CHINA CLASSIFICATION SOCIETY

RULES FOR CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK

AMENDMENTS

2022

Beijing

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PART TWO CLASSIFICATION SURVEY AND ADDITIONAL REQUIREMENTS FOR HULL STRUCTURE

Chapter A2 CLASSIFICATION AND SURVEYS

Section 2 CHARACTERS OF CLASSIFICATION AND CLASS NOTATIONS

A2.2.2 Class Notations

A2.2.2.4 ~~Class notations of~~ Type of ship notation, cargo and loading characteristics notation of ships carrying liquefied gases in bulk are as follows, which are to be assigned in accordance with principles for identification in Appendix 1, Chapter 2, PART ONE of CCS Rules for Classification of Sea-going Steel Ships:

(1) Type of ship notation is assigned in the order of ship type, protection against cargo leakage and tank type, which are separated by comma:

① Ship type

~~①~~ (a) Liquefied Gas Carrier

For ships mainly carrying one or more of the products listed in Chapter 19 of PART THREE of the Rules, the words "for+ product name" may be appended after notation "Liquefied Gas Carrier". The product name is to be in accordance with column "a" of the table of minimum requirements in Chapter 19 of PART THREE of the Rules, e.g.:

Class notation of ships carrying liquefied ethane: Liquefied Gas Carrier for Ethane

Class notation of ships carrying liquefied butane, butane/propane mixture: Liquefied Gas Carrier for Butane, ~~Butane and Propane~~ Butane-propane mixture

~~②~~ (b) For liquefied gas carriers dedicated to carry liquefied natural gas, the following class notation may be assigned:

LNG Carrier

~~(2) Other class notations~~

② Protection against cargo leakage

~~①~~(a) In accordance with the degree of protection against cargo leakage and the requirement for the distance between cargo tanks and shell plating, the following class notations will be appended to the ship type ~~notation "Liquefied Gas Carrier"~~ respectively:

Type 1G
Type 2G
Type 2PG
Type 3G

~~②~~(b) For the ships carrying liquefied gases in bulk which were built before 1 July 1986, and complying with IMO resolution A.328(IX) Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (hereinafter referred to as GC code), in accordance with the degree of protection against cargo leakage and the requirement for the distance between cargo tanks and shell plating, the following class notations will be appended to the ship type ~~notation "Liquefied Gas Carrier"~~ respectively:

Type IG
Type IIG
Type IIPG
Type IIIG

③ Tank type

In accordance with the type of cargo containment system, the following class notations will be appended to protection against cargo leakage respectively:

Type A Independent Tank

Type B Independent Tank

Type C Independent Tank

Integral Tank

Membrane Tank

Semi-membrane Tank

(2) Cargo and loading characteristics notation

③① Where the scantlings of structural members of cargo tanks are determined according to the designed maximum vapour pressure, the class notation for the maximum permissible vapour pressure is to be appended, e.g.:

Max. Vapour Pressure XXXMPa

② Where the scantlings of structural members of cargo tanks are determined according to the designed maximum permissible full tank cargo density, the class notation for the maximum permissible cargo density is to be appended, e.g.:

Max. Cargo Density XXX t/m^3

Note: For liquefied natural gas carriers, the maximum design cargo density is normally taken as 0.5t/m^3, and the maximum cargo density may not be indicated.

④③ For cargo tanks carrying cargo at the certified design temperature, the class notation for the cargo minimum cargo temperature is to be appended:

Min. Cargo Temperature XXX℃

⑤ The scantling of cargo tank structural members are to be determined according to the maximum design cargo density. The class notation for the maximum cargo density is to be appended, e.g.:

Max. Cargo Density XXX t/m^3

Note: For liquefied natural gas carriers, the maximum design cargo density is normally taken as 0.5t/m^3, therefore the maximum cargo density is not indicated.

⑥ In accordance with the type of cargo containment system, the following class notations are to be appended respectively:

Type A Independent Tank

Type B Independent Tank

Type C Independent Tank

Integral Tank

Membrane Tank

Semi-membrane Tank

Section 3 SURVEYS

A2.3.2 Surveys after construction

A2.3.2.2 Annual surveys

(1) The applicable requirements of 5.4.2, 5.6.2, 5.9.2, 5.10.2 and 5.16.2 in Chapter 5 of PART ONE of CCS Rules for Classification of Sea-Going Steel Ships are to be complied with.

(2) To confirm that any special arrangements to survive condition of damage are in order.

(3) To examine, where applicable, the alternative design and arrangements for the segregation of the cargo area, in accordance with the test and inspection requirements, if any, specified in the approved documentation.

(4) To confirm that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends in the cargo area are in a satisfactory condition.

(5) To examine the cargo machinery spaces and cargo compressor rooms, including their escape routes.

(6) To confirm that the manually operated ESD (emergency shutdown system) together with the automatic shutdown of the cargo pumps and compressors are satisfactory.

(7) To examine the cargo control room.

(8) To examine the gas detection arrangements for cargo control rooms and the measures taken to exclude ignition sources where such spaces are classified as hazardous areas.

(9) To confirm the arrangements for the air locks are being properly maintained.

(10) To examine, as far as practicable, the bilge, ballast and oil fuel arrangements.

(11) To examine, when applicable, the bow or stern loading and unloading arrangements with

particular reference to the electrical equipment, fire-fighting equipment and means of communication between the cargo control room and the shore location.

(12) To confirm that the sealing arrangements at the gas domes are satisfactory.

(13) To confirm that the portable or fixed drip trays or deck insulation for cargo leakage is in order.

(14) To examine the cargo and process piping, including the expansion arrangements, insulation from the hull structure, pressure relief and drainage arrangements, and water curtain protection as appropriate.

(15) To confirm that the cargo tank and interbarrier space pressure and relief valves, including safety systems and alarms, are satisfactory.

(16) To confirm that any liquid and vapour hoses are suitable for their intended purpose and type-approved or marked with date of testing.

(17) To examine the arrangements for the cargo pressure/temperature control including, when fitted, the thermal oxidation systems and any refrigeration system and to confirm that any associated safety measures and alarms are satisfactory.

(18) To examine the cargo, bunker, ballast and vent piping systems, including pressure relief valves (PRVs), vacuum relief valves, vent masts and protective screens, as far as practicable, and confirming that the PRVs are type-approved or marked with date of testing;

(19) To confirm that arrangements are made for sufficient inert gas to be carried to compensate for normal losses and that means are provided for monitoring the spaces.

(20) To confirm that the use of inert gas has not increased beyond that needed to compensate for normal losses by examining records of inert gas usage.

(21) To confirm that any air drying system and any interbarrier and hold space purging inert gas system are satisfactory.

(22) To confirm that electrical equipment in hazardous areas is in a satisfactory condition and is being properly maintained.

(23) To examine the arrangements for the fire protection and fire extinction and testing the remote means of starting one main fire pump.

(24) To examine the fixed fire-fighting system for the enclosed cargo machinery spaces, and the enclosed cargo motor room within the cargo area and confirming that its means of operation is clearly marked.

(25) To examine the water spray system for cooling, fire protection and crew protection and to confirm that its means of operation is clearly marked.

(26) To examine the dry chemical powder fire-extinguishing system for the cargo area and to confirm that its means of operation is clearly marked.

(27) To examine the appropriate fire-extinguishing system for the enclosed cargo machinery spaces for ships that are dedicated to the carriage of a restricted number of cargoes and the internal water spray system for the turret compartments and to confirm their means of operation is clearly marked.

(28) To examine, as far as practicable, and confirm the satisfactory operation of the arrangements for the mechanical ventilation of space in the cargo area normally entered during cargo handling operations.

(29) To examine and confirm the satisfactory operation of the arrangements for the mechanical ventilation of spaces normally entered, other than those covered by (28).

(30) To examine and test, as appropriate and as far as practicable, the liquid level indicators, overflow control, pressure gauges, high pressure and, when applicable, low pressure alarms, and

~~temperature indicating devices for the cargo tanks.~~

~~(31) To examine and test, as appropriate, the gas detection equipment.~~

~~(32) The cargo compatibility, proper cargo handling and daily liquefying time or evaporation rate of cargo are to be entered in the cargo record book.~~

~~(33) All accessible gas-tight bulkhead penetrations including gas-tight shaft sealings are to be visually examined.~~

~~(34) The means for accomplishing gas tightness of the wheelhouse doors and windows is to be examined. All windows and sidescuttles required to be of the fixed (non-opening) type are to be examined for gas tightness. The closing devices for all air intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and approved openings in superstructures and deckhouses facing the cargo area or bow and stern loading/unloading arrangements, are to be examined.~~

~~(35) Cargo handling systems: The cargo handling piping and machinery, e.g. cargo and process piping, cargo heat exchangers, vapourizers, pumps, compressors and cargo hoses are to be visually examined, as far as possible, during operation.~~

~~(36) Cargo containment venting systems:~~

~~A general examination is to be carried out visually for venting systems, including protection screens, for the cargo tanks, interbarrier spaces and hold spaces, to verify that the cargo tank relief valves are sealed and that the certificate for the relief valves opening/closing pressures is available onboard.~~

~~(37) Instrumentation and safety systems~~

~~① The instrumentation of the cargo installations with regard to pressure, temperature and liquid level is to be verified in good working order.~~

~~② The logbooks are to be examined for confirmation that the emergency shutdown device has been tested.~~

~~(38) Environmental control for cargo containment systems~~

~~① Inert gas/dry air installations including the means for prevention of backflow of cargo vapour to gas-safe spaces are to be verified as being in satisfactory operating condition.~~

~~② For cargo containment system of membrane type tanks, the nitrogen control system used for inerting of insulation and interbarrier spaces is to be verified as being in normal operating condition.~~

~~(39) Miscellaneous~~

~~① It is to be verified that all accessible cargo piping systems are electrically bonded to the hull.~~

~~② Arrangements for burning methane boil-off are to be visually examined as far as practicable.~~

~~The instrumentation and safety systems are to be verified as being in good working order.~~

~~The relevant instruction and information such as cargo handling plans, filling limit, cooling down procedures, etc. are to be verified as being onboard.~~

~~Mechanical ventilation fans in gas-dangerous spaces and zones are to be visually examined.~~

(2) Confirming, when appropriate, that the requisite arrangements to regain steering capability in the event of the prescribed single failure are being maintained.

(3) Examining the cargo tank openings, including gaskets, covers, coamings and screens.

(4) Examining the cargo tank pressure/vacuum valves and devices to prevent the passage of flame.

(5) Examining the devices to prevent the passage of flame on vents to all bunker, oily-ballast and oily-slop tanks and void spaces, as far as practicable.

(6) Examining the cargo tank venting, cargo tank purging and gas freeing and other ventilation systems.

(7) Examining the cargo, cargo tank washing, ballast and stripping systems both on deck and in the cargo pump-rooms and the bunker system on deck.

(8) Examining that all electrical equipment in dangerous zones is suitable for such locations, is in good condition and is being properly maintained.

(9) Examining that potential sources of ignition in or near the cargo pump-room are eliminated, such as loose gear, combustible materials, etc., that there are no signs of undue leakage and that access ladders are in good condition.

(10) Examining all pump-room bulkheads for signs of oil leakage or fractures and, in particular, the sealing arrangements of all penetrations of cargo pump-room bulkheads.

(11) Examining, as far as practicable, the cargo, bilge, ballast and stripping pumps for undue gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of cargo pump-room bilge system, and to check that pump foundations are intact.

(12) Examining that the pump-room ventilation system is operational, ducting intact, dampers operational and screens clean.

(13) Verifying that installed pressure gauges on cargo discharge lines and level indicator systems are operational.

(14) Examining arrangement of access to bow.

(15) Examining the towing arrangement for tankers of not less than 20,000 tonnes deadweight.

(16) Confirming that the corrosion prevention system fitted to dedicated ballast water tanks is maintained when appropriate.

(17) Examining the emergency lighting in all cargo pump-rooms of tankers constructed after 1 July 2002.

(18) Confirming that any special arrangements to survive conditions of damage are in order.

(19) Examining, where applicable, the alternative design and arrangements for the segregation of the cargo area, in accordance with the test and inspection requirements, if any, specified in the approved documentation.

(20) Confirming that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends in the cargo area are in a satisfactory condition.

(21) Examining the cargo machinery spaces and cargo compressor rooms, including their escape routes.

(22) Confirming that the manually operated ESD (emergency shutdown system) together with the automatic shutdown of the cargo pumps and compressors are satisfactory.

(23) Examining the cargo control room.

(24) Examining the gas detection arrangements for cargo control rooms and the measures taken to exclude ignition sources where such spaces are classified as hazardous areas.

(25) Confirming the arrangements for the air locks are being properly maintained.

(26) Examining, as far as practicable, the bilge, ballast and oil fuel arrangements.

(27) Examining, when applicable, the bow or stern loading and unloading arrangements with particular reference to the electrical equipment, fire-fighting equipment and means of

communication between the cargo control room and the shore location.
(28) Confirming that the sealing arrangements at the gas domes are satisfactory.
(29) Confirming that the portable or fixed drip trays or deck insulation for cargo leakage is in order.
(30) Examining the cargo and process piping, including the expansion arrangements, insulation from the hull structure, pressure relief and drainage arrangements, and water curtain protection as appropriate.
(31) Confirming that the cargo tank and interbarrier space pressure and relief valves, including safety systems and alarms, are satisfactory.
(32) Confirming that any liquid and vapour hoses are suitable for their intended purpose and type-approved or marked with date of testing.
(33) Examining the arrangements for the cargo pressure/temperature control including, when fitted, the thermal oxidation systems and any refrigeration system and confirming that any associated safety measures and alarms are satisfactory.
(34) Examining the cargo, bunker, ballast and vent piping systems, including pressure relief valves (PRVs), vacuum relief valves, vent masts and protective screens, as far as practicable, and confirming that the PRVs are type-approved or marked with date of testing;
(35) Confirming that arrangements are made for sufficient inert gas to be carried to compensate for normal losses and that means are provided for monitoring the spaces.
(36) Confirming that the use of inert gas has not increased beyond that needed to compensate for normal losses by examining records of inert gas usage.
(37) Confirming that any air drying system and any interbarrier and hold space purging inert gas system are satisfactory.
(38) Confirming the requirements of A2.3.2.2(8).
(39) Examining the arrangements for the fire protection and fire extinction and testing the remote means of starting one main fire pump.
(40) Examining the fixed fire-fighting system for the enclosed cargo machinery spaces, and the enclosed cargo motor room within the cargo area and confirming that its means of operation is clearly marked.
(41) Examining the water spray system for cooling, fire protection and crew protection and confirming that its means of operation is clearly marked.
(42) Examining the dry chemical powder fire-extinguishing system for the cargo area and confirming that its means of operation is clearly marked.
(43) Examining the appropriate fire-extinguishing system for the enclosed cargo machinery spaces for ships that are dedicated to the carriage of a restricted number of cargoes and the internal water spray system for the turret compartments and confirming their means of operation is clearly marked.
(44) Examining, as far as practicable, and confirming the satisfactory operation of the arrangements for the artificial ventilation of space in the cargo area normally entered during cargo handling operations.
(45) Examining and confirming the satisfactory operation of the arrangements for the artificial ventilation of spaces normally entered, other than those covered by (44).
(46) Examining and testing, as appropriate and as far as practicable, the liquid level indicators, overflow control, pressure gauges, high pressure and, when applicable, low pressure alarms, and

temperature indicating devices for the cargo tanks.
(47) Examining and testing, as appropriate, the gas detection equipment.
(48) The log books are to be examined with regard to correct functioning of the cargo containment and cargo handling systems. The hours per day of the reliquefaction plants or the boil-off rate is to be considered.
(49) All accessible gas-tight bulkhead penetrations including gas-tight shaft sealings are to be visually examined.
(50) The means for accomplishing gas tightness of the wheelhouse doors and windows is to be examined. All windows and sidescuttles required to be of the fixed (non-opening) type are to be examined for gas tightness. The closing devices for all air intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and approved openings in superstructures and deckhouses facing the cargo area or bow and stern loading/unloading arrangements, are to be examined.
(51) Cargo handling systems: The cargo handling piping and machinery, e.g. cargo and process piping, cargo heat exchangers, vapourizers, pumps, compressors and cargo hoses are in general to be visually examined, as far as possible, during operation.
(52) Cargo containment venting systems:
Venting systems, including protection screens if provided, for the cargo tanks, interbarrrier spaces and hold spaces are to be visually examined externally. It is to be verified that the cargo tank relief valves are sealed and that the certificate for the relief valves opening/closing pressures is onboard.
(53) Instrumentation and safety systems
① The instrumentation of the cargo installations with regard to pressure, temperature and liquid level is to be verified in good working order.
② The logbooks are to be examined for confirmation that the emergency shutdown device has been tested.
(54) Environmental control for cargo containment systems
① Inert gas/dry air installations including the means for prevention of backflow of cargo vapour to gas-safe spaces are to be verified as being in satisfactory operating condition.
② For cargo containment system of membrane type tanks, the nitrogen control system used for inerting of insulation and interbarrier spaces is to be verified as being in normal operating condition.
(55) Miscellaneous
① It is to be verified that all accessible cargo piping systems are electrically bonded to the hull.
② Arrangements for burning methane boil-off are to be visually examined as far as practicable. The instrumentation and safety systems are to be verified as being in good working order.
③ The relevant instructions and information such as cargo handling plans, filling limit information, cooling down procedures, etc. are to be verified as being onboard.
④ Mechanical ventilation fans in gas-dangerous spaces and zones are to be visually examined.

A2.3.2.3 Intermediate surveys
(1) The applicable provisions of 5.4.3, 5.6.3, 5.9.3, 5.10.3 and 5.16.3 in Chapter 5 of PART ONE of CCS Rules for Classification of Sea-Going Steel Ships.

(2) The provisions of A2.3.2.2(2) to (~~38~~55) of the Rules.

(3) Confirming, where applicable, that pipelines and independent cargo tanks are electrically bonded to the hull.

(4) Generally examining the electrical equipment and cables in hazardous areas and zones such as cargo machinery spaces and areas adjacent to cargo tanks to check for defective equipment, fixtures and wiring; the insulation resistance of the circuits should be tested and in cases where a proper record of testing is maintained consideration should be given to accepting recent readings.

(5) Confirming that the heating arrangements, if any, for steel structures are satisfactory.

(6) Instrumentation and safety systems

① The instrumentation of the cargo installations with regard to pressure, temperature and liquid level is to be visually examined and to be tested by changing the pressure, temperature and level and comparing with test instruments. Simulated testing may be accepted for sensors which are not accessible or for sensors located within cargo tanks or inerted hold spaces. The testing is to include testing of alarm and safety functions.

② The piping of the gas detection system is to be visually inspected for corrosion and damage as far as practicable. The integrity of the suction lines between suction points and analyzing units is to be verified as far as possible. Gas Detectors are to be calibrated or verified with sample gases.

③ The emergency shutdown system is to be tested, without flow in the pipe lines, to verify that the system will cause the cargo pumps and compressors to stop.

(7) Electrical equipment: Electrical equipment in gas-dangerous spaces and zones is to be examined as far as practicable with particular respect to the following:

① protective earthing (spot check);

② integrity of flameproof enclosures;

③ damage of outer sheath of cables;

④ function testing of pressurized equipment and of associated alarms;

⑤ testing of systems for de-energizing non-certified safe electrical equipment located in spaces protected by air locks, such as electrical motor-rooms, cargo control rooms, etc.;

⑥ testing of insulation resistance of circuits.

(8) Miscellaneous

The instrumentation and safety systems for burning cargo as fuel are to be examined.

Appendix 2 ADDITIONAL REQUIREMENTS FOR CARRIERS WITH TYPE C INDEPENDENT TANK

Section 6 SIMPLIFIED CALCULATION OF TEMPERATURE FIELD AND THERMAL STRESS AND SELECTION OF STEEL GRADE FOR TYPE C INDEPENDENT TANK

6.6 Selection of steel grades

6.6.4 The scope of application of different ambient conditions is to be determined in accordance with Table 6.6.4 while selecting the steel grades.

Scope of application of selected steel grade **Table 6.6.4**

	IGC	~~USCG (except for Alaska)~~	~~USCG (Alaska)~~	Maximum design ambient temperature (see 7.2 of Chapter 7, PART THREE of the Rules)
Scope of application of selected steel grade	The whole cargo tank region	~~Inner shell of cargo tank region and its connected members~~	~~Inner shell of cargo tank region and its connected members~~	N/A
Note: N/A means not applicable.				

Appendix 3 ADDITIONAL REQUIREMENTS FOR FATIGUE STRENGTH ASSESSMENT OF CARRIERS WITH INDEPENDENT TANKS

The whole Section 4 FRACTURE CRACK PROPAGATION ASSEEMENT AND LEAKAGE ANALYSIS FOR TYPE B INDEPENDENT TANKS is replaced by the following:

Section 4 FATIGUE CRACK PROPAGATION ASSESSMENT AND LEAKAGE ANALYSIS FOR TYPE B INDEPENDENT TANKS

4.1 General requirements

4.1.1 The requirements of this Section apply to fatigue crack propagation assessment and leakage analysis for type B independent tanks based on fracture mechanics. Fatigue crack propagation assessment means the fracture mechanics analysis of fatigue crack propagation from initial crack to propagation to ligament instability stage. Leakage analysis means the fracture mechanics analysis of the through thickness crack propagation from the detection of cargo leakage to the stage of failure of the cargo tank structure.

4.1.2 At assessment, the tank under the most severe internal dynamic pressure is to be selected for the fatigue crack propagation analysis. The forward most cargo tank is normally selected as a target cargo tank for the analysis if the shape and size is similar to other tanks.

4.1.3 For fatigue crack propagation assessment and leakage analysis for type B independent tanks, the following positions are at least to be included:

(1) Positions subject to fatigue crack propagation assessment:

① connections of tank boundary plating (tank top plating, tank bottom plating, bulkhead plating) to internal members (internal primary members and stiffeners);

② connections of tank boundary plating to supporting structures;

③ other areas of tank boundary plating considered to be at risk.

(2) Positions subject to leakage analysis:

① tank lower positions, e.g. connections of tank boundary plating to supporting structures;

② tank upper positions, e.g. tank boundary plating adjacent to liquid cargo free surface.

4.1.4 In accordance with the extent of crack propagation, the process of fatigue crack propagation and cargo leakage consists of 4 stages as follows, see Figure 4.1.4:

(1) Initial crack propagation (stage 1): An initial crack is a semi-elliptical surface crack initiating from the initiation side (initial crack depth a_0, initial crack length $2c_0$), which propagates in both depth (plate thickness) and length directions of the initial crack until the crack depth reaches the ligament instability depth t_{lig}, and the crack length of initiation side is $2c_{ip}$. t_{lig} is determined in accordance with factors such as materials of assessed area, loads and current crack size.

(2) Crack snap through (stage 2): The crack depth snaps from the ligament instability depth t_{lig} to through thickness *t*, and the crack length at initiation side is still $2c_{ip}$.

(3) Fast propagation of a crack at penetration side to a moment that leakage can be detected (stage 3): The through thickness crack propagates quickly until cargo leakage can be detected at the penetration side, and the crack length at initiation side is $2c_{i0}$.

(4) Cargo leakage (stage 4): The through thickness crack continues to propagate until the crack length reaches the critical state and structural failure occurs. The estimated remaining time of failure development is to be taken as not less than 15 days when the leakage can be reliably detected via leakage detection; for other cases, it is to be in accordance with the requirements of 4.18.2.8 and 4.18.2.9, Chapter 4, PART THREE of the Rules. The shape of equivalent crack during cargo leakage is to be taken the same as the through thickness crack in stage 2. At the end of estimated remaining time of failure development, the initiation side crack length is $2c_{if}$, and the penetration side crack length is $2c_{pf}$.

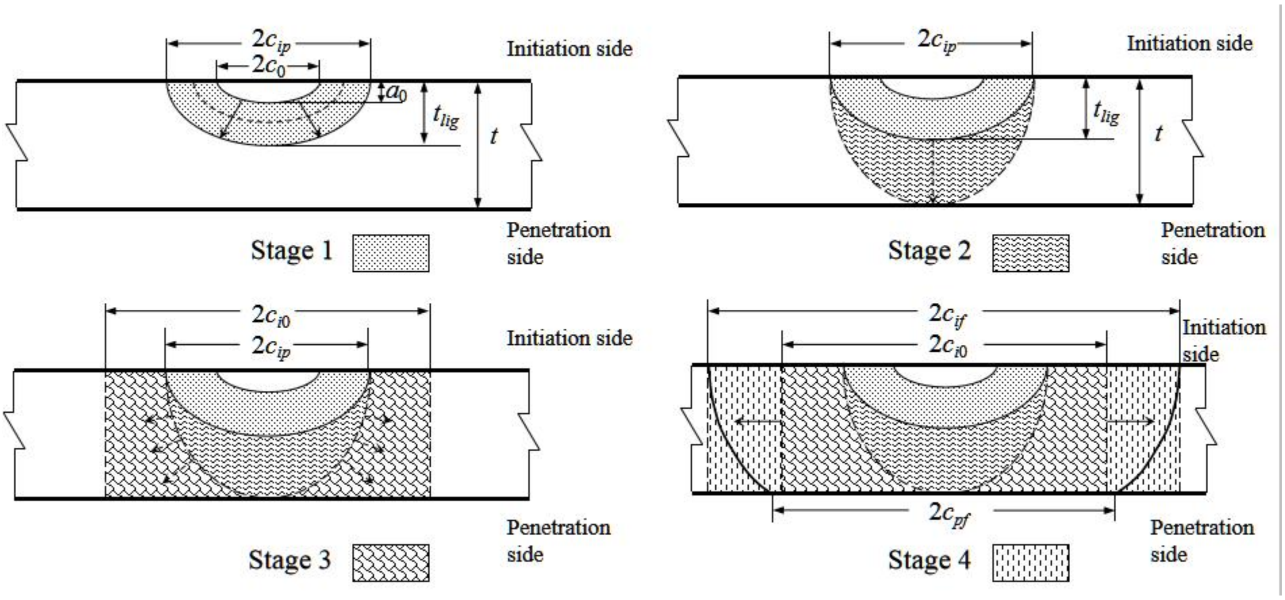

Figure 4.1.4 Four Stages of Fatigue Crack Propagation and Cargo Leakage

4.1.5 The flowchart of fatigue crack propagation assessment during design life of type B independent tanks is shown in Figure 4.1.5(1), the flowchart of 15-day leakage analysis is shown in Figure 4.1.5(2), and assessment criteria are given in 4.3.4.

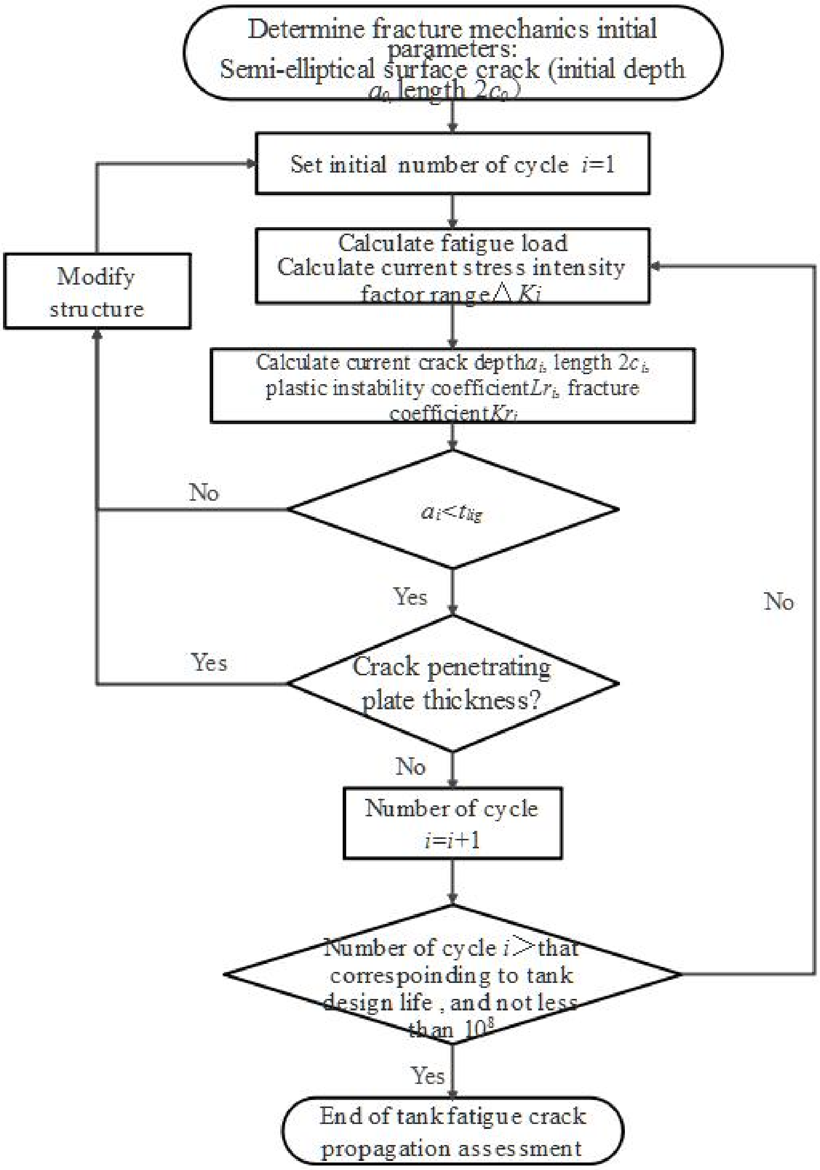

Figure 4.1.5(1) Flowchart of Fatigue Crack Propagation Assessment During Design Life of Type B Independent Tanks

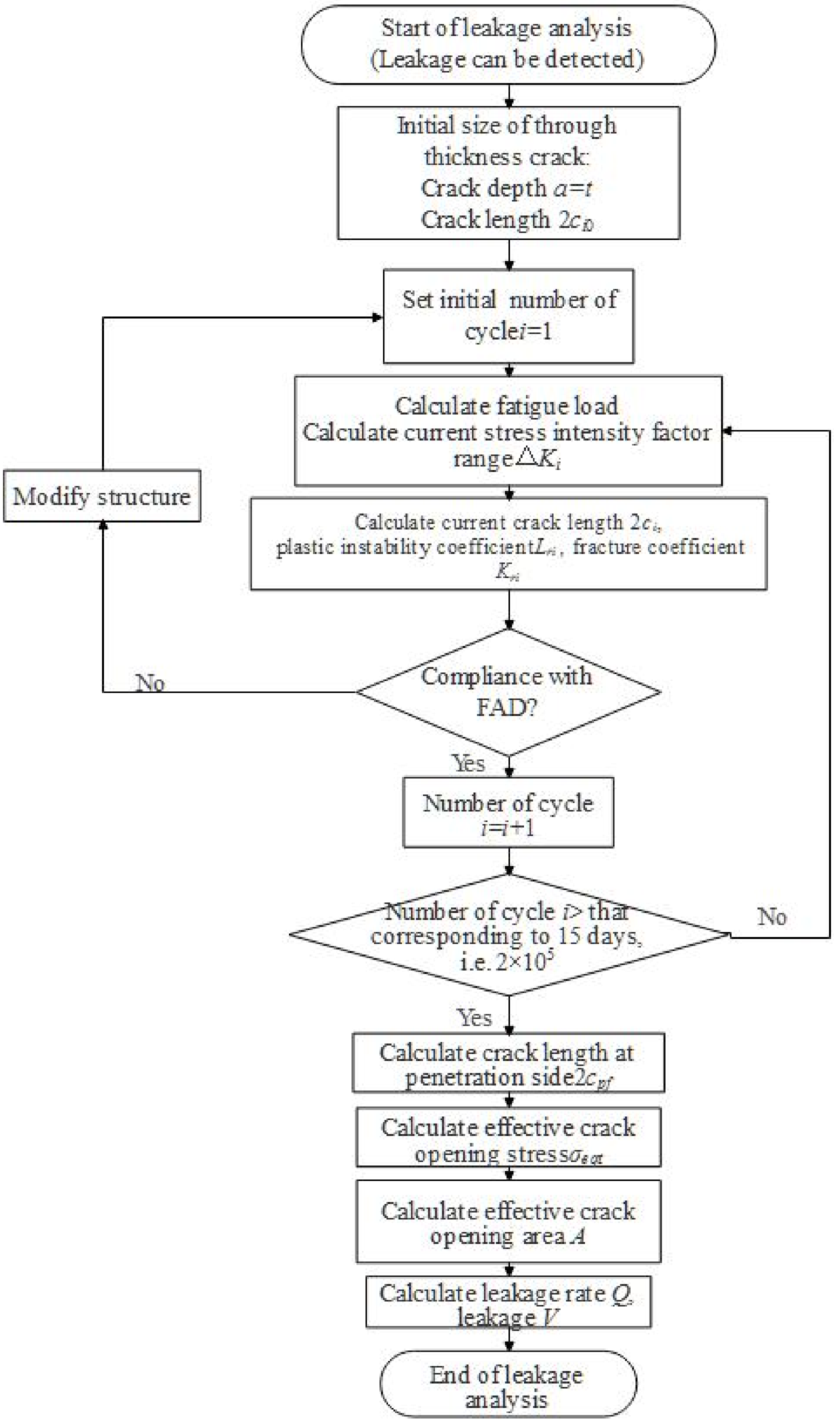

Figure 4.1.5(2) Flowchart of 15-day Leakage Analysis of Type B Independent Tanks

4.2 Stress range distribution

4.2.1 For fatigue crack propagation analysis, the stress range of dominant load case in way of hot spot corresponding to the crack is to be taken.

4.2.2 The dynamic load spectrum used in fatigue crack propagation analysis is based on the long-term distribution of North Atlantic Ocean wave spectrum during the design life of the ship. The exceedance probability level of the maximum load that might be encountered is 10^{-8}.

4.2.3 The long term distribution of the stress range of fatigue crack propagation is described by the two-parameter Weibull distribution, with shape parameter taken as 1.0, and the simplified stress range distribution relationship is:

$$\frac{\Delta\sigma}{\Delta\sigma_0} = 1 - \frac{\log_{10} N}{\log_{10} N_0}$$

where: $\Delta\sigma$ — stress range used for the calculation of stress intensity factor range, in $\mathrm{N/mm^2}$;

$\Delta\sigma_0$ — design stress range corresponding to exceedance probability level of 10^{-8}, in $\mathrm{N/mm^2}$, with calculation method given in 3.3 of Chapter 3 of CCS Guidelines for Fatigue Strength of Ship Structure;

N — number of cycles corresponding to stress range $\Delta\sigma$;

N_0 — total number of load cycles during ship operation, to be generally taken as 10^8 for design life of 20 years.

4.2.4 The number of load cycles corresponding to 15-day leakage analysis is 2×10^5, and the corresponding simplified stress range distribution relationship is:

$$\frac{\Delta\sigma}{\Delta\sigma_0} = 1 - \frac{\log_{10} N_1}{\log_{10}\left(2\times10^5\right)}$$

where: N_1 — number of cycles corresponding to stress range $\Delta\sigma$.

4.3 Fatigue crack propagation analysis

4.3.1 The initial crack usually occurs at the structural surface of high stress area of the tank, e.g. structural surface of tank fillet welding or butt welding. The initial crack size may be determined by non-destructive testing, and is not to be less than the values given in Table 4.3.1.

Initial crack size **Table 4.3.1**

Type of welded joints	Initial crack depth a_0 (mm)	Initial crack length $2c_0$ (mm)
Fillet welding	0.5	5
Butt welding	0.5	5

4.3.2 Crack propagation rate of a semi-elliptical surface crack in a single load cycle is to be calculated according to the following formulae:

Crack propagation rate in depth: $\frac{da}{dN} = C(\Delta K_a)^m$ mm/cycle, when $\Delta K_a > \Delta K_{th}$;

$\frac{da}{dN} = 0$ mm/cycle, when $\Delta K_a \le \Delta K_{th}$.

Crack propagation rate in length: $\frac{dc}{dN} = C(\Delta K_c)^m$ mm/cycle, when $\Delta K_c > \Delta K_{th}$;

$\frac{dc}{dN} = 0$ mm/cycle, when $\Delta K_c \le \Delta K_{th}$.

where: a — depth of the semi-elliptical surface crack, in mm;

c — half-length of the semi-elliptical surface crack, in mm;

N — number of stress cycles;

C — crack propagation coefficient. Where there is no exact value, it is taken in accordance with Table 4.3.2;

m — crack propagation indicator, generally a constant. Where there is no exact value, it is taken in accordance with Table 4.3.2;

ΔK — stress intensity factor range, in $\mathrm{MPa}\sqrt{\mathrm{m}}$, to be calculated in accordance with the following formula:

$$\Delta K = K_{max} - K_{min}$$

K — stress intensity factor, in $\text{MPa}\sqrt{\text{m}}$, to be calculated in accordance with the following formula:

$K = Y\sigma\sqrt{\pi a}$

Y — related to crack type, size and structural geometry, which may be calculated in accordance with BS 7910:2005-Guide to methods for assessing the acceptability of flaws in metallic structures (BS 7910 for short). Where there is no same or similar joint type in BS 7910, numerical calculation method may be used and the calculation information is to be submitted to CCS for information;

σ — stress in way of crack, in MPa;

ΔK_a、ΔK_c — stress intensity factor ranges at the deepest point on the crack front and at the ends of the crack, respectively, in $\text{MPa}\sqrt{\text{m}}$;

ΔK_{th} — crack growth threshold, in $\text{MPa}\sqrt{\text{m}}$; where there is no exact value, it is taken in accordance with Table 4.3.2.

Fracture mechanics constants for common materials Table 4.3.2

Material	m	C	ΔK_{th}（$\text{MPa}\sqrt{\text{m}}$）
Stainless steel	3.0	1.19×10^{-11}	2.0
9% nickel alloy	3.0	5.14×10^{-12}	2.0
Aluminium alloy	3.0	2.03×10^{-10}	0.7
Note: If the above materials are not used in the tank, fracture mechanical parameters may be determined by tests, and the relevant information is to be submitted to CCS.			

4.3.3 Crack propagation rate of a through thickness crack in a single load cycle is to be calculated according to the following formulae:

$$\frac{dc}{dN} = C(\Delta K_c)^m \qquad \text{mm/cycle, when } \Delta K_c > \Delta K_{th}$$

$$\frac{dc}{dN} = 0 \qquad \text{mm/cycle, when } \Delta K_c \le \Delta K_{th}$$

where: ΔK_c — stress intensity factor range of the through thickness crack, in $\text{MPa}\sqrt{\text{m}}$;

c — half-length of the through thickness crack, in mm;

Other symbols are given in 4.3.2.

4.3.4 The failure assessment diagram (FAD) is used for the fracture mechanics analysis criterion of crack propagation, in which the failure assessment curve adopts the method 2A specified in BS 7910. This method is used to investigate all possible failure behaviors of structures with planar flaws from brittle fracture to plastic instability. The influence of fracture toughness and plastic failure resistance on the safety assessment of a flawed structure can be considered at the same time. The steps are as follows:

(1) Calculate membrane stress and bending stress in accordance with the stress distribution on crack surface or the estimation formula;

(2) Determine the fracture toughness of material K_{mat} and the calibrated lower limit of the yield stress at room temperature R_e;

(3) Determine crack type and crack size parameters;

(4) Calculate the crack reference stress σ_{ref} and stress intensity factor K, and further calculate the value of plastic instability coefficient L_r and fracture coefficient K_r of the crack;

(5) Draw the assessment points on the FAD, and carry out structural safety assessment according to the location of the assessment points. An example of FAD is shown in Figure 4.3.4. The structure is safe only when the assessment point is within the range bounded by the failure assessment curve and the coordinate axis.

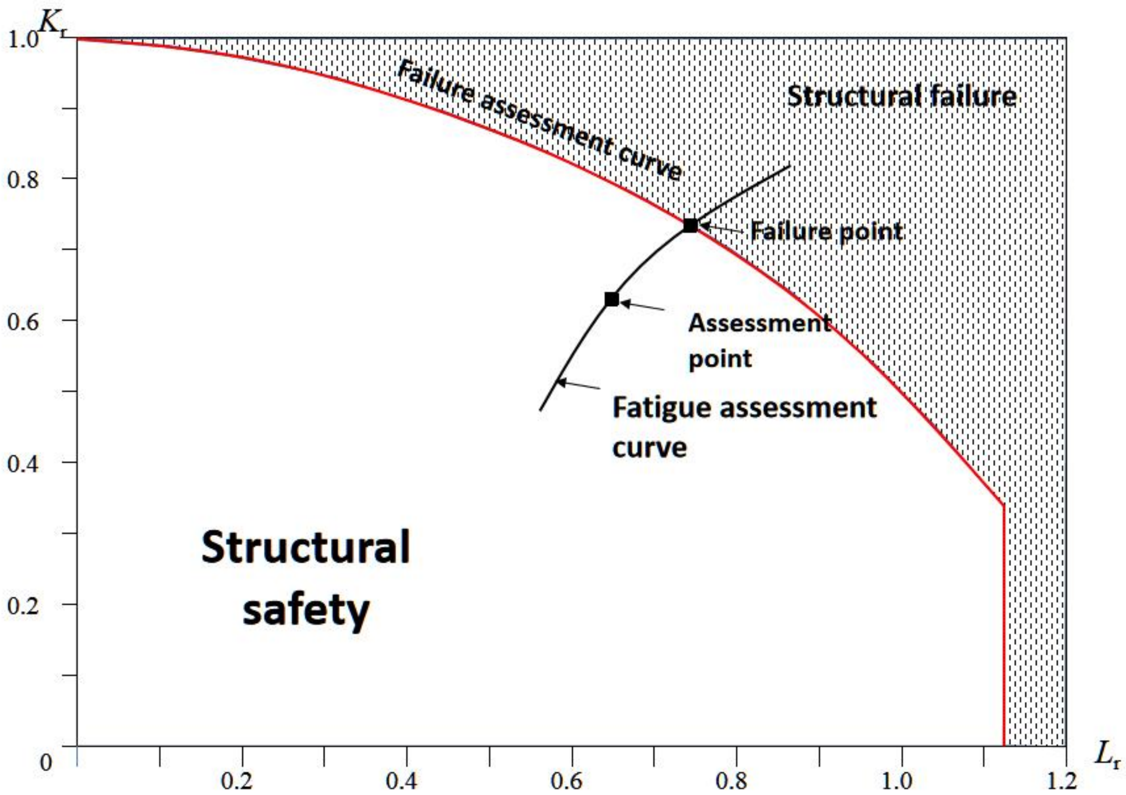

Figure 4.3.4 Typical Failure Assessment Diagram

The plastic instability coefficient L_r is calculated in accordance with the following formula:

$$L_r = \frac{\sigma_{ref}}{R_e}$$

where: σ_{ref} — reference stress in case of plastic failure of structure on FAD, in N/mm^2;

R_e — calibrated lower limit of the yield stress at room temperature, in N/mm^2, see 4.18.1.3, Chapter 4, PART THREE of the Rules.

The fracture coefficient K_r of fatigue crack propagation is calculated in accordance with the following formula:

$$K_r = \frac{K}{K_{\mathrm{mat}}}$$

where: K — stress intensity factor, in $\mathrm{MPa}\sqrt{\mathrm{m}}$, see 4.3;

K_{mat} — fracture toughness of material, in $\mathrm{MPa}\sqrt{\mathrm{m}}$, which may be taken as plane-strain fracture toughness K_{IC} of material.

The failure assessment curve is calculated in accordance with the following formula:

$$K_r = \left(1 - 0.14L_r^2\right)\left[0.3 + 0.7\exp\left(-0.65L_r^6\right)\right], \quad \text{when } L_r \le L_{r\max};$$

$$K_r = 0, \quad \text{when } L_r > L_{r\max}.$$

where: $L_{r\max}$ — maximum plastic instability coefficient, to be calculated in accordance with the following formula:

$$L_{r\max} = \frac{R_e + R_m}{2R_e}$$

R_e, R_m — see 4.18.1.3, Chapter 4, PART THREE of the Rules.

4.3.5 The crack size of cargo tank during the design life (20 years, corresponding to not less than 10^8 load cycles) is to meet the following criteria:

$$a < t_{lig} \quad \text{and}$$

$$a < t$$

where: a — semi-elliptical surface crack depth during design life, in mm, see 4.3.2;

t_{lig} — crack depth at ligament instability, to be calculated in accordance with FAD, in mm, see 4.3.4;

t — plate thickness in way of the crack, in mm.

4.4 15-day leakage analysis

4.4.1 Initial crack size for leakage analysis is to be determined by fatigue crack propagation assessment. Crack length at the initiation side $2c_{i0}$ is the length of the through-thickness crack after it undergoes slipping, to be calculated in accordance with the following formula:

$$2c_{i0} = 2c_{ip} + t \quad \text{mm}$$

where: c_{ip} — half-length of semi-elliptical crack at initiation side when ligament instability occurs, in mm, see 4.3.2;

t — plate thickness, in mm.

4.4.2 The crack final length $2c_{if}$ at initiation side after 15 days is determined by fracture mechanics analysis of the through thickness crack, and the load spectrum is given in 4.2.4.

4.4.3 The crack half length c_{pf} at penetration side after 15 days is calculated in accordance with the following formula:

$$c_{pf} = \sqrt{c_{if}^2 - \left(\frac{c_{ip}}{t_{lig}}\right)^2 t^2} \quad \text{mm}$$

where: c_{if} — half-length of the through thickness crack at initiation side after 15 days, in mm, see 4.3.3;

c_{ip} — half-length of semi-elliptical crack at initiation side when ligament instability occurs, in mm, see 4.3.3;

t_{lig} — depth of semi-elliptical crack when ligament instability occurs, in mm; for the sake of safety, it may be taken as t during calculation;

t — plate thickness, in mm.

4.4.4 Effective crack opening stress, σ_{eqt}, is calculated in accordance with the following formulae:

$$\sigma_{eqt} = \sigma_{sm} + \frac{\sigma_{dm} - \sigma_{sm}}{2} + \frac{\sigma_{db}}{3} \quad \text{MPa,} \quad \text{when } \sigma_{sm} \le \sigma_{dm};$$

$$\sigma_{eqt} = \sigma_{sm} + \frac{\sigma_{db}}{3} \quad \text{MPa,} \quad \text{when } \sigma_{sm} > \sigma_{dm}.$$

where: σ_{sm} — static membrane stress in way of crack, in MPa, see Figure 4.4.4(1);

σ_{dm} — dynamic membrane stress in way of crack, in MPa, see Figure 4.4.4(2);

σ_{db} — dynamic bending stress in way of crack, in MPa, see Figure 4.4.4(2).

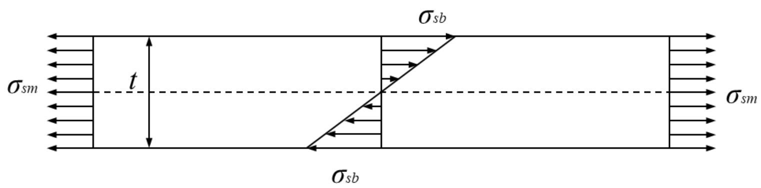

Figure 4.4.4(1) Static Membrane Stress and Static Bending Stress

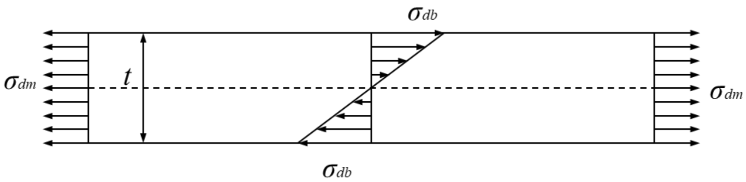

Figure 4.4.4(2) Dynamic Membrane Stress and Dynamic Bending Stress

4.4.5 Effective crack opening area, *A*, is calculated in accordance with the following formula:

$$A = \pi c_{pf} \delta \qquad \text{mm}^2$$

where: δ — maximum crack opening half-displacement, in mm, see Figure 4.4.5, to be calculated in accordance with the following formula:

$$\delta = \frac{2\sigma_{eqt} c_{pf}}{E}$$

π — Pi, taken as 3.14;

σ_{eqt} — effective crack opening stress, in N/mm^2, see 4.4.4;

c_{pf} — half crack length at penetrations side after 15 days, in mm, see 4.4.3;

E— elasticity modulus, in N/mm^2.

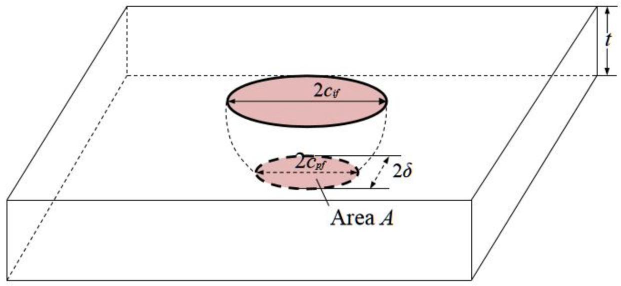

Figure 4.4.5 Effective Crack Opening

4.4.6 Leakage rate *Q* may be calculated according to the following formula:

$$Q = 1000 C_d A \sqrt{2gh + 2000 \frac{p_1 - p_2}{\rho}} \qquad \text{mm}^3/\text{s}$$

where: C_d — cargo leakage coefficient, generally to be taken as 0.1;

A— effective crack opening area, in mm^2, see 4.4.5;
h— vertical distance from the crack location to the top of the tank, in m;
ρ —liquid cargo density, in t/m^3;

p_1， p_2 — the pressure inside and outside the tank, in MPa;

g — acceleration of gravity, taken as 9.81 m/s^2.

4.4.7 The 15-day cargo leakage *V*, which the secondary drip tray is to be able to contain, is calculated in accordance with the following formula:

$$V = 1.296 Q \times 10^{-3} \qquad \text{m}^3$$

where:*Q*——leakage rate, in mm^3/s, see 4.4.6.

PART THREE THE INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK

Preamble

11 The Code incorporates the amendments adopted by MSC by the following resolutions:

No.	Resolution	Adopted on	Deemed to have been accepted on	Date of entry into force
1	MSC 30(61)	11 December 1992	1 January 1994	1 July 1994
2	MSC 17(58)	24 May 1990		3 February 2000
3	MSC 32(63)	23 May 1994	1 January 1998	1 July 1998
4	MSC 59(67)	5 December 1996	1 January 1998	1 July 1998
5	MSC 103(73)	5 December 2000	1 January 2002	1 July 2002
6	MSC.177(79)	10 December 2004	1 January 2006	1 July 2006
7	MSC.220(82)	8 December 2006	1 January 2008	1 July 2008
8	MSC.370(93)	22 May 2014	1 July 2015	1 January 2016
9	MSC.411(97)	25 November 2016	1 July 2019	1 January 2020
10	MSC.441(99)	24 May 2018	1 July 2019	1 January 2020
11	MSC.476(102)	11 November 2020	1 July 2023	1 January 2024

CHAPTER 4 CARGO CONTAINMENT

PART G GUIDANCE

4.28 Guidance notes for chapter 4

4.28.1 Guidance to detailed calculation of internal pressure for static design purpose

CCS 4.28.1.2.c For type C independent cargo tanks, internal pressure head P_{gdi} *which, based on the ellipse method, applies to single tank, bi-lobe tank and tri-lobe tank, may be determined according to the following method (applying to "transverse + vertical" plane, in MPa):*

(a) Single tank

$$P_{\mathrm{gd},i} = \frac{a_y^2\cos\beta_i + a_y a_z\sqrt{(a_y\cos\beta_i)^2+(a_z\sin\beta_i)^2-(\sin\beta_i)^2}}{(a_y\cos\beta_i)^2+(a_z\sin\beta_i)^2}\cdot\left[R+(R-z)\cos\beta_i - y\sin\beta_i\right]\frac{\rho}{1.02\times10^5}$$

where: a_y, a_z —— *see 4.28.2.1;*

β_i ——*see CCS 4.28.1.2.b;*

ρ ——*see 4.28.1.2;*

~~*g* ——*acceleration of gravity, in m/s², taken as 9.81;*~~

R ——*radius of tank, in m, see figure CCS 4.28.1.2.c(1);*

y, z —— *transverse and vertical coordinates of the calculation points on the tank body, in m, and the origin of coordinates is given in Figure ~~CCS 4.28.1.2(3)(a)~~CCS 4.28.1.2.c(1).*

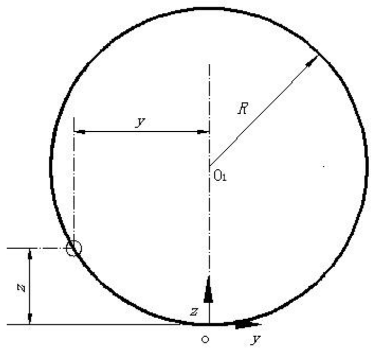

Figure ***CCS 4.28.1.2.c(1) Geometry of single tank***

(a) Bi-lobe tank

$$P_{\mathrm{gd},i} = \frac{a_y^2\cos\beta_i + a_y a_z\sqrt{(a_y\cos\beta_i)^2+(a_z\sin\beta_i)^2-(\sin\beta_i)^2}}{(a_y\cos\beta_i)^2+(a_z\sin\beta_i)^2}\cdot\left[R+(R-z)\cos\beta_i+(\frac{L}{2}-y)\sin\beta_i\right]\frac{\rho}{1.02\times10^5}$$

where: R——radius of tank, in m, see Figure CCS 4.28.1.2.c (2);

L—— distance between centers of the left and right tanks, in m, see Figure CCS 4.28.1.2.c(2);

y, z——transverse and vertical coordinates of the calculation points on the tank body, in m, and the origin of coordinates is given in Figure CCS 4.28.1.2.c(2);

Other symbols ——*see CCS 4.28.1.2.c (1).*

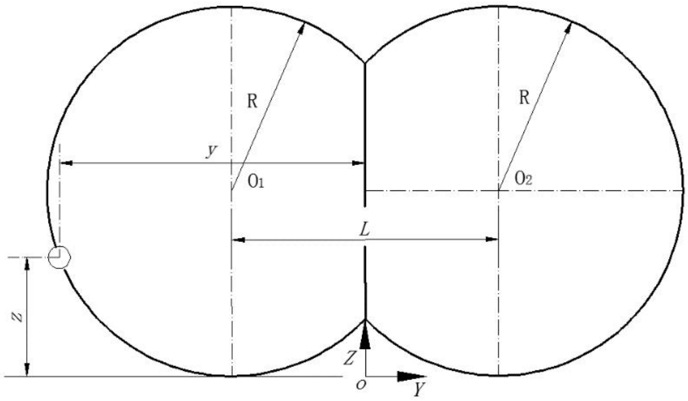

Figure CCS 4.28.1.2.c（2）Geometry of bi-lobe tank

(3) Tri-lobe tank

$$P_{\mathrm{gd},i}=\frac{a_y^2\cos\beta_i+a_y a_z\sqrt{(a_y\cos\beta_i)^2+(a_z\sin\beta_i)^2-(\sin\beta_i)^2}}{(a_y\cos\beta_i)^2+(a_z\sin\beta_i)^2}\cdot\left[R+\frac{L\cos(\frac{\theta}{2}-\beta_i)}{2\sin\frac{\theta}{2}}+(R-z)\cdot\cos\beta_i-(y+\frac{L}{2})\sin\beta_i\right]\frac{\rho}{1.02\times10^5}$$

where: R——radius of tank, in m, see Figure CCS 4.28.1.2.c（3）;

L——distance between centers of the left and right tanks, in m, see Figure CCS 4.28.1.2.c（3）;

y、z——transverse and vertical coordinates of the calculation points on the tank body, in m, and the origin of coordinates is given in Figure CCS 4.28.1.2.c（3）;

θ——the angle between the lines connecting the center of the top tank and the centers of the two lower tanks, in（°）, see figure CCS 4.28.1.2.c（3）;

Other symbols——see CCS 4.28.1.2.c（1）.

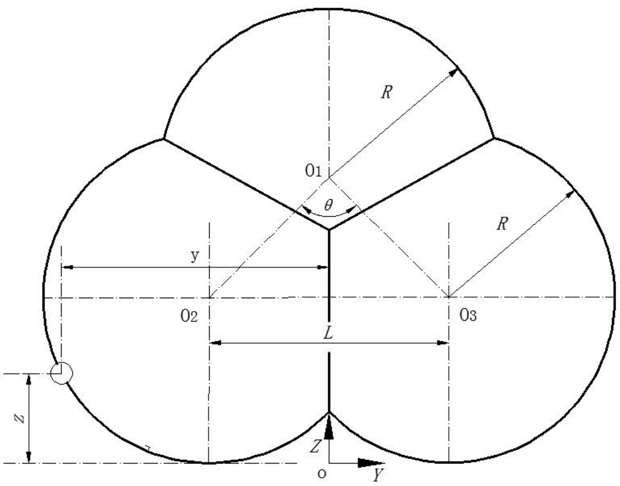

Figure CCS4.28.1.2.c（3）Geometry of Tri-lobe tank

CHAPTER 5 PROCESS PRESSURE VESSELS AND LIQUID, VAPOUR AND PRESSURE PIPING SYSTEMS

5.4 Design pressure

5.4.4 The design pressure of the outer pipe or duct of gas fuel systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively, for gas fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

CCS5.4.4 The expression "design pressure of the outer pipe or duct" in 5.4.4 is either of the following:
(1) The maximum pressure that can act on the outer pipe or equipment enclosure after the inner pipe rupture as documented by suitable calculations taking into account the venting arrangements; or
(2) For gas fuel systems with inner pipe working pressure greater than 1 MPa, the "maximum built-up pressure arising in the annular space", after the inner pipe rupture, which is to be calculated in accordance with paragraph 9.8.2 of the IGF Code as adopted by MSC.391(95).

5.6 Cargo transfer arrangements

5.6.5 ***Cargo sampling connections***

5.6.5.1 Connections to cargo piping systems for taking cargo liquid samples shall be clearly marked and shall be designed to minimize the release of cargo vapours. For vessels permitted to carry toxic products, the sampling system shall be of a closed loop design to ensure that cargo liquid and vapour are not vented to atmosphere.

CCS5.6.5.c These requirements are only applicable if such a sampling system is fitted on board. Connections used for control of atmosphere in cargo tanks during inerting or gassing up are not considered as cargo sampling connections.

5.6.6 ***Cargo filters***

The cargo liquid and vapour systems shall be capable of being fitted with filters to protect against damage by extraneous objects. Such filters may be permanent or temporary, and the standards of filtration shall be appropriate to the risk of debris, etc., entering the cargo system. Means shall be provided to indicate that filters are becoming blocked, and to isolate, depressurize and clean the filters safely.

CCS 5.6.6.a Blockage of filters may be determined by means of a pressure indicator.

CCS5.6.6.b Means to indicate that filters are becoming blocked and filter maintenance is required is to be provided for fixed in-line filter arrangement and portable filter installations where dedicated filter housing piping is provided. Where portable filters for fitting to manifold presentation flanges are used without dedicated filter housing, and these can be visually inspected after each loading and discharging operation, no additional arrangements for indicating blockage or facilitating drainage are required.

5.13 Testing requirements

5.13.2 ***System testing requirements***

5.13.2.4 In double wall gas-fuel piping systems, the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

CCS5.13.2.4 The expression "maximum pressure at gas pipe rupture" in 5.13.2.4 is the maximum pressure to which the outer pipe or duct is subjected after the inner pipe rupture and for testing purposes it is the same as the design pressure used in 5.4.4.

5.13.2.5 All piping systems, including valves, fittings and associated equipment for handling cargo or vapours, shall be tested under normal operating conditions not later than at the first loading operation, in accordance with recognized standards.

CHAPTER 6 MATERIALS OF CONSTRUCTION AND QUALITY CONTROL

Table 6.1

PLATES, PIPES (SEAMLESS AND WELDED)[See notes 1 and 2], SECTIONS AND FORGINGS FOR CARGO TANKS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES NOT LOWER THAN 0°C		
CHEMICAL COMPOSITION AND HEAT TREATMENT		
Carbon-manganese steel		
Fully killed fine grain steel		
Small additions of alloying elements by agreement with the Administration		
Composition limits to be approved by the Administration		
Normalized, or quenched and tempered [See note 4]		
TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS		
Sampling frequency		
Plates	Each "piece" to be tested	
Sections and forgings	Each "batch" to be tested	
Mechanical properties		
Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [See note 5]	
Toughness (Charpy V-notch test)		
Plates	Transverse test pieces. Minimum average energy value (*KV*) 27J	
Sections and forgings	Longitudinal test pieces. Minimum average energy (*KV*) 41J	
Test temperature	Thickness t (mm)	Test temperature (°C)
	$t \leqslant 20$	0
	$20 < t \leqslant 40$ [See note 3]	-20

Notes

1 For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by the Administration or the recognized organization acting on its behalf (see CCS①).

2 Charpy V-notch impact tests are not required for pipes.

3 This table is generally applicable for material thicknesses up to 40 mm. Proposals for greater thicknesses shall be approved by the Administration or the recognized organization acting on its behalf (see CCS②).

4 A controlled rolling procedure or TMCP may be used as an alternative.

5 Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration or the recognized organization acting on its behalf. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones. See CCS~~②~~③.

Notes: CCS① ~~The chemical compositions and mechanical properties of the materials used for~~ Welded pressure pipes~~, cargo tanks and process pressure vessels~~ are to comply with Chapter ~~3~~4, PART ONE of CCS Rules for Materials and Welding.

CCS② For materials of 40 mm ＜t≤50 mm, Charpy v-notch impact tests shall be carried out in accordance with the following requirements:

CHARPY V-NOTCH IMPACT TEST REQUIREMENTS		
TEST TEMPERATURE	*Thickness t (mm)*	*Test temperature (℃)*
	40＜t≤50 (1)	*-20 (2)*
	40＜t≤50 (1)	*-30 (3)*

Notes:

(1) A further set of impact test at mid thickness for products with t>40mm is required except rolled steels specified in Sections 2 and 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding.

(2) Applies to type C independent tanks and process pressure vessels. In addition, post-weld stress relief heat treatment shall be performed. Exemption to post-weld stress relief heat treatment based on alternative approach (e.g. Engineering Critical Assessment) shall be approved by CCS or shall be to recognized standards.

(3) Applies to cargo tank other than type C independent tanks.

CCS~~②~~③ Where the carried cargo may cause stress corrosion cracking of cargo tanks or process pressure vessels, it is recommended that stress relief heat treatment be appropriately carried out for the whole cargo tank or process pressure vessel so that the hardness of the weld metal and heat-influenced zone does not exceed 250 HV.

Table 6.2

PLATES, SECTIONS AND FORGINGS [See note1] FOR CARGO TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO -55°C Maximum thickness 25 mm [See note 2]

CHEMICAL COMPOSITION AND HEAT TREATMENT

- ◆ Carbon-manganese steel
- ◆ Fully killed, aluminium treated fine grain steel
- ◆ Chemical composition (ladle analysis)

C	Mn	Si	S	P
0.16%max [See note 3]	0.7~1.60%	0.1~0.50%	0.025% max	0.025% max

Optional additions: Alloys and grain refining elements may be generally in accordance with the following:

Ni	Cr	Mo	Cu	Nb	V
0.8% max	0.25% max	0.08% max	0.35% max	0.05% max	0.1% max

Al content total 0.02% min (Acid soluble 0.015% min)

- ◆ Normalized, or quenched and tempered [See note 4]

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

Sampling frequency

◆ Plates	Each "piece" to be tested
◆ Sections and forgings	Each "batch" to be tested

Mechanical properties

Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [See note 5]

Toughness (Charpy V-notch impact test)

◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J
◆ Test temperature	5°C below the design temperature or -20°C, whichever is lower

Notes

1 The requirements for Charpy V-notch impact test and chemical composition for forgings may be specially considered by the Administration.

2 For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

Material Thickness(mm)	Test Temperature (°C)
25 < t ≤ 30	10°C below design temperature or –20 whichever is lower
30 < t ≤ 35	15°C below design temperature or –20 whichever is lower
35 < t ≤ 40	20°C below design temperature
40 < t	Temperature approved by the Administration or the recognized organization acting on behalf of the Administration (see CCS②)

The impact energy value shall be in accordance with the table for the applicable type of test specimen.

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C, whichever is lower.

For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness.

3 By special agreement with the Administration, the carbon content may be increased to 0.18% maximum, provided the design temperature is not lower than -40°C.

4 A controlled rolling procedure or TMCP may be used as an alternative.

5 Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration or the recognized organization acting on its behalf. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Guidance:

For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with Table 6.3 of this Chapter may be necessary.

CCS① Where the carried cargo may cause stress corrosion cracking of cargo tanks or process pressure vessels, it is recommended that stress relief heat treatment be appropriately carried out for the whole cargo tank or process pressure vessel so that the hardness of the weld metal and heat-influenced zone does not exceed 250 HV.

CCS② For tanks of -10℃≤design temperature＜0℃, Charpy v-notch impact tests for materials of 40 mm＜t≤50 mm shall be carried out in accordance with the following requirements:

CHARPY V-NOTCH IMPACT TEST REQUIREMENTS		
TEST TEMPERATURE	Thickness t (mm)	Test temperature (℃)
	40＜t≤50 (1)	5℃ below design temperature or －20℃, whichever is lower(2)
	40＜t≤45 (1)	25℃ below design temperature (3)
	45＜t≤50 (1)	30℃ below design temperature (3)
Notes:		
(1) A further set of impact test at mid thickness for products with t>40mm is required except rolled steels specified in Sections 2 and 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding. (2) Applies to type C independent tanks and process pressure vessels. In addition, post-weld stress relief heat treatment shall be performed. Exemption to post-weld stress relief heat treatment based on alternative approach (e.g. Engineering Critical Assessment) shall be approved by CCS or shall be to recognized standards. (3) Applies to cargo tank other than type C independent tanks.		

For tanks of -55℃≤design temperature＜-10℃, charpy v-notch impact tests for materials of 40 mm＜t≤50 mm shall be carried out in accordance with the following requirements:

CHARPY V-NOTCH IMPACT TEST REQUIREMENTS		
TEST TEMPERATURE	Thickness t (mm)	Test temperature (℃)
	40＜t≤50 (1)	5℃ below design temperature or －20℃, whichever is lower(2)
	40＜t≤45 (1)	25℃ below design temperature (3)
	45＜t≤50 (1)	30℃ below design temperature (3)
Notes:		
(1) A further set of impact test at mid thickness for products with t>40mm is required except rolled steels specified in Sections 2 and 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding. (2) Section 6.6.2.2 of this Chapter applies with regards to post-weld stress relief heat treatment. Exemption to post-weld stress relief heat treatment based on alternative approach (e.g. Engineering Critical Assessment) shall be approved by CCS or shall be to recognized standards. (3) Applies to cargo tank other than type C independent tanks.		

Table 6.3

PLATES, SECTIONS AND FORGINGS See note 1 FOR CARGO TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW -55°C AND DOWN TO -165°C See note 2 Maximum thickness 25 mm See notes 3 and 4		
Minimum design temperature (°C)	Chemical composition See note 5 and heat treatment	Impact test temperature (°C)
-60	1.5% nickel steel – normalized or normalized and tempered or quenched nd tempered or TMCP See note 6	-65
-65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP See notes 6 and 7	-70
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP See notes 6 and 7	-95
-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered See notes 6, 7 and 8	-110
-165	9% nickel steel – double normalized and tempered or quenched and tempered See note 6	-196
-165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated See note 9	-196
-165	Aluminium alloys; such as type 5083 annealed	Not required
-165	Austenitic Fe-Ni alloy (36% nickel). Heat treatment as agreed	Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

Sampling frequency	
◆ Plates	Each spieces to be tested
◆ Sections and forgings	Each ons and forgingssted
Toughness (Charpy V-notch impact test)	
◆ Plates	Transverse test pieces. Minimum average energy value (*KV*) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (*KV*) 41J

Notes

1 The Charpy V-notch impact test required for forgings used in critical applications shall be subject to special consideration by the Administration.

2 The requirements for design temperatures below -165°C shall be subject to special agreement with the Administration.

3 For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, the Charpy V-notch impact tests shall be conducted as follows:

Material Thickness(mm)	Test Temperature (°C)
$25 < t \leqslant 30$	10°C below design temperature
$30 < t \leqslant 35$	15°C below design temperature
$35 < t \leqslant 40$	20°C below design temperature

The energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered. (see CCS②)

4 For 9% Ni steels, austenitic stainless steels* and aluminium alloys, thickness greater than 25 mm may be used.

5 The chemical composition limits shall be in accordance with recognized standards.

6 TMCP nickel steels will be subject to acceptance by the Administration. 7 A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Administration. 8 A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to -165°C, but the Charpy V-notch impact test is to be carried out in -196°C. 9 The Charpy V-notch impact test may be omitted, subject to agreement with the Administration.

*CCS① Austenitic steels may be used as per CCS requirements.

CCS② Charpy v-notch impact tests for materials of 40 mm＜t≤50 mm shall be carried out in accordance with the following requirements:

CHARPY V-NOTCH IMPACT TEST REQUIREMENTS	
Thickness t (mm)	Test temperature (℃)
40＜t≤45 (1)	25℃ below design temperature
45＜t≤50 (1)	30°C below design temperature
(1) A further set of impact test at mid thickness for products with t>40mm is required except rolled steels specified in Sections 2 and 3, Chapter 3, PART ONE of CCS Rules for Materials and Welding.	

6.5 Welding of metallic materials and non-destructive testing

6.5.3.5 Each test shall satisfy the following requirements:

.1 tensile tests: cross-weld tensile strength shall not be less than the specified minimum tensile strength for the appropriate parent materials. For materials such as aluminium alloys, reference shall be made to 4.18.1.3 with regard to the requirements for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture shall be recorded for information;

CCS 6.5.3.b It may also be accepted subject to agreement with CCS that the transverse weld tensile strength is not to be less than the specified minimum tensile strength for the deposited metal, where the weld metal has lower tensile strength than that of the parent metal.

CCS 6.5.3.c For longitudinal weld tensile test, the yield stress of deposited weld metal is not to be less than that specified for the parent material or the minimum design yield stress.

CHAPTER 13 INSTRUMENTATION AND AUTOMATION SYSTEMS

13.2 Level indicators for cargo tanks

13.2.2 Where only one liquid level gauge is fitted, it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

CCS13.2.2 Where only one liquid level gauge is fitted, any part of the level gauge other than passive parts can be overhauled while the cargo tank is in service. Passive parts are those parts assumed not subject to failures under normal service conditions.

13.2.3 Cargo tank liquid level gauges may be of the following types, subject to special requirements for particular cargoes shown in column "g" in the table of chapter 19:

.1 indirect devices, which determine the amount of cargo by means such as weighing or in-line flow metering;

.2 closed devices which do not penetrate the cargo tank, such as devices using radio-isotopes or ultrasonic devices;

.3 closed devices which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If closed gauging device is not mounted directly onto the tank, it shall be provided with a shutoff valve located as close as possible to the tank; and

.4 restricted devices which penetrate the tank and, when in use, permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation shall ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices shall be so designed that the maximum opening does not exceed 1.5 mm diameter or equivalent area, unless the device is provided with an excess flow valve.

CCS13.2 The liquid level gauge containing liquid cargo fitted outside the cargo tank is to be so arranged that it can be isolated in the event of failure.

13.3 Overflow control

13.3.5 The position of the sensors in the tank shall be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high-level alarms shall be conducted by raising the cargo liquid level in the cargo tank to the alarm point.

~~*CCS 13.3.5 "Each dry-docking" means surveys of outer bottom shell of a vessel as required by renewal of safety construction certificates for cargo ships and/or safety certificates for cargo ships.*~~

13.6 Gas detection

13.6.4 Where indicated by an "A" in column "*f*" in the table of chapter 19 ships certified for carriage of non-flammable products, oxygen deficiency monitoring shall be fitted in cargo machinery spaces and hold spaces for independent tanks other than type C tanks. Furthermore, oxygen deficiency monitoring equipment shall be installed in enclosed or semi-enclosed spaces containing equipment that may cause an oxygen-deficient environment such as nitrogen generators, inert gas generators or nitrogen cycle refrigerant systems.

CCS13.6.4 Two oxygen sensors are to be positioned at appropriate locations in the space or spaces containing the inert gas system, in accordance with paragraph 15.2.2.4.5.4 of the FSS Code, for all gas carriers, irrespective of the carriage of cargo indicated by an "A" in column "f" in the table in chapter 19 of the Code.

16.7 Special requirements for gas-fired internal combustion engines

16.7.1.4 Unless designed with the strength to withstand the worst case overpressure due to ignited gas leaks, air inlet manifolds, scavenge spaces, exhaust system and crank cases shall be fitted with suitable pressure relief systems. Pressure relief systems shall lead to a safe location, away from personnel.

CCS16.7.1.4 For the pressure relief systems in 16.7.1.4:

(1) A suitable pressure relief system for air inlet manifolds, scavenge spaces and exhaust system is to be provided unless designed to accommodate the worst-case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation regarding the hazard potential of overpressure in air inlet manifolds, scavenge spaces and exhaust system is to be carried out and reflected in the safety concept of the engine.

(2) In the case of crankcases, the explosion relief valves, as required by Regulation 27.4 of SOLAS Chapter II-1 are to be considered suitable for the gas operation of the engine. For engines not covered by said Regulation, a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase is to be carried out.

17.21 Carbon dioxide: high purity

17.21.4 Cargo tanks shall be continuously monitored for low pressure when a carbon dioxide cargo is carried. An audible and visual alarm shall be given at the cargo control position and on the bridge. If the cargo tank pressure continues to fall to within 0.05 MPa of the “triple point” for the particular cargo, the monitoring system shall automatically close all cargo manifold liquid and vapour valves and stop all cargo compressors and cargo pumps. The emergency shutdown system required by 18.10 may be used for this purpose.

CHAPTER 18 OPERATING REQUIREMENTS

18.9 Cargo sampling

18.9.1 Any cargo sampling shall be conducted under the supervision of an officer who shall ensure that protective clothing appropriate to the hazards of the cargo is used by everyone involved in the operation.
18.9.2 When taking liquid cargo samples, the officer shall ensure that the sampling equipment is suitable for the temperatures and pressures involved, including cargo pump discharge pressure, if relevant.
18.9.3 The officer shall ensure that any cargo sample equipment used is connected properly to avoid any cargo leakage.
18.9.4 If the cargo to be sampled is a toxic product, the officer shall ensure that a "closed loop" sampling system as defined in 1.2.15 is used to minimize any cargo release to atmosphere.
18.9.5 After sampling operations are completed, the officer shall ensure that any sample valves used are closed properly and the connections used are correctly blanked.
CCS18.9 These requirements are only applicable if such a sampling system is fitted on board. Connections used for control of atmosphere in cargo tanks during inerting or gassing up are not considered as cargo sampling connections.

18.10 Cargo emergency shutdown (ESD) system

18.10.3 ***ESD system controls***

18.10.3.2 The ESD system shall be automatically activated on detection of a fire on the weather decks of the cargo area and/or cargo machinery spaces. As a minimum, the method of detection used on the weather decks shall cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly. Detection may be by means of fusible elements designed to melt at temperatures between 98°C and 104°C, or by area fire detection methods.

Table 18.1 – ESD functional arrangements

	Pumps		**Compressor systems**				**Valves**	**Link**
Shutdown action → **Initiation ↓**	Cargo pumps/ cargo booster pumps	Spray/ stripping pumps	Vapour return compressors	Fuel gas compressors	Reliquefaction plant***, including condensate return pumps, if fitted	Gas combustion unit	ESD valves	Signal to ship/ shore link****
Emergency push buttons (see 18.10.3.1)	√	√	√	Note 2	√	√	√	√
Fire detection on deck or in compressor house* (see 18.10.3.2)	√	√	√	√	√	√	√	√
High level in cargo tank (see 13.3.2 and 13.3.3)	√	√	√	Note 1 Note 2	Note1 Note 3	Note 1	Note 6	
Signal from ship/shore link (see 18.10.1.4)	√	√	√	Note 2	Note 3	n/a	√	n/a
Loss of motive power to ESD valves**	√	√	√	Note 2	Note 3	n/a	√	√
Main electric power failure ("blackout")	Note 7	Note 7	Note 7	Note 7	Note 7	Note 7	√	√
Level alarm override (see 13.3.7)	Note 4	Note 4 Note 5	√	Note 1	Note1	Note 1	√	√

Note 1: These items of equipment can be omitted from these specific automatic shutdown initiators, provided the equipment inlets are protected against cargo liquid ingress.

Note 2: If the fuel gas compressor is used to return cargo vapour to shore, it shall be included in the ESD system when operating in this mode.

Note 3: If the reliquefaction plant compressors are used for vapour return/shore line clearing, they shall be included in the ESD system when operating in that mode.

Note 4: The override system permitted by 13.3.7 may be used at sea to prevent false alarms or shutdowns. When level alarms are overridden, operation of cargo pumps and the opening of manifold ESD valves shall be inhibited except when high-level alarm testing is carried out in accordance with 13.3.5 (see 18.10.3.4).

Note 5: Cargo spray or stripping pumps used to supply forcing vaporizer may be excluded from the ESD system only when operating in that mode.

Note 6: The sensors referred to in 13.3.2 may be used to close automatically the tank filling valve for the individual tank where the sensors are installed, as an alternative to closing the ESD valve referred to in 18.10.2.2. If this option is adopted, activation of the full ESD system shall be initiated when the high-level sensors in all the tanks to be loaded have been activated.

Note 7: These items of equipment shall be designed not to restart upon recovery of main electric power and without confirmation of safe conditions.

* Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck.

** Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators.

*** Indirect refrigeration systems which form part of the reliquefaction plant do not need to be included in the ESD function if they employ an inert medium such as nitrogen in the refrigeration cycle.

**** Signal need not indicate the event initiating ESD.

√ Functional requirement.

N/A Not applicable.

CCS table 18.1 In applying the second sentence of note 4 of table 18.1, a hardware system such as an electric or mechanical interlocking device is to be provided to prevent inadvertent operation of cargo pumps and inadvertent opening of manifold ESD valves.

Appendix 1 NON-METALLIC MATERIALS

5.2 ***QA/QC during component manufacture***

The QA/QC programme in respect of component manufacture should include, as a minimum but not limited to, the following items.

5.2.1 Component identification

5.2.1.1 For each material, the manufacturer should implement a marking system to clearly identify the production batch. The marking system should not interfere, in any way, with the properties of the product.

5.2.1.2 The marking system should ensure complete traceability of the component and should include:

- .1 date of production and potential expiry date;
- .2 manufacturer's references;
- .3 reference specification;
- .4 reference order; and
- .5 when necessary, any potential environmental parameters to be maintained during transportation and storage.