B] and [C]
$\sigma_m + \sigma_b \leq 1.5f$	$\sigma_{e\_surface} \leq 1.5f$ 1)	See [A] and [C]
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$	$\sigma_{e\_surface} \leq 3.0f$ 1), 2)	See [A] and [C]
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$	$\sigma_{e\_surface} \leq 3.0f$ 1), 2)	See [B] and [C]

where:

$\sigma_{e\_membrane}$ is element equivalent stress derived from the stress components at the mid layer/thickness of the element.

$\sigma_{e\_surface}$ is element equivalent stress derived from the stress components at the top and bottom layer/surface of the element, whichever is greater.

Note:
For accident and testing load conditions, the allowable stresses can be modified according to paragraphs 4.23.5.2 and 4.23.6.1 of the IGC Code.

Other notes are as follows:

1) The factor f is defined in paragraph 4.23.3 of the IGC Code.

2) For the criterion $\leq 3.0f$, it should be carefully evaluated especially for materials with under matched weld properties. In such cases, the transverse weld tensile strength shall not be less than the actual yield strength of the

parent metal, the respective R_e and R_m of the weld, after any applied heat treatment, shall be used.

D2 Draft unified interpretation of paragraph 4.23.3.2 of the IGC Code on "buckling assessment of type C cargo tanks"

Paragraph 4.23.3.2 of the IGC Code reads:

"4.23.3.2 Buckling criteria shall be as follows: the thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length."

Interpretation

1 General

1.1 The scantling of a type C tank subject to external pressure should not be less than the value required by the formulas in paragraph 2 below. Alternatively, the buckling assessment based on recognized standards (e.g. ASME, PD5500, EN13445-3) or equivalent should be acceptable to recognized organization/classification society.

1.2 Regarding the lateral buckling of stiffening ring, it should be considered additionally in accordance with international standards (e.g. PD5500) or equivalent regulations.

1.3 For novel configurations where the requirements given in this document or recognized standards are not applicable, more advanced buckling assessment methods may be used as deemed appropriate by the Administration or its recognized organization.

1.4 Non-linear finite element analysis considering geometrical and material nonlinearity may be accepted as an advanced method, provided that the buckling capacity reflects the plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

2 Scantling of shells and stiffening rings under external pressure

2.1 For cylindrical shell, the critical buckling pressure P_c, in MPa, can be taken as:

$$P_c = \frac{1}{3}\left[n^2 - 1 + \frac{2n^2 - 1 - \nu}{n^2\left(\frac{2L}{\pi D}\right)^2 - 1}\right]\frac{2E}{(1-\nu^2)}\left(\frac{t}{D}\right)^3 + \frac{2E\,\frac{t}{D}}{(n^2-1)\left[n^2\left(\frac{2L}{\pi D}\right)^2 + 1\right]^2}$$

where:

D=outside diameter of the cylindrical shell, in mm, based on gross scantling
t=net thickness of the cylindrical shell, in mm, exclusive of corrosion allowance
E=Young's modulus, in N/mm^2
ν =Poisson's ratio
n= number of circumferential buckling waves. It is to be taken as the integral value to minimize the critical pressure P_c with $n \geq Max\left(2, \frac{\pi D}{2L}\right)$.
L=effective distance between stiffening rings, in mm

2.2 For spherical shells such as hemispherical, torispherical and ellipsoidal ends, the critical buckling pressure P_c, in MPa, can be taken as:

$$P_c = 1.21\mathrm{E}\left(\frac{t}{R}\right)^2$$

where:

R=outside radius of the sphere shell, in mm, based on gross scantling
E=Young's modulus, in N/mm^2
t=net thickness of the spherical shell, in mm, exclusive of corrosion allowance

The critical buckling pressure formula for the spherical shell above should be used for hemispherical, tori spherical and ellipsoidal tank ends, where R is taken as the outside radius of the corresponding spherical shell for hemispherical and tori spherical tank ends, and the maximum outside radius of the crown for an ellipsoidal tank end, i.e. $D^2/(4h)$, where h is the external height of the tank end measured based on gross scantling from the connection plane between the cylindrical shell and tank end.

2.3 For stiffening ring, the moment of inertia *I*, in mm^4, should not be less than

$$I = \frac{0.18D^3LP_e}{E}$$

where:

D = outside diameter of the cylindrical shell, in mm, based on gross scantling
E=Young's modulus, in N/mm^2
L=effective distance between stiffening rings, in mm
P_e=external design pressure, in MPa

The width of shell, in mm, contributing to the moment of inertia should not be greater than $0.75\sqrt{Dt}$, where t=net thickness of the cylindrical shell, in mm, exclusive of corrosion allowance.

2.4 Cylindrical and spherical shells should satisfy the following criteria:

$$\frac{P_c}{P_e} \geq 4 \text{ for cylindrical shell}$$

$$\frac{P_c}{P_e} \geq 15 \text{ for spherical shell}$$

where:

Pc=critical buckling pressure, in MPa
Pe=external design pressure, in MPa

D3 Draft unified interpretation of paragraphs 4.23.1.1, 4.23.1.2, 4.23.2.5 and 4.23.4 of the IGC Code (fatigue analysis of type C cargo tanks)

Paragraphs 4.23.1.1, 4.23.1.2, 4.23.2.5 and 4.23.4 of IGC Code read:

"4.23.1.1 The design basis for type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in 4.23.1.2 is intended to ensure that the dynamic stress is sufficiently low, so that an initial surface flaw will not propagate more than half thickness of the shell during the lifetime of the tank.

4.23.1.2 The design vapour pressure shall not be less than:

$$P_0 = 0.2 + AC(\rho_r)^{1.5} \text{ (MPa)}$$

where:

$$A = 0.00185\left(\frac{\sigma_m}{\Delta\sigma_A}\right)^2$$

with:

σ_m = design primary membrane stress;

$\Delta\sigma_A$ = allowable dynamic membrane stress (double amplitude at probability level Q = 10^{-8}) and equal to:

- 55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel;
- 25 N/mm^2 for aluminium alloy (5083-O);

C = a characteristic tank dimension to be taken as the greatest of the following:
h, 0.75b or 0.45ℓ

with:
h = height of tank (dimension in ship's vertical direction) (m);
b = width of tank (dimension in ship's transverse direction) (m);
ℓ = length of tank (dimension in ship's longitudinal direction) (m);
ρr = the relative density of the cargo (ρr = 1 for fresh water) at the design temperature.

When a specified design life of the tank is longer than 10^8 wave encounters, ΔσA shall be modified to give equivalent crack propagation corresponding to the design life.

4.23.2.5 Stress analysis in respect of static and dynamic loads shall be performed as follows:

.1 Pressure vessel scantlings shall be determined in accordance with 4.23.2.1 to 4.23.2.4 and 4.23.3.

.2 Calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in 4.12 to 4.15 shall be used, as applicable. Stresses in way of the supporting structures shall be to a recognized standard acceptable to the Administration or recognized organization acting on its behalf. In special cases, a fatigue analysis may be required by the Administration or recognized organization acting on its behalf.

.3 If required by the Administration or recognized organization acting on its behalf, secondary stresses and thermal stresses shall be specially considered.

4.23.4 Fatigue design condition

For large type C independent, where the cargo at atmospheric pressure is below -55°C, the administration or recognized organization acting on its behalf may require additional verification to check their compliance with 4.23.1.1 regarding static and dynamic stress."

Interpretation

1 Factor of safety for the fracture mechanics analysis of fatigue crack growth

Factor of safety 2 should be applied to the dynamic stress range to ensure that equivalent level of safety to the design vapour pressure calculation formula is achieved.

2 Maximum allowable cumulative fatigue damage ratio for the fatigue analysis

Maximum allowable cumulative fatigue damage ratio, C_w, for the tank shell should not exceed 0.1.

E Draft amendments to MSC.1/Circ.1625 on unified interpretation of paragraph 5.12.3.1 of the IGC Code

Section 6 "Cargo piping insulation (paragraph 5.12.3.1)" is proposed to be amended as follows:[*]

"6.1 The expression "a thermal insulation system as required to minimize heat leak into the cargo during transfer operations" means that properties of the piping insulation should be taken into consideration when calculating the heat balance of the containment system and capacity of the pressure/temperature control system.

6.2 The expression "cargo piping systems shall be provided with a thermal insulation system as required ... to protect personnel from direct contact with cold surfaces" means that surfaces of cargo piping and/or equipment (including process pressure vessels) ~~systems~~ with which personnel are likely to have contact under normal conditions should be protected by a thermal insulation, with the exception of the following examples:

.1 surfaces of cargo piping and/or equipment ~~systems~~ which are protected by physical screening measures to prevent such direct contact;

.2 surfaces of manual valves having extended spindles that protect the operator from the cargo temperature; ~~and~~

.3 surfaces of cargo piping and/or equipment ~~systems~~ whose design temperature (to be determined from inner fluid temperature) is above minus 10°C; and

.4 surfaces of cargo piping and/or equipment situated in the places where it is unlikely or not practicable for personnel to contact under normal conditions based on recognized national or international standards, preferably more than 2.0 meter[m] vertically and/or 0.6 meter[m] horizontally away from walkways and working areas etc."

F Draft unified interpretation of paragraph 5.12.4 of the IGC Code for cargo piping located on exposed open deck

Paragraph 5.12.4 of the IGC Code states:

"5.12.4 Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt-laden atmosphere, adequate measures to avoid this occurring shall be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection."

[*] Here and further in the document, tracked changes are indicated using "strikeout" for deleted text and "grey shading" to highlight all modifications and new insertions, including deleted text.

Interpretation

When cargo piping system is located on open deck and it is fabricated using stainless steel having a pitting resistance equivalent number (PREN = 1 • %Cr + 3.3 (%Mo + 0.5 • %W) + 16 • %N) less than 22, cargo pipes should be protected by a coating suitable for the intended service conditions including cryogenic temperature, if applicable, and or using stainless steel having PREN no less than 22 such as 316/316L or higher.

Detailed specification of the coating and its application should be submitted.

Where piping, whether it is made of corrosion resistant material or protected by a coating, is covered by thermal insulation, arrangements should be provided to regularly carry out inspections for condition of the piping, as required.

***

ANNEX 2

PROPOSED DRAFT AMENDMENTS TO THE IGC CODE INCORPORATING REQUIREMENTS ADDRESSING ISSUES RAISED AS UNIFIED INTERPRETATIONS CONTAINED IN ANNEX 1 OF THIS DOCUMENT

A Draft amendment of paragraphs 5.2.2.1 and 16.4.1 of the IGC Code on connections between inert gas / nitrogen systems and systems containing cargo liquid or vapours (cargo system and gas fuel system)

The following amendments are proposed:

"5.2.2 Arrangements: general

5.2.2.1 Any piping system addressed in 5.1.1 that may contain cargo liquid or vapour shall:

.1 be segregated from other piping systems, except where interconnections are required for cargo related operations such as purging, gas freeing or inerting. The requirements of 9.4.4 and 16.4.1.3 shall be taken into account with regard to preventing back-flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections;

.2 except as provided in chapter 16, not pass through any accommodation space, service space or control station or through a machinery space other than a cargo machinery space;

.3 be connected to the cargo containment system directly from the weather decks except where pipes installed in a vertical trunkways or equivalent are used to traverse void spaces above a cargo containment system and except where pipes for drainage, venting or purging traverse cofferdams;

.4 be located in the cargo area above the weather deck except for bow or stern loading and unloading arrangements in accordance with 3.8, emergency cargo jettisoning piping systems in accordance with 5.3.1, turret compartment systems in accordance with 5.3.3 and except in accordance with chapter 16; and

.5 be located inboard of the transverse tank location requirements of 2.4.1, except for athwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning piping systems. ";

"16.4 Gas fuel supply

16.4.1 General

16.4.1.1 The requirements of this section shall apply to gas fuel supply piping outside of the cargo area. Fuel piping shall not pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. The routeing of the pipeline shall take into account potential hazards, due to mechanical damage, in areas such as stores or machinery handling areas.

16.4.1.2 Provision shall be made for inerting and gas freeing that portion of the gas fuel piping systems located in the machinery space.

16.4.1.3 Where permanent inert gas connection is required between inert gas line and gas fuel line, such connection shall be equipped with a set of double block and bleed valves to preventing backflow of gas fuel into inert gas line. In addition, a closable non-return valve shall be installed between the double block and bleed arrangement and the gas fuel system."

B Draft amendment of paragraph 16.3.4 of the IGC Code regarding separation between fuel gas and cargo containment vent systems

A new sub-paragraph of 16.3.4 of the IGC Code is proposed to be added as follows:

"16.3 Arrangement of spaces containing gas consumers

16.3.4 All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space and be fitted with a flame screen.

16.3.4.1 Piping for the fuel gas vent system from gas consumers shall be maintained independent from vent systems for cargo containment."

C Draft amendment of paragraph 17.4 of the IGC Code on refrigeration systems

Paragraph 17.4 of the IGC Code is proposed to be amended as follows:

"17.4 Refrigeration systems

The special requirements described hereafter as listed under column "i" in the table of chapter 19 of the IGC Code are applicable only when a refrigeration system is required or used to maintain the cargo tank pressure and temperature within design limits of the containment system and/or carriage requirements of the cargo indicated on the Certificate of Fitness.

17.4.1 Only the indirect system described in 7.3.1.2 shall be used.

17.4.2 For a ship engaged in the carriage of products that readily form dangerous peroxides, recondensed cargo shall not be allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:

.1 using the indirect system described in 7.3.1.2, with the condenser inside the cargo tank; or

.2 using the direct system or combined system described in 7.3.1.1 and .3 respectively, or the indirect system described in 7.3.1.2 with the condenser outside the cargo tank and designing the condensate system to avoid any places in which liquid could collect and be retained. Where this is impossible, inhibited liquid shall be added upstream of such a place.

17.4.3 If the ship is to consecutively carry products as specified in 17.4.2 with a ballast passage between, all uninhibited liquid shall be removed prior to the ballast voyage. If a second cargo is to be carried between such consecutive cargoes, the reliquefication system shall be thoroughly drained and purged before loading the second cargo. Purging shall be carried out using either inert gas or vapour from the second cargo, if compatible. Practical steps shall be taken to ensure that polymers or peroxides do not accumulate in the cargo system."

D0 Draft amendment to paragraph 4.23.3 of the IGC Code (type C independent tanks)

Paragraph 4.23.3 of the IGC Code is proposed to be amended as follows:

"4.23 Type C independent tanks

4.23.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5f$
$\sigma_L + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$,

where:

σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;
σ_g = equivalent secondary stress; and
f = the lesser of R_m /A or R_e /B,

with R_m and R_e as defined in 4.18.1.3. With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in 4.28.3 are referred. The values A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least the following minimum values:

	Nickel steels and carbon-manganese steels	**Austenitic steels**	**Aluminium alloys**
A	3	3.5	4
B	1.5	1.5	1.5

4.23.3.2 Buckling criteria shall be as follows: the thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

4.23.3.3 Guidance is given in 4.28.4 and 4.28.5 for finite element analysis and buckling assessment respectively."

D1 Draft amendments to paragraph 4.28.4 of the IGC Code

A new paragraph 4.28.4 of the IGC Code is proposed as follows:

"4.28 Guidance notes for chapter 4

4.28.4 Guidance to finite element analysis of type C tanks

4.28.4.1 General

1. The allowable stresses described in 4.23.3.1 are applicable for the finite element analysis of the type C tanks.

2. As a supplement to the prescriptive requirements, the finite element analysis of the type C cargo tanks may be carried out for the following cases:

   a. Locations where a structural strength cannot be assessed by the prescriptive requirements, e.g. structural discontinuities in way of tank support, Y connection of bi-lobe and multi-lobe tank, etc.

   b. Tanks of novel design or configuration

3. The procedure for finite element analysis should be in accordance with the recognized standards such as ASME Boiler and Pressure Vessel Code, section VIII, Division 2 or other equivalent which is acceptable to the Administration provided the maximum strength utilizations in 4.23.3.1 are complied with.

4. The scantling defined by the prescriptive requirements on the type C tank of the Code is not to be reduced by any form of alternative calculations using finite element analysis.

5. For calculation of reaction forces at the tank supports, the following factors should be taken into account using finite element method:

   a. Elasticity of support material (intermediate layer of wood or similar material).

   b. Change in contact surface between tank and support, and of the relevant reactions, due to thermal shrinkage of tank, elastic deformations of tank and support material. The final distribution of the reaction forces at the supports should not show any tensile forces.

4.28.4.2 Allowable stresses for finite element analysis:

1. In general, finite element models composed of 2D shell element or solid 3D element are considered acceptable for stress calculation.

2. The application of allowable stresses for linear finite element analysis of the type C tank body using 2D shell element or solid 3D element is given in the following table.

3. The strength of stiffening rings of type C tanks are to be checked, the calculated stresses of the stiffening ring of type C tanks using finite element method are to be performed according to 4.28.4, and the permissible stresses of the stiffening rings shall not exceed that of the tank body defined in 4.28.4.

Application of allowable stresses for finite element analysis of the Type C tank body using the FE 2D shell element or 3D element

Code Criterion given in 4.23.3.1	Application for FE 2D shell element or 3D element	
	Finite Element Results Check	**Locations where check should be applied**
$\sigma_m \leq f$	$\sigma_{e\_membrane} \leq f$ 1)	[A] Areas remote from structural discontinuities
$\sigma_L \leq 1.5f$	$\sigma_{e\_membrane} \leq 1.5f$ 1)	[B] Area in way of structural discontinuities
$\sigma_b \leq 1.5f$	$\sigma_{e\_surface} \leq 1.5f$ 1)	[C] Any area([A] or [B]) where bending stresses exist
$\sigma_L + \sigma_b \leq 1.5f$	$\sigma_{e\_surface} \leq 1.5f$ 1)	See [B] and [C]
$\sigma_m + \sigma_b \leq 1.5f$	$\sigma_{e\_surface} \leq 1.5f$ 1)	See [A] and [C]
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$	$\sigma_{e\_surface} \leq 3.0f$ 1), 2)	See [A] and [C]
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$	$\sigma_{e\_surface} \leq 3.0f$ 1), 2)	See [B] and [C]

where:

$\sigma_{e\_membrane}$ is element equivalent stress derived from the stress components at the mid layer/thickness of the element.

$\sigma_{e\_surface}$ is element equivalent stress derived from the stress components at the top and bottom layer/surface of the element, whichever is greater.

Note:
For accident and testing load conditions, the allowable stresses can be modified according to the 4.23.5.2 and 4.23.6.1of the IGC Code.

Other notes are as follow:

1) The factor f is defined in the IGC Code 4.23.3.

2) For the criterion $\leq 3.0f$, it should be carefully evaluated especially for materials with under matched weld properties. In such cases, the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal, the respective R_e and R_m of the weld, after any applied heat treatment, shall be used.

"

D2 Draft amendments to paragraph 4.28.5 of the IGC Code

A new paragraph 4.28.5 of the IGC Code is proposed as follows:

"4.28 Guidance notes for chapter 4

4.28.5 Buckling assessment of type C cargo tanks

4.28.5.1 General

1.1 The scantling of type C tank subject to external pressure is not to be less than the value required by the formulas in 4.28.5.2. Alternatively, the buckling assessment based on recognized standards (e.g. ASME, PD5500, EN13445-3) or equivalent is acceptable to the Administration.

1.2 Regarding the lateral buckling of stiffening ring, it should be considered additionally in accordance with international standards (e.g PD5500) or equivalent regulations.

1.3 For novel configurations where the requirements given in this subsection or recognized standards are not applicable, more advanced buckling assessment methods may be used as deemed appropriate by the Administration.

1.4 Non-linear finite element analysis considering geometrical and material non-linearity may be accepted as an advanced method, provided that the buckling capacity reflects the plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

4.28.5.2 Scantling of shells and stiffening rings under external pressure

.2.1 For cylindrical shell, the critical buckling pressure P_c, in MPa, can be taken as:

$$P_c = \frac{1}{3}\left[n^2 - 1 + \frac{2n^2 - 1 - \nu}{n^2\left(\frac{2L}{\pi D}\right)^2 - 1}\right]\frac{2E}{(1-\nu^2)}\left(\frac{t}{D}\right)^3 + \frac{2E\frac{t}{D}}{(n^2-1)\left[n^2\left(\frac{2L}{\pi D}\right)^2 + 1\right]^2}$$

where:
D=outside diameter of the cylindrical shell, in mm, based on gross scantling
t=net thickness of the cylindrical shell, in mm, exclusive of corrosion allowance
E=Young's modulus, in N/mm^2
v=Poisson's ratio
n= number of circumferential buckling waves. It is to be taken as the integral value to minimize the critical pressure P_c with $n \geq Max\left(2, \frac{\pi D}{2L}\right)$.
L=effective distance between stiffening rings, in mm

.2.2 For spherical shells such as hemispherical, torispherical and ellipsoidal ends, the critical buckling pressure P_c, in MPa, can be taken as:

$$P_c = 1.21\mathrm{E}\left(\frac{t}{R}\right)^2$$

where:
R=outside radius of the sphere shell, in mm, based on gross scantling
E=Young's modulus, in N/mm^2
t=net thickness of the spherical shell, in mm, exclusive of corrosion allowance

The critical buckling pressure formula for the spherical shell above is to be used for hemispherical, tori spherical and ellipsoidal tank ends, where R is taken as the outside radius of the corresponding spherical shell for hemispherical and tori spherical tank ends, and the maximum outside radius of the crown for an ellipsoidal tank end, i.e. $D^2/(4h)$, where h is the external height of the tank end measured based on gross scantling from the connection plane between the cylindrical shell and tank end.

.2.3 For stiffening ring, the moment of inertia *I*, in mm^4, shall not be less than

$$I = \frac{0.18 D^3 L P_e}{E}$$

where:
D = outside diameter of the cylindrical shell, in mm, based on gross scantling
E=Young's modulus, in N/mm^2
L=effective distance between stiffening rings, in mm
P_e=external design pressure, in MPa
The width of shell, in mm, contributing to the moment of inertia shall not be greater than $0.75\sqrt{Dt}$, where t=net thickness of the cylindrical shell, in mm, exclusive of corrosion allowance.

.2.4 Cylindrical and spherical shells are to satisfy the following criteria:

$$\frac{P_c}{P_e} \geq 4 \text{ for cylindrical shell}$$

$\frac{P_c}{P_e} \geq 15$ for spherical shell
where:
P_c=critical buckling pressure, in MPa
P_e=external design pressure, in MPa".

D3 Draft amendments to paragraph 4.23.4 of the IGC Code (Fatigue analysis of type C cargo tanks)

Paragraph 4.23.4 of the IGC Code is proposed to be amended as follows:

"4.23 Type C independent tanks

4.23.4 Fatigue design condition

For large type C independent tanks, where the cargo at atmospheric pressure is below -55°C, the Administration or recognized organization acting on its behalf may require additional verification to check their compliance with 4.23.1.1 regarding static and dynamic stress.

4.23.4.1 Factor of safety 2 shall be applied to the dynamic stress range to ensure that equivalent level of safety to that of design vapour pressure calculation formula is achieved.

4.23.4.2 Maximum allowable cumulative fatigue damage ratio, C_w, for the tank shell shall not exceed 0.1."

E ***Draft amendment of paragraph 5.12.3.1 of the IGC Code on cargo piping insulation***

Paragraph 5.12.3.1 of the IGC Code is proposed to be amended as follows:

"5.12.3 Cargo piping insulation system

5.12.3.1 Cargo piping systems shall be provided with a thermal insulation system as required to minimize heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces, taking into account:

.1 the expression "a thermal insulation system as required to minimize heat leak into the cargo during transfer operations" means that properties of the piping insulation shall be taken into consideration when calculating the heat balance of the containment system and capacity of the pressure/temperature control system; and

.2 the expression "cargo piping systems shall be provided with a thermal insulation system as required ... to protect personnel from direct contact with cold surfaces" means that surfaces of cargo piping and/or equipment (including process pressure vessels) with which personnel are likely to have contact under normal conditions shall be protected by a thermal insulation, with the exception of the following examples:

  .1 surfaces of cargo piping and/or equipment which are protected by physical screening measures to prevent such direct contact;

  .2 surfaces of manual valves having extended spindles that protect the operator from the cargo temperature;

  .3 surfaces of cargo piping and/or equipment whose design temperature (to be determined from inner fluid temperature) is above minus 10°C; and

  .4 surfaces of cargo piping and/or equipment situated in the places where it is unlikely or not practicable for personnel to contact under normal conditions based on recognized national or international standards, preferably more than 2.0 meter[m] vertically and/or 0.6 meter[m] horizontally away from walkways and working areas etc."

F ***Draft amendment of paragraph 5.12.4 of the IGC Code for cargo piping located on exposed open deck***

Paragraph 5.12.4 of the IGC Code is proposed to be amended as follows:

"5.12.4 Where the cargo piping system is ~~of a material susceptible to stress corrosion cracking~~ in the presence of a salt-laden atmosphere (exposed deck), adequate measures to avoid ~~this~~ corrosion and stress corrosion cracking occurring shall be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection.

5.12.4.1 For cargo piping system located on open exposed deck, the pipes shall be fabricated using stainless steel having a pitting resistance equivalent number (PREN = 1 • %Cr + 3.3 (%Mo + 0.5 • %W) + 16 • %N) no less than 22 such as 316/316L or higher; otherwise cargo pipes are to be protected by a corrosion coating system suitable for the intended service conditions."